Regional Municipality of Halton

# New North Oakville Transportation Corridor and Crossing of Sixteen Mile Creek

# Appendix G: Fluvial Geomorphological Assessment

**NEW NORTH OAKVILLE TRANSPORTATION CORRIDOR (BURNHAMTHORPE ROAD) – CLASS EA STUDY**

**~ FLUVIAL GEOMORPHOLOGICAL COMPONENT ~**

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*16 MILE CREEK, NORTH OAKVILLE, ONTARIO*

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**SUBJECT:** EROSION ASSESSMENT – NEW NORTH OAKVILLE TRANSPORTATION CORRIDOR (BURNHAMTHORPE ROAD) – CLASS EA STUDY

(FINAL)

**DATE:** APRIL 2008

PARISH geomorphic

## INTRODUCTION

A new transportation corridor was considered for North Oakville to alleviate some of the travelling congestion experienced on some of the main connecting roadways in this area. The extension of Burnhamthorpe Road over the 16 Mile Creek valley corridor has been highlighted as the preferred route alignment that would eliminate this traffic congestion. As a part of this consideration and the environmental assessment required for this crossing proposal, a geomorphological assessment of the study area (See **Figure 1**) was completed. The purpose of this assessment was to investigate the migration rates and pattern of this valley system to facilitate the most appropriate location for the bridge alignment based on channel conditions. In order to achieve this goal, the following tasks were performed:

- Geological analysis;
- Site characterization and reach delineation;
- Historical assessment of the channel reaches using aerial photographs;
- Calculation of channel migration using historical aerial photographs;
- Delineation of meander belt widths for each reach; and,
- Collection of detailed geomorphological field information.

## GEOLOGY

A general understanding of the underlying geology provides insight into the existing channel form. Geology influences the rate of channel change (e.g. migration), defines the quantity and type of channel sediments, and channel geometry. Channels flowing over loose alluvial material more readily change form and position than channels flowing over bedrock/shale and till due to the additional resistance to erosion. According to the Geological Highway Map of Southern Ontario (MNR, 1979), the underlying geology surrounding the study area consisted of Queenston Formation composed of red shale. Shale out-croppings were visible in the eroded valley walls of the study area and throughout the valley corridor. The information collected from this analysis was then combined with aerial photographic and floodplain mapping to delineate reaches for the study area.


***Figure 1.*** *Map identifying the area included in the study and assessment of an appropriate watercourse crossing or the Burnhamthorpe road extension.*

Channel form is a product of the flow (magnitude) and the channel materials (sediment type, supply, and bed/bank strength). If one of these parameters is altered, the channel adjusts its form to retain or find a new 'dynamic equilibrium'. The characteristics of the flow or channel materials can change along a creek or stream. In order to account for these changes, channels are separated into reaches - generally several hundred meters to several kilometres in length. Delineation of a reach considers sinuosity, gradient, hydrology, local geology, degree of valley confinement, and vegetative control using methods outlined in PARISH Geomorphic Ltd. (2001). The section of 16 Mile Creek being considered for potential bridge crossing locations was broken down into two reaches based mainly on channel confinement and surrounding land use (See **Figure 2**).

## HISTORICAL ASSESSMENT

To better understand the current state of a channel, it is important to consider the changes it has undergone in the past, including changes in surrounding land-use. These changes were identified through a historical assessment using a series of air photos. Photographs used for this investigation were taken from 1954 (1:15,807), 1978 (1:10,048) and 1999 (digital aerial photographs). Using these aerial photographs, migration rates were also measured. Migration rates quantify the rate that a meander bend of a stream moves across its valley and are used to help predict future shifts of the channel. Measurements are taken from a benchmark that is consistent in each aerial photograph to the outer extent of a meander bend.

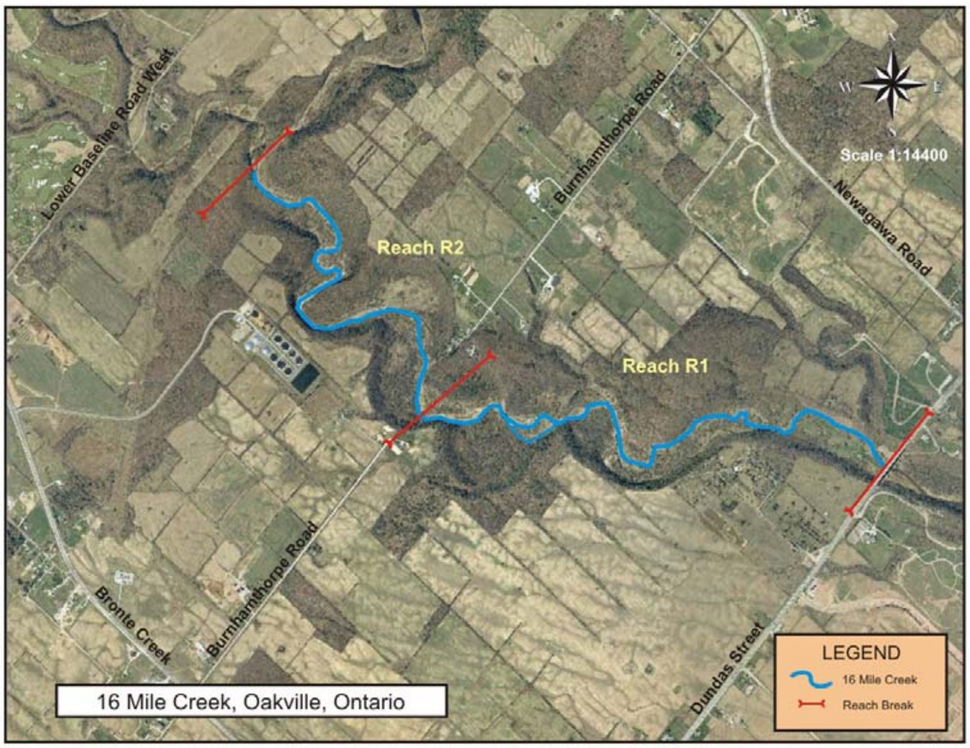



***Figure 2.*** *Map identifying the reaches delineated from historical aerial photographs and topographic mapping.*

*Land Use and Channel Planform*

This section of 16 Mile Creek in north Oakville had a meandering planform that flowed through valley lands and mixed forest areas. There was also a small portion of the downstream segment of reach R1 that was surrounded by a parkland area with active recreational trails. The lands on the tops of the valley walls consisted of agricultural fields and a hydro corridor. From the aerial photographs, it appeared that a large portion of the watercourse had some form of valley wall contact involved as well. **Table 1** lists the changes in surrounding land uses observed between the years studied.

**Table 1.** Historic land use and channel change for the 16 Mile Creek in North Oakville.

| Years | Land Use | Channel Change |
|---|---|---|
| **1954** | **Overall**<br>• Predominantly agricultural<br>• Riparian cover moderately established along reaches<br>• Vegetation mostly trees and shrubs with moderate to high density<br>***R1***<br>• Riparian conditions best established at upstream end near confluence<br>***R2***<br>• Reduced riparian conditions and more evidence of development | **Overall**<br>• Channel widths vary greatly<br>• Sinuosity is high and irregular<br>• Channel extremely braided with evidence of high flow channel, meander scars etc.<br>• Depositional features visible throughout reach<br>• Broad floodplains in some locations<br>***R1***<br>• Channel widths more consistent<br>***R2***<br>• Planform of channel very irregular and undefined |
| **1978** | **Overall**<br>• Agriculture remained the dominant form of land-use<br>• Increased industrial development<br>• Riparian conditions increased throughout the site mostly on non-vegetated floodplains<br>***R1***<br>• River corridor conditions improved with increased riparian vegetation<br>***R2***<br>• More intense land use practices, increased infrastructure | **Overall**<br>• Channel widths seem more consistent throughout the site<br>• Sinuosity remains high<br>• Braiding still evident with scars<br>• Depositional features remain visible<br>***R1***<br>• Increased braiding upstream of Burnhamthorpe Rd.<br>***R2***<br>• Main channel planform changes drastically with new meanders and side channels |
| **1999** | **Overall**<br>• Dominant land use activity remains agriculture<br>• Riparian conditions remain relatively the same<br>• The surrounding transportation network has increased<br>***R1***<br>• Industrial development increases (i.e. water treatment plant)<br>• Urban development increased north of the site (i.e. golf course)<br>***R2***<br>• Residential developments flourished south of Dundas St. | **Overall**<br>• Channel planform seems to become more stable, less braiding and visible scars<br>• Sinuosity remains high<br>• Depositional features less apparent<br>***R1***<br>• Large island created upstream of Burnhamthorpe Rd.<br>***R2***<br>• Some evidence of braiding remains |

### *Migration Rates*

Migration rates were calculated for both lateral and downstream movements of the channel using the historical aerial photographs and the ortho photographs. Since the aerial photographs were clear and the vegetation sparse in areas, four identical points of interest could be measured for both reaches R1 and R2. However, because of a lack of suitable benchmark points for the down-valley migrations characteristics, only three separate points of interest were available for both reaches. **Table 2** highlights the amount of change observed in each reach between the years studied and their overall conclusions.

**Table 2.** Lateral and down-valley migration rates calculated from historical aerial photographs for reaches R1 and R2.

| Reach | Lateral Migration (m/yr) | | Down-Valley Migration (m/yr) | |
|---|---|---|---|---|
| **Reach R1** | 1954 - 1978 | 0.033 | 1954 - 1978 | 0.171 |
| | 1978 - 1999 | 0.244 | 1978 - 1999 | 0.798 |
| | Overall Average | **0.139** | Overall Average | **0.313** |
| **Reach R2** | 1954 - 1978 | 1.675 | 1954 - 1978 | 0.184 |
| | 1978 - 1999 | 0.883 | 1978 - 1999 | 0.831 |
| | Overall Average | **0.396** | Overall Average | **0.323** |

According to the migration rates calculated above, Reach R1 appeared to have laterally migrated at an average rate of 0.14 m/yr, with an associated down-valley migration of 0.31 m/yr. In the same time frame, Reach R2 migrated laterally by an average rate of 0.40 m/yr and down-valley at 0.32 m/yr. The values obtained for these reaches were typical of similar channels observed in southern Ontario, however, they are likely somewhat controlled by the relatively resistant nature of the bedrock substrate and banks of 16 Mile Creek at this location.

### MEANDER BELT WIDTH

The meander belt width assessment is important from a channel crossing perspective. All streams move and shift across their floodplain. In stable channels, this rate is often low but can become quite dramatic after large flow events. Rapid changes in planform may indicate an attempt by the stream to adjust to changes in the system's flow or sediment regime. The meander belt width represents the stream corridor that the channel has in the past, and more importantly, could in the future occupy. The associated historic assessment of channel planform change gives an indication of how rapidly the channel is moving and is useful for determining buffers for defined belt widths. This insight is beneficial in planning stream crossings, in order to minimize risk to the structure from channel migration.

Based on the initial characterization and the historical assessment, meander belt widths for Reaches R1 and R2 were defined for the study area based on the methods outlined in *Belt Width Delineation Procedures* (PARISH Geomorphic Ltd., 2001b). The results of this analysis have been mapped in **Figure 3** and described in **Table 3.**

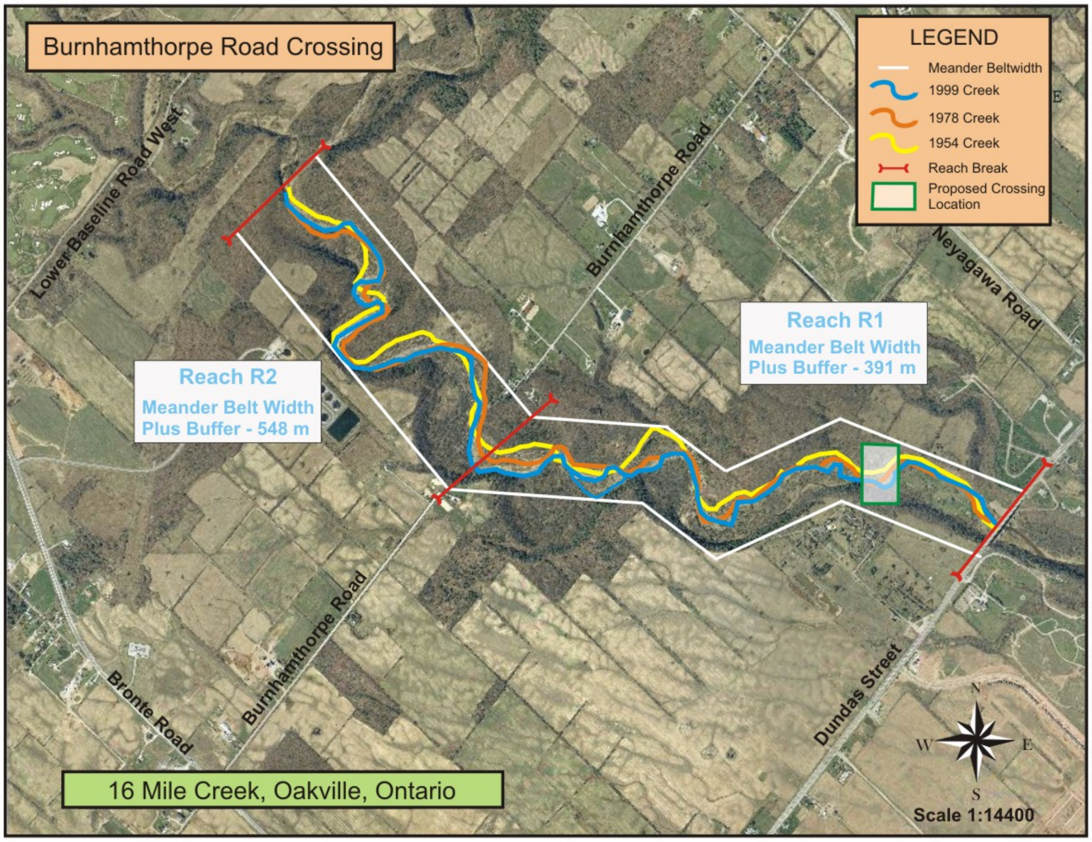



***Figure 3.*** *Historical overlay of 16 Mile Creek from 1954 to 1999, and the associated meander belt widths calculated from the historic assessment.*

As per the protocol, any belt width greater than 50 meters wide requires an additional buffer or safety factor of 10% to account for the fact that the existing meander belt does not necessarily reflect a quasi-equilibrium form. The resultant meander belt width is generally divided over the centre line of the reach or valley.

**Table 3**. Meander belt widths and buffers for reaches R1 and R2.

| Reach Name | Meander Belt Width | Meander Belt Width plus 10% Buffer |
|---|---|---|
| **R1** | 355 m | 391 m |
| **R2** | 498 m | 548 m |

The extent of any belt width is based on the largest meander form observed within the valley corridor (based on the centre line of the channel). In such, the belt width values calculated for both reaches were based on the largest of all meander bends observed within the study area. However, the location of the proposed crossing in Reach R1 has a smaller meander amplitude then the meander bend used to calculate the belt width. Therefore, the final meander belt width should be considered a conservative value with respect to the application of the proposed road crossing in reach R1.

### FIELD RECONNAISSANCE

The initial component of the fieldwork entailed a walking reconnaissance of the identified reaches. During the reconnaissance, any areas of substantial erosion were mapped and rapid assessments were completed (Rapid Geomorphic Assessment and Rapid Stream Assessment Technique). A Rapid Geomorphic Assessment, or RGA, (MOE, 1999) documents observed indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity to aggradation, degradation, channel widening and planimetric adjustment. The index produces values that indicate whether the channel is "in regime" (i.e. stable) (<0.20), stressed/transitional (0.21-0.40) or adjusting (e.g. incision) (0.41).

A Rapid Stream Assessment, or RSAT, provides a broader view of the system by also considering the ecological functioning of the stream (Galli, 1996). Observations include instream habitat, water quality, riparian conditions, and biological indicators. RSAT scores rank the channel as maintaining a low (<20), moderate (20-35) or high (>35) degree of stream health. Additionally, the RSAT approach includes rough measures of bankfull channel dimensions, type of substrate, vegetative cover, and channel disturbance. RGA and RSAT scores are provided in **Table 4**, along with a reach-by-reach description of the study area.

**Table 4.** Reach descriptions and RGA and RSAT scores.

| Reach | Description |
|---|---|
| ***R1*** | • Exposed shale and valley wall contact on both banks<br>• Shale lined channel with cobble and gravel bar formations<br>• Exposed consolidated clay in bed and on banks<br>• Exposed bridge footings/abutments with erosion and outflanking on both banks<br>• Undermined gabion baskets on left bank immediately upstream of foot bridge<br>• Presence of leaning/fallen trees and erosion of bank faces exposing tree roots throughout reach<br>• Formation of islands, chutes and cut off channels observed upstream of first major meander bend<br>• Moderate gradient with a moderate to high entrenchment<br>• Bankfull widths between 15 and 35 m, with depths between 0.5 and 1.5 m<br>• **RGA Score 0.49, In a State of Adjustment**, dominant geomorphological process observed was widening<br>• **RSAT Score 22.5, moderate stability index** |
| ***R2*** | • Exposed shale and valley wall contact on both banks<br>• Shale lined channel with fragmented shale bar and riffle features<br>• Exposed consolidated clay in bed and on banks<br>• Exposed bridge footings/abutments at Highway 407 crossing<br>• Presence of leaning/fallen trees and erosion of bank faces exposing tree roots throughout reach<br>• Moderate channel gradient with a low to high degree of entrenchment<br>• Bankfull widths between 12 and 40m. with depths between 0.5 and 1.0 m<br>• **RGA Score 0.45, In a state of Adjustment**, dominant geomorphological process observed was widening<br>• **RSAT Score 20, moderate stability index** |

In summary, Reach R1 was characterized as a highly eroding section of 16 Mile Creek that had incised into the underlying Queenston Shale geology. The dominant geomorphological process observed was channel widening supported by evidence of fallen/leaning trees; exposed tree roots on the banks; erosion of the valley wall faces; basal scour along both banks through the riffle features; and erosion of more then 50% of the reach. Wetted widths for this reach ranged from 8 to 25 m, with associated depths between 0.05 and 1.0 m. This section of channel had a low sinuosity but with the formation of high flow channels, chutes and cut-off channels in the upstream section of the reach.

Reach R2 was very similar to Reach R1 in regards to being lined by shale, with erosion of the banks and contact with the large exposed shale valley walls. The dominant geomorphological process observed for this reach was also widening. The evidence supporting this conclusion for R2 consisted of the fallen/leaning trees on the banks and in the channel; exposed tree root masses on both banks; exposure of the Highway 407 bridge foundations, and the outflanking of the large concrete chunk in the channel downstream of the road crossing. This reach appeared wider then R1 with a more sinuous channel planform. Wetted widths for this reach ranged between 8 and 25 m with wetted depths between 0.05 and 0.6 m. This reach also appeared to lack deeper pool areas that were observed in reach R1.

Based on the rapid assessment analysis, Reach R2 appeared to be slightly more stable then R1. The rapid assessment analysis is normally used to determine which reach is the most sensitive to channel change. That information is then used to determine where the most appropriate crossings locations would be. In this case, both reaches were similar in stability index (0.49 and 0.45) and channel characteristics. Therefore, other parameters had to be considered. The fact that Reach R2 was more sinuous and had a higher rate of channel migration made it less suitable as a location for a crossing. Therefore, based on this information it was recommended that the crossing should be sited somewhere in Reach R1. To facilitate the planning and design of the crossing in this location a more detailed field analysis of Reach R1 was completed.

### DETAILED FIELD ASSESSMENT

Detailed geomorphic assessments for this study included measurements of channel and bank characteristics and bankfull flow conditions. As part of the detailed field assessments, standard protocols and known field indicators were used to quantify the bankfull cross-sectional dimensions of the reaches (e.g. bankfull depth and width). A modified Wolman pebble count was used to characterize the channel bed substrate materials. In addition to collecting a sediment sample of the bank, an *in situ* shear stress test was performed on bank materials in addition to noting bank characteristics (e.g. height and composition). These measurements were completed at ten cross-sections. A level survey provided a measure of the local energy gradient.

Parish Geomorphic Ltd had historically completed detailed field work on 16 Mile Creek which included the establishment of a monumented cross section immediately downstream of the proposed crossing location in what has now been labelled Reach R1. During the recent field investigation field staff tried to find the monumented pins to re-measure the cross section. By obtaining the more recent cross-sectional parameters, information regarding the amount of channel change could have been gathered. However, originally one of the monumented bank pins was installed in the actively eroding western bank of the channel in the meander bend downstream of the proposed crossing location. This bank could not be located and it was assumed that the pin had eroded out of the bank as the channel migrated downstream. The eastern bank pin from the original monitoring cross section could not be located either so the old monitoring cross section and associated data could not be used for this study. That being said, a new monumented top-of-bank cross section (included within the 10 cross-sections of the more recent field investigation) was installed in approximately the same location as the old monitoring cross section to measure future changes in channel form and function. The installation of this monitoring site also included the establishment of five 1m long re-bar erosion pins in the eroding faces of the banks throughout the detailed site. The erosion pins were installed as a secondary measure for channel migration for possible future monitoring visits.

Measurements from the detailed analysis are summarized in **Appendix A**. Based on field observations, the average bankfull width observed was 24.87m with an associated average bankfull depth of 0.84m. The average wetted width measured was 15.45m with an average depth of 0.33m. Bank heights ranged from 0.4m to the top of the valley walls (greater then 10m), with slope angles between 7 and 62 degrees. The average bank was over 50% protected by vegetation and the channel bed was predominantly shale with some cobbles and boulders sitting on top as riffle and bar features. The maximum pool depth observed was 1.97m and the riffle-pool spacing was calculated at 33.03m, with riffle lengths averaging 13.44 m. The information regarding the establishment of the erosion pins has been included in **Table 5**.

**Table 5.** Location and initial exposure measurements for the erosion pins installed at the monitoring site.

| Erosion Pin Number | Installation Location | Initial Exposure (cm) |
|---|---|---|
| **1** | - 25 m downstream of cross section # 4 in left bank (valley wall) | 64 |
| **2** | - 1m downstream of monitoring cross section (#6) in right bank (outside of meander bend) | 11.5 |
| **3** | - 3m upstream of monitoring cross section (#6) in right bank (outside of meander bend) | 15.5 |
| **4** | - installed at bankfull level in the right bank near cross section # 7 | 16.5 |
| **5** | - installed in the left bank of cross section # 10 (most upstream cross section) | 29.5 |

### SUMMARY

An erosion assessment was completed for a small portion of 16 Mile Creek north of Dundas Street between Neyaguawa Boulevard and Bronte Road. This assessment was completed to facilitate the appropriate siting of an extension to Burnhamthorpe Road in the northern Oakville area. The analysis included a historical assessment; calculation of migration rates; field reconnaissance; identification of meander belt widths; and the completion of detailed field work.

Based on the desktop historical assessment, two reaches were identified for the study area. Based on the migration analysis, Reach R1 had a lateral channel migration rate of 0.14 m/yr, and reach R2 had a rate of 0.40 m/yr. This theory would suggest that reach R1 would be the more appropriate location for the proposed crossing.

The meander belt width identified for Reach R1 was 391 m, and 548 m for Reach R2, including the buffer limits outlined in the protocols used. In theory, the proposed crossing location should span this width, however, in design this is most likely not obtainable. Therefore, it is recommended that the footings for the crossing be installed well outside the natural area of the existing channel and lined by large substrate to ensure that erosion and out-flanking of the footings does not occur.

A monitoring cross section was installed in Reach R1 within the detailed field site in order that future changes in the channel form and function can be analyzed. Five erosion pins were also installed throughout this site and will be key in determining the rate of bank

erosion and migration for future monitoring of the channel. It is recommended that monitoring of the area continue leading up to the construction of the crossing to obtain a better understanding of channel processes in the area of the proposed crossing. Continued monitoring would determine local migration rates, possible erosion thresholds, and placements of the footings for the crossing.

**References**

Chow, V.T., 1959. *Open-channel hydraulics*. McGraw Hill. Boston MA.

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

PARISH Geomorphic Ltd. 2001a. *Belt Width Delineation Procedures*. Submitted to: Toronto and Region Conservation Authority.

PARISH Geomorphic Ltd. 2001. *Geomorphological protocols for subwatershed studies*. Submitted to: Regional Municipality of Ottawa-Carleton.

Ministry of Natural Resources, 1979. Geological Highway Map – Southern Ontario

# APPENDIX A

FLUVIAL GEOMORPHOLOGY SUMMARY

## 16 Mile Creek - Burnhamthorpe Road Crossing

| | |
|---|---|
| **Site Location:** | North of Dundas Street between Neyagaua and Bronte Road on 16 Mile Creek |
| **Length surveyed:** | 833.36 m |
| **Number of cross-sections:** | 10 |
| **Date of Survey:** | July 25, 2006 |

*Controlling Factors*

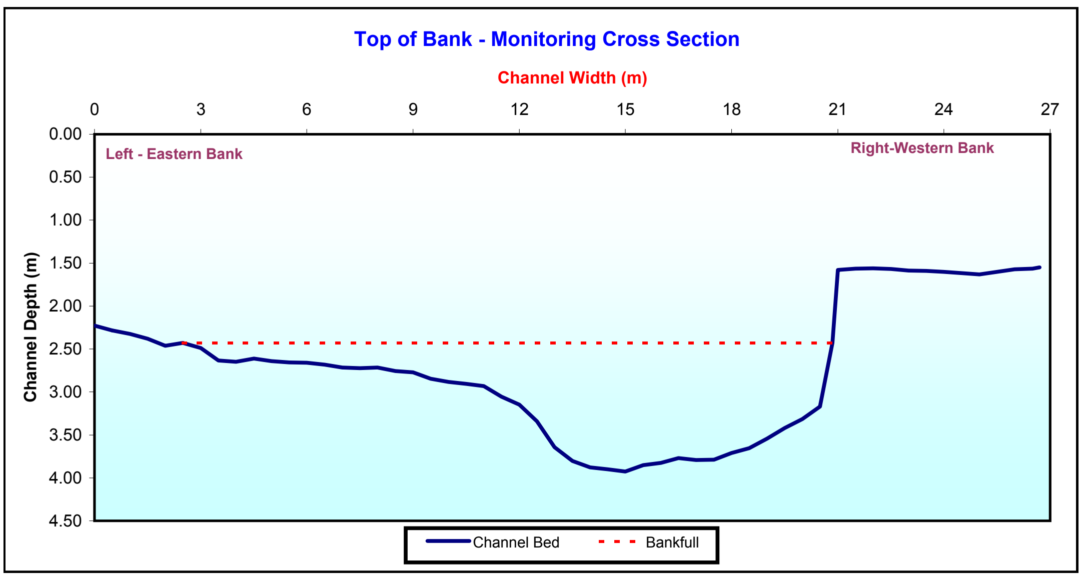
**Geology / Soils:** Bedrock and shale, fragemented from the valley walls.

*Modifying Factors*

| | |
|---|---|
| **Surrounding Land Use:** | The lower western bank of the site was composed of a parkland area, the rest of the site was valley wall and floodplain. |
| **General Riparian Vegetation:** | A mixture of trees, shrubs, tall and short grasses and herbaceous vegetation. |
| **Existing Channel Disturbances:** | Pedestrian bridge at the downstream end of the site, Dundas Street bridge and footings, and a man made weir structure near the downstream end of the site. |
| **Woody Debris:** | |

*Cross-Sectional Characteristics*

| | Range | Average |
|---|---|---|
| **Bankfull Width (m)** | 17.96 - 32.85 | 24.87 |
| **Bankfull Depth (m)** | 0.62 - 1.15 | 0.84 |
| **Width / Depth** | 19.91 - 48.53 | 31.18 |
| **Wetted Width (m)** | 9.22 - 25.03 | 15.45 |
| **Water Depth (m)** | 0.09 - 0.59 | 0.33 |
| **Width / Depth** | 41.64 - 193.22 | 107.43 |
| **Entrenchment (m)** | 45.43 - 60.85 | 52.98 |
| **Entrenchment Ratio** | 1.80 - 2.52 | 2.16 |




*Bank Characteristics*

| | Range | Average |
|---|---|---|
| **Bank Height (m)** | 0.4 - 20 | 3.1 |
| **Bank Angle (degrees)** | 7 - 62 | 26.6 |
| **Root Depth (cm)** | 3.0 - 100 | 29.9 |
| **Root Density** ***(1=Low - 5=High)*** | 1 - 4 | 2.6 |
| **Protected by vegetation (%)** | 5 - 95 | 57.3 |
| **Amount of undercut (cm)** | 0.0 - 45 | 4.9 |
| **Banks with undercuts (%)** | | |

| **Bank Materials** | **Torvane values (kg/cm2)** | |
|---|---|---|
| si/fs/ms | 0.24 | |
| si/fs/vfs | 0.21 | |
| si/vfs/cl | 0.26 | * |
| si/ms/fs/cl | 0.28 | |
| si/vfs/cl/fs | 0.20 | |
| si/vfs | 0.29 | |
| fs/ms/vcs | 0.05 | |
| cl/si | 0.23 | |

* - Dominant Material

## *Planform Characteristics*

*Long Profile (avg)*

| | | |
|---|---|---|
| **Bankfull Gradient:** | 0.35 | % |
| **Inter-Pool Gradient:** | 0.48 | % |
| **Inter-Riffle Gradient:** | 0.41 | % |
| **Riffle Gradient:** | 2.54 | % |
| **Riffle Length:** | 13.44 | m |
| **Riffle-Pool Spacing:** | 33.03 | m |
| **Max Pool Depth:** | 1.97 | m |

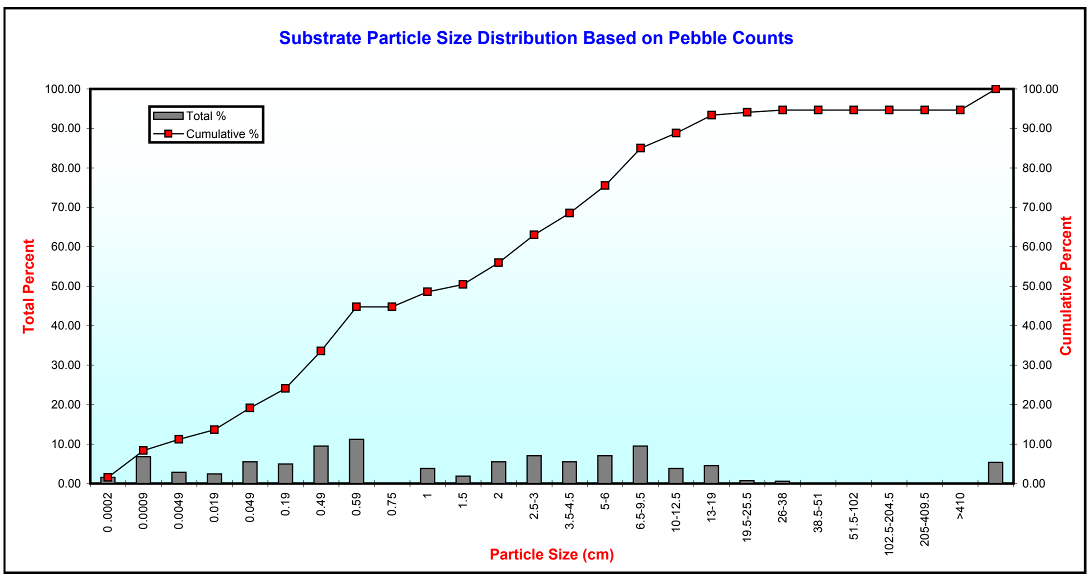
## *Substrate Characteristics*

| | | Range | Average |
|---|---|---|---|
| **Particle Shape (cm)** | | | |
| | **X** | 4 - 31 | 12.0 |
| | **Y** | 3 - 16 | 8.1 |
| | **Z** | 0.5 - 10.5 | 2.6 |
| **Hydraulic Roughness (cm)** | | | |
| | **Maximum** | 3 - 56 | 23.9 |
| | **Median** | 0.59 - 5 | 2.6 |
| | **Minimum** | 0 - 0.0009 | 0.0 |
| **Embeddedness (%)** | | 0 - 25 | 9.5 |

**Sub-pavement**
-100% bedrock

**Particle Sizes (cm)**

| | Pebble Counts | | |
|---|---|---|---|
| **D10** | 0.0015 | cm | |
| **D50** | 0.90 | cm | does not include bedrock |
| **D90** | 8.17 | cm | |




## *Field Observations*

XS 1 - Fish species include: hognose, johnny darter, and bass. XS is 8m d/s from gully, cobble/gravel deposit on bank.
XS 2 - Exposed clay in bed, exposed roots and scoured bank on right bank, valley wall on left bank.
XS 3 - Lots of algae in water, vegetated island in middle of channel.
XS 4 - Groundwater weeping from valley wall just downstream, algae everywhere (filamentous).
XS 5 - Fish prevelant
XS 6 - XS @ apex of bend, large eroding right bank. Right pin just behind the flagged tree, left pin in grassy area.  Large point bar feature on left bank.
XS 7 - Toe erosion on both banks, fallen tree on right bank u/s of XS.
XS 8 - Major woody debris 3m u/s of XS on left bank.
XS 9 - Large bedrock shelf in channel, XS 10m d/s from tributary confluence. Bar deposit on left bank. Valley wall contact on right bank.
XS 10 - Large woody debris jam u/s of XS.