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Appendix D

Fluvial Geomorphological Assessment Report and Memorandum

Region of Peel
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Peel Region Snow Storage Sites Analysis - FINAL

Fluvial Geomorphological Assessment

Region of Peel

Project number: 60646784

June 1, 2024

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Quality information

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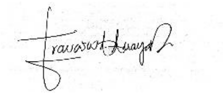		
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Revision History

Revision	Revision date	Details
Draft 1	January 15, 2024	Draft Project File submitted to the Region
Draft 2	April 3, 2024	Draft Project File circulated for Agency Review
Final	June 1, 2024	Report Signed and Finalized.

Distribution List

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Executive Summary

As part of a Schedule 'B' Municipal Class Environmental Assessment (MCEA) and preliminary design, AECOM Canada Ltd. was retained by the Region of Peel to complete required investigations of identified sites considered as potential near and long-term snow storage solutions for the Region of Peel. The sites being investigated will serve as the destination for accumulated snow from bridges and overpasses, intersections with sightline issues, and roadway areas with narrow boulevards/space restrictions, and Regional facilities. As part of this work, a fluvial geomorphological investigation was completed to assess the existing conditions of the potential sites in order to complete a meander belt assessment and an erosion threshold assessment, where permissible, considering the potential impacts of the snow melt.

A total of nine (9) sites were originally included as potential snow storage sites but four (4) were excluded in the initial phase of this study due to conflicting uses, expansion plans or perceived contamination. Out of the five (5) proposed storage sites, four (4) (Sites 3, 5, 6, and 9) have been identified as having watercourses within or adjacent to the properties, which will be the primary focus of the fluvial geomorphic assessment.

- Site 1 – Highway 50 Carpool Lot: Southwest corner of intersection of Highway 50 and Mayfield Road.
- Site 3 – West Brampton Reservoir: West of Mississauga Road, south of Bovaird Drive West.
- Site 5 – Johnston Sports Park: Northwest of the intersection of Centreville Creek Road and King Street.
- Site 6 – Tullamore Reservoir and Pumping Station: Northwest of the intersection of Innis Lake Road and Mayfield Road.
- Site 9 – Alloa Reservoir: West of the intersection of Creditview Road and Mayfield Road

The objective of the fluvial geomorphic assessment is to characterize fluvial geomorphological processes within the study sites and to define management recommendations that will maintain the current channel processes and limit adverse impacts to channel morphology. At Site 1 - Highway 50 Carpool Lot, historical aerial imagery showed no visible watercourse within the proposed snow storage site and fieldwork confirmed this. Fluvial geomorphological reach characterization was completed at four locations proposed for snow storage. Further assessment occurred at two sites (Site 5 – Johnston Sports Park and Site 6 - Tullamore Reservoir), including Rapid Geomorphic Assessments, quantitative geomorphological data collection, calculation of an erosion threshold, and calculation of the meander belt. The remaining two sites were not further assessed due to watercourse being located on private property. For Site 3 – West Brampton Reservoir a site visit was conducted at Bovaird Drive where the channel was only slightly defined and approximately 1 m wide. At Site 9 – Alloa Reservoir a site visit was conducted at Mississauga Road and Creditview Road where the channel is defined and approximately 4 m wide.

As part of the fluvial assessment, a Rapid Geomorphic Assessment (RGA), an erosion threshold assessment and a meander belt width delineation were completed on Site 5 – Johnston Sports Park and Site 6 – Tullamore Reservoir and Pumping Station.

The RGA completed at Site 5 – Johnston Sports Park found that the channel is in a "Transitional or Stressed" condition with aggradation and planimetric form adjustment as the main geomorphological processes taking place. In addition, the erosion threshold assessment calculated the critical discharge value required for bed material entrainment was on average 0.15 m^3/s. Lastly, the meander belt width was determined using the empirical approach due to historical alterations of the channel and calculated at 33.5m

The RGA Assessment completed at Site 6 – Tullamore Reservoir identify the channel to be in "Regime" with widening and planimetric form adjustment identified as the main geomorphological processes taking place. Minimal evidence of erosion was found within this reach. The erosion threshold identified that the critical discharge value required to entrain or begin to transport bed material is on average 0.13 m^3/s. Lastly, the meander belt width was completed using the mapping approach and is 158m.

The results of the assessments are further discussed in the in body of the report. Based on the results of the fluvial geomorphic assessment, the following recommendations are made.

- Increases in flow to the watercourses from the snow melt should consider the erosion threshold conditions for Site 5 – Johnston Sports Park and Site 6 - Tullamore Reservoir. The erosion threshold provides targets for the drainage network. Increases in flow have the potential to result in channel instability and lead to morphological adjustment. It should be noted that at Site 5 - Johnston Sports Park, that aggradation of fine sediment was found along the bed of the watercourse and that increases in flow will help to alleviate this. At Site 6 – Tullamore Reservoir, shale bedrock identified along the bed of the watercourse will provide resistance to erosional processes, but no shale was noted along the banks. It is recommended that care is taken to maintain vegetation cover along and within the watercourses in order to maintain the existing channel stability.
- The meander belt refers to the lateral extent of floodplain occupation by a meandering watercourse both now and into the future. Protecting the meander belt area from encroachment serves the dual purposes of enabling a continuity of natural channel processes and of protecting property and structures from erosion. To prevent, eliminate or minimize the risks to life and property caused by erosion hazards, it is recommended to maintain the meander belt boundary.
- Due to the location of the watercourses on private property at Site 3 – West Brampton Reservoir and Site 9 – Alloa Reservoir and no permission to enter (PTE), a scoped fluvial geomorphological assessment was completed. Future detailed assessments are recommended when permission to enter granted.

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Figures

Tables

1. Introduction

As part of a Schedule 'B' Municipal Class Environmental Assessment (MCEA) and preliminary design, AECOM Canada Ltd. was retained by the Region of Peel to complete the required investigations of identified sites considered as potential near and long-term snow storage solutions for the Region of Peel. The sites being investigated will serve as the destination for accumulated snow from bridges and overpasses, intersections with sightline issues, and roadway areas with narrow boulevards/space restrictions, and Regional facilities. As part of this work, a fluvial geomorphological investigation was completed to assess the existing conditions of the potential sites in order to complete a meander belt assessment and an erosion threshold assessment, where permissible, considering the potential impacts of the snow melt.

1.1 Study Area

A total of nine (9) sites were originally included as potential snow storage sites but four (4) were excluded in the initial phase of this study due to conflicting uses, expansion plans or perceived contamination. **Table 1-1** describes the location of the five (5) remaining sites, followed by a complete set of figures of the proposed location (**Figure 1-1** to **Figure 1-5**). Out of the five (5) proposed storage sites, four (4) (Sites 3, 5, 6, and 9) have been identified as having watercourses within or adjacent to the properties, which will be the primary focus of the fluvial geomorphic assessment.

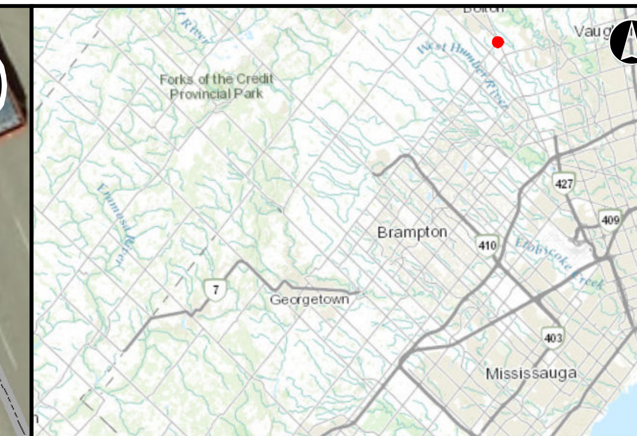
Table 1-1. Site Locations

Site Name	Location	Watershed
Site 1 - Highway 50 Carpool Lot	Southwest corner of intersection of Highway 50 and Mayfield Road.	Humber River (Main)
Site 3 - West Brampton Reservoir	West of Mississauga Road, south of Bovaird Drive West.	Credit River
Site 5 - Johnston Sports Park	Northwest of the intersection of Centreville Creek Road and King Street.	Humber River (West)
Site 6 - Tullamore Reservoir and Pumping Station	Northwest of the intersection of Innis Lake Road and Mayfield Road.	Etobicoke Creek
Site 9 – Alloa Reservoir	West of the intersection of Creditview Road and Mayfield Road	Etobicoke Creek

1.2 Aims and Objectives

The key objective of the fluvial geomorphic assessment is to characterize fluvial geomorphological processes within the study sites in order to define management recommendations that will maintain important channel processes and limit adverse changes to channel morphology. Specifically, the scope of work has included:

- Background review;
- Delineation of geomorphological reaches;
- Reach-scale geomorphological field reconnaissance;
- Detailed geomorphological data collection;
- Meander Belt Assessment and,
- Erosion Threshold Assessment.



Legend

- Property Boundary
- Potential Snow Storage Area

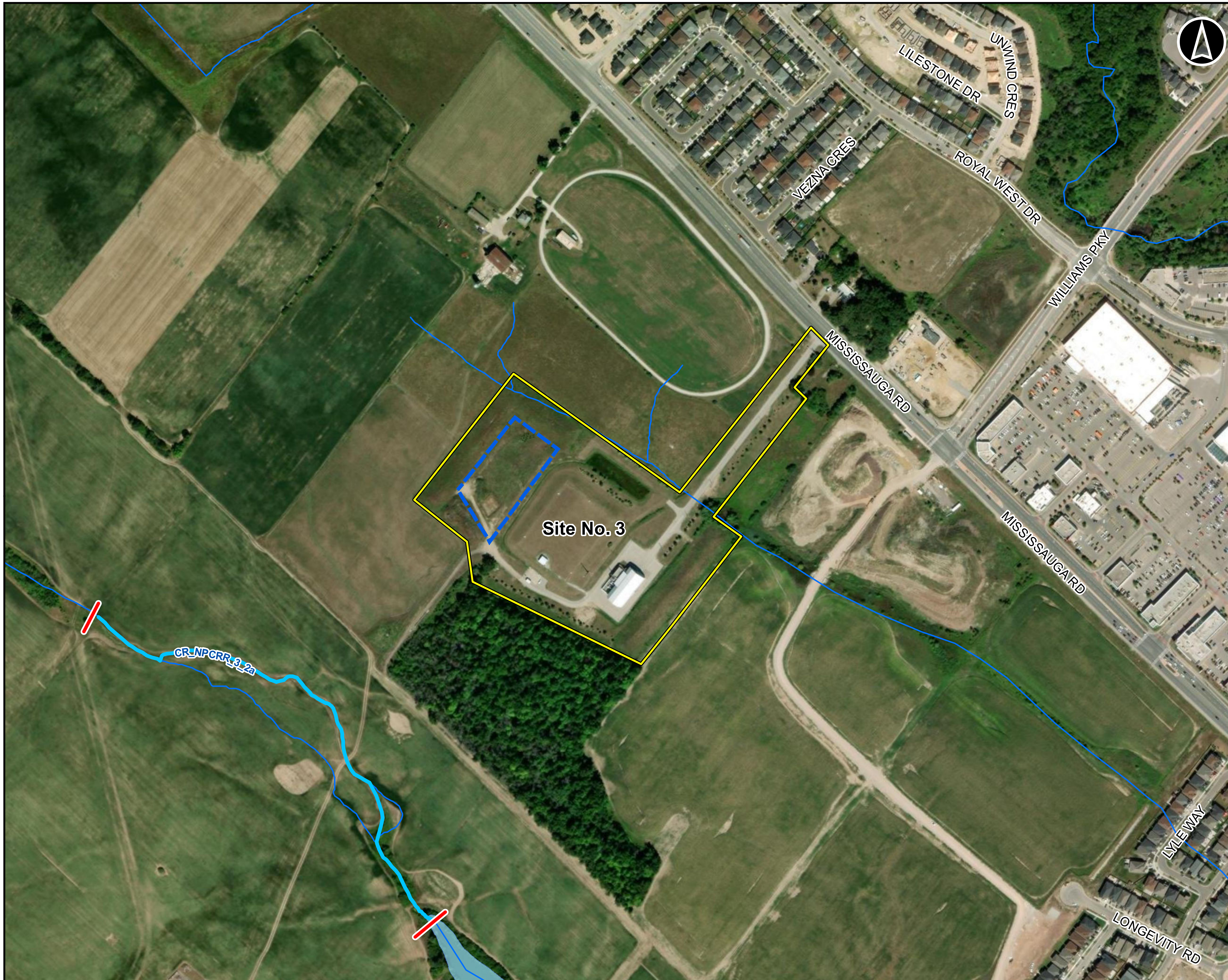
0 15 30
Metres

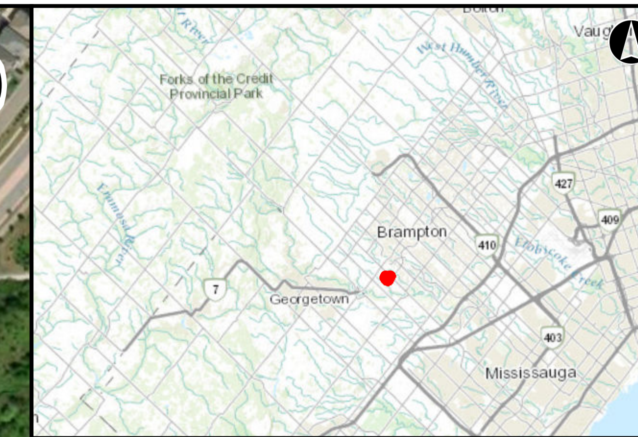
Peel Snow Storage Sites Analysis and Conceptual Design

Study Area in Detail
Highway 50 Carpool Lot

Jan, 2024	1:480 * when printed 11"x17"	Datum: NAD 1983 UTM Zone 17N Source: MNRF, The Regional Municipality of Peel
P#: 60646784		**Figure 1-1**

AECOM





Legend

- Reach
- Reach Break
- Watercourse
- Waterbody
- Property Boundary
- Potential Snow Storage Area

0 50 100 200 300
Metres

Peel Snow Storage Sites Analysis and Conceptual Design

Study Area in Detail
West Brampton Reservoir and Pumping Station

Jan, 2024	1:4,500 * when printed 11"x17"	Datum: NAD 1983 UTM Zone 17N Source: MNRF, The Regional Municipality of Peel
P#: 60646784		**Figure 1-2**

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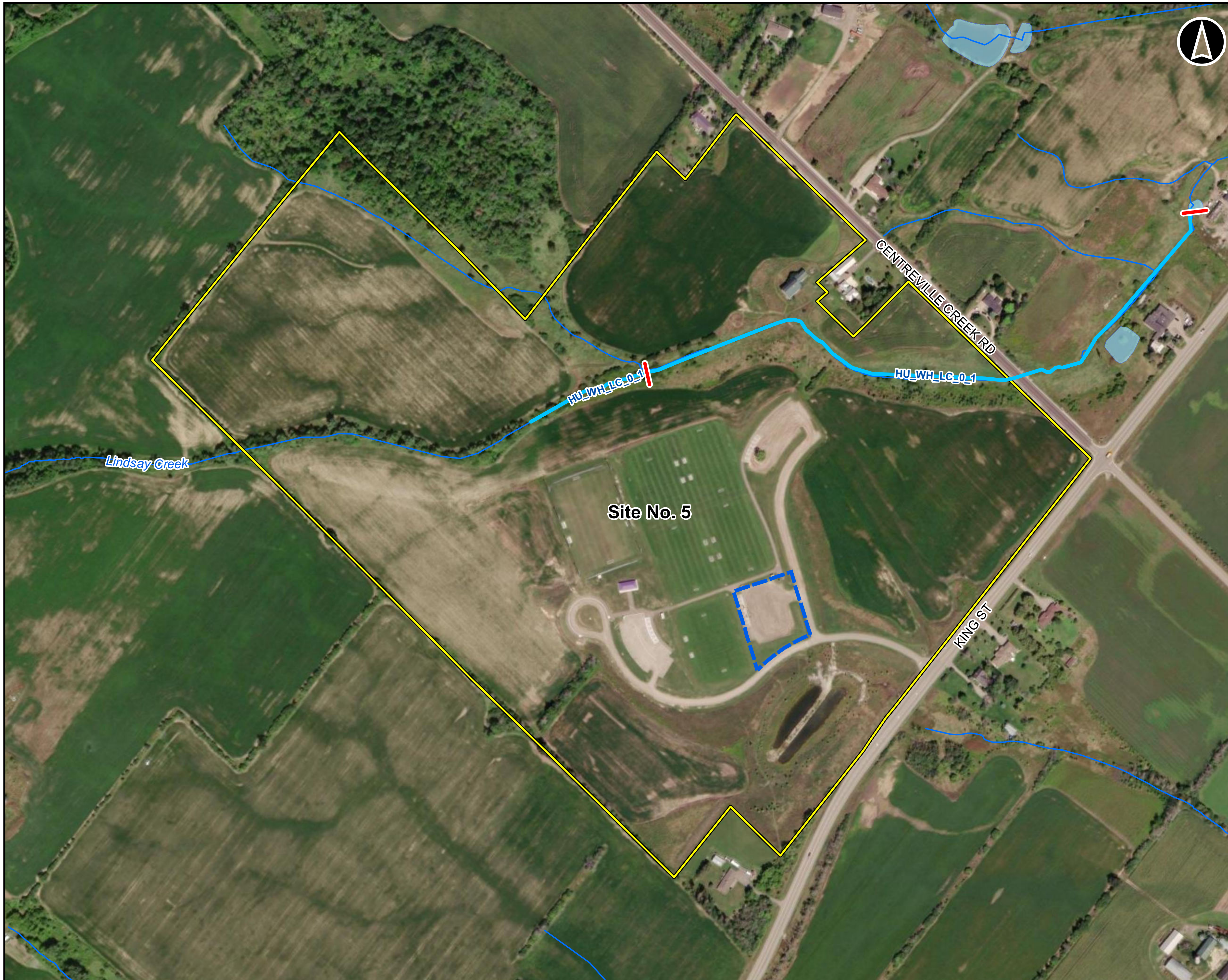

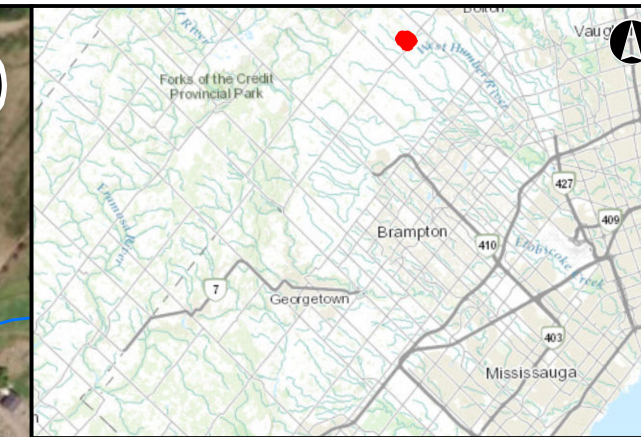

Legend

- Reach
- Reach Break
- Watercourse
- Waterbody
- Property Boundary
- Potential Snow Storage Area

0 50 100 200 300
Metres

Peel Snow Storage Sites Analysis and Conceptual Design

Study Area in Detail
Johnston Sports Park

Jan, 2024	1:4,200 * when printed 11"x17"	Datum: NAD 1983 UTM Zone 17N Source: MNRF, The Regional Municipality of Peel
P#: 60646784		**Figure 1-3**

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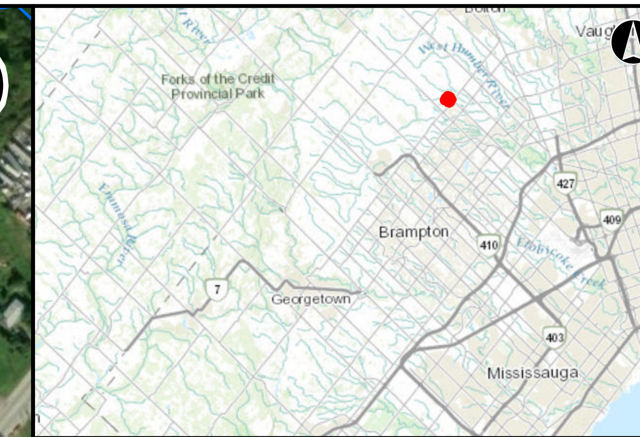


Legend

- Reach
- Reach Break
- Watercourse
- Waterbody
- Property Boundary
- Potential Snow Storage Area

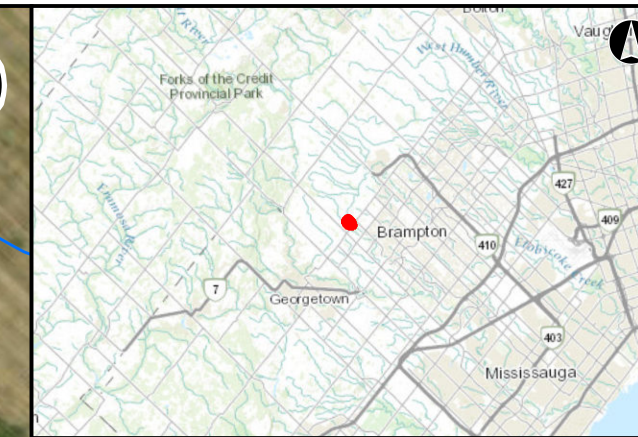
0 50 100 200 300
Metres

Peel Snow Storage Sites Analysis and Conceptual Design

Study Area in Detail
Tullamore Reservoir and Pumping Station

Jan, 2024	1:5,000 * when printed 11"x17"	Datum: NAD 1983 UTM Zone 17N Source: MNRF, The Regional Municipality of Peel
P#: 60646784		**Figure 1-4**

AECOM



Legend

- Reach
- Reach Break
- Watercourse
- Property Boundary
- Potential Snow Storage Area

0 50 100 200
Metres

Peel Snow Storage Sites Analysis and Conceptual Design

Study Area in Detail
Alloa Reservoir and Pumping Station

Jan, 2024	1:3,500 * when printed 11"x17"	Datum: NAD 1983 UTM Zone 17N Source: MNRF, The Regional Municipality of Peel
P#: 60646784		**Figure 1-5**

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2. Desk-Based Assessment

A review of watershed characteristics, physiography, geology, and topography provides context for characterization of the proposed snow storage sites and previous studies were also reviewed to extract pertinent information concerning the proposed snow storage sites and watercourses (when present) in/or immediately adjacent to the proposed sites. Only relevant information has been extracted and reviewed – further details can be obtained within the referenced reports.

2.1 Watershed Characteristics

The proposed locations are within the watersheds of Credit River, Etobicoke Creek and West Humber River subwatershed. A general description of the watersheds and subwatersheds along with an overview of the local physiography, surficial geology, topography, and land use surrounding the proposed locations is presented in the following sections.

2.1.1 Credit River Watershed

The Credit River Watershed has an approximate area of 950 km^2 within the Greater Golden Horseshoe area. Land cover within the watershed consists of natural cover (35%), agriculture and open space (34%) and urban land use (31%). The are covered by natural land is made up of upland forests (12%), wetlands (7%) and a small proportion of aquatic habitat and other natural cover such as beaches and bluffs (1%). It also includes cultural forest (6%) or successional communities (9%) that have a history of human origin (CVC, 2019). Only one study site (**Site 3 - West Brampton Reservoir**) is located within this watershed.

2.1.1.1 Physiography and Surficial Geology

The physiography and geology for the proposed snow storage site located within the Credit River watershed are presented in Table 2-1.

Table 2-1. Physiography and Surficial Geology for Site 3

Site Name	Physiography and Surficial Geology
Site 3 – West Brampton Reservoir	The Credit River watershed is divided in nine (9) physiographic regions. Lake Iroquois Plain, South Slope, Peel Plain, Niagara Escarpment, Oak Ridges Moraine, Horseshoe Moraines, Guelph Drumlin Field, Hillsburgh Sandhills and the Dundalk Till Plain (Chapman et al., 1984; OGS, 2010). Proposed Site 3 – West Brampton Reservoir is located within the South Slope, which consists of low-lying fine-grained ground moraine and knolls (CVC, 2011). The surficial geology of the site is primarily composed of till (clay to silt derived from glaciolacustrine deposits or shale) (Chapman et al., 1984; OGS, 2010).

2.1.1.2 Site Topography

The topography within the proposed snow storage site located within the Credit River watershed are described Table 2-2 below:

Table 2-2. Site Topography for Site 3

Site Name	Site Topography
Site 3 – West Brampton Reservoir	The study area gently slopes to the east and no noticeable valley setting is present along the watercourse. Local site topography does indicate the presence of berms within the area (Google Earth, 2022; ESRI, 2021).

2.1.1.3 Land Use

The land use within the proposed snow storage sites is presented in Table 2-3 below:

Table 2-3. Land Use for Site 3

Site Name	Land Use
Site 3 – West Brampton Reservoir	The current land use surrounding of the site is predominantly agricultural, woodlot and commercial.

2.1.2 Etobicoke Creek Watershed

The Etobicoke Creek watershed has an approximate area of 224.04 km^2 and is distributed between the Cities of Mississauga, Brampton and Toronto and the Town of Caledon. Current land uses within the watershed are represented by 59.5% Urban, 12.3% natural cover and 28.2% rural (TRCA, 2021). Two of the study sites (**Site 6 – Tullamore Reservoir and Site 9 – Alloa Reservoir**) are located within this watershed.

2.1.2.1 Physiography and Surficial Geology

The physiography and geology for the proposed snow storage sites located within the Etobicoke Creek watershed are presented in Table 2-4:

Table 2-4. Physiography and Surficial Geology for Sites 6 and 9

Site Name	Physiography and Surficial Geology
Site 6 - Tullamore Reservoir	Located within the Peel Plain Region to the south east and the South Plain to the north west of the study site. The surficial geology of the site is characterized by till deposits (clay to silt derived from glaciolacustrine deposits or shale). Salt Creek, located to the west of the site, reportedly flows of top of Paleozoic bedrock (Chapman et al., 1984; OGS, 2010).
Site 9 – Alloa Reservoir	Located within the physiographic region of the South Slope and its surficial geology is characterized by till deposits (clay to silt derived from glaciolacustrine deposits or shale) (Chapman et al., 1984; OGS, 2010).

2.1.2.2 Site Topography

The topography within the proposed snow storage sites located within the Etobicoke Creek watershed are described Table 2-5 below:

Table 2-5. Site Topography for Sites 6 and 9

Site Name	Site Topography
Site 6 - Tullamore Reservoir	The site topography is relatively flat ranging from 233 m asl on the north east corner of the site to 228 m asl to the south west corner of the site. The site topography slopes towards a watercourse (Salt Creek) that flows along the western limit of the site from north to south (Google Earth, 2022; ESRI, 2021)
Site 9 – Alloa Reservoir	The site topography is relatively flat ranging from approximately 262 m asl on the north portion of the site to approximately 264 m asl to the south west of the site. There are areas of increased topographic relief (max 270 m asl) (Google Earth, 2022; ESRI, 2021)

2.1.2.3 Land Use

The land use within the proposed snow storage sites is presented in Table 2-6 below:

Table 2-6. Land Use for Sites 6 and 9

Site Name	Land Use
Site 6 - Tullamore Reservoir	The land use surrounding the site is predominantly agricultural, Conservation Authority regulated lands and commercial/industrial.

Site Name	Land Use
Site 9 – Alloa Reservoir	The land use surrounding the site is predominantly agricultural, Conservation Authority regulated lands and commercial/industrial.

2.1.3 Humber River Watershed

The Humber River watershed is the largest within the TRCA jurisdiction and encompasses an approximate area of 911 km^2. The Humber's waters originate on the Niagara Escarpment and the Oak Ridges Moraine. Its main branch flows for approximately 126 km before discharging in Lake Ontario (TRCA, 2022). The watershed's land cover is 37 percent urban, 30 percent rural and 33 percent natural cover (TRCA, 2018) The watershed is subdivided between the West Humber, Main Humber, East Humber, Lower Humber, and the Black Creek subwatersheds. The West Humber subwatershed has an approximate area of 205 km^2 (OFAT MNFR, 2020) and **Site 5 - Johnston Sports Park** is located within this subwatershed, while the Main Humber subwatershed has an approximate area of 360 km^2 and **Site 1 - Highway 50 Carpool Lot** is located within (OFAT MNFR, 2020; TRCA, 2022).

2.1.3.1 Physiography and Surficial Geology

The physiography and geology of the proposed snow storage sites located within the West Humber subwatershed watershed are described in Table 2-7:

Table 2-7. Physiography and Surficial Geology for Sites 1 and 5

Site Name	Physiography and Surficial Geology
Site 1 - Highway 50 Carpool Lot	Located within the Bevelled Till Plains region and its surficial geology characterized by till deposits (clay to silt derived from glaciolacustrine deposits or shale) to the north west of site and fine texture glaciolacustrine deposits of silt and clay with minor sand and gravel (interbedded silt and clay and gritty pebbly flow till and rainout deposits) to the south east of site (Chapman et al., 1984; OGS, 2010)
Site 5 - Johnston Sports Park	Located within the South Slope physiographic region and its surficial geology characterized by till deposits (clay to silt derived from glaciolacustrine deposits or shale) (Chapman et al., 1984; OGS, 2010).

2.1.3.2 Topography

The local topography within the proposed snow storage sites the West Humber subwatershed is described in Table 2-8 below:

Table 2-8. Topography for Sites 1 and 5

Site Name	Topography
Site 1 - Highway 50 Carpool Lot	The topography of the site indicates that the area is mostly flat ranging from approximately 227 m on the north west portion to 226 m to the south of the study site (Google Earth, 2022; ESRI, 2021).
Site 5 - Johnston Sports Park	The site topography is relatively flat ranging from 277 m asl on the north west corner of the site to 267 m asl. The site topography slopes towards a watercourse (Lindsay Creek) that traverses the site from the north west to the south east of the site (Google Earth, 2022; ESRI, 2021)..

2.1.3.3 Land Use

The land use within the proposed snow storage sites is described in Table 2-9 below:

Table 2-9. Land Use for Sites 1 and 5

Site Name	Land Use
Site 1 - Highway 50 Carpool Lot	The land use surrounding the area is primarily urban (roads, parking lots), lawn, agricultural, woodlot and CA regulated.
Site 5 - Johnston Sports Park	The land use surrounding the site is predominantly institutional (parkland), agricultural and CA regulated lands.

2.2 Reach Delineation

Reaches can be defined as lengths of the channel that display similar physical characteristics and have a setting that remains nearly constant along their length. Reaches are relatively homogeneous in channel form, function, and process. They are influenced by similar controlling (discharge and slope) and modifying factors (vegetation) to which the channel has become or is becoming adjusted.

The desk -based assessment indicated that out of the five (5) proposed snow storage sites to be investigated, only Sites 5 and 6 had watercourses present within the property; Sites 3 – West Brampton Reservoir and 9 – Alloa Reservoir have watercourses adjacent, but not within the property boundaries. There were no watercourses identified within Site 1 during the desk-based assessment. Reaches were only delineated for the features found within Sites 5 and 6, and adjacent to Sites 3 and 9. Criteria for selection of reach breaks and reach names are presented in Table 2-10.

Table 2-10. Reach Delineation Criteria

Reach	Limit	Coordinates*	Justification
Site 3 - West Brampton Reservoir **CR_NP_CRR_3_2a**	Upstream	594298.00 m E; 4834344.00 m N	Apparent confluence of agricultural drainage features
	Downstream	594705.00 m E; 4834006.00 m N	Feature flows into an on-line pond. Change is surficial geology from till to Paleozoic bedrock
Site 5 - Johnston Sports Park **HU_WH_LC_0_1**	Upstream	596608.00 m E; 4855947.00 m N	Confluence with agricultural drain.
	Downstream	597226.00 m E; 4856129.00 m N	Feature flows into an on-line pond.
Site 6 - Tullamore Reservoir **HU_WH_SAL_2_1a**	Upstream	599485.00 m E; 4850630.00 m N	Selected based on surficial geology. The watercourse flows on Paleozoic bedrock from this point onwards
	Downstream	600448.00 m E; 4850176.00 m N	Change in riparian/bank cover vegetation. Woodlot type downstream of this location
Site 9 - Alloa Reservoir **EC_EH_ETW_10_1a**	Upstream	591012.00 m E; 4839338.00 m N	Change in surficial geology from fine-textured glaciolacustrine deposits to modern alluvial deposits.
	Downstream	591348.00 m E; 4839949.00 m N	Change in surficial geology from modern alluvial deposits to fine-textured glaciolacustrine deposits.

*Coordinates in UTM Zone 17

3. Historical Aerial Imagery Assessment

An analysis of historical aerial imagery from 1978, 1996 and 2018 provided by the Region of Peel was undertaken for three (5) of the proposed snow storage sites to determine changes in land use. These sites were analysed based on the presence of watercourses in or immediately adjacent to the proposed study area and the result of the analysis are presented in **Table 3-1** and is the basis for the determination of a meander belt completed in **Section 8** of this report. Multi-decade analysis was not possible for all sites as there was limited availability of historical imagery. The historical imagery can be accessed in **Appendix A**.

Table 3-1. Historical Imagery Analysis

Year	1967	1978	1985	1996	2018
Site	**Planform and Land Use**	**Planform and Land Use**	**Planform and Land Use**	**Planform and Land Use**	**Planform and Land Use**
Site 1 – Highway 50 Carpool	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	There are no visible watercourses within the proposed snow storage site.
Site 3 – West Brampton Reservoir	Feature's flow appears to split just downstream of the current upstream reach break selection. Channel located to the east appears sinuous and possibly meandering through an agricultural field. The riparian vegetation appears minimal or not present. Channel located to the west appear more straightened with some sinuosity further downstream. Riparian vegetation appears to be minimal or not present. A road connected to the west channel from a farm building located to the west of the feature.	The portion of the channel located on the east appear to retain its sinuous planform. The riparian vegetation remains minimal or not present. The planform of the channel located to the west appear to have regained some sinuosity, which was not present or not clearly visible on the 1967 aerial imagery. A large pond is not present downstream of the current downstream reach break.	The channel located to the east appear less defined and is only visible by the image shading. The sinuosity is still present and there are not apparent changes to is riparian vegetation. The channel located to the west has also retained the sinuous planform observed in the 1978 imagery, but it appears that the agricultural activities have encroached closer to the feature as track marks appear over the feature itself.	NO IMAGERY AVAILABLE	The channel located to the west is not longer present or defined and is only discernable by the shading effect on the aerial imagery. The channel to the east appears more defined than in the 1985 aerial imagery. There is sinuosity to the channel, but its original/natural planform has likely been altered by the adjacent agricultural activities.
Site 5 - Johnson Sports Park	The feature traversing the proposed site appears to have been straightened prior to 1967. Adjacent agricultural activities have encroached the feature and minimal riparian vegetation is present. Downstream of Centreville Creek Rd. the feature displays a more sinuous planform.	The feature’s corridor remains straightened, however there is a slight display of sinuosity along the main channel path, upstream of Centreville Creek Rd. No other significant changes are visible since 1967.	No major changes are visible since 1978.	The feature remains with a straightened planform and agricultural continues to be the dominant land use surrounding the feature. Downstream of the Centreville Creek Rd. crossing the feature is not visible (due to image quality).	The feature's riparian vegetation zone has widened. Grasses and woody vegetation have established, and dense in-channel vegetation is now present within the channel. The feature's corridor remains straightened, although there appears to be increases to the main channel’s sinuosity. Immediately downstream of the Centreville Creek Rd. crossing the planform of the feature appears more straightened that in previous years.
Site 6 - Tullamore Reservoir	The reach displays a natural meandering planform. The adjacent land use is dominated by agricultural activities and the riparian vegetation appears to be minimal. Towards Mayfield Rd. a portion of the channel appears to display a multi-channel form the meander bends with what appears to be a meander cut-off.	The reach displays a natural meandering planform. The adjacent land use is dominated by agricultural activities and the riparian vegetation appears to be minimal. The meander cut-off reported in the 1967 remains in place with no significant changes to be reported.	NO IMAGERY AVAILABLE	Downstream of Mayfield Rd. the riparian vegetation appears to be establishing more successfully (woody vegetation appears to be dominant in the areas) than in the areas upstream of Mayfield Rd. In addition, it appears that the size of the feature is reduced but may be attributed to temporal differences in the image collection.	Significant urban development has taken place on the right bank of the feature, downstream of Mayfield Rd. Two large warehouses are also now present of the close to the right bank of the feature, north of Mayfield Rd. east of Airport Rd. The riparian vegetation along the riparian zone of the feature continues to improve with woodlot type vegetation becoming more dominant. However, immediately upstream of Mayfield Rd. the riparian vegetation appears dominated by grasses.
Site 9 – Alloa Reservoir	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	NO IMAGERY AVAILABLE	A watercourse located on an adjacent property north of the proposed snow storage site appears to have been channelized. There is little sinuosity to the feature and agricultural lands have encroached the riparian zone, suggesting that the straightened planform is the result of agricultural activities.

4. Field Based Assessment

Field assessments were completed as follows:

- October 13, 2021 - Site 5;
- November 4, 2021 - Site 6 and 9; and
- November 11, 2021 - Sites 1, and 3.

Due to accessibility restrictions (absence of Permission to Enter where the watercourse is present), assessment for Sites 1, 3, and 9 were completed off the right of way (ROW) and at the upstream downstream locations of the watercourse, where present.

The field-based assessment verified the reach breaks and identified local geomorphological form and function of the watercourses in the vicinity of the proposed storage sites. Rapid geomorphological assessments and detailed geomorphological data collection (where able) were completed as part of the field investigation. The following sections describe the conditions encountered during the field-based assessments. A photographic record of the assessed sites can be found in Appendix A.

4.1 Geomorphological Reach Characterization

4.1.1 Site 1 - Highway 50 Carpool Lot

Reach characterization for Site 1 was not possible as the desktop assessment did not identify a watercourse within the proposed snow storage site. During the site visit no watercourses were visible within the site and the area was covered by grasses, herbaceous species, and scattered trees. Approximately 160 m west of the site a corrugated steel pipe conveys flow from the north side of Mayfield Road and into an agricultural field downstream of the crossing. There was water present downstream of the crossing but not flow at the time of the assessment.

4.1.2 Site 3 - West Brampton Reservoir – Reach CR_NP_CRR_3_2a

Direct assessment to the adjacent watercourse of the proposed snow storage site was not possible due to accessibility restrictions (absence of Permission to Enter). The inspection for Reach CR_NP_CRR_3_2a, a tributary of the Credit River, took place at Bovaird Drive, located approximately 1,050 m northwest of the proposed storage site, where the watercourse flows southeast under the road from an adjacent agricultural field. Upstream of Bovaird Drive the feature appears to be an ephemeral low topographic point that has been impacted by agricultural activities. No defined channels were noted upstream of the crossing, but stationary water was present at the low topographic point. A vegetated buffer of grasses and herbaceous plants separated the agricultural field from the road. At the crossing, flow contributions from adjacent roadside ditches were present and water flowed into a 1.6 m wide concrete box culvert. East of the crossing, a wetland type vegetated area was present. Downstream of the crossing water flowed into a slightly defined channel of an estimated bankfull of 1.0 m. As the feature flows downstream in between two agricultural fields, vegetation on the banks becomes denser and appears to flow through a treed area further downstream. Downstream of the crossing roadside ditches and a plastic culvert appear to contribute to the flow. No erosion was observed during the inspection at the roadway and a precipitation event took place prior to the inspection.

4.1.3 Site 5 - Johnston Sports Park – Reach HU_WH_LC_0_1

Reach HU_WH_LC_0_1 is part of the main branch of the Lindsay Creek, a tributary of the West Humber River. The upstream reach break is downstream of the confluence of Lindsey Creek and an adjacent agricultural channel. The upstream reach break was selected based on riparian vegetation changes as the grasses lining the banks transition to trees and shrubs, in addition to the flow inputs. The entire reach is covered with in-channel vegetation and the banks and riparian zone are densely vegetated with grasses and herbaceous plants. The bed morphology of the feature is poorly defined and unconsolidated fined sediments of approximately 0.3 to 0.4 m in depth are present on the bed of the feature along the entire reach.

Although a focused channel can be observed in most of the reach, the flow is dissipated into multiple channels in several locations of the reach. In the locations where the channel is focused, the flow is narrow and deep. Movement of fines is more visible on the portions where the flow is more focused and the channel more defined.

4.1.4 Site 6 - Tullamore Reservoir – Reach HU_WH_SAL_2_1a

Inspection of Reach HU_WH_SAL_2_1a was limited due to access to adjacent properties. Only a portion of the Salt Creek that meanders into the property was investigated. The feature's banks and riparian zone was densely vegetated with grasses, herbaceous plants, and scattered trees and shrubs. The feature's bankfull width and depth were estimated at approximately 5 m and 0.4 m, respectively. Wetted width and depth were estimated at approximately 3 m and 0.3 m, respectively. The entire section of the watercourse that was investigated flows on shale bedrock and the banks are composed of fines (silt, clay and sand). In the upstream portion the feature appears to flow in a multi-channel fashion. In the central portion of the reach a debris jam has created a deep and large pool and bankfull was difficult to determine at this location. Downstream of the pool, the feature regains a more focused flow and transport of fine sediments is observed in the flow. The feature's gradient is low to moderate and bed substrate varies from fines to gravel, to boulders in some of the surveyed cross sections. Riffle-pool morphology was poorly defined within the surveyed portion of the feature and the planform was meandering. Multiple debris lines were observed on the vegetated banks, identifying overbank flows exist along this section of channel. Evidence of erosion was minimal and consisted of exposed tree roots and few leaning trees. Woody debris was observed on the left bank of the feature.

4.1.5 Site 9 - Alloa Reservoir – Reach EC_EH_ETW_10_1a

One watercourse was identified during the desk-based assessment to the north of Site 9 within an adjacent property. Due to accessibility restrictions, the assessment of the feature took place at Mississauga Road (upstream portion of the reach), and Creditview Road (downstream portion of the reach). At Mississauga Road the channel was densely vegetated by grasses and shrubs and the riparian zone was covered with small trees and shrubs. In this location the planform is straight, and the feature has likely been altered by the adjacent agricultural activities. Flow was present, but low at the time of the assessment and no evidence of erosion was observed. The bankfull width at this location was estimated at approximately 4 m and the wetted depth at approximately 3 m. From Creditview Road, upstream end of the reach, the feature's planform appeared slightly more sinuous upstream of the road as it flows through the adjacent undulating agricultural fields. The bankfull width at the road was estimated at approximately 4 m and the wetted width was approximately 2 m. The feature flows through three large, corrugated steel pipes under Creditview Road. Based on the setting of feature (within agricultural field and the straightening observed during the desktop assessment), it appears that the bankfull flow is contained within the feature as it appears to be entrenched.

4.2 Rapid Geomorphic Assessment (RGA)

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of the Environment, Conservation and Parks (MECP) (1999) to assess reaches in urban channels. This technique uses visual indicators to document evidence of channel instability using presence/ absence methodology. Stability is determined by adjustment in slope, either an increase (aggradation) due to sediment deposition or a decrease (degradation) due to bed erosion. It also considers an increase in the bank-to-bank width (widening) and by any evidence indicating adjustment in the planimetric form regime. Each of the geomorphic indicators is documented throughout the reach and upon completion, is tallied by category. These data are then used to calculate an overall reach stability index which classifies the reach as 'stable', 'transitional', or 'in-adjustment' corresponding to their relative sensitivity to altered sediment and flow regimes. The classification and interpretation as defined by the factor value (total score) are identified in Table 4-1 (taken from the MECP, 2003).

Table 4-1. Rapid Geomorphic Classification

Vector Value	Classification	Interpretation
≤ 0.20	In Regime or Stable (Least Sensitive)	Channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river propagation processes.

Vector Value	Classification	Interpretation
0.21 – 0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent.
≥ 0.41	In Adjustment (Most Sensitive)	Channel morphology is not within a range of variance and evidence of instability is widespread.

Due to the previously mentioned accessibility restrictions, only two RGA were completed. Reach HU_WH_LC_0_1, located within Site 5 - Johnston Sports Park had a Stability Index of 0.21, reflecting that the reach is in the lower limit for the "Transitional or Stresses" condition. Field indicators suggest that the dominant process occurring within the reach is aggradation, which is largely due to the presence of loose, unconsolidated material on the bed which is causing the coarser material to be buried or embedded. The surrounding agricultural field is a major source of fine material. As well, the dense in-stream vegetation reduces flow velocities and includes sedimentation which causes the relative elevation of the bed to rise (i.e. aggradation).

Reach HU_WH_SAL_2_1a, located within Site 6- Tullamore Reservoir, has an overall score of 0.17 on the Stability Index, meaning that the reach is "In Regime". Field indicators suggest that planimetric form adjustment as well as channel widening are the dominant processes occurring within the reach.

The results of the assessment are presented in **Table 4-2**.

Table 4-2. RGA Results

Reach	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
Site 5 Johnston Sports Park Reach HU_WH_LC_0_1	0.43	0.0	0.0	0.43	0.21	Transitional or Stressed
Site 6 Tullamore Reservoir Reach HU_WH_SAL_2_1a	0.0	0.0	0.25	0.43	0.17	In Regime

5. Quantitative Geomorphological Data Collection

Only Site 5 - Johnston Sports Park and Site 6 - Tullamore Reservoir were subject to quantitative geomorphological data collection as these were the only study sites with watercourses flowing within the property boundaries. The remaining sites have watercourses beyond their property limits or defined fluvial features were not observed in their vicinity. The data collection took place on October 13 (Site 5) and November 4 (Site 6), 2021 and it included:

- Cross-Sectional Survey;
- Longitudinal Profile;
- Bank Characterization Data;
- Bed Characterization; and
- Photographic Record

The following sections present the results of the analysis of the data collected and inform the management recommendations for the sites expected to become snow storage facilities. A photographic record of the surveyed reaches and assessed sites can be found in **Appendix A**.

5.1 Cross-Sectional Survey

A total of eight (8) detailed cross sections were collected along Reach HU_WH_LC_0_1 located within Site 5 - Johnston Sports Park (**Table 5-1**), as well as along Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir (**Table 5-2**). Based on the channel dimensions and available hydraulic data, bankfull velocity and discharge were also calculated.

The cross-sections along both reaches are predominantly wide and shallow, resulting in a high width to depth ratio. This indicates that the hydraulic stresses will be higher along the channel banks. Deposition of sediment is also more common due to the fact that the over widened channel loses its ability to transport sediment caused by decreases in velocity and shear stress. This was observed during field reconnaissance at both locations as deposits of unconsolidated sediment were present along the bed. Sediment deposition was further impacted by the dense in-channel vegetation present throughout the reach at Johnston Sports Park.

At Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir the substrate along the bed appeared to be shale bedrock and therefore more resistant to erosion than the channel banks.

Table 5-1. Cross Sectional Metrics for Reach HU_WH_LC_0_1 at Site 5 - Johnston Sports Park

Parameter	Reach:	HU_WH_LC_0_1							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
	Feature:	Run	Run	Run	Run	Run	Run	Run	Run
Bankfull Width (m)		5.36	5.98	8.70	7.17	7.62	7.21	6.19	5.85
Average Bankfull Depth (m)		0.27	0.19	0.25	0.39	0.39	0.34	0.31	0.27
Maximum Bankfull Depth (m)		0.63	0.55	0.63	0.73	0.70	0.63	0.78	0.63
Bankfull Width:Depth		19.69	32.01	34.84	18.54	19.74	21.02	20.12	21.43
Cross-sectional Area (m^2)		1.03	0.76	1.36	2.15	2.43	2.19	1.60	1.26
Bankfull Discharge (m^3/s)		0.56	0.36	0.66	1.63	1.80	1.54	0.95	0.72
Average Bankfull Velocity (m/s)		0.52	0.39	0.48	0.67	0.68	0.64	0.55	0.50

Table 5-2. Cross Sectional Metrics for Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir

Parameter	Reach:	HU_WH_SAL_2_1a							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
	Feature:	Run	Pool	Riffle/ Run	Pool	Run	Riffle/ Run	Pool	Pool
Bankfull Width (m)		7.15	2.82	4.75	9.15	4.85	7.06	15.64	6.57
Average Bankfull Depth (m)		0.25	0.37	0.29	0.35	0.31	0.35	0.57	0.29
Maximum Bankfull Depth (m)		0.49	0.50	0.53	0.59	0.53	0.67	1.00	0.58
Bankfull Width:Depth		28.87	7.67	16.41	26.13	15.61	19.97	27.30	22.31
Cross-sectional Area (m^2)		1.51	1.10	1.14	2.50	1.31	1.79	8.23	1.75
Bankfull Discharge (m^3/s)		1.36	1.37	1.23	2.55	1.41	1.97	14.98	2.05
Average Bankfull Velocity (m/s)		0.74	1.03	0.85	0.98	0.88	0.94	1.40	0.87

5.2 Longitudinal Profile

A longitudinal survey was completed for the reaches investigated at Reach HU_WH_LC_0_1 located within Site 5 - Johnston Sports Park, as well as along Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir. The longitudinal channel profile survey extended beyond the location of the cross sections to better identify bed forms and bed gradient. Channel bed forms and bed gradients are of important geomorphological consideration, as the bed gradient is a primary control of tractive forces within a reach and, therefore, is a major determinant of morphological form and function.

The longitudinal profile for Reach HU_WH_LC_0_1 (Site 5 - Johnston Sports Park) extended for an approximate distance of 310.5 m. Based on the analysis of the survey results, the channel bed gradient was calculated at 0.0059 m/m for the surveyed length of channel; the bankfull gradient was 0.0071 m/m; and a Manning's number of 0.06 was selected based on the observed conditions of the entire channel (densely vegetated in channel). Channel bathymetry, bankfull and the location of the cross sections along the reach are presented in **Figure 5-1**.

The longitudinal survey for Reach HU_WH_SAL_2_1a (Site 6 - Tullamore Reservoir) extended for approximately 194 m. Based on the analysis of the survey results, the channel bed gradient was calculated at 0.0052 m/m for the surveyed length of channel; the bankfull gradient was 0.0060 m/m; and a Manning's number of 0.035 was selected based on the observed conditions of the entire channel. Upstream of cross section 6 (XS-6) a debris jam, visible as a peak on the bathymetry line, created a large pool in the channel, submerging the banks. Channel bathymetry, bankfull and the location of the cross sections along the reach are presented in **Figure 5-2**.

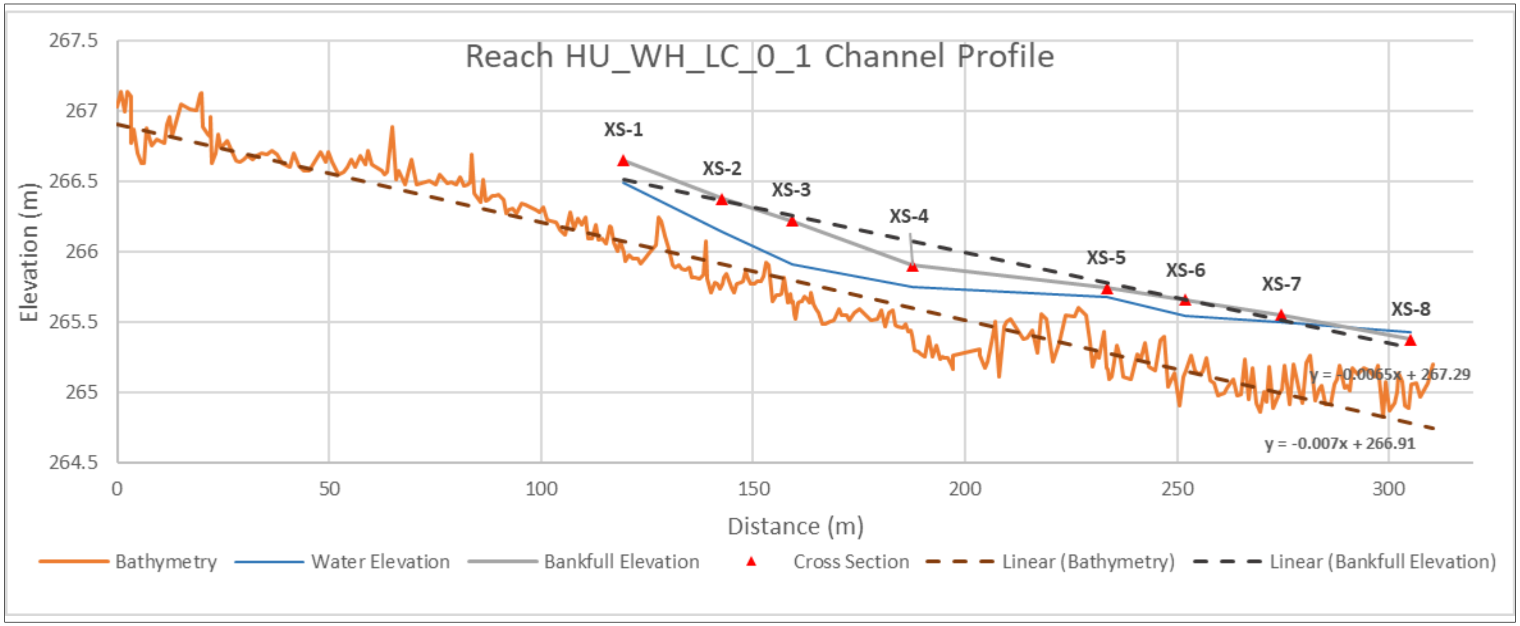


Figure 5-1. Longitudinal Profile for Reach HU_WH_LC_0_1 at Site 5 - Johnston Sports Park

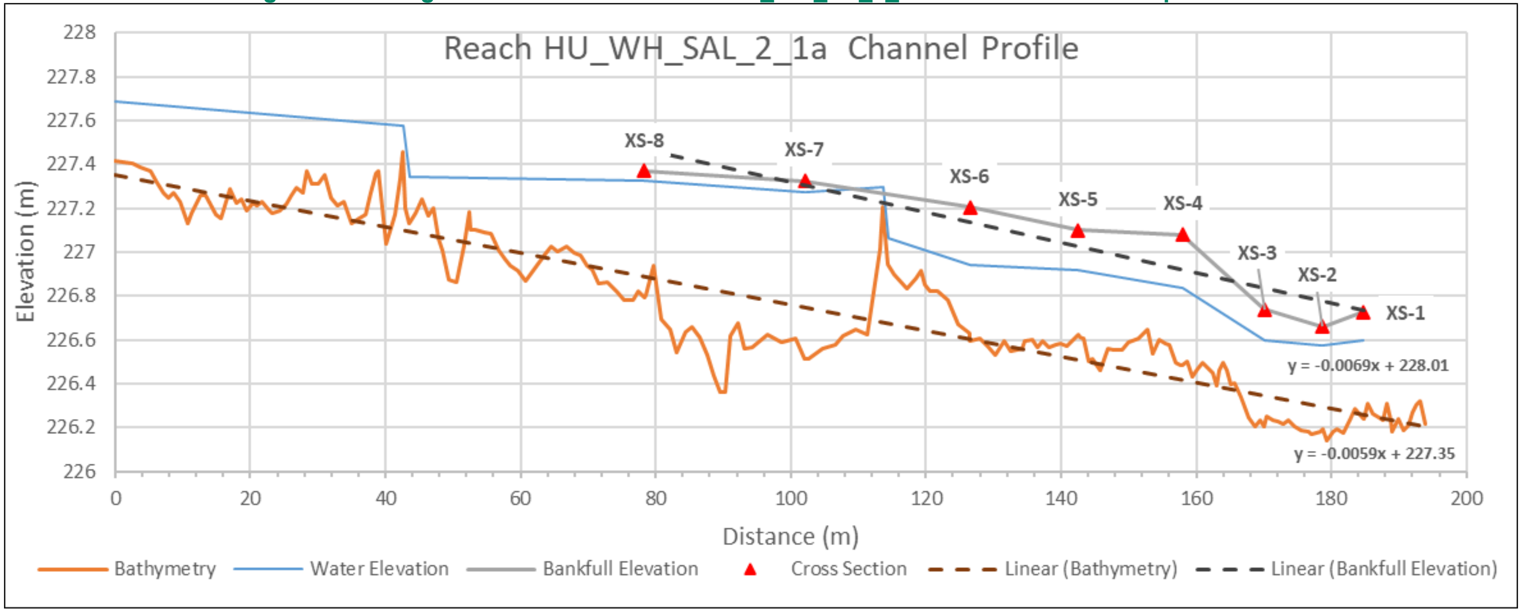


Figure 5-2. Longitudinal Profile for Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir

5.3 Bank Characterization

Rooting depth, riparian vegetation, and the degree of undercutting were documented for both the right and the left bank throughout Reaches HU_WH_LC_0_1 (Site 5 - Johnston Sports Park) and HU_WH_SAL_2_1a (Site 6 - Tullamore Reservoir). These data are used to identify the stability of the channel banks and further informs the fluvial geomorphological assessment.

Within Reach HU_WH_LC_0_1 the bankfull heights ranged from 0.14 m to 0.41 m; the rooting depth was identified to be to bottom of bank in the locations surveyed; and the bank angle ranged from 2.5 to 17.8 degrees and can be considered as low to moderate. Undercutting was only identified in cross section 3. Results of bank characteristics for Reach HU_WH_LC_0_1 are presented in Table 5-3. Soil texture within the study area was determined to be clay to silty clay based on the feel method and the Soil Texture Triangle, which assigns a classification based on various combinations of sand, silt, and clay. Based on the hierarchy of soil erodibility (from Rusle2) (CISEC Canada, January 2019 Slide Deck), the silt loam and silty clay loam fall into the most erodible category, with clay being the least erodible.

Table 5-3. Bank Characterization for Reach HU_WH_LC_0_1 - Johnston Sports Park

Parameter	Reach:	HU_WH_LC_0_1							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
	Unit:	Run	Run	Run	Run	Run	Run	Run	Run
Height (m)	Left Bank	0.19	0.14	0.21	0.33	0.41	0.33	0.25	0.14
	Right Bank	0.17	0.16	0.19	0.35	0.33	0.32	0.23	0.36
Angle (°)	Left Bank	10.4	13.8	9.0	11.0	16.2	10.4	11.4	7.2
	Right Bank	7.8	4.0	2.5	10.8	9.1	12.1	16.5	17.8
Rooting Depth (m)	Left Bank	BOB	BOB	BOB	BOB	BOB	BOB	BOB	BOB
	Right Bank	BOB	BOB	BOB	BOB	BOB	BOB	BOB	BOB
Undercut (m)	Left Bank	NA	NA	~0.2	NA	NA	NA	NA	NA
	Right Bank	NA	0.48	NA	NA	NA	NA	NA	NA

BOB: Bottom of bank

Within Reach HU_WH_SAL_2_1a the bankfull heights ranged from 0.20m to 1.0m; the rooting depth was identified to be to bottom of bank in the locations surveyed; and the bank angle ranged from 8.3 to 58.7 degrees and can be considered as low to moderate. No undercutting was identified in the surveyed cross sections. Results of bank characteristics for Reach HU_WH_SAL_2_1a are presented in Table 5-4. Soil texture within the study area was determined to be clay to silty clay loam based on the feel method and the Soil Texture Triangle, which assigns a classification based on various combinations of sand, silt, and clay. Based on the hierarchy of soil erodibility (from Rusle2) (CISEC Canada, January 2019 Slide Deck), the silt loam and silty clay loam fall into the most erodible category, with clay being the least erodible.

Table 5-4. Bank Characterization for Reach HU_WH_SAL_2_1a - Site 6 - Tullamore Reservoir

Parameter	Reach:	HU_WH_SAL_2_1a							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
	Unit:	Run	Pool	Riffle/ Run	Pool	Run	Riffle/ Run	Pool	Pool
Height (m)	Left Bank	0.41	0.41	0.47	0.37	0.45	0.67	1.00	0.42
	Right Bank	0.20	0.47	0.51	0.36	0.44	0.53	0.91	0.50
Angle (°)	Left Bank	9.3	41.7	31.9	52.0	53.7	21.1	10.5	6.5
	Right Bank	14.2	58.7	10.3	10.1	11.4	8.3	12.3	49.7
Rooting Depth (m)	Left Bank	BOB	BOB	BOB	BOB	BOB	BOB	BOB	BOB
	Right Bank	BOB	BOB	BOB	BOB	BOB	BOB	BOB	BOB
Undercut (m)	Left Bank	NA	NA	NA	NA	NA	NA	NA	NA
	Right Bank	NA	NA	NA	NA	NA	NA	NA	NA

BOB: Bottom of bank

5.4 Bed Characterization

The Wolman (1954) pebble count method was used at the surveyed cross sections of the two investigated reaches within sites 5 and 6 to determine the grain size distribution of in-channel substrate within the reaches. The grain size distribution influences sediment transport and flow resistance within a given reach. A modified Wentworth (1922) grain size scale was used to classify particles into discrete groupings. A step-toe procedure was used to select 100 grains along each cross section. The b-axis of each selected stone was measured using a ruler. Grains that were less than 2mm were assigned to a fine sediment category according to the modified Wentworth grain size scale.

Grain size distributions were then calculated based on the Wolman (1954) pebble counts completed at each of the surveyed cross sections. The D16 (16% of the same is equal to or smaller than), D50 (medium grain size), and D84 (84% of the sample is equal to or smaller than) are summarized in **Table 5-5** for Reach HU_WH_LC_0_1 (Site 5 - Johnston Sports Park) and in **Table 5-6** for Reach HU_WH_SAL_2_1a (Site 6 - Tullamore Reservoir). The materials along the bed of Reach HU_WH_LC_0_1 ranged from clay to smaller fractions of coarse sand and gravel. There was no defined longitudinal bed sorting of sediments as the bed morphology of the channel was poorly defined within this reach.

Within Reach HU_WH_SAL_2_1a the sediment sized ranged from smaller fractions of clay and silt to predominantly sand, gravel and minimal amounts of cobbles. The longitudinal sorting of material was poor as there was poorly defined bed morphology along the investigated section of the reach.

Table 5-5. Summary Statistics of Pebble Counts for Reach HU_WH_LC_0_1 at Site 5 - Johnston Sports Park

Parameter:	Reach:	HU_WH_LC_0_1							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
D16 (mm):		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D50 (mm):		0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.001
D84 (mm):		2.23	0.69	0.69	0.69	0.07	0.07	0.11	0.08

Table 5-6. Summary Statistics of Pebble Counts for Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir

Parameter:	Reach:	HU_WH_SAL_2_1a							
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
D16 (mm):		0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001
D50 (mm):		1.16	0.52	0.67	0.71	0.60	1.08	0.002	1.04
D84 (mm):		11.83	14.33	16.50	18.50	33.00	17.00	0.94	21.00

6. Hydraulic Analysis

Hydraulic analysis was completed for the detailed site surveyed reaches at Site 5 - Johnston Sports Park and Site 6 - Tullamore Reservoir. At each site, reach-averaged bankfull hydraulics was calculated using the surveyed data for the bankfull channel, as well as determination of Manning's 'n', an indicator of hydraulic roughness. Determining Manning's 'n' is dependent on many factors including substrate composition, aquatic vegetation, and sinuosity. Environmental conditions observed at each reach were compared to published tables of Manning's 'n' values (Chow, 1959). The estimated 'n' value for each reach (and justification for its choosing) is provided below.

Site 5 – Johnston Sports Park: 0.06 due to presence of in-channel vegetation and dense vegetation on banks.

Site 6 – Tullamore Reservoir: 0.035 due to vegetation on banks and slightly sinuous planform.

Bankfull hydraulic simulations were averaged across the measured cross sections for each site along the surveyed reaches (**Table 6-1**). Cross section 7 at Site 6 - Tullamore Reservoir was not included in the analysis due to ponded water caused by a debris dam that increased the cross-sectional area of the watercourse at this location.

Table 6-1. Reach Averaged Hydraulics at Bankfull Conditions

Parameters	Site 5 – Johnston Sports Park	Site 6 – Tullamore Reservoir
Bankfull Discharge (m^3/s)	1.03	1.70
Average Bankfull Velocity (m/s)	0.55	0.90
Maximum Bankfull Velocity (m/s)	1.00	1.49
Average Shear Velocity [u*] (m/s)	0.12	0.12
Stream Power (W/m)	71.56	100.31
Stream Power per unit Width (W/m^2)	10.40	17.61
Average Shear Stress (N/m^2)	15.05	14.40
Maximum Shear Stress (N/m^2)	42.29	31.77
Left Bank Shear Stress (N/m^2)	10.83	9.19
Right Bank Shear Stress (N/m^2)	10.31	9.34

7. Erosion Threshold Assessment

In natural systems, creeks regularly see flows that entrain and transport sediment; this is part of the natural process that maintains creek form. However, issues arise when changes in the watershed's hydrology results in an increase in the frequency or period of erosive events or a cumulative increase in the quantity of flow that can entrain and transport sediment (CVC, 2010). The collection of detailed geomorphological field data enables the calculation of erosion thresholds representative of specific reaches, which relate to the point at which sustained flows will theoretically start to entrain and transport bed or bank sediments within the reach. Associated critical discharge values are calculated based on channel geometry and bed/bank substrate.

The erosion threshold assessment, at minimum (according to CVC's 2010 guidance), should consist of:

- Reach delineation (refer to **Table 2-10**)
- Rapid assessment to evaluate stability of reaches (refer to **Section 4**).
- Detailed examination of most sensitive reaches (refer to **Section 4**)
- Definition of erosion thresholds based on scientifically defensible models. Modeled results should also be compared to actual field observations – the simplest method being spot observations of active or inactivity of entrainment at different velocities, discharges and/or flow depths.

Once the cross-sectional form, substrate composition, and bank materials at each cross-section were established, empirical relations were utilized to determine the flow conditions at which theoretically the substrate and bank materials would be entrained. This was achieved by imposing a water surface elevation of 0.01 m above the maximum depth at each cross section. The water surface elevation was iteratively increased until the water surface elevation was above bankfull conditions. For each iteration, hydraulic properties (i.e., depths, velocities, discharge, shear stresses) were determined for the imposed water level. The energy gradient (bankfull) and hydraulic roughness (Manning's 'n') remained constant for all iterations.

7.1 Bed Material Thresholds

There are many commonly used empirical formulae for determining when critical hydraulic conditions are met for sediment entrainment. All of the formulae have strengths and limitations stemming from the different data sets that were used to develop the equations. For analysis at both Site 5 - Johnston Sports Park and Site 6 - Tullamore Reservoir, an empirical relation proposed by Neill (1967) which relates entrainment of a particular grain size (D) to critical velocity ($\bar{U}_c$) was used.

Equation 1

$$\bar{U}_c = \sqrt{\frac{2.5D^{0.8}g\varsigma}{d_b^{-0.2}}}$$

where d_b is bankfull depth, g is the acceleration due to gravity (9.81 m/s^2), and ς is the submerged specific gravity (1.65). $\bar{U}_c$ has units of m/s and D has units of m for this particular form of the equation.

The equation was developed using data from uniform sand bed rivers and given the amount of fine sediment present within the reach, it was deemed appropriate. The D_{84} grain size was used for the entrainment analysis due to the predominantly fine-grained sediment sizes along the bed. Consideration for the presence of shale bedrock at Site 6-Tullamore Reservoir is not considered in the erosion threshold. The hydraulic conditions at which entrainment of the particles would theoretically occur for the surveyed reach are presented in Table 7-1 and Table 7-2.

Based on the results (Table 7-1 and Table 7-2) critical discharge for sediment entrainment varies between cross-sections within the study area, with an average critical discharge at Site 5 - Johnston Sports Park of **0.15 m^3/s** and Site 6 - Tullamore Reservoir of **0.13 m^3/s.** The variation in values is due to variation in cross-sectional characteristics, substrate and geomorphological processes along the reach, as observed during field reconnaissance. For example, at Site 5 - Johnston Sports Park cross sections 1 to 4 are located upstream of the CSP crossing, which can constrain, and pond flows upstream. The critical discharge values identify that a lower flow is required to entrain or begin to transport bed material due to the fact that the substrate gradation is smaller (visual assessment of sediment in suspension was identified at both sites during field reconnaissance). Consideration for in-channel vegetation at Site 5 - Johnston Sports Park and shale bedrock at Site 6 - Tullamore Reservoir is not considered as part of the assessment and would increase the critical discharge along the bed of the channel.

Table 7-1. Results of Erosion Threshold Analysis for Bed Materials at Site 5 Johnston Sports Park

Parameter	HU_WH_LC_0_1							
	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
Critical Discharge (m^3/s)	0.49	0.15	0.12	0.21	0.06	0.06	0.07	0.05
Critical/ Bankfull Discharge	87.61%	40.65%	18.57%	13.08%	3.47%	4.14%	6.98%	7.42%
Critical Maximum Depth (m)	0.57	0.44	0.45	0.35	0.22	0.20	0.42	0.26
Critical Average Depth (m)	0.25	0.13	0.15	0.18	0.12	0.12	0.14	0.11
Critical Maximum Velocity (m/s)	0.93	0.79	0.81	0.69	0.51	0.49	0.66	0.56
Critical Average Velocity (m/s)	0.49	0.27	0.30	0.39	0.30	0.30	0.28	0.26

Table 7-2. Results of Erosion Threshold Analysis for Bed Materials at Site 6 Tullamore Reservoir

Parameter	HU_WH_SAL_2_1a							
	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	XS-7	XS-8
Critical Discharge (m^3/s)	0.35	0.04	0.10	0.19	0.07	0.08	-	0.09
Critical/ Bankfull Discharge	24.65%	2.83%	8.37%	7.42%	5.14%	4.16%	-	4.53%
Critical Maximum Depth (m)	0.28	0.09	0.16	0.25	0.15	0.17	-	0.16
Critical Average Depth (m)	0.14	0.06	0.13	0.14	0.08	0.09	-	0.08
Critical Maximum Velocity (m/s)	0.93	0.41	0.62	0.87	0.56	0.60	-	0.61
Critical Average Velocity (m/s)	0.51	0.27	0.53	0.50	0.34	0.34	-	0.34

8. Meander Belt Width Assessment

In support of the Fluvial Geomorphological Assessment for the existing conditions at the proposed snow storage sites for the Region of Peel, a Meander Belt Width Assessment was completed for the two water features present within the proposed snow storage sites 5 - Johnston Sports Park and 6 - Tullamore Reservoir. Sites 3 – West Brampton Reservoir and 9 – Alloa Reservoir had adjacent watercourses; however, the watercourses were located within property to which there was no permission to enter and therefore, no field data was collected to complete the meander belt.

The meander belt is defined as the area that a channel currently occupies or is expected to occupy in the future. The associated erosion and deposition that occurs as a result of meander development and migration processes can cause loss or damage to private property and/or infrastructure. For this reason, it is a good practice to define a corridor that contains the natural meander and migration tendencies of the channel. Outside of this corridor, it is assumed that public and private property, and structures beyond the delimited corridor, will not be at risk from fluvial erosion. The space that a meandering watercourse occupies on its floodplain, and in which all associated natural channel processes are expected to occur, is commonly referred to as the meander belt.

8.1 Meander Belt Width Delineation Procedures

The Toronto and Region Conservation Authority (TRCA) guidance publication "Belt Width Delineation Procedures, 2004" provides the basis and protocols used for delimiting appropriate meander belt widths for unconfined and confined systems using mapping and empirical approaches. Mapping approaches, provided within the TRCA 2004 guideline, can be applied to delimit the preliminary meander belt widths for watercourses based on historical channel planform, aerial photography, and topographic mapping (particularly to define meander belt widths for partially confined and confined reaches). A partially confined system is a watercourse that comes into contact with the valley wall on one side of the channel which restricts meander migration, with no limits on the side of the channel that is not restricted by a valley wall. A confined system comes into contact with the valley wall on both sides of the channel and restricts the channel from occupying its potential meander belt width. In a confined system it is expected that the space that the watercourse occupies within the valley corridor increases in area towards the lower reaches as the drainage area of the system increases and with it the flow inputs. Unconfined systems have no limits on the spatial occupation of the floodplain (TRCA, 2004).

The preferred approach for meander belt delineation involves drawing tangential lines parallel to the meander belt axis (i.e., valley axis) along the outside bends of meanders that are situated at the edge of the floodplain. The distance perpendicularly between these two lines represents the meander belt width. In addition, the mapping approach requires the use of a minimum 30 years of historical imagery, including imagery with the current watercourse conditions, to calculate migration rates within the meander corridor to add accuracy to the final meander belt calculation (TRCA, 2004). Analysis of aerial imagery was completed of **Section 3**.

Based on available aerial imagery, topographic maps, LiDAR derived terrain models, and the field reconnaissance, it was determined that the investigated Reach HU_WH_LC_0_1 at Site 5 - Johnston Sports Park is situated within an unconfined system and has unrestricted access to the adjacent flood plain and Reach HU_WH_SAL_2_1 at Site 6 - Tullamore Reservoir is located within an unconfined system of undulating topography and has unrestricted access to its adjacent flood plain.

Determination of a meander belt for the watercourses located within sites 3 – West Brampton Reservoir and 9 – Alloa Reservoir (reaches CR_NP_CRR_3_2a and EC_EH_ETW_10_1a, respectively) was not possible due to absence of permission to access, preventing collection of data for empirical determination of the meander belt. Furthermore, analysis of available current and historical imagery (**Table 3-1**) suggests that the watercourses (reaches CR_NP_CRR_3_2a and EC_EH_ETW_10_1a) have undergone artificial alterations over time, rendering the determination of meander belt using the mapping approach not possible. The empirical and mapping approaches are further explained in **Section 8.1.1**.

8.1.1 Preliminary Meander Belt Width

A preliminary meander belt was calculated for the delineated reaches at Lindsay Creek (HU_WH_LC_0_1), within Site 5 - Johnston Sports Park, and Salt Creek (HU_WH_SAL_2_1a), located within Site 6 - Tullamore Reservoir. Given the history of adjacent agricultural activities to these watercourses, in particular the apparent alterations (channelized/straightening) to Reach HU_WH_LC_0_1, the empirical approach was taken as the first step into determining the preliminary meander belt for both reaches.

Empirical Analysis

The empirical process uses a range of published empirical models based on channel and drainage metrics drawing on the following input variables: bankfull width (W_{bf}), bankfull depth (D_{bf}), bankfull maximum depth (D_{max}), bankfull area (A_{bf}), drainage area (A_w), and bankfull grade (S). The values used in the empirical assessment were calculated based on the averages taken from the detailed survey and are summarized on a reach basis in the Input Parameters for Empirical Analysis Tables 8-1 and 8-2.

Table 8-1. Input Parameters for Empirical Assessment of Reach HU_WH_LC_0_1 Site 5 - Johnston Sports Park

Channel Parameters (Input for Empirical Assessment)	HU_WH_LC_0_1		
	Notation	Units	Average
Bankfull Width	W_{bf}	m	6.76
Bankfull Depth	D_{bf}	m	0.30
Maximum Bankfull Depth	D_{max}	m	0.66
Bankfull Area	A_{bf}	m^2	1.60
Bankfull Discharge	Q_{bf}	m^3	1.04
Drainage Area	A_w	km^2	3.17
Grade	S	m/m	0.007

Table 8-2. Input Parameters for Empirical Assessment of Reach HU_WH_SAL_2_1a Site 6 - Tullamore Reservoir

Channel Parameters (Input for Empirical Assessment)	HU_WH_SAL_2_1a		
	Notation	Units	Average
Bankfull Width	W_{bf}	m	6.05
Bankfull Depth	D_{bf}	m	0.32
Maximum Bankfull Depth	D_{max}	m	0.56
Bankfull Area	A_{bf}	m^2	1.94
Bankfull Discharge	Q_{bf}	m^3	1.70
Drainage Area	A_w	km^2	19.47
Grade	S	m/m	0.006

Based on the results of the empirical approach, the preliminary meander belt for Reach HU_WH_LC_0_1 at Site 5 - Johnston Sports Park is **28.6m.** This preliminary result is based on the average of the empirical models used. Results of the models are presented in Table 8-3.

Table 8-3. Empirical Determination of Preliminary Meander Belt Width for Reach HU_WH_LC_0_1 - Site 5 - Johnston Sports Park

Source	Conditions / Applications	Input variable	Equation	Meander Belt Width (m)
Ward et al. (2002)	W_{bf} in feet - no factor of safety	Bankfull Width (ft)	$4.8 * W_{bf}^{1.08}$	41.5
Ward et al. (2002)	W_{bf} in feet - with factor of safety	Bankfull Width (ft)	$6 * W_{bf}^{1.12}$	58.7
Williams (1986)	W_{bf} > 1.5 m	Bankfull Width (m)	$4.3 * W_{bf}^{1.12}$	36.5
Piegay et al. (2005) and Bravard et al. (1999)	Average	Bankfull Width (m)	$10 * W_{bf}$	67.5
NRCS manual TS14S (2007)		Bankfull Width (m)	$6 * W_{bf}$	40.5
Lorenz and Heinze (1985)		Bankfull Width (m)	$7.53 * W_{bf}^{1.01}$	51.8
Malavoi et al. (1998)		Bankfull Width (m)	$10 * W_{bf}$	67.5
Kline and Dolan (2008)	Vermont - general guidance	Bankfull Width (m)	$6 * W_{bf} + 1 W_{bf}$ on either side = $8 * W_{bf}$	54.0
			Mean	**52.3**
Williams (1986)		Bankfull Depth (m)	$148 * D_{bf}^{1.52}$	23.7
Bridge and Mackey (1993)		Bankfull Depth (m)	$59.9 * D_{bf}^{1.8}$	6.9
Collinson (1978)		Bankfull Maximum Depth (m)	$65.6 * D_{max}^{1.57}$	34.2
			Mean	**21.6**
Williams (1986)	Bankfull area > 0.04 m^2	Bankfull area (m^2)	$18 * A_{bf}^{0.65}$	28.5
			Mean	**28.5**
Annable (1996)	E type river (r^2 = 0.61)	Bankfull Discharge (m^3/s)	$16.3 * Q_{bf}^{0.88}$	16.9
Chitale (1973)	Achers and Charlton	Bankfull Discharge (m3/s)	$18.5 * Q_{bf}^{0.5}$	18.9
Carlston (1965)		Mean Annual Discharge (m3/s)	$65.8 * Q_{mean}^{0.47}$	0.0
			Mean	**11.9**
Preliminary Meander Belt Width (m)				**28.6**

The preliminary meander belt for Reach HU_WH_SAL_2_1a at Site 6 - Tullamore Reservoir was calculated at **27.8m**, based on the results of the empirical approach**.** This preliminary result is based on the average of the empirical models used. Results of the models are presented in **Table 8-4**.

Table 8-4. Empirical Determination of Preliminary Meander Belt Width for Reach HU_WH_SAL_2_1a - Site 6 - Tullamore Reservoir

Source	Conditions / Applications	Input variable	Equation	Meander Belt Width (m)
Ward et al. (2002)	W_{bf} in feet - no factor of safety	Bankfull Width (ft)	$4.8 * W_{bf}^{1.08}$	36.9
Ward et al. (2002)	W_{bf} in feet - with factor of safety	Bankfull Width (ft)	$6 * W_{bf}^{1.12}$	52.0
Williams (1986)	$W_{bf} > 1.5$ m	Bankfull Width (m)	$4.3 * W_{bf}^{1.12}$	32.3
Piegay et al. (2005) and Bravard et al. (1999)	Average	Bankfull Width (m)	$10 * W_{bf}$	60.5
NRCS manual TS14S (2007)		Bankfull Width (m)	$6 * W_{bf}$	36.3
Lorenz and Heinze (1985)		Bankfull Width (m)	$7.53 * W_{bf}^{1.01}$	46.4
Malavoi et al. (1998)		Bankfull Width (m)	$10 * W_{bf}$	60.5
Kline and Dolan (2008)	Vermont - general guidance	Bankfull Width (m)	$6 * W_{bf} + 1\ W_{bf}$ on either side = $8 * W_{bf}$	48.4
			Mean	**46.7**
Williams (1986)		Bankfull Depth (m)	$148 * D_{bf}^{1.52}$	26.2
Bridge and Mackey (1993)		Bankfull Depth (m)	$59.9 * D_{bf}^{1.8}$	7.7
Collinson (1978)		Bankfull Maximum Depth (m)	$65.6 * D_{max}^{1.57}$	26.4
			Mean	**20.1**
Williams (1986)	Bankfull area > 0.04 m^2	Bankfull area (m^2)	$18 * A_{bf}^{0.65}$	27.7
			Mean	**27.7**
Annable (1996)	E type river ($r^2 = 0.61$)	Bankfull Discharge (m^3/s)	$16.3 * Q_{bf}^{0.88}$	26.0
Chitale (1973)	Achers and Charlton	Bankfull Discharge (m3/s)	$18.5 * Q_{bf}^{0.5}$	24.1
Carlston (1965)		Mean Annual Discharge (m3/s)	$65.8 * Q_{mean}^{0.47}$	0.0
			Mean	**16.7**
Preliminary Meander Belt Width (m)				**27.8**

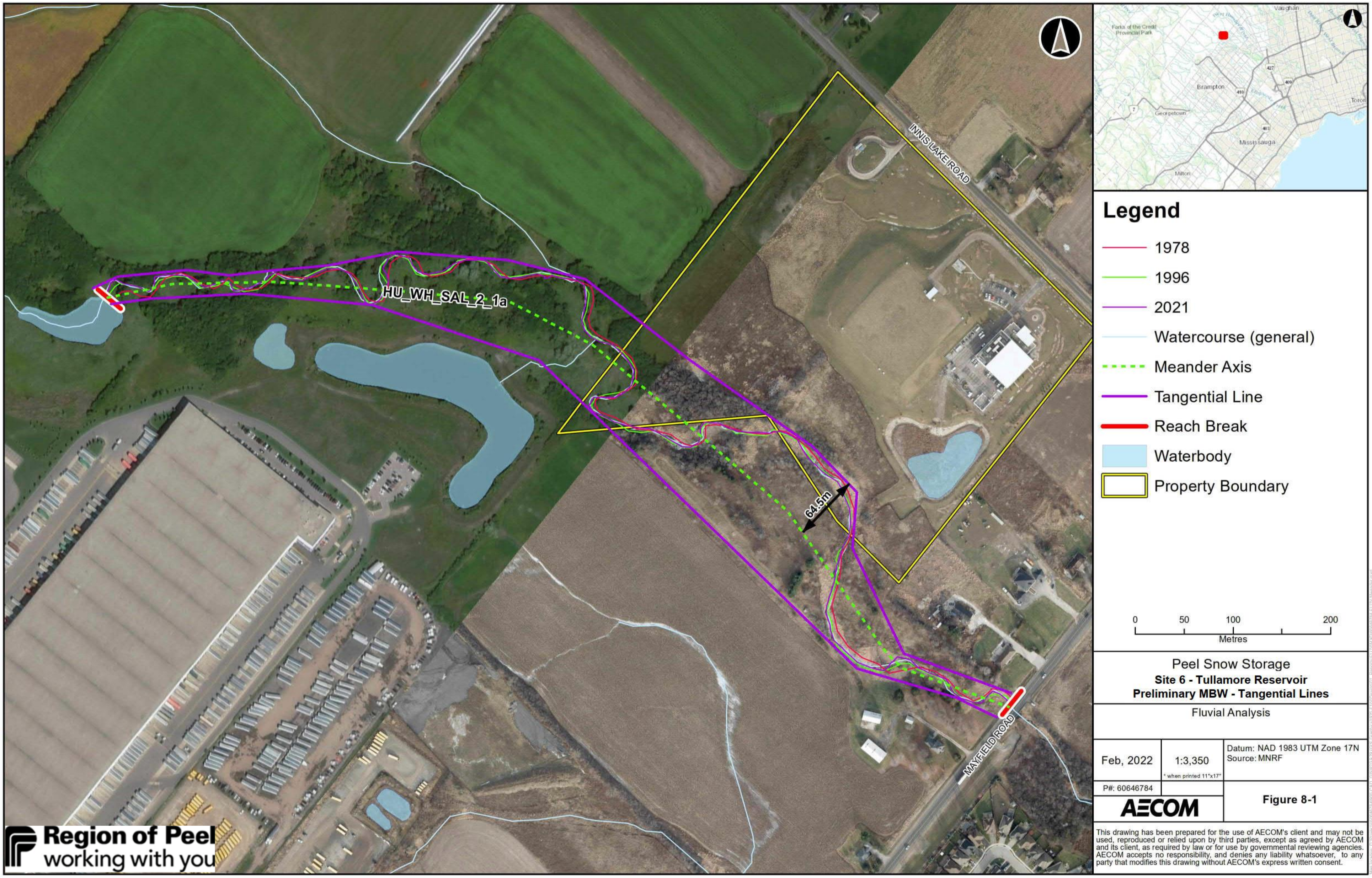
Given the apparent alterations to its planform and the lack of surrogate reaches, the empirical approach was the only option available to determine a preliminary meander belt for Reach HU_WH_LC_0_1 (Site 5 - Johnston Sports Park).

Planform Mapping Approach

Further to the empirical determination of preliminary meander belt, a planform mapping approach was also completed for Reach HU_WH_SAL_2_1a (). The planform approach is generally the preferred procedure when watercourses are un-altered, and their meandering history can be tracked on aerial imagery (TRCA, 2004). Furthermore, surrogate reaches can also be used for watercourses whose planform have been artificially modified over time (TRCA, 2004).

Using the available protocols from the TRCA 2004 Belt Width Delineation Procedures, where the meander belt allowance (preliminary meander belt) is determined by drawing tangential lines along of outer meanders, including the overlaid historical imagery. The outermost meander (meander amplitude) was measured perpendicular to the meander axis, providing a preliminary meander belt for Reach HU_WH_SAL_2_1a of **129m**. **Figure 8-1** displays the tangential lines used to determine the preliminary meander belt along with the historical positions of the watercourse. Measurements were completed using GIS tools.

Figure 8-1. Preliminary Meander Belt for Reach HU_WH_SAL_2_1a – Site 6 – Tullamore Reservoir



8.1.2 Erosion Setback

In addition to the preliminary meander belt width, an erosion allowance is required to account for the 100-year erosion potential. A minimum of 20-30 years of historical data are required to provide a measure of reliability when determining the average annual recession rate extended over 100-years (TRCA, 2004; TRCA, 2015).

Measurement of erosion rates (lateral migration of the watercourse) is completed by overlaying the available historical imagery and the migration rates were measured at the apex and immediately downstream of the apex of the outside of all meander bends (TRCA, 2015). However, given the low quality of the historical imagery, measurement of lateral meander migration was not possible. The TRCA Crossings Guideline for Valley and Stream Corridors suggests that in the case that accurate delineation of the historic planforms is not possible, the criteria outlined in Table 4 of the Ministry of Natural Resources (MNR) Natural Hazards Training Manual (2013) can be used to select a 100-year erosion rate. A copy of the table can be found in **Appendix C**. Based on the surficial geology of the site (described in **Section 2.1.2**), the highest 100-year erosion rate of **8m** was selected for Reach HU_WH_SAL_2_1a as a conservative measure and is to be applied to either side of the preliminary meander belt.

A similar approach was taken for Reach HU_WH_LC_0_1 and MNR's Table 4 was also used to estimate a 100-year erosion rate based on the conditions observed on the reach and the area's surficial geology. The selected 100-year erosion rate for Reach HU_WH_LC_0_1 is **1m** and is to be applied to either side of the preliminary meander belt.

8.1.3 Final Meander Belt Width

The meander belt width represents the maximum corridor of the meander pattern and therefore this corridor covers the lateral area where the channel could potentially occupy over time.

Historical adjustments along Reach HU_WH_LC_0_1 (Site 5 - Johnston Sports Park) have disturbed the dynamic equilibrium of the creek and it is assumed that the contemporary channel conditions do not represent the pre-modified channel and are not in equilibrium with natural physical processes. This assumption is backed by the results of the RGA (**Section 4.2**), which classified the reach as in "Transitional or Stressed" condition and identified aggradation and planimetric form adjustment as the main geomorphological processes taking place, and the historical imagery analysis (**Section 3**) which provides evidence of channelization along the corridor of the feature. In contrast, Reach HU_WH_SAL_2_1a (Site 6 - Tullamore Reservoir) has no evidence of historical artificial alterations to its planform in the investigated portion of the reach.

A range for preliminary and final meander belt dimensions generated through the use of the empirical approach (for reaches HU_WH_LC_0_1 and HU_WH_SAL_2_1a) and the planform approach (for Reach HU_WH_SAL_2_1a only), are provided **Table 8-5.** Based on the empirical analysis, the selected 100-year erosion rate, and the safety factor, the final meander belt for Reach HU_WH_LC_0_1) has an estimated width of **33.5m**. The estimated final meander belt width for Reach HU_WH_SAL_2_1a, including the 100-year erosion rate and safety factor, is **158m**. The results of the final meander belt calculations are presented in **Table 8-5**. The empirical analysis performed on Reach HU_WH_SAL_2_1a (**Table 8-4**) was observed below the predicted meander belt width using mapping and was only calculated as procedural step. The final meander belt width limits for Reach HU_WH_LC_0_1 (Site 5 - Johnston Sports Park) are presented in **Figure 8-2,** and in **Figure 8-3** for Reach HU_WH_SAL_2_1a (Site 6 - Tullamore Reservoir).

Table 8-5. Final Meander Belt Width Calculation

Location	Site 5 - Johnston Sports Park - Reach HU_WH_LC_0_1	Site 6 - Tullamore Reservoir - Reach HU_WH_SAL_2_1a
Preliminary Meander Belt (m)	28.6	129
Safety Factor	1.1	1.1
100-yr Erosion Rate (m)*	2	16
Final Meander Belt Width (m)	33.5	158

*Approximate 100-yr toe erosion rate selected using MNR's Table 4 as indicated in TRCA's 2015 Crossings Guideline

Figure 8-2. Final Meander Belt for Reach HU_WH-LC_0_1 - Site 5 - Johnston Sports Park

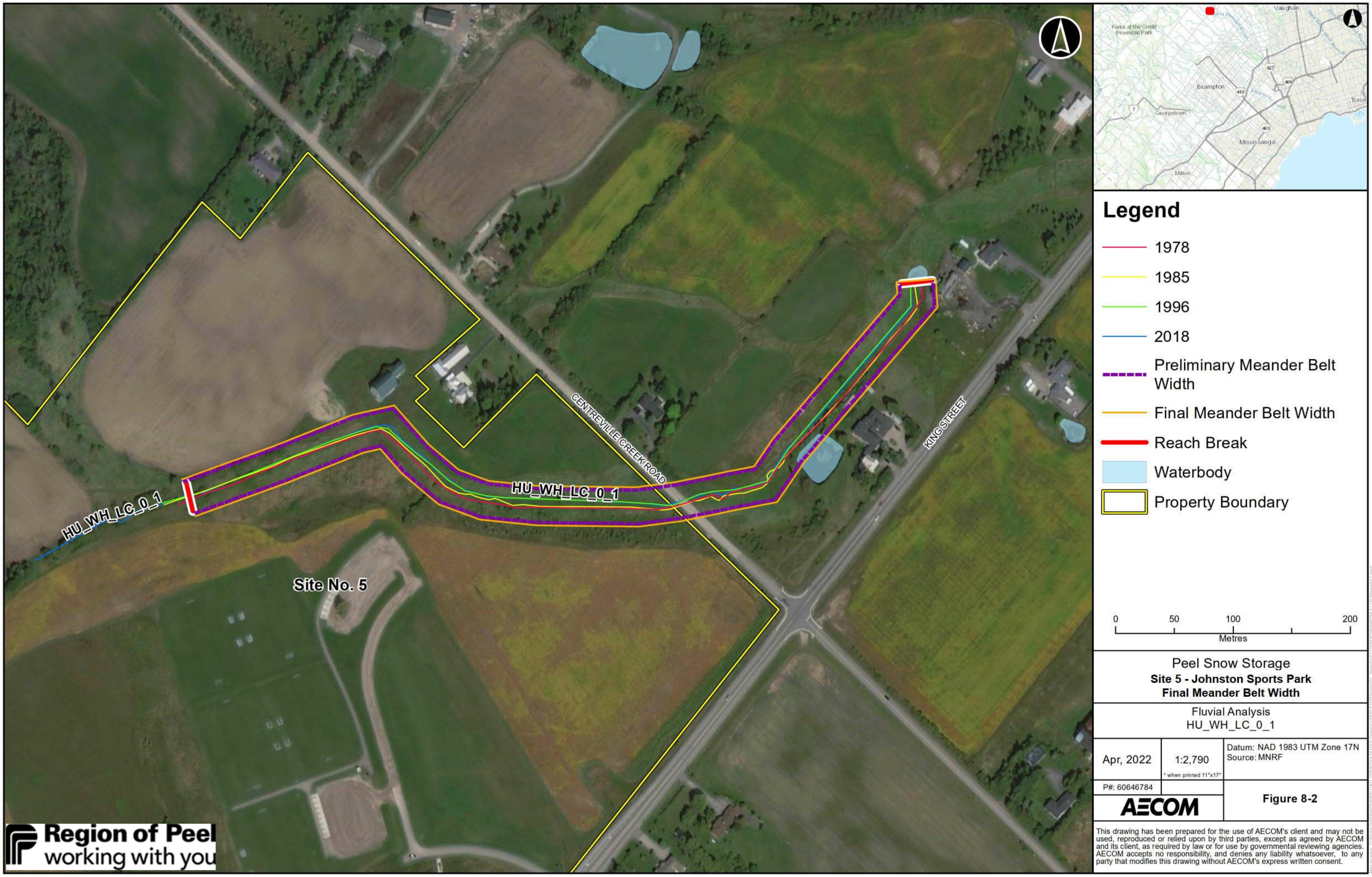
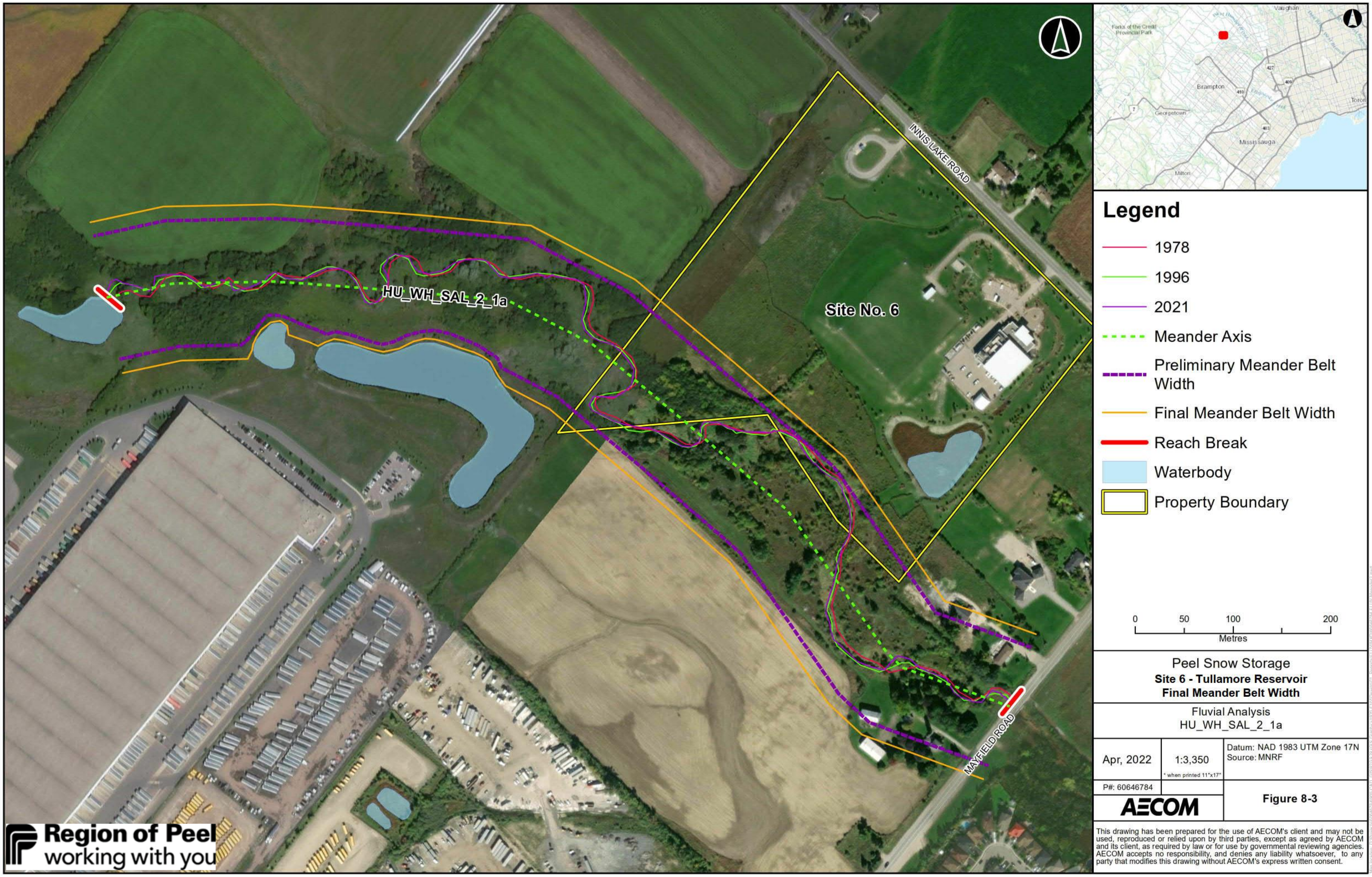


Figure 8-3. Final Meander Belt Width for Reach HU_WH_SAL_2_1a - Site 6 - Tullamore Reservoir



9. Summary and Conclusions

As part of the proposed snow storage sites, a fluvial geomorphological assessment and the meander belt width determination were completed for sites 5 – Johnston Sports Park and 6 - Tullamore Reservoir as these were the only locations where access and collection of quantitative data was permissible. The remaining sites 1 – Highway 50 Carpool Lot, 3 – West Brampton Reservoir, and 9 – Alloa Reservoir did not have watercourses within the property boundary, or the watercourses were located on adjacent and inaccessible properties.

9.1 Key Findings

Based on the fluvial geomorphological data collected the following key findings and conclusions were made:

- The historical analysis for reaches Site 3 – West Brampton Reservoir, Site 5 – Johnston Sports Park, and Site 9 – Alloa Reservoir indicate that artificial alteration to the channels' planform have taken place and is likely due to agricultural activities in the vicinity.
- At Site 1 - Highway 50 Carpool Lot, historical aerial imagery showed no visible watercourses within the proposed snow storage site and fieldwork confirmed this.
- Fluvial geomorphological reach characterization was completed at four locations proposed for snow storage. Further assessment occurred at two sites (Site 5 – Johnston Sports Park and Site 6 - Tullamore Reservoir), including Rapid Geomorphic Assessments, quantitative geomorphological data collection, calculation of an erosion threshold, and calculation of the meander belt. The remaining two sites were not further assessed due to watercourse being located on private property. For Site 3 – West Brampton Reservoir a site visit was conducted at Bovaird Drive where the channel was only slightly defined and approximately 1 m wide. At Site 9 – Alloa Reservoir a site visit was conducted at Mississauga Road and Creditview Road where the channel is defined and approximately 4 m wide.
- Grain size distribution at both locations was predominantly fines (silt, clay, and sand), with some very fine gravel and bedrock located at Site 6 – Tullamore Reservoir. No bedrock was identified along the banks at Tullamore Station.
- The Rapid Geomorphic Assessment completed at Site 5 – Johnston Sports Park found that the current condition of the channel is "Transitional or Stressed" with aggradation and planimetric form adjustment as the main geomorphological processes taking place. No evidence of erosion was noted at the time of assessment.
- The dense riparian and in-channel grassy and herbaceous vegetation encountered along watercourse strengthen the channel bed and banks limit the erosion potential.
- The Rapid Geomorphic Assessment completed at Site 6 – Tullamore Reservoir identify the channel to be in "Regime" with widening and planimetric form adjustment identified as the main geomorphological processes taking place. Minimal evidence of erosion was found within this reach.
- The dense riparian vegetation encountered along the riparian zone strengthen the channel's banks. Shale bedrock identified along portions of the channel bed also provide stability and resistance to erosional forces.
- The calculated critical discharge values for bed material entrainment on average were **0.15 m^3/s** for Site 5 - Johnston Sports Park, and **0.13 m^3/s** for Site 6 – Tullamore Reservoir. The critical discharge values identify that a lower flow is required to entrain or begin to transport bed material due to the fact that the substrate gradation is smaller. Consideration for in-channel vegetation at Site 5 - Johnston Sports Park and shale bedrock at Site 6 – Tullamore Reservoir is not considered at part of the assessment and would increase the critical discharge along the bed of the channel.
- The determination of a meander belt for the watercourse at Site 5 – Johnston Sports Park was completed using the empirical approach due to historical alterations and the final meander belt is **33.5m**.

- The final meander belt for Site 6 – Tullamore Reservoir was completed using the mapping approach and is **158m**.

9.2 Recommendations

Based on the results of the fluvial geomorphic assessment, the following recommendations are made.

- Increases in flow to the watercourses from the snow melt should consider the erosion threshold conditions for Site 5 – Johnston Sports Park and Site 6 - Tullamore Reservoir. The erosion threshold provides targets for the drainage network. Increases in flow have the potential to result in channel instability and lead to morphological adjustment. It should be noted that at Site 5 - Johnston Sports Park, that aggradation of fine sediment was found along the bed of the watercourse and that increases in flow will help to alleviate this. At Site 6 – Tullamore Reservoir, shale bedrock identified along the bed of the watercourse will provide resistance to erosional processes, but no shale was noted along the banks. It is recommended that care is taken to maintain vegetation cover along and within the watercourses in order to maintain the existing channel stability.
- The meander belt refers to the lateral extent of floodplain occupation by a meandering watercourse both now and into the future. Protecting the meander belt area from encroachment serves the dual purposes of enabling a continuity of natural channel processes and of protecting property and structures from erosion. To prevent, eliminate or minimize the risks to life and property caused by erosion hazards, it is recommended to maintain the meander belt boundary.
- Due to the location of the watercourses on private property at Site 3 – West Brampton Reservoir and Site 9 – Alloa Reservoir and no permission to enter (PTE), a scoped fluvial geomorphological assessment was completed. Future detailed assessments are recommended when permission to enter granted.

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Appendix A – Photographic Log

Site 1 – Highway 50 Carpool Lot

Photograph 1. ↑
Looking south at proposed snow storage site from middle northern limit of site.

Photograph 2. ↑
Looking southeast at proposed site from the northwest corner.

Site 3 – West Brampton Reservoir and Pumping Station

Photograph 3. ↑
Looking southeast at watercourse from Bovaird Rd W. (approximately 1km northwest of Site 3)

Photograph 4. ↑
Looking south at watercourse from Bovaird Rd W. (approximately 1km northwest of Site 3)

Site 5 - Johnston Sports Park

Photograph 5.
Looking upstream at **cross section 1**. Densely vegetated banks and channel.

Photograph 6.
Looking downstream at **cross section 1**. Densely vegetated banks and channel.

Photograph 7.
Looking upstream at **cross section 2**. Dense in-channel vegetation.

Photograph 8.
Looking downstream at **cross section 2**. Channel not visible due to densely vegetated banks.

Photograph 9. ↑
Looking upstream at **cross section 3**. Dense in-channel vegetation.

Photograph 10. ↑
Looking downstream at **cross section 3**. Dense in-channel vegetation.

Photograph 11. ↑
Looking upstream at **cross section 4.**

Photograph 12. ↑
Looking downstream at **cross section 4.**

Photograph 13. ↑
Looking upstream at **cross section 5.**

Photograph 14. ↑
Looking downstream at **cross section 5.**

Photograph 15. ↑
Looking upstream at **cross section 6**. Dense in-channel vegetation.

Photograph 16. ↑
Looking downstream at **cross section 6**. Dense in-channel vegetation.

Photograph 17. ↑
Looking upstream at **cross section 7.**

Photograph 18. ↑
Looking downstream at **cross section 7.**

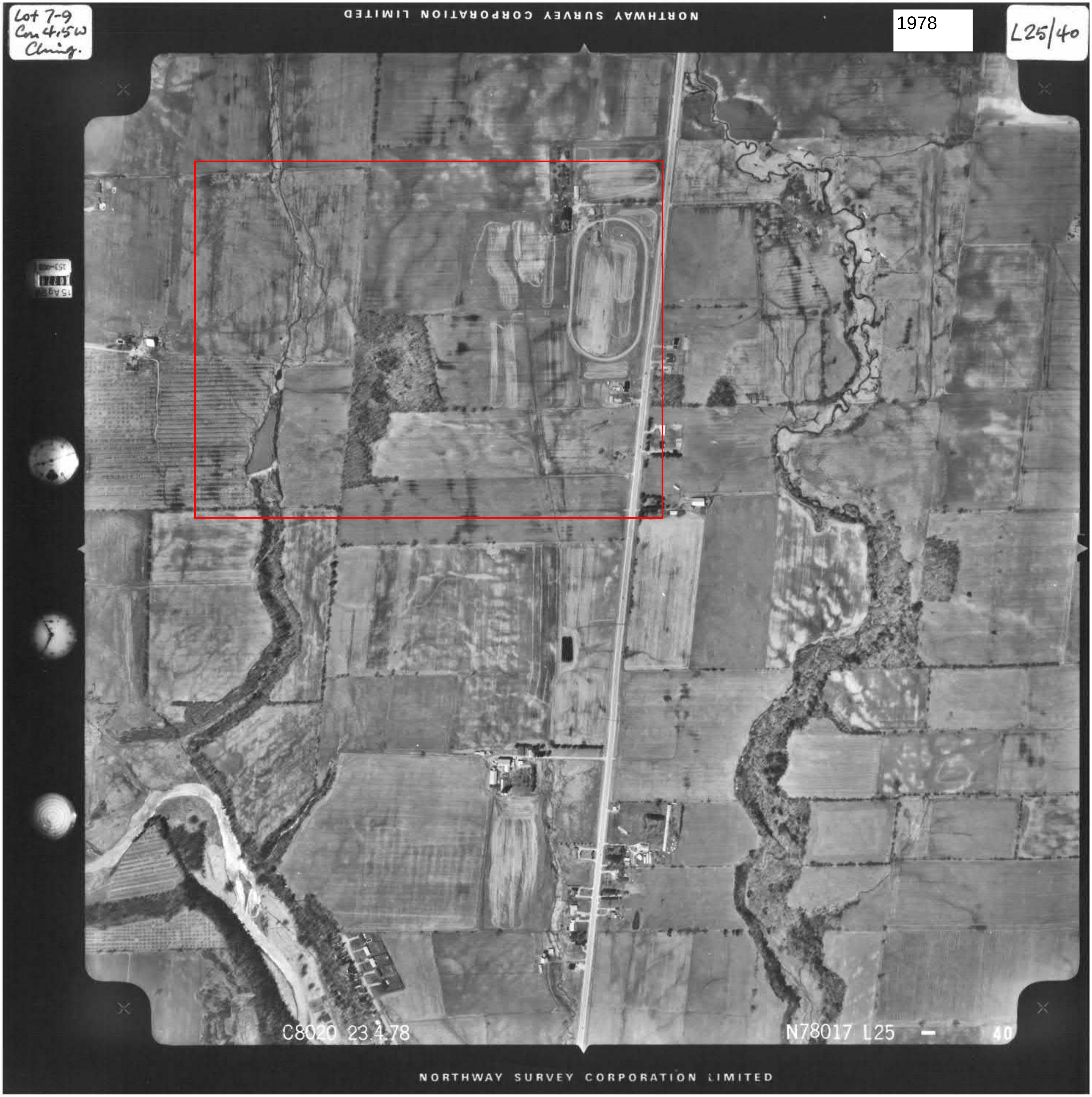
Photograph 19. ↑
Looking upstream at **cross section 8.**

Photograph 20. ↑
Looking downstream at **cross section 8.**

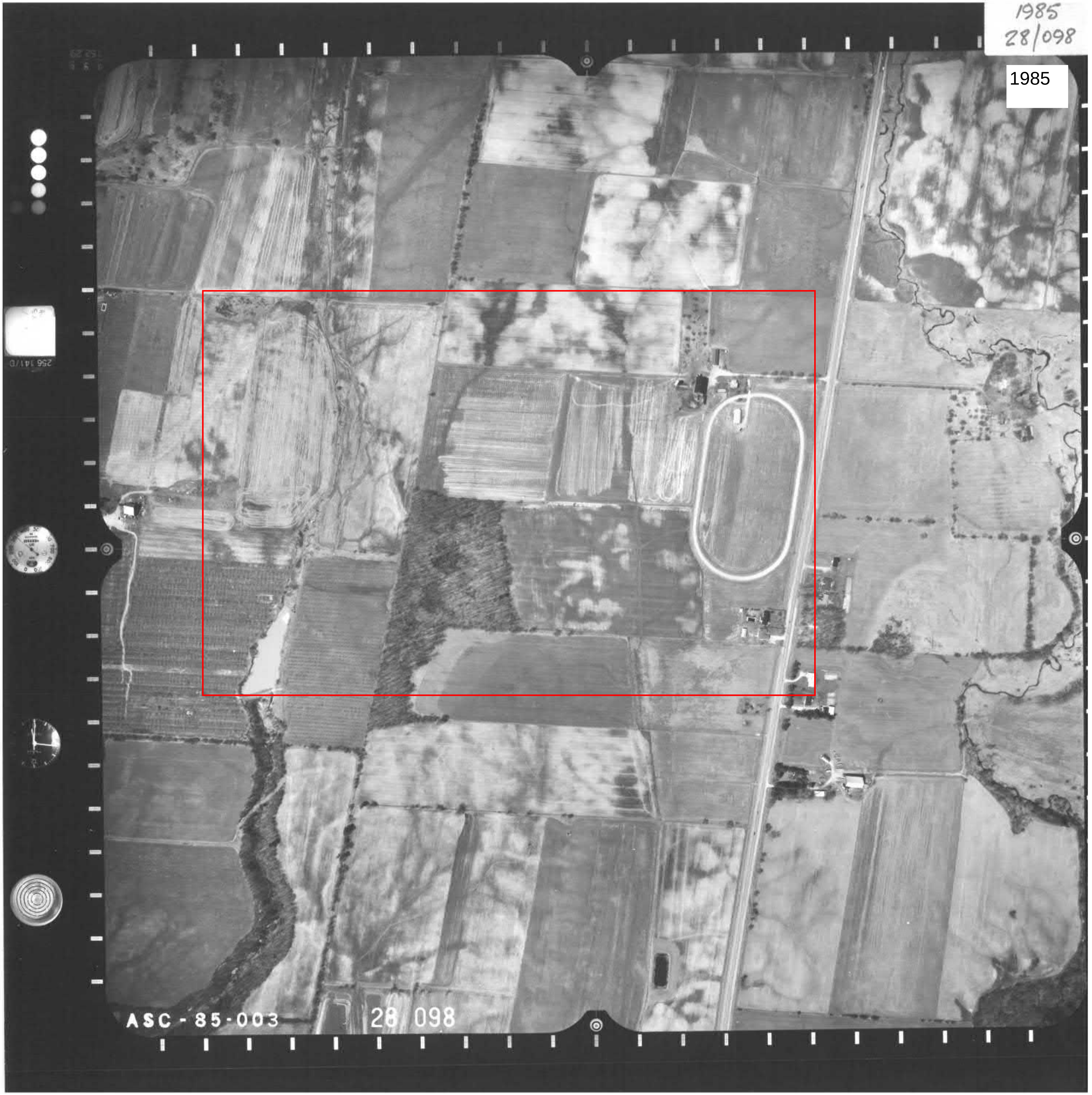
Appendix B – Historical Imagery

Site 3 – West Brampton Reservoir


1967
Spartan Air
Services Ltd.
150



Lot 7-9
Con 4:5W
Chnig.
NORTHWAY SURVEY CORPORATION LIMITED
1978
L25/40
C8020 23.4.78
N78017 L25
40
NORTHWAY SURVEY CORPORATION LIMITED


1985
28/098
1985
ASC-85-003
28 098

Site 5 – Johnston Sports Park


5430-198
Spartan Air Services Ltd


Spartan Air Services Ltd


10th S.RD.
Con 2,3 Ab.
Lot 9-11
L17/62
C8020 (23.4.78)
N78016 L17-62
NORTHWAY SURVEY CORPORATION LIMITED


1985
19/407
ASC-85-002
19 407

1996
L24/83

Site 6 – Tullamore Reservoir and Pumping Station


Spartan Air
Services Ltd.
5427-92
KODAK SAFETY FILM


Spartan Air
Services Ltd.
5429-18

J
3/138

17th S. RD.
Con 1,2 Alb.
Con 7,8 T.G.
L21/186
NORTHWAY SURVEY CORPORATION LIMITED
C8020 23.4.78
N78017 L21
186
NORTHWAY SURVEY CORPORATION LIMITED


1996
L28/196
265 011A
152.17
15-5-96 ASC96090 - 28 - 196

Appendix C – MNR Table 4 - Approximate 100-Year Toe Erosion Rates

Table 4: Approximate 100-year toe erosion rates for watercourses <5 meters in width

Type of material OR Native soil OR Structure	Evidence of active erosion* OR where the bankfull flow competence exceeds the erosion threshold	No Evidence of Active Erosion
Hard Rock (e.g. granite)	0 – 2 m	0 m
Soft rock (e.g. shale, limestone), cobbles, boulders.	2 – 5 m	0 m
Clays, clay-silt, gravels	5 – 8 m	1 m
Sand, silt	8 - 15 m	1 – 2 m

**Note that Active Erosion is defined as channel banks exposed directly to stream flow under normal or flood flow conditions and/or where undercutting, oversteepening, slumping of a bank or down stream sediment loading is occurring. It is expected that the majority of watercourses with defined bed and banks will display evidence of active erosion or will have bankfull flow competence in excess of the erosion threshold. Only very small watercourses with heavily vegetated bed and banks are expected to exhibit no evidence of active erosion

Extracted from TRCA Crossings Guidelines, 2015

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Project name:
Peel Region Snow Storage Site Analysis
Fluvial Geomorphic Assessmentt

Project ref:
Additional Site: 7120 Hurontario Street >

From:
Rhonneke Van Riezen, P.Geo
Senior Fluvial Geomorphologist

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Intermediate Fluvial Geomorphologist

Meghan Sauro. M.Sc.
Fluvial Specialist

Date:
June 2024

FINAL

To:
Syeda Basira Banuri, Program Manager,
Infrastructure Programming, Region of Peel

CC:
Derek R. Gray, P.Eng., A.A.E (AECOM),
Bill Trenouth, PhD., P.Eng., PMP (AECOM)

Memorandum

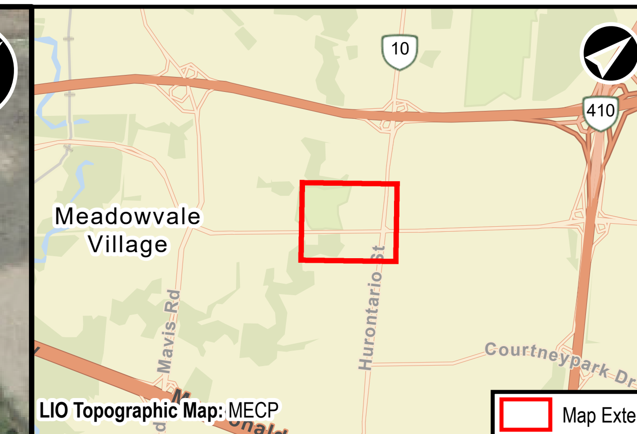
Subject: <Peel Region Snow Storage Site Analysis – Additional Site: 7120 Hurontario Street>

1. Introduction

As part of a Schedule 'B' Municipal Class Environmental Assessment (MCEA), AECOM Canada Ltd. was retained by the Region of Peel to complete required investigations of identified sites considered potential near and long-term snow storage solutions for the Region of Peel. As a result, AECOM produced the *Peel Region Snow Storage Site Analysis Fluvial Geomorphic Assessment Draft Report (2022)* (hereafter AECOM 2022 Fluvial Draft) for 5 (five) sites within the boundaries of Peel Region. Following the issuing of the AECOM 2022 Fluvial Draft, 7120 Hurontario Street was identified as a potential Storage Site by the Client and added to the investigation. An additional fluvial geomorphological investigation was requested and completed for a watercourse adjacent to 7120 Hurontario Street, to assess the existing conditions and impacts of the receiving watercourse to snow melt originating from the proposed Storage Site. A meander belt assessment and an erosion threshold assessment were completed for the watercourse. The assessment followed the same methodologies and protocols described in the AECOM 2022 Fluvial Draft. The results of the additional fluvial geomorphological investigation for 7120 Hurontario Street are provided as an addendum to the original draft report. This addended memo is to be read in conjunction with the previously issued AECOM 2022 Fluvial Draft.

1.1 Study Area

The study site is located at 7120 Hurontario Street, Mississauga, northwest of Derry Road. The site is within the Credit River watershed, and there is one watercourse located within the area of influence of the site. Based on the existing stormwater network it was identified that Fletchers Creek, a tributary of the Credit River, will be the receiving watercourse south of the intersection of Derry Road and Maritz Drive. Fletcher Creek flows south and drains into the Credit River east of Creditview Road, south of Highway 401. The proposed location for the snow storage site and the delineated reach of Fletchers Creek are presented in **Figure 1**.



Legend

- ★ 7120 Hurontario
- Approximate Property Boundary
- Proposed Snow Storage Site
- Fluvial Study Area
- Reach Break

General Features

- District, County, or Regional Road

Peel Region Snow Storage Sites - 7120 Hurontario

Study Area and Storage Site

0 50 100 200 M

NAD 1983 CSRS UTM Zone 17N

Sep, 2023	1:3,000	**Data Sources:** Contains Information licensed under the Open Government License Ontario
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Figure 1

2. Desk-Based Assessment

2.1 Watershed Characteristics

The Study Area is located within the Fletcher's Creek subwatershed, which covers approximately 4273 Ha. As of 2012, 62% of the subwatershed was classified as urban, with approximately 16% remaining natural area and 19.3% being classified as agricultural. This is a large increase from a study completed in 1996, which found that only 25% of the subwatershed was developed at that time (CVC, 2012). Rapid urbanization can result in increased stormwater runoff during stormwater events due to the higher percentage of impervious surfaces. This increased runoff has the potential to cause significant erosion issues for watercourses downstream of the urbanized area.

2.2 Physiography and Surficial Geology

The study area is divided between the Bevelled Till Plains of the Peel Plain Physiographic region at the location of the Storage Site for the upstream portion of the delineated reach, and the Drumlinized Till Plains of the South Slope physiographic region, starting approximately 200m downstream (south) of Derry Road (Chapman *et al*.., 2007). The Peel Plain has a relatively flat topography and is characterized by clay soils that have much lower infiltration rates which results in higher surface runoff. During storm events high stormwater flows could result in erosion and increased flooding. The Peel Plain extends through the central portions of the Regional Municipalities of York, Peel, and Halton. The South Slope gently slopes to the southeast and consists of shallow shale and till plains.

Fletcher's Creek flows over modern alluvial deposits of clay, silt, sand and gravel that may also contain organic remains. Silty clay loam has a moderate soil erodibility (TRCA, 2019). Paleozoic bedrock is also present in sections of the watercourse corridor within the valley. Above the valley and at the proposed storage site, the surficial geology is characterized by clay to silt-textured tills of glaciolacustrine origin (OGS, 2010).

2.3 Reach Delineation

A reach (FLE_CRK_01) was delineated from downstream (southeast) of Derry Road to approximately 330m east of McLaughlin Road. Coordinates and criteria for reach delineation are presented on **Table 1**. The reach delineation was completed using the methodology presented in the TRCA *Belt Width Delineation Procedures (2004)* and the MNR *Technical Guide – River and Stream Systems: Erosion Hazard Limit (2002)* documents. Through the desktop background review of available stormwater sewer network, it was determined that this reach would be the receiving watercourse of the snow melt.

Table 1. Reach Delineation Criteria

Reach	Limit	Coordinates (17 T)	Justification
7120 Hurontario Street **FLE_CRK_01**	Upstream	603980.00 m E; 4832875.00 m N	Change in valley confinement and riparian cover. Watercourse becomes more confined by the valley walls
	Downstream	604518.00 m E; 4831775.00 m N	Change in valley confinement. Valley floor and floodplain more accessible to the watercourse.

3. Historical Imagery Assessment

An analysis of historical aerial imagery from 1974, 1985, 1996, 2011 and 2017 provided by the Region of Peel was undertaken for the 7120 Hurontario St proposed snow storage site to determine changes in land use. These sites were analysed based on the presence of watercourses in or immediately adjacent to the proposed study area and the result of the analysis are presented in **Table 2** and is the basis for the determination of a meander belt completed in **Section 7** of this report. The historical imagery is presented in **Appendix A**.

Table 2. Historical Imagery Assessment

Year	Planform and Land Use
1974	The reach displays a natural meandering planform. The adjacent land use is dominated by agricultural activities. Upstream of Derry Road, the golf course appears to be in construction. The riparian vegetation is minimal upstream of Derry Rd with increased riparian vegetation present approximately 100m downstream of Derry Rd.
1985	The reach continues to displays a natural meandering planform. The adjacent land use remains dominated by agricultural activities with a few residential dwellings being built to the west of the watercourse. The riparian vegetation remains minimal downstream of Derry Road. An increase in riparian vegetation is observed near the downstream end of the reach.
1996	No changes to the natural meandering planform of the watercourse. Upstream of Derry Road, the golf course is present surrounding the watercourse. The riparian vegetation has slightly increased downstream of Derry Road. East of Hurontario Street, there is significant development, and land use is primarily industrial. Sometime between 1985 and 1996, Derry Road has been widened.
2011	The reach displays a natural meandering planform. There is significant urban development to both east and west of the watercourse. The east portion of the golf course had been developed into commercial buildings and parking lots, while the agricultural land to the west of the golf course has been developed into residential dwellings. Upstream of Derry Road and to the east of Fletcher's Creek, an off-line stormwater management (SWM) pond is now present. Downstream of Derry Road, there has also been development directly adjacent, and two SWM pond are also present to the east of the watercourse. Riparian vegetation remains the same.
2017	The reach displays a natural meandering planform. Land use remains the same, with primarily residential housing to the west and industrial/commercial land use to the east. Riparian vegetation has increased downstream of Derry Road.

4. Field Reconnaissance

A field investigation was completed on July 26, 2023, to verify the reach breaks and to identify local geomorphological form and function of the receiving watercourse in the vicinity of the proposed Storage Site. A rapid geomorphological assessment (RGA) and detailed geomorphological data collection (where possible) were completed as part of the field investigation. A photographic record of the reach conditions is presented in **Appendix B**. The watercourse conditions are described in the following sub-sections.

4.1 Geomorphological Reach Characterization

Reach FLE_CRK_01 is part of Fletcher's Creek, a tributary of the Credit River. The upstream reach break was selected based on land use and riparian vegetation changes, as upstream of the reach (upstream of the Derry Road bridge crossing) Fletcher's Creek flows through a golf course. The reach banks and riparian zone are densely vegetated by shrubs, grasses, herbaceous plants, and trees. An offline stormwater pond is present east of the reach and a drainage tributary, which appears to convey surface runoff from Derry Road, was observed discharging off the left (east) bank, by the most upstream outer meander. There is also an outlet pipe present along the left (east) bank ~ 50 m upstream of where the tributary outlets (just upstream of the most upstream outer meander). Riffle-pool morphology was well defined along the reach with an approximate spacing of 30-40m. The channel exhibits a meandering planform with a moderate gradient. Evidence of erosion was minimal and consisted of leaning trees, and basal scour on inside meander bends and through riffles. Woody debris was present along the banks for the majority of the reach, however there was minimal woody debris within the channel, except from the remains of a what appeared to be a beaver dam, downstream of cross section XS-3 (refer to **Section 5.1** for details about cross sections). On the day of the assessment the water was very turbid and contained abundant suspended sediment. Soft sediment was also present along the channel bed. Although exposed bedrock occurred in the area, no outcrops of bedrock were observed in the channel. The average bankfull width and depth were measured at approximately 11.7 m and 0.8 m, respectively.

4.2 Rapid Geomorphic Assessment (RGA)

Refer to AECOM, 2022 for a description of the Rapid Geomorphic Assessment technique and applicability. Reach FLE_CRK_01 was identified as the receiving watercourse of the 7120 Hurontario St. Snow Storage Site. It has an overall score of 0.18 on the stability index, meaning that the reach is "In Regime". Field indicators suggest that widening is the dominant process occurring within the reach, with lesser indicators of aggradation and planimetric form adjustment.

Evidence of channel widening included fallen/ leaning trees, basal scour on the inside of meander bends, and basal scour on both side of the channel through riffles.. As banks erode and collapse the river becomes wider and shallower over time (Maine, 2007). There was limited evidence of aggradation and planimetric form adjustment. The evidence of aggradation included to poor longitudinal sorting of bed materials, and the evidence of planimetric form adjustment included an absence of bar forms. The results of the assessment are presented below, in **Table 3**.

Table 3. Rapid Geomorphic Assessment Results

Reach	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
FLE_CRK_01	0.14	0	0.43	0.14	0.18	In Regime

Based on the results of the RGA, it can be concluded that at the time of the assessment, the watercourse is only displaying isolated evidence of instability that is associated with normal river processes. Therefore, the reach morphology is within a range of variance for streams of similar hydrographic characteristics (MOE, 2003).

5. Quantitative Geomorphological Data Collection

A detailed survey of the receiving watercourse located downstream of Derry Road. The quantitative geomorphological data collection captured the following characteristics of the watercourse along 5 cross sections:

- Cross-Sectional Survey;
- Longitudinal Profile;
- Bank Characterization Data;
- Bed Characterization;
- Pebble count; and
- Photographic Record

The following sections present the results of the analysis of the data collected and inform the erosion threshold assessment and meander belt assessment. A photographic record of the surveyed reaches and assessed sites can be found in Appendix A.

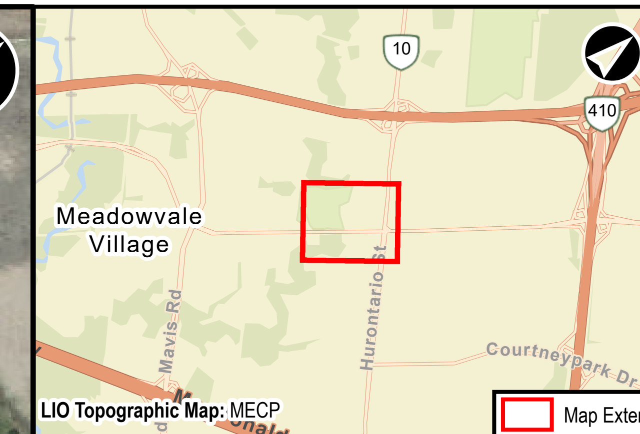
5.1 Cross Sectional Survey

A total of five (5) cross sections were collected along the investigated reach. The cross sections were collected at morphological features such as riffles, runs and pools. Results of the cross-section surveys are presented in **Table 4**. **Figure 2** depicts the locations of the cross-sections.

Results indicate that the bankfull width remains relatively consistent throughout the Study Area with the widest portion of the channel occurring at the location of XS-3 immediately downstream of the meander bend. The channel is also shallower at this location. The bankfull width:depth ratio ranges from 10 to 34.8, with the highest ratio occurring at XS-3, with a less high value also occurring at XS-1. The high width:ratio indicates that at the location of XS-1 and XS-3 the watercourse is shallow and wide. These cross sections were collected at riffles, which by nature are shallower in depth. These types of channels tend to experience higher hydraulic stresses against the channel bank, as well as deposition of their sediment load due to the over-widened channel losing its ability to transport sediment, caused by decreases in shear stress and velocity. This result agrees with the RGA assessment results that indicated that channel widening was the dominant process occurring in the reach (refer to **Section 4.2**). The high width:depth ratio at XS-3 may also in part be attributed to the remains of a beaver dam that was observed downstream of XS-3. The presence of a beaver dam would interrupt the flow and cause disruption in natural channel dynamics. The width:depth ratio at the remaining cross section locations ranges from 10 – 11.4. Studies have shown that a ratio value of approximately 12 is the most frequently observed value and is related to a relatively stable system with changes occurring when the width:depth ratio is significantly altered (U.S. Environmental Protection Agency, 2023).

Table 4. Bankfull Hydraulics Results

Parameter	Reach:	FLE_CRK_01					
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5	Average
	Feature:	Riffle	Pool/Run	Riffle	Pool	Riffle	
Bankfull Width (m)		12.0	9.3	17.5	9.6	10.1	**11.7**
Average Bankfull Depth (m)		0.7	0.9	0.5	0.9	0.9	**0.8**
Maximum Bankfull Depth (m)		1.2	1.3	1.1	1.3	1.3	**1.2**
Bankfull Width:Depth		17.2	10.0	34.8	11.0	11.4	**16.9**
Cross-sectional Area (m^2)		7.8	9.4	12.8	10.0	9.8	**9.9**
Bankfull Discharge (m^3/s)		9.3	11.8	13.4	12.4	11.6	**11.7**
Average Bankfull Velocity (m/s)		0.9	1.0	0.7	1.0	1.0	**0.9**



Legend

- ★ 7120 Hurontario
- Approximate Property Boundary
- Proposed Snow Storage Site
- Fluvial Study Area
- Cross Sections
- Reach Break

General Features

- District, County, or Regional Road

Peel Region Snow Storage Sites - 7120 Hurontario

Location of Cross Sections

0 50 100 200 M

NAD 1983 CSRS UTM Zone 17N

Aug, 2023	1:3,000	**Data Sources:** Contains Information licensed under the Open Government License Ontario
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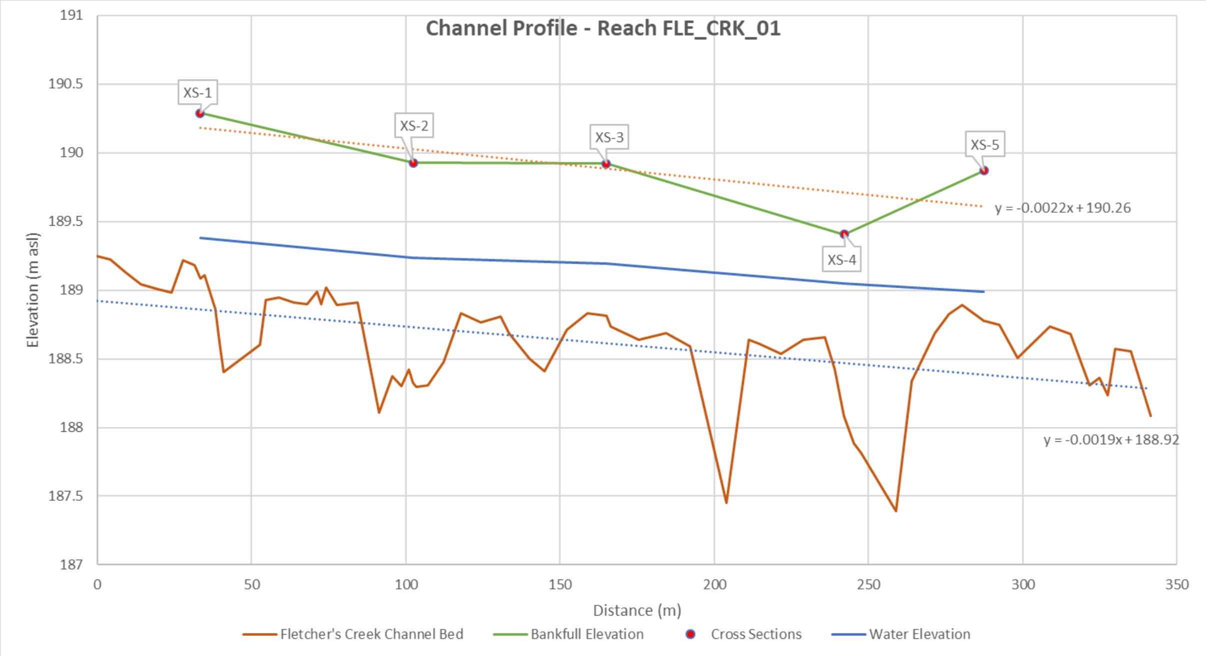
Figure 2

5.2 Longitudinal Profile

The longitudinal channel profile survey (approximately 341 m) extended beyond the location of the cross sections to better identify bed forms and bed gradient. The change in bed elevation from the most upstream point to the most downstream was calculated at 1.163 m. Based on the analysis of the survey results, the channel bed gradient was calculated at 0.002 m/m; the bankfull gradient was 0.0022 m/m; and a Manning's number of 0.04 was selected based on the observed conditions of the entire channel. **Figure 3**, below, shows the location of the collected cross sections, and bank full elevation in relation to the channel bed elevation.

Figure 3: Longitudinal Channel Profile for Reach FLE_CRK_01



5.3 Bank Characterization

The results of the bank characterization assessment are provided in **Table 5**. Rooting depth, riparian vegetation, and the degree of undercutting were documented for both the right and the left bank throughout. The bankfull heights ranged from 0.8 m to 1.2 m among the cross sections taken and the bank angle ranged from 6.9 – 50.9 degrees with an average of a moderate slope of 34 degrees. The rooting depth at all but one cross section extended to the bottom of the bank.

Bank undercutting was noted at all five cross sections and occurred along both the left and right banks.

Table 5. Bank Characterization

Parameter	Reach:	FLE_CRK_01				
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5
	Unit:	Riffle	Pool/Run	Riffle	Pool	Riffle
Height (m)	Left Bank	1.1	1.1	0.9	1.2	1.0
	Right Bank	1.1	1.1	1.0	0.8	1.1
Angle (°)	Left Bank	13.1	50.9	23.1	33.9	50.6
	Right Bank	17.1	35.9	6.9	54.0	59.2
Rooting Depth (m)	Left Bank	Bottom of bank	Bottom of bank	Bottom of bank	Bankfull	Bottom of bank
	Right Bank	Bottom of bank	Bottom of bank	Bottom of bank	Waters edge	Bottom of bank
Undercut (m)	Left Bank	None	Height: 1.19 Amount: 0.29	Height: 0.8	Height: 0.1 Amount: 0.1	Height: 0.2 Amount: 0.15
	Right Bank	Height: 0.10 – 0.5 Amount: 0.05 – 0.2	None	None	Height: 0.55 Amount: 0.18	Height: 1 Amount: 0.15

5.4 Bed Characterization

The Wolman (1954) pebble count method was used at the surveyed cross sections of the investigated reach to determine the grain size distribution of in-channel substrate. The grain size distribution influences sediment transport and flow resistance within a given reach. A modified Wentworth (1922) grain size scale was used to classify particles into discrete groupings. A step-toe procedure was used to select 100 grains along each cross section. The b-axis of each selected stone was measured using a ruler. Grains that were less than 2mm were assigned to a fine sediment category according to the modified Wentworth grain size scale.

Grain size distributions were then calculated based on the Wolman (1954) pebble counts completed at each of the surveyed cross sections. The D16 (16% of the same is equal to or smaller than), D50 (medium grain size), and D84 (84% of the sample is equal to or smaller than) are summarized in **Table 6**.

Table 6. Summary Statistics of Pebble Count

Parameter:	Reach:	FLE_CRK_01				
	Cross Section:	XS-1	XS-2	XS-3	XS-4	XS-5
	Unit:	Riffle	Pool/Run	Riffle	Pool	Riffle
D16 (mm):		0.83	0.04	0.67	0.42	0.10
D50 (mm):		10.26	2.68	7.45	15.60	9.29
D84 (mm):		83.18	31.38	41.70	53.00	48.80

Overall, the bed sediment size was variable across the Study Area but the D16 size faction generally decreases in the downstream direction.

6. Erosion Threshold Assessment

In natural systems, creeks regularly see flows that entrain and transport sediment; this is part of the natural process that maintains creek form. However, issues arise when changes in the watershed's hydrology results in an increase in the frequency or period of erosive events or a cumulative increase in the quantity of flow that can entrain and transport sediment (CVC, 2010). The collection of detailed geomorphological field data enables the calculation of erosion thresholds representative of specific reaches, which relate to the point at which sustained flows will theoretically start to entrain and transport bed or bank sediments within the reach. Associated critical discharge values are calculated based on channel geometry and bed/bank substrate.

The erosion threshold assessment, at minimum (according to CVC's 2010 guidance), should consist of:

- Reach delineation (refer to **Table 1**)
- Rapid assessment to evaluate stability of reaches (refer to **Section 4.2**).
- Detailed examination of most sensitive reaches (refer to **Section 5**)
- Definition of erosion thresholds based on scientifically defensible models. Modelled results should also be compared to actual field observations – the simplest method being spot observations of active or inactivity of entrainment at different velocities, discharges and/or flow depths.

Empirical relations were utilized to determine the flow conditions at which theoretically the substrate and bank materials would be entrained. This was achieved by imposing a water surface elevation of 0.01 m above the maximum depth at each cross section. The water surface elevation was iteratively increased until the water surface elevation was above bankfull conditions. For each iteration, hydraulic properties (i.e., depths, velocities, discharge, shear stresses) were determined for the imposed water level. The energy gradient (bankfull) and hydraulic roughness (Manning's 'n') remained constant for all iterations. It is also noted that empirical analysis assumes that a reach is in equilibrium with prevailing flow and sediment supply conditions.

As noted in **Section 4.1**, the water within the channel was turbid during the field assessment (visual assessment of sediment in suspension was identified at site during field reconnaissance) and loose unconsolidated sediment was present along the channel bed within the pools and near the channel banks. For this analysis, an empirical relation proposed by Komar (1987) was used, as it was developed for gravel bed streams and deemed appropriate for this watercourse. The medium grain size (D50) was used for the entrainment analysis. The hydraulic conditions at which entrainment would theoretically occur for channel reach is presented in **Table 7**.

Table 7. Results of Erosion Threshold Analysis for Bed Materials

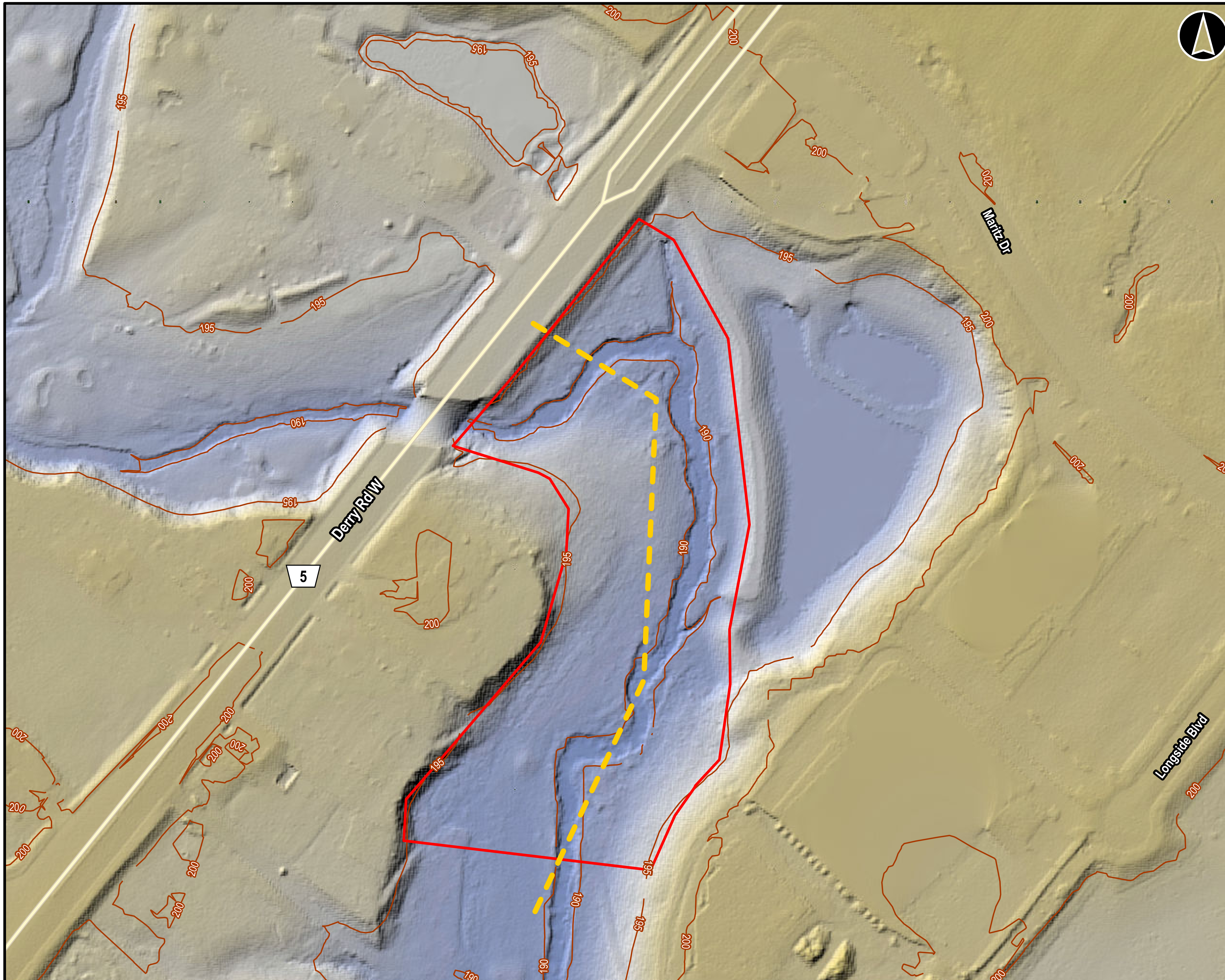
Parameter	Reach FLE_CRK_01					
	XS-1	XS-2	XS-3	XS-4	XS-5	Average
Critical Discharge (m^3/s)	0.87	0.44	1.84	1.41	1.59	1.23
Critical/ Bankfull Discharge	10.63	3.68	14.10	11.30	13.61	0.11
Critical Maximum Depth (m)	0.42	0.28	0.48	0.50	0.50	0.44
Critical Average Depth (m)	0.30	0.17	0.13	0.31	0.32	0.25
Critical Maximum Velocity (m/s)	0.63	0.46	0.69	0.71	0.71	0.64
Critical Average Velocity (m/s)	0.46	0.29	0.21	0.47	0.48	0.38
Model used in calculation	(Komar, 1987)					
Model Equation	$\tau_c = 0.045(\rho_s - \rho)gD_{84}{}^{0.6}D^{0.4}$					

7. Meander Belt Width Assessment

Delineation procedures and definitions of the meander belt width are presented in the main report to which this memo is addended to. For more details refer to AECOM, 2022. Analysis of a LiDAR derived digital terrain model indicated that the watercourse is confined within a large valley. During the site visit it was confirmed that at no point the reach is in immediate contact with any of the valley walls or within 15 m of the valley toe, with the exception of the crossing under Derry Road West.

7.1 Preliminary Meander Belt Width

A preliminary meander belt was calculated for the Reach FLE_CRK_01 using the TRCA 2004 Meander Belt Procedures mapping approach. The preliminary meander belt was calculated at approximately 130 m and is presented in **Figure 4**, below.



Aerial imagery provided by: Town of Oakville, Maxar, Microsoft, Province of Ontario, Esri Canada, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, NRCan, Parks Canada

LIO Topographic Map: MECP

Map Extents

Legend

- Preliminary Meander Belt Width
- Belt Axis
- Contour (5m interval)

General Features

- District, County, or Regional Road

Peel Region Snow Storage Sites - 7120 Hurontario

Preliminary Meander Belt Width

0 25 50 100 150 M

NAD 1983 CSRS UTM Zone 17N

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AECOM

Figure 4

7.2 100-year Erosion Rate

Using the historical imagery from 1996 and 2022 (26-year span), the 100-year erosion rate was calculated for the receiving watercourse. The calculation of the erosion followed the recommendations on provided in the CVC Fluvial Geomorphic Guidelines (2015), TRCA Belt Delineation Procedures (2004), and the TRCA Crossing Guidelines (2015).

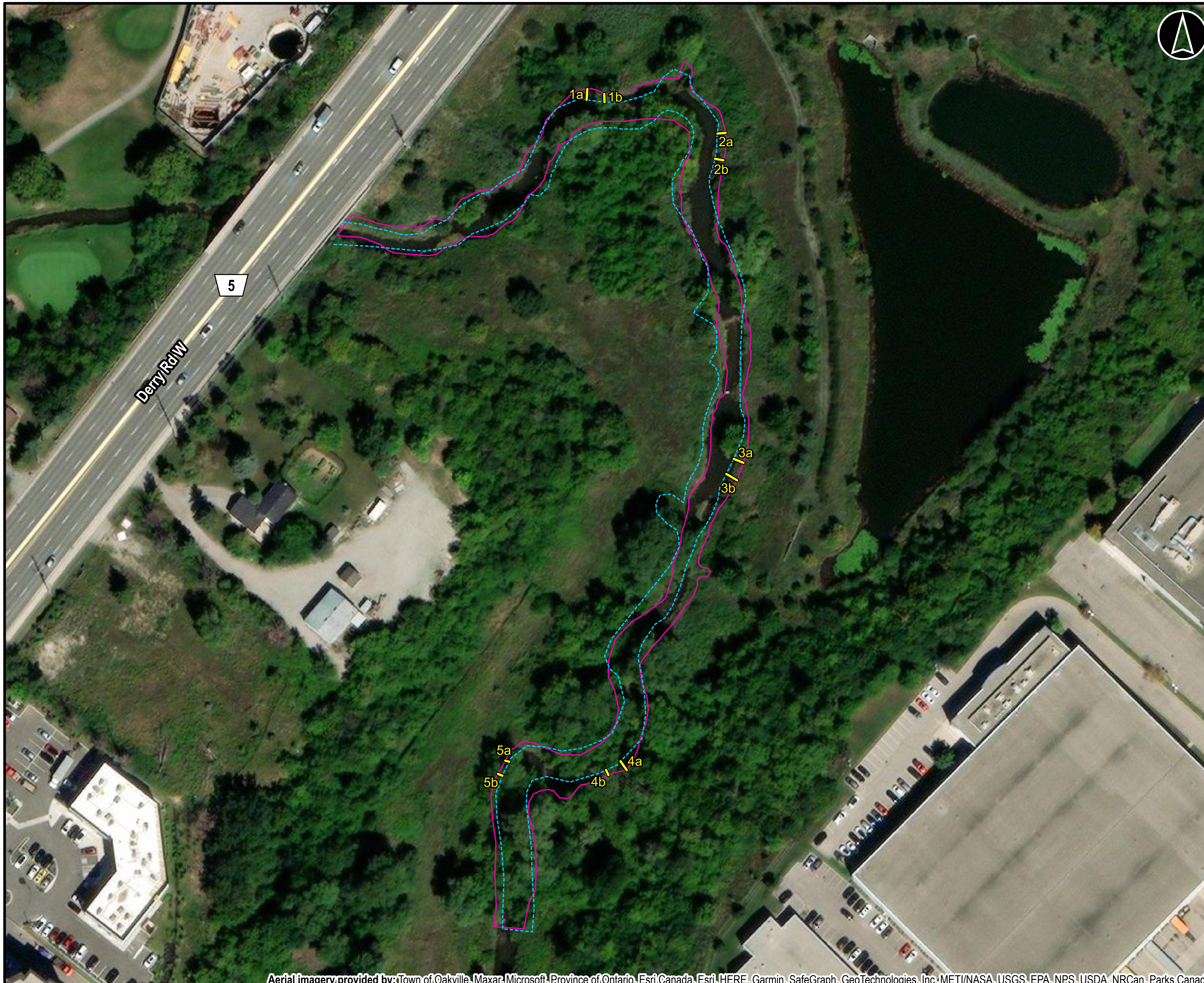
The erosion measurements were collected in five (5) locations along the investigated reach. The results and the location of the measurements are presented in **Table 8 and Figure 5**, respectively. It should be noted that even though the historical imagery analysis was completed as far back as 1974, the resolution of the older imagery did not allow for a reliable delineation of the historical bank positions therefore the years used to calculate the 100-year erosion rate were 1996 and 2022.

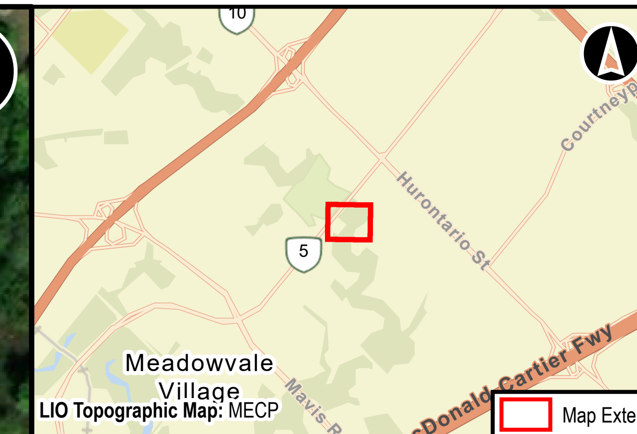
Table 8. 100-Year Erosion Rate Calculation

Measurement Location	Measurement (m)	Historical Year	Most Recent Year	Total Years	Erosion Rate (m/year)	100-Year Erosion Rate (m/100years)
1a	3.53	1996	2022	26	0.14	13.58
1b	2.62	1996	2022	26	0.10	10.08
2a	2.72	1996	2022	26	0.10	10.46
2b	2.76	1996	2022	26	0.11	10.62
3a	3.38	1996	2022	26	0.13	13.00
3b	4.03	1996	2022	26	0.16	15.50
4a	3.47	1996	2022	26	0.13	13.35
4b	1.8	1996	2022	26	0.07	6.92
5a	1.33	1996	2022	26	0.05	5.12
5b	1.55	1996	2022	26	0.06	5.96
					Average 100-year Rate=	10.46

Based on historical imagery the 100-year erosion rate for reach FLE_CRK_01 is approximately 10.46 m. This erosion rate is higher than expected considering the minimal erosion observed in the field during the assessment. The dense riparian vegetation in the aerial photos on either side of the channel (refer to Section 4.1 for a description of the riparian vegetation) made it challenging to properly delineate the channel banks in some sections for the 2022 and 1996 aerial photographs.

An alternative way to determine the erosion rate is to use Table 3 in the Technical Guide for River and Stream Systems: Erosion Hazard Limit (Ontario Ministry of Natural Resources, 2002) which identifies that for stiff/ hard cohesive soil (clays, clay silt), and coarse granular (gravel) tills the expected erosion rate should range from 5 – 8 m where there is evidence of active erosion. For the purposes of interpreting the table, active erosion includes areas where bank material is exposed directly to flow as evidenced by bank undercutting, oversteepening, or slumping (Ontario Ministry of Natural Resources, 2002). This indicates that a 100-year erosion rate of 10.46 m is higher than it should be for the reach.





Legend

Bank Position

- Year 2022
- Year 1996
- Erosion Measurement Location

General Features

- District, County, or Regional Road

Peel Region Snow Storage Sites - 7120 Hurontario

100-Year Erosion Rate

0 10 20 40 60 80 M

NAD 1983 CSRS UTM Zone 17N

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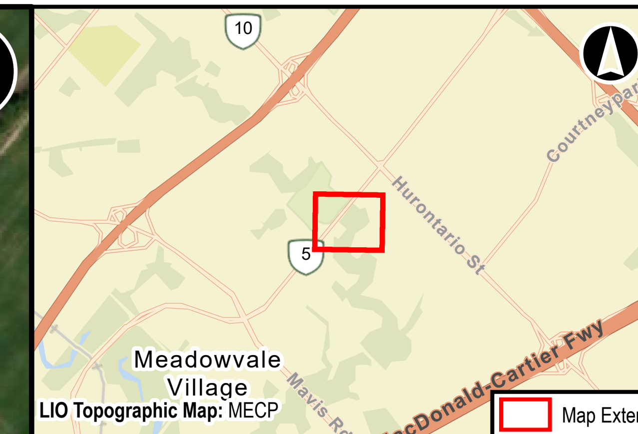
Figure 5

7.3 Final Meander Belt Width

Given that the meander belt width for confined systems is defined by the distance between the valley walls confining the watercourse, the belt boundary is placed at an average distance between the top and bottom of the valley walls along both sides of the watercourse (TRCA, 2004). A maximum width of 130 m was selected as the Final Meander Belt Width (as measured in **Section 7.1**, above). It follows then, that for confined systems the final meander belt width equates the preliminary meander belt width:

$$Final\ MBW = Preliminary\ MBW\ Limited\ by\ Confining\ Wall$$

Furthermore, since lateral migration of watercourses within confined systems is limited by the valley walls, the calculated erosion rates (10.5 m/100-year) within the valley were not added to the meander belt. The final meander belt width has been provided in **Figure 6**.



Legend

- Final Meander Belt Width
- Belt Axis
- Contour (5m interval)

General Features

- District, County, or Regional Road

Peel Region Snow Storage Sites - 7120 Hurontario

Final Meander Belt Width

0 25 50 100 150 M

NAD 1983 CSRS UTM Zone 17N

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Figure 6

Project Location: D:\Projects\60646784-SnowStorage\WORKING\Design\01_Reports\7120 HURONTARIO\60646784_SnowStorage_Historical\60646784_SnowStorage_Historical.aprx **Layout:** FLUV4 - Final Meander Belth Width
Date Saved: 9/19/2023 2:32 PM **User:** MarincS

8. Summary and Conclusions

As part of the proposed snow storage sites, a fluvial geomorphological assessment and meander belt width determination were completed for the study site located at 7120 Hurontario Street, Mississauga, northwest of Derry Road.

8.1 Key Findings

Based on the fluvial geomorphological data collected the following key findings and conclusions were made:

- The receiving watercourse is confined within a valley.
- An offline stormwater pond is present east of the reach and a drainage tributary which appears to convey surface runoff from Derry Road outlets into the channel from the east bank by the most upstream outer meander of the reach.
- There is an outlet pipe present along the left (east) bank ~ 50 m upstream of where the tributary outlets (just upstream of the most upstream outer meander).
- Dense riparian vegetation surrounds the channel which strengthens the channel banks and limits the erosion potential.
- The final meander belt was calculated at approximately 130 m using the mapping approach, and its extent is limited by the confining valley walls.
- The erosion rate was calculated at approximately 10.5 m per 100-year, although this rate is likely higher than the actual erosion due to the lack of erosion observed in the field and the difficulty tracing the bankfull limits in air photos due to dense riparian vegetation. The calculation was completed for a 26-year period (1996 to 2002) due to poor resolution on older air photos.
- Based on the results of the site visit and the RGA, the investigated reach was found to be “In Regime”, with no significant evidence of instability.
- The reach has an average bankfull width of 11.7 and an average bankfull depth of 0.8 m.
- The channel bed gradient was shallow and measured 0.002 m/s for the surveyed portion of the reach.
- The bankfull height ranged from 0.8 to 1.2 m, and banks had an average slope of approximately 34 degrees (moderate gradient).
- The calculated critical discharge for the bed material entrainment at Fletchers Creek, on average, is 1.23 m^3/s. This critical discharge value is less than 1/3 of the calculated bankfull discharge of 11.7 m^3/s.
- Visual assessment of sediment in suspension was identified at the site during field reconnaissance.

8.2 Recommendations

Based on the results of the fluvial geomorphic assessment, the following recommendations are made.

- Increases in flow to the watercourses from the snow melt should consider the erosion threshold conditions for the site along Hurontario Street. The erosion threshold provides targets for the drainage network. Increases in flow have the potential to result in channel instability and lead to morphological adjustment. Aggradation of fine sediment was found along the bed of Fletchers Creek and that increases in flow will help to alleviate this but may also lead to increased erosion rates. It is recommended that care is taken to maintain vegetation cover along and within the watercourses in order to maintain the existing channel stability.

- The meander belt refers to the lateral extent of floodplain occupation by a meandering watercourse both now and into the future. Protecting the meander belt area from encroachment serves the dual purposes of enabling a continuity of natural channel processes and of protecting property and structures from erosion. To prevent, eliminate or minimize the risks to life and property caused by erosion hazards, it is recommended to maintain the meander belt boundary.

Special consideration should be given to the stormwater pond in the floodplain adjacent to the channel (east of the channel). The stormwater pond conveys surface runoff from Derry Road and discharges runoff into the channel by the most upstream meander of the reach. Use of the existing storm pond for snow melt could be further assessed.

9. References

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Appendix A Historic Aerial Imagery


1996
L39/73
25-5-96 ASC96089 39 73


1985
35/061
ASC-85-004
35 061


E
2/45
2-T-74-150-45

Appendix B Photographic Log

Site 1 – 7120 Hurontario

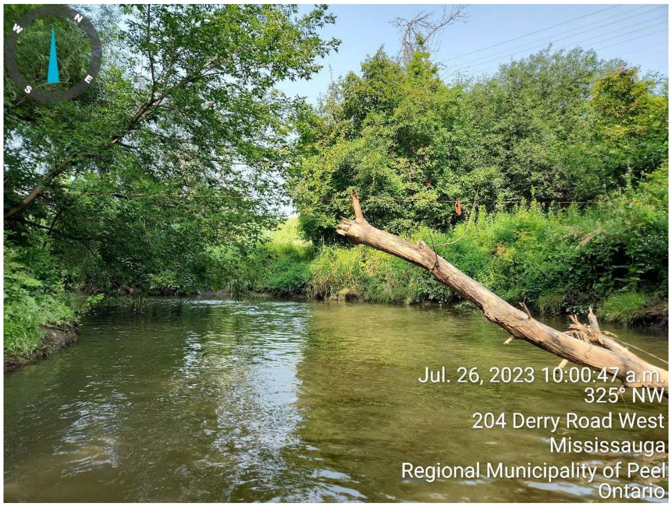
Photograph 1.
Looking upstream at **cross section 1**. Densely vegetated banks through riffle with boulders.

Photograph 2.
Looking downstream at **cross section 1**. Densely vegetated banks through riffle with boulders.

Site 1 – 7120 Hurontario

Photograph 3.
Left bank at **cross section 1**.

Photograph 4.
Right bank at **cross section 1**..



Photograph 5.
Looking upstream at **cross section 2**. Densely vegetated banks through pool.

Photograph 6.
Looking downstream at **cross section 2**. Densely vegetated banks through pool with in-stream woody debris.

Site 1 – 7120 Hurontario

Photograph 7.
Left bank at **cross section 2**.

Photograph 8.
Right bank at **cross section 2**.

Photograph 9.
Looking upstream at **cross section 3**. Densely vegetated banks through riffle.

Photograph 10.
Looking downstream at **cross section 3**. Densely vegetated banks through riffle.

Site 1 – 7120 Hurontario

Photograph 11.
Left bank at **cross section 3**.

Photograph 12.
Right bank at **cross section 3**.

Photograph 13. ↑
Looking upstream at **cross section 4.** Densely vegetated banks through pool.

Photograph 14. ↑
Looking downstream at **cross section 4.** Densely vegetated banks through pool. Piece of concrete diverting flow in channel.

Site 1 – 7120 Hurontario

Photograph 15. ↑
Left bank at **cross section 4**.

Photograph 16. ↑
Right bank at **cross section 4**.

Photograph 17.
Looking upstream at **cross section 5.** Vegetated Island (possible collapsed bank) in channel through riffle.

Photograph 18.
Looking downstream at **cross section 5.** Collapsed bank in channel through riffle.

Site 1 – 7120 Hurontario

Photograph 19.
Left bank at **cross section 5**.

Photograph 20.
Right bank at **cross section 5**.