GUIDING SOLUTIONS IN THE
NATURAL ENVIRONMENT

Fluvial Geomorphology Report
in support of a
Master Environmental Servicing Plan
4134 16th Avenue, City of Markham

Prepared For:

Sixteenth Land Holdings Inc.

Prepared By:

Beacon Environmental Limited

Date: *Project:*

September 2016 **215200.1**

MARKHAM	BRACEBRIDGE	GUELPH	PETERBOROUGH	OTTAWA
144 Main St. North, Suite 206	126 Kimberley Avenue	373 Woolwich Street	305 Reid Street	470 Somerset Street West
Markham, ON L3P 5T3	Bracebridge, ON P1L 1Z9	Guelph, ON N1H 3W4	Peterborough, ON K9J 3R2	Ottawa, ON K1R 5J8
T)905.201.7622 ❖ F)905.201.0639	T)705.645.1050 ❖ F)705.645.6639	T)519.826.0419 ❖ F)519.826.9306	T) 705.243.7251	T) 613.627.2376

Table of Contents

page

Figures

Tables

Appendices

1. Introduction

Sixteenth Land Holdings Inc. has retained Beacon Environmental Limited (Beacon) to prepare this Fluvial Geomorphology Report in support of an Official Plan Amendment (“OPA”) application to permit the development of a residential community on the subject property.

The property is municipally known as 4134 16th. Avenue, in the City of Markham, Region of York. The property is located in Part lots 16, 17 and 18, Concession 5 (**Figure 1**). Except for an area adjacent to Kennedy Road, the balance of the property is currently used by its former owner York Downs Golf & Country Club for a golf course.

The property is a total of 168.64 hectares (416.72 acres), and is located on the north side of 16th. Avenue, on the west side of Kennedy Road, and has a small amount of frontage onto the east side of Warden Avenue as well. There is existing residential development surrounding the property on all sides.

Berczy Creek crosses the western portion of the property, and the Bruce Creek traverses the property in a roughly north / south direction, bisecting the property into west and east tableland areas.

The current golf course use has been in operation since York Downs Golf & Country Club opened on site in the early 1970’s. The current Official Plan designation of ‘Private Open Space’ for the areas outside of the valleylands reflects this historic golf course use.

Sixteenth Land Holdings Inc. intends to develop the property for a residential community and is submitting an OPA to re-designate the developable portion of the property from ‘Private Open Space’ to appropriate urban residential designations to permit the development of residential uses.

This report has been prepared in conjunction with the OPA application in support of the redesignation as proposed in the draft OPA and in the Planning Report (Gatzios Planning, September 2016). Please refer to the draft OPA and to the Planning Report for a description of the proposed Official Plan land use designations proposed for the property.

The proposed residential development is detailed in the two draft plan of subdivision applications that accompany this OPA application. There is one draft plan of subdivision for the east portion of the property and one for the west portion of the property. The west draft plan of subdivision also contains the valleylands associated with both the Berczy creek and the Bruce creek. References in this report to the two draft plans or to specific lots / blocks will include ‘East’ or ‘West’ to denote the appropriate area.

The East draft plan of subdivision contains a mix of residential, open space blocks, an elementary school block and SWM ponds.

The West draft plan of subdivision contains a mix of residential, mixed use, open space blocks, parks and SWM ponds.

The purpose of this Fluvial Geomorphology Report is to summarize the existing conditions, contribute to the determination of development constraints, and provide input to stormwater servicing plans for the subject property.

In accordance with the approved Terms of Reference for the overall MESP report, the following tasks were undertaken in support of this study:

- Background review of available materials (topographic mapping, aerial photography, watershed reports, relevant studies, site plan);
- Desktop assessment to delineate reaches based on underlying geomorphic controls and establish changes in land use and channel planform over time (referencing available history aerial imagery);
- Mapping analysis to delineate the meander belt width for stream corridors (unconfined watercourses) in accordance with relevant policies and guidelines to aid in the determination of erosion hazard limits;
- Delineation of occupied Redside Dace regulated habitat in conformance with Ontario Regulation 242/08 (meander belt width plus 30 m) for stream and valley corridors to aid in the determination of development limits;
- Field investigations including:
    - Rapid field assessment on a reach basis to characterize existing geomorphic conditions and document evidence of active channel processes; and
    - Detailed field assessments of two (2) sites for the purpose of determining erosion thresholds;
- Analysis of detailed geomorphic field data to determine erosion thresholds;
- Impact assessment of proposed development plan to evaluate potential impacts on channel morphology; and
- Analysis of fluvial geomorphology requirements for Natural Heritage System (NHS) crossings.

2. Background Review

2.1 Watershed Conditions

2.1.1 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 Richmond Hill Station, located northwest of the subject property, averaged 69 mm per month in winter (November through February), and 86 mm in summer (July and August; Environment Canada, 2015). This increase over the summer months is likely a result of

Stantec
BEACON ENVIRONMENTAL
BURNSIDE

1:17,000

0 75 150 300 450 600

Legend
- Subject Property
- Draft Plan Boundary
- Watercourse

MASTER ENVIRONMENTAL SERVICING PLAN FOR 4134 16TH AVE

FIGURE 1 Site Location

First Base Solutions Web Mapping Service 2015
UTM Zone 17 N, NAD 83

September 2016

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.

2.1.2 Geology

The planimetric form of a watercourse is fundamentally a product of the channel flow regime and the availability of sediments (i.e., surficial geology) within the stream corridor. 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 is located within the Peel Plain physiographic region (Chapman and Putnam, 1984); a thin veneer of silt and clay glaciolacustrine deposits that were deposited over the underlying Halton Till. This region is predominantly comprised of clay, with localized clay loam and loam deposits. Although the topography is relatively flat, infiltration is limited by the clay content of the soils. Surficial geology within the property is dominated by the Halton Till formation, a sandy silt to clayey silt till interbedded with silt, clay, sand and gravel. Locally, within the stream corridor, both Berczy and Bruce Creeks rework a veneer of modern alluvial sand and gravel deposits (TRCA, 2007a).

2.1.3 Rouge River State of the Watershed Report (2007)

The Toronto and Region Conservation Authority (TRCA) and Rouge Park Alliance, in cooperation with the multi-stakeholder Rouge Watershed Task Force, undertook the development of an integrated watershed plan for the Rouge River watershed. This report provided the basis for the updated Rouge River Watershed Plan, and provided an overview of existing environmental conditions within the watershed. Berczy Creek and Bruce Creek represent two of the five tributaries that make up the Middle Rouge tributaries within the Rouge River watershed.

The Rouge River and its tributaries are referred to as 'semi-alluvial' in nature meaning these systems flow through both older glacial deposits as well as their own eroded deposits (alluvium) (TRCA, 2007a). The morphology of semi-alluvial channels is partially controlled by the properties of the glacial deposits through which they flow, as well as by the characteristics of alluvium transported from upstream. In the Rouge River watershed, glacial lacustrine (till) deposits and glacial outwash material represent the primary underlying controls on morphology (TRCA, 2007a).

As with the majority of watersheds in southern Ontario, the Rouge River watershed has been altered by human activity (TRCA, 2007a). The influence of uncontrolled stormwater inputs to the downstream watershed from older development areas have resulted in notable changes to the hydrologic regime, and subsequently channel morphology and stability (TRCA, 2007a).

2.1.3.1 Fluvial Geomorphology

Berczy Creek

The portion of Berczy Creek flowing through the subject property was characterized as a third order stream through the watershed report (TRCA, 2007b). The report also noted that, through their Regional Watershed Monitoring Network, TRCA established a long-term geomorphic monitoring station (GR-12) downstream of the Subject Property in 2002. Morphologic characteristics reported for station GR-12 indicated an average bankfull width of 5.33 m, average bankfull depth of 0.71 m and bankfull gradient of 0.23%. Bank heights averaged 1.1 m in height, while the median grain size for the site fell within the small gravel size class.

Bruce Creek

The portion of Bruce Creek flowing through the property was characterized as a third order stream through the watershed report (TRCA, 2007b). The report also noted that, through their Regional Watershed Monitoring Network, TRCA established a long-term geomorphic monitoring station (GR-17) downstream of the subject property in 2002. Morphologic characteristics reported for station GR-17 indicated an average bankfull width of 5.66 m, average bankfull depth of 0.55 m and bankfull gradient of 0.41%. Bank heights averaged 1.1 m in height, while the median grain size for the site fell within the small gravel size class.

2.1.4 Aquatic Habitat

The watershed report identifies the portion of Bruce Creek within the subject property as falling within Fishery Management Zone (FMZ) 3, while the portion of Berczy Creek within the subject property falls within FMZ 2, as documented in the Rouge River State of the Watershed Report (TRCA, 2007c). These zones delineate areas within which fish communities, thermal regimes and underlying environmental controls remain relatively consistent.

The report classifies Berczy Creek as a riverine cool water system based on the known groundwater discharge areas upstream of the subject property. FMZ 2 is managed for the following key target species:

- Redside dace (*Clinostomus elongatus*);
- Brassy minnow *(Hybognathus hankinsoni);*
- Rainbow darter (*Etheostoma caeruleum*); and
- American Brook Lamprey (*Lethenteron appendix*).

Occurrences of migratory salmonids have been recently documented and much of Berczy Creek is also known habitat for Redside Dace. In addition to its Provincially Endangered status, it is also listed on the federal Species at Risk Act as Special Concern. Records as recent have 2005 have been documented for reaches just downstream of the golf course lands and existing populations are known in other nearby reaches.

The report classifies Bruce Creek as a riverine warm water system. Groundwater discharge areas are present just upstream of the subject property but the influence of several golf courses and urbanization cause a warming effect, which results in the warm water designation. FMZ 3 is managed for the following key target species:

- Redside dace (*Clinostomus elongatus*);
- Brook trout (*Salvelinus fontinalis*);
- Rainbow darter (*Etheostoma caeruleum*);
- Mottled sculpin *(Cottus bairdi)*; and
- American Brook Lamprey (*Lethenteron appendix*).

According to the report, Bruce Creek provides very high quality fish habitat that supports Brook Trout (Salvelinus fontinalis) in the upper reaches (upstream of the subject property), and an abundant Redside Dace population through the mid-lower reaches (including through the subject property). Similar to Berczy Creek, records as recent as 2005 have been documented at a sampling site immediately downstream of 16th Avenue. The reaches that flow through the subject property also have documented occurrences of migratory salmonids. The overall species profile for Bruce Creek is primarily warmwater with at least 26 species identified in recent years. Water quality is considered 'very good' in the mid to lower reaches of the subwatershed. Bruce Creek is the only watercourse with such a rating in the entire Rouge River watershed. The thermal rating was classified as unstable.

2.2 City-Wide Stream Erosion Master Study Update (AECOM, 2014)

As an update to the 2007 Erosion Restoration Implementation Plan, the City of Markham completed a City-Wide Stream Erosion Study Update (prepared by AECOM, 2014) to re-examine previously identified erosion concerns and document new sites. Of the watercourse reaches delineated within the City's municipal boundary, three were relevant to the subject property: Reaches BRU-3 and BRU-2 (Bruce Creek) and BZ-2 (Berczy Creek). Reach BRU-3 captures almost the entire length of the Bruce Creek within the subject property, with the exception of the portion of Bruce Creek just upstream of 16th Avenue. This portion was delineated as part of BRU-2 which extended downstream of Toogood pond to the Carlton Road crossing in Unionville. Reach BZ-2 encompasses the entire portion of Berczy Creek within the subject property and extends just south of 16th Avenue.

Through the study, two (2) major erosion sites were identified on BRU-2, and five (5) major and one (1) minor erosion sites were identified on BZ-2. The erosion sites were prioritized based on risk to public safety and infrastructure, and degree of channel instability. Conceptual remediation designs were developed to address localized bank erosion at two (2) erosion sites on Berczy Creek (BZ-ES-12 and BZ-ES-14) within the subject property as part of the study.

3. Planning and Environmental Policy Context

The following Federal, Provincial, Regional, TRCA and Municipal planning and environmental policies are applicable to this report:

3.1 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).

3.2 Region of York Official Plan (2009)

The Region of York Official Plan was adopted in 2009 and approved by the Ministry of Municipal Affairs and Housing in September 2010 incorporating several modifications. The OP identifies a Regional Greenlands System. The policies detailed in the plan are intended to identify, protect and restore the Greenlands System as a permanent resource for the Region. Lands designated Greenlands in the Region of York Official Plan are subject to development constraints.

The boundaries and extent of the Greenlands System identified on Map 2 of the Official Plan are approximate. Specific delineation or clarification of greenland boundaries may be undertaken when applications for development are received. Refinements to the boundaries may occur through environmental evaluation, and do not require an amendment to the plan.

Development applications within or on lands close to the Greenlands System must be accompanied by an environmental evaluation of impacts the development will have or is expected to have on the environmental functions, attributes, or linkages of the Greenlands System. The evaluation must also provide the details of any mitigation measures that will ensure that the Greenlands features will not be adversely impacted.

3.3 Town of Markham Official Plan (1987)

Markham's new Official Plan was adopted by Council on December 10, 2013, and approved by York Region on June 12, 2014. The new Official Plan has been appealed to the Ontario Municipal Board and is not yet in force. Until an Ontario Municipal Board decision to approve all or part of the new Official Plan has been made, the current Official Plan (Revised 1987), as amended, continues to remain in force and hence has been reviewed and applied to the subject property.

Schedule A (Land Use) identifies the subject property as Open Space, Hazard Land and the north east corner as Future Urban Area. Schedule I (Environmental Protection Areas) of the Markham Official Plan identifies Valleylands on the subject property which includes the Hazard Lands depicted on Schedule A. As outlined in the Markham OP:

> ‘*Environmental Protection Area identifies lands and water bodies containing natural features and/or ecological functions of such significance to the Town or sensitivity to disturbance as to warrant long term protection. Corresponding objectives for their preservation will be implemented through detailed policies which address specific subcategories as follows:*
>
> - *Locally Significant Area Complexes;*
> - *Valleylands including HAZARD LANDS designated on Schedule ‘A’ - LAND USE; and*
> - *Woodlots and other Significant Vegetation Communities.’*

Section 2.2.2.9 c) and f) of the Official Plan speaks to Environmental Buffers, which calls for the minimum width of an environmental buffer to be 10 m from the stable top of bank or predicted stable top of bank or the Regulatory Flood Line, drip line of the trees at the edge of the woodlot, or as defined by an Environmental Impact Study.

3.3.1 Greenway System

Appendix Map 1 of the Town of Markham OP identifies Bruce Creek, Berczy Creek, the eastern woodlot and a Bruce Creek Tributary as part of the Greenway System (Beacon, 2016).

The purpose of the Greenway System was to:

- Support ecological functions;
- Provide access to natural areas; and,
- Provide continuous trails linking the Town's Greenway System with the Rouge Park, the Oak Ridges Moraine and the Don River Valley south of Steeles Avenue.

The Greenway System as shown on Map 4 in the City of Markham 2014 OP incorporates the same areas/features as the 1987 Greenway System, with one exception, the 2014 Greenway System does not include the Bruce Creek tributary.

3.4 Endangered Species Act (2007)

The reaches of Bruce and Berczy Creeks within and adjacent to the subject property have been classified by the Ontario Ministry of Natural Resources and Forestry (MNRF) as watercourses that are being used, or were used at any time during the previous 20 years, by a Redside Dace, and that provide suitable conditions for a Redside Dace to carry out its life processes. This minnow species and its habitat receive protection under the *Ontario Endangered Species Act* (*ESA*, 2007). Redside Dace occupied habitat is defined under Ontario Regulation 242/08 as any part of a stream or other watercourse, the area encompassing the meander belt width of said watercourse, and the vegetated area or agricultural lands that are within 30 metres of the meander belt width.

3.5 Toronto and Region Conservation Authority Regulations and Guidelines

3.5.1 Conservation Authorities Act (Ontario Regulation 166/06)

The Toronto and Region Conservation Authority (TRCA) regulates land use activities in and adjacent to wetlands, watercourses and valleylands under Ontario Regulation 166/06 (*Regulation for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*) made under the *Conservation Authorities Act.*

Subject to conformity with the municipality's Official Plan, the completion of appropriate studies and application for Conservation Authority permits, The Authority may grant permission for development within these areas if it can be proven that control of flooding, erosion, pollution or the conservation of land will not be affected by the development.

3.5.2 The Living City Policies (2014)

The TRCA's Living City Policy was approved in November 2014 and replaces the Valley and Stream Corridor Management Program (1994). The Living City Policy document, among other matters, implements current federal, provincial and municipal legislation, policies and agreements affecting conservation authorities; and implements the policies for TRCA's updated section 28 of Ontario Regulation 166/06. For purposes of implementing TRCA's Environmental Management Policies:

a) Confined River or Stream Valleys are considered **Valley Corridors**; and
b) Unconfined River or Stream Valleys are considered **Stream Corridors**.

According to the Living City Policy, the boundaries of a valley or stream corridor generally require a minimum 10 m setback from the greater of:

- Physical top of the valley feature;
- Long term stable top of slope, where geotechnical concerns exist (which must be confirmed through an appropriate geotechnical analysis);
- Regulatory floodplain;
- Meander belt; and
- Limits of significant vegetation which is contiguous with the valley corridor.

It is the policy of TRCA:

> *"That erosion hazard limits will be determined through site specific field investigations and technical reports where required, in accordance with the text of TRCA's Regulation and Provincial and TRCA standards. Where erosion hazard limits are required and not available, or where existing erosion hazard information does not meet current Provincial or TRCA standards, TRCA may require the erosion hazard to be determined by a qualified professional, at the expense of the proponent, to the satisfaction of TRCA."*

The Belt Width Delineation Procedures (Parish Geomorphic Ltd., 2004) document outlines standards for delineating the meander belt width in TRCA jurisdiction.

4. Characterization of Existing Conditions

4.1 Reach Delineation

To facilitate a systematic evaluation of the portions of Bruce Creek and Berczy Creek within the subject property, the watercourses were delineated into reaches (**Figure 2**). 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).

The determination of reach extents was initially based on a desktop evaluation of degree of valley confinement, sinuosity, and transitions in riparian vegetation. Verification of reach limits was undertaken in the field to confirm that the extent of mapped features accurately reflected existing

Stantec
BEACON ENVIRONMENTAL
BURNSIDE

1:8,000

0 45 90 180 270 360

Legend

- Subject Property
- Watercourse
- Reach Break
- Surface Drainage Feature
- Enclosed Water Supply
- Photo Locations

First Base Solutions, 2014. First Base Solutions Web Mapping Service York Region 2014 Air Photo.
Beacon Environmental, 2016. Reach Extents, Reach Breaks, Watercourse, Enclosed Water Supply, Photo Locations, Subject Property

MASTER ENVIRONMENTAL SERVICING PLAN FOR 4134 16TH AVE

FIGURE 2: Reach and Photo Locations

UTM Zone 17 N, NAD 83

Project 215200.1
September 2016

conditions and underlying geomorphic controls. It should be noted that, where appropriate, reach delineation extended beyond the property limits to capture portions of reach that were relevant to the subject property. Field confirmation of reach extents and existing conditions was limited to mapped features within the property boundary, and those lands beyond the subject property that are in public ownership.

4.2 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, for the unconfined portions of the watercourses, 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.

4.2.1 Historic Assessment

The following section presents an overview of historic conditions in the vicinity of the subject property with respect to land use, land cover and channel conditions. Historic analyses provide insight into the scale of natural and human-induced changes within a watershed, particularly the degree to which channel planform adjustment and land use has changed over time. In support of the historic 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** and **Table 1**).

Table 1 provides a summary of specific observations regarding change in channel planform and land use based on available historical aerial imagery.

Table 1. Summary of Key Historical Observations

Time Period	Scale, Source	Observations
1961	1:12,000 Northway Photomap/Remote Sensing Ltd.	Forested areas converted to agricultural fields, with hedgerows, isolated pockets of forest cover and naturally vegetated areas restricted to the Berczy and Bruce Creek valley systems.
		Both the Berczy Creek and Bruce Creek channels are observed to have moderately sinuous planforms and are well-defined. Evidence active adjustment include the presence of avulsion (oxbow) scars within the floodplain, and bank erosion at meander bend (channel migration).
		Existing disturbances to Berczy and Bruce Creeks include several informal lane crossings, and the 16th Avenue and Warden Road crossings. West of the subject property, an online pond with an island can be observed on Berczy Creek.
		An open drainage feature can be observed draining to Bruce Creek within the subject property.
		Construction of Glenbourne Park Drive, northwest of the subject property, can be observed.

Time Period	Scale, Source	Observations
		A few residential homes can be observed along Kennedy Road, just north of 16th Avenue.
1974	1:12,000 Northway Photomap/Remote Sensing Ltd.	The majority of York Downs Golf and Country Club, including the Club House and maintenance building, has been constructed.
		Modifications to Bruce Creek associated with land use change included extensive channelization of the watercourse, and the construction of five (5) irrigation ponds within the floodplain. Eight (8) cart path crossings of Bruce Creek can be observed. With isolated exceptions, manicured grass and fairway extend to the edge of active watercourse.
		Modifications to Berczy Creek the construction one (1) cart path and the transition of naturalized buffer to manicured grass and fairway along the active watercourse.
		Berczy Creek has been straightened to accommodate the widening of 16th Avenue and associated crossing structure.
		Portions of the Bruce Creek open drainage feature have been piped to accommodate the golf course.
		Residential development can be observed along Glenbourne Park Drive and Cachet Parkway, northwest of the subject property. Residential development has also occurred south of 16th Avenue.
		Downstream of the confluence of Berczy and Bruce Creeks, Toogood Pond can be observed.
2002	1:15,000 First Base Solutions	The York Downs golf course has expanded. An additional **crossing of Bruce Creek** can be observed. **Two (2) additional cart path crossings of Berczy Creek** can be observed.
		A stormwater facility has been constructed in the north east corner of the subject property at the upstream extent of the **Bruce Creek drainage feature. The drainage feature has been enclosed along the majority of its length.**
		Increased residential development within the lands surrounding the subject property. Angus Glen Golf Club has been constructed along Bruce Creek to the north of the subject property.
2012	1:15,000 First Base Solutions	An additional irrigation pond can now be observed adjacent to the golf club house parking lot within the subject property. Additional residential development observed north of the subject property and east of Kennedy Road.

4.2.2 Stream Corridors (Unconfined Valley Settings)

Following the TRCA (2004) Chapter 5 procedures, the meander belt width was initially delineated for all unconfined portions of watercourse based on the position of governing meander bends within each reach. Using high resolution digital aerial imagery, historical imagery and topographic mapping, these belt width limits were then refined to ensure that the dimension was also sufficient to capture areas historical channel locations and zones of frequent inundation. The resultant preliminary belt widths are presented in **Table 2**. In accordance with the TRCA (2004) procedures, a 20% factor of safety (10% either side) was then applied to the preliminary belt width dimensions in order to account for long-term adjustments in channel form (channel erosion and migration), as well as potential post-development changes in hydrologic regime.

To review the meander belt width dimension, an empirical modelling approach was also employed that considers the channel dimensions, referencing geomorphic field data. To determine the belt width (B_w), 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 a 20% factor of safety, was applied.

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

The results of the empirical relation analysis, which are summarized in **Table 2**, generally correlated to the desktop approach, with Reaches BR-2 and BER-3 representing notable outliers.

Recommended meander belt width dimensions presented in **Table 2** and **Figures 3A/3B** are based on the desktop mapping approach, and were verified through the field investigation (refer to **Section 4.3**) for the determination of erosion hazard limits for unconfined reaches. The recommended belt width dimensions include a 20% factor of safety which was deemed sufficient to account for long-term adjustments in channel form (channel erosion and migration) under the post-development condition.

It should be noted that while a meander belt width of 84 m is recommended for Reach BER-5 to provide continuity to this assessment, this reach was not walked as part of the field investigation. The belt width dimension for BER-5, instead, referenced historical and recent aerial imagery, and reference reaches immediately upstream and downstream (BER-4 and BER-6).

4.2.2.1 Erosion Hazard Limit

The erosion hazard limit for unconfined valley systems, as defined under the Provincial Policy Statement (MMAH, 2014), is delineated by the greater of the meander belt (**Table 2**) or flooding hazard limit, plus an additional erosion access allowance. In accordance with Provincial Policy, TRCA (O. Reg. 166/06) generally requires that an erosion access allowance of 10 m be applied to the greater of the meander belt or regulatory floodline. **Figure 5** of the Natural Environment Report/Environmental Impact Study (Beacon, 2016) summarizes environmental constraints relevant to the subject property.

Table 2. Recommended Meander Belt Widths

Reach	Empirical Approach			Desktop Approach (Field Verified)		Recommended Meander Belt Width (m)
	Williams – Area (m) (1986)	Williams – Width (m) (1986)	Ward – Width (m) (2001)	Preliminary Belt Width (m)	Preliminary Belt Width plus 20% Factor of Safety (m)	
BR-2	72	56	75	100	120	**120**
BR-3	68	61	81	80	96	**96**
BR-4	67	56	75	80	96	**96**
BR-5	66	62	82	80	96	**96**
BER-3	53	43	58	130	156	**156**
BER-4	66	55	73	70	84	**84**
BER-5	Not Relevant to Subject Property (Reference Reach Approach)					**84**
BER-6	42	42	57	70	84	**84**

4.2.3 Valley Corridors (Confined Valley Settings)

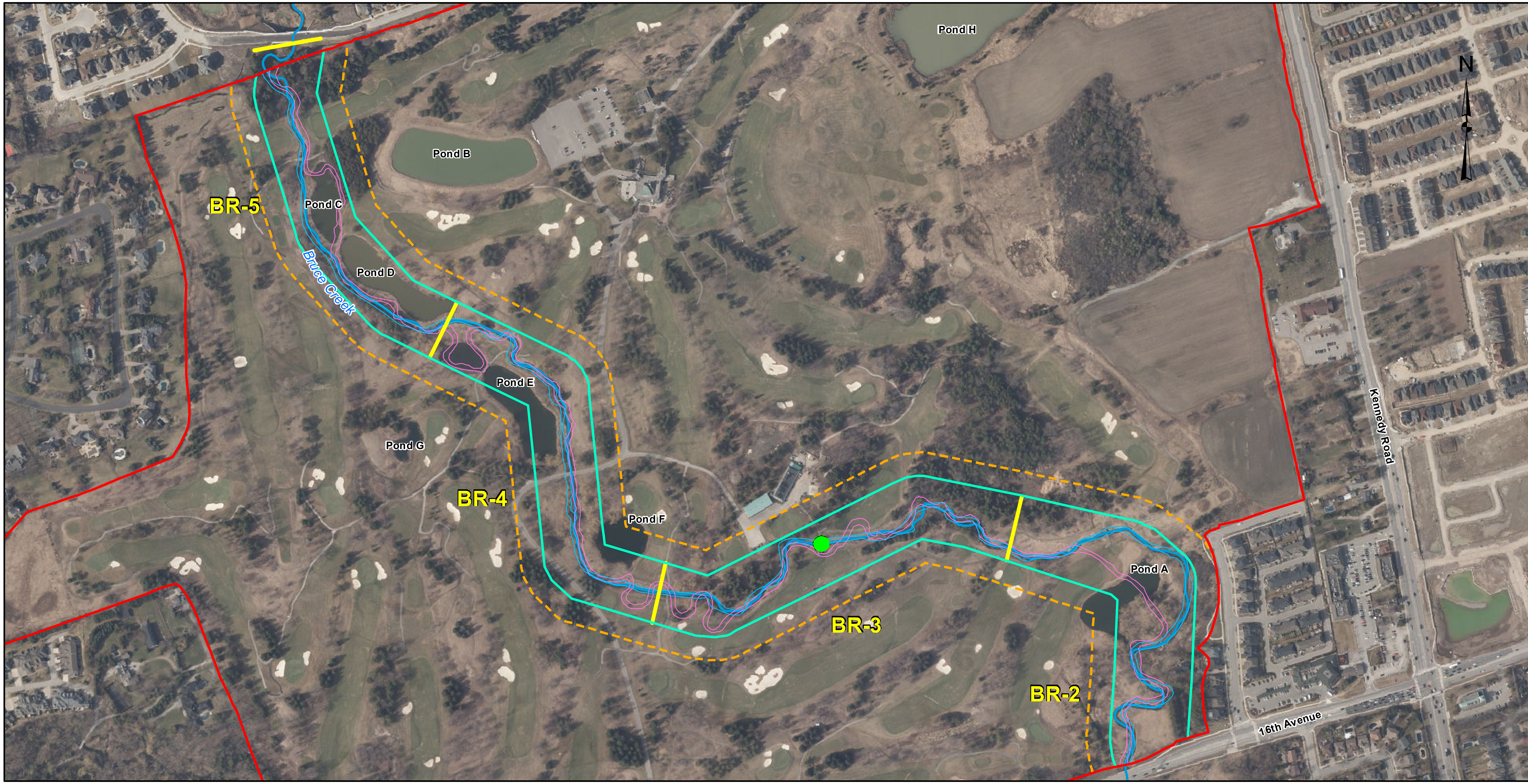
4.2.3.1 Toe Erosion Allowance (MMAH, 2014)

Portions of Bruce Creek and Berczy Creek within or adjacent to the subject property are situated within a confined valley system. A detailed geotechnical study is required to determine the erosion hazard limit for such areas. Technical support to geotechnical studies is typically provided from a geomorphic perspective through the recommendation of a toe erosion allowance. A toe erosion allowance setback should be applied in the determination of the long-term stable slope at any location where the watercourse is within 15 metres of the base of the valley wall (MMAH, 2014).

Bruce Creek

A geotechnical study for the subject property was completed by Golder Associates (2016). Two (2) boreholes were completed in the vicinity of the creek to acquire soil conditions at creek elevation. Based on soil consisting of stiff to hard sandy silty clay till and sandy clayey silt till and referencing MNR Guidelines (Table 3, 2002), a toe erosion allowance of 8 m was recommended.

From a geomorphic perspective, the 8 m toe erosion allowance is considered appropriate, as it is in accordance with Provincial Policy (MMAH, 2014) and is reflective of field observations relating to soil



Stantec
BEACON ENVIRONMENTAL
BURNSIDE

1:5,000

0 25 50 100 150 200

Legend

- Subject Property
- Reach Break
- Watercourse
- Historic Watercourse (1974)
- Historic Watercourse (1961)
- Meander Belt Width
- Meander Belt + 30m
- Bruce Creek Detailed Field Site

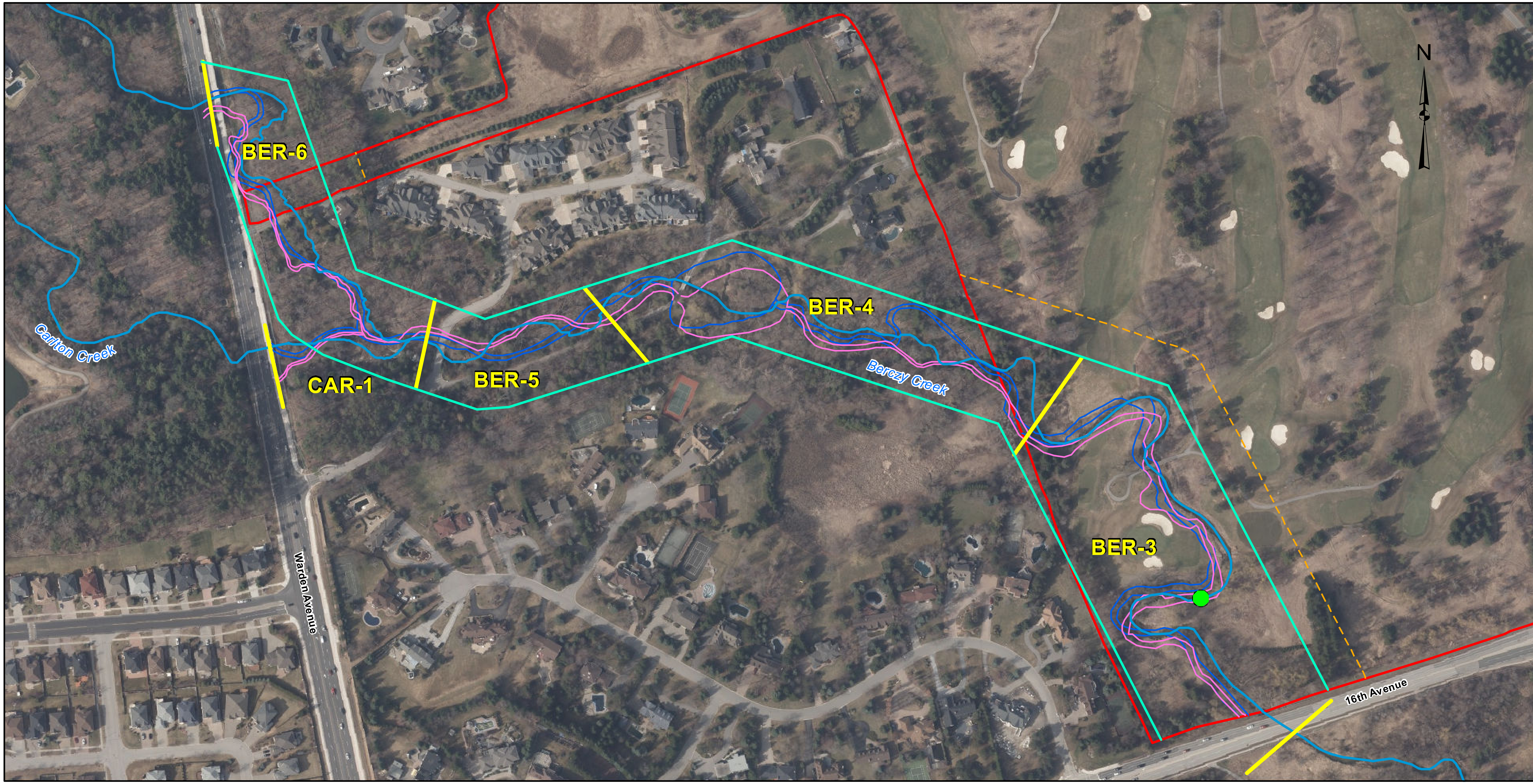
First Base Solutions, 2014. First Base Solutions Web Mapping Service,York Region 2014 Air Photo. Beacon Environmental, 2016. Reach Extents, Reach Breaks, Watercourse, Subject Property

MASTER ENVIRONMENTAL SERVICING PLAN FOR 4134 16TH AVE

FIGURE 3A: Meander Belt Width

UTM Zone 17 N, NAD 83

Project 215200.1
September 2016



Stantec
BEACON ENVIRONMENTAL
BURNSIDE

1:3,000

0 15 30 60 90 120

Legend

- Subject Property
- Reach Break
- Watercourse
- Historic Watercourse (1961)
- Historic Watercourse (1974)
- Meander Belt Width
- Meander Belt + 30m
- Berczy Creek Detailed Field Site

First Base Solutions, 2014. First Base Solutions Web Mapping ServiceYork Region 2014 Air Photo. Beacon Environmental, 2016. Reach Extents, Reach Breaks, Watercourse, Subject Property

MASTER ENVIRONMENTAL SERVICING PLAN FOR 4134 16TH AVE

FIGURE 3B: Meander Belt Width

UTM Zone 17 N, NAD 83

Project 215200.1
September 2016

composition along the relevant reaches of watercourse, and rapid assessment results pertaining to channel stability.

Berczy Creek

Golder Associates provided comments on slope stability and natural hazard setback requirements for Berczy Creek in a technical memorandum (2016). Based on a visual inspection and soil conditions from boreholes drilled in the general area (soft to hard silty clay with zones of till-like silty clay), a toe erosion allowance of 15 m was recommended. From a geomorphic perspective, this toe erosion allowance is considered conservative, and in accordance with Provincial Policy (MMAH, 2014).

Figure 5 of the Natural Environment Report/Environmental Impact Study (Beacon, 2016) summarizes environmental constraints (including the Long Term Stable Slope limit) relevant to the subject property.

4.2.4 Stream and Valley Corridors

4.2.4.1 Ontario Regulation 242/08

As Ontario Regulation 242/08 does not distinguish between confined and unconfined systems, **Figures 3A** and **3B** identify lands within 30 m of the meander belt along the entire extent of Berczy Creek and Bruce Creek within the subject property in order to delineate the limits of occupied Redside Dace habitat. This procedure is in accordance with applicable guidelines (TRCA, 2004), and it is our opinion that the findings of this report are in conformance with Ontario Regulation 242/08. **Figure 5** of the Natural Environment Report/Environmental Impact Study (Beacon, 2016) summarizes environmental constraints relevant to the subject property.

4.3 Rapid Assessments

4.3.1 Methods

In order to characterize existing geomorphic conditions along relevant portions of Bruce Creek and Berczy Creek within the subject property, rapid field assessments were conducted on October 1 and October 7, 2015. The following standardized rapid visual assessment methods were applied:

1. 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).

2. 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.

3. 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.

4.3.2 Results

Results of the rapid assessments are summarized in **Table 3** and **Table 4** below. A photographic record of site conditions at the time of the assessment is provided in **Appendix B**. Photo locations are shown in **Figure 2**.

Bruce Creek

4.3.2.1 Reach BR-2

Reach BR-2 was characterized as a low-moderately sinuous, historically straightened channel situated within a partially confined valley setting. The reach displayed a moderate gradient and low degree of entrenchment. Riparian vegetation was characterized as fragmented, extending 5-25 m laterally and consisted of shrubs and herbaceous species with few trees. Channel morphology was heavily influenced by the grade control and backwater effect of Toogood Pond. Bank angles were steep with 30-100% of banks exhibiting erosion in the form of scour, slumping and undercutting. Bank materials were dominated by sand. Bankfull channel dimensions ranged from 5.5-8.7 m in width and 0.75-1.0 m in depth. Existing channel disturbances included the 16th Ave crossing, a 1250 mm pond outlet, and cart path and trail crossings.

Rapid assessment results indicated that Reach BR-2 was 'in adjustment', with a score of 0.43. Widening was identified as the dominant mode of adjustment with aggradation and planimetric form adjustment and degradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris, basal scour through both sides of channel through riffles and slumping banks. Planimetic form adjustment was documented by chute formation, misaligned thalweg and poorly formed bars. Evidence of aggradation was observed via siltation, lateral bar formation and coarse material embedded in riffles. Degradation was noted in the form of exposed bridge/culvert footings and a visible suspended armour layer in the bank. An RSAT score of 16.5 indicated a 'fair' degree of overall ecological health, with channel stability and riparian habitat conditions identified as the primary limiting factors. The Downs model reflected the RGA evaluation of this reach through a classification of M - ‘lateral migration’ and R - ‘recovering’ based on observed evidence of migration at most bends within a previously straightened channel.

4.3.2.2 Reach BR-3

Reach BR-3 was characterized as a well-defined channel situated within a partially confined valley setting. The reach displayed a moderate gradient and moderate degree of entrenchment. Riparian vegetation was characterized as fragmented, extending <1-5 channel widths laterally. Vegetation consisted of trees, shrubs and herbaceous species. Bank angles ranged from moderately steep to steep. Bank materials were dominated by sand. Bankfull widths and depths ranged from 9.0-9.8 m and 0.7-1.55 m, respectively. Riffle substrate consisted of sand, gravel and cobble with scattered boulders. Pool substrate consisted of clay/silt and sand at the margins and gravel and scattered boulders. Evidence of active erosion was observed in the form of undercutting, basal scour and slumping. Historically, the upstream portion of the reach has been channelized.

Rapid assessment results indicated that Reach BR-3 was ‘in adjustment’, with a score of 0.52. Widening was identified as the dominant mode of adjustment with degradation, planimetric form adjustment and aggradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris, basal scour through greater than 50% of the reach including both sides of channel through riffles, outflanked gabion baskets, exposed previously buried pipe and slumping banks. Degradation was noted in the form of exposed bridge/culvert footings, undermined gabion baskets, a visible suspended armour layer in the bank and channel worn into undisturbed overburden (till). Planimetic form adjustment was documented via chute formation, misaligned thalweg and poorly formed bars. Evidence of aggradation included observed deposition in the overbank zone and coarse material embedded in riffles. An RSAT score of 19.5 indicated a ‘fair’ degree of overall ecological health, with channel stability and riparian habitat conditions identified as the primary limiting factors. The Downs model reflected the RGA evaluation of this reach through a classification of M - ‘lateral migration’ based on observed evidence of migration at most bends.

4.3.2.3 Reach BR-4

Reach BR-4 was characterized as a straightened, well-defined channel situated within an unconfined valley setting. The reach displayed a moderate gradient and moderate degree of entrenchment. Riparian vegetation was characterized as fragmented, extending less than one channel width laterally. Vegetation consisted of shrubs and herbaceous species, with few trees. Bank angles were steep with some banks displaying erosion and undercutting. Bank materials were dominated by sand. Bankfull channel dimensions ranged from 6.0-10.7 m in width and 0.85-1.25 m in depth. Riffle substrate consisted of sand to cobble and pool substrate ranged from clay/silt to gravel. Existing channel disturbances included an internal road crossing for the golf course, as well as cart path crossings and, tile drain outlets and pond outlet. Historically, the reach has been channelized.

Rapid assessment results indicated that Reach BR-4 was ‘in transition’, with a score of 0.37. Widening was identified as the dominant mode of adjustment with degradation, planimetric form adjustment and aggradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris, basal scour on both sides of the channel through riffles and slumping banks. Planimetric form adjustment was observed through misaligned thalweg and poorly formed bars. Evidence of aggradation was observed via lateral bar formation and coarse material embedded in riffles. Degradation was noted in the form of exposed bridge/culvert footings and a visible suspended armour layer in the bank. An RSAT score of 17 indicated a 'fair' degree of overall ecological health, with channel stability and riparian habitat conditions identified as the primary limiting factors. The Downs model reflected the RGA evaluation of this reach through a classification of m - 'lateral migration' based on observed alternating bank erosion in a previously straightened channel.

4.3.2.4 Reach BR-5

Reach BR-5 was characterized as a well-defined channel situated within a partially confined valley setting. The reach displayed a moderate gradient and moderate degree of entrenchment. Riparian vegetation was characterized as fragmented extending less than one channel width laterally. Vegetation consisted of herbaceous species with some trees. Banks were steep with most banks displaying evidence of active erosion including scour and slumping. Bank materials were dominated by sand. Bankfull channel dimensions ranged from 5.9-12.6 m in width and 0.7-0.9 m in depth. Riffle substrate consisted of particles ranging from sand to cobble with some scattered boulders. Pool substrate consisted of mostly sand. Existing channel disturbances included golf cart and pedestrian crossings. Historically, the reach has been channelized.

RGA results indicated that Reach BR-5 was 'in transition', with a score of 0.35. Widening was identified as the dominant mode of adjustment with degradation, planimetric form adjustment and aggradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris, basal scour on both sides of the channel through riffles and slumping banks. Planimetic form adjustment was observed through chute formation, misaligned thalweg and poorly formed bars. Degradation was noted in the form of exposed bridge/culvert footings and channel worn into undisturbed overburden (till). Minor evidence of aggradation in the form of later bar formation was observed. An RSAT score of 18.5 indicated a 'fair' degree of overall ecological health, with riparian habitat conditions and channel stability identified as the primary limiting factors. The Downs model reflected the RGA evaluation of this reach through a classification of m - 'lateral migration' based on observed alternating bank erosion in a previously straightened channel.

Berczy Creek

4.3.2.5 Reach BER-3

Reach BER-3 was characterized as a well-defined channel situated within a partially confined valley setting. The reach displayed a moderate sinuosity, gradient and degree of entrenchment. Riparian vegetation was characterized as fragmented, extending less than one channel width laterally. Vegetation consisted of grasses and herbaceous species, with mature trees along the valley slopes. Bank angles were moderately steep to steep with most banks displaying erosion including slumping. Bank materials were dominated by sand and silt with some clay. Bankfull channel dimensions ranged from 5.0-11.3 m in width and 0.7-1.6 m in depth. Riffle substrate consisted of sand and gravel and pool substrate was comprised of silt, sand, gravel and till. Existing channel disturbances included tile drains, pedestrian crossing, gabion baskets and stone toe protection.

Rapid assessment results indicated that Reach BER-3 was 'in adjustment', with a score of 0.46. Widening was identified as the dominant mode of adjustment with planimetric form adjustment degradation, and aggradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris basal scour through greater than 50% of the reach including both sides of channel through riffles and inside meander bends and slumping banks. Planimetic form adjustment was observed through chute formation, misaligned thalweg and poorly formed bars. Degradation was noted in the form of exposed bridge/culvert footings, undermined gabion baskets and channel worn into undisturbed overburden (till). Minor evidence of aggradation in the form of later bar formation and deposition in the overbank zone was observed. An RSAT score of 19.5 indicated a 'fair' degree of overall ecological health, with channel stability and riparian habitat conditions identified as the primary limiting factors. The Downs model reflected the RGA evaluation of this reach through a classification of U – 'undercutting' based on observed erosion along outer bank, scoured bed and low embeddedness.

4.3.2.6 Reach BER-4

Based on the extent assessed, Reach BER-4 was characterized as a well-defined channel situated within a partially confined valley setting. The reach displayed a moderate sinuosity and gradient and low degree of entrenchment. Riparian vegetation was characterized as fragmented extending 6.0-30 m laterally. Vegetation consisted of deciduous and cedar trees and shrubs. Bank angles were moderately steep with bank treatment failure and undercutting. Bank materials were dominated by silt and fine sand. Bankfull channel dimensions ranged from 6.0-8.6 m in width and 0.8-1.3 m in depth. Riffle substrate was comprised of gravel and cobble with some sand and pool substrate was comprised of silt, sand and fine gravel.

Rapid assessment results indicated that Reach BER-4 was 'in adjustment', with a score of 0.43. Widening was identified as the dominant mode of adjustment with planimetric form adjustment degradation, and aggradation as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, large organic debris, basal scour on inside meander bends and outflanked bank treatments. Planimetic form adjustment was observed through chute formation, misaligned thalweg and poorly formed bars. Degradation was noted in the form of undermined crib walls, cut face on bar formations and channel worn into undisturbed overburden (till). Minor evidence of aggradation in the form of later bar formation and deposition in the overbank zone was observed. An RSAT score of 19 indicated a 'fair' degree of overall ecological health, with riparian habitat conditions and physical instream habitat identified as the primary limiting factors. The Downs model classified the reach as U – 'undercutting' based on observed erosion along outer bank, scoured bed and low embeddedness.

4.3.2.7 Reach BER-6

Based on the extent assessed, Reach BER-6 was characterized as a well-defined channel situated within an unconfined valley setting. The reach displayed a moderate sinuosity, gradient and degree of entrenchment. Riparian vegetation was characterized as fragmented extending 6.0-30 m laterally. Vegetation consisted of established trees, shrubs and herbaceous species. Bank angles were moderately steep with bank treatment failure and undercutting. Bank materials were dominated by silt and fine sand. Bankfull channel dimensions ranged from 6.5-6.6 m in width and 0.55-0.6 m in depth. Riffle substrate was comprised of gravel, cobble, boulder and till and pool substrate was comprised of clay/silt, sand and fine gravel. Existing channel disturbances included Warden Ave crossing, debris jam, pedestrian crossing and road runoff outlet.

Rapid assessment results indicated that Reach BER-4 was 'in transition', with a score of 0.21. Widening was identified as the dominant mode of adjustment with degradation and planimetric form adjustment as secondary processes. Evidence of widening was observed in the form of leaning/fallen trees, exposed tree roots, basal scour on inside meander bends and outflanked bank treatments. Degradation was noted in the form of exposed bridge footings, undermined bank protection, and channel worn into undisturbed overburden (till). Minor evidence of planimetic form adjustment was observed through poorly formed bars. An RSAT score of 18 indicated a 'fair' degree of overall ecological health, with riparian habitat conditions and physical instream habitat identified as the primary limiting factors. The Downs model classified the reach as M – 'lateral migration' based on observed migration of most bends.

4.3.2.8 Ponds and Surface Drainage Features

There are a total of eight (8) ponds on the subject property, five of which are located within the Bruce Creek floodplain (Ponds C to F, and Pond A). The remaining ponds are located in the northeast corner of the property (Pond H – existing SWM Pond), one near the clubhouse (Pond B) and a smaller pond within the golf course (Pond G).

Several surface drainage features were identified through aerial photo interpretation and were investigated as part of the field program (**Figure 2**). All of these features are highly altered as a result of historic agricultural land use practices, and the current golf course land use. A description of their current form is provided in this section. A photographic record of conditions observed at the time of survey is provided in **Appendix B**.

<u>Ponds</u>

Pond A is located at the southern extent of the property adjacent to Bruce Creek. The water level in this pond is controlled with a spillway. Overflow from the pond spills into Bruce Creek.

Pond B is used for irrigation purposes and was constructed after 2009. This pond is contained within a large berm and does not discharge to Bruce Creek.

Ponds C and D, function in series with an outlet at the south end and are used for golf course hazards and historically for irrigation purposes. Pond E is used for golf course hazard and backup irrigation purposes. Through discussions with golf course staff, it is our understanding that these ponds have not overtopped their banks in this history of the golf course.

Pond G is an isolated golf course hazard pond with no connection to Bruce Creek.

Pond H is a SWM pond that receives drainage from the existing Upper Unionville community development east of Kennedy Road, and possible surface water run-off from Surface Drainage Feature A (SDF-A). Pond H discharges in three different ways to three different locations as described below:

- To Bruce Creek via an existing storm sewer outfall;
- Auxiliary pipe connection to Pond E to augment water for irrigation (Pond H was retrofitted in the early 2000's with a pipe and valve system and water was conveyed through a pipe under Bruce Creek and discharged in to Pond E as a backup); and

- A valve at the outlet of the pond historically conveyed flows via a buried stone trench to an area of open conveyance (refer to **Figure 2**, **Photo Location #68**). However, the control valve is not functional; in the event of a large precipitation event, flow is conveyed overland (refer to **Figure 2**, **Photo Location #67**).

Surface Drainage Feature A

Surface Drainage Feature A (SDF-A) is small undefined drainage feature that appears to originate near Kennedy Road and drains into Pond H in the northeast corner of the property. Pond H currently services the Upper Unionville community development. A valve at the outlet to Pond H controlled discharge from the pond historically, but it is no longer functional and was not observed to be flowing during the field investigation. Consequently, SDF-A terminates in Pond H.

Surface Drainage Feature B

Surface Drainage Feature B (SDF-B) originates from a pipe that conveys flow from irrigation and rain events across the driving range and discharges at the top of the open, vegetated area through a pipe. Water has been observed flowing from this outfall during the site visits but not from the Pond H stone trench outfall. Localized pockets of standing water and saturated soil conditions were observed at the time of survey within this open area. SDF-B flow is then conveyed through a pipe under the golf course fairway and outlets in a wooded area. A small, intermittently-defined, meandering feature traverses this area. Standing water conditions were observed at the time of survey. SDF-B is then conveyed via another pipe until it outlets into a forested area along the Bruce Creek corridor, where it converges with flow from SDF-C, then splits into two features and finally discharges into Bruce Creek. At the time of survey, the majority of flow being conveyed to Bruce Creek was observed in the eastern drainage feature.

Surface Drainage Feature C

Surface Drainage Feature C (SDF-C) originates in the eastern woodlot/wetland. The feature is poorly defined with extensive vegetative encroachment. Standing water with very minimal flow was observed within this upper portion of the feature during the field investigation. The feature is then piped under the golf course fairway for approximately 80 m where it flows into an open channel in the Bruce Creek wooded area. Drainage is conveyed through the open feature for a distance of approximately 50 m before flowing through a second culvert under a the fairway. This culvert contributes flows to the piped segment of SDF-B and combined flows outlet to the Bruce Creek wooded area through a CSP culvert, where it then splits into two features and finally discharges into Bruce Creek (refer to **Figure 2**, highlighted circle).

Surface Drainage Feature D

Surface Drainage Feature D (SDF-D) is a small gully feature that outlets from a culvert at the edge of the wooded area at the top of the valley slope to Bruce Creek (Reach BR-5) near the northwest boundary of the subject property (refer to **Figure 2**, **Photo Location #82**). The feature exhibited evidence of active erosion (widening and incision) within the gully portion along the valley slope.

Surface Drainage Feature E

Surface Drainage Feature E (SDF-E) was characterized as a gully feature that originates on the west side of a golf cart trail. Surface drainage from the golf course is conveyed under the trail via a small CSP culvert which outlets into the gully feature that connects to Berczy Creek (refer to **Figure 2**, **Photo Location #85**). The channel is approximately 20 m long, poorly vegetated, and exhibits evidence of active erosion. Stone protection (cobble and small bounders) has been placed around the outlet, presumably in an effort to mitigate this erosion.

Table 3. General Reach Characteristics – Bruce Creek and Berczy Creek

Reach	Bankfull Width (m)	Bankfull Depth (m)	Substrate	Riparian Vegetation	Notes
BR-2	7.2-8.7	0.75-1.0	Clay/silt, sand, gravel, cobble and boulder	Shrubs and herbaceous species with limited trees	• Undercuts: 0.35-1.0 m • 1250 mm storm outfall • Channel morphology heavily influenced by Toogood Pond
BR-3	7.1-15.0	0.7-1.25	Clay/silt, sand, gravel, cobble and boulder, till	Trees, shrubs and herbaceous species	• Undermined and outflanked gabion baskets • Riprap bank protection • Woody debris
BR-4	6.0-10.7	0.85-1.25	Clay/silt, sand, gravel, cobble and boulder	Trees, shrubs and herbaceous species	• Undercut: 1.0 m • Slumping
BR-5	6.0-12.6	0.7-0.9	Sand, gravel, cobble and some boulder	Tress and herbaceous species	• Exposed till • Chute formation
BER-3	6.0-11.3	0.7-1.6	Silt, sand and gravel	Grasses and herbaceous species with limited trees	• Undermined gabion baskets • Exposed bridge footings • Stone toe protection
BER-4	6.0-8.6	0.8-1.3	Silt, sand, fine gravel, cobble	Trees and shrubs	• Undercuts: >1.5 m • Exposed till • Thalweg misalignment
BER-6	6.5-6.6	0.55-0.6	Clay/silt, sand, gravel, cobble and boulder, till	Trees, shrubs and herbaceous species	• Channel morphology influenced by Warden Ave crossing and road embankment

Table 4. Rapid Assessment Results – Bruce Creek and Berczy Creek

Reach	Rapid Geomorphic Assessment (RGA)			Rapid Stream Assessment Technique (RSAT)			Downs Classification Method
	Score	Condition	Dominant Mode of Adjustment	Score	Condition	Limiting Feature	
BR-2	0.43	In Adjustment	Widening with Aggradation and Planimetric Form Adjustment	16.5	Fair	Channel Stability, Riparian Habitat Conditions	M – 'lateral migration'
BR-3	0.52	In Adjustment	Widening with Degradation and Planimetric Form Adjustment	19.5	Fair	Channel Stability, Riparian Habitat Conditions	M – 'lateral migration' & R- 'recovering'
BR-4	0.37	In Transition	Widening with Planimetric Form Adjustment	17	Fair	Channel Stability, Riparian Habitat Conditions	m – 'lateral migration'
BR-5	0.35	In Transition	Widening with Planimetric Form Adjustment	18.5	Fair	Channel Stability, Riparian Habitat Conditions	m – 'lateral migration'
BER-3	0.46	In Adjustment	Widening with Planimetric Form Adjustment	19.5	Fair	Channel Stability, Riparian Habitat Conditions	U – 'undercutting'
BER-4	0.43	In Adjustment	Widening with Degradation and Planimetric Form Adjustment	19	Fair	Channel Stability, Physical Instream Habitat	U – 'undercutting'
BER-6	0.21	In Transition	Widening with Degradation	18	Fair	Physical Instream Habitat, Riparian Habitat Conditions	M – 'lateral migration'

4.4 Detailed Geomorphic Field Investigation

4.4.1 Selection Criteria for Detailed Field Sites

In support of the MESP, the purpose of undertaking detailed geomorphic data collection is to both provide calibration of the hydrologic model for more frequent return-period flow events, and determine thresholds for sediment entrainment that are used to guide the design of stormwater management facilities. The establishment of formalized geomorphic stations within the subject property will also support post-development monitoring of channel morphology. In consideration of these objectives, the selection of detailed field sites was governed by the following factors:

c) Spatial representation of the subject property;
d) Rapid assessment results which
    - Identify those reaches most sensitive to changes in land use and flow regime (i.e., exhibit evidence of instability); and
    - Classify indicators of channel instability into modes of adjustment to designate dominant processes on a reach basis, but also within the overall watercourse system;
e) Presence of a (relatively) natural channel form (i.e., minimal evidence of channelization or hardening);
f) Location of proposed location of stormwater management facilities (determine which stream reaches will receive stormwater contributions post-development); and
g) Land ownership (i.e., working within the subject property or public lands).

Based on these criteria, Reaches BER-3 and BR-3 were selected as detailed geomorphic field stations (**Figures 3A** and **3B**):

h) Both reaches provided appropriate spatial representation of the subject property;
i) RGA scores identified both reaches as the most sensitive reaches to alterations in land use and flow regime within each system based on
    - Highest overall score; and
    - Exhibiting modes of adjustment that were reflective of the overall system – specifically, both reaches exhibited evidence of bank erosion and widening which was flagged as a dominant theme along both Berczy Creek and Bruce Creek;
j) Presence of a (relatively) natural channel form
    - Results of the historic assessment identified extensive channelization along both Berczy and Bruce Creek – relative to other reaches within the subject property, Reaches BR-3 and BER-3 have retained a more natural meander geometry and channel form (i.e., sinuous planform with minimal bank protection);
k) Both reaches will receive stormwater post-development; and
l) Both reaches are located within the subject property.

By selecting the most sensitive reaches on each system, the erosion threshold will represent a conservative approach to managing the release of stormwater to Berczy and Bruce Creeks. The ultimate objective associated with this methodology is to minimize the risk of exacerbating existing rates of erosion within each watercourse (i.e., avoidance of impacts to channel morphology and aquatic habitat) under the post-development scenario.

4.4.2 Methodology and Results

Detailed geomorphic data collection was completed on various dates between December 2015 and April 2016. 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, bank materials (type and strength) and general channel condition were documented using standard field protocols. A pebble count following Wolman (1954) was completed for each surveyed cross-section. Sediment samples of riffle substrate, pool substrate, composite bed materials, and bank materials were also collected and submitted to Thurber Engineering for laboratory analysis. Selected channel parameters from the detailed assessment are provided in **Table 5**, while a detailed summary of data collection results has been provided in **Appendix C**.

4.4.2.1 Bruce Creek, Reach BR-3

Overall, the surveyed portion of **Reach BR-3** had an average bankfull gradient of 0.44%. The channel displayed a moderate degree of entrenchment, and riffle-pool bed morphology. Bankfull channel widths (riffles and pools) varied from approximately 7.1 to 15.6 m, averaging about 10.7 m. The average bankfull depth was 0.65 m, resulting in a width-to-depth ration of 16.6. Selected channel parameters from the detailed assessment are provided in **Table 5**.

Cross-section measurements, bankfull characteristics and channel roughness were used to back-calculate bankfull hydraulics. Using a simple Manning's n (0.033) approach, the calculated bankfull velocity was 1.40 m/s and the calculated bankfull discharge was 6.6 m^3/s. The flow competency and critical shear stress for D_{50} (median particle size) were calculated using Komar (1987). A comparison of flow competency calculations to bankfull hydraulics indicates that sediment entrainment theoretically occurs well below the bankfull event; however, armouring of the coarsest component of the bed materials (large gravel to cobble) will not only influence hydraulic conditions under which bed mobilization occurs, but the boundary layer associated with these materials will influence the hydraulic conditions associated with 'threshold conditions' (i.e., entrainment of the median particle size).

4.4.2.2 Berczy Creek, Reach BER-3

Overall, the surveyed portion of **Reach BER-3** had an average bankfull gradient of 0.30%. The channel displayed a moderate degree of entrenchment, and riffle-pool bed morphology. Bankfull channel widths (riffles and pools) varied from approximately 6.0 to 11.9 m, averaging about 8.7 m. The average bankfull depth was 0.67 m, resulting in a width-to-depth ration of 14.4. Selected channel parameters from the detailed assessment are provided in **Table 5**.

Cross-section measurements, bankfull characteristics and channel roughness were used to back-calculate bankfull hydraulics. Using a simple Manning's n (0.033) approach, the calculated bankfull velocity was 1.20 m/s and the calculated bankfull discharge was 7.24 m^3/s. The flow competency and critical shear stress for D_{50} (median particle size) were calculated using Komar (1987).). As with BR-3, a comparison of flow competency calculations to bankfull hydraulics indicates that sediment entrainment theoretically occurs well below the bankfull event; however, armouring of the coarsest component of the bed materials (large gravel to cobble) will not only influence hydraulic conditions under which bed mobilization occurs, but the boundary layer associated with these materials will influence the hydraulic conditions associated with 'threshold conditions' (i.e., entrainment of the median particle size).

Table 5. Summary of Field-based and Calculated Parameters – Detailed Field Sites

Parameter	BR-3	BER-3
Governing energy gradient (%)	0.44	0.30
Average bankfull width (m)	10.7	8.7
Average bankfull depth (m)	0.65	0.67
Maximum bankfull depth (m)	0.85	0.92
Average width-depth ratio	16	13
Bank angles (degrees)	20-90	
Bank materials	Silt, sand, clay, gravel (with exposed till)	Silt, sand and gravel (with exposed till, cobble, boulder)
Undercut banks (%)	44	20
D10 (mm) – riffle	--	--
D50 (mm) – riffle	9.3	6.3
D84 (mm) - riffle	49	40
Manning's n-value (estimated)	0.030	0.030
Bankfull discharge (m^3/s)	6.60	7.2
Bankfull velocity (m/s)	1.40	1.2
Unit stream power (W/m^2)	29	22
Tractive force (N/m^2)	23	20
Flow competency for D_{50} (Komar, 1987 - m/s)	0.60	0.50

5. Analysis

The following section outlines methods of analysis and results for the fluvial geomorphic component of the MESP.

5.1 Erosion Threshold Determination

Erosion and deposition are natural processes that are necessary for the maintenance of channel form and function. Changes in land use can result in changes in the magnitude and duration of surface runoff produced by rain events, which can result in increased rates of erosion. Appropriate stormwater management techniques can typically mitigate the impacts associated with land use change by reducing the magnitude of post-development storm events. Surface runoff is collected and detained in stormwater management facilities (SWMF), then released at a prescribed flow rate. Ideally, this controlled release also closely mimics the duration of pre-development storms. The total volume of post-development runoff can also be reduced through the implementation of low impact development techniques (LIDs). The overall objective of these management tools is to match, to the extent possible, pre-development flow conditions.

Erosion thresholds often represent the hydraulic parameter by which pre- and post-development flow conditions are compared. An erosion threshold defines the theoretical hydraulic conditions under which sediment is entrained and transported within the channel. Specifically, the threshold represents a depth, velocity, or discharge at which sediment of a particular size class (usually the median or average grain size material) may potentially be entrained. This does not necessarily imply that systemic erosion (i.e., widening or degradation of the channel) will occur if the threshold is exceeded; it simply indicates flow conditions at which sediment entrainment (i.e. initiation of motion of materials) is likely to occur.

The TRCA (2012) Stormwater Management Criteria, provides geomorphologic methodologies for determining erosion thresholds. **Table 6** presents an overview of threshold analysis resources presented in the TRCA guidance document.

Table 6. Overview of Commonly Applied Sediment Entrainment Models (TRCA, 2012)

Sediment Entrainment Model	Type	Range of Applicability
Chow (1959)	Critical Shear Stress	Cohesive materials (Clay and Silt)
Fischenich (2001)	Critical Shear Stress	Cohesive and non-cohesive material
Hjulstrom (1967)	Critical Velocity	Non-cohesive material (sand and coarser)
Komar (1987)	Critical Velocity	Non-cohesive material (gravel and larger)
Miller et al. (1977)	Critical Shear Stress	Non-cohesive material (sand and coarser)
Neill (1967)	Critical Velocity	Non-cohesive material (sand and coarser)
Temple (1982)	Tractive Force	Vegetated Channels
vanRijn (1984)	Critical Shear Stress	Non-cohesive material (medium sand and coarser)

5.1.1 Methodology and Results

For the purposes of this study, both Komar (1987) and Miller, *et al.* (1977) were applied to two reference riffle cross-sections for both Reaches BR-3 and BER-3 to determine hydraulic thresholds for sediment entrainment. Reach-averaged grain size distribution data (riffles and pools) was referenced to calculate the median grain size (D_{50}). It should be noted that the D_{50} for both sites fell within the fine gravel size class. Further, within both sites, hydraulic boundary roughness associated with an armoured gravel and cobble component of the bed was observed to limit the capacity of Berczy and Bruce Creeks to transport sediment under more frequent flow conditions.

In reviewing the calculated critical shear stress (Miller, *et al.*, 1977) and permissible velocity (Komar, 1987) identified for each reach based on the D_{50}, and comparing this value to flow conditions (average and maximum water depth) observed at the time of survey, it was determined that a critical shear stress represented the most appropriate hydraulic parameter by which to establish an erosion threshold for Reaches BR-3 and BER-3. Based on our analysis of each system, the Komar (1987) model under-predicted velocities required for sediment entrainment. The source of this under-prediction by the theoretical model was attributed to the lack of uniform bed materials, and the influence of the coarser bed component on boundary layer conditions (larger substrate creating a ‘sheltering’ effect).

Critical shear stress values of 9.6 N/m^2 and 6.5 N/m^2 were identified for Bruce Creek and Berczy Creek, respectively. Based on this critical shear stress, threshold-condition hydraulic parameters were then back-calculated to identify an associated maximum water depth, average water depth, velocity and discharge values that would correlate to this condition. Results of the erosion threshold analysis are presented in **Appendix D** and **Table 7**. While the recommended thresholds were based on the median grain size of the bed materials, the potential for bank erosion under threshold hydraulic conditions was also considered through this analysis. As a result, the proposed targets are considered appropriate and reflective of the morphologic processes observed along Bruce Creek and Berczy Creek within the subject property.

Table 7. Summary of Erosion Threshold Analysis – Reaches BR-3 and BER-3

Watercourse	Erosion Threshold	Threshold-Condition Hydraulic Parameters (calculated using representative cross-sections)				Threshold Discharge as a Percentage of Bankfull Discharge (%)
	Critical Shear Stress (N/m^2)	Maximum Water Depth (m)	Average Water Depth (m)	Velocity (m/s)	Discharge (m^3/s)	
Bruce Creek (Reach BR-3)	9.6	0.31	0.22	0.74	0.90	14
Berczy Creek (Reach BER-3)	6.5	0.33	0.22	0.61	0.89	12

It should be noted that, in natural systems, erosion thresholds are exceeded regularly, ensuring the downstream delivery of sediment. As such, the key to maintaining natural channel function of a system is not to prevent exceedance of the threshold, but to ensure that the frequency and duration of time for which it is exceeded does not substantively increase under the post-development conditions (i.e., existing rates of erosion should not be exacerbated under the future land use scenario). **Section 6.0** describes additional verification of the erosion threshold through integration with the pre and post-development hydrologic and hydraulic modelling being completed by Stantec Engineering, as well as the results of the erosion threshold exceedance analysis.

6. Impact Assessment

6.1 Proposed Development

The proposed residential development is detailed in the two draft plan of subdivision applications that accompany this OPA application (**Figure 1**). There is one draft plan of subdivision for the east portion of the property and one for the west portion of the property. The West draft plan of subdivision contains a mix of residential, mixed use, open space blocks, parks, and SWM ponds. The west draft plan of subdivision also contains the valleylands associated with both the Berczy creek and the Bruce creek. The East draft plan of subdivision contains a mix of residential, open space blocks, elementary school block, parks, and SWM ponds. In order to understand the potential impacts of the proposed development plan on channel morphology, an impact assessment was undertaken with respect to stormwater erosion control, in addition to road and servicing stream corridor crossings.

6.2 Stormwater Erosion Control

6.2.1 Agency Consultation

Per the TRCA Watercourse Erosion Analysis Design and Submission Requirements in Support of Secondary Plans (2007d),

> *"When preparing a Master Environmental Servicing Plan, erosion analysis is required to assess the impact of development on in-stream erosion potential, and to establish erosion control targets for Stormwater Management facilities."*

Erosion analysis objectives include the determination of erosion thresholds along reaches sensitive to erosion through desktop and field analysis, prediction of stream response to changes in flow regime as a result of development and establishment of erosion control criteria to maintain existing in-stream erosion potential under post-development conditions (TRCA, 2007d).

A meeting with the TRCA was held on June 6, 2015 to review preliminary results relating to the fluvial geomorphic assessment, and discuss MESP submission requirements relating to stormwater management for erosion control for the subject property. Based on this consultation process, the following methology was established for stormwater erosion analyses:

- Identification of reaches, of both Bruce Creek and Berczy Creek, sensitive to erosion based on collected detailed geomorphic field data;
- Referencing TRCA SWM criteria and flow conditions at the time of survey, establish thresholds for sediment entrainment for Bruce Creek and Berczy Creek;
- Estimate baseflow conditions for Bruce Creek and Berczy Creek, referencing TRCA gauging data, stream flow monitoring data, and geomorphic field data for each watercourse;
- Integrate the estimated baseflow component with the hydrologic model output (VO2) - 25 mm, 30 mm and 35 mm synthetic events;
- Calibrate and verify output from the VO2 hydrologic model by comparing the existing condition model to field-based estimates of flow (i.e., bankfull flow);
- Undertake a comparison pre- and post-development (controlled) flow conditions for the 25 mm, 30 mm and 35 mm storm events under 24 hour, 48 hour and 72 hour detention scenarios (event-based modelling) for nodes located at the downstream limit of the site to evaluate how closely post-development conditions can replicate existing condition hydrograph (peak, volume and form), focussing on those portions of the hydrograph above the critical discharge;
- Integration of the VO2 model output from the above scenarios into a software program which uses representative surveyed cross-sections of the active (bankfull) channel to calculate pre-development and post-development cumulative exceedance of the erosion threshold parameters for Bruce Creek and Berczy Creek. In this sense, continuous modelling for threshold exceedance will be undertaken for a finite time series (i.e., length of generated 25 mm, 30 mm and 35 mm storm event). Model outputs include:
  - Time of exceedance;
  - Cumulative effective velocity;
  - Cumulative effective discharge; and
  - Cumulative effective work/shear stress;

- For the purposes of the MESP, pre- to post-development flow conditions will be considered a match if post-development hours of exceedance are within 5% of the existing condition.

6.2.2 Modelled Storm Events

Field-based estimates of bankfull flow were compared to the modelled 25 mm and 2-year storm event. Results of the comparison (presented in **Table 8**) indicated a correlation between the modelled frequent flows, and the field-estimated bankfull discharge. Further, representative cross-sections from the detailed field investigation could be used to back-calculate flow depths associated with the modelled storm events (**Figure 4**)

Table 8. Verification of VO2 Synthetic Storm Events

Watercourse and Reach	Field-based Estimate Bankfull Discharge (m^3/s)	Modelled 25 mm Storm Event (m^3/s)	Modelled 2-year Storm Event (m^3/s)
Bruce Creek (Reach BR-3)	6.60	4.4	13.3
Berczy Creek (Reach BER-3)	7.24	3.6	11.5

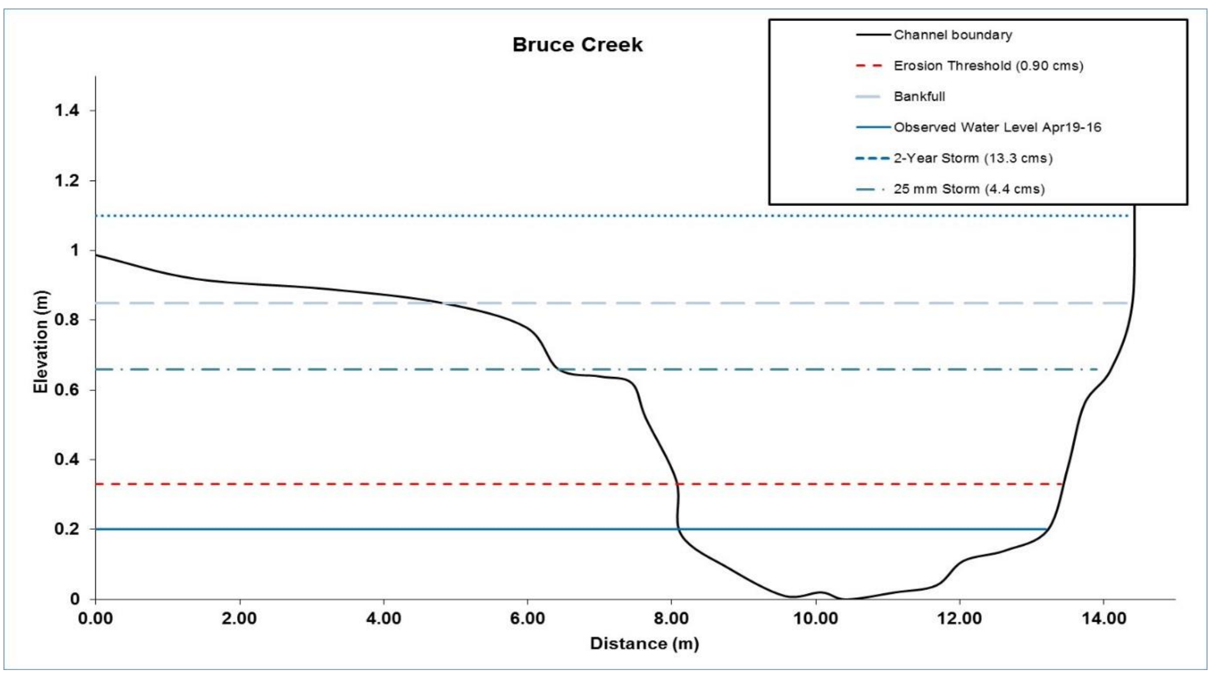


Figure 4. Sample verification of VO2 synthetic storm events (Bruce Creek).

6.2.3 Estimation of Baseflow Component

As the synthetic storm events generated by the VO2 model do not account for a baseflow condition within the watercourse, estimates of baseflow were developed for both Berczy and Bruce Creek. The estimated flows were back-calculated based on average water depths identified during the rapid field assessment work and two representative riffle cross-sections, the following baseflows were recommended:

- Berczy Creek: 0.12 cms (max water depth of 0.15 m, ave water depth of 0.08 m); and
- Bruce Creek: 0.22 cms (max water depth of 0.17 m, ave water depth of 0.12 m through riffle).

These flows were manually added to flows provided in the raw VO2 output files provided by Stantec Engineering to develop hydrographs for the 25 mm, 30 mm and 35 mm storm events which incorporated a baseflow component.

6.2.4 Exceedance Analysis (Post-Development Condition)

For the erosion control analysis, output from the V02 model provided by Stantec Engineering was analyzed using an in-house erosion analysis model. In addition to the raw hydrograph time-step data, the following input parameters are required by the model:

- Representative channel cross-section – for the bankfull channel, a representative riffle cross-section from the detailed field investigation was used. For the floodplain and corridor dimension, a representative cross-section from the HEC-RAS model was provided by Stantec;
- Energy gradient – energy gradients referenced in the determination of erosion thresholds were used for the exceedance analysis;
- Manning's 'n' roughness coefficient – a roughness coefficient of 0.033 was utilized for the bankfull channel, and a roughness coefficient of 0.08 was utilized for the floodplain and corridor; and
- Erosion threshold – the critical shear stress of 9.6 N/m^2 and 6.5 N/m^2 was utilized for Bruce Creek and Berczy Creek, respectively.

The model then iterates the hydrograph flows through the representative cross-section and calculates the cumulative exceedance for each hydraulic parameter in relation to the entered erosion threshold value. An example cross-section is provided in **Figure 5**. Effectively, the model represents a tool by which the volume, magnitude and duration of post-development hydrologic events can be compared to pre-development conditions. The erosion threshold represents the control point of comparison by which to evaluate difference and, as such, potential impact. Hydraulic parameters provided as output from the exceedance model were validated by comparing depths and flows to output data for the representative HEC-RAS cross-sections.

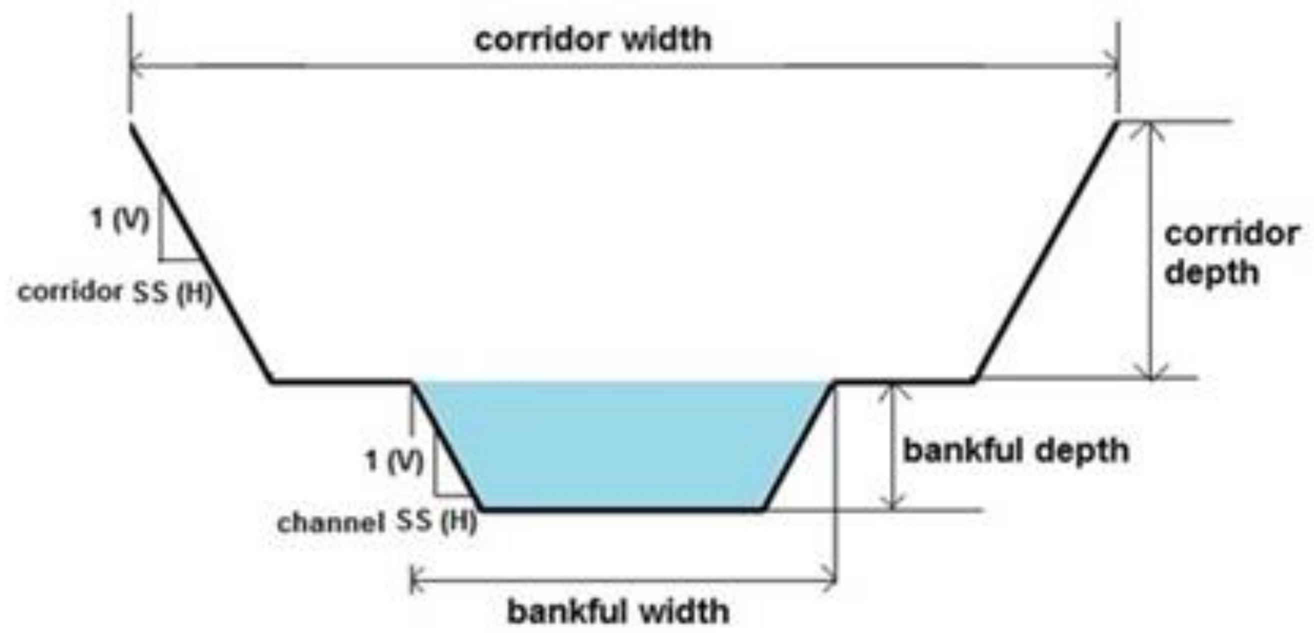


Figure 5. Schematic example of modelled cross-section.

6.2.4.1 Results

The cumulative exceedance analysis results for all evaluated pre-development and post-development scenarios are presented in **Tables 9** and **10**. These raw values were then converted to a percent difference to allow a quantitative comparison of pre-development and post-development hydraulic conditions within each watercourse (**Tables 11** and **12**).

Table 9. Berczy Creek Pre- and Post-development Cumulative Exceedance Results

Rain Event	Development Condition	Detention Time	Berczy Creek Cumulative Pre-Development vs. Post-Development Conditions				
			Time (hr)	Discharge (cms)	Velocity (m/s)	Shear Stress (N/m^2)	Work/Stream Power (N/m)
25 mm	Pre		18.6	92734.7	12784.4	207673.6	181822.5
	Post	24 hour	18.7	93995.5	12908.6	209819.9	184253.7
		48 hour	18.8	92341.2	12733.0	206806.8	181000.7
		72 hour	18.7	91516.8	12637.6	205202.8	179383.1
30 mm	Pre		20.2	166082.1	19544.9	326569.1	323354.0
	Post	24 hour	20.4	167549.3	19671.8	328778.8	326038.5
		48 hour	20.4	165561.4	19515.2	325929.0	322258.2
		72 hour	20.4	164532.8	19418.1	324237.3	320289.3
35 mm	Pre		21.3	248821	25545.4	436753.4	476377.4
	Post	24 hour	21.5	250489.8	25690.8	439242.3	479299.5
		48 hour	21.6	248129.4	25547.4	436492.7	475008.8
		72 hour	21.5	246867.1	25445.4	434669.3	472668.4

Table 10. Bruce Creek Pre- and Post-development Cumulative Exceedance Results

Rain Event	Development Condition	Detention Time	Bruce Creek Cumulative Pre-Development vs. Post-Development Conditions				
			Time (hr)	Discharge (cms)	Velocity (m/s)	Shear Stress (N/m^2)	Work/Stream Power (N/m)
25 mm	Pre		14.5	83236.3	11444.2	249170.5	269894
	Post	24 hour	15.5	95540.0	12884.2	281206.4	309868
		48 hour	15.2	89898.9	12256.2	267134.1	291532.7
		72 hour	14.9	86487.4	11848.8	258096.7	280452
30 mm	Pre		17	157085.4	18750	415767.2	507828.7
	Post	24 hour	17.6	173579.9	20305.4	451473.6	560475.9
		48 hour	17.5	166566.6	19672.8	436849.2	538132.6
		72 hour	17.1	162616.6	19244.1	427219.4	525492.5
35 mm	Pre		18.7	245364.2	25830.2	582579.5	784651.6
	Post	24 hour	19	265304.3	27413.1	619856.6	846556.7
		48 hour	19	258099.5	26836.8	606307.7	824184.9
		72 hour	18.6	254199.1	26438.2	597293.7	811889.2

The results of the exceedance analysis presented in **Table 11** indicate a minimal change in flow conditions under all evaluated scenarios. These results are reflective of the subject property's relatively small contribution to the total catchment area of Berczy Creek. That being stated, the 48-hour detention scenario achieves the closest replication of pre-development conditions.

Table 11. Berczy Creek Exceedance Analysis – Percent Difference

Rain Event	Detention Time	Berczy Creek Cumulative Exceedence Parameters (%) Pre-Development vs. Post-Development Conditions				
		Time (hr)	Discharge (cms)	Velocity (m/s)	Shear Stress (N/m^2)	Work/Stream Power (N/m)
25 mm	24 hour	0.9%	1.4%	1.0%	1.0%	1.3%
	48 hour	0.0%	0.0%	0.0%	0.0%	0.0%
	72 hour	0.8%	-1.3%	-1.1%	-1.2%	-1.3%
30 mm	24 hour	0.9%	0.9%	0.6%	0.7%	0.8%
	48 hour	1.2%	-0.3%	-0.2%	-0.2%	-0.3%
	72 hour	1.0%	-0.9%	-0.6%	-0.7%	-0.9%
35 mm	24 hour	1.0%	0.7%	0.6%	0.6%	0.6%
	48 hour	1.4%	-0.3%	0.0%	-0.1%	-0.3%
	72 hour	1.2%	-0.8%	-0.4%	-0.5%	-0.8%

For Bruce Creek, the exceedance results presented in **Table 12** reflect the larger contribution of drainage area from the subject property relative to the upstream catchment area. While the majority of the cumulative times of exceedance are greater for all of the evaluated scenarios, the 48-hour detention approach provides a post-development condition that most accurately reflects modelled existing conditions. Overcontrol of stormwater (negative exceedance values) within Bruce Creek and Berczy Creek is undesirable as the transport of sand-sized material and washload within both systems is critical to the long-term maintenance of channel form and function.

Table 12. Bruce Creek Exceedance Analysis – Percent Difference

Rain Event	Detention Time	Bruce Creek Cumulative Exceedence Parameters (%) Pre-Development vs. Post-Development Conditions				
		Time (hr)	Discharge (cms)	Velocity (m/s)	Shear Stress (N/m^2)	Work/Stream Power (N/m)
25 mm	24 hour	7.3%	14.8%	12.6%	12.9%	14.8%
	48 hour	5.2%	8.0%	7.1%	7.2%	8.0%
	72 hour	2.8%	3.9%	3.5%	3.6%	3.9%
30 mm	24 hour	3.4%	10.5%	8.3%	8.6%	10.4%
	48 hour	2.8%	6.0%	4.9%	5.1%	6.0%
	72 hour	0.5%	3.5%	2.6%	2.8%	3.5%
35 mm	24 hour	1.8%	8.1%	6.1%	6.4%	7.9%
	48 hour	1.4%	5.2%	3.9%	4.1%	5.0%
	72 hour	-0.7%	3.6%	2.4%	2.5%	3.5%

6.2.5 SWMF Outfalls

The location of proposed SWMF outfalls are identified on Figures 2.8-2.11 of the MESP Servicing and Grading Report (Stantec, 2016). All of the proposed SWMF outfalls achieve an appropriate offset from the active channel in order to mitigate long-term risk of erosion to this infrastructure. Outfalls associated with Ponds 1, 3 and 4 are located outside of the meander belt limit. The Pond 2 design proposes the use of an existing headwall that is located at the meander belt limit. The use of this existing headwall will minimize disturbance to the stream corridor and, based on observations collected during the field investigation, no erosion or channel impacts were observed at the time of assessment.

6.2.6 Foundation Drain Collectors and Roof Leader Collectors

A foundation drain collection (FDC) system is needed in areas where the storm sewer is not low enough for basement connections (Stantec, 2016). The proposed FDC will collect cool clean water which can be directly released into the valley system through stone trenches. Perforated Roof Leader Collector (RLC) pipes are proposed to collect roof drainage and promote infiltration within the road right-of-way. In one location, a perforated RLC pipe will outlet into an FDC pipe, and is referred to as an FDRLC. This pipe outlets to wetland stone reservoir within the old golf course irrigation pond. A separate RLC pipe is proposed to collect clean water and release it to a proposed enhancement ‘Area E’ located west of Street “D” East. A flow dispersal mechanism will be installed at the outfall of the RLC pipe prior to release of the flow into the open space area.

Figure 2.13 of the MESP Servicing and Grading Report (Stantec, 2016) illustrates the proposed FDC, RLC, and FDRLC as well as outlet locations. **Figure 2.13A** illustrates the proposed FDC outfall detail. The volume of drainage being directed to these outlets will be reviewed during subsequent stages of the detailed design process in order to ensure that potential impacts relating to erosion are mitigated.

6.3 NHS Crossings

6.3.1 Bruce Creek Road Crossing

One internal road crossing of the NHS is proposed as part of the development plan (refer to Figure 8.1 of the MESP Servicing and Grading Report). In order to ensure that the proposed 40 m clear-span bridge considers watercourse erosion hazards and avoids impacts to channel form and function (**Figure 6**), the following design criteria were considered in accordance with the TRCA Crossing Guideline for Valley and Stream Corridors (2015):

- The crossing location should be located:
  - Along a relatively straight reach of channel, where possible;
  - Outside of the potential future migration zone of upstream meanders (a 100-year planning horizon);
  - At an orientation that is perpendicular to the channel, whenever possible.

- The crossing opening should address the potential for channel migration, with the aim to minimizing or avoiding the requirements for armouring or impacting channel migration or adjustment, considering post-development conditions (i.e., abutments are located outside the 100 year erosion limit).

- Crossings will avoid, to the best extent possible, watercourses that have fine sediment banks and are vegetation controlled. Where it is not possible to avoid fine sediment banks and vegetation control, formalizing the channel with appropriate bed and/or bank treatments may be required to avoid splaying/braiding under low flow conditions.

- The crossing opening should not:
  - Impact channel velocity for frequent storm events;
  - Impact the local existing meander pattern; and
  - Impact sediment transport processes for frequent storm events.

The proposed road crossing location generally meets all of the geomorphic design criteria. The crossing is located on a (relatively) straight section of Bruce Creek, along a riffle feature and the orientation of the road approaches an angle that is perpendicular to the central tendency of the watercourse. In order to evaluate the proposed 40 m span, a scoped field investigation was undertaken to confirm bankfull dimensions in vicinity of the crossing. **Table 15** provides the results of this scoped assessment, in addition to relevant data from the reach-based rapid field assessment.

In the immediate vicinity of the proposed crossing, a governing meander amplitude of 23.5 m was measured in the field; bankfull widths ranged from 5.80 to 6.80 m. While evidence of widening (slumping banks, basal scour) was observed within the channel, the majority of this erosion was attributed to the influence of an existing cart path crossing, and localized stone toe protection measures that had been implemented in an attempt to mitigate the influence of this undersized crossing. RGA results for Reach BR-4 indicated that the reach was in a stressed, or transitional state, with evidence of widening.

In considering the 40 m span, this dimension was deemed sufficient to accommodate the field-based meander amplitude in addition to a factor of safety equivalent to 8.25 m on either side of the channel if the crossing is set at an optimal skew. This factor of safety is deemed sufficient to address long-term rates of channel widening and adjustments in channel planform. That being stated, it is understood that an optimal skew to the channel planform may not be achievable based on road alignment design constraints. With this in mind, a meander amplitude of 30 m was also considered. At 40 m, the proposed span also accommodates a 30 m amplitude, while providing a factor of safety of 5 m on either side of the watercourse. This dimension approximates local bankfull dimensions at the proposed crossing and was, therefore deemed an appropriate allowance to account for long-term adjustments in channel form or meander geometry.

The 40 m span also accommodates historic (1961) planform dimensions at the crossing location. While meander belt width and historic meander amplitude dimensions were also considered as factors in the geomorphic evaluation of the proposed crossing span, these dimensions were not considered relevant to the span analysis, as the relative risk of these factors to the crossing was low, given the optimal location and orientation of the road. Further, it was noted that a 40 m clear span bridge was recently constructed immediately upstream of the subject property for extension of Angus Glen Boulevard across Bruce Creek. This crossing was constructed at a less optimal orientation to the watercourse, but, based on observations collected during the field investigation, no erosion or channel impacts were observed at the time of assessment. The proposed crossing location and design will need to be reviewed, confirmed and refined in the future as part of the detailed design process.

Table 13. NHS Road Crossing Span Analysis

Reach	Meander Amplitude to be Accommodated		Bankfull Width in Vicinity of Crossing (m)	RGA Score	Bank Materials	Crossing Span (m)
	Optimal Skew (m)	Road Alignment (m)				
BR-4	23.5	30	5.8 - 6.8	0.37 (in transition)	Silt, sand and clay (some gravel)	**40**

Output data from the HEC-RAS model as provided by Stantec Consulting for Bruce Creek upstream and downstream of the crossing are summarize in **Table 16**. Data from the model indicates a minimal impact on instream hydraulics as a result of the crossing under the more frequent storm events. It is not anticipated that this increase will result in exacerbated rates of erosion within Bruce Creek.

Table 14. Review of Channel Hydraulics at Proposed Crossing Location

River Station	Location of Station Relative to Proposed Crossing	Velocity (m/s)		Bruce Creek Bankfull Velocity (m/s)
		2 Year	5 Year	
7216.175	Upstream	1.27	1.18	1.40
7216.172		1.65	1.89	
7216.171		1.34	1.32	
Road Crossing				
7216.168	Downstream	1.73	1.94	
7216.165		1.45	1.60	
7216.16		1.43	1.66	

6.3.2 NHS Trail Crossings

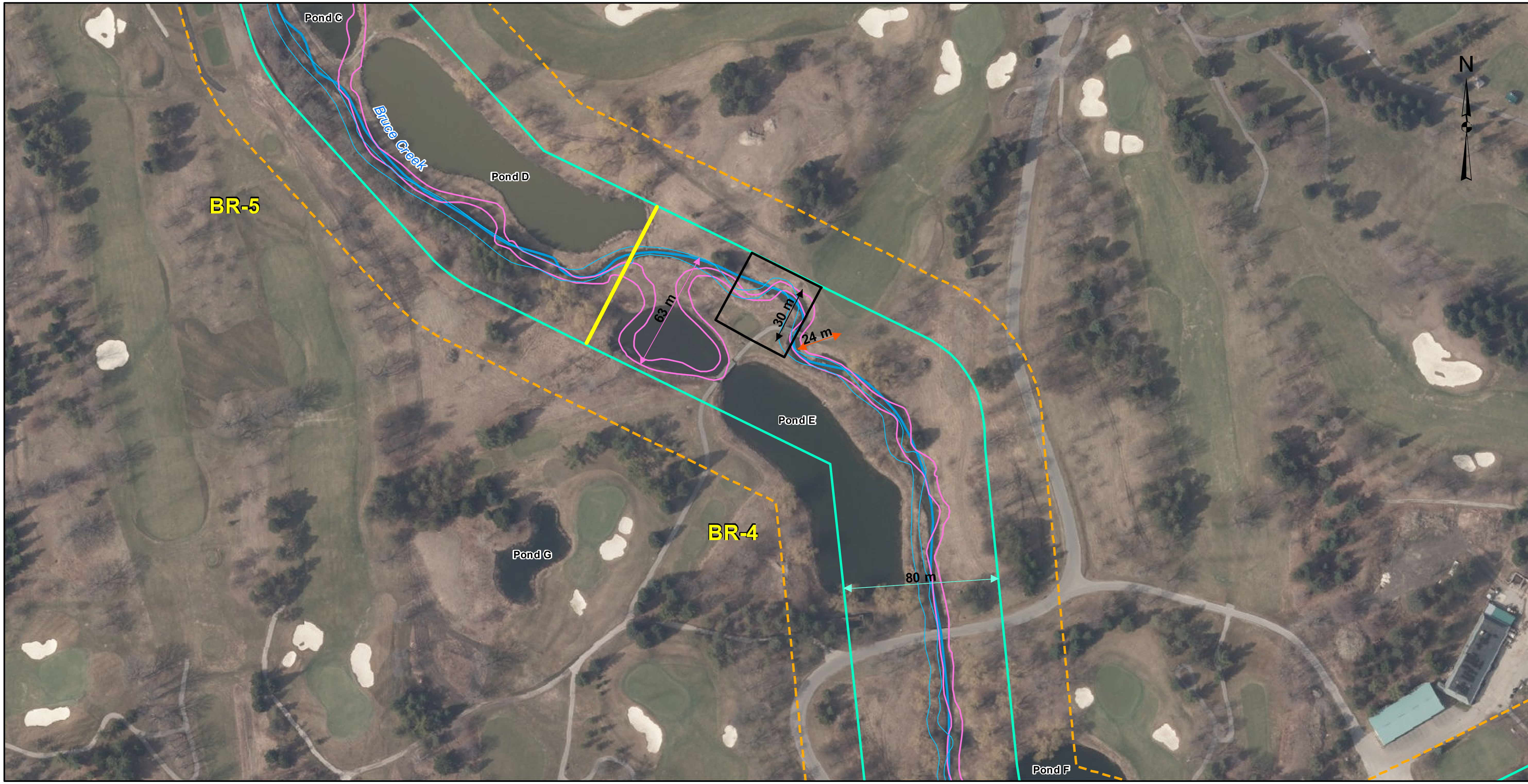
Two (2) pedestrian crossings are proposed as part of the trail system: one crossing of Berczy Creek and one crossing of Bruce Creek. The proposed trail crossings will be located at existing cart path crossings and will utilize the existing bridge footings. While this approach will avoid requirements for instream works, it is recommended that, at subsequent detailed design stages, the proposed crossings are reviewed to ensure that potential risk of channel erosion and migration to the crossings has been mitigated.

6.3.3 Bruce Creek Sanitary Sewer Crossing

One (1) sanitary sewer crossing of Bruce Creek is proposed. The crossing will be installed using directional drilling and will achieve a depth of cover of 1.5 m under the channel bed invert. While observations collected during the field investigation did not identify substantial evidence of downcutting (incision) in vicinity of the proposed sanitary crossing, it is recommended that, at subsequent detailed design stages, a scour analysis be undertaken to confirm the depth of cover required to mitigate long-term potential erosion risks to the sewer.

7. Policy Conformance

It is our opinion that the methods and procedures outlined above are consistent with the applicable policy including municipal Region of York Official Plan (2009) and Town of Markham Official Plan (2014). Furthermore, it is our opinion that the intent of the PPS (2014), TRCA LCP (2014), Belt Width Delineation Procedures (2004) document, Stormwater Management Criteria (2012) and Crossings Guideline for Valley and Stream Corridors (2015) has been met. It is our understanding that the meander belt width procedures as identified in this document are in conformance with Ontario Regulation 242/08.



Stantec
BEACON ENVIRONMENTAL
BURNSIDE

1:2,000 — 0 10 20 40 60 80

Legend

- Reach Break
- Watercourse
- Historic Watercourse 1974
- Historic Watercourse 1961
- Meander Belt Width
- Meander Belt + 30m
- Proposed 40 m Clear Span Bridge
- Meander Amplitude - Optimal Skew (24 m)
- Meander Amplitude - Road Alignment (30 m)
- Historic Meander Amplitude (63 m)
- Meander Belt Width Dimension (80 m)

First Base Solutions, 2014. First Base Solutions
Web Mapping Service York Region 2015 Air Photo.
Beacon Environmental, 2016. Reach Extents,
Reach Breaks, Watercourse

MASTER ENVIRONMENTAL SERVICING PLAN FOR 4134 16TH AVE

FIGURE 6: Road Crossing Analysis

UTM Zone 17 N, NAD 83

Project 215200.1
September 2016

8. Conclusions

The purpose of this assessment was to characterize existing geomorphic conditions, contribute to the determination of development constraints, and provide input to stormwater servicing plans for the subject property. Based on a background review of available materials (topographic mapping, aerial photography, watershed reports, relevant studies, site plan), portions of Berczy Creek and Bruce Creek relevant to the subject property were delineated into reaches. An historic assessment was then undertaken to determine changes in land use and channel planform over time. Results of this assessment identified extensive channelization of both Berczy and Bruce Creek within the subject property between 1961-present. Many of the ponds currently being used by the golf course for irrigation are located in former channel meander bends. This information was referenced in the delineation of meander belt limits for stream corridors (unconfined watercourses) to aid in the determination of erosion hazard limits, and the delineation of occupied Redside Dace regulated habitat (referencing meander belt plus 30 m) for stream and valley corridors to aid in the determination of development limits for the subject property.

In order to characterize existing geomorphic conditions, standard rapid field assessment tools (RGA, RSAT, Down's) were applied on a reach basis. Results of this field investigation identified channel widening as the dominant mode of adjustment along both Berczy and Bruce Creeks. Reaches BR-3 (Bruce Creek) and BER-3 (Berczy Creek) were identified within their respective systems as being the most sensitive to land use change (i.e., highest RGA scores). Detailed field assessments, including a topographic survey of the channel centerline and cross-sectional form, were completed on each of these reaches for the purpose of determining erosion thresholds. Referencing the median grain size and flow conditions at the time of survey, critical shear stress values of 9.6 N/m^2 and 6.5 N/m^2 were identified for Bruce Creek and Berczy Creek, respectively.

In order to understand the potential impacts of the proposed development plan on channel morphology, an impact assessment was undertaken with respect to stormwater erosion control, in addition to road and servicing stream corridor crossings. For the erosion control analysis, a comparison pre- and post-development (controlled) flow conditions for the 25 mm, 30 mm and 35 mm storm events under 24 hour, 48 hour and 72 hour detention scenarios was undertaken for nodes located at the downstream limit of the subject property to evaluate how closely post-development conditions can replicate existing condition hydrograph (peak, volume and form), focusing on those portions of the hydrograph above the critical discharge. Results of the analysis indicated that, for both Berczy Creek and Bruce Creek, the 48-hour detention scenario was able to most closely replicate modelled existing conditions (i.e., difference in pre to post cumulative time of exceedance within 5%) without resulting in an over-control of flows. Overcontrol of stormwater within the system is undesirable as the transport of sand-sized material and washload within both Berczy and Bruce Creeks is critical to the maintenance of channel form and function. As such, the 48-hour detention scenario was identified as the preferred erosion control approach for Berczy Creek and Bruce Creek, through which existing rates of channel erosion are not anticipated under the post-development condition.

Only one road crossing of the Natural Heritage System (NHS) is proposed through the development plan. A 40 m clear span bridge is proposed to cross Bruce Creek. In accordance with the TRCA Crossings Guideline for Valley and Stream Corridors, an evaluation of channel planform (both current and historic) was undertaken at the proposed crossing location. Based on this evaluation, the 40 m span was deemed sufficient to accommodate the governing meander amplitude in vicinity of the crossing, in addition to a factor of safety which would accommodate for long-term adjustments in channel form. Further, a review of the HEC-RAS model output for more frequent storm events in vicinity of the proposed crossing indicated a minimal impact on instream hydraulics.

Two (2) pedestrian crossings are proposed as part of the trail system: one crossing of Berczy Creek and one crossing of Bruce Creek. The proposed trail crossings will be located at existing cart path crossings and will utilize the existing bridge footings. As no instream works are proposed in association with the trail crossings, and the existing crossings appear to be performing well, additional geomorphic design criteria have not been identified for these crossings.

A sanitary sewer crossing of Bruce Creek is also proposed. The crossing will be installed using directional drilling and will achieve a depth of cover of 1.5 m under the existing channel bed. Based on the results of the rapid assessments, which indicated widening as the dominant process along Bruce Creek, the 1.5 m depth of cover was deemed sufficient to mitigate long-term risk to this infrastructure due to active erosion (i.e., channel incision).

Report prepared by:
Beacon Environmental

M. Attard

Maureen Attard, M.Sc.
Geomorphic Systems Analyst

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

Report reviewed by:
Beacon Environmental

Imran Khan, M.Sc., P.Geo.
Senior Geomorphologist

9. References

AECOM. 2014.
City-Wide Stream Erosion Master Study Update – FINAL.

Beacon Environmental Limited. September 2016.
Natural Environment Report/Environmental Impact Study in support of a Master Environmental Servicing Plan - 4134 16th Avenue. Submitted to: Sixteenth Land Holdings Inc.

Chapman and Putnam. 1984.
Physiography of Southern Ontario, 3rd Edition. Ontario Geological Survey, Special Vol. 2.

Chow, V.T. 1959.
Open Channel Hydraulics. McGraw Hill, Boston.

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. 2015.
Canadian Climate Normals 1981-2010
http://climate.weatheroffice.gc.ca/climate_normals/index_e.html

Fischenich, C. 2001.
Stability Thresholds for Stream Restoration Materials. Technical report EMRRP SR-29, Vicksburg, MS: USACE ERDC, Environmental Laboratory.

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

Golder Associates. 2016.
Geotechnical Report: Slope Stability Analysis of York Downs Golf Club Redevelopment Markham, Ontario. Submitted to: Kylemore/Metropia (YD) Management Ltd.

Komar, P. 1987.
Selective gravel entrainment and the empirical evaluation of flow competence. Sedimentology: Volume 34, Issue 6, p. 1165–1176.

Miller, M.C., McCave, I.N., and Komar, P.D., 1977.
Threshold of sediment motion under unidirectional currents. Sedimentology, 24, 507-27.

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

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

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

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

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

Richards C, Haro RJ, Johnson LB, Host GE. 1997.
Catchment- and reach-scale properties as indicators of macroinvertebrate species traits. Freshw. Biol. 37:219–30

Stantec. September 2016.
MESP Servicing and Grading Report - 4134 16th Avenue Residential Development.
Submitted to: Sixteenth Land Holdings Inc.

Toronto and Region Conservation Authority. 2006.
Ontario Regulation 166/06 - Regulation for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses. May 4, 2006.

Toronto and Region Conservation Authority. 2007b.
Rouge River State of the Watershed Report. Fluvial Geomorphology.

Toronto and Region Conservation Authority. 2007a.
Rouge River State of the Watershed Report. Study Area and Physical Setting.

Toronto and Region Conservation Authority (TRCA). 2007c.
Rouge River State of the Watershed Report: Aquatic System.

Toronto and Region Conservation Authority (TRCA). 2007d.
Watercourse Erosion Analysis Design and Submission Requirements in Support of Secondary Plans (As a component of MESP).

Toronto and Region Conservation Authority (TRCA). 2012.
Stormwater Management Criteria. Version 1.0. August 2012.

Toronto and Region Conservation Authority (TRCA). 2014.
The Living City Policies.

Toronto and Region Conservation Authority (TRCA). 2015.
Crossings Guideline for Valley and Stream Corridors. September 2015.

Ward, A., Mecklenburg, D., Mathews, J. and Farver, D. 2002.
Sizing stream setbacks to help maintain stream stability. ASAE Meeting Paper No. 022239 St. Mich.: ASAE.

Williams, G.P. 1986.
River Meanders and Channel Size. Journal of Hydrology 88:147-164.

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

Appendix A

Historic Aerial Imagery

Coverage: Spring 1961 **Scale:** 1:12,000

Image ID: 1961_6446_L14_32 **Source:** Northway Photomap/Remote Sensing Ltd.

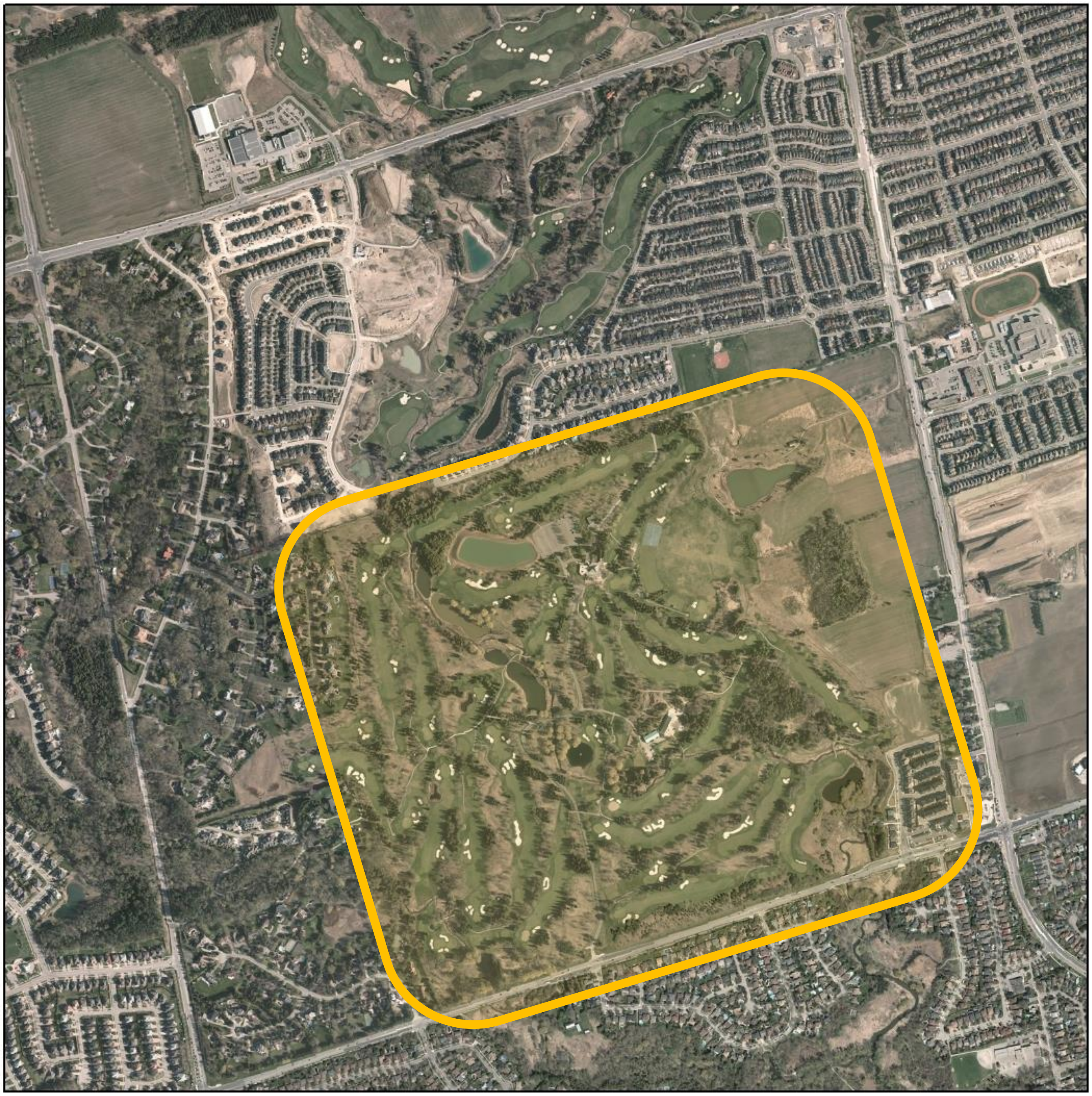
Coverage: Spring 1974 **Scale:** 1:12,000

Image ID: 1974_74023_L15_32 **Source:** Northway Photomap/Remote Sensing Ltd.

Coverage:	Spring 1974	**Scale:**	1:12,000
Image ID:	1974_74023_L15_32	**Source:**	Northway Photomap/Remote Sensing Ltd.

Coverage: 2002 **Scale:** 1:15,000

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



Coverage: 2012 **Scale:** 1:15,000

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

Appendix B

Photographic Record

Photo 1
BR-1. Downstream view from pedestrian trail bridge at upstream reach extent. Note widened channel due to backwater from downstream Toogood Pond.

Photo 2
BR-2. Upstream view from pedestrian trail crossing at downstream reach extent.

Photo 2
BR-2. Downstream view of general channel conditions. Note stone bank protection on left bank.

Photo 4
BR-2. Looking upstream at failing (undermined and outflanked) cribwall along outside meander bend.

Photo 5
BR-2. Downstream view under 16th Avenue crossing.

Photo 6
BR-2. Basal scour on both side through riffle.

Photo 7
BR-2. Exposed tree roots and slumping banks at outside meander bend viewed downstream.

Photo 8
BR-2. Vegetated bar with chute formation viewed upstream.

Photo 9
BR-2. Vegetated bar viewed downstream. Note also old bridge footing remains within channel.

Photo 10
BR-2. Valley wall contact on left bank (photo right) viewed upstream.

Photo 11
BR-2. 1250 mm storm outfall on left bank.

Photo 12
BR-2. Looking upstream at pedestrian crossing. Note vegetated bar within the channel.

Photo 13
BR-2. Looking upstream toward golf cart path crossing.

Photo 14
BR-2. Looking upstream at pedestrian crossing at upstream extent of the reach. Note the slumping with chute formation in behind.

Photo 15
BR-3. Looking downstream at exposed tree roots and under right bank.

Photo 16
BR-3. Looking downstream confluence with SDF-B. Note large sand deposit.

Photo 17
BR-3. Looking upstream at debris jam creating backwater area. Note confluence with drainage feature into backwater area.

Photo 18
BR-3. Looking upstream pedestrian crossing. Note gravel bar within the channel.

Photo 19
BR-3. Looking upstream from pedestrian crossing at golf cart path crossing. Note manicured grass riparian vegetation.

Photo 20
BR-3. Looking upstream at exposed previously buried pipes in left bank (photo right/centre).

Photo 21
BR-3. Looking downstream at outflanked and undermined gabion basket on right bank.

Photo 22
BR-3. Looking at upstream at golf cart path crossing.

Photo 23
BR-4. Looking at upstream at general reach conditions. Note degree of entrenchment.

Photo 24
BR-4. Looking downstream erosion along right bank.

Photo 25
BR-4. Looking upstream at driveway crossing.

Photo 26
BR-4. Looking downstream at bar formation

Photo 27
BR-4. Looking downstream at fallen cedar tree, exposed roots and undercut bank.

Photo 28 (Location 28)
BR-4. Looking downstream from golf cart path crossing. Note proximity to pond.

Photo 29 (Location 28)
BR-4. Looking upstream from golf cart path crossing at meander bend. Note manicure grass riparian vegetation.

Photo 30 (Location 29)
BR-4. Pond outlet to creek.

Photo 31 (Location 30)
BR-5. Tile drain outlet on right bank.

Photo 32 (Location 31)
BR-5. Looking downstream at general conditions. Note vegetated island within the channel and degree of entrenchment.

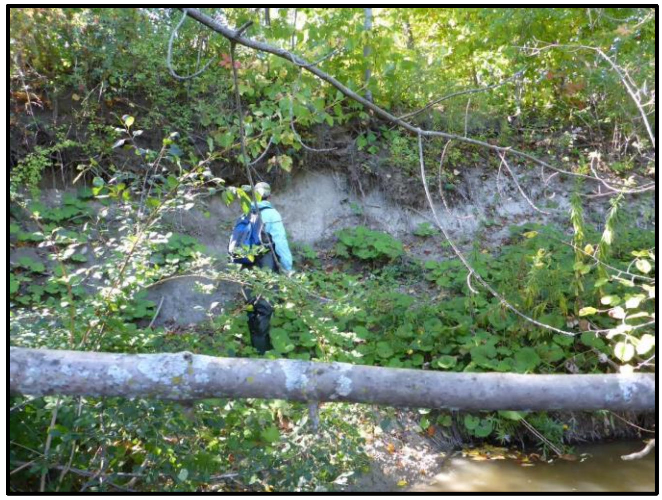


Photo 33 (Location 32)
BR-5. Looking downstream at erosion along right bank.

Photo 34 (Location 33)
BR-5. Looking downstream at surface drainage feature through an actively farmed field. Note lack of defined channel and isolated pockets of standing water

Photo 35 (Location 33)
BR-5. Looking upstream at wood debris jam and pedestrian crossing.

Photo 36 (Location 34)
BR-5. Looking downstream at island within the channel. Note the armoustone bank treatment along the left bank.

Photo 37 (Location 35)
BR-5. Looking upstream at golf cart path crossing. Note riffle substrate size.

Photo 38 (Location 36)
BR-5. Exposed bridge footings of pedestrian crossing on right bank viewed downstream.

Photo 39 (Location 37)
BR-5. Looking downstream of fallen cedar tree and bar formation. Note the confluence with surface drainage feature (D).

Photo 40 (Location 38)
BER-3. Looking downstream at ad-hoc bank protection on right bank.

Photo 41 (Location 39)
BER-3. Looking downstream at pedestrian crossing.

Photo 42 (Location 40)
BER-3. Looking upstream at valley wall contact and outflanked gabion basket bank protection on left bank (photo right).

Photo 43 (Location 41)
BER-3. Looking downstream at leaning tree with exposed roots at sharp meander bend with a deep pool.

Photo 44 (Location 42)
BER-3. Looking upstream at golf cart path crossing.

Photo 45 (Location 43)
BER-3. Looking downstream at general reach conditions. Note degree of entrenchment.

Photo 46 (Location 44)
BER-3. Looking downstream at pedestrian crossing.

Photo 47 (Location 45)
BER-3. Looking downstream at sharp meander bend. Note erosion on outside of bend, point bar formation on inside and basal scour on both sides.

Photo 48 (Location 46)
BER-3. Looking downstream at leaning tree and lateral bar.

Photo 49 (Location 47)
BER-3. Looking downstream toward meander bend and general conditions.

Photo 50 (Location 48)
BER-3. Looking upstream at meander bend. Note point bar formation on left bank (photo right) and scour on inside bend.

Photo 51 (Location 49)
BER-3. Looking downstream at 16th Avenue Road crossing.

Photo 52 (Location 50)
BER-4. Looking downstream at large wood debris jam.

Photo 53 (Location 51)
BER-4. Looking downstream at riffle within a meander bend. Note point bar with cut face and exposed tree roots.

Photo 54 (Location 52)
BER-4. Looking upstream at leaning tree with exposed roots on the left bank.

Photo 55 (Location 53)
BER-4. Looking downstream at lateral bar and valley wall contact on left bank. Note also misalignment of thalweg.

Photo 56 (Location 54)
BER-6. Looking downstream at a bridge crossing at the downstream extent assessed. Note the large deep scour pool and failing footings under the bridge and the erosion on right bank (photo left).

Photo 57 (Location 55)
BER-6. Looking upstream at meander bend against Warden Avenue bridge.

Photo 58 (Location 56)
BER-6. Looking upstream at boulder step-pool. Note outer bank erosion on meander bend in background.

Photo 59 (Location 57)
BER-6. Looking upstream at Warden Avenue crossing.

Photo 60 (Location 58)
Looking at wetted meadow area.

Photo 61 (Location 59)
SDF-C. 500 mm metal culvert under farm crossing.

Photo 62 (Location 60)
SDF-C. Looking downstream within the wetland. Note heavy degree of vegetation and poorly defined flow path.

Photo 63 (Location 61)
SDF-C. Looking downstream across the golf green. Feature is piped.

Photo 64 (Location 62)
SDF-C. Looking upstream at tile pipe outlet to flow path. Note minimal flow and standing water.

Photo 65 (Location 63)
SDF-C. Looking upstream at perched culvert under golf cart path. Note scour pool immediately downstream.

Photo 66 (Location 64)
SDF-C. Looking downstream at multiple flow paths.

Photo 67 (Location 65)
SDF-C. Embedded 300 mm CSP culvert.

Photo 68 (Location 66)
Catch basin adjacent to pond H.

Photo 69 (Location 67)
Southern view of driving range golf green overtop of piper drainage.

Photo 70 (Location 68)
Enclosed water supply outlet pipe.

Photo 71 (Location 69)
SDF-B. Looking upstream at poorly defined flow path.

Photo 72 (Location 70)
SDF-B. Looking downstream at pipe under golf green.

Photo 73 (Location 71)
SDF-B. Looking downstream at flow path with standing water.

Photo 74 (Location 72)
SDF-B. Looking upstream at poorly defined flow path towards culvert under golf cart path.

Photo 75 (Location 73)
SDF-BC. Looking upstream at perched culvert pipe from under golf green.

Photo 76 (Location 74)
SDF-BC. Looking upstream woody debris and poorly defined flow path.

Photo 77 (Location 75)
SDF-BC. Looking downstream flow path.

Photo 78 (Location 76)
SDF-BC. Looking upstream at poorly defined flow path.

Photo 79 (Location 77)
SDF-BC. Looking upstream confluence with BR-3. Note medial bar formation.

Photo 80 (Location 78)
SDF-BC. Looking downstream flow path.

Photo 81 (Location 79)
SDF-BC. Looking upstream at culvert under cart path within the woodlot.

Photo 82 (Location 80)
SDF-BC. Looking upstream at confluence with BR-3. Note 0.4 m drop to creek bed.

Photo 83 (Location 81)
SDF-D. Looking upstream at depression within the meadow adjacent to the golf green.

Photo 84 (Location 81)
SDF-D. Looking downstream at depression within the meadow adjacent to the golf green. Note start of the forested segment.

Photo 85 (Location 82)
SDF-D. Looking upstream at start of Segment 2 within a gully feature

Photo 86 (Location 82)
SDF-D. Looking downstream at the gully feature towards the confluence with the creek. Note tile drain pipe which outlets to the creek at the confluence.

Photo 87 (Location 83)
SDF-A. Looking upstream at depression within the meadow adjacent towards Kennedy Road.

Photo 88 (Location 84)
SDF-A. Looking downstream at depression within the meadow toward the pond.

Photo 89 (Location 85)
SDF-E. Looking downstream at feature upstream of golf green and cart culvert crossing.

Photo 90 (Location 86)
SDF-E. Looking upstream at feature towards the golf green.

Appendix C

Summary of Detailed Field Data

BEACON ENVIRONMENTAL

Geomorphology Group
Summary of Detailed Field Data

Date:	November 2015, April 2016	**Project:**	215200.1
Client:	Sixteenth Land Holdings Inc.	**Watercourse:**	Berczy Creek
Location:	4134 16th Avenue, Markham, ON	**Reach:**	BER-3
Length Surveyed:	**199 m**	Number of Cross Sections:	**8**

General Site Characteristics

Drainage Area:	**Not measured**	Riparian Vegetation:	
Geology/Soils:	**Glacial lacustrine (Till)**	Dominant Type:	**Trees, shrubs, grasses**
Surrounding Land Use:	**Golf Course**	Buffer Zone Continuity:	**Fragmented**
Channel Disturbances:	**Channelization, crossings, bank protection**	Channel Encroachment:	**Minimal**
Aquatic Vegetation:		Large Woody Debris:	**Moderate**
Dominant Type:	**N/A**		
Portion of Reach:	**0%**		

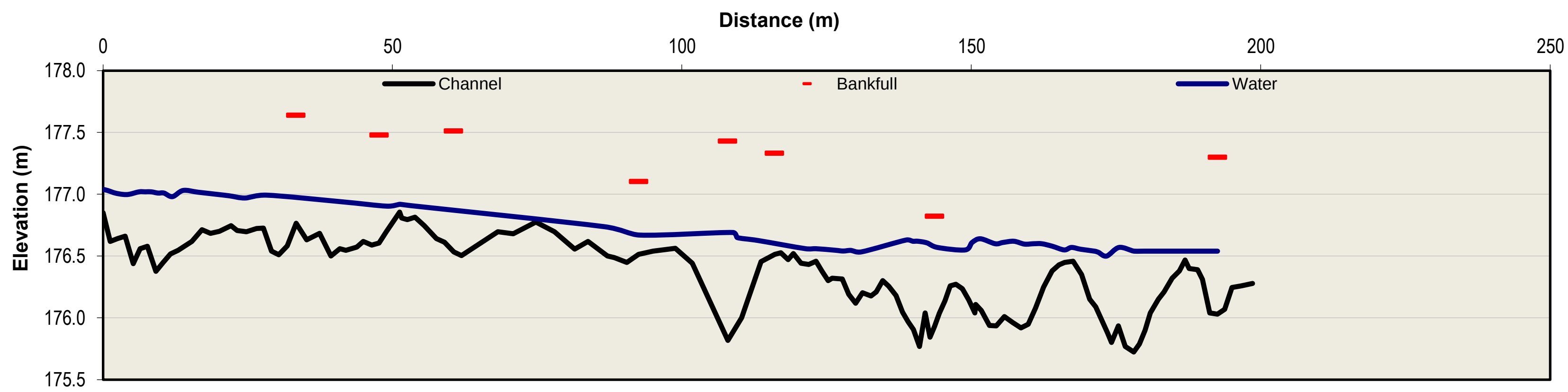
General Field Observations

Reach BER-3 was characterized as a historically modified (channelized) watercourse flowing within a partially-confined valley setting. The reach exhibited evidence of widening, with degradation, planimetric form adjustment and aggradation as secondary processes. Evidence of active erosion was observed in the form of undercutting, basal scour and slumping.

Planform Characteristics

Profile			*Meander Geometry*		
Bankfull Gradient:	**0.30**	%	Sinuosity:	**2.7**	
Channel Bed Gradient:	**0.36**	%	Belt Width:	**156**	m
Max Riffle Gradient:	**3.6**	%	Radius of Curvature:	**Not calculated**	m
Riffle Length:	**n/a**	m	Amplitude:	**Not calculated**	m
Riffle-Pool Spacing:	**n/a**	m	Wavelength:	**Not calculated**	m

Longitudinal Profile



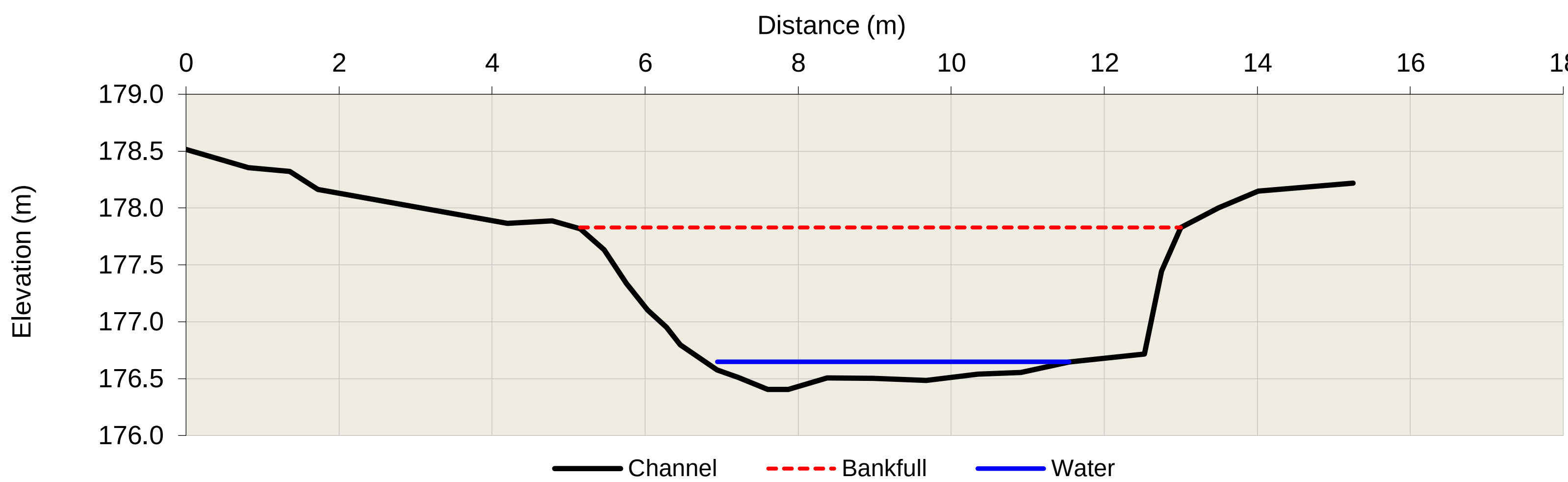
Bank Characteristics

	Minimum	*Maximum*	*Average*
Bank Height (m):	**0.80**	**1.60**	**1.21**
Bank Angle (degrees):	**45**	**90**	**82**
Root Depth (m):	**0.05**	**0.50**	**0.28**
Root Density (%):	**0**	**90**	**33**
Undercut Banks (%)		**20**	
Depth of Undercut (m):	**0.11**	**0.25**	**0.17**
Bank Strength:			
Torvane Value (kg/cm^2):	**0.07**	**0.20**	**0.13**
Penetrometer Value (kg/cm^2):	**0.73**	**1.25**	**0.97**

Bank Material (range): **silt - gravel and till with some cobble, boulder, clay**

Cross-sectional Characteristics

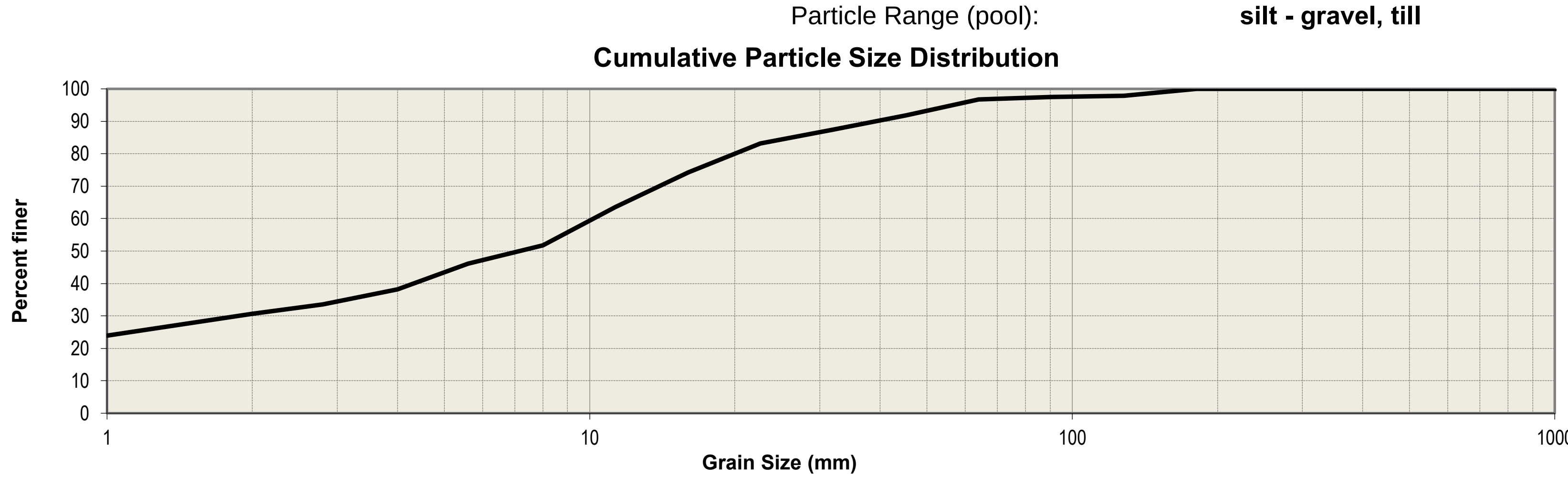
	Minimum	*Maximum*	*Average*
Bankfull Width (m):	**6.0**	**11.9**	**8.7**
Average Bankfull Depth (m):	**0.47**	**1.15**	**0.67**
Bankfull Width/Depth:	**5.8**	**22.1**	**14.4**
Wetted Width (m):	**5.1**	**9.7**	**6.2**
Average Water Depth (m):		**0.67**	
Average Wetted Width/Depth:		**41.6**	
Max. Wetted Depth (m):		**1.0**	
Manning's n:		**0.030**	



Substrate Characterization

Particle size		
D_{10}	**-**	mm
D_{50}	**6.3**	mm
D_{90}	**40**	mm

Subpavement:	**till**
Particle shape:	**sub-angular**
Embeddedness (%):	**10-20**
Particle range (riffle):	**sand - gravel**
Particle Range (pool):	**silt - gravel, till**



Hydrology

Measured Discharge:	**Not measured**	m^3/s
Modelled 2-year Discharge:	**11.5**	m^3/s
Modelled 2-year Velocity:	**1.36**	m/s
Calculated Bankfull Discharge:	**7.20**	m^3/s
Calculated Bankfull Velocity:	**1.20**	m/s

Channel Thresholds

Flow Competency:		
for D_{50}:	**0.5**	m/s
for D_{84}:	**0.9**	m/s
Unit Stream Power at Bankfull:	**22.3**	W/m^2
Tractive Force at Bankfull:	**20**	N/m^2
Tractive Force at 2-year flow:	**Not calculated**	N/m^2
Critical Shear Stress:	**6.5**	N/m^2
Critical Discharge:	**0.89**	m^3/s
Critical Water Depth:	**0.33**	m

Geomorphology Group
Summary of Detailed Field Data

Date:	November 2015, April 2016	**Project:**	215200.1
Client:	Sixteenth Land Holdings Inc.	**Watercourse:**	Bruce Creek
Location:	4134 16th Avenue	**Reach:**	BR-3
Length Surveyed:	**228 m**	Number of Cross Sections:	**8**

General Site Characteristics

Drainage Area:	**Not measured**	Riparian Vegetation:	
Geology/Soils:	**Glacial lacustrine (Till)**	Dominant Type:	**Trees, shrubs, grasses**
Surrounding Land Use:	**Golf Course**	Buffer Zone Continuity:	**Fragmented**
Channel Disturbances:	**Channelization, crossings, VWCs, woody debris**	Channel Encroachment:	**Minimal**
Aquatic Vegetation:		Large Woody Debris:	**Moderate**
Dominant Type:	**N/A**		
Portion of Reach:	**N/A**		

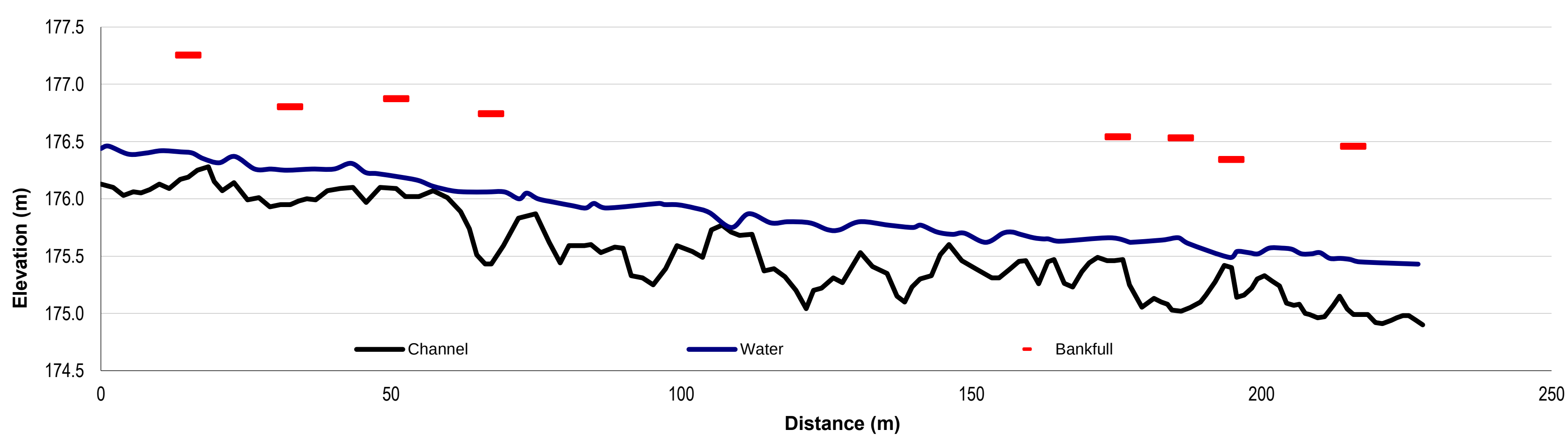
General Field Observations

Reach BR-3 was characterized as a historically modified (channelized) watercourse flowing within a partially-confined valley setting. The reach exhibited evidence of widening, with degradation, planimetric form adjustment and aggradation as secondary processes. Evidence of active erosion was observed in the form of undercutting, basal scour and slumping.

Planform Characteristics

Profile			*Meander Geometry*		
Bankfull Gradient:	**0.3**	%	Sinuosity:	**1.4**	
Channel Bed Gradient:	**0.5**	%	Belt Width:	**96**	m
Max Riffle Gradient:	**0.6**	%	Radius of Curvature:	**Not calculated**	m
Riffle Length:	**13.0**	m	Amplitude:	**Not calculated**	m
Riffle-Pool Spacing:	**33.0**	m	Wavelength:	**Not calculated**	m

Longitudinal Profile



Bank Characteristics

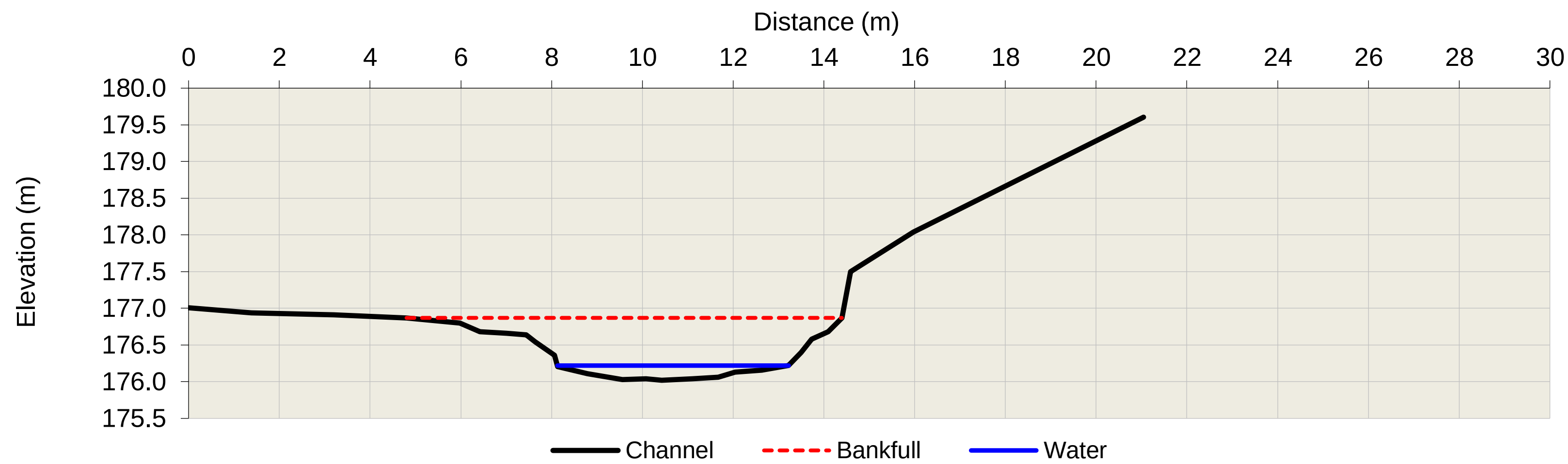
	Minimum	*Maximum*	*Average*
Bank Height (m):	**0.30**	**1.30**	**0.79**
Bank Angle (degrees):	**20**	**90**	**68**
Root Depth (m):	**0.00**	**0.50**	**0.18**
Root Density (%):	**5**	**75**	**29**
Undercut Banks (%)		**44**	
Depth of Undercut (m):	**0.00**	**0.22**	**0.03**
Bank Strength:			
Torvane Value (kg/cm^2):	**0.04**	**0.16**	**0.10**
Penetrometer Value (kg/cm^2):	**0.60**	**1.23**	**0.90**

Bank Material (range): **Silt, sand, clay, gravel, till**

Cross-sectional Characteristics

	Minimum	*Maximum*	*Average*
Bankfull Width (m):	**7.1**	**15.6**	**10.7**
Average Bankfull Depth (m):	**0.48**	**0.76**	**0.65**
Bankfull Width/Depth:	**9.7**	**23.5**	**16.6**
Wetted Width (m):	**2.1**	**6.3**	**4.5**
Average Water Depth (m):		**0.65**	
Average Wetted Width/Depth:		**16.6**	
Max. Wetted Depth (m):		**0.7**	
Manning's n:		**0.030**	

Representative Cross-Section (#6)



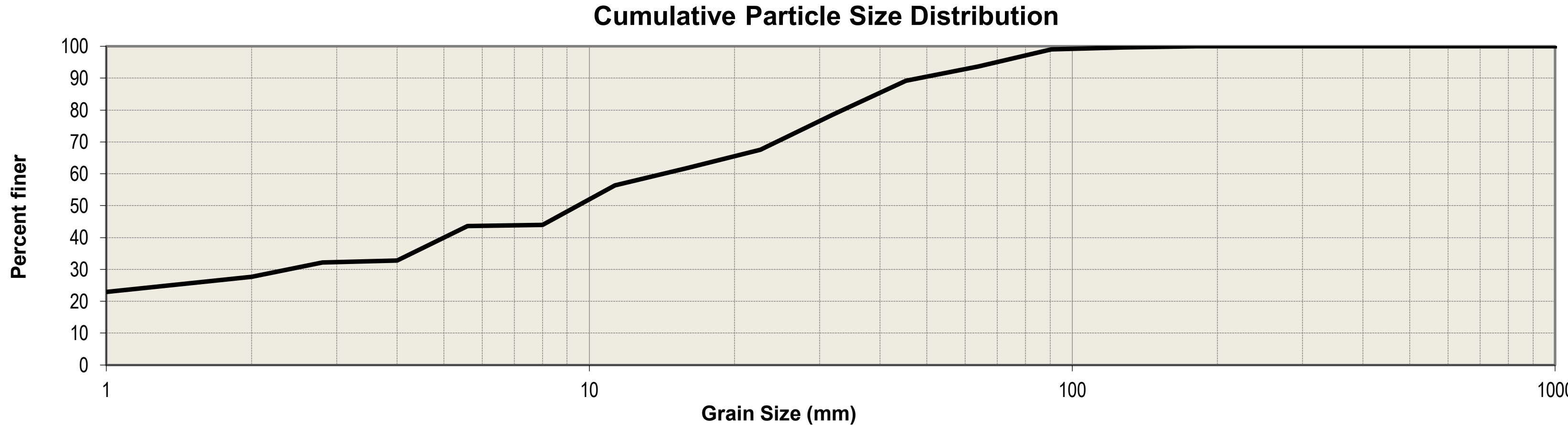
Substrate Characterization

Particle size

D_{10}	**-**	mm
D_{50}	**9.3**	mm
D_{90}	**49**	mm

Subpavement:	**sand, gravel**
Particle shape:	**sub-rounded**
Embeddedness (%):	**20-30**
Particle range (riffle):	**sand - boulder**
Particle range (pool):	**clay - gravel**

Cumulative Particle Size Distribution



Hydrology

Measured Discharge:	**Not measured**	m^3/s
Modelled 2-year Discharge*:	**13.6**	m^3/s
Modelled 2-year Velocity*:	**1.33**	m/s
Calculated Bankfull Discharge:	**6.60**	m^3/s
Calculated Bankfull Velocity:	**1.40**	m/s

Channel Thresholds

Flow Competency:		
for D_{50}:	**0.6**	m/s
for D_{84}:	**1.1**	m/s
Unit Stream Power at Bankfull:	**29.0**	W/m^2
Tractive Force at Bankfull:	**23**	N/m^2
Tractive Force at 2-year flow:	**Not calculated**	N/m^2
Critical Shear Stress:	**9.6**	N/m^2
Critical Discharge:	**0.9**	m^3/s
Critical Water Depth:	**0.31**	m

Appendix D

Summary of Erosion Threshold Analysis

BEACON ENVIRONMENTAL

Geomorphology Group

Summary of Erosion Threshold Analysis

Date:	May 2016	**Project:**	215200.1
Client:	Kylemore/Metropia (YD) Management Ltd.	**Watercourse:**	Berczy Creek
Location:	York Downs Golf Club, Markham, ON	**Reach:**	BER-3
Length Surveyed:	200 m	**Representative Cross-sections:**	XS 1 and 3 (of 8)

Summary of Calculated Hydraulic Parameters

Bankfull Channel:

Discharge (m^3/s):	**7.24**
Velocity (m/s):	**1.20**
Maximum Depth (m):	**0.92**
Tractive Force (N/m^2):	**17.8**
Flow Competency (Komar, 1987):	
for D_{50} (m/s):	**0.46**
for D_{84} (m/s):	**0.92**
Shear Stress (Miller et al., 1977):	
for D_{50} (N/m^2):	**4.6**
for D_{84} (N/m^2):	**20.4**

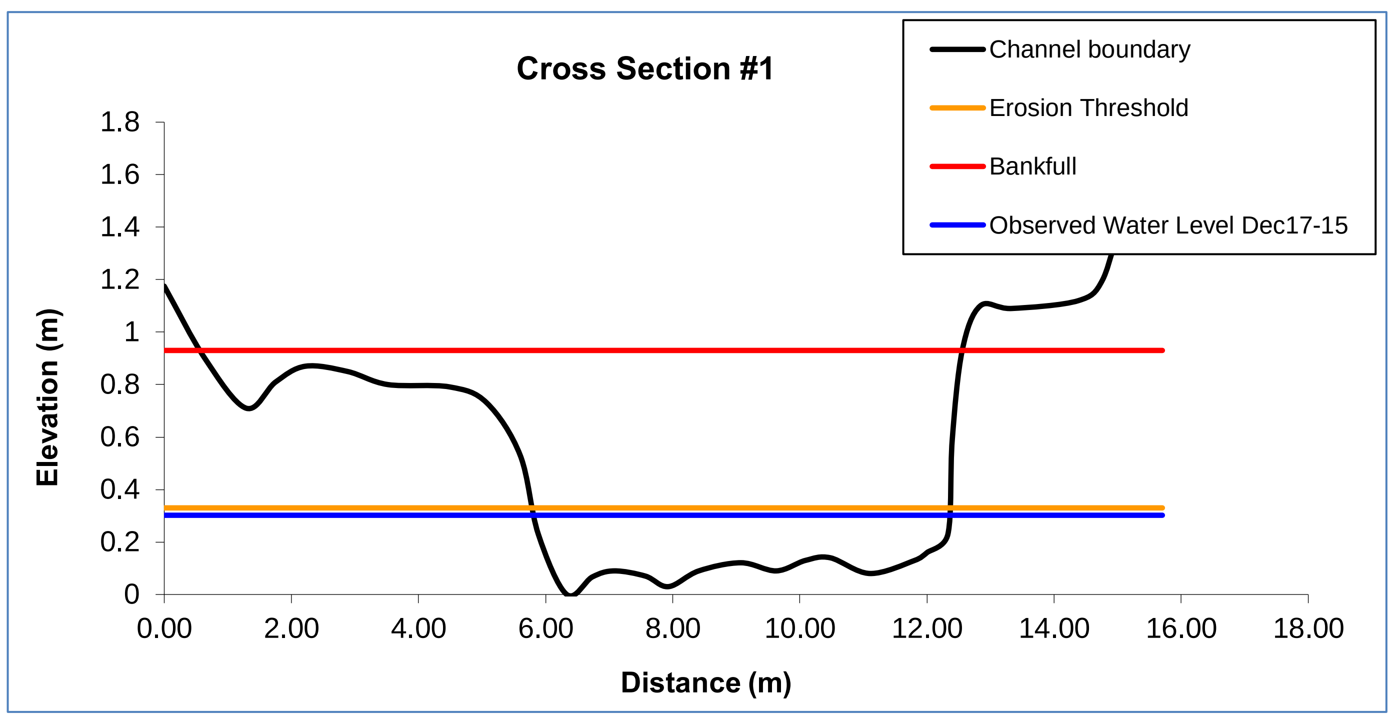
Erosion Threshold:

Critical Discharge (m^3/s):	**0.89**
Critical Velocity (m/s):	**0.61**
Critical Depth (m):	**0.33**
Critical Shear Stress (N/m^2):	**6.5**
Percent of Bankfull Discharge (%):	**12**

* Sediment entrainment not observed at the time of survey

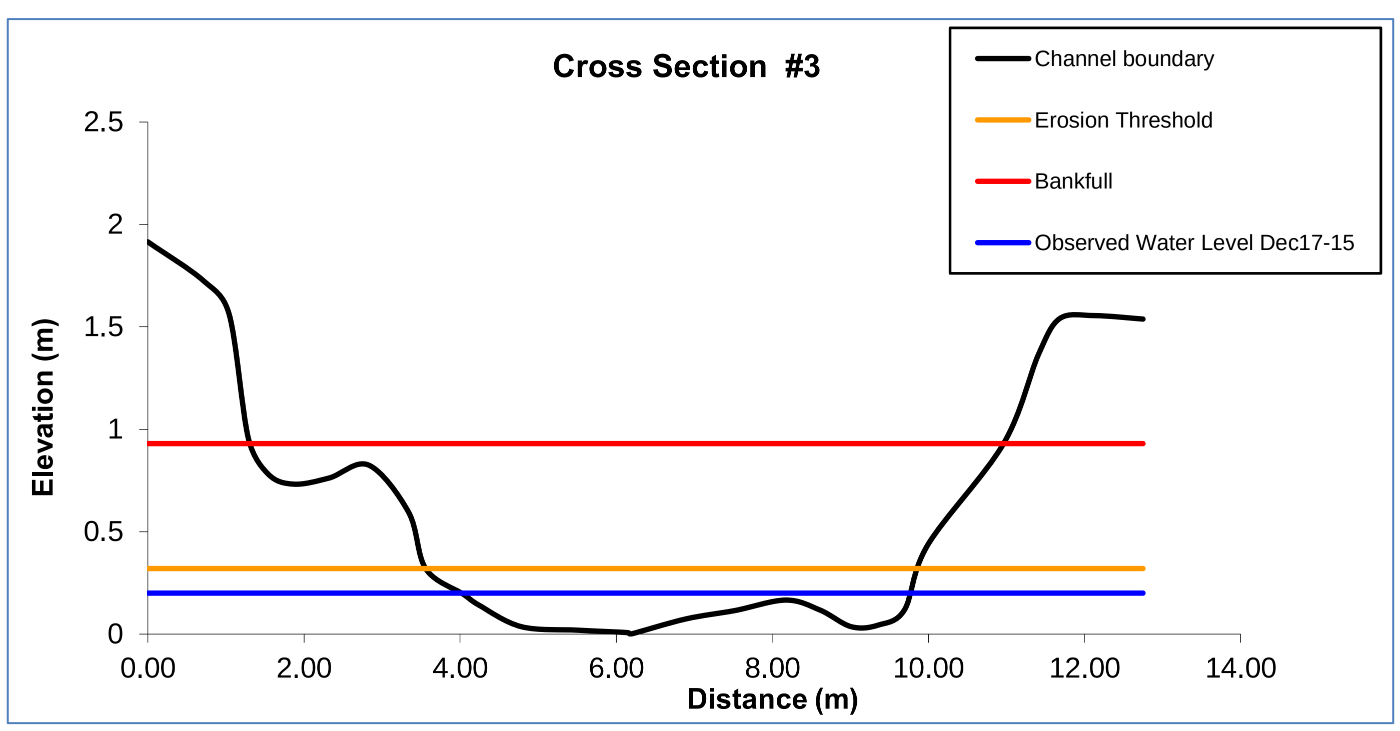
Cross-Section 1:

Critical Depth (m)	0.33
Slope (m/m)	0.003
Manning's n	0.033
Average Water Depth (m)	0.22
Velocity (m/s)	0.60
Discharge (m^3/s)	0.90
Bed Shear Stress (N/m^2)	6.5
Bed Sediments	
D_{50} (m)	0.0063
D_{84} (m)	0.028
Komar (1987) D_{50} (m/s):	0.46
Miller et al (1977) D_{50} (N/m^2)	4.59



Cross-Section 2:

Water Depth (m)	0.32
Slope (m/m)	0.003
Manning's n	0.033
Average Water Depth (m)	0.22
Velocity (m/s)	0.61
Discharge (m^3/s)	0.87
Bed Shear Stress (N/m^2)	6.5
Bed Sediments	
D_{50} (m)	0.0063
D_{84} (m)	0.028
Komar (1987) D_{50} (m/s):	0.46
Miller et al (1977) D_{50} (N/m^2)	4.59



BEACON ENVIRONMENTAL

Geomorphology Group

Summary of Erosion Threshold Analysis

Date:	May 2016	**Project:**	215200.1
Client:	Sixteenth Land Holdings Inc.	**Watercourse:**	Bruce Creek
Location:	York Downs Golf Club, Markham, ON	**Reach:**	BR-3
Length Surveyed:	230 m	**Representative Cross-sections:**	XS 6 and 7 (of 8)

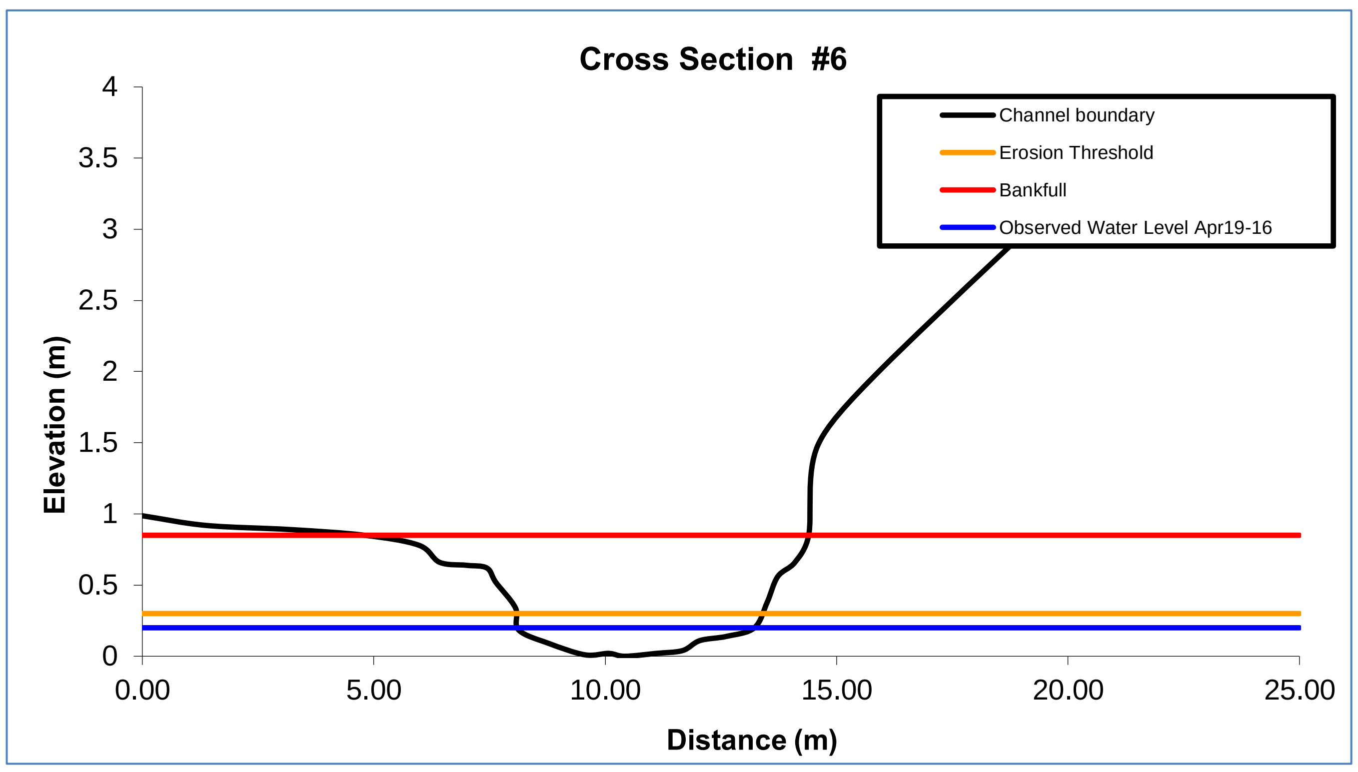
Summary of Calculated Hydraulic Parameters

Bankfull Channel:		*Erosion Threshold:*	
Discharge (m^3/s):	**6.60**	Critical Discharge (m^3/s):	**0.90**
Velocity (m/s):	**1.40**		
Maximum Depth (m):	**0.85**	Critical Velocity (m/s):	**0.74**
Tractive Force (N/m^2):	**21.8**		
		Critical Depth (m):	**0.31**
Flow Competency (Komar, 1987):			
for D_{50} (m/s):	**0.55**	Critical Shear Stress (N/m^2):	**9.6**
for D_{84} (m/s):	**1.05**		
		Percent of Bankfull Discharge	**14**
Shear Stress (Miller et al., 1977):			
for D_{50} (N/m^2):	**6.8**		
for D_{84} (N/m^2):	**27.7**		

* Sediment entrainment not observed at the time of survey

Cross-Section 1:

Critical Depth (m)	0.30
Slope (m/m)	0.0044
Manning's n	0.033
Average Water Depth (m)	0.22
Velocity (m/s)	0.72
Discharge (m^3/s)	0.85
Bed Shear Stress (N/m^2)	9.4
Bed Sediments	
D_{50} (m)	0.0093
D_{84} (m)	0.038
Komar (1987) D_{50} (m/s):	0.55
Miller et al(1977) D_{50} (N/m^2)	6.77



Cross-Section 2:

Water Depth (m)	0.32
Slope (m/m)	0.0044
Manning's n	0.033
Average Water Depth (m)	0.23
Velocity (m/s)	0.76
Discharge (m^3/s)	0.95
Bed Shear Stress (N/m^2)	9.8
Bed Sediments	
D_{50} (m)	0.0093
D_{84} (m)	0.038
Komar (1987) D_{50} (m/s):	0.55
Miller et al(1977) D_{50} (N/m^2)	6.77