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Appendix E

Fluvial Geomorphology Assessment Report

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Fluvial Geomorphic Assessment Report

Peel Region

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January 2026

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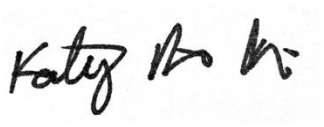
Authors

Report Prepared By:

Meghan Sauro

Megan Elliott

Report Checked By:



Kathy Robitaille-Feick



Report Verified By:



Rhonneke Van Riezen



Revision History

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1	2026-01-30	Meghan Sauro	Updated to append ESR

Distribution List

# Hard Copies	PDF Required	Association / Company Name
	✓	Regional Municipality of Peel
	✓	AECOM Canada ULC

Executive Summary

AECOM Canada ULC (AECOM) was retained by the Regional Municipality of Peel (Peel Region) to conduct a Fluvial Geomorphology Assessment ahead of the proposed Kennedy Road Sanitary Trunk Sewer (STS) Project as part of the "FLOW Central Brampton" infrastructure delivery program, in the Town of Caledon and the City of Brampton, Ontario. The Study Area is located within part of the geographic Townships of Chinguacousy and Toronto, County of Peel, now the Regional Municipality of Peel. The Region of Peel (Peel Region) City of Brampton central wastewater system consists of two separate gravity sanitary trunk sewer systems, West Trunk System (Fletchers Creek Sanitary Trunk Sewer) and the East Trunk System (Etobicoke Creek Sanitary Trunk Sewer), which ultimately send flow to the Clarkson Water Resource Recovery Facility and G. E. Booth Water Resource Recovery Facility, respectively.

Bill 23, the “More Homes Built Faster Act”, by Ontario supports the province’s Housing Supply Action Plan. The plan aims to build more homes for Ontario families. With Bill 23, Peel Region’s water and wastewater infrastructure needs are drastically accelerated. Housing targets for 2051 need to be met almost 20 years sooner. That means more than 245,000 residential units in Peel Region; of which 113,000 are in Brampton and 13,000 are in Caledon. To address near term water and wastewater infrastructure requirements in the Central Brampton area, the Region has initiated an accelerated water and wastewater infrastructure delivery program (officially referred to as "FLOW Central Brampton").

To meet the Provincial housing targets for Brampton and Caledon and to address the need for increased wastewater capacity by 2030, the Region has launched the Kennedy Road Sanitary Trunk Sewer Municipal Class Environmental Assessment study. The Kennedy Road Sanitary Trunk Sewer Project is a critical wastewater project as part of the overall "FLOW Central Brampton" infrastructure delivery program. Following the 2023-amended Schedule C process set by the Municipal Engineers Association, this study will develop recommendations to ensure reliable sanitary services for existing and future growth while building flexibility for long-term wastewater management and conveyance capacity expansion. The Environmental Assessment (EA) study will include comprehensive public and stakeholder consultations, an evaluation of alternatives, and impact mitigation measures, ensuring a transparent, reproducible decision-making process.

The fluvial geomorphic investigation is part of the baseline natural features assessment in support of the EA to understand the existing conditions of the watercourses in the vicinity of the recommended preferred trunk sewer route. The main objective of this assessment is to determine existing and future fluvial hazards including vertical and lateral scour as well as erosion thresholds for watercourses crossed in the Study Area.

The results of the fluvial geomorphic study will provide input to the design process so that fluvial hazards within the Study Area are minimized. The Study Area for the fluvial geomorphic assessment is extends 20 m on either side of the preferred route, which measures approximately 18.5 km in length.

Based on the results of the assessments completed, the following recommendations can be made for the preferred route to limit adverse impacts to channel morphology and risk to the proposed trunk sewers:

1. Recommended burial depth (see Table 8-8) should consider proximity to existing undersized crossing structures (see Section 3.2). Undersized structures constrain flow which can cause additional localized bed erosion. As such, the recommended burial depth in some cases may be an underestimate.
2. Burial depth considerations should extend laterally past the active channel and ideally should extend to the limit of the Final Meander Belt (see Table 6-8), or at a minimum, the limits of the 100-year erosion rate on either side of the active channel (Table 6-6) to achieve long-term stability.
3. The erosion threshold assessment (see Section 7.1) suggests the bed material is stable for both WC-04 and WC-08 at bankfull flows. This provides confidence in the recommended burial depth. Before detailed design, it is recommended that field surveys and erosion threshold assessments be considered for any watercourses classified as main channels that were not accessible due to PTE constraints. These assessments should consider factors such as the reach's energy gradient, bank dimensions, bed substrate and bank composition.
4. It is recommended that additional hydraulic modelling be conducted to confirm the velocities and shear stresses for larger flow events (e.g., 50-year and 100-year flows). Modelling would enable calculation of the estimated scour depths using the Detailed Method, for the projected lifespan of the buried infrastructure which would inform and help refine the recommended burial depths (see Table 8-8).
5. It is well established that large woody debris (LWD) can increase scour depths (Abbe & Montgomery, 1996; Webb & Erskine, 2005; Pagliara & Carnacina, 2011). An ongoing maintenance plan should be developed by a qualified professional to monitor and address LWD, as this debris can cause additional scour beyond the recommended burial depths.

It is recommended that a fluvial geomorphologist be directly involved in the subsequent detailed design of the new proposed trunk sewers to specifically address the observed geomorphological issues with the watercourses along the recommended preferred route and to provide further input on channel realignments.

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1. Introduction

The current sanitary trunk sewers in the City of Brampton (Brampton) lack sufficient capacity to meet projected demands. Peel Region must increase sewer capacity by 2030 to support planned development in central Brampton and parts of the Town of Caledon (Caledon). To address this, Peel Region is planning to build a new large sanitary trunk sewer, to move wastewater, by gravity, to future and existing trunk sewer systems to increase conveyance capacity in central Brampton and southern Caledon.

This lack of capacity to meet projected demands is based on Bill 23, the "More Home Built Faster Act", requiring the Region of Peel to upgrade their water and wastewater infrastructure. Bill 23 impacts the Region's water and wastewater infrastructure by:

- Accelerating housing targets from the planned timeline of 2051 to 2031.
- The provincial target is to build more than 245,000 residential units in local municipalities; of which 113,000 in Brampton and 13,000 in Caledon apply.

To address the accelerated demand requirements, a Kennedy Road Sanitary Trunk Sewer (STS) is proposed, approximately 19 km long sewer, 1500–2100 mm in diameter, running from Old School Road and Hurontario Street (Caledon) to the future Etobicoke Creek Sanitary Trunk Sewer at Kennedy Road South (Brampton). A 1200 mm Queen Street STS from Rutherford Road North to this proposed Kennedy Road STS is also included in the project scope.

To meet the Provincial housing targets for Brampton and Caledon and address the need for increased wastewater capacity by 2030, the Region has launched the Kennedy Road Sanitary Trunk Sewer Municipal Class Environmental Assessment study. The Kennedy Road Sanitary Trunk Sewer Project is a critical wastewater project as part of the overall "FLOW Central Brampton" infrastructure delivery program. Following the 2024-amended Schedule C process set by the Municipal Engineers Association, this study will develop recommendations to ensure reliable sanitary services for existing and future growth while building flexibility for long-term wastewater management and conveyance capacity expansion. The Environmental Assessment (EA) study will include comprehensive public and stakeholder consultations, an evaluation of alternatives, and impact mitigation measures, ensuring a transparent, reproducible decision-making process.

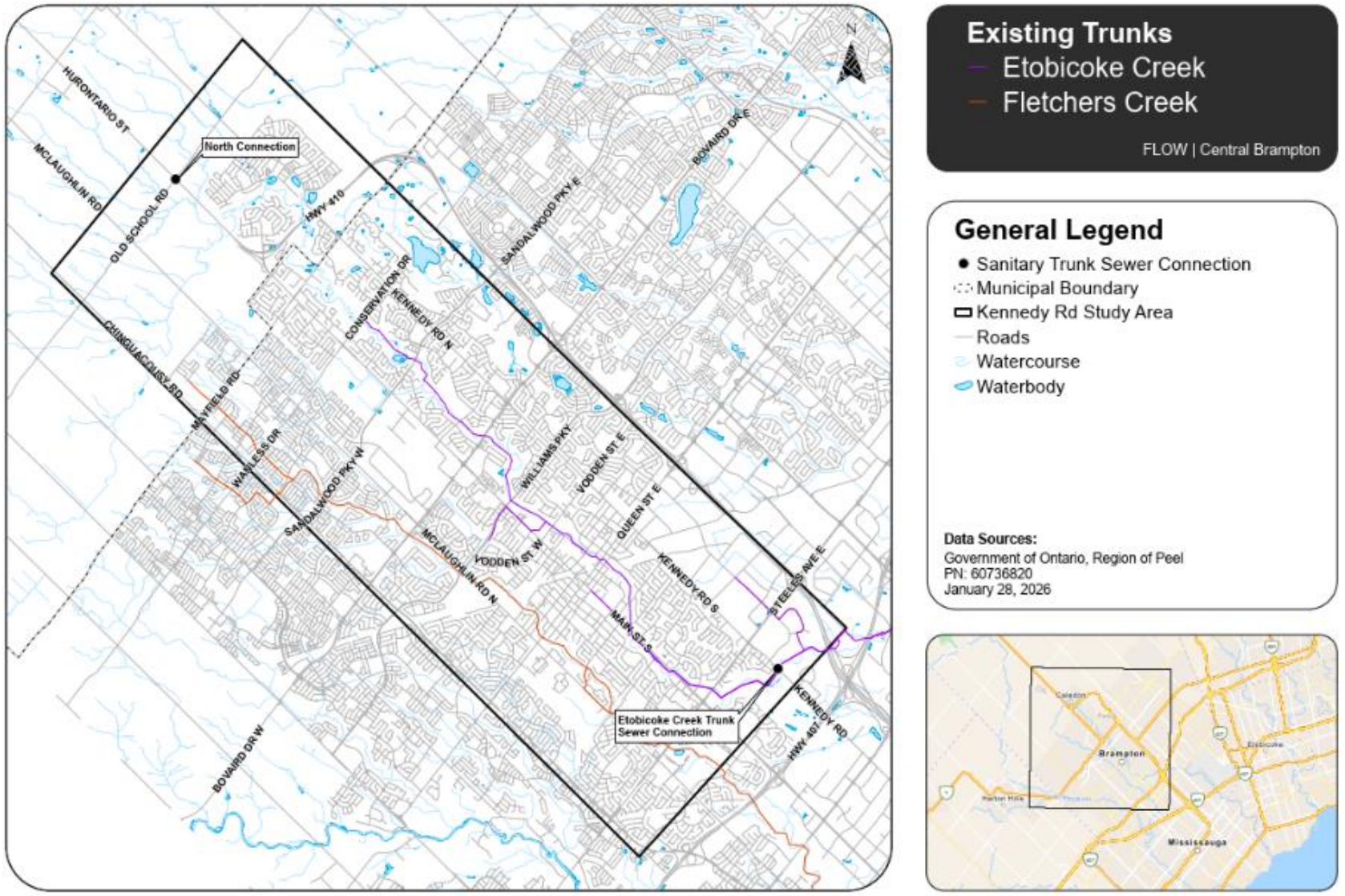
The fluvial geomorphic investigation is part of the baseline natural features assessment in support of the EA to understand the existing conditions of the watercourses in the vicinity of the recommended preferred trunk sewer route to determine existing and future fluvial hazards including vertical and lateral scour as well as erosion thresholds in the case that the resultant design increases the flow to receiving watercourses in the Study Area. The results of the fluvial geomorphic study will provide input to the design

process to ensure fluvial hazards within the Study Area are minimized, and the natural environment is maintained.

1.1 Study Area

The General Study Area is primarily located in the central part of the City of Brampton, with the northern limits extending in the Town of Caledon, all within Peel Region. The proposed Kennedy Road Sanitary Trunk Sewer is to extend approximately 19km from the future Etobicoke Creek Trunk Sewer Connection on Kennedy Road (City of Brampton) to the North Connection at the intersection of Hurontario Street and Old School Road (Town of Caledon). The Study Area limits for the Kennedy Road STS connection points are shown in **Figure 1-1**. The General Study Area is bound by Old School Road in the north, and just south of Steeles Avenue in the south. Highway 410 forms the easterly border and Chinguacousy Road forms the westerly border of the Study Area. In addition, a Local Study Area was defined as 120 metres of adjacent lands around the entire length of each alternative sanitary trunk sewer route to allow for better understanding of potential impacts from construction.

Figure 1-1: Study Area



1.2 Aims and Objectives

The main objective of the fluvial geomorphic assessment is to characterize fluvial geomorphological processes and define erosion hazards for the fourteen (14) watercourses identified within the Study Area to provide recommendations for the recommended preferred route to limit adverse changes to channel morphology and risk to the proposed trunk sewers. This report aims to define the overall bed scour risk due to geomorphological conditions, watercourse stability, and issues from existing infrastructure like watercourse crossings to inform the future stability of watercourses that cross the recommended preferred route to inform appropriate trunk sewer burial depths.

The report includes a desk-based assessment which outlines all relevant background studies, and a review of historical aerial imagery to define channel migration patterns. It also includes the results of the field assessment, which was completed to characterize each fluvial geomorphic reach. The field assessment portion of this report includes a full comprehensive description of each reach, an assessment of the overall stability of each reach performed through a Rapid Geomorphic Assessment (RGA), and a photographic record of key features. A detailed field survey was also completed for the two watercourses that were publicly accessible. This included the collection of multiple cross-sections and a longitudinal profile.

Based on the results of the desktop and field reconnaissance, 100-year erosion rates and meander belt widths were delineated for all defined watercourses that cross the recommended preferred route. For the two watercourses that were publicly accessible, an erosion threshold assessment was also performed to inform future erosion risk. Additionally, a bed scour assessment was performed for all 14 features to determine appropriate trunk sewer burial depths.

2. Desktop Background Assessment

A desk-based background review was conducted to better understand the watercourses that cross the proposed Study Area.

2.1 Watercourse Crossings

Fourteen (14) watercourse crossings were identified along the recommended preferred route. The crossing IDs and their respective crossing locations are outlined in Table 2-1.

Table 2-1: Watercourse Crossings

Conservation Authority	Crossing ID	Crossing Co-ordinates (UTM Zone 17T)
TRCA	WC-35	592231.00 m E 4844863.00 m N
TRCA	WC-34	591997.00 m E 4844548.00 m N
TRCA	WC-33	591803.00 m E 4844291.00 m N
TRCA	WC-13	591932.00 m E 4844077.00 m N
TRCA	WC-12	592693.00 m E 4843333.00 m N
TRCA	WC-04	599347.00 m E 4838745.00 m N
TRCA	WC-02	601933.00 m E 4837692.00 m N
CVC	WC-10	594621.00 m E 4841975.00 m N
CVC	WC-08	596724.00 m E 4838612.00 m N
CVC	WC-07	597345.02 m E 4839291.82 m N
CVC	WC-06	597542.97 m E 4839141.79 m N
CVC	WC-06a	597410.67 m E 4839266.70 m N
CVC	WC-05	598162.22 m E 4838516.08 m N
CVC	WC-05a	597861.94 m E 4838808.10 m N

2.2 Reach Delineation

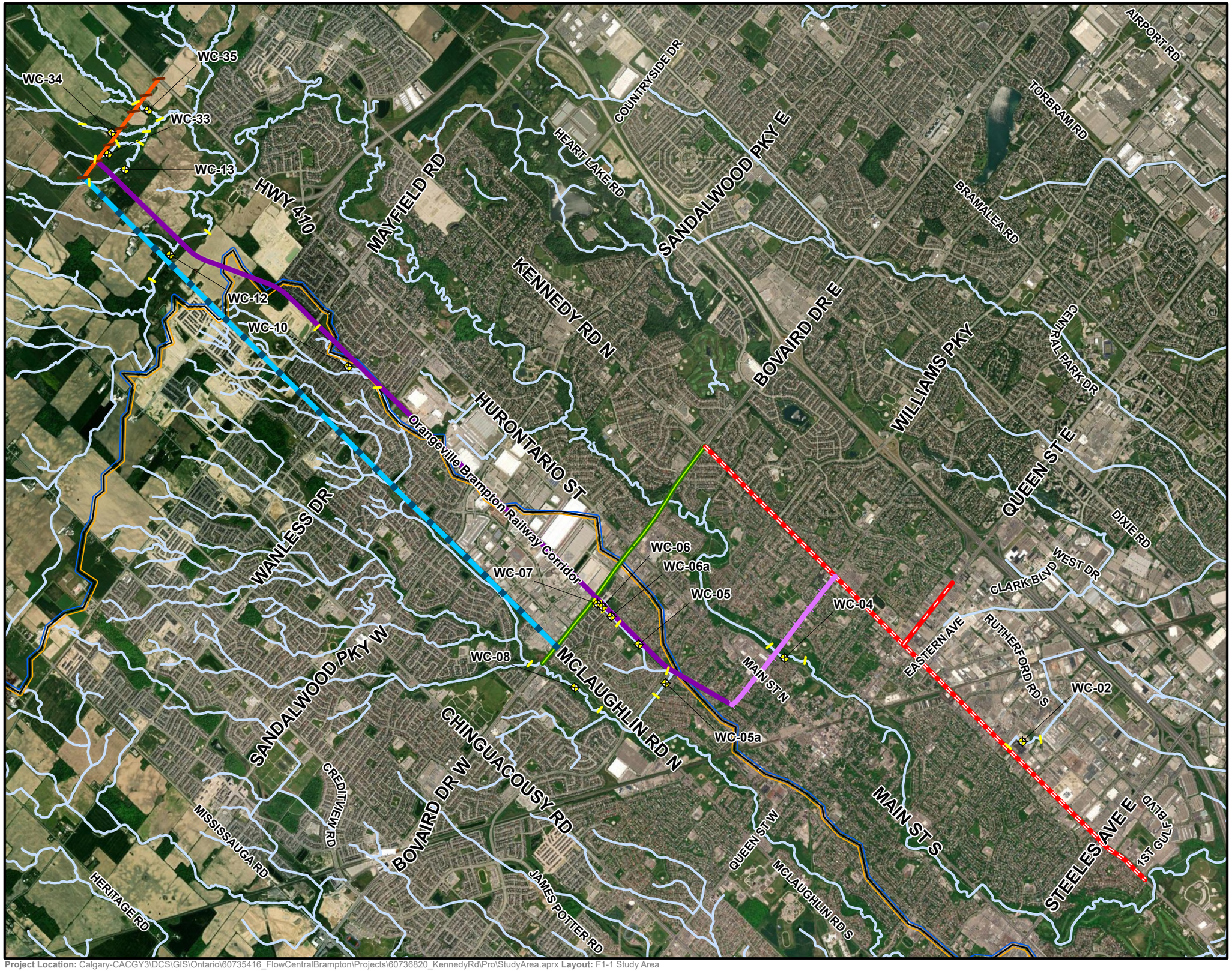
A reach is a section of watercourse that exhibits similar physical characteristics and has a setting that remains nearly constant along its length. Reaches are relatively homogenous in channel form, function, and process. They are influenced by similar controlling (e.g., discharge and slope) and modifying (e.g., vegetation and anthropogenic) factors to which the channel has become adjusted, or will become adjusted to, in the future. Changes to the land around the watercourse may affect the characteristics that define a reach which could change the behaviour of the watercourse.

Reach breaks within the Study Area were first delineated through a desktop assessment of tributary locations, channel gradient, geology, valley setting, sinuosity, and riparian vegetation using Geographic Information System (GIS) layers. The reaches were subsequently confirmed in the field as much as permission to enter limitations allowed. The reach breaks and their justification are presented in Table 2-2. A map showing the reach breaks is presented in Figure 2-1 to Figure 2-3.

Table 2-2: Reach Delineation

Conservation Authority	Watershed	Watercourse Name	Watercourse Crossing	Fluvial Geomorphic Reach ID	Limit	Co-ordinates (UTM Zone 17T)	Justification
TRCA	Etobicoke Creek	Etobicoke Creek (Headwaters)	WC-35	WC-35	Upstream	592072.22 m E 4844908.49 m N	■ Confluence ■ Change in planform (less of a meandering profile downstream)
					Downstream	592466.22 m E 4844698.03 m N	■ Confluence ■ Change in planform (more of a meandering profile downstream)
TRCA	Etobicoke Creek	Etobicoke Creek (Headwaters)	WC-34	WC-34	Upstream	591601.81 m E 4844644.38 m N	■ Change in vegetation from wooded meadow to dense forest ■ Change in planform from straight to a meandering channel
					Downstream	592314.83 m E 4844562.05 m N	■ Confluence
TRCA	Etobicoke Creek	Etobicoke Creek (Headwaters)	WC-33	WC-33	Upstream	591745.16 m E 4844253.52 m N	■ Change in riparian vegetation from agricultural land to grassy corridor ■ Marks the start of where channel has been realigned to accommodate road
					Downstream	592004.56 m E 4844414.75 m N	■ Change in vegetation from grass to dense forest cover ■ Change in surficial geology from clay to silt till to modern alluvial deposits of clay, silt, sand, and gravel ■ Change in planform from straight to sinuous channel
TRCA	Etobicoke Creek	Etobicoke Creek (Headwaters)	WC-13	WC-13	Upstream	591680.31 m E 4843993.03 m N	■ Reach begins at a pond feature
					Downstream	592249.02 m E 4844435.09 m N	■ Confluence
TRCA	Etobicoke Creek	Etobicoke Creek (Headwaters)	WC-12	WC-12	Upstream	592377.55 m E 4842899.99 m N	■ Change in planform from sinuous to straightened
					Downstream	592798.47 m E 4843393.72 m N	■ Change in planform from straightened feature to a meandering channel ■ Change in riparian vegetation from wetland to forested area ■ Change in channel width (watercourse becomes wider downstream of reach break)
TRCA	Etobicoke Creek	Etobicoke Creek West Branch	WC-04	WC-04	Upstream	599275.17 m E 4838814.84 m N	■ Change in planform from a straight watercourse to a more meandering feature
					Downstream	599667.61 m E 4838654.15 m N	■ Change in surficial geology to shale bedrock (updated based on field observations)
TRCA	Etobicoke Creek	Etobicoke Creek	WC-02	WC-02	Upstream	601932.44 m E 4837688.84 m N	■ Approximate, start of headwater feature; marked by a depressed area immediately downstream of Kennedy Road South. Feature appears to be piped at this location
					Downstream	602041.88 m E 4837809.66 m N	■ Approximate, end of depressed area before paved area. Due to lack of PTE, it cannot be confirmed if the feature daylights between selected upstream and downstream reach breaks.
CVC	Fletchers Creek	Engineered Watercourse	WC-11	WC-10	Upstream	594223.38 m E 4842371.27 m N	■ Confluence between sinuous headwater features ■ Upper reach break marks where the watercourse begins to occupy a constructed drainage ditch
CVC	Fletchers Creek	Engineered Watercourse	WC-10				
CVC	Fletchers Creek	Engineered Watercourse	WC-09		Downstream	594911.40 m E 4841698.64 m N	■ Lower reach break marks where the watercourse discharges into a ponded area
CVC	Fletchers Creek	Fletchers Creek	WC-08	WC-08	Upstream	596593.56 m E 4838610.17 m N	■ Confluence
					Downstream	597381.13 m E 4838096.29 m N	■ Confluence
CVC	Fletchers Creek	Engineered Watercourse	WC-07	WC-07	Upstream	597311.97 m E 4839293.52 m N	■ Start of a defined channel. Flow likely piped north of this

Conservation Authority	Watershed	Watercourse Name	Watercourse Crossing	Fluvial Geomorphic Reach ID	Limit	Co-ordinates (UTM Zone 17T)	Justification
					Downstream	597393.11 m E 4839280.99 m N	■ Confluence – flow contributions from outfall
CVC	Fletchers Creek	Engineered Watercourse	WC-06	WC-06a	Upstream	597395.44 m E 4839279.95 m N	■ Confluence – flow contributions from outfall
					Downstream	597433.23 m E 4839248.72 m N	■ Change in vegetation from meadowlands to forested area
				WC-06	Upstream	597434.12 m E 4839248.38 m N	■ Change in vegetation from meadowlands to forested area
					Downstream	597624.66 m E 597624.66 m E	■ Start of impounded water due to beaver activity
CVC	Fletchers Creek	Engineered Watercourse	WC-05	WC-05a	Upstream	597635.73 m E 4839052.96 m N	■ Start of impounded water due to beaver activity
					Downstream	598122.34 m E 4838547.02 m N	■ Start of concrete lining
				WC-05	Upstream	598128.89 m E 4838543.57 m N	■ Start of concrete lining
					Downstream	598004.50 m E 4838262.94 m N	■ Narrowing of watercourse and end of concrete lining





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Conservation Authority Boundaries

- Toronto and Region Conservation Authority
- Credit Valley Conservation

Roads

Flow | Central Brampton

Kennedy Rd | Study Area

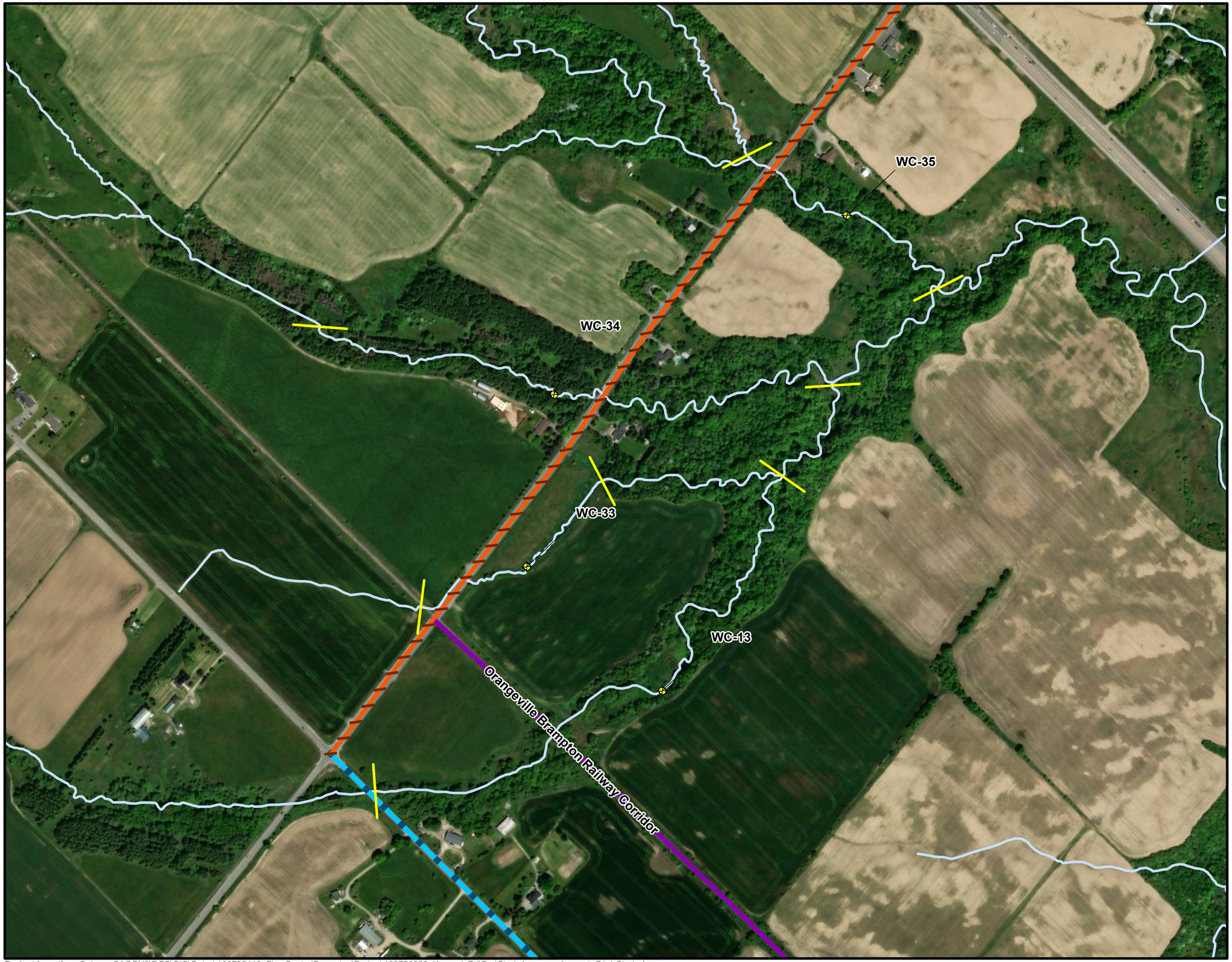
0 490 980 1,470 1,960

Meters
Scale: 1:40,000

N

PN: 60736820	Figure 2-1
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Conservation Authority Boundaries

- Toronto and Region Conservation Authority
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Roads

Flow | Central Brampton

Kennedy Rd | Study Area

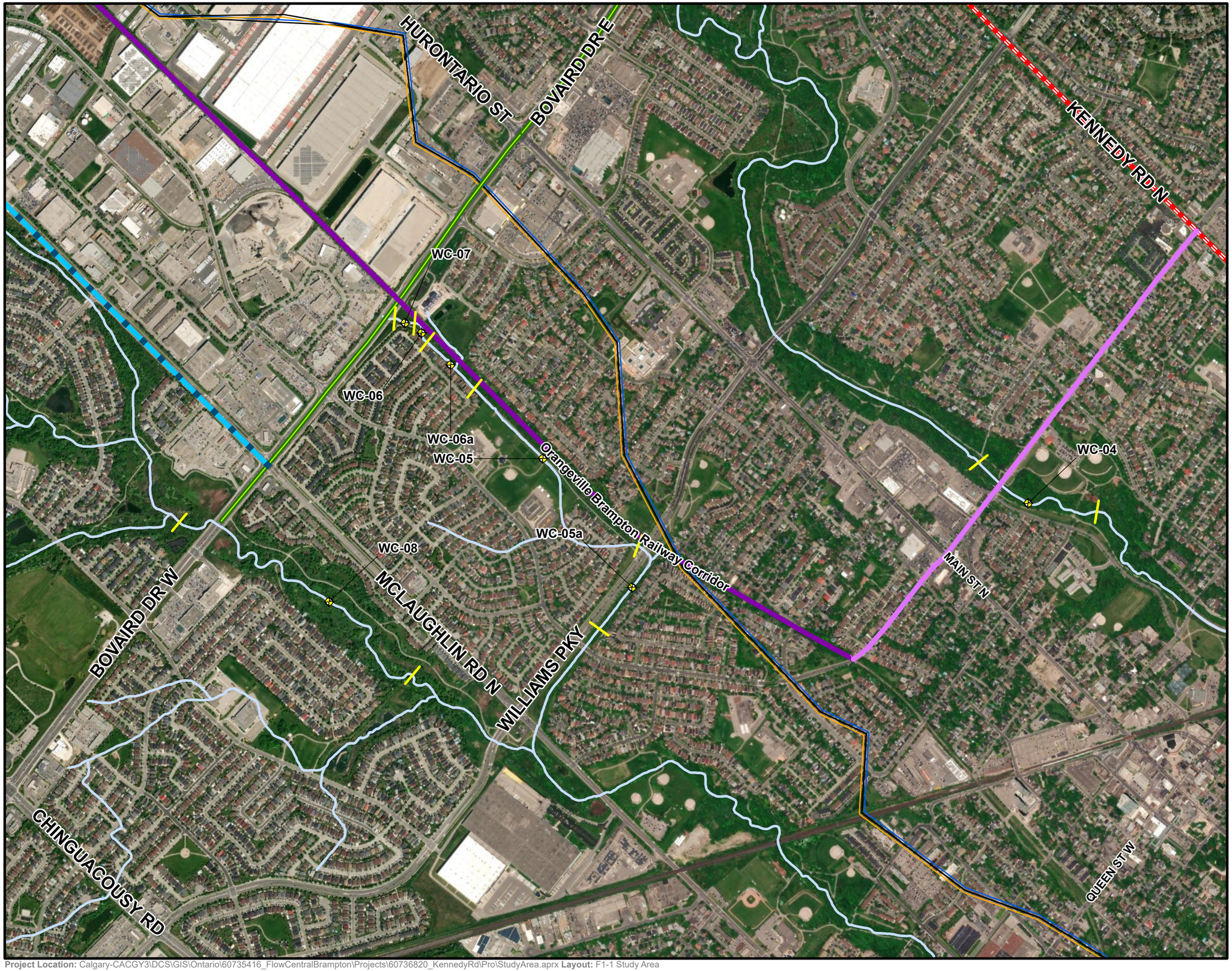
0 40 80 120 160 200 240

Meters
Scale: 1:5,000

N

PN: 60736820	Figure 2-2
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Conservation Authority Boundaries

- Toronto and Region Conservation Authority
- Credit Valley Conservation
- Roads

Flow | Central Brampton

Kennedy Rd | Study Area

0 100 200 300 400 500 600

Meters
Scale: 1:12,000

N

PN: 60736820	Figure 2-3
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

2.3 Watershed Characteristics

2.3.1 Conservation Authority

The Study Area falls at the boundary between the Toronto and Region Conservation Authority (TRCA) and the Credit Valley Conservation Authority (CVC). Conservation Authority boundaries are delineated based on watershed boundaries. Therefore, watershed characteristics for each conservation authority area are described separately.

2.3.1.1 Toronto and Region Conservation Authority

The Study Area is located at the western boundary of the Etobicoke Creek watershed, which is regulated by the TRCA. The Etobicoke Creek watershed is 21,100 ha (TRCA, 2021). The watershed is highly urbanized, with thousands of meters of natural watercourses previously straightened and reinforced into engineered stormwater management systems (TRCA, 2018).

Many of the features near Old School Road are headwater drainage features, which are typically smaller features that occur at the outer boundaries of drainage networks. Headwater features capture water and transport it downstream to larger streams and rivers.

West of Highway 10 the drainage features converge to become the Etobicoke Creek (West Branch), which meanders southeast through the more urbanized portion of the Study Area.

2.3.1.2 Credit Valley Conservation Authority

In the Study Area, the boundary between the TRCA and CVC is approximately 300 – 700 m southwest of, and parallel to, Hurontario Street. The watercourses crossed by the recommended preferred route are located in the eastern portion of the Fletchers Creek subwatershed, which encompasses 4273 Ha (CVC, 2024). Fletchers Creek has also been heavily impacted due to significant urbanization, affecting runoff and increasing peak flows (City of Brampton, 1995) (CVC, 2012).

The watercourses are identified in the CVC hydraulic network as engineered drainage features until they converge to become part of Fletchers Creek north of Regional Road 107. The watercourses east of Royal Orchard Drive are also classified as engineered drainage features and discharge into Fletchers Creek.

2.3.2 Physiographic Region

The Study Area occurs at the divide between the South Slope and Peel Plain physiographic regions (Figure 2-4 to Figure 2-6). The divide occurs between Regional Road 107 (Bovaird Drive)

and Williams Parkway. The South Slope gently slopes to the southeast and is characterized by shallow shale and glacial till plains (Region of Peel, 2020). The Water & Wastewater Master Plan for the Lake-Based System (2020) identified that locally the South Slope is dominated by glacial till soils.

The Peel Plain also has a relatively flat to gently sloping topography (City of Brampton, 1995) and is characterized by clay soils (Region of Peel, 2020). The clay-rich soils a low infiltration rate which results in higher surface runoff. During storm events, high stormwater flows could result in erosion and increased flooding.

Locally both the South Slope and Peel Plains are dominated by drumlinized and beveled till plains, as identified in Table 2-3 and Figure 2-7 to Figure 2-9.

2.3.3 Surficial Geology

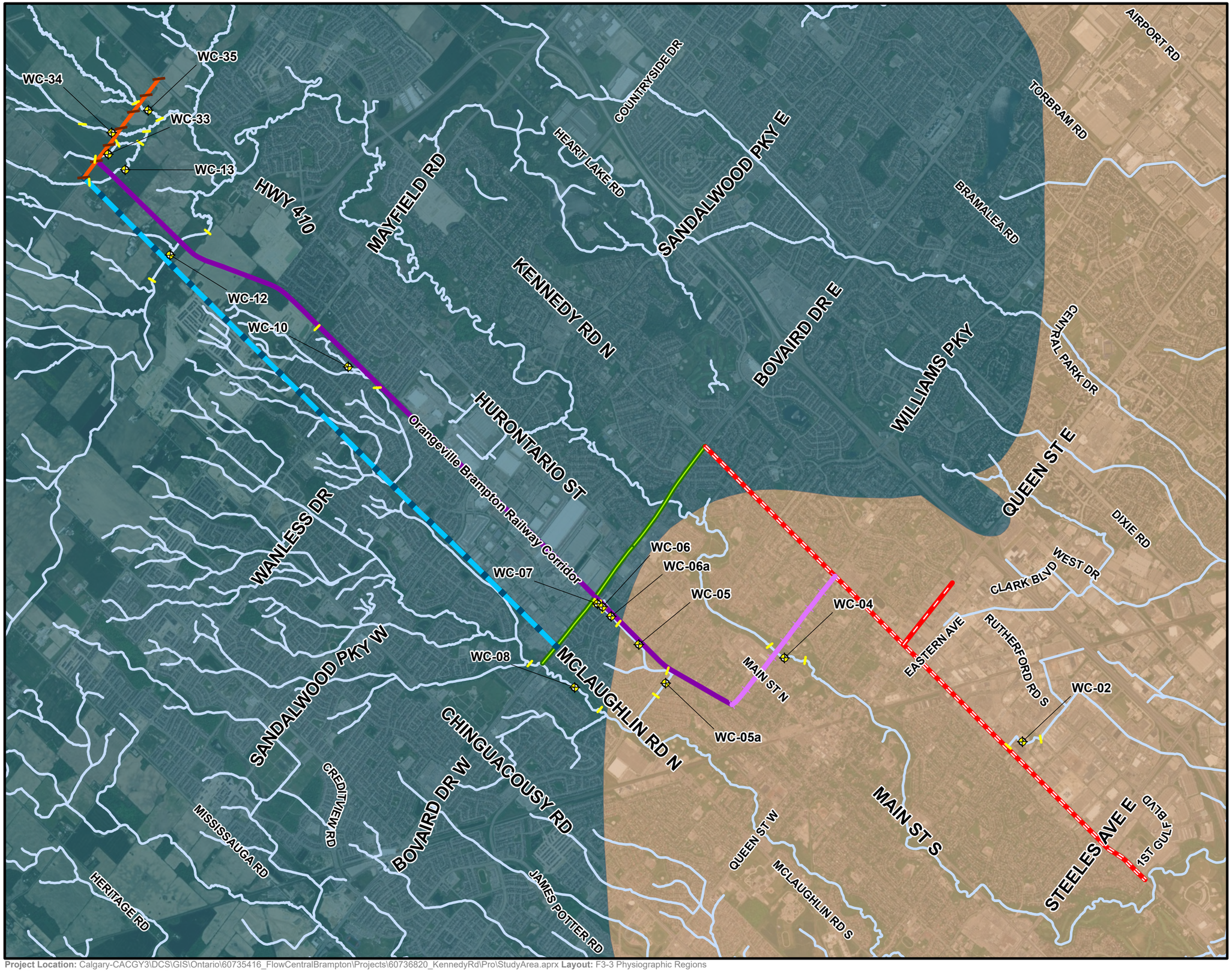
The surficial geology throughout the Study Area consists of silt to clay rich glaciolacustrine till and modern alluvial deposits with varying amounts of clay, silt, sand, and gravel, as identified in Table 2-3 and Figure 2-10 to Figure 2-12. The glaciolacustrine-derived silty to clayey glacial till was derived from sediments deposited in glacial lakes, while the modern alluvium deposits are accumulations of sediment deposited by fluvial processes within river channels, floodplains, and deltas. Alluvial deposits are composed of varying proportions of sands, silts, clays, gravels, cobbles and organic matter, and reflect ongoing erosion upstream and the transport dynamics of rivers. They form through the continuous cycle of sediment erosion, transportation, and deposition, influenced by seasonal fluctuations in river discharge and interactions with slower-moving water bodies.

In general, the erodibility of the till and alluvial deposits will be controlled by the localized proportion of clay, silt, sand, and gravel. Sandy channels are more easily eroded than clay-rich channels due to the cohesive nature of clay. Similarly, sand is more easily eroded than larger gravel-sized material because the energy needed to move gravel is greater.

Locally there are also small pockets of exposed Paleozoic bedrock of the Queenston Formation.

Table 2-3: Physiography and Surficial Geology

Reach ID	Physiographic Region (Chapman & Putnam, 2007)	Physiography (Chapman & Putnam, 2007)	Surficial Geology (Ontario Geological Survey, 2010)
WC-35	South Slope	Drumlinized Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till
WC-34	South Slope	Drumlinized Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till
WC-33	South Slope	Drumlinized Till Plains	■ Clay to silt-textured till in proximity to modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter
WC-13	South Slope	Drumlinized Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till
WC-12	South Slope	Drumlinized Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter. Surrounded by clay to silt-textured till and fine-textured glaciolacustrine deposits of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.
WC-04	Peel Plain	Bevelled Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.
WC-02	Peel Plain	Bevelled Till Plains	■ Clay to silt textured till.
WC-10	South Slope	Drumlinized Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till. There are also Paleozoic bedrock outcrops in the surrounding area. There are also fine-textured glaciolacustrine deposits nearby of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.
WC-08	South Slope	Drumlinized Till Plains and Bordering Bevelled Till Plains	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.
WC-07	South Slope	Drumlinized Till Plains and Bordering Bevelled Till Plains	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.
WC–06a	South Slope	Drumlinized Till Plains and Bordering Bevelled Till Plains	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.
WC-06	South Slope	Drumlinized Till Plains and Bordering Bevelled Till Plains	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.
WC-05a	Peel Plain	Bevelled Till Plains	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.
WC-05	Peel Plain	Bevelled Till Plains	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Physiographic Regions

- 32, South Slope
- 33, Peel Plain

Flow | Central Brampton

Kennedy Rd | Physiographic Regions

0 0.5 1 1.5 2

Kilometers
Scale: 1:40,000

N

PN: 60736820	Figure 2-4
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-3 Physiographic Regions
Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Reach Break
- McLaughlin Rd
- Old School Rd
- Watercourse

Physiographic Regions

- 32, South Slope

Flow | Central Brampton

Kennedy Rd | Physiographic Regions

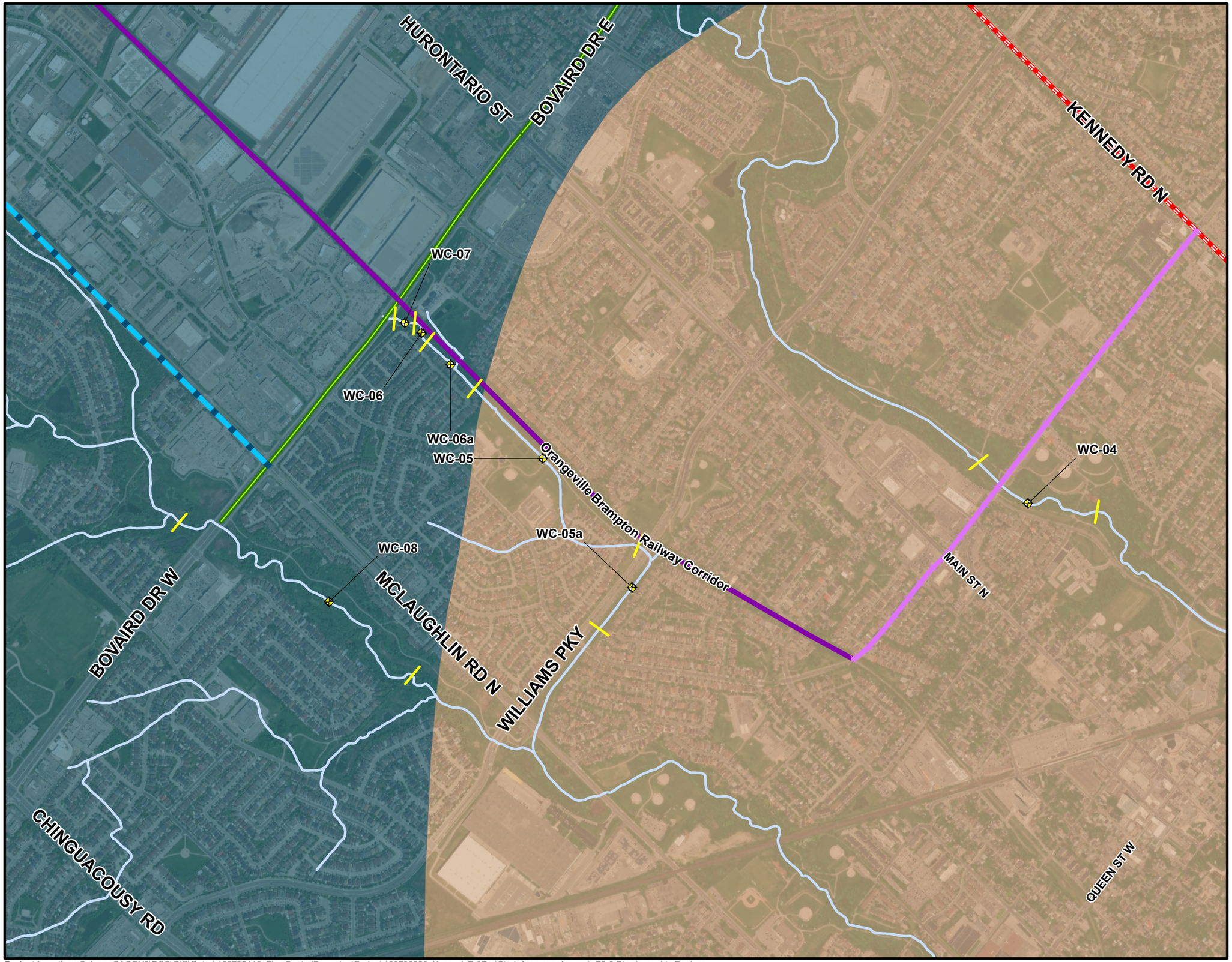
0 0.06 0.12 0.18 0.24

Kilometers
Scale: 1:5,000

N

PN: 60736820	Figure 2-5
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Vodden St
- McLaughlin Rd
- Watercourse

Physiographic Regions

- 32, South Slope
- 33, Peel Plain

Flow | Central Brampton

Kennedy Rd | Physiographic Regions

0 0.15 0.3 0.45 0.6

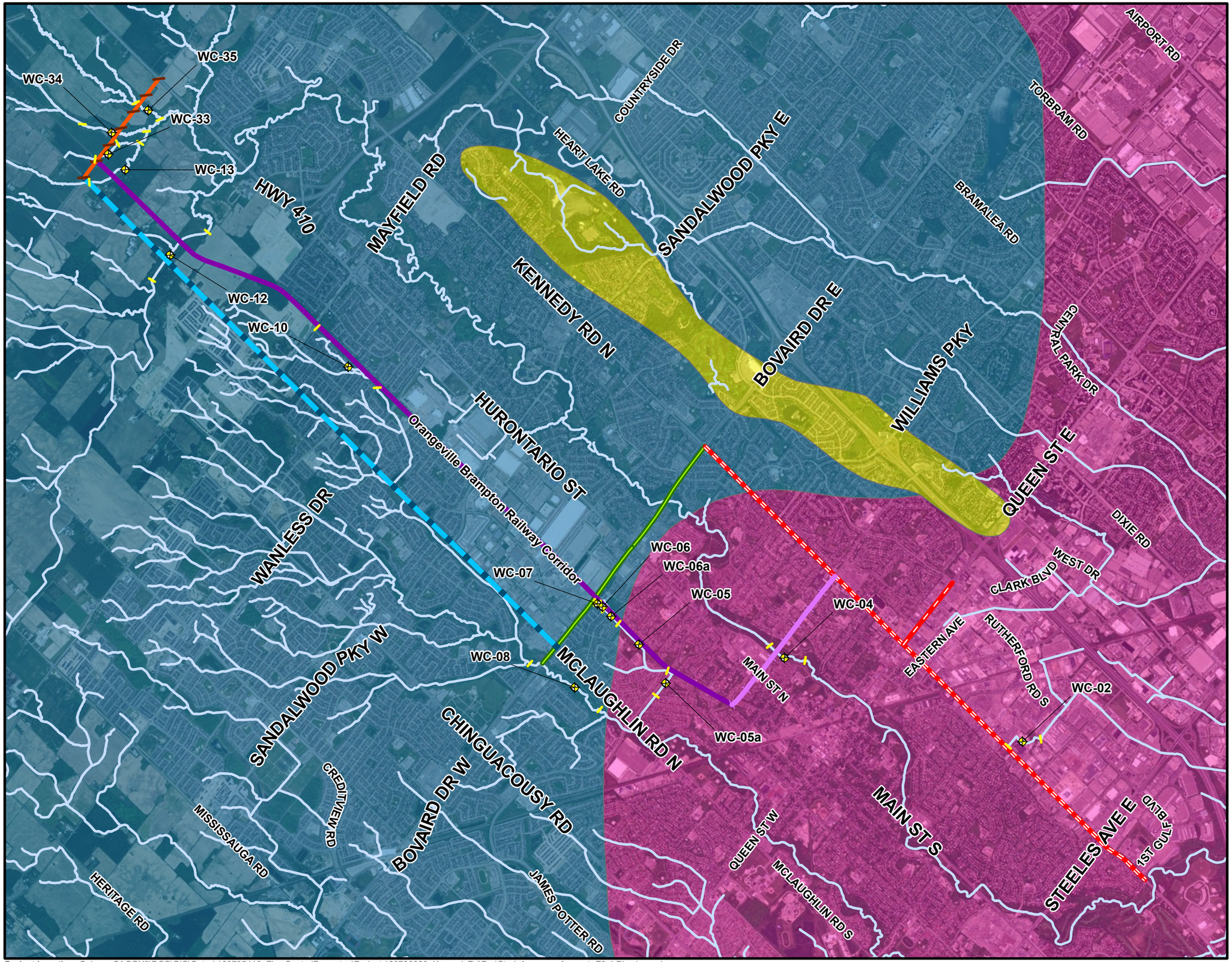
Kilometers
Scale: 1:12,000

N

PN: 60736820	Figure 2-6
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-3 Physiographic Regions
Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Physiography

- Bevelled Till Plains
- Eskers
- Till Plains (Drumlinized)

Flow | Central Brampton

Kennedy Rd | Physiographic Landforms

0 0.5 1 1.5 2
Kilometers
Scale: 1:40,000

N

PN: 60736820	Figure 2-7
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-4 Physiography
Date Saved: June 17, 2025 **User:** WangS12





Reach
Reach Break
McLaughlin Rd
Old School Rd
Watercourse

Physiography

Till Plains (Drumlinized)

Flow | Central Brampton

Kennedy Rd | Physiographic Landforms

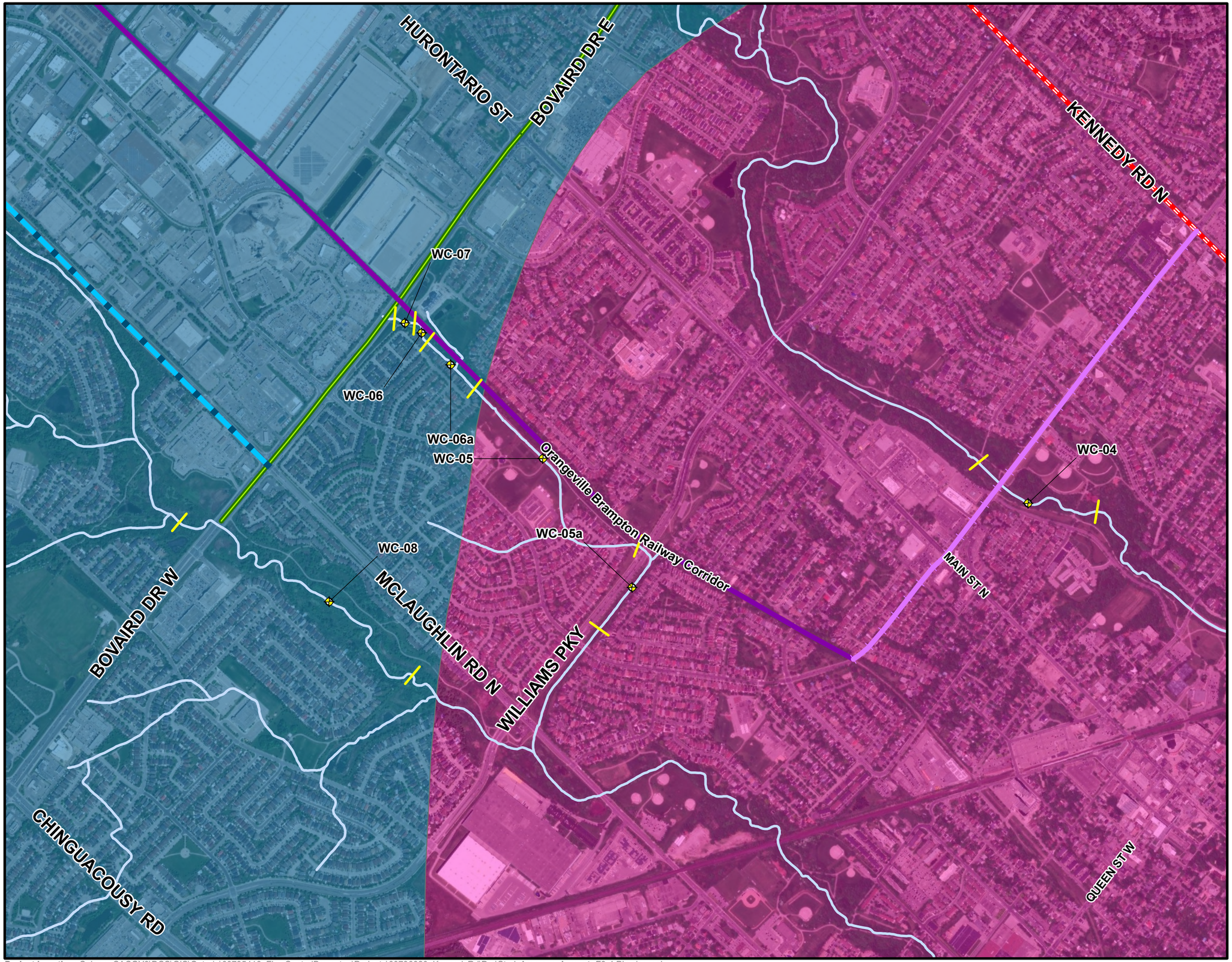
0 0.06 0.12 0.18 0.24

Kilometers
Scale: 1:5,000

N

PN: 60736820	Figure 2-8
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Vodden St
- McLaughlin Rd
- Watercourse

Physiography

- Bevelled Till Plains
- Till Plains (Drumlinized)

Flow | Central Brampton

Kennedy Rd | Physiographic Landforms

0 0.15 0.3 0.45 0.6

Kilometers
Scale: 1:12,000

N

PN: 60736820	Figure 2-9
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-4 Physiography
Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Watercourse

Surficial Geology

- 3: Paleozoic bedrock
- 5d: Glaciolacustrine-derived silty to clayey till
- 8b: Interbedded flow till, rainout deposits and silt and clay
- 9c: Foreshore-basinal deposits
- 19: Modern alluvial deposits
- 20: Organic deposits

Flow | Central Brampton

Kennedy Rd | Surficial Geology

0 0.5 1 1.5 2

Kilometers
Scale: 1:40,000

N

PN: 60736820	Figure 2-10
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-5 Surficial Geology
Date Saved: June 17, 2025 **User:** WangS12





Reach
Reach Break
McLaughlin Rd
Old School Rd
Watercourse

Surficial Geology

5d: Glaciolacustrine-derived silty to clayey till
19: Modern alluvial deposits

Flow | Central Brampton

Kennedy Rd | Surficial Geology

0 0.06 0.12 0.18 0.24

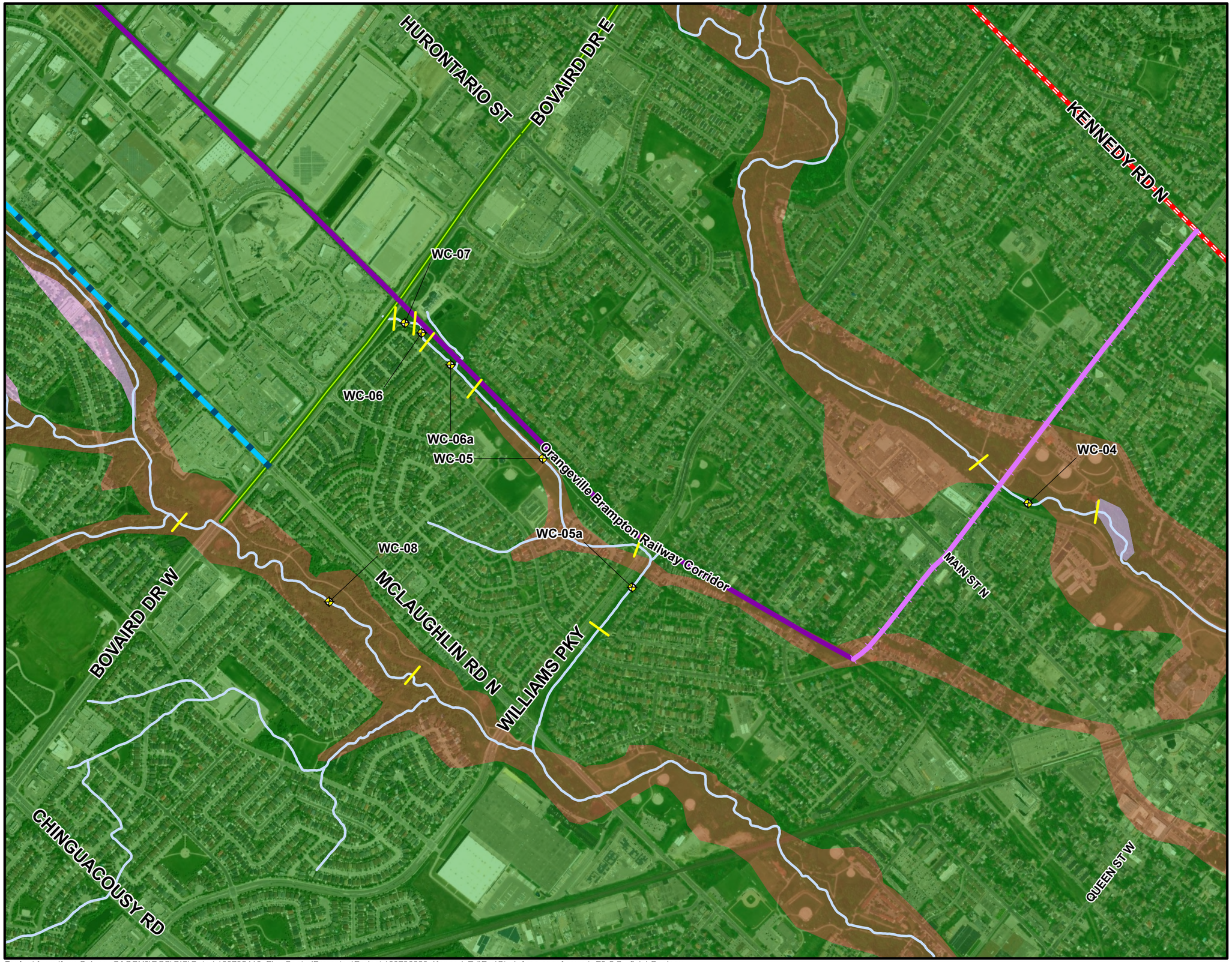
Kilometers
Scale: 1:5,000

N

PN: 60736820	Figure 2-11
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-5 Surficial Geology
Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Reach Break
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Vodden St
- McLaughlin Rd
- Watercourse

Surficial Geology

- 3: Paleozoic bedrock
- 5d: Glaciolacustrine-derived silty to clayey till
- 19: Modern alluvial deposits

Flow | Central Brampton

Kennedy Rd | Surficial Geology

0 0.15 0.3 0.45 0.6

Kilometers
Scale: 1:12,000

N

PN: 60736820	Figure 2-12
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-5 Surficial Geology
Date Saved: June 17, 2025 **User:** WangS12

2.3.4 Topography

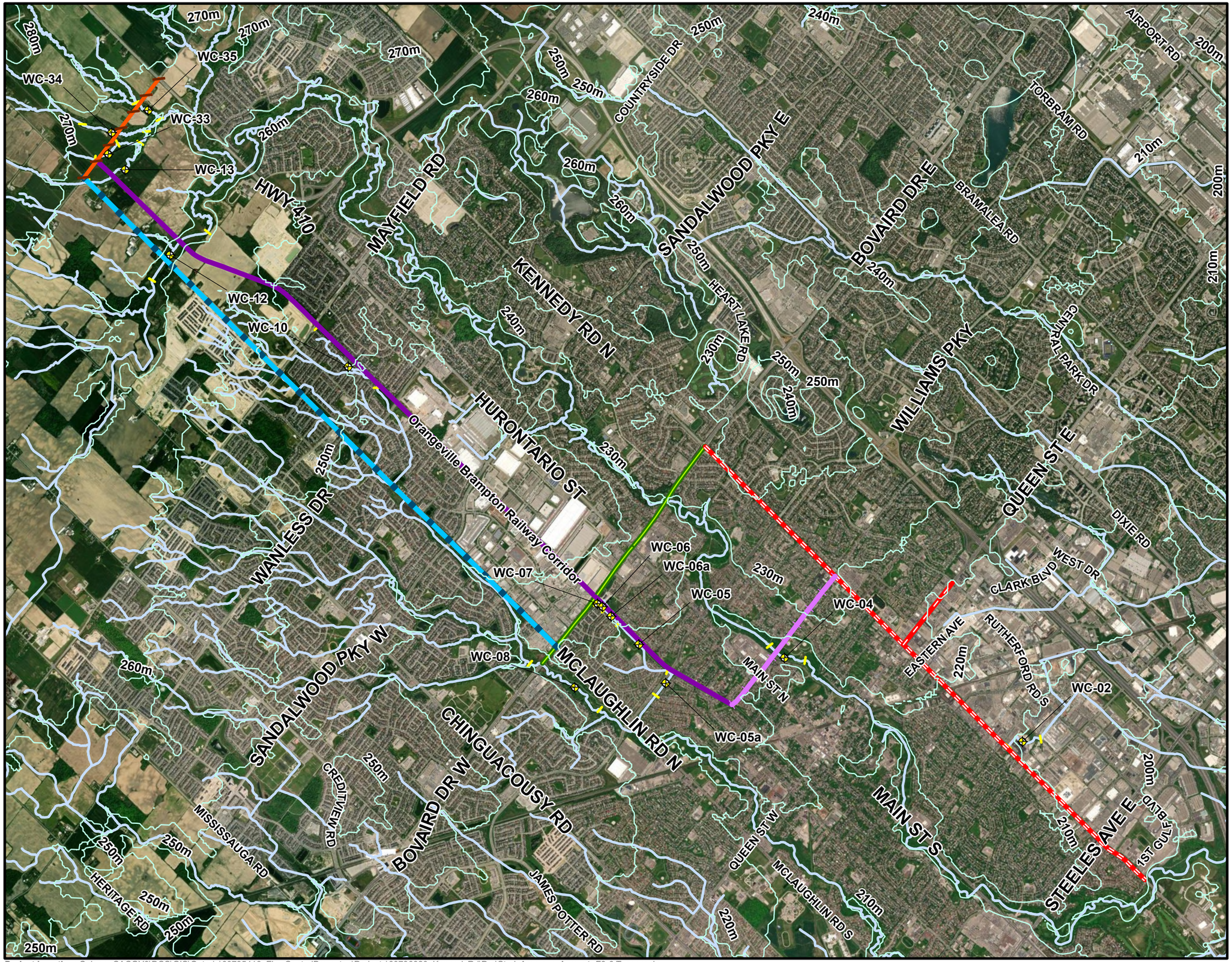
The longitudinal profile is one of the primary controls of tractive forces within a reach. Generally, the steeper the longitudinal profile the more erosive a channel can be. The Study Area includes upstream portions of Fletchers Creek and Etobicoke Creek (Figure 2-13 to Figure 2-15).

Fletchers Creek follows an overall low average gradient of approximately 0.007 m/m over its length (Ontario Geological Survey, 2005). In the Study Area, the headwater features north of Old School Road begin around 255 m above sea level (mASL). These, and other headwater drainage features converge 350 m north of Regional Road 107 at 225 mASL (approximately 5 km downstream) which corresponds to an overall gradient of 0.006 m/m.

In the Study Area the headwaters for Etobicoke Creek originate at 260 mASL north of Old School Road and the most downstream crossing occurs approximately 17.2 km downstream at around 215 mASL at Vodden Street East. This corresponds to an overall channel slope of 0.0026 m/m.

2.3.5 Land Use

Land use in the Study Area is a mix of rural and urbanized land uses. The upper portions of Etobicoke Creek north of Collingwood Ave/Mayfield Road are surrounded by agricultural practices. The remainder of the Study Area is highly urbanized and has modified stormwater management creeks. Urbanization has likely led to an increased runoff in the more urbanized portions of the Study Area, leading to increased peak discharge being contained in the channels which typically results in creek enlargement (TRCA, 2021).





- Reach
- Contour Lines (10m Interval)
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Queen St
- Vodden St
- McLaughlin Rd
- Old School Rd
- Reach Break
- Watercourse

Flow | Central Brampton

Kennedy Rd | Topography

0 0.5 1 1.5 2

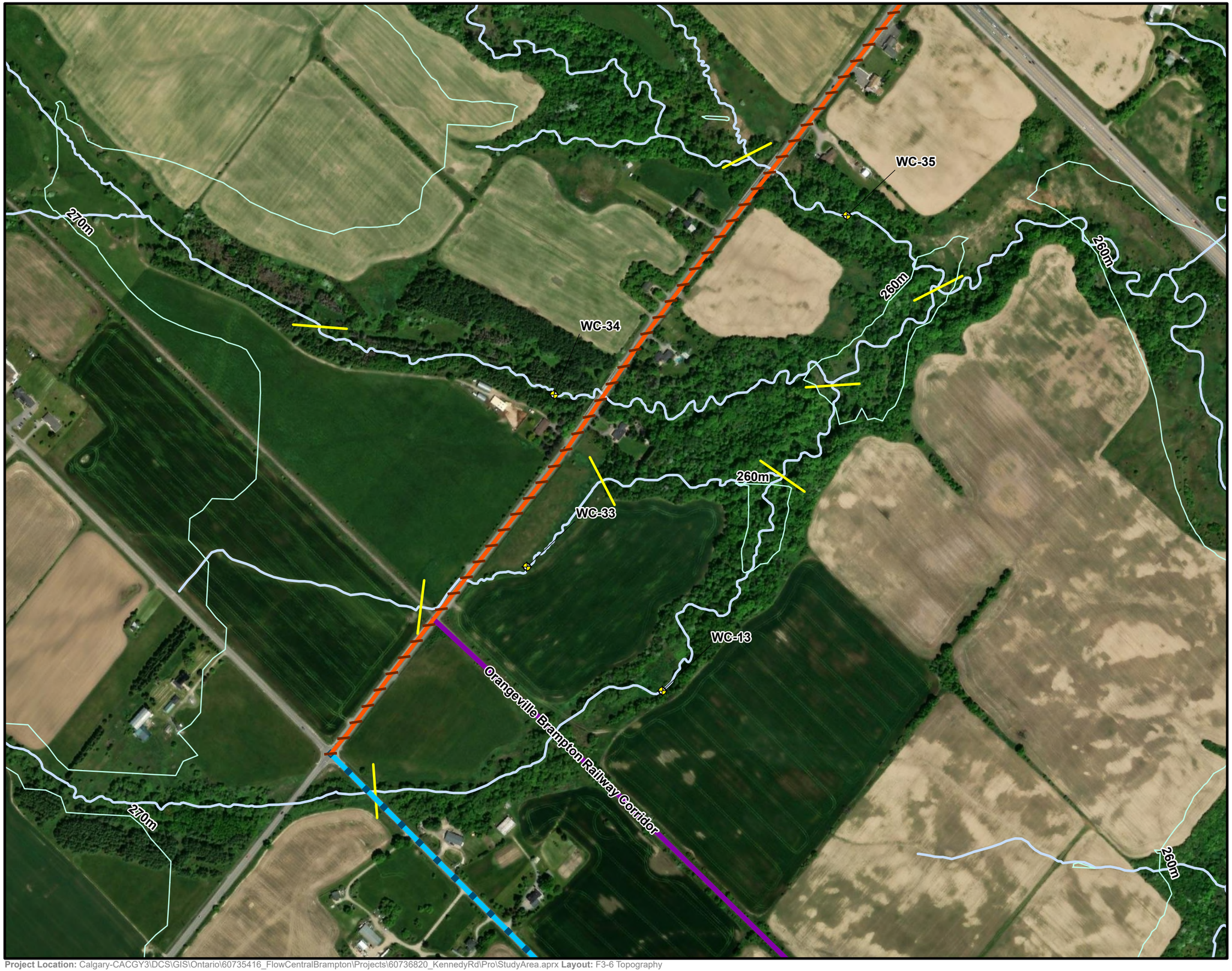
Kilometers
Scale: 1:40,000

N

PN: 60736820	Figure 2-13
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-6 Topography
Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Contour Lines (10m Interval)
- McLaughlin Rd
- Old School Rd
- Reach Break
- Watercourse

Flow | Central Brampton

Kennedy Rd | Topography

0 0.06 0.12 0.18 0.24

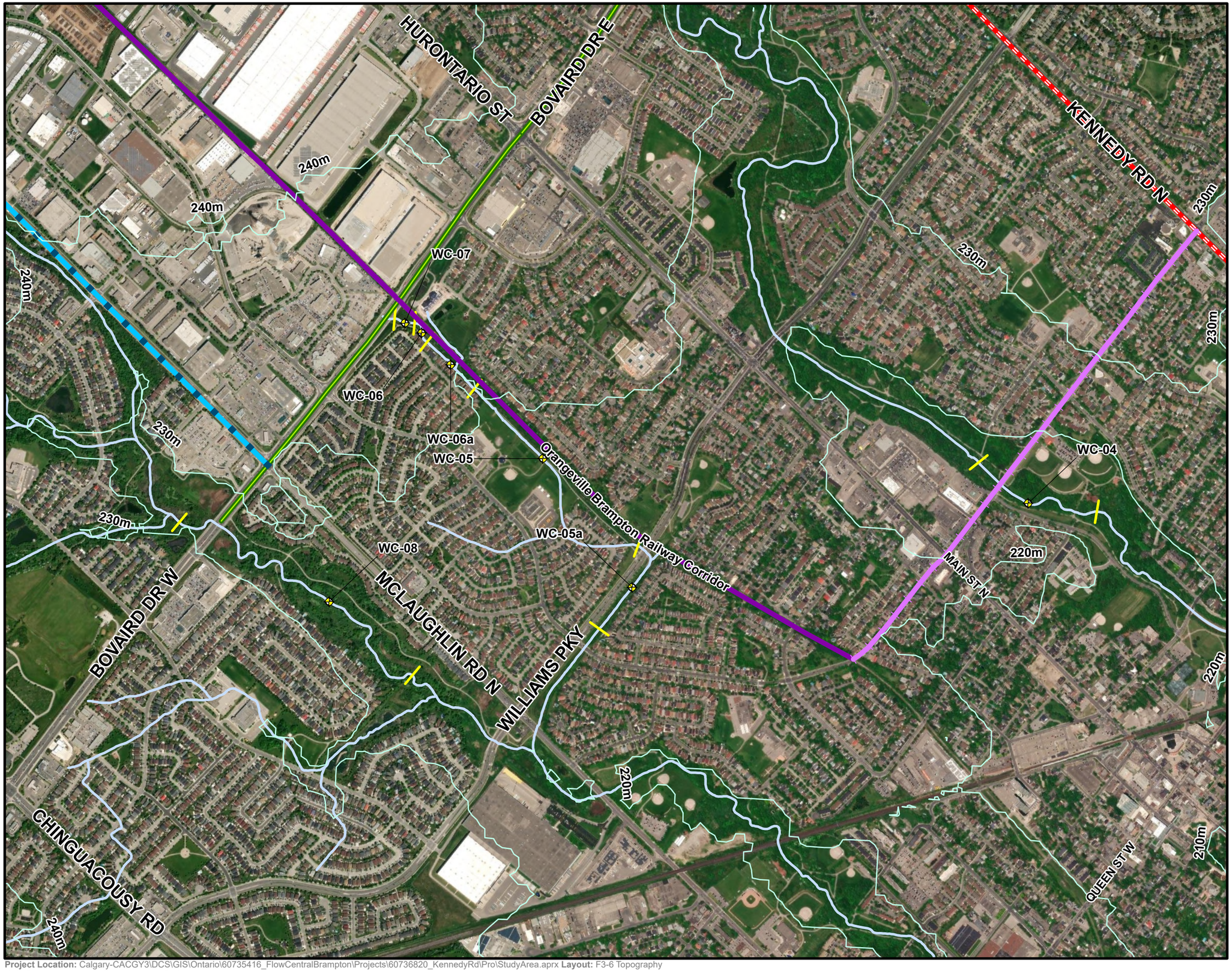
Kilometers
Scale: 1:5,000

N

PN: 60736820	Figure 2-14
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

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Date Saved: June 17, 2025 **User:** WangS12





- Reach
- Contour Lines (10m Interval)
- Bovaird Dr
- Kennedy Rd
- Orangeville Brampton Railway Corridor
- Vodden St
- McLaughlin Rd
- Reach Break
- Watercourse

Flow | Central Brampton

Kennedy Rd | Topography

0 0.15 0.3 0.45 0.6

Kilometers
Scale: 1:12,000

N

PN: 60736820	Figure 2-15
June 17, 2025	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F3-6 Topography
Date Saved: June 17, 2025 **User:** WangS12

2.4 Previous Studies

A background review of the Study Area was conducted to provide a general understanding of the natural and anthropogenic alterations that influence channel morphology and watercourse stability at the location of the proposed crossings. Sources guiding this review include previous studies, assessments, online documentation, topographic maps, and aerial imagery falling within the project footprint.

A list of the reviewed studies and data are listed below. Only the most pertinent references guiding the fluvial geomorphic assessment have been summarized in the following sections.

- Water and Wastewater Master Plan for Lake-Based Systems (Region of Peel, 2020)
- Etobicoke Creek Watershed Plan 20024-2034 (TRCA, 2024)
- Etobicoke Creek Erosion Control – Bloor Street to Ponytrail Drive (KSGS Engineering Corp., 2022)
- Fletchers Creek Subwatershed Plan (City of Brampton, 1995)
- Fletchers Creek Restoration Study (CVC, 2012)

Water and Wastewater Master Plan for Lake-Based Systems 2020

The Region of Peel 2020 Water and Wastewater Master Plan for the Lake-Based Systems documents the preferred wastewater servicing strategy and provides detailed information on proposed capital works to be implemented over the twenty-year planning horizon.

As a result of Bill 23, the Region is anticipating significant population growth and accelerated timing of this growth, resulting in increased demand on water and wastewater services. The impact of Bill 23 is to move the planning year from 2051, used in the 2020 Water and Wastewater Master Plan, to 2041. To meet the planned growth, it is critical to continue developing capacity and system redundancy in Peel's lake-based water and wastewater systems. As a result, Peel will be updating its 2020 Water and Wastewater Master Plan to support existing servicing needs and future growth from the planning year 2051 to 2041 to accommodate the accelerated growth in Mississauga, Brampton, and parts of Caledon.

The Kennedy Road Sanitary Trunk Sewer (STS) was not captured in the 2020 Master Plan until after the release of the Province of Ontario's Bill 23 which requires accelerated growth in the Study Area. The Kennedy Road STS was identified by the Region to allow increased wastewater service capacity in downtown Brampton in addition to South Central Caledon.

Etobicoke Creek Watershed Plan 2024-2034 (2024)

The TRCA prepared a watershed plan for Etobicoke Creek. In the watershed plan, Figure 10: *FVCs and Brampton Esker* identifies that the southeastern portion of the Study Area between

Williams Parkway East and Clarence Street are located within a flood vulnerable cluster, which is also interpreted to have a medium or high erosion sensitivity. Additionally, Natural Hazards – Flooding and Natural Hazards – Erosion Tables in the plan show that flood risk and erosion risk are likely to increase with urban expansion and climate change but can be reduced with different watershed enhancement options.

Etobicoke Creek Erosion Control – Bloor Street to Ponytrail Drive, 2022

KSGS Engineering Corp. and Beacon Environmental prepared a report for the City of Mississauga to identify a strategy to mitigate erosion in a section of Etobicoke Creek downstream of the current Study Area. Erosion in this area was attributed to deterioration of existing erosion protection.

Fletchers Creek Subwatershed Plan 1995

Paragon Engineering Limited created a Subwatershed plan for Fletchers Creek in anticipation of future development and growth in the City of Brampton and the Town of Caledon. The subwatershed plan provided valuable background information that has been discussed as appropriate in Section 2.3 - 2.3.5.

Fletchers Creek Restoration Study 2012

CVC created the Fletchers Creek Restoration Study (draft) in collaboration with the City of Brampton. The study summarized that there has been significant urban development, impacting the watershed. Specifically, discharge in the upstream portion of the watershed was noted to have increased rapidly with maximum flows increasing more than 10-fold. Base flow in the creek was also noted to have increased by two orders of magnitude, despite stormwater management. This has led to extensive bank slumping and erosion in the upstream portion of Fletchers Creek.

2.5 Historical Imagery Assessment

An analysis of available historical aerial imagery was performed to determine the extent and type of change to channel planform, adjacent land use, and anthropogenic alterations have occurred for the subject watercourses (refer to Appendix A). The historical images were individually georeferenced in ArcGIS Pro and then assessed. Results of the historical analysis for each of the investigated reaches are presented in Table 2-4 and are also the basis for the 100-year erosion rate calculation.

Table 2-4: Historical Aerial Imagery Assessment

Water Crossing	1970	1974	1999	2005	2015	2024
WC-35	■ N/A	■ Planform: Reach is a sinuous watercourse. ■ Land Use: The reach flows through a forested corridor between agricultural fields. It is crossed by Old School Road and there are a series of buildings (likely agricultural) present within the agricultural field to the southwest.	■ Planform: The watercourse follows the same general planform with slight possible changes to the meander geometry, near the downstream reach break. ■ Land Use: No significant changes to land use. Minor amounts of development (a few small buildings were built south of Old School Road near the upstream reach break).	■ Planform: No major changes. ■ Land Use: No significant changes to land use. Buildings removed north of Old School Road near the upstream reach break.	■ Planform: No major changes. Meander bend immediately upstream of lower reach break has shifted slightly. ■ Land Use: No significant changes to land use.	■ Planform: No major changes. ■ Land Use: No significant changes to land use.
WC-34	■ N/A	■ Planform: Upstream of Old School Road there appears to be a series of drainage ditches that converge upstream of the road crossing. They have likely been dredged for agricultural purposes. Downstream of Old School Road the watercourse meanders through a forested corridor. ■ Land Use: The reach is surrounded by agricultural fields. It is crossed by Old School Road. Downstream of Old School Road the reach has a well-established forested riparian buffer.	■ Planform: Upstream of Old School Road the reach now occupies one main channel and has a sinuous planform. No major changes downstream of Old School Road (slight migration of meander bends). ■ Land Use: Upstream of Old School Road the agricultural land immediately surrounding the reach now contains numerous trees. No significant changes to land use downstream of Old School Road.	■ Planform: No major changes. ■ Land Use: No significant changes to land use. Upstream of Old School Road the tree cover has increased.	■ Planform: No major changes. ■ Land Use: No significant changes to land use. Upstream of Old School Road the tree cover has increased.	■ Planform: No major changes. ■ Land Use: No significant changes to land use. Upstream of Old School Road the tree cover has increased.
WC-33	■ N/A	■ Planform: The feature is only visible in some areas. It has a weakly sinuous planform. ■ Land Use: The reach is surrounded by agricultural fields. It is crossed by Old School Road and rail tracks.	■ Planform: The feature is only visible in some areas. It appears to have been realigned so that it's parallel to Old School Road between the rail corridor and Old School Road. Otherwise, no major changes to planform were observed. ■ Land Use: No significant changes to land use.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes to land use.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes to land use.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes to land use.
WC-13	■ N/A	■ Planform: The reach begins at a man-made pond that is located west of McLaughlin Road. Between McLaughlin Road until 135 m east of the rail corridor, the channel is straight. It was likely altered for agricultural purposes. Further to the east the channel is a more natural, meandering feature. Multiple meander scars are visible in the aerial imagery. ■ Land Use: The watercourse is surrounded by agricultural fields. There is a small riparian buffer consisting of trees in some areas. The portion of the reach that lacks a riparian bugger (northeast of the rail corridor) appears to be more of a wetland-type area.	■ Planform: Channelized portion of watercourse is now slightly more sinuous. Otherwise, there are no major changes. ■ Land Use: No significant changes in land use. The riparian buffer is better established in many areas.	■ Planform: Channelized portion of watercourse is now slightly more sinuous. Otherwise, there are no major changes. ■ Land Use: A trail has been constructed east of McLaughlin Road, likely for agricultural purposes. As part of this trail, there is now a new crossing over the reach just east of McLaughlin Road. ■ Additionally, the riparian buffer is better established in many areas. The resolution on the 2005 aerial imagery is better than the 1917 and 1999 aerial imagery and it clearer that the area that lacks a riparian buffer is likely a wetland.	■ Planform: Channelized portion of watercourse is now slightly more sinuous. Otherwise, there are no major changes. ■ Land Use: No significant changes in land use. The riparian buffer is better established in many areas.	■ Planform: Channelized portion of watercourse is now slightly more sinuous. Otherwise, there are no major changes. ■ Land Use: No significant changes in land use. The riparian buffer is better established in many areas.

Water Crossing	1970	1974	1999	2005	2015	2024
WC-12	■ N/A	■ Planform: From the upper reach break until approximately 50 m west of the rail corridor the reach has been straightened. Past this until the lower reach break, the watercourse is a meandering channel. ■ Land Use: The surrounding land appears to be more of a wetland. No trees are present in the riparian zone. Past this, the land is occupied by agricultural fields.	■ Planform: The meandering portion of the channel has now been channelized. The entire reach is now straightened. ■ Land Use: No significant changes in land use or the riparian zone.	■ Planform: No significant changes. ■ Land Use: No significant changes.	■ Planform: No significant changes. ■ Land Use: No significant changes.	■ Planform: No significant changes. ■ Land Use: No significant changes.
WC-04	■ N/A	■ N/A	■ Planform: The channel appears to have been straightened upstream of Vodden Street East and has a more meandering profile downstream. ■ Land Use: The watercourse is surrounded by a series of residential and houses and recreational/ industrial facilities.	■ Planform: No significant changes. ■ Land Use: No significant changes.	■ Planform: No significant changes. ■ Land Use: No significant changes. Minor development between Sproule Drive and Ken Whillans Drive near the downstream end of the reach.	■ Planform: No significant changes. ■ Land Use: No significant changes.
WC-02	■ N/A	■ N/A	■ Planform: The feature appears to be an urban drainage ditch that begins east of Kennedy Road South. It has a straightened planform that appears to have been adjusted in the past to accommodate a series of facilities. The feature flows through what appears to be culverts under multiple sets of rail tracks. ■ Land Use: The feature occurs within a narrow grassy corridor in an urbanized land parcel. No significant riparian zone can be observed in the aerial imagery.	■ Planform: No significant changes. ■ Land Use: No significant changes.	■ Planform: No significant changes. ■ Land Use: No significant changes.	■ Planform: Due to expansion of the facilities at 134 Kennedy Road South in 2020, the feature appears to have been altered. It is likely that the feature is now piped and is no longer visible in aerial imagery except for a short 115 m section between the edge of the parking lot and where the feature crosses under the rail corridor. ■ Land Use: Slight changes to land use (see above).
WC-10	■ Planform: The watercourse is not clearly visible in aerial imagery. A series of branching dark patches are visible in the agricultural field west of the rail corridor that are likely headwater features. ■ Land Use: The surrounding area is dominated by agricultural fields. The rail corridor is present.	■ N/A	■ Planform: The watercourse is not clearly visible in aerial imagery. A series of branching dark patches are visible in the agricultural field west of the rail corridor that are likely headwater features. ■ Land Use: Residential development north of the rail corridor between Mayfield Road and Cresthaven Road.	■ Planform: The watercourse is not clearly visible in aerial imagery. A series of branching dark patches are visible in the agricultural field west of the rail corridor that are likely headwater features. A stormwater pond has been constructed at the location of the downstream reach break. ■ Land Use: Significant residential development has occurred in the area. Residential housing now spans from Collingwood Avenue to Wanless Drive northeast of the tracks, and between Wanless Drive to Sandalwood Parkway southwest of the tracks.	■ Planform: To accommodate the residential development, it appears flow has been redirected to a drainage swale parallel to the rail corridor. Short sections of pooled water are visible but no fully defined channel can be identified. ■ Land Use: Significant residential development south of the rail corridor between Mayfield Road and Wanless Drive.	■ Planform: No significant changes. ■ Land Use: Additional residential development, especially west of the feature. Multiple stormwater ponds are now present north of Wanless Drive near the upstream reach break.

Water Crossing	1970	1974	1999	2005	2015	2024
WC-08	■ Planform: The feature appears to be a relatively straightened feature upstream of Bovaird Drive West. Beginning approximately 200 m upstream of the crossing the feature has more of a meandering profile. ■ Land Use: The feature is surrounded by agricultural lands. It is crossed by Bovaird Drive West and what appears to be an access driveway. The feature largely lacks a riparian zone. **Only partial imagery was attainable, downstream section of reach was cut off*	■ N/A	■ Planform: No significant changes. ■ Land Use: Residential development east of watercourse northeast of McLaughlin Road.	■ Planform: No significant changes. ■ Land Use: Continued extensive residential development. Increase in tree cover in the riparian zone.	■ Planform: No significant changes. Crossing over Bovaird Drive West appears to have been replaced, likely as part of road widening efforts. A retaining all is now also present north of Bovaird Drive West, likely to prevent erosion of the road embankment. ■ Land Use: Continued residential development. Increase in tree cover in the riparian zone.	■ Planform: No significant changes. ■ Land Use: No significant changes. Increase in tree cover in the riparian zone.
WC-07	■ Planform: Feature is a sinuous drainage ditch. ■ Land Use: Surrounding land is largely agricultural east of the rail tracks and is industrial west of the rail tracks.	■ N/A	■ Planform: Feature has been channelized and is now relatively straight. ■ Land Use: Significant residential development.	■ Planform: No significant changes. ■ Land Use: Continued residential development. Slight increase in tree cover.	■ Planform: Channel has become slightly more sinuous. ■ Land Use: No significant changes. Slight increase in tree cover.	■ Planform: Channel has become slightly more sinuous. ■ Land Use: Continued urbanization. A new residential facility has been built at 100 Manett Crescent, just east of the rail tracks.
WC–06a	■ Planform: Feature is a sinuous drainage ditch. ■ Land Use: Surrounding land is largely agricultural east of the rail tracks and is industrial west of the rail tracks.	■ N/A	■ Planform: Feature has been channelized and is now relatively straight. A stormwater pond has been created east of the rail tracks and outlets at the lower reach break. ■ Land Use: Significant residential development.	■ Planform: No significant changes. ■ Land Use: Continued residential development. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes. Slight increase in tree cover.
WC-06	■ Planform: Feature is difficult to identify in the aerial imagery. Short sections of ponded water are visible parallel to the rail corridor. ■ Land Use: Surrounding land is largely agricultural east of the rail tracks and is industrial west of the rail tracks.	■ N/A	■ Planform: Feature has been channelized and is now relatively straight. A stormwater pond has been created east of the rail tracks and outlets at the upper reach break. ■ Land Use: Significant residential development.	■ Planform: No significant changes. ■ Land Use: Continued residential development. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant changes. Slight increase in tree cover.
WC-05a	■ Planform: Feature is difficult to identify in the aerial imagery. Short sections of ponded water are visible parallel to the rail corridor. ■ Land Use: Surrounding land is largely agricultural east of the rail tracks and is industrial west of the rail tracks. ■ **Only partial imagery was attainable. The downstream section of the reach was cut off*	■ N/A	■ Planform: Feature has been channelized and is now visible in aerial imagery. ■ Land Use: Significant residential development.	■ Planform: No significant changes. ■ Land Use: Continued residential development. Slight increase in tree cover.	■ Planform: Sections of pooled water are present within the reach and could be due to an impoundment, additional flows from urbanization, or due to the time of the year the imagery was taken (e.g., during the spring freshet or after a rain event). The feature has a relatively straight planform. ■ Land Use: No significant changes. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant change to land use.

Water Crossing	1970	1974	1999	2005	2015	2024
WC-05	■ Feature not visible in aerial imagery (imagery does not cover this area).	■ N/A	■ Planform: Feature crosses Willims Parkway and is fully lined with concrete. ■ Land Use: Significant residential development.	■ Planform: No significant changes. ■ Land Use: Continued residential development. Slight increase in tree cover.	■ Planform: Sections of pooled water are present within the reach and could be due to an impoundment, additional flows from urbanization, or due to the time of the year the imagery was taken (e.g., during the spring freshet or after a rain event). The feature has a relatively straight planform. ■ Land Use: No significant changes. Slight increase in tree cover.	■ Planform: No significant changes to planform. ■ Land Use: No significant change to land use.

2.6 Regulatory Requirements

Among other roles and responsibilities in the land use planning and development process, the TRCA and CVC administer Ontario Regulation 41/24 "Prohibited Activities, Exemptions, and Permits" to ensure the protection of life and property from natural hazards such as flooding, erosion, dynamic beaches or unstable soil or bedrock. Each Conservation Authority provides their own guidelines for fluvial geomorphic assessments including scour and erosion threshold assessments. Relevant guidelines for specific geomorphic assessments can be found in their respective sections below.

3. Field Based Assessment

Fluvial geomorphic site investigations were conducted April 16th and 23rd, and a detailed channel survey of two watercourses that were publicly accessible was completed on April 25th. Due to the absence of permission to enter, field work was limited to observations from the Right of Way (ROW) and surrounding road networks. Field staff walked along the accessible portions of each reach during the assessment. It was beyond the scope of this investigation to collect detailed geomorphic data for reaches within the Study Area that were poorly defined ephemeral streams, and/or where permission to enter (PTE) was not granted.

A photographic record of the assessed sites was also created which contains representative photographs of each reach as observed in the field (Appendix B).

3.1 Methods

3.1.1 Geomorphic Reach Characterization

During the field reconnaissance, basic geomorphological data were collected. This included:

- Typical bankfull dimensions (width and depth),
- Bed and bank materials,
- Surrounding land use,
- Riparian vegetation,
- Valley and bank stability,
- Degree of channel-floodplain connectivity, and
- The location of erosion and channel modification and completion of a Rapid Geomorphic Assessment (RGA)
- Any site-specific issues that may pose a constraint.

The hydraulic regime of each watercourse was also inferred based on a combination of field observations and aerial imagery analysis (where aerial imagery was available for multiple months including the spring freshet, dry summer months, autumn, and winter). Each watercourse was classified based on its inferred hydrologic flow regime including:

1. Permanent Watercourse – maintains continuous surface flows most years, well-defined, low-flow.
2. Intermittent Watercourse – water flows for several months during the year, typically during the spring and early summer when the water table is high, and late fall; these watercourses have a defined high-flow channel with a poorly defined or absent low-flow channel.

3. Ephemeral Watercourse – water flows for a short period of time primarily in response to snow melt (spring freshet) or storm events, typically lack clearly defined high or low-flow channel or sorting of substrate. Often occurs as vegetated swales or bare soil rills in agricultural fields and are often ploughed through.

3.1.2 Rapid Geomorphic Assessment (RGA)

Streams seek a state of dynamic equilibrium between the imposed conditions of valley slope, discharge, and sediment supply. Over time the channel will adjust in terms of width, depth, velocity, reach slope, roughness, and sediment supply to attempt to reach this dynamic equilibrium (Lane, 1955). Changes due to human activity, climate change, and extreme events interfere with this equilibrium and markers of instability will become apparent in the field.

The Rapid Geomorphological Assessment (RGA) was designed by the Ontario Ministry of the Environment (1999) to assess reaches in urban channels. This technique uses visual indicators to document evidence of channel instability using a presence/ absence methodology. Stability is determined by adjustments 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 evidence of planimetric form adjustment (changes to a channel overall shape). The geomorphic indicators are documented throughout the reach and 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 3-1 (Ontario Ministry of the Environment, 2003).

Table 3-1: RGA Classification and Interpretation Reproduced from MECP (2003)

Factor 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 meander propagation processes
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 the range of variance and evidence of instability is wide spread

3.1.3 Crossing Assessment

Data relating specifically to the existing crossing structures was collected and documented as part of a Watercourse Crossing Assessment. This assessment was performed to identify any impact that existing crossings structures were having on the watercourse. Undersized crossings will constrict flow and impact sediment transport capacity which can lead to bed scour and channel downcutting (TRCA, 2015). This creates an additional localized scour hazard risk in addition to background scour rates which could put buried infrastructure at risk. As per TRCA, 2015 and CVC, 2012, the performance of existing or nearby structures on the same watercourse should be considered as part of the scour assessment. Similarly, poorly configured crossing structures could contribute to frequent debris jams (TRCA, 2015). Large woody debris jams create blockages which impact flow dynamics and can result in additional localized scour. For this reason, any woody debris jams observed from the ROW were noted as part of the assessment, and any evidence of bed scour associated with the debris jams was documented. The information recorded as part of the crossing assessment included:

- Hydraulic characteristics of the structure, including the span, height, length, inlet and outlet characteristics, skew, and construction materials.
- Assessment of the potential issues relating to the crossing structure (e.g., bank erosion, bed scour, debris trapping, and fish passage).
- A photographic record of the existing inlet and outlet features, as well as the typical channel configurations upstream and downstream of the crossing.

The Watercourse Crossing assessment sheets are provided in Appendix C. A summary of each crossing has been provided below.

3.2 Results

3.2.1 WC-35

3.2.1.1 Reach Characterization

The assessment of WC-35 was completed from the ROW due to PTE limitations. The feature flows southeast through a concrete box culvert (approximately 5 m wide) under Old School Road, then flows southeast for approximately 300 m where the downstream reach break occurs.

Based on the desktop assessment, the feature is a meandering watercourse with high sinuosity. It follows a low to moderate gradient and it is located within a partially confined valley.

During the field assessment the bankfull width and depth were estimated to be approximately 1.5 m to 4.0 m, and 0.3 m to 0.8 m, respectively. On the day of the assessment, the wetted widths and depths ranged from approximately 1 m – 3 m and 0.1 – 0.3 m, respectively. At the Old School Road crossing the channel has defined banks and a defined bed morphology consisting of riffles and pools. The bed substrate on both channel banks consisted of fines (silt, clay, and sand) up to cobble-sized materials. The watercourse is confined along the right (northwest) bank. The surrounding vegetation is primarily trees and grasses, with limited shrubs present. Leaning and fallen trees were observed upstream and downstream of the crossing. Multiple debris jams within the channel were observed. The channel has access to the floodplain along both banks downstream of the crossing but is disconnected from its floodplain upstream.

3.2.1.2 RGA Results

The RGA results for WC-35 should be interpreted with caution and may not be representative of the entire reach as the assessment was done from the ROW. The results indicate that the reach is in a "Transitional or Stressed" state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-2.

Table 3-2: WC-35 RGA Results

Reach	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-35	0.08	0.23	0.57	0.14	0.26	Transitional/ Stressed

The dominant process occurring within Reach WC-35 is channel widening. Evidence of channel widening included leaning and fallen trees, the presence of large woody debris, exposed tree roots, as well as basal scour along both banks. Channel widening typically occurs in response to instability in a watercourse, which is often influenced by changes in discharge, sediment load, morphological characteristics, and changes in flow regime. Based on the results of the historic assessment (see Section 2.5) indicate there have been no significant changes to land use or channel planform since 1974, although there has been significant urban development in the watershed further downstream.

Because the RGA was limited to the ROW, it is also possible that the evidence of instability is over-represented in the RGA if the source of the instability is associated with the crossing under Old School Road. Based on field evidence, the watercourse had a bankfull width of approximately 3 – 5 m at the crossing, while the crossing had a span of 5 m (see crossing assessment for more details).

Another source of instability identified in the field are multiple debris jams, which were observed upstream and downstream of the crossing. Evidence of degradation, including a small scour pool that was located approximately 15 m upstream of the crossing was located immediately downstream of a woody debris jam. This suggests flow is being impacted in the area by the debris jams, resulting in erosion. Exposed clay along the bed upstream of the crossing was also observed in the vicinity of the crossing inlet, which could also have resulted from changes in discharge.

Lesser evidence of aggradation and planimetric form adjustment were also observed. Evidence of aggradation was observed downstream of the crossing and included accretion on point bars. Evidence of planimetric form adjustment included poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

3.2.1.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to reach WC-35 where the watercourse crosses Old School Road.

- The culvert is a single-cell concrete box structure that is 5 m wide.
- The bankfull width at the crossing location was approximately 3 - 5 m.
- Bank erosion was observed upstream and downstream of the crossing.
- There was a large woody debris jam approximately 10 m upstream of the crossing. A scour pool was observed immediately downstream of the woody debris jam.
- A fallen tree was present approximately 5 m upstream of the crossing. It was oriented perpendicular to the channel.
- Sedimentation was observed downstream of the crossing along the left bank.
- There was exposed clay along the channel bed (bed degradation).
- The watercourse has access to the floodplain.

Limitations:

- The assessment was limited to the ROW.
- It could not be determined if the culvert was open or closed bottom.
- It could not be determined if the culvert was perched or undercut.

Key Findings:

- The woody debris jams are causing localized bed scour.

3.2.2 WC-34

3.2.2.1 Reach Characterization

The assessment of WC-34 was completed from the ROW due to PTE limitations. The feature flows southeast through a concrete box culvert (approximately 2.5 m wide) under Old School Road, then flows southeast for approximately 300 m where the downstream reach break occurs.

Based on the desktop assessment, the feature is a meandering channel with high sinuosity. It follows a low to moderate gradient and is located within a confined valley.

During the field assessment the bankfull width and depth were estimated to be approximately 1.0 m to 2.0 m, and 0.3 m to 0.6 m, respectively. On the day of the assessment, the wetted widths and depths ranged from approximately 1 m – 2 m and 0.05 – 0.1 m, respectively.

Near Old School Road, the channel has defined banks and a defined bed morphology consisting of riffles and pools. There is evidence of bed degradation with exposed clay along the channel bed observed. The bed substrate consisted of fines (silt, clay, and sand) to cobble-sized materials. The watercourse is confined with little to no access to the valley on the upstream (northwest) side. The surrounding vegetation is primarily trees and grasses, with limited shrubs present. Leaning and fallen trees were observed in the downstream channel. Erosion was observed at the culvert inlet along both banks. The culvert inlet is located at a meander bend. Flows are not centred through the culvert, which is causing erosion adjacent to the culvert inlet along the right (east) channel bank where the flow is directed

3.2.2.2 RGA Results

The RGA results for WC-34 should be interpreted with caution and may not be representative of the entire reach as the assessment was done from the ROW only. Results of the RGA indicate that there was minor evidence of degradation, channel widening, and planimetric form adjustment, but was overall in regime (stable). This rating applies to channels that have a morphology within a typical range of variance. Results of the RGA are presented in Table 3-3.

Table 3-3: WC-34 RGA Results

Reach	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-34	0.0	0.13	0.20	0.14	0.12	In Regime

Limited evidence of channel instability was noted. Evidence of channel widening included limited evidence of fallen/leaning tees, the presence of large organic debris, and exposed tree roots, as well as basal scour on both sides of the channel through a riffle feature. Bed

degradation was also observed, notably by the presence of exposed clay along the bed of the channel upstream of the crossing. Evidence of planimetric form adjustment included the presence of poorly formed/ removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

Because the RGA was limited to the ROW, it is also possible that the evidence of instability is over-represented in the RGA if the source of the instability is associated with the crossing under Old School Road. Based on field evidence, the watercourse had a bankfull width of approximately 3 – 5 m at the crossing, while the crossing had a span of 4 - 5 m (see crossing assessment for more details). Flow is not centred through the culvert, and this is resulting in erosion adjacent to the culvert inlet along the eastern channel bank. This is likely contributing to the evidence of instability noted during the RGA assessment. Another source of instability is also caused by anthropogenic alteration of the watercourse between 1974 and 1999. While the watercourse was adjusted greater than 25 yeas ago, the channel may still be adjusting to the change in channel planform and reduction of channel length upstream of the Old School Road crossing.

3.2.2.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to reach WC-34 where the watercourse crosses Old School Road.

- The culvert is a single-cell concrete box structure.
- The bankfull width was 3-5 m and the span was approximately 4-5 m wide.
- Bank erosion was observed upstream and downstream of the crossing.
- Bed degradation was observed upstream of the crossing with exposed clay present along the channel bed
- The culvert inlet is located at a meander bend. Flows are not centred through the culvert, which is causing erosion adjacent to the culvert inlet along the right (east) channel bank where the flow is directed.
- The watercourse has access to the floodplain.

Limitations:

- The assessment was limited to the ROW.
- It could not be determined if the culvert was open or closed bottom.
- It could not be determined if the culvert was perched or undercut.

Key Findings:

- There was bed degradation present upstream of the crossing which could be caused by the existing crossing, likely because flow is not centred through the existing culvert.

3.2.3 WC-33

3.2.3.1 Reach Characterization

The assessment of WC-33 was completed from the ROW due to PTE limitations. Based on the desktop and field assessment reach WC-33 is an ephemeral channel that begins as a straightened drainage swale that flows along the north side of Old School Road. The feature flows northeast then south through an approximately 1.3 m wide CSP culvert under Old School Road, then flows east for approximately 200 m until the downstream reach break occurs.

No flow was observed upstream of the crossing on the day of the assessment. The swale on the upstream side of the crossing is approximately 1 m wide and placed rip rap is present along the bottom. Stagnant water was present downstream of the crossing, with fines accumulated. The desktop assessment results indicate that the feature appears to become more defined further downstream of the crossing, however, due to PTE constraints this could not be confirmed in the field.

3.2.3.2 RGA Results

A RGA was not completed for Reach WC-33 due to the lack of a natural defined channel.

3.2.3.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to WC-33 where the feature crosses Old School Road.

- Crossing WC-33 consisted of a corrugated steel pipe (CSP) culvert with a span of approximately 1.3 m.
- There was no flow observed upstream of the crossing. Stagnant flow was observed in short sections within the culvert, at the outlet, and the downstream channel.
- There was minor erosion along the right (south) bank upstream of the crossing behind the culvert. This may be due to the steepness of the ditch wall and not erosion from flows in reach WC-33.
- There was placed rip rap (cobbles) along the bed upstream of the feature.
- Sedimentation was noted within the culvert.
- The channel was not defined directly downstream of the crossing.

Limitations:

- The assessment was limited to the ROW.

Key Findings:

- The existing crossing does not appear to be causing bed scour.

3.2.4 WC-13

3.2.4.1 Reach Characterization

The assessment of WC-13 was completed from the ROW due to PTE limitations. The feature flows northeast through a single-cell concrete arch structure (approximately 4 m wide), under the Orangeville-Brampton Railway (OBR), then flows northeast for approximately 600 m where the downstream reach break occurs.

Based on the desktop assessment, the feature has an intermittent hydraulic regime and is a well-defined sinuous to meandering feature that flows through a wooded area.

During the field assessment the bankfull width and depth were estimated to be approximately 1.5 m, however the bankfull width was wider near the crossing inlet (3.5 m). On the day of the assessment the wetted width was approximately 1 m, and wetted depth was approximately 0.2 m.

The watercourse had low banks that consisted of silt and muck. In-stream watercress vegetation was observed, indicating there are likely groundwater contributions to flow.

Upstream of the OBR crossing there was clay exposed along the channel bed. Siltation was noted in the pool feature upstream of the OBR crossing.

Downstream of the crossing, the left (north) bank wingwall has failed and collapsed within the channel, creating a debris jam. Sedimentation in response to the debris jam was observed.

3.2.4.2 RGA Results

The RGA results for WC-13 should be interpreted with caution and may not be representative of the entire reach as the assessment was done from the ROW. The results indicate that the reach is in a “Transitional or Stressed” state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-4.

Table 3-4: WC-13 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-13	0.14	0.25	0.29	0.23	0.23	Transitional/Stressed

The dominant process occurring within Reach WC-13 is channel widening. Evidence of channel widening included fallen/leaning trees, exposed roots, and basal scour on both sides of the channel through riffles. Channel degradation was also observed, which included the presence of a scour pool at the culvert outlet and exposed clay along the bed upstream of the crossing. Lesser evidence of planimetric form adjustment and aggradation were also noted. Evidence of planimetric form adjustment included the absence of bar forms (which is commonly observed in watercourses in Southern Ontario) and the channel's evolution from pool-riffle morphology to low bed relief form. Evidence of aggradation was only observed upstream of the crossing and included siltation along the channel bed.

Because the RGA was limited to the ROW, it is also possible that the evidence of instability is over-represented in the RGA if the source of the instability is associated with where the watercourse crosses the OBR corridor. Based on field evidence, the watercourse in general had a bankfull width of approximately 1.5 m, while the crossing had a span of 4 m (see crossing assessment for more details). Immediately upstream of the crossing, the bankfull width increases to 3.5 m before entering the culvert. The increase in bankfull width is likely a natural adjustment of the channel to accommodate 4 m wide crossing width through the culvert. Additionally, the left (north) downstream outlet wingwall has failed and collapsed within the channel. This has created a debris jam and is causing flow and sedimentation issues.

Channel widening typically occurs in response to instability in a watercourse, which is often influenced by changes in discharge, sediment load, morphological characteristics, and changes in flow regime. Based on the results of the historic assessment (see Section 2.5), sections of the channel were channelized prior to 1974. These straightened portions of the channel have become progressively more sinuous from 1974 to 2024. This suggests that the channel is still adjusting to the past anthropogenic alterations and potentially increased discharge resulting from wider catchment changes including upstream urbanization and surrounding agricultural fields.

3.2.4.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to WC-13 where the watercourse crosses the OBR corridor.

- The culvert is an approximately 4 m wide single-cell concrete arch structure with a closed bottom.
- The bankfull width was approximately 1.5 m but widened to 3.5 m at the crossing inlet where a pool is located.
- Wingwalls were present at the culvert inlet and outlet.
- The left (north) bank downstream wingwall has failed and collapsed within the channel, creating a debris jam and sedimentation issues.
- Bed degradation was observed upstream of the crossing.
- The watercourse is poorly defined directly downstream of the crossing structure.
- Siltation was observed upstream of the crossing and sedimentation was observed downstream of the crossing.
- The feature has access to the floodplain.

Limitations:

- The assessment was limited to the ROW.

Key findings:

- Bed degradation was present upstream and downstream of the crossing. It is likely associated with the failed and collapsed wingwall, which has created a debris jam and is causing sedimentation issues.

3.2.5 WC-12

3.2.5.1 Reach Characterization

The assessment of WC-12 was completed from the ROW due to PTE limitations. From the upper reach break, the feature flows northeast and crosses under the OBR through a 10 m wide open bottom metal bridge. The channel then curves and flows approximately 300 m east to the downstream reach break.

Based on the desktop assessment, the watercourse is a permanent feature which has been straightened in the past. The entire reach flows through a wetland complex.

During the field assessment the bankfull width was estimated to be approximately 3 – 4 m and the bankfull depth was estimated to be 0.5 m. On the day of the assessment the feature had a wetted width of 2 – 3 m and a wetted depth of 0.1 m. Flow was stagnant on the day of the assessment and the channel follows a low gradient.

The banks were 0.5 – 1 m high and were composed of muck and silt. Bank erosion was noted upstream of the OBR crossing along the right bank. The channel bed was composed of silt and sand. The watercourse appears to be entrenched, and clay was exposed along the channel bottom, although this is likely due to anthropogenic dredging of the channel bottom and not due to fluvial geomorphic processes.

Downstream of the OBR crossing riprap has been placed in the channel and along both banks. At the crossing, gabion protection was noted along the west (left) embankment.

3.2.5.2 RGA Results

The RGA results for WC-12 should be interpreted with caution and may not be representative of the entire reach as the assessment was completed from the ROW. Results of the RGA indicate that there was evidence of channel widening, planimetric form adjustment, and degradation, but was overall in regime (stable). This rating applies to channels that have a morphology within a typical range of variance. Results of the RGA are presented in Table 3-5.

Table 3-5: WC-12 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-12	0.00	0.13	0.29	0.14	0.14	In Regime/Stable

Limited evidence of instability was noted. The dominant process occurring within Reach WC-12 was channel widening. Evidence of channel widening included leaning and fallen trees and basal scour on the inside of meander bends and through >50% of the reach. Additional evidence of instability included exposed clay along the bed of the channel (degradation) however, this was attributed to anthropogenic alterations of the channel (i.e., likely due to suspected dredging of the channel bottom as part of the channel straightening between 1974 and 1999) and not due to fluvial geomorphic processes. Limited evidence of planimetric form adjustment was also noted (poorly formed bars) however this is not uncommon for watercourses in Southern Ontario.

Because the RGA was limited to the ROW, it is also possible that the evidence of instability is over-represented in the RGA if the source of the instability is associated with the crossing under the OBR. Based on field evidence, the watercourse had a bankfull width of approximately 3 – 4 m, while the crossing had a span of 10 m (see crossing assessment for more details).

The most likely source of instability in the channel is due to anthropogenic alteration. The results of the historic assessment (see Section 2.5) indicate that there have been significant past changes to the channel. Upstream (west) of the OBR corridor the channel had been straightened prior to 1974. Following this, between 1974 and 1999 the remainder of the reach was straightened. While the watercourse was adjusted more than 25 yeas ago, the channel may still be impacted by the anthropogenic change in channel planform and reduction of channel length.

3.2.5.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations relating to reach WC-12 where the watercourse crosses the OBR corridor:

- The structure is an approximately 10 m wide open bottom metal bridge.
- There was placed rip rap erosion protection and gabion embankment protection on the downstream side of the water crossing.
- The entrenchment and exposed clay appear to be due to anthropogenic dredging of the channel bottom and not due to fluvial geomorphic processes.
- The channel has been artificially straightened. It lacks a defined bed morphology.
- The watercourse has access to the floodplain.

Limitations:

- The assessment was limited to the ROW.

Key Findings:

- There was exposed clay which typically indicates bed scour has occurred however, field observations suggest that the exposed clay is suspected to be due to anthropogenic dredging of the channel bottom as part of the channel widening that occurred between 1974 and 1999 and not due to fluvial geomorphic processes.

3.2.6 WC-04

3.2.6.1 Reach Characterization

Reach WC-04 is an unconfined and well-defined watercourse, beginning approximately 100 m upstream of Vodden Street East, flowing southeast for approximately 500 m, until the downstream reach break. The Vodden Street East crossing is an open bottom culvert with a span of approximately 10 m. The watercourse follows a meandering planform and a low gradient.

During the field assessment the bankfull width and depth ranged from approximately 6 – 8 m and 0.5 m, respectively. On the day of the assessment, the wetted widths and depths ranged from approximately 5 m – 6 m and 0.05 – 0.1 m, respectively. The channel had a well-defined bed morphology consisting of riffles and runs with minimal pools due to the limited bends in the reach.

Bank heights ranged from approximately 0.5 – 1.5 m and were composed of fines, muck, and silt where exposed. The channel was entrenched in areas, especially along the right (west) bank. The bed substrate consisted of clay, fines and gravels to cobbles and small boulders. Bed and bank erosion were observed throughout the reach and included bank undercutting, bank slumping, and exposed clay along the bed.

Near the upstream end of the reach, there was a large (approximately 1 m diameter) outfall along the left (north) bank. The outfall was slightly perched (approximately 0.2 m) with a scour pool downstream. Erosion along the outfall channel was observed, with rock bank protection failing and displaced.

Directly upstream of the Vodden Street East crossing, there were large amounts of woody debris due to fallen trees. Sediment accumulation (cobbles) was also noted through the culvert crossing. Directly downstream of the Vodden Street East crossing, there are two outfalls present. The outfalls are located on the left and right bank and are approximately 0.5 m in diameter. Evidence of erosion associated with these outfalls was observed.

The riparian buffer zone was continuous and dominated by grasses with shrubs and trees.

3.2.6.2 RGA Results

The results of the RGA for WC-04 indicate that the reach is in a “Transitional or Stressed” state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-6.

Table 3-6: WC-04 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-04	0.27	0.27	0.69	0.08	0.33	Transitional/Stressed

The dominant process occurring within Reach WC-04 is channel widening. Evidence of channel widening was widespread and included: leaning and fallen trees, the presence of large woody debris, exposed tree roots, basal scour on both sides of the channel through riffles, and basal scour through >50% of the reach. In addition, there were also fracture lines on the top of the banks where there was undercutting. There was lesser evidence of aggradation and

degradation. Evidence of aggradation included siltation in pools, accretion on point bars and deposition in the overbank zone. Sedimentation (accumulation of cobbles) was present through the crossing structure and water spanned the entire width of the crossing (i.e., no low flow channel). Evidence of degradation included scour pools downstream of stormwater outflows directly downstream of the Vodden Street East crossing. In some sections, the channel also had eroded into the underlying clay layer and even into bedrock, with shale fragments transported downstream. Minor evidence of planimetric adjustment was also noted but was limited to poorly formed bars, a feature commonly observed in watercourses across Southern Ontario.

Based on field evidence, the watercourse has a bankfull width of approximately 6 – 8 m, while the crossing has a span of 10 m (see crossing assessment for more details). The stormwater outfalls downstream of the Vodden Street East crossing are likely contributing to bed degradation downstream of the crossing.

The results of the historic assessment (see Section 2.5) suggest that the channel was straightened upstream of Vodden Street East prior to 1999. The historical assessment was limited due to poor imagery but the surrounding land use in 1999 was primarily residential and industrial with no significant changes in planform or land use since. While the watercourse was modified over 25 years ago, the channel may still be adjusting to the altered planform and reduced length caused by straightening. Similarly, it may be responding to changes in the flow regime resulting from urban development in the area, which also occurred more than 25 years ago.

3.2.6.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to the WC-04 where the watercourse crosses Vodden Street East.

- The culvert is a single-cell ellipse-shaped concrete structure that is approximately 10 m wide and has an open bottom.
- The bankfull width of the channel is approximately 6 – 8 m.
- Wingwalls are present at the culvert inlet and outlet.
- There are two outfalls present (one on each bank) directly downstream of the culvert outlet. Minor erosion was noted to be associated with each culvert.
- Sedimentation (accumulation of cobbles) was present through the crossing structure, which may be causing flow issues.
- Heavy bank erosion was present along both banks upstream and downstream of the crossing structure.

- Woody debris accumulation and leaning trees were present approximately 5 m upstream of the crossing structure.
- The watercourse is entrenched in areas and disconnected from the floodplain.

Key Findings:

- Bed degradation (scour pools) were observed directly downstream of the Vodden Street East crossing and was associated with two outfalls. While the crossing itself does not appear to be causing bed scour, the outfalls do appear to be and flow dissipation should be considered to reduce the impacts of scour.
- Because the watercourse is disconnected from its floodplain, more flow needs to be contained within the channel itself, which could result in increased peak flows and velocities within the channel and potentially more intense flooding.
- The existing Etobicoke Creek Sanitary Trunk Sewer runs parallel to the east bank. A connection to the proposed Kennedy Road Sanitary Sewer along with a diversion chamber is required on the south side of Vodden Street East.

3.2.7 WC-02

3.2.7.1 Reach Characterization

The assessment of WC-02 was completed from the ROW due to PTE limitations. During the field assessment no watercourse feature was visible from Kennedy Road South. It is likely that at this location the feature is piped underground and outlets further downstream. Due to PTE limitations, this feature could not be assessed.

3.2.7.2 RGA Results

No RGA was completed for this reach as no defined feature was observed.

3.2.7.3 Crossing Assessment

No crossing assessment was completed for this reach as no crossing was observed from Kennedy Road South.

3.2.8 WC-10

3.2.8.1 Reach Characterization

The assessment of WC-10 was completed from the ROW due to PTE limitations. In some areas, the feature was difficult to access due to fences restricting access. The reach is a drainage ditch that begins at Mayfield Road and flows to the southeast, parallel to the OBR corridor for approximately 1 km until it discharges into a stormwater pond north of Wanless Drive. There

are several stormwater outfalls present along the OBR corridor that contribute flow to the reach.

During the field assessment it was identified that the feature is an ephemeral straightened swale that occurs within a constructed ditch/ valley with 3 m high walls. It was dry on the day of the assessment and contained abundant in-channel vegetation (shrubs, grasses, phragmites).

3.2.8.2 RGA Results

A rapid geomorphic assessment was not completed for Reach WC-10 due to the lack of a natural defined channel. No evidence of erosion was noted during the field reconnaissance.

3.2.8.3 Crossing Assessment

A crossing assessment was not completed at WC-10 as the reach does not cross a roadway.

3.2.9 WC-08

3.2.9.1 Reach Characterization

Reach WC-08 is an unconfined and well-defined watercourse. The upstream reach break begins approximately 100 m upstream (northwest) of Bovaird Drive West. The feature flows southeast through a close bottom culvert (approximately 12 m wide) under Bovaird Drive West, then flows southeast for approximately 900 m, where the downstream reach break occurs. Downstream of the crossing the watercourse follows a meandering planform and has a low to moderate gradient. The reach is identified by the aquatics team as being regulated Redside Dace (RSD) habitat.

During the field assessment the bankfull width and depth were identified to range from approximately 4 – 10 m and 0.5 – 1 m, respectively. On the day of the assessment, the wetted widths and depths ranged from approximately 3 – 10 m and 0.05 – 0.3 m, respectively. The channel had a well-defined bed morphology consisting of riffles and pools.

Approximately 10 m downstream of the Bovaird Drive West crossing, live stake restoration consisting of conifer trees and log treatments was present on the right bank along the first outer meander bend. Bed and bank erosion were observed, including left and right bank undercutting, bank slumping, and exposed clay along the bed, which is likely being targeted by the channel restoration efforts.

Bank heights ranged from approximately 1 – 2 m and were composed of fines and muck where exposed. The channel was entrenched in some areas. Bed substrate consisted of clay, fines and gravels to cobbles and small boulders. The majority of the cobble-sized material appears to have been placed as part of the restoration efforts within this reach.

Adjacent to the Bovaird Drive West crossing outlet, there was a large (approximately 1 m diameter) outfall along the left (east) bank. The outfall was slightly perched (approximately 0.1 m) and a small scour pool was observed directly downstream of the outfall. Erosion along the left bank adjacent to the outfall was also observed, and debris accumulation was present at the outfall.

The riparian buffer zone was continuous and dominated by grasses, with shrubs and trees. Woody debris was present along channel banks, and deposition in the overbank zone was observed.

3.2.9.2 RGA Results

The results of the RGA for WC-08 indicate that the reach is in a "Transitional or Stressed" state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-7.

Table 3-7: WC-08 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-08	0.33	0.33	0.38	0.17	0.30	Transitional/Stressed

The dominant process occurring within Reach WC-08 is channel widening. Evidence of channel widening included fallen trees and exposed tree roots, large organic debris, basal scour inside meander bends and though >50% of the reach. Abundant evidence of aggradation and channel widening was also observed. Signs of aggradation included coarse material embedded in riffles, siltation in pools, and deposition in the overbank zone. Indicators of degradation included exposed clay on the bottom of the channel, the presence of a visible suspended armor layer, and scour pools located downstream of elevated stormwater outfalls. Lesser evidence of planimetric form adjustment was also observed. This evidence included chutes and the presence of poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

Approximately 10 m downstream of the Bovaird Drive West crossing, live stake restoration was observed at the location where bed and bank erosion were noted (bank undercutting, slumping, and exposed clay). The erosion is likely being targeted by the channel restoration efforts.

Based on field evidence, the watercourse had a bankfull width of approximately 6 - 10 m at the crossing, while the crossing had a span of 12 m (see crossing assessment for more details).

The results of the historic assessment (see Section 2.5) suggest that the channel was straightened upstream of Bovaird Drive West prior to 1974. Only partial imagery was attainable for 1974 and the downstream section of the reach was cut off. Since 1974 no significant planform changes were observed but there was extensive residential development in the surrounding area between 1974 and 2015. While the watercourse was modified over 25 years ago, the channel may still be adjusting to the altered planform and reduced length caused by straightening. Additionally, it is likely responding to changes in the flow regime resulting from urban development in the area, which has been extensive between 1974 and 2015.

3.2.9.3 Crossing Assessment

To assess the impacts that the existing crossing has on channel scour (as per CVC, 2012 and TRCA, 2015), a crossing assessment was performed. The following summarizes key observations related to the WC-08 where the watercourse crosses Bovaird Drive W.

- The crossing is a concrete arch culvert with an open bottom. Crossing span of approximately 12 m.
- The bankfull width in the vicinity of the crossing ranged from 6 to 10 m.
- The water depth was approximately 0.05 m through the crossing structure.
- Bank erosion was noted throughout the reach (including upstream and downstream of the crossing).
- A scour pool was noted at the culvert inlet at a possibly over widened meander bend. The pool contained soft sediment aggradation.
- There was a stormwater outfall adjacent to the crossing.
  - A scour pool was present immediately downstream of the stormwater outfall.
- Sediment was partially embedded at the culvert.
- The watercourse is disconnected from its floodplain.

Key Findings:

- A scour pool was present at an over widened portion of the meander bend as well as downstream of a stormwater outfall. While the crossing itself does not appear to be causing bed scour, the outfall appears to be and flow dissipation should be considered to reduce the impacts of scour.
- Because the watercourse is disconnected from its floodplain, more flow needs to be contained within the channel itself, which could result in increased peak flows and velocities within the channel and potentially more intense flooding.

- The existing Fletchers Creek Sanitary Trunk Sewer runs parallel to the east bank. A connection to the proposed Kennedy Road Sanitary Trunk Sewer along with a diversion chamber is required on the south side of Bovaird Drive West.

3.2.10 WC-07

3.2.10.1 Reach Characterization

The feature is a permanent, artificially straightened feature that begins south of Bovaird Drive West at a 0.5 m wide concrete box culvert. It follows a low channel gradient and is surrounded by grasses, phragmites, and shrubs.

The field assessment identified that the bankfull width of the feature ranged from 1 – 1.5 m, with a bankfull depth of 0.3 – 0.5 m. On the day of the assessment the wetted width was 0.5 – 1 m, and the wetted depth was 0.1 - 0.2 m. Flow was stagnant on the day of the assessment.

The feature had 0.5 m high channel banks that were composed of silt and muck. It's located in a confining valley with walls 2 m high and is entrenched. There was no access to the floodplain.

Bed substrate consisted of fines to gravel sized fragments with small boulders.

3.2.10.2 RGA Results

Results of the RGA for WC-07 indicate that there was evidence of channel widening, planimetric form adjustment, and degradation, but was overall in regime (stable). This rating applies to channels that have a morphology within a typical range of variance. Results of the RGA are presented in Table 3-8.

Table 3-8: WC-07 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-07	0.00	0.14	0.33	0.14	0.15	In Regime/Stable

The dominant process occurring within Reach WC-07 is channel widening. Evidence of channel widening included basal scour on both sides of the channel through riffles and in >50% of the reach as well as fracture lines on the top of the bank. Lesser evidence of instability observed in the field included degradation and planimetric adjustment. Evidence of degradation included the channel being worn into the overburden. Evidence of planimetric form adjustment included poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

Channel widening typically occurs in response to instability in a watercourse, which is often influenced by changes in discharge, sediment load, morphological characteristics, and changes in flow regime. Based on the results of the historic assessment (see Section 2.5) the feature, a sinuous drainage ditch, was channelized and straightened sometime between 1970 and 1999. From 1999 to 2024 the surrounding land use has become increasingly urbanized, and the planform became slightly more sinuous.

3.2.10.3 Crossing Assessment

A crossing assessment was not completed for WC-07 as the upstream reach break is located downstream of the Bovaird Street West crossing.

3.2.11 WC-06a

3.2.11.1 Reach Characterization

The feature is a permanent, artificially straightened watercourse that begins downstream of WC-07. The upstream reach break is marked by a change in riparian vegetation to dense shrubs and phragmites. The feature flows to the southeast.

The field assessment identified that the bankfull width of the feature is approximately 1.5 – 2 m and the bankfull depth of 0.2 – 0.4 m. On the day of the assessment the wetted width was approximately 1 m, and the wetted depth was approximately 0.1 – 0.2 m. The bed substrate ranged from silt/clay sized material to large boulders.

The feature is entrenched and located in a confining valley with walls 2 m high. There was no access to the floodplain.

Bank erosion was observed throughout the reach. A constructed riffle was identified near the upstream end of the reach, which consisted of cobbles and boulders.

3.2.11.2 RGA Results

The results of the RGA for WC-06a indicate that the reach is in a “Transitional or Stressed” state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-9.

Table 3-9: WC-06a RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-06a	0.17	0.13	0.54	0.14	0.24	Transitional / Stressed

The dominant process occurring within Reach WC-06a is channel widening. Evidence of channel widening included fallen/leaning trees, exposed tree roots, fracture lines on the top of bank, and basal scour on both sides though riffles, and basal scour through >50% of the reach. Other evidence of instability observed in the field included evidence of aggradation (coarse material embedded in riffles and poor sorting of bed materials), degradation (scour pools located downstream of culvert outfalls), and planimetric form adjustment. Evidence of planimetric form adjustment included poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario. Lesser evidence of instability included degradation as evidenced by scour pools downstream of stormwater outfalls and incision of the channel into the underlying clay.

Based on the results of the historic assessment (see Section 2.5) the feature, a sinuous drainage ditch, was channelized and straightened sometime between 1970 and 1999. From 1999 to 2024 the surrounding land use became increasingly urbanized, but there have been no significant changes in planform. While the watercourse was modified over 25 years ago, the channel may still be adjusting to the altered planform and reduced length caused by straightening. Similarly, it may be responding to changes in the flow regime resulting from urban development in the area, which occurred more recently.

3.2.11.3 Crossing Assessment

A crossing assessment was not completed for WC-06a as the reach does not cross a roadway.

3.2.12 WC-06

3.2.12.1 Reach Characterization

The feature is a permanent, artificially straightened feature that begins downstream of WC-06a. The upstream reach break is marked by a change in riparian vegetation where feature becomes surrounded by dense woody vegetation. The feature flows to the southeast.

The field assessment identified that the bankfull width of the feature is approximately 2.5 – 3.0 m wide with a bankfull depth of 0.5 m. On the day of the assessment the wetted width was approximately 1 m, and the wetted depth was approximately 0.1 – 0.2 m. Bed substrate ranged from silt/clay sized material to large boulders. Woody debris was noted along the channel banks throughout the reach. There was a sunken concrete stormwater outfall within the reach.

The watercourse is located in a confining valley with walls 2 m high and is entrenched. The feature has no access to the floodplain.

3.2.12.2 RGA Results

The results of the RGA for WC-06 indicate that the reach is in a "Transitional or Stressed" state. This indicates that channel morphology is within a typical range of variance, but that evidence of instability is frequent. Results of the RGA are presented in Table 3-10.

Table 3-10: WC-06 RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-06	0.23	0.00	0.60	0.14	0.24	Transitional/ Stressed

The dominant process occurring within Reach WC-06 is channel widening. Evidence of channel widening included fallen/leaning trees, large organic debris, exposed tree roots, fracture lines on the top of bank, and basal scour on both sides though riffles and basal scour through >50% of the reach and armour stone out flanked. Other evidence of instability observed in the field included aggradation (coarse material embedded in riffles and siltation in pools) and planimetric adjustment. Evidence of planimetric form adjustment was limited to poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

Based on the results of the historic assessment (see Section 2.5) the feature was channelized and straightened sometime between 1970 and 1999 and the planform has remained stable since. From 1970 to 2005 the surrounding land use became increasingly urbanized, with no significant changes in land use since 2005. While the watercourse was modified over 25 years ago, the channel may still be adjusting to the altered planform and reduced length caused by straightening. The feature may also be responding to changes in the flow regime resulting from changes in the surrounding land use, in particular urban development, which occurred prior to 2005.

3.2.12.3 Crossing Assessment

A crossing assessment was not completed for WC-06 as the reach does not cross a roadway.

3.2.13 WC-05a

3.2.13.1 Reach Characterization

The feature is a permanent, artificially straightened watercourse that begins downstream of WC-06 where an outfall contributes flow to the watercourse and where the watercourse becomes influenced by beaver activity. The feature flows to the southeast.

The field assessment identified that the bankfull width of the feature is approximately 4 to 8 m wide with a bankfull depth of 0.3 to 1.0 m. On the day of the assessment the wetted width was approximately 2 to 6 m, and the wetted depth was approximately 0.1 m. Flow was stagnant on the day of the assessment. Bed substrate ranged from silt/clay sized material to boulders.

Bank height was estimated at approximately 0.2 to 0.4 m high. The feature is located in a confining valley with walls 1.5 to 2 m high and is entrenched. The watercourse has no access to the floodplain.

At the upstream end of the reach, armourstone has been placed along both banks along a distance of approximately 100 m. In some areas, the armourstone has failed and has been displaced within the channel. An additional two areas of armourstone were identified within the reach. Each section was approximately 10 m long and was located proximal to stormwater outlets.

There were debris jams in multiple locations (attributed to beaver activity) within the reach that are contributing to backwatering.

3.2.13.2 RGA Results

Results of the RGA for WC-05a indicate that there was evidence of channel widening, planimetric form adjustment, degradation, and aggradation, but was overall in regime (stable). This rating applies to channels that have a morphology within a typical range of variance. Results of the RGA are presented in Table 3-11.

Table 3-11: WC-05a RGA Results

Reach ID	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Form Adjustment		
WC-05a	0.14	0.14	0.26	0.14	0.17	In Regime/Stable

The dominant process occurring within Reach WC-05a is channel widening. Evidence of channel widening included basal scour on both sides of the channel through riffles and in >50% of the reach as well as large organic debris and outflanking of armourstone. Other evidence of instability observed in the field included aggradation (siltation in pools), degradation (scour

pools located downstream of stormwater culverts) and planimetric adjustment. Evidence of planimetric form adjustment included poorly formed/removed bar forms throughout the reach, which is commonly observed in watercourses in Southern Ontario.

Based on the results of the historic assessment (see Section 2.5), prior to 1970 the feature was poorly defined and occurred as a series of short sections of ponded water. The feature was channelized and straightened sometime between 1970 and 1999 and the planform has remained stable since. From 1970 to 2005 the surrounding land use became increasingly urbanized, with no significant changes in land use since 2005. Sections of pooled water are present in 2015 imagery and may be due to impoundment, flows from urbanization or due to the time of year the imagery was taken. Despite being modified over 25 years ago, the channel may still be adjusting to the altered planform and reduced length caused by straightening. The feature may also be responding to changes in the flow regime resulting from changes in the surrounding land use, in particular urban development, which occurred prior to 2005.

3.2.13.3 Crossing Assessment

A crossing assessment was not completed for WC-5a as the reach does not cross a roadway.

3.2.14 WC-05

3.2.14.1 Reach Characterization

The feature is a permanent, artificially straightened feature that begins downstream of WC-05a. The upper reach break corresponds with where the channel becomes lined with concrete just upstream of Williams Parkway. The feature flows southeast through the crossing then immediately curves and flows southwest to the downstream reach break.

The field assessment identified that the channel width is approximately 2 to 3 m wide with depth of 0.4 m (not a true bankfull). On the day of the assessment the wetted width was approximately 1 m, and the wetted depth was approximately 0.1 to 0.2 m. The reach is completely lined with concrete banks that were approximately 3 m tall.

Sedimentation within the Williams Parkway culvert was noted in the field.

Debris jams in the reach are causing backwatering and can likely be attributed to beaver activity.

3.2.14.2 RGA Results

No RGA was completed at WC-05, as it was a concrete lined channel.

3.2.14.3 Crossing Assessment

A crossing assessment was not completed for WC-05 as the watercourse is completely lined with concrete.

4. Channel Definition

4.1 Field Reconnaissance Observations

The type of channels within the Study Area ranged from well-defined to poorly defined and included some watercourses that have been modified in the past. Watercourses were classified as “defined” when channel banks were clearly discernible in the field, indicative of a concentration of flow that is sufficient to erode and transport sediment. A defined channel section can occur along an otherwise undefined or poorly defined reach and coincide with the presence of vegetation (i.e., grassy hedgerow) and tile drains, which suggests that local effects can alter channel-forming processes.

While the nuances of a given channel’s form are determined by site-specific influences, all streams with well-defined channel forms generally self-develop through shear-related processes rather than external controls such as vegetation. Channel form is intimately and intricately associated with channel morphology or boundary material resistance, the physical characteristics of the sediment load, and Stream Energy (specific stream power) (Aquafor Beech 2006).

A number of the channels within the Study Area were identified to be undefined features. Most of these undefined features were identified to be headwater drainage features at the upper end of the watershed. Headwater features are non-permanently flowing drainage features with flows that are most active during the spring thaw season or during or after large precipitation events. Their flow paths occur along topographic lows but the flow generally lacks the energy to scour into a distinct channel except on steep slopes (Irwin et al. 2013). Consequently, erosion rates and meander belt widths were not calculated for these features. Table 4-1 contains a summary of channel width characteristics.

4.1.1 Channel Definition from Survey

Two watercourses were accessible through public access. For these two watercourses (WC-04 and WC-08) detailed cross-sections including a longitudinal profile of the channel thalweg (deepest point of the channel) and cross-sections that extended beyond the top of bank were collected. The data was used to refine the cross-sectional geometry and was used to inform the erosion threshold assessment and scour assessment as per regulatory policies and guidelines (CVC, 2019; CVC, 2012, and TRCA, 2012). A minimum of five cross-sections were collected as per CVC, 2012 and TRCA, 2012, to collect an accurate representation of the channel geometry. As noted above both WC-04 and WC-08 include existing Etobicoke Creek and Fletchers Creek Sanitary Trunk Sewers, respectively which will be connected to the new Kennedy Road Sanitary

Trunk Sewer. Detailed cross-sections will be reviewed and considered in the preliminary design stage.

Table 4-1: Summary of Channel Characteristics

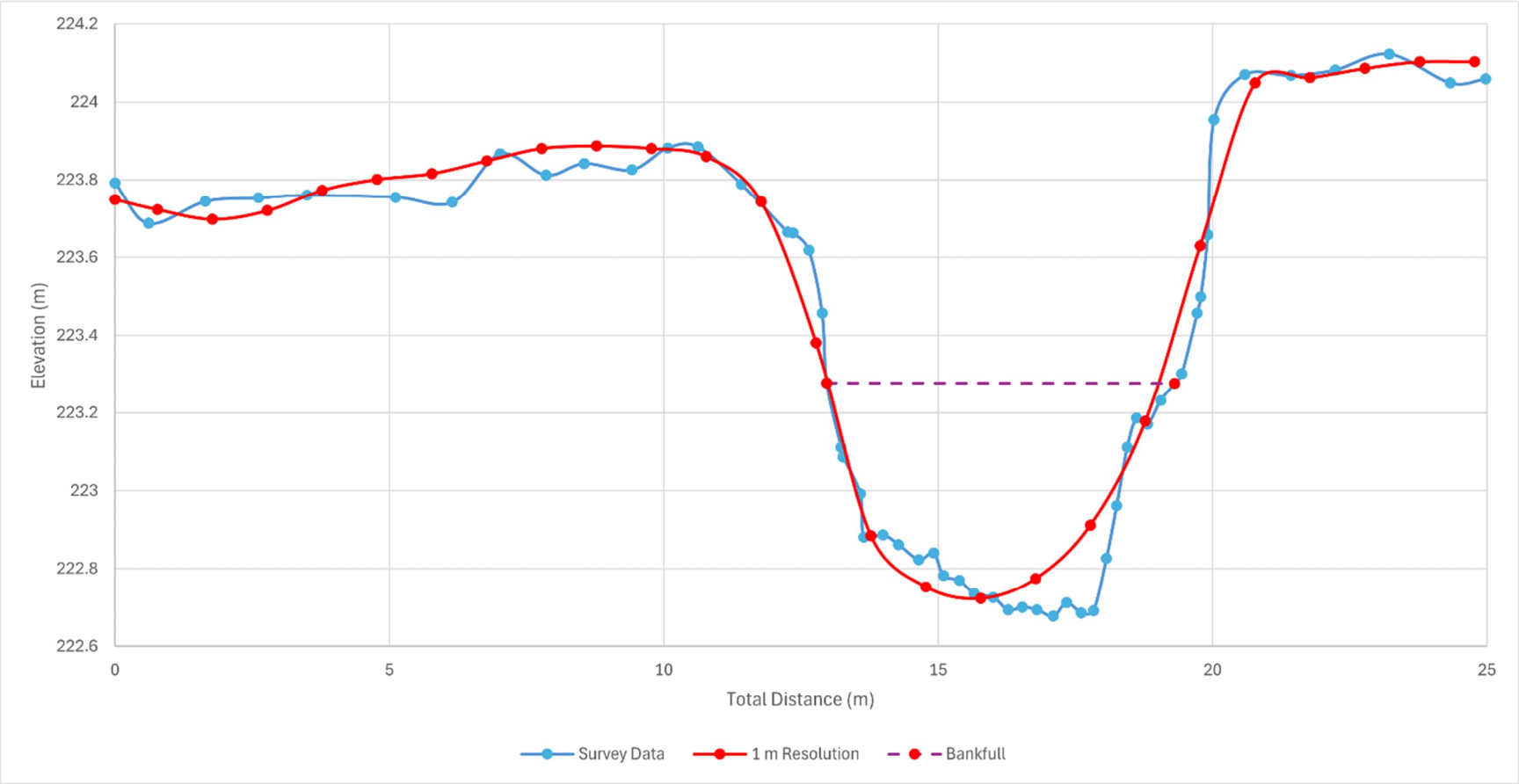
Watercourse ID	Channel Definition	PTE	Field Observations		Surveyed Cross-sections			Lidar Observations					Channel Alteration (e.g., Dredging, straightening, hardening)
			Bankfull Width (Approximate observed in field)	Bankfull Depth (Approximate observed in field)	Bankfull Width (m)	Average Bankfull Depth (m)	Maximum Bankfull Depth (m)	Lidar Details	# of Cross-sections for Analysis	Approximate Channel Width (m)	Approximate Average Channel Depth (m)	Approximate Maximum Channel Depth (m)	
WC-35	Defined	Roadside Survey	1.5 – 4.0	0.3 – 0.8	N/A	N/A	N/A	2023 TRCA Lidar (0.5 m resolution)	10	3.90	0.11	0.18	None
WC-34	Defined	Roadside Survey	1.0 – 2.0	0.3 – 0.6	N/A	N/A	N/A	2023 TRCA Lidar (0.5 m resolution)	10	2.11	0.06	0.10	Altered between 1974 and 1999
WC-33	Swale	Roadside Survey	No Defined Channel	No Defined Channel	N/A	N/A	N/A	2023 TRCA Lidar (0.5 m resolution)	10	2.5 (Approximate Channel Width)	0.13 (Approximate Average Channel Depth)	0.20 (Approximate Maximum Channel Depth)	Altered between 1974 and 1999
WC-13	Defined	Roadside Survey	Upstream: 1.5 – 3.5 Poorly defined downstream	Upstream: 0.2 Poorly defined downstream	N/A	N/A	N/A	2023 TRCA Lidar (0.5 m resolution)	10	2.86	0.06	0.11	Likely straightened prior to 1974
WC-12	Defined	Roadside Survey	3 – 4	0.5	N/A	N/A	N/A	2023 TRCA Lidar (0.5 m resolution)	10	5.29	0.10	0.18	A large portion of the reach was straightened prior to 1974. The remaining portion straightened between 1974 and 1999.
WC-04	Defined	Channel Survey	8	0.4 – 0.8	11.04	0.67	0.87	Surveyed	N/A - Used Survey Data				A portion of the reach was lightly straightened prior to 1999.
WC-02	No Feature - Piped	Roadside Survey	No Defined Channel	No Defined Channel	N/A	N/A	N/A	NA	N/A - Channel Note Defined				The reach is an urban drainage ditch that was likely straightened prior to 1999. Between 2015 and 2024 the feature was piped and only a 115 m section of channel can be observed in aerial imagery.
WC-10	Swale	Roadside Survey	No Defined Channel	No Defined Channel	N/A	N/A	N/A	NA	N/A - Channel Note Defined				The flow was redirected from agricultural fields west of the OBR corridor into a drainage swale parallel to the OBR corridor between 2005 and 2015
WC-08	Defined	Channel Survey	4 - 10	0.5 – 1.0	5.93	0.43	0.60	Surveyed	N/A - Used Survey Data				The reach was likely straightened prior to 1970.
WC-07	Defined	Roadside Survey	1.0 – 1.5	0.3 – 0.5	N/A	N/A	N/A	2019 Lidar (1 m resolution)	5	2.04	0.05	0.09	The feature was channelized between 1970 and 1999.
WC-06a	Defined short	Roadside Survey	1.0 – 1.5	0.3 – 0.5	N/A	N/A	N/A	2019 Lidar (1 m resolution)	5	1.45	0.02	0.05	The feature was channelized between 1970 and 1999.
WC-06	Defined	Roadside Survey	2.0	0.2	N/A	N/A	N/A	2019 Lidar (1 m resolution)	10	2.32	0.04	0.08	The feature was channelized between 1970 and 1999.
WC-05a	Defined	Roadside Survey	10.0	0.8	N/A	N/A	N/A	2019 Lidar (1 m resolution)	6	9.44	0.38	0.66	The feature was channelized between 1970 and 1999.
WC-05	Concrete Defined	Roadside Survey	10.0	0.8	N/A	N/A	N/A	2019 Lidar (1 m resolution)	5	10.38	0.09	0.13	Feature fully lined with concrete prior to 1999.

4.1.2 Channel Definition from DEM

Due to the absence of permissions to entry, field work was limited to observations from the Right of Way (ROW) and surrounding road networks. To supplement the field observations, channel width measurements were also taken from the publicly available Digital Elevation Model (DEM) from the National Hydro Network. This ensured that an approximate channel width could be collected further upstream and downstream than was possible during the field reconnaissance visit. Where possible, at least 10 cross-sections were taken upstream and downstream of the proposed crossing location.

It should be noted that there are challenges to using Lidar-derived DEMs for cross-sectional analysis. Typically, bankfull indicators are identified in the field, which are used to define bankfull characteristics. When using cross-sections taken from Lidar, no bankfull indicators can be identified and therefore, general cross-sectional shape must be used to get an approximate channel shape. The data obtained from Lidar can be used to supplement field observations but should not be used in place of traditional methods. Additionally, since Lidar cannot penetrate far into water it may not be possible to get accurate cross-sections for reaches with water depths exceeding certain depths. There are also issues with DEM resolution. The available Lidar data for this project has a resolution of 0.5 m and 1 m, depending on the dataset, which is not as detailed as channel surveying. The result is a more generalized and flattened profile which may underestimate the channel width (see Figure 4-1). The lower the resolution, the more generalized and flattened the shape becomes. This is why the approximate channel depth is much smaller than the bankfull depth observed in the field in Table 4-1. Finally, while aerial imagery can be used to help pinpoint the location of key features like waters edge, it has limited use in heavily vegetated areas and slight offsets between the Lidar and aerial imagery mean it can be difficult to corroborate the two data sets.

Figure 4-1: Comparison of Survey Data vs. 1 m Resolution Data for WC-08 (XS-5)



5. Channel Geometry and Bankfull Hydraulics

5.1 Cross-sectional Analysis

Cross-sections were collected for the two watercourses that could be accessed through public areas (see Figure 5-1 and Figure 5-2).

5.1.1 WC-04

A total of six cross-sections were collected for WC-04. Three cross-sections (XS-1, XS-2, and XS-3) were collected upstream of Vodden Street East and three cross-sections (XS-4, XS-5, and XS-6) were also collected downstream. An overview of channel dimensions is provided in Table 5-1.

Overall, the results indicate that the channel has an average bankfull width of 11.04 m and an average bankfull depth of 0.67 m. The channel is slightly wider at riffle features and also has a higher bankfull width:depth ratio at these locations. Studies have shown that a ratio value of approximately 12 is the most frequently observed value (U.S Environmental Protection Agency, 2023).

The bankfull characteristics indicate that the feature has an average bankfull discharge of 6.77 m^3/s, and an average bankfull velocity of 0.78 m/s.

Table 5-1: Overview of Existing Chanel Dimensions and Hydraulics for WC-04

Parameter	Cross-section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	Average
	Feature:	Riffle	Run	Run	Riffle	Riffle	Run	
Bankfull Width (m)		10.50	9.51	10.49	13.63	11.56	10.53	11.04
Average Bankfull Depth (m)		0.63	0.66	0.81	0.52	0.66	0.73	0.67
Maximum Bankfull Depth (m)		0.87	0.81	0.98	0.80	0.82	0.95	0.87
Bankfull Width:Depth		16.72	14.30	13.02	26.41	17.58	14.51	17.09
Cross-sectional Area (m^2)		6.60	6.32	8.46	7.03	7.60	7.64	7.27
Bankfull Discharge (m^3/s)		6.16	5.70	8.52	6.00	6.85	7.36	6.77
Average Bankfull Velocity (m/s)		0.77	0.74	0.86	0.68	0.81	0.80	0.78

5.1.2 WC-08

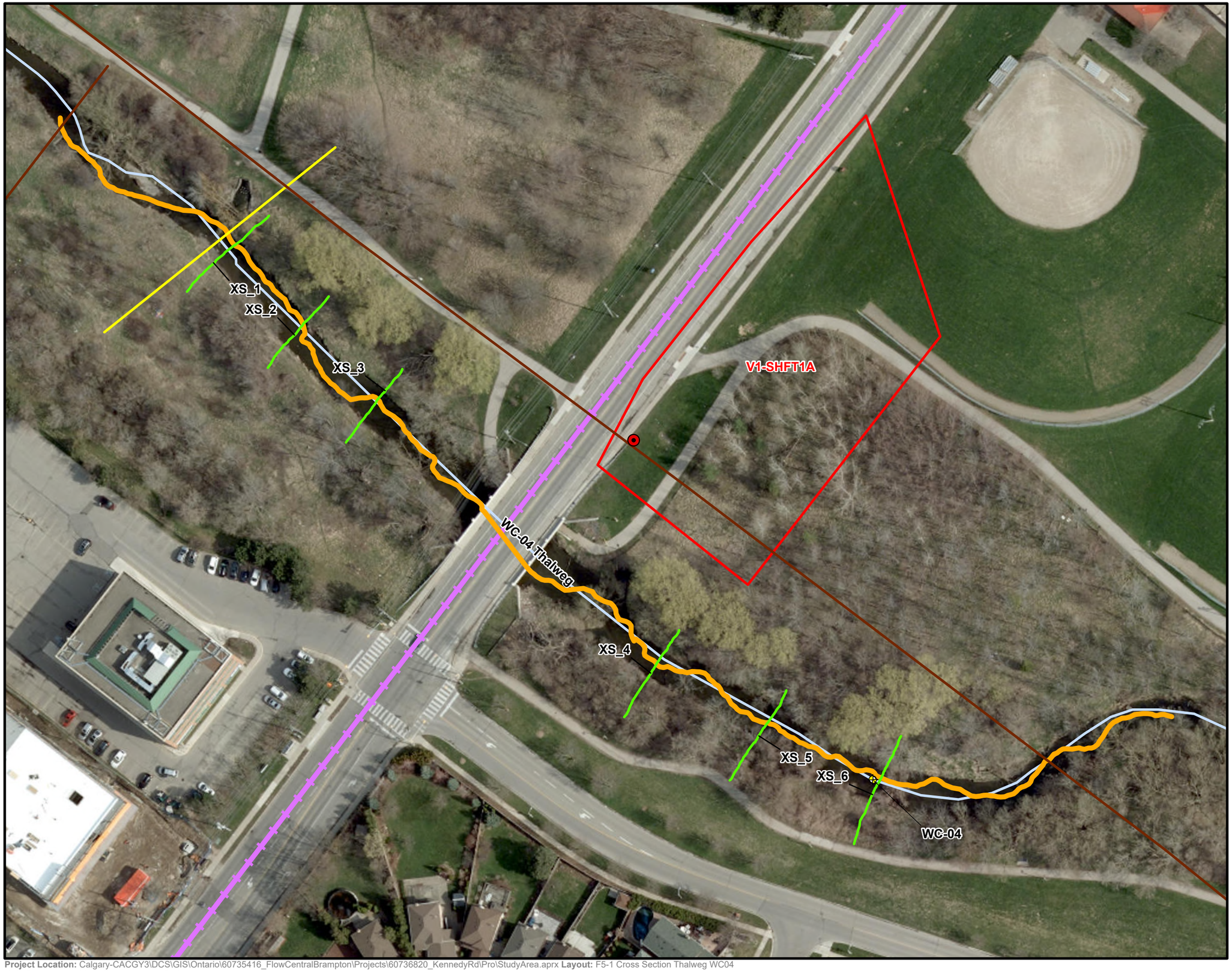
A total of six cross-sections were collected for WC-08. Three cross-sections (XS-1, XS-2, and XS-3) were collected upstream of Bovaird Drive West and three cross-sections (XS-4, XS-5, and XS-6) were also collected downstream. An overview of channel dimensions is provided in Table 5-2.

Overall, the results indicate that the channel has an average bankfull width of 5.93 m and an average bankfull depth of 0.43 m. The channel has a bankfull width: depth ratio of 13.92. As mentioned above, studies have shown that a ratio value of approximately 12 is the most frequently observed ratio (U.S Environmental Protection Agency, 2023).

The bankfull characteristics indicate that feature has an average bankfull discharge of 2.54 m^3/s, and an average bankfull velocity of 0.84 m/s.

Table 5-2: Overview of Existing Channel Dimensions and Hydraulics for WC-08

Parameter	Cross-section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	Average
	Feature:	Riffle	Riffle	Pool	Pool/Run	Riffle	Riffle	
Bankfull Width (m)		4.38	5.25	7.37	5.83	6.34	6.42	5.93
Average Bankfull Depth (m)		0.45	0.44	0.40	0.44	0.41	0.44	0.43
Maximum Bankfull Depth (m)		0.65	0.58	0.64	0.54	0.60	0.57	0.60
Bankfull Width:Depth		9.71	11.80	18.62	13.27	15.56	14.57	13.92
Cross-sectional Area (m^2)		1.97	2.33	2.92	2.56	2.58	2.83	2.53
Bankfull Discharge (m^3/s)		2.30	2.31	2.78	2.48	2.60	2.76	2.54
Average Bankfull Velocity (m/s)		0.96	0.84	0.81	0.81	0.80	0.84	0.84





- Reach
- Reach Break
- Cross Section
- MTBM Shaft Compound Preferred
- Connections
- Thalweg
- Vodden St
- Watercourse

Existing Sanitary Trunk Sewer

- Etobicoke Creek

Flow | Central Brampton

Kennedy Rd | Cross Section and Thalweg Location WC-04

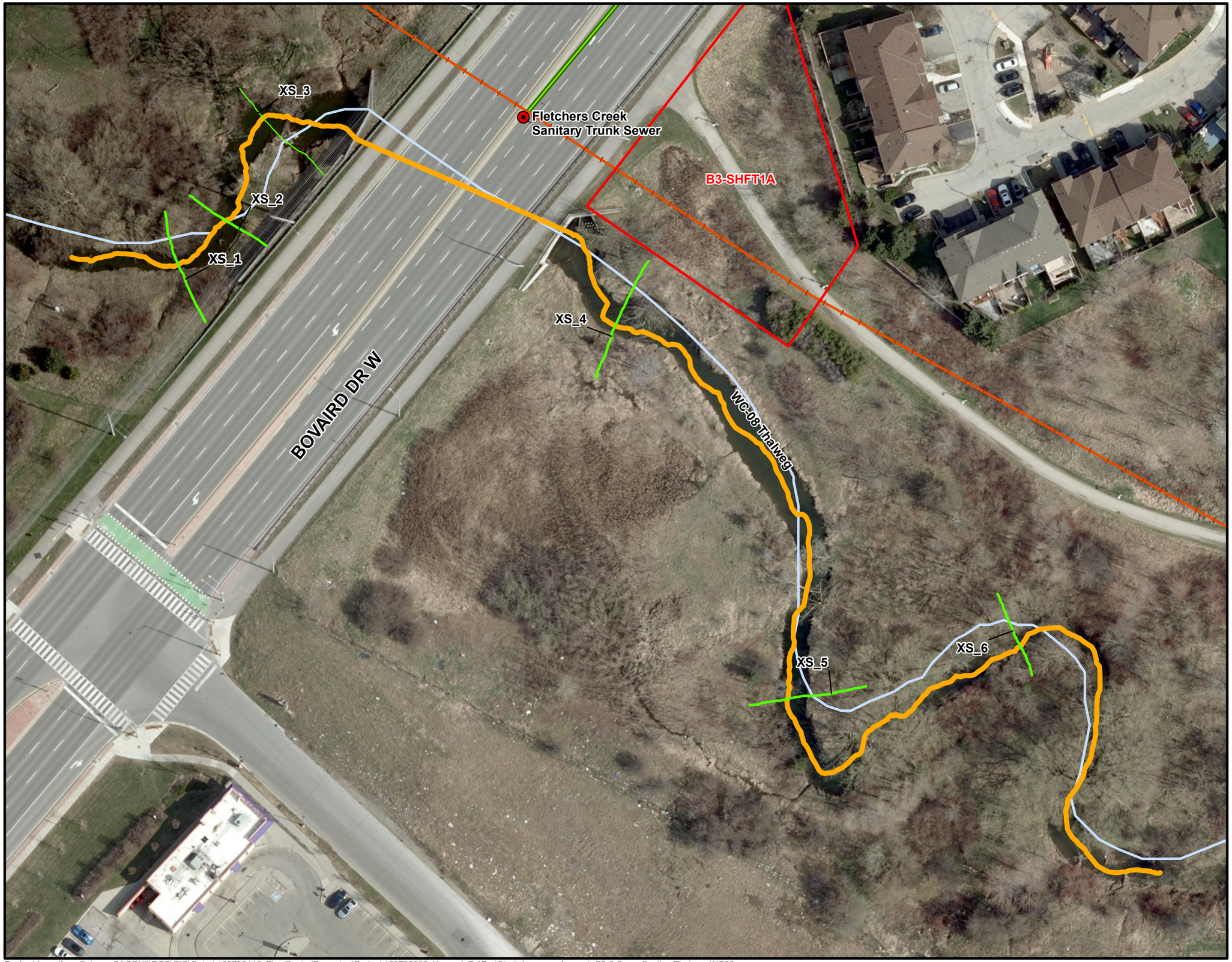
0 10 20 30 40

Meters
Scale: 1:908

N

PN: 60736820	Figure 5-1
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Cross Section
- Thalweg
- Bovaird Dr
- Watercourse
- MTBM Shaft Compound Preferred
- Connections

Existing Trunks

- Fletchers Creek

Flow | Central Brampton

Kennedy Rd | Cross Section and Thalweg Location WC-08

0 9.5 19 28.5 38

Meters
Scale: 1:750

N

PN: 60736820	Figure 5-2
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-2 Cross Section Thalweg WC08
Date Saved: June 20, 2025 **User:** WangS12

5.2 Bank Characterization

Field data was collected along both banks at the surveyed cross-section locations. Rooting depth, vegetation, and degree of undercutting were documented for both the left and right banks at each of the surveyed cross-sections. The data are used to identify the stability of the channel banks.

5.2.1 WC-04

Results of the bank characterization for WC-04 are provided in Table 5-3. Bank heights ranged from approximately 0.3 m to 1.6 m. The bank angles along the entire reach were steep, apart from one gradual slope at the location of XS-5. Steep and vertical banks angles are generally unstable and may indicate a susceptibility to erosion sloughing or collapse (Sholtes & Giordanengo, 2017).

The banks were largely composed of sand and muck (a fine mixture of sand, silt, and organic matter) with lesser amounts of clay. Fine sandy substrate is typically more easily transported through a watercourse than clays or boulder-sized material because the energy needed to move the substrate is greater. Therefore, the banks are relatively erodible based on their composition.

Trees, shrubs and grasses covered the banks, with variable rooting depths (from top of bank to bottom of bank) and rooting density ranging from 2 – 5 (out of 5). The percent of bank protected by vegetation was also highly variable and ranged from 10 to 90%. It was generally higher on the left (east) bank. Dense root systems of riparian vegetation that extend to the bottom of the bank provide critical erosion resistance and structural support to streambanks (Polster, 2010). Exposed banks are susceptible to erosion.

Bank undercutting was observed at all but one of the cross-sections, further emphasizing that the reach is currently unstable. Bank slumping was also observed for one cross-section immediately downstream of the Vodden Street East road crossing at the location of XS-4. There was major woody debris on the banks downstream.

5.2.2 WC-08

Results of the bank characterization for WC-08 are provided in Table 5-4. Bank heights ranged from 0.45 to 1.5 m. The bank angles along the entire reach were primarily moderate to steep, with the exception of one gradual bank that was observed at the location of XS-3.

Table 5-3: WC-04 Bank characterization

Parameter	Cross-section:	XS-1		XS-2		XS-3		XS-4		XS-5		XS-6	
	Feature:	Riffle		Run		Run		Riffle		Riffle		Run	
	Bank:	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)
Bank Height (m)		1 - 2	0.5	0.7	1	0.8	1.6	0.3	1	1.2	1	1.2	1.2
Bank Angle		Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Gradual	Steep	Steep	Steep
Material Composition		Silt, Sand, Muck	Silt, Sand, Muck	Sand, Muck	Sand, Muck	Clay, Sand, Muck	Clay, Sand	Sand, Muck	Sand, Clay, Muck	Sand, Silt, Muck	Sand, Silt, Muck	Sand, Muck	Muck, Dirt, Sand
Vegetation		Trees, Shrubs, Short Grasses	Trees, Shrubs, Short Grasses	Trees, Shrubs, Short Grasses	Trees, Grasses	Trees, Shrubs, Short Grasses	Trees, Short Grasses	Trees, Grasses	Trees, Shrubs, Short Grasses	Trees, Shrubs, Short Grasses	Trees, Shrubs, Short Grasses	Trees, Short Grasses	Trees, Shrubs, Short Grasses
Rooting Depth (cm)		Bottom of Bank	Bankfull	Bottom of Bank	Mid Bank	Bottom of Bank	Bottom of Bank	Bottom of Bank	Top of Bank	Bottom of Bank	Bankfull	Bottom of Bank	Top of Bank
Rooting Density (1 low – 5 high)		4	4	5	3	4	4	5	3	3	2	5	2
% of bank protected by vegetation		50 - 70	50 - 70	60 - 80	30 - 40	60 - 80	40 - 60	80 - 90	10 - 20	40 - 50	20 - 30	70 - 80	20 - 30
Undercutting (m)		None	Height: 30 cm Amount: 30 cm	None	Height: 40 cm Amount: 30 cm	Height: 30 cm Amount: 20 cm	Height: 30 cm Amount: 40 cm	Height: 10 cm Amount: 10 cm	Height: 100 cm Amount: 10 cm	None	None	Height: 15 cm Amount: 15 cm	None
On Bank Woody Debris		None	None	Minor	Minor	Minor	None	None	Major	Major	Major	Minor	None
Comments								Right bank slump failure		Deposition in overbank zone			

Table 5-4: WC-08 Bank characterization

Parameter	Cross-section:	XS-1		XS-2		XS-3		XS-4		XS-5		XS-6	
	Feature:	Riffle		Riffle		Pool		Pool/Run		Riffle		Riffle	
	Bank:	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)	Left Bank (East)	Right Bank (West)
Bank Height (m)		0.8	0.9	0.6	0.9	0.8	0.45	0.7	1.8	0.9	1-1.5	1.2	0.9
Bank Angle		Moderate	Steep	Steep	Steep	Gradual	Steep	Steep	Steep	Moderate – Steep	Moderate	Moderate	Steep
Material Composition		Sand, Silt	Clay, Silt, Sand, Gravel	Silt, Muck, Sand	Clay, Silt, Gravel, Cobbles	Sand, Silt, Muck	Muck, silt, sand	Sand, Silt, small gravel, muck	Sand, Silt, Muck	Sand, Muck, Sand	Sand, Silt, Muck	Sand, Silt, Muck	Silt, Sand, Muck
Vegetation		Trees, Shrubs, Tall and short Grasses	Trees, Shrubs, Tall and short Grasses	Trees, Shrubs, short grasses	Short Grasses	Shrubs, Tall Grasses	Tall Grasses	Trees, Shrubs, Tall Grasses, Short Grasses		Trees, Tall grasses	Trees, Shrubs, Tall Grasses, Short Grasses	Trees, Shrubs, Short Grasses	Trees, Shrubs, Tall Grasses
Rooting Depth (cm)		Mid Bank	Bottom of Bank	Mid Bank	Top of Bank/ Bankfull	Bottom of Bank	Mid Bank	Mid-Bank	Top of Bank	Bottom of Bank	Bottom of Bank	Bottom of Bank	Top of Bank
Rooting Density (1 low – 5 high)		3	4	4	4	2	4	2 – 3	4	3	2-3	4	4
% of bank protected by vegetation		50 - 60	50 - 60	60 - 80	10 – 20	30 – 40	50 – 70	20 – 30	50 – 60	50 – 60	50 - 60	20 – 40	60 – 80
Undercutting (m)		None	Height: 30 cm Amount: 20 cm	Height: 20 cm Amount: 15 cm	Height: 70 cm Amount: 22 cm	None	Height: 15 cm Amount: 20 cm	Height: 30 cm Amount: 15 cm	Height: 150 cm Amount: 10 – 30 cm	None	None	None	Height: 60 cm Amount: 20 cm
On Bank Woody Debris		None	None	Major	None	Minor	None	Minor	Minor	Minor	Major	Minor	Major
Comments		Right bank – bank slumping		Bank slumping along the right bank and deposition in overbank along the left bank		Shallow pool at bend		Placed tree restoration at this location along the right bank (trees held in place with wire). Bank slumping and overhanging present.		Riffle at bend		Chute Channel present behind Left Bank	

A range of bank materials were observed including muck, clay, silt, sand, small gravel, and cobbles. The cobbles appear to have been placed in the channel bed as a form of channel restoration efforts. The overall erodibility of the sediment will be controlled by the relative proportion of each component, but overall it is expected to have a moderate soil erodibility (TRCA, 2019). It is likely that the placed cobbles will provide an amount of bank hardening and resistance to erosion.

Banks were well generally vegetated by trees, shrubs, and grasses, although the banks immediately upstream of the Bovaird Drive West crossing (XS-2 and XS-3) were limited to grassy vegetation. The rooting depth was variable and ranged from top of bank to bottom of bank. Similarly, the rooting density ranged from low to high, and the % of bank covered by vegetation ranged from 10% to 80%.

Bank undercutting was observed at more than half the banks assessed, further emphasizing that the reach is currently unstable. There was minor to major woody debris buildup on the banks at all but one cross-section (XS-1). Bank slumping was found at XS-1, XS-2, and XS-4, and a chute was found at XS-6.

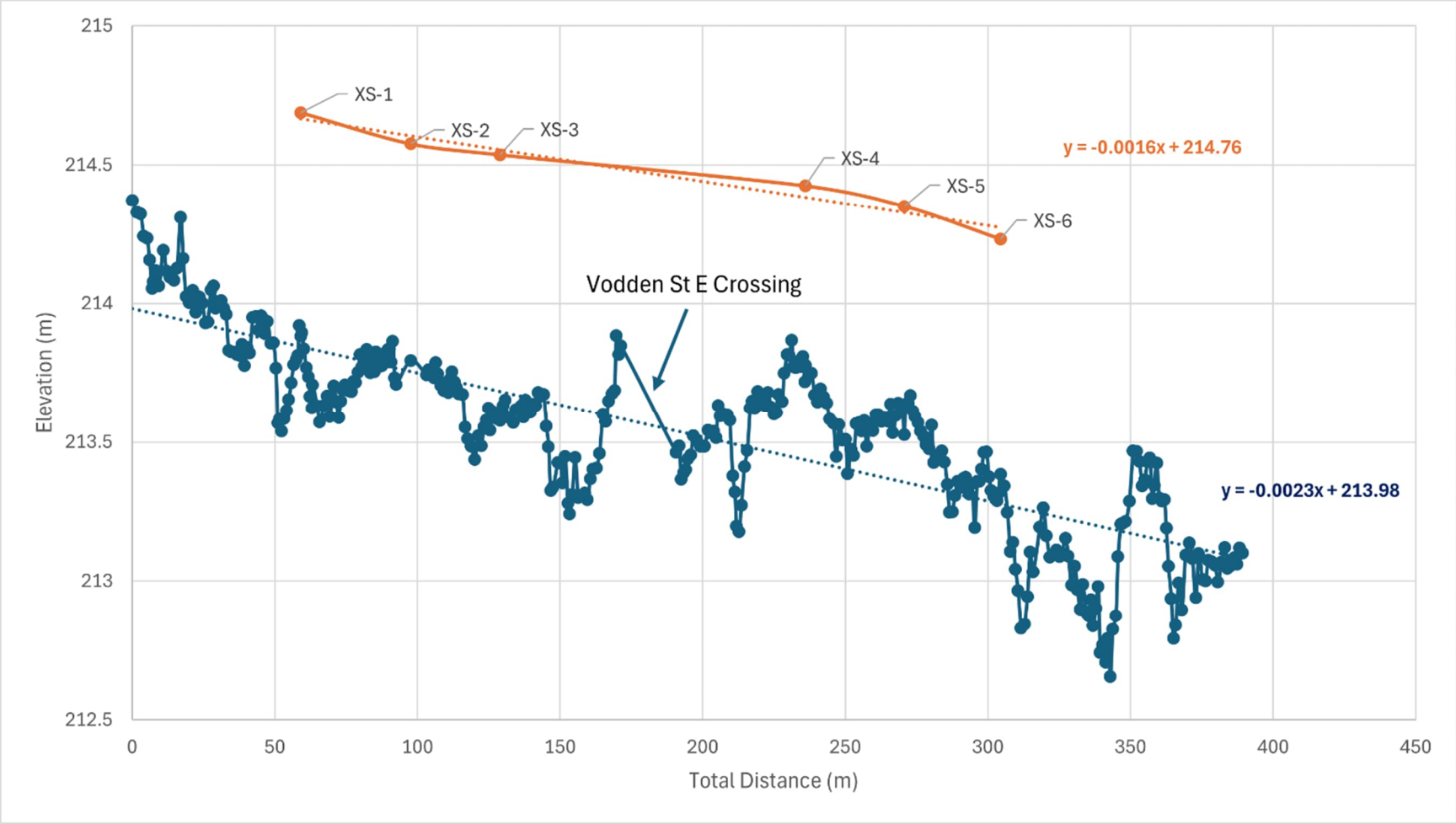
5.3 Longitudinal Profile

The longitudinal profile identifies the channel bed forms and local bed gradients and is a primary control of tractive forces within a reach and a major determinant of morphological form and function.

5.3.1 WC-04

The longitudinal profile of WC-04 extended along a cumulative distance of approximately 390 m (Figure 5-3). The overall slope of the channel thalweg was 0.23%, while the bankfull slope was slightly less steep at 0.16%. The watercourse is dominated by well formed riffles and runs. The crossing forms a significant discontinuity in the longitudinal profile. A scour pool can be identified in the longitudinal profile immediately upstream of the Vodden Street East crossing. This scour pool was noted in the field, where a large, perched, 1 m wide outfall was observed to be discharging into the watercourse. Rock bank protection was identified to be displaced and failing at this location.

Figure 5-3: Longitudinal Profile of WC-04

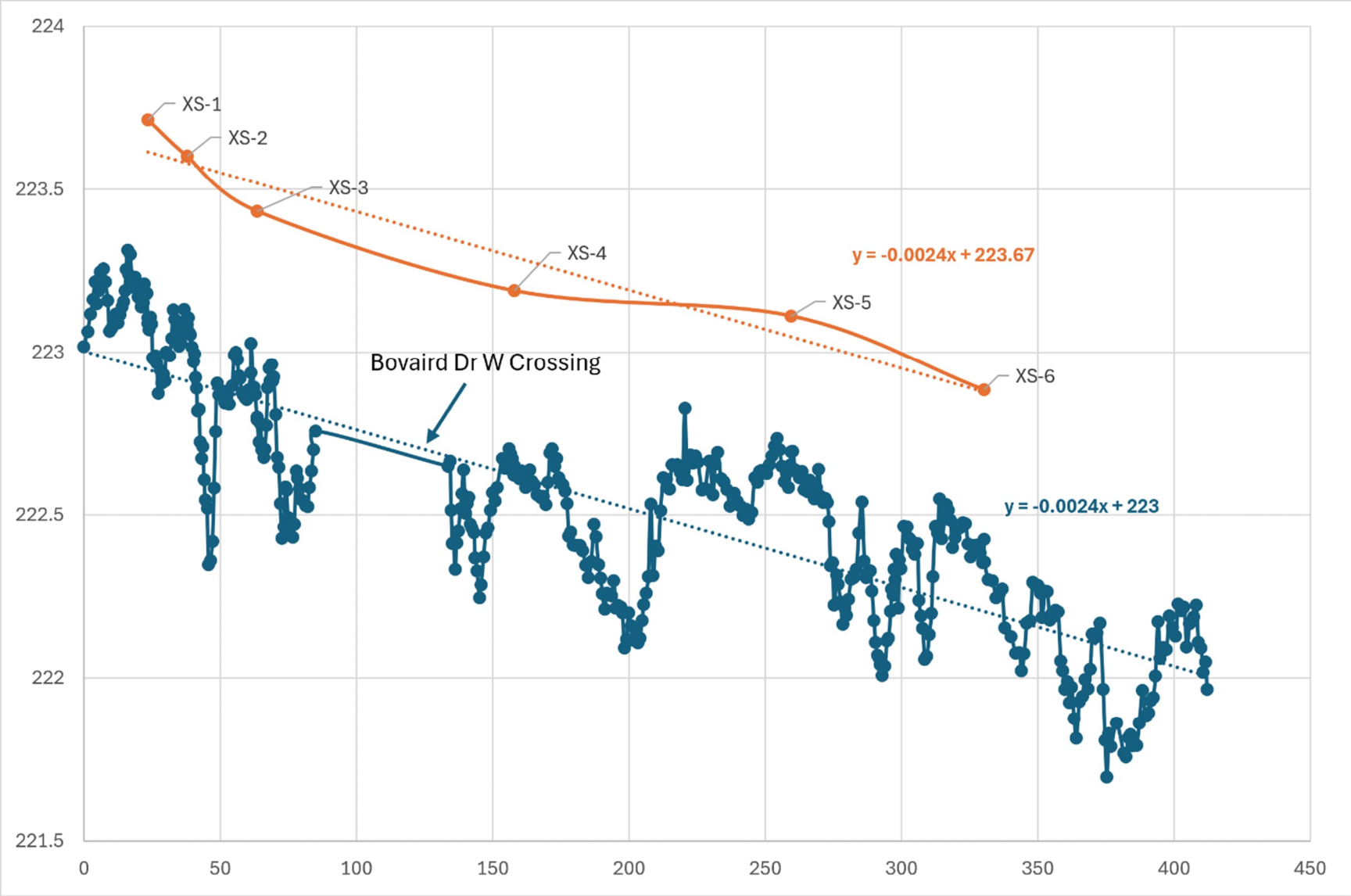


5.3.2 WC-08

The longitudinal profile of WC-08 extended along a cumulative distance of approximately 412 m (Figure 5-4). The overall slope of the channel thalweg matched the overall slope of the bankfull elevation at 0.24%. The watercourse is dominated by well formed riffles and runs. A pool can be observed in the profile downstream of the crossing. This was identified as a scour pool in the field, where a large, perched, 1 m wide outfall was observed to discharge into the watercourse.

Field evidence suggests that this reach is the target of channel restoration efforts. Live stakes consisting of Christmas trees and log treatments were observed downstream of the Bovaird Drive West crossing. Bank undercutting, bank slumping, and exposed clay along the channel bed were noted here, which is likely the target of the channel restoration efforts.

Figure 5-4: Longitudinal Profile of WC-08



5.4 Bed Characterization

The Wolman (1954) pebble count method was used 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 2 mm 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 D_{16} (16% of the same is equal to or smaller than), D_{50} (median grain size), and D_{84} (84% of the sample is equal to or smaller than).

5.4.1 WC-04

The bed materials of WC-04 ranged from silt to cobbles, shown in Table 5-5. Bed substrate was coarsest at riffle features (XS-1, XS-4, and XS-5). The reach had a relatively low about of silt and clay, except for XS-4, which was collected downstream of the Vodden Street East crossing. The larger proportion of fine sediment at this location may be due to sediment being washed out of the scour pool (located immediately upstream of the crossing), or due to the culvert itself.

Table 5-5: WC-04 Bed Substrate Composition

Parameter	Cross-section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	Average
	Feature:	Riffle	Run	Run	Riffle	Riffle	Run	
D_{16} (mm)		0.24 Fine Sand	0.32 Medium Sand	0.16 Fine Sand	0.02 Silt	0.60 Coarse Sand	0.40 Medium Sand	0.29 Medium Sand
D_{50} (mm)		6.92 Fine Gravel	0.93 Coarse Sand	0.98 Coarse Sand	15.00 Medium Gravel	8.50 Medium Gravel	6.21 Fine Gravel	6.42 Fine Gravel
D_{84} (mm)		65.00 Cobbles	50.00 Very Coarse Gravel	34.00 Very Coarse Gravel	67.50 Cobbles	67.10 Cobbles	48.60 Very Coarse Gravel	55.37 Very Coarse Gravel
% Silt-Clay		6.00	0.00	10.00	31.00	0.00	0.00	7.83

5.4.2 WC-08

The bed materials of WC-08 ranged from clay to cobbles, shown in Table 5-6. Grain sizes were coarsest at the riffle features upstream of the Bovaird Drive West crossing (XS-1 and XS-2). There was also a higher proportion of silt and clay at these locations, compared to downstream. Cobbles within the reach are interpreted to have been placed on the channel bed as a form of channel restoration efforts and may not be representative of the underlying surficial geology.

Table 5-6: WC-08 Bed Substrate Composition

Parameter	Cross-section:	XS-1	XS-2	XS-3	XS-4	XS-5	XS-6	Average
	Feature:	Riffle	Riffle	Pool	Pool/Run	Riffle	Riffle	
D16 (mm)		0.00 Clay	0.00 Clay	0.00 Clay	0.00 Clay	1.60 Very Coarse Sand	0.19 Fine Sand	0.30 Medium Sand
D50 (mm)		7.78 Fine Gravel	3.00 Pebbles	1.22 Very Coarse Sand	0.74 Coarse Sand	5.88 Fine Gravel	1.65 Very Coarse Sand	3.38 Pebbles
D84 (mm)		60.00 Very Coarse Gravel	70.00 Cobbles	24.60 Coarse Gravel	20.00 Coarse Gravel	36.25 Very Coarse Gravel	23.33 Coarse Gravel	39.03 Very Coarse Gravel
% Silt-Clay		32.00	35.00	21.78	20.00	0.00	10.00	19.80

6. Meander Belt Width and 100-Year Erosion Rates

The meander belt (MBW) is defined as the area or corridor that a channel currently occupies or is expected to occupy in the future. It includes the area that a meandering watercourse occupies on its floodplain, and in which all associated natural channel processes are expected to occur. Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform.

The associated erosion and deposition that occurs from meander development and migration processes can cause loss or damage to private property and/or infrastructure. For this reason, it is 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 watercourses that cross the Study Area are located within CVC and TRCA jurisdiction. Each Conservation Authority provides guidance on how to delineate the meander belt. Key guidance is included in the Fluvial Geomorphic Guidelines (CVC, 2015) and Technical Guidelines for Water Crossings (CVC, 2019) released by the CVC, and Belt Width Delineation Procedures (Parish Geomorphic Ltd., 2004) and Crossings Guideline for Valley and Stream Corridors (TRCA, 2015) for the TRCA.

Meander belt delineation approaches (i.e., mapping and empirical) are the most accepted methods for defining the meander belt. The “Belt Width Delineation Procedures” (TRCA, 2004) provides the most detailed protocol for defining the meander belt width for unconfined, partially confined and confined systems.

The results of the desktop and field assessment (Sections 2 & 3) were used to determine the meander belt width and erosion rate of all defined channels that cross the recommended preferred route. Channels that lacked definition (WC-10 and WC-02) were not considered in the meander belt width assessment as such features generally have insufficient energy to alter their margins. Additionally, reach WC-05 was lined with concrete and was therefore excluded from the meander belt width assessment.

6.1 Preliminary Meander Belt Width

The preferred approach for delineating a meander belt involves defining the meander belt axis (i.e., the general down-valley trend of the planform) and then delineating the meander belt boundaries. This is done by drawing tangential lines along the outside meanders on both sides of the reach on a map and then drawing a line down the centre of the corridor. The greatest perpendicular distance between these two lines represents the preliminary meander belt width

in an unconfined system. In partially confined and confined systems, where one or both sides of a watercourse, respectively, are restricted by valley walls, the meander belt is contoured to the valley wall contact. The planform mapping approach should be used where the watercourse is a naturally meandering, unaltered watercourse, where a meandering history can be tracked using aerial imagery. This method was used to delineate the preliminary meander belt for WC-34, WC-04, and WC-08, as identified in Table 6-2.

In instances where the planform of the watercourse has been artificially altered by human activities and surrogate reach could not be identified, or the watercourse is not large/visible enough to be accurately mapped, the empirical approach is used. The empirical approach uses a range of published empirical models based on channel and drainage metrics drawing on the following input variables: bankfull width (Wbf), bankfull depth (Dbf), bankfull maximum depth (Dmax), bankfull area (Abf), drainage area (Aw), and bankfull grade (S). The equations used are presented in Table 6-1, below. The values used in the empirical assessment were calculated based on the averages taken from the cross-sections cut from the DEM.

Both mapped and empirical results are presented in Table 6-2. Final meander belt widths (see Section 6.3) are available in Appendix D.

Table 6-1: Empirical Equations Used to Determine Meander Belt Widths

Source	Conditions/ Applications	Input Variable	Equation
Ward et al. (2002)	W_{bf} in feet - no factor of safety	Bankfull Width (ft)	$4.8 * W_{bf}^{1.08}$
Ward et al. (2002)	W_{bf} in feet - with a factor of safety	Bankfull Width (ft)	$6 * W_{bf}^{1.12}$
Williams (1986)	$W_{bf} > 1.5$ m	Bankfull Width (m)	$4.3 * W_{bf}^{1.12}$
USDA (2007)		Bankfull Width (m)	$6 * W_{bf}$
Lorenz and Heinze (1985)		Bankfull Width (m)	$7.53 * W_{bf}^{1.01}$
Kline and Dolan (2008)	Vermont - general guidance	Bankfull Width (m)	$6 * W_{bf} + 1 W_{bf}$ on either side = $8 * W_{bf}$
TOTAL AVERAGE			Average calculated width

Table 6-2: Preliminary Meander Belt Width Results

Reach ID	Bankfull/Channel Width (m)	Preliminary MBW (m)	Method*		Channel Confinement
WC-35	3.9 (Approximate channel width from DEM)	26.47	Empirical	Feature planform cannot be accurately traced in aerial imagery due to tree cover. Empirical approach used	Partially Confined
WC-34	2.11 (Approximate channel width from DEM)	30.00	Mapping	Feature was adjusted between 1974 and 1999. No significant changes since. Mapping approach used	Partially Confined
WC-33	Swale feature was approximately 2.5 m wide based on DEM (not bankfull)	16.58	Empirical	Feature is a poorly defined, narrow swale-like feature and was realigned between 1974 and 1999. Empirical approach used	Unconfined
WC-13	2.86 (Approximate channel width from DEM)	19.10	Empirical	Feature altered by human activity and has been increasing in sinuosity since. Empirical approach used	Partially Confined
WC-12	5.29 (Approximate channel width from DEM)	36.49	Empirical	Feature significantly altered by human activity. A large portion was straightened before 1974 and the remainder was straightened between 1974 and 1999. Empirical approach used	Partially Confined
WC-04	11.04	48.00	Mapping	A portion of the feature was likely straightened prior to 1999 but banks can clearly be traced and there have been no significant changes to planform or land use since. Mapping approach used	Partially Confined
WC-02	Undefined watercourse. No MBW delineated				
WC-10	Undefined watercourse. No MBW delineated				
WC-08	5.93	58.00	Mapping	A portion of the feature was likely straightened prior to 1970 but banks can clearly be traced and there have been no significant changes to planform or land use since. Mapping approach used	Partially Confined
WC-07	2.04 (Approximate channel width from DEM)	13.39	Empirical	Feature channelized and straightened by human activity between 1970 and 1999. Empirical approach used	Artificially Confined
WC-06a	1.45 (Approximate channel width from DEM)	9.36	Empirical	Feature channelized and straightened by human activity between 1970 and 1999. Empirical approach used	Artificially Confined
WC-06	2.32 (Approximate channel width from DEM)	15.33	Empirical	Feature channelized and straightened by human activity between 1970 and 1999. Empirical approach used	Artificially Confined
WC-05a	9.44 (Approximate channel width from DEM)	67.19	Empirical	Feature channelized and straightened by human activity between 1970 and 1999. Empirical approach used	Artificially Confined
WC-05	Feature lined with concrete. No MWB delineated				

Note: * Bankfull depth could not be accurately determined using the cross-sections cut from the DEM, as outlined in Section 4.1.2 and therefore, bankfull depth was not considered for the empirical calculations.

6.2 100-Year Erosion Rate

6.2.1 100-Year Erosion Rates from Mapping

Once the preliminary meander belt width was determined, an erosion allowance was applied to account for the 100-year erosion potential. For defined and unaltered watercourses that could be traced on a map (i.e., bankfull width greater than 3 m and not masked by vegetation), the erosion rate can be defined using historic meander changes based on aerial imagery. A minimum of 20-30 years of historical data are required for reliable estimates of erosion rates, which are extrapolated to cover the 100-year interval (TRCA 2004; TRCA 2015). This method was used to delineate the 100-year erosion rate of WC-04 and WC-08. Aerial imagery from 1999 was compared to imagery from 2024 to determine the shift in channel planform. The 1999 imagery was somewhat blurry compared to the clearer 2024 imagery but was clear enough for bank delineations.

6.2.1.1 WC-04

To delineate the 100-year erosion rate for WC-04, measurements were taken from a series of meander bends within the reach as well as from two meander bends from the reach directly downstream (surrogate reach) as shown in Figure 6-1. All results have been presented in Table 6-3. The average erosion rate determined for WC-04 from measurements taken directly from the reach was 8.12 +/- 3 m, while the average from two meander bends from the surrogate reach was 9.42 +/- 3 m. This yields a total 100-year erosion rate of 8.51 +/- 3 m.

Table 6-3: Measured Erosion Rates WC-04

Location	Start Year	End Year	No. of Years	Distance of Channel Movement Observed (m)	Annual Erosion Rate (m/year)	100-Year Erosion Rate	Description
M1a	1999	2024	25	3.71	0.15	14.85 +/- 3 m	Within Reach
M2a	1999	2024	25	1.09	0.04	4.36 +/- 3 m	Within Reach
M2b	1999	2024	25	2.36	0.09	9.45 +/- 3 m	Within Reach
M3a	1999	2024	25	0.73	0.03	2.91 +/- 3 m	Within Reach
M3b	1999	2024	25	1.74	0.07	6.98 +/- 3 m	Within Reach
M4a	1999	2024	25	2.73	0.11	10.91 +/- 3 m	Within Reach
M4b	1999	2024	25	1.85	0.07	7.39 +/- 3 m	Within Reach
M5a	1999	2024	25	3.87	0.15	15.50 +/- 3 m	Downstream surrogate reach
M5b	1999	2024	25	2.18	0.09	8.73 +/- 3 m	Downstream surrogate reach
M6a	1999	2024	25	1.01	0.04	4.03 +/- 3 m	Downstream surrogate reach
Average Within Reach						8.12 +/- 3 m	
Average Surrogate Reach						9.42 +/- 3 m	
Average All Measurements						8.51 +/- 3 m	

6.2.1.2 WC-08

To delineate the 100-year erosion rate for WC-08, measurements were taken from a series of meander bends within the reach, as shown in Figure 6-2. All results have been presented in Table 6-4. The results yield a total 100-year erosion rate of 7.79 +/- 3 m.

Table 6-4: Measured Erosion Rates WC-08

Location	Start Year	End Year	No. of Years	Distance of Channel Movement Observed (m)	Annual Erosion Rate (m/year)	100-Year Erosion Rate	**Description**
M1a	1999	2024	25	3.19	0.13	12.77 +/- 3 m	Within Reach
M1b	1999	2024	25	1.66	0.07	6.62 +/- 3 m	Within Reach
M2a	1999	2024	25	0.79	0.03	3.15 +/- 3 m	Within Reach
M2b	1999	2024	25	2.21	0.09	8.83 +/- 3 m	Within Reach
M3a	1999	2024	25	3.04	0.12	12.1 +/- 3 m 4	Within Reach
M5a	1999	2024	25	1.88	0.08	7.54 +/- 3 m	Within Reach
M5b	1999	2024	25	1.79	0.07	7.17 +/- 3 m	Within Reach
M6a	1999	2024	25	1.47	0.06	5.88 +/- 3 m	Within Reach
M6b	1999	2024	25	1.49	0.06	5.98 +/- 3 m	Within Reach
Average All Measurements						7.79 +/- 3 m	





- Vodden St
- Erosion Measurements
- Etobicoke Creek 1999 Banks
- Etobicoke Creek 2024 Banks
- Reach Breaks
- MTBM Shaft Compound Preferred
- Connections

Existing Trunks

- Etobicoke Creek

Flow | Central Brampton

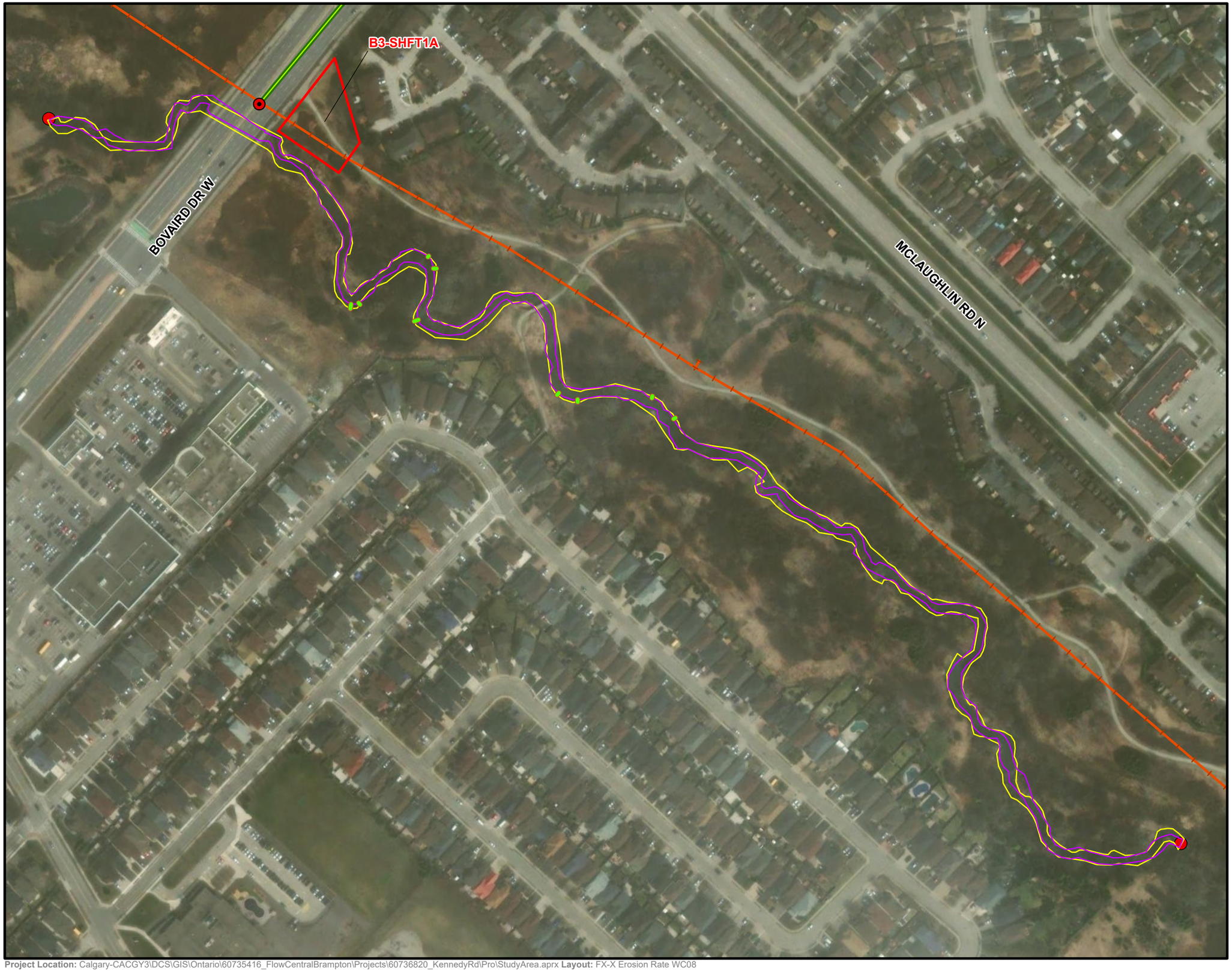
Kennedy Rd | Erosion Rate
WC-04

0 20 40 60 80
Meters
Scale: 1:1,600

N

PN: 60736820	Figure 6-1
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Bovaird Dr
- Erosion Measurements
- Fletcher's Creek 1999 Banks
- Fletcher's Creek 2024 Banks
- Reach Breaks
- MTBM Shaft Compound Preferred
- Connections

Existing Trunks

- Fletchers Creek

Flow | Central Brampton

Kennedy Rd | Erosion Rate
WC-08

0 0.03 0.06 0.09 0.12

Kilometers
Scale: 1:2,500

N

PN: 60736820	Figure 6-2
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** FX-X Erosion Rate WC08
Date Saved: January 26, 2026 **User:** WangS12

6.2.2 100-Year Erosion Rates based on Risk Assessment

For reaches that have been artificially altered, or those for which the aerial imagery is poor in quality, two different methods are often used to define the 100-year erosion rate.

1. Reference numbers can be selected from the Ministry of Natural Resources (MNR)'s Table 3 in the Technical Guide – River and Stream Systems: Erosion Hazard Limit (2002) (see Table 6-5), or
2. A factor of safety, equivalent to 20% of the preliminary meander belt width can be calculated and used as an equivalent to the 100-year erosion rate.

Both methods were evaluated to select the final 100-year erosion rate for watercourses in the Study Area. The final recommended values (Table 6-6) was selected based on a consideration of the following:

- Surficial Geology & Boundary Materials (channel bed sediment)
  In general, a channels erodibility will be controlled by the localized proportion of clay, silt, sand, and gravel. Sandy channels are more easily eroded than clay-rich channels due to the cohesive nature of clay. Similarly, sand is more easily eroded than larger gravel-sized material because the energy needed to move gravel is greater.
- Hydraulic Regime/ Feature Type
  If flowing water has sufficient energy, over time it will erode sediment along its flow path eventually producing defined channel banks. Eroded sediment is generally deposited downstream in point bars, resulting in a balance between erosional and depositional processes over time (Sholtes and Giordanengo 2017). In general, intermittent to permanent watercourses have defined banks as the water flowing through these systems has enough energy to produce defined channel banks. Ephemeral channels generally lack the energy to create defined channel banks during periods of flow (i.e., low risk) (Irwin et al. 2013).
- Channel Confinement
  Confining valleys constrain and limit where a watercourse can flow. Over time, a confined watercourse may be able to cause sufficient erosion to increase the width of the valley floor only if the valley walls are relatively erodible. To refine the 100-year erosion rate, watercourses that were confined were considered to have a low to moderate risk compared to unconfined watercourses which were given a high risk. This factored into the determination of the 100-year erosion rate.

Table 6-5: Reproduced Table 3 Determination of Toe Erosion Allowance from (MNR, 2002)

Type of Material Native Soil Structure	Evidence of Active Erosion** or Bankfull Flow Velocity > Competent Flow Velocity*** Range of Suggested Toe Erosional Allowances	No Evidence of Active Erosion** or Bankfull Flow velocity < Competent Flow Velocity		
		Bankfull Width		
		< 5 m	5-30 m	> 30 m
Hard Rock (granite)*	0 – 2 m	0 m	0 m	1 m
Soft Rock (shale, limestone), Cobbles, Boulders*	2 – 5 m	0 m	1 m	2 m
Stiff/Hard Cohesive Soil (clays, clay silt), Coarse Granular (gravels), Tills*	5 – 8 m	1 m	2 m	4 m
Soft/Firm Cohesive Soil, loose granular, (sand, silt) Fill*	8 – 15 m	1 – 2 m	5 m	7 m

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

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

*** *Competent Flow Velocity is the flow velocity that the bed material in the stream can support without resulting in erosion or scour.*

Table 6-6: 100-Year Erosion Rate

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Hydraulic Regime	Confinement	Bankfull/Channel Width	Historical Summary	RGA Rating	Evidence of channel Scour and Erosion	Value from MNR Table 3 (m)	Erosion Rate from Mapping Approach	Preliminary MBW (m)	10% Buffer on Preliminary MBW (10% to be applied on either side) (m)	Final 100-Year Erosion Rate (m)
WC-35	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Muck, Silt, sand, clay, gravel to cobbles	■ Permanent	■ Partially Confined	■ 3.9 (Approximate channel width from DEM)	■ No significant changes in channel planform or land use since 1974	■ Transitional/Stressed. ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ Multiple debris jams present. Scour pool and exposed clay along the channel bed were observed downstream of a debris jam near crossing ■ Exposed clay (bed scour) in vicinity of crossing	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - Tree cover makes historic channel delineation difficult. Cannot use mapping to delineate 100-year erosion rate.	■ 26.47	■ 2.65	■ 2.65 ■ 10% of MBW selected as appropriate 100-year erosion rate due to the fact that the feature has not changed significantly since 1974 and much of the erosion observed was due to the debris jams
WC-34	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Silt, sand, muck, clay, gravels and cobbles (not natural)	■ Permanent	■ Partially Confined	■ 2.11 (Approximate channel width from DEM)	■ The channel was adjusted between 1974 and 1999. No significant changes in planform since. Increase in riparian buffer over time.	■ In Regime/Stable ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ The culvert inlet is located at a meander bend. Flow is not centred through the culvert, which is causing erosion adjacent to the culvert inlet along the eastern channel bank ■ Exposed clay (bed scour) in vicinity of crossing	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - Channel less than 3 m wide and has been altered by human activity. Cannot use mapping to delineate 100-year erosion rate.	■ 30.00	■ 3.00	■ 3.00 ■ 10% of MBW selected as appropriate 100-year erosion rate due to the fact that the feature is a narrow, partially confined feature that hasn't changed significantly since 1999, the feature is in regime, and the fact that erosion issues seem to stem from the fact that flow is not centred through the culvert
WC-33	■ Clay to silt-textured till in proximity to modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter	■ Silt, muck, gravel and placed cobbles (not natural)	■ Ephemeral Swale	■ Unconfined	■ Swale feature was approximately 2.5 m wide based on DEM (not bankfull)	■ Channel realignment occurred between 1974 and 1999. No significant changes to channel planform or land use since.	■ Feature is undefined and therefore no RGA was completed ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ There was minor erosion along the right (south) bank upstream of the crossing behind the culvert. This may be due to the steepness of the ditch wall and not erosion from flows in reach WC-33	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - Channel less than 3 m wide, and is poorly defined, and has been altered by human activity. Cannot use mapping to delineate 100-year erosion rate.	■ 16.58	■ 1.66	■ 1.66 ■ 10% of MBW selected as appropriate 100-year erosion rate due to the fact that the feature is more of an ephemeral swale with a narrow channel width, lack of significant changes in planform since 1999, in regime RGA rating, and minimal evidence of erosion
WC-13	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Silt, muck, clay	■ Intermittent	■ Partially Confined	■ 2.86 (Approximate channel width from DEM)	■ The reach was likely straightened prior to 1974. Slight increase in sinuosity since. Minimal changes in land use since 1974. Improvement in the riparian buffer over the years assessed.	■ Transitional/Stressed ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ Evidence of channel widening was observed from the ROW including fallen/leaning trees, exposed roots, and basal scour on both sides of the channel through riffles ■ Scour pools present at the culvert outlet. Exposed clay also noted ■ The left (north) downstream outlet wingwall has collapsed and is now within the channel. This has created a debris jam and is causing flow and sedimentation issues. ■ Channel was channelized prior to 1974 and has been regaining sinuosity since	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - Channel less than 3 m wide and has been altered by human activity. Cannot use mapping to delineate 100-year erosion rate.	■ 19.10	■ 1.91	■ 5.00 ■ Value from MNR Table 3 selected as appropriate 100-year erosion rate. While the channel is narrow and partially defined, a value higher than 20% the preliminary MBW was deemed more acceptable due to increase in sinuosity since 1974, RGA rating, and evidence of erosion observed in the field.

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Hydraulic Regime	Confinement	Bankfull/Channel Width	Historical Summary	RGA Rating	Evidence of channel Scour and Erosion	Value from MNR Table 3 (m)	Erosion Rate from Mapping Approach	Preliminary MBW (m)	10% Buffer on Preliminary MBW (10% to be applied on either side) (m)	Final 100-Year Erosion Rate (m)
WC-12	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter. Surrounded by clay to silt-textured till and fine-textured glaciolacustrine deposits of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.	■ Clay, silt, sand, muck, cobbles (not natural)	■ Permanent	■ Partially Confined	■ 5.29 (Approximate channel width from DEM)	■ A large portion of the reach was straightened prior to 1974. The remaining portion straightened between 1974 and 1999. No significant changes to planform and land use since 1999.	■ In Regime/Stable ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ The entire feature was straightened by 1999. It has been relatively stable since ■ The watercourse appears to have been dredged, which has exposed clay along the bottom of the channel. This was likely anthropogenic, and not due to fluvial geomorphic processes	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - Channel was straightened between 1974 and 1999 and therefore, cannot use mapping to delineate 100-year erosion rate.	■ 36.49	■ 3.65	■ 3.65 ■ Value from MNR Table 3 selected as appropriate 100-year erosion date due to in Regime rating and minimal evidence of erosion.
WC-04	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.	■ Fines and gravels to cobbles and small boulders.	■ Permanent	■ Partially Confined	■ 11.04	■ A portion of the reach was lightly straightened prior to 1999. No significant changes to planform or land use since.	■ Transitional/Stressed	■ Abundant evidence of channel widening was observed (leaning and fallen trees, large woody debris, exposed tree roots, basal scour, and fracture lines along the top of the bank) ■ An accumulation of cobbles was present through the crossing structure. No low flow channel was present ■ Scour pools were noted downstream of the Vodden Street East crossing where stormwater outfalls were located ■ The channel upstream of the Vodden Street East crossing was straightened prior to 1999	■ N/A	■ 8.51 +/- 3 m (from mapping)	■ 48.00 ■	■ 4.80	■ 8.51 ■ Mapping method preferred method for determining 100-year erosion rate
WC-02	■ Clay to silt textured till.	■ N/A	■ N/A – flow is piped	■ N/A – flow is piped	■ Flow at this location is piped.	■ The reach is an urban drainage ditch that was likely straightened prior to 1999. Between 2015 and 2024 the feature was piped and only a 115 m section of channel can be observed in aerial imagery.	■ Flow at this location is piped. No channel was observed from ROW therefore no RGA was completed ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated.*	■ No evidence of erosion was observed	■ Piped feature. No 100-year erosion rate estimated.				
WC-10	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till. There are also Paleozoic bedrock outcrops in the surrounding area. There are also fine-textured glaciolacustrine deposits nearby of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.	■ N/A	■ Ephemeral swale	■ Confined	■ Feature is undefined	■ The flow was redirected from agricultural fields west of the OBR corridor into a drainage swale parallel to the OBR corridor between 2005 and 2015. No significant change in channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ Feature is undefined and therefore no RGA was completed ■ *RGA limited to ROW. Evidence of erosion may be overexaggerated. In some areas the feature was difficult to access due to fences restricting access.*	■ No evidence of erosion was observed	■ Ephemeral swale. No 100-year erosion rate estimated.				
WC-08	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.	■ Fines and gravels to cobbles and small boulders	■ Permanent	■ Partially confined	■ 5.93	■ The reach was likely straightened prior to 1970. No significant changes to the channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ Transitional/Stressed	■ Abundant evidence of channel widening was observed (fallen trees, exposed tree roots, large organic debris, basal scour) ■ Aggradation (coarse material embedded in riffles, siltation in pools, and deposition in overbank zone) and degradation (exposed clay, exposed suspended armour	■ N/A	■ 7.79 +/- 3 m (From mapping)	■ 58.00	■ 5.80	■ 7.79 ■ Mapping method preferred method for determining 100-year erosion rate

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Hydraulic Regime	Confinement	Bankfull/Channel Width	Historical Summary	RGA Rating	Evidence of channel Scour and Erosion	Value from MNR Table 3 (m)	Erosion Rate from Mapping Approach	Preliminary MBW (m)	10% Buffer on Preliminary MBW (10% to be applied on either side) (m)	Final 100-Year Erosion Rate (m)
								layer, and scour pools located downstream of elevated stormwater outfalls) was also observed ■ Live stake restoration was observed at this location and is likely being used to mitigate erosion issues in the reach ■ Channel likely straightened prior to 1974 upstream of Bovaird Drive West					
WC-07	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to gravel sized fragments with small boulders	■ Permanent	■ Artificially Confined	■ 2.04 (Approximate channel width from DEM)	■ The feature was channelized between 1970 and 1999. No significant changes to the channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ In Regime/Stable	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Evidence of channel widening included basal scour and fracture lines along the top of the bank. ■ Lesser evidence of bed degradation (channel worn into overburden) was also observed	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - The feature was channelized between 1970 and 1999. Therefore, cannot use mapping to delineate 100-year erosion rate.	■ 13.39	■ 1.34	■ 1.34 ■ 10% of MBW selected as appropriate 100-year erosion rate due to narrow channel width, lack of significant changes in planform since 1999, minimal evidence of erosion, and artificial confinement of feature
WC–06a	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders	■ Permanent	■ Artificially Confined	■ 1.45 (Approximate channel width from DEM)	■ The feature was channelized between 1970 and 1999. No significant changes to the channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ Transitional/Stressed	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Abundant evidence of channel widening was observed (fallen/leaning trees, exposed tree roots, and fracture lines on top of the bank, as well as basal scour) ■ Lesser evidence of aggradation (coarse material embedded in riffles and poor sorting of bed materials), and degradation (scour pools located downstream of culvert outfalls) was present	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - The feature was channelized between 1970 and 1999. Therefore, cannot use mapping to delineate 100-year erosion rate.	■ 9.36	■ 0.94	■ 5.00 ■ Value from MNR Table 3 selected as appropriate 100-year erosion rate. While the feature has a narrow channel width, lack of significant changes in planform since 1999, and artificial confinement, there was evidence of active erosion visible in the field.
WC-06	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders	■ Permanent	■ Artificially Confined	■ 2.32 (Approximate channel width from DEM)	■ The feature was channelized between 1970 and 1999. No significant changes to the channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ Transitional/Stressed	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Abundant evidence of channel widening was observed (fallen/leaning trees, large organic debris, exposed tree roots, and outflanked armourstone, as well as basal scour) ■ Lesser evidence of aggradation was also noted (coarse material embedded in riffles and siltation in pools)	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - The feature was channelized between 1970 and 1999. Therefore, cannot use mapping to delineate 100-year erosion rate.	■ 15.33	■ 1.54	■ 5.00 ■ Value from MNR Table 3 selected as appropriate 100-year erosion rate. While the feature has a narrow channel width, lack of significant changes in planform since 1999, and artificial confinement, there was evidence of active erosion visible in the field.
WC-05a	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders	■ Permanent	■ Artificially Confined	■ 9.44 (Approximate channel width from DEM)	■ The feature was channelized between 1970 and 1999. No significant changes to the channel planform since. Significant residential development occurring in vicinity of reach since 1999.	■ In Regime/Stable	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Minor evidence of channel widening was observed (basal scour, presence of large organic debris, and outflanked armourstone)	■ 5 – 8 m (based on Table 3 from MNR, 2013)	■ N/A - The feature was channelized between 1970 and 1999. Therefore, cannot use mapping to delineate 100-year erosion rate.	■ 67.19	■ 6.72	■ 5.00 ■ Value from MNR Table 3 selected as appropriate 100-year erosion rate. While the feature lacks significant changes in planform since 1999, and is artificially confined, there was minor evidence

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Hydraulic Regime	Confinement	Bankfull/Channel Width	Historical Summary	RGA Rating	Evidence of channel Scour and Erosion	Value from MNR Table 3 (m)	Erosion Rate from Mapping Approach	Preliminary MBW (m)	10% Buffer on Preliminary MBW (10% to be applied on either side) (m)	Final 100-Year Erosion Rate (m)
								■ Lesser evidence of aggradation (siltation in pools) and degradation (scour pools located downstream of stormwater outfalls) was also observed					of active erosion visible in the field.
WC-05	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders. Channel lined with concrete.	■ Permanent	■ Artificially Confined (lined with concrete)	■ 10.38 (Approximate channel width from DEM). Feature fully lined with concrete.	■ Feature fully lined with concrete prior to 1999. No significant changes to the channel planform since. Significant residential development occurred in vicinity of reach between 1999 and 2005. No significant changes since.	■ The feature is lined with concrete. Therefore, no RGA was completed.	■ The entire reach has been lined with concrete. No evidence of erosion was observed.	■ Fully concrete-lined channel. No 100-year erosion rate estimated.				

- Bankfull/ Channel Width

  The behaviour and morphology of a watercourse is strongly impacted by the upstream discharge (Lagasse et al. 2004). Very small drainage areas typically correlate with narrow and poorly defined headwater drainage features. Headwater streams are typically stabilized by vegetation on the bed and banks and show minimal evidence of erosion. Larger drainage areas result in wider permanent features that have erosive forces exceeding the forces provided by vegetation. Aerial imagery and bankfull/channel width were used to infer how erosive a feature could be. This factored into the determination of the 100-year erosion rate.

- Historical Assessment

  Meanders can migrate at different speeds. More actively meandering systems will continually change their position and shape across the meander belt while less active systems will change shape gradually over a long period of time. Historical aerial imagery was used to define the rate of change for the watercourses. This factored into the determination of the 100-year erosion rate.

- RGA Rating

  The Rapid Geomorphic Assessment is a tool developed by the MECP (1999) to assess the stability of a watercourse based visible evidence of channel processes (aggradation, degradation, widening, and planimetric form adjustment). To determine an appropriate 100-year erosion rate the following were considered (1) overall frequency of visible evidence of instability, (2) type of channel process/ evidence of instability, (3) the likely source of instability, and (4) the watercourses equilibrium/ disequilibrium state. In general, watercourses with a greater frequency of instability indicators that could not be accounted for by anthropogenic alteration (e.g., a watercourse that is small and crosses an agricultural field through a dug-out channel) were considered to be a higher risk while watercourses showing little to no evidence of instability were considered a lower risk. This factored into the determination of the 100-year erosion rate.

- Evidence of Scour and Erosion

  Erosion is a natural process that is a necessary part of meander migration. In meandering systems sediment is eroded from the outer meander bend and is deposited on the inner meander bend, resulting in a shift across the meander belt over time. Channel meandering occurs in most alluvial systems (Lagasse et al. 2004). Erosion can also occur as a result of a channel disturbance. There is a complex inter-relationship between channel dimensions, patterns, sediment supply, streambed roughness, and steepness. Alterations in one component will impact the other components. Alterations can be local or can affect the entire drainage network. Abundant evidence of erosion observed in the field that could not be accounted for as a natural part of meander migration was used as an indication that the watercourse reach is in a period of adjustment. The amount and type of erosion identified in the field was factored into the determination of the 100-year erosion rate.

6.3 Final Meander Belt Width

Final meander belt widths were calculated based on "Belt Width Delineation Procedures" (Parish Geomorphic Ltd., 2004) summarized in Table 6-7. Final meander belt widths have been provided in Table 6-8. Final meander belt width figures have been provided in Appendix D.

Table 6-7: Final Meander Belt Width Equations

Meander Belt Width Equations		
Unconfined Systems	Preliminary BMW<50 m	Final MBW=Preliminary MBW+2x Erosion Rate
	Preliminary MBW≥50 m	Final MBW=Preliminary MBW*1.10
Confined Systems	Final MBW=Preliminary MBW Limited by Confining Walls	

Table 6-8: Final Meander Belt Widths

Reach	Preliminary MBW (m)	100-Year Erosion Rate	Final MBW (m)	Equation Used	Channel Confinement
WC-35	26.47	2.65 m (10% of MBW)	31.8	Final MBW=Preliminary MBW+2x Erosion Rate (limited by confining walls where appropriate)	Partially Confined
WC-34	30.00	3.00 m (10% of MBW)	36.0	Final MBW=Preliminary MBW+2x Erosion Rate (limited by confining walls where appropriate)	Partially Confined
WC-33	16.58	1.66 (10% of MBW)	19.9	Final MBW=Preliminary MBW+2x Erosion Rate	Unconfined
WC-13	19.10	5.00 (MNR Table 3)	29.1	Final MBW=Preliminary MBW+2x Erosion Rate (limited by confining walls where appropriate)	Partially Confined
WC-12	36.49	3.65 (10% of MBW)	43.8	Final MBW=Preliminary MBW+2x Erosion Rate (limited by confining walls where appropriate)	Partially Confined
WC-04	48.00	8.51 +/-3 m (From mapping)	65.0	Final MBW=Preliminary MBW+2x Erosion Rate (limited by confining walls where appropriate)	Partially Confined
WC-08	58.00	7.79 +/- 3 m (From mapping)	63.8 Final meander belt with + RSD Buffer = 123.8	Final MBW=Preliminary MBW*1.10	Partially Confined
WC-07	13.39	1.34 (10% of MBW)	16.1	Final MBW=Preliminary MBW+2x Erosion Rate	Artificially Confined
WC-06a	9.36	5.00 (MNR Table 3)	19.4	Final MBW=Preliminary MBW+2x Erosion Rate	Artificially Confined
WC-06	15.33	5.00 (MNR Table 3)	25.3	Final MBW=Preliminary MBW+2x Erosion Rate	Artificially Confined
WC-05a	67.19	5.00 (MNR Table 3)	73.9	Final MBW=Preliminary MBW*1.10	Artificially Confined

7. Erosion Threshold Assessment

Am erosion threshold assessment was completed to provide insight on future stability of the watercourses in the Study Area. It documents the volume of water that the watercourse can convey without causing increased erosion and incision of the channel bed, which is an important consideration for future development. This is especially important in urbanized areas, which often experience increased surface runoff and reduced infiltration, resulting in additional flows being conveyed by the watercourse. It is also important for future land use planning since discharging more flow to the watercourse via storm sewers or other infrastructure could result in increased erosion downstream due to larger flows. The assessment was limited to watercourses WC-04 and WC-08 where the channel could be surveyed through publicly accessible land.

In natural systems, channels regularly experience flows that entrain and transport sediment; this is part of the natural process that maintains channel form. Natural rates of erosion are expected to maintain channel form and function. Changes in flow due to alterations in the watershed's hydrology, such as those caused by urbanization, agricultural practices, or anthropogenic modifications like channel straightening, can adversely affect channel stability and result in increased erosion. Therefore, an erosion threshold assessment is crucial for determining the critical hydraulic conditions at which erosion is likely to begin in the channel.

An erosion threshold assessment was completed using the methods outlined in both the TRCA's Stormwater Management Criteria (2012) and the CVC Fluvial Geomorphic Guidelines (2015). The collection of detailed geomorphic field data enables the calculation of erosion thresholds, which consider multiple techniques for determining the critical velocities and shear stresses needed to mobilize the existing bed sediments and derive their respective critical discharges (Q_{cr}). The results are then assessed for convergence and general agreement with field observations of water levels and evidence of sediment transport at the time of the survey to determine a final reach-averaged value.

The general procedures of the erosion threshold assessment consisted of:

- Reach delineation (refer to Table 2-2).
- Rapid geomorphic assessment to evaluate reach stability (refer to Section 3.2).
- Detailed examination of reaches in the Study Area to identify the most sensitive reach (typically, the most sensitive reach identified in the rapid assessments is used to guide the detailed field work for the erosion threshold calculations).
- 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 sediment entrainment (or lack thereof) at different velocities, discharges and/or flow depths.

The critical discharge calculations themselves are dependent on the reach's longitudinal profile, energy gradient, bankfull dimensions, bed substrate composition, and bank materials at each of the measured cross-sections. The calculation procedure for these discharges is determined through the iterative procedure described below. Note that the energy gradient is held constant during these calculations, whereas Manning's 'n' values vary with water depth to account for relative roughness.

1. Channel cross-sections are divided into a series of vertical sub-panels whose widths are determined by the lateral spacing between adjacent cross-section survey points.
2. Left and right bank toe positions are established to identify sub-panels that are associated with the channel bed.
3. Initial water depths are set to 1 mm.
4. Velocities, shear stresses and discharges are calculated for each of the wetted sub-panels. Cross-section discharges are the sum of the individual wetted panel discharges.
5. Results from Step 4 are compared against the critical stresses needed for sediment entrainment.
6. If the critical velocity/stress of a particular threshold formula is exceeded over a given percentage of the bed (50% in this particular study), calculations for that formula cease. Otherwise, water depths are increased by 1 mm, and steps 4-6 are repeated until the threshold criteria are met.

7.1 Critical Discharge Results

Once channel dimensions, substrate composition, and bank materials were established, empirical relations were utilized to determine the flow conditions at which bed sediments would theoretically be entrained. There are many commonly used empirical formulae for determining when critical hydraulic conditions are met for sediment entrainment. All the formulae have strengths and limitations stemming from the different data sets that were used to develop the equations. For this analysis, the empirical relation proposed by Komar (1987), which was developed for gravel rivers, was utilized for WC-04, while the relation by Neil (1967), tailored for rivers with very coarse sand (ranging from 6 mm to 30 mm), was applied to WC-08. These relations were selected from a list of several to ensure that the sediment and hydraulics conditions for each site are accurately represented.

- It's important to note that both formulas assume that a reach is in equilibrium with prevailing flow and sediment supply conditions. However, both WC-04 and WC-08, displayed evidence of bank instability and deposition with both receiving an RGA

rating of Transitional or Stressed (see Section 3.2.1.2, and Section 3.2.4.2 respectively). As such, both watercourses are adjusting under current conditions, and the erosion thresholds must be considered in this context as indicative only.

7.1.1 WC-04

The erosion threshold assessment for WC-04 utilizes an empirical relation proposed by Komar (1987) that was developed for gravel-bedded rivers. The results are presented in Table 7-1. The critical discharge (Q_{cr}) was determined to be 1.65 m^3/s for WC-04. This value represents the average critical discharge across 4 of the 6 surveyed cross-sections. Cross-sections 2 (XS-2) and 3 (XS-3) were excluded from this result as their respective D_{50} values are less than 1 mm in diameter and are not representative of the reach as a whole. Additionally, the grain size distributions for XS-2 and XS-3 are both bimodal, meaning that the median grain size (D_{50}) does not properly characterize the bed material. Furthermore, the maximum depth at the critical discharge at XS-2 and XS-3 was less than the maximum water depth observed during the survey, at which time no sediment movement was observed. For all these reasons, XS-2 and XS-3 were excluded from the analysis.

The average bankfull discharge (Q_{bf}) was approximately 6.5 m^3/s (Table 7-1). This value was used to help determine the most appropriate empirical relation for calculating Q_{cr}. Other methods were unsuitable due to being designed for alternative bed compositions, deeper flows or resulting in unrealistically high Q_{cr} that exceeded bankfull conditions. An empirical relation proposed by Yang (1973) yielded a slightly higher result (Q_{bf} of approximately 2.75 m^3/s), which is nearly half the bankfull discharge. As a factor of safety, the Komar (1967) relation was utilized, resulting in a final critical discharge value of 1.65 m^3/s.

Critical threshold values were also calculated for the D_{65} values for each cross-section to both corroborate findings and assess the stability of the bed material. The Q_{crit} for the D_{65} was calculated to be approximately 5.85 m^3/s, which is nearly the same as the bankfull discharge (6.5 m^3/s) (Table 7-1). This result suggests that a large portion of the bed would be stable at bankfull conditions. Despite the RGA rating of Transitional or Stressed, this suggests that the bed material of the reach is stable.

Table 7-1: Erosion Threshold Assessment Results WC-04

Cross-section:	XS-1		XS-2		XS-3		XS-4		XS-5		XS-6		Average (Excludes XS-2 & XS-3)	
Feature:	Riffle		Run / Riffle		Run		Riffle		Riffle		Run			
Maximum Water Depth at Time of Survey (m)	0.20		0.23		0.47		0.13		0.10		0.37		0.20	
Sediment Movement Observed in Field?	No		No		No		No		No		No		N/A	
Characteristic Particle size	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}
d_{cr} (mm)	6.92	25.00	0.93	13.00	0.98	15.50	15.00	35.00	8.50	29.56	6.21	23.38	9.16 medium gravel	28.23 Coarse Gravel
v_{Avg} (m/s)	0.39	0.69	0.17	0.52	0.19	0.59	0.55	0.77	0.47	0.80	0.41	0.67	0.46	0.73
Q_{cr} (m^3/s)	1.10	4.61	0.15	2.17	0.23	3.13	2.71	7.56	1.67	6.60	1.12	4.62	1.65	5.85
Q_{bf} (m^3/s)	5.89		5.71		8.68		5.84		6.85		7.36		6.49	
Maximum Water Depth (m) at Q_{cr}	0.43	0.78	0.15	0.49	0.21	0.60	0.55	0.88	0.41	0.80	0.39	0.75	0.44	0.80

Note: d_{cr}: Critical particle diameter used in the analysis. v_{Avg}: Average velocity at the critical discharge Q_{cr}. τ_{cr}: Critical stress required for sediment entrainment. Q_{cr}: Critical discharge required for sediment entrainment. Q_{bf}: Bankfull discharge. Note that the above critical discharges represent those required for incipient motion, or the threshold for the particle of interest (in this case D50 and D65) to initially be mobilized.

7.1.2 WC-08

The erosion threshold assessment for WC-08 utilizes an empirical relation proposed by Neil (1967) that was developed for rivers with very coarse sand (ranging from 6 mm to 30 mm). The results are presented in Table 7-2. The critical discharge (Q_{cr}) was determined to be 0.75 m^3/s for WC-08. This value represents the average critical discharge across 4 of the 6 surveyed cross-sections. Cross-sections 3 (XS-3) and 4 (XS-4) were excluded from this result as they represent pool features, and as a consequence, their respective D_{50} values are less than 2 mm in diameter and are not representative of the reach. Furthermore, for XS-3 and XS-4, the maximum depth at the critical discharge is less than or very close to the maximum water depth observed at the time of the survey, and no sediment movement was observed during the field visit. For these reasons, XS-3 and XS-4 were excluded from the analysis.

The average bankfull discharge (Q_{bf}) was approximately 2.42 m^3/s Table 7-2. This value was used to help determine the most appropriate empirical relation for calculating Q_{cr}. Other methods were unsuitable due to being designed for alternative bed compositions, deeper flows or resulting in unrealistically high Q_{cr} that exceeded bankfull conditions. An empirical relation proposed by Komar (1987) yielded a lower result (Q_{bf} of approximately 0.25 m^3/s), which seems unrealistically low when compared to the bankfull discharge (~9% of bankfull). As such, the Komar (1967) relation was utilized, resulting in a final critical discharge value of 0.75 m^3/s.

Critical threshold values were also calculated for the D_{65} values for each cross-section to both corroborate findings and assess the stability of the bed material. The Q_{crit} for the D_{65} was calculated to be approximately 2.72 m^3/s, which is greater than the bankfull discharge (2.42 m^3/s) Table 7-2. This result suggests that a large portion of the bed would be stable at bankfull conditions. Despite the RGA rating of Transitional or Stressed, this suggests that the bed material of the reach is stable.

Table 7-2: Erosion Threshold Assessment Results WC-08

Cross-section:	XS-1		XS-2		XS-3		XS-4		XS-5		XS-6		Average (Excludes XS-3 & XS-4)	
Feature:	Riffle		Riffle		Pool		Pool / Run		Riffle		Run			
Maximum Water Depth at Time of Survey (m)	0.20		0.16		0.26		0.20		0.13		0.12		0.15	
Sediment Movement Observed in Field?	No		No		No		No		No		No		N/A	
Characteristic Particle size	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}	D_{50}	D_{65}
d_{cr} (mm)	7.78	20.00	3.00	30.00	1.22	5.650	0.74	2.00	5.88	10.00	1.65	5.83	4.57 Very Coarse Sand	16.46 Coarse Gravel
v_{Avg} (m/s)	0.70	1.02	0.50	1.27	0.35	0.62	0.28	0.39	0.58	0.68	0.41	0.66	0.55	0.90
Q_{cr} (m^3/s)	1.19	1.01	0.63	5.32	0.37	1.27	0.20	0.46	0.77	1.36	0.42	1.32	0.75	2.72
Q_{bf} (m^3/s)	2.01		2.31		2.77		2.49		2.59		2.76		2.42	
Maximum Water Depth (m) at Q_{cr}	0.51	0.75	0.31	0.85	0.31	0.48	0.18	0.25	0.34	0.44	0.24	0.40	0.35	0.61

Notes: d_{cr}: Critical particle diameter used in the analysis. v_{Avg}: Average velocity at the critical discharge Q_{cr}.: Critical velocity required for sediment entrainment. τ_{cr}: Critical stress required for sediment entrainment. Q_{cr}: Critical discharge required for sediment entrainment. Q_{bf}: Bankfull discharge. Note that the above critical discharges represent those required for incipient motion, or the threshold for the particle of interest (in this case D50 and D65) to initially be mobilized.

8. Bed Scour Assessment

The assessment of bed scour is crucial for buried infrastructure because it helps identify potential risks associated with vertical erosion and degradation of stream and riverbeds. By understanding these risks, infrastructure such as sewers, utilities, and bridge footings are installed below the scour depth to prevent damage and maintain the integrity of these structures over time. Fact sheet VI Scour Analysis from Credit Valley Conservation provides a standardized approach to evaluate and mitigate scour hazards, ensuring long-term safety and functionality of buried infrastructure (CVC, 2019). Methodology for determining the Scour Hazard Limit must be consistent with the Scour Hazard Limit Reference Table, which has been reproduced below (Table 8-1).

Table 8-1: Scour Hazard Limit Reference Table, Reproduced from CVC, 2019

Scour Hazard Limit" Options	Small Channels $D_{BF} \leq 0.5$ m	Main Channels $d_{BF} = 0.5 – 2$ m
Simplified Standard Method Scour Hazard Limit (SHL) Factor of Safety** (FS) = 2.0	SHL = 1.25 m x 2.0 = 2.5 m	SHL = [d_{BF} x 2.5] x FS = 2.5 to 10 m
Application of Detailed Methods Scour Hazard Limit (SHL)	Select Equation 1, 2, or 3	Select Equation 1, 2, or 3
Natural Scour (N_s)	N_s = 1.25 (minimum)	$N_S = d_{BF}$ x 2.5 (or other approved method)
Factor of Safety** (Add bankfull depth)	FS = d_{BF}	FS = d_{BF}
Equation 1 In vicinity of culvert or weir structures, assuming $L_S > G_S$		SHL = $L_S + N_S$ + FS**
Equation 2 For open channels without structures		SHL = $G_S + N_S$ + FS**
Equation 3 In vicinity of bridge piers		SHL = $G_S + L_S + N_S$ + FS**

Notes: N_S = *Natural Scour*
G_S = *General Scour*
L_S = *Local Scour*
d_{BF} = *average bankfull depth (m)*

* *Scour Hazard Limit (SHL) is to be vertically offset from the average riffle grade elevation, or the average bed elevation where riffles are not present.*

** *Recommended Factor of Safety (FS) unless otherwise justified. For cases where all scour coefficients are available/ calculated a FS is not necessary as most empirical models account for a FS. For cases where one or more scour coefficients are missing/ not calculated then a FS should be applied*

8.1 Scour Depth Calculations

8.1.1 Simplified Standard Method

Due to a lack of hydraulic modelling data, it is recommended that the Simplified Standard Method be used to define the scour depth of the projected life of the infrastructure (assumed to be 100 years). CVC (2019) provides two different equations for this, based on channel size, as outlined in Equation 8-1 and Equation 8-2. Results of the calculations are provided in Table 8-2, below.

Equation 8-1: Scour Hazard Limit for Small Channels ($d_{BF} \leq 0.5$ m)

$$SHL = 1.25\ m\ x\ 2.0 = 2.5\ m$$

Equation 8-2: Scour Hazard Limit for Main Channels (d_{BF} = 0.5 – 2 m)

$$SHL = [d_{BF} x 2.5] x\ FS$$

Where: d_{BF} = Average bankfull depth (m)
FS = 2.0 for small channels, or bankfull depth for main channels

Table 8-2: Simplified Standard Method Scour Depth Results

Reach ID	Bankfull Depth (Approximate observed in field)	Bankfull Depth (from survey)	Channel Classification (from CVC, 2019)	Simplified Standard Method Predicted Scour of 100-years (m)
WC-35	0.3 – 0.8 Average: 0.55	N/A	Main Channel Average bankfull depth between 0.5 – 2 m	2.75
WC-34	0.3 – 0.6 Average: 0.45	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-33	No Defined Channel	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-13	Upstream: 0.2 Poorly defined downstream	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-12	0.5	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-04	0.4 – 0.8 Average: 0.6	0.67	Main Channel Average bankfull depth between 0.5 – 2 m	3.35
WC-02	No Defined Channel	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-10	No Defined Channel	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-08	0.5 – 1.0 Average: 0.75	0.43	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-07	0.3 – 0.5 Average: 0.4	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC–06a	0.3 – 0.5 Average: 0.4	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-06	0.2	N/A	Small Channel Average bankfull depth less than or equal to 0.5 m	2.5
WC-05a	0.8	N/A	Main Channel Average bankfull depth between 0.5 – 2 m	4
WC-05	0.8	N/A	Main Channel Average bankfull depth between 0.5 – 2 m	Entire channel bed is lined with concrete. No scour analysis performed.

8.1.2 Application of Detailed Methods

For the purposes of due diligence, the predicted scour under bankfull conditions was also defined using detailed methods as a point of comparison. The Scour Hazard Limit (SHL) defines the maximum depth that a channel is likely to scour below the existing channel (Δz). The SHL must consider the cumulative effects of three types of scour, and is defined as:

Equation 8-3: Scour Hazard Limit

$$SHL = L_s + G_s + N_s + FS^{**},$$

Where: L_s: Local scour (m) - localized erosion of the channel bed around in-stream structures/flow obstructions over the course of a single event to years.

G_s: General scour (m) – a lowering of the channel bed that affects most/all of the channel cross-section over the course of a single event to years.

N_s: Natural scour (m) – a lowering of the channel bed that affects the entire reach due an imbalance between channel dimensions and the river's flow regime over the course of decades to centuries.

FS^{**}: Safety factor (m) – accounts for inherent uncertainties related to the response of dynamic systems. Typically, $FS = 1d_{BF}$ (d_{BF}: bankfull depth).

*Note: ** "Recommended Factor of Safety (FS) unless otherwise justified. For cases where all scour coefficients are available/ calculated a FS is not necessary as most empirical models account for a FS. For cases where one or more scour coefficients are missing/ not calculated then a FS should be applied."(CVC, 2019)*

8.1.2.1 Local and General Scour

Equations provided in the National Engineering Handbook Part 654 (USDA, 2007) were used to calculate the anticipated scour based on bankfull dimensions. This includes equations proposed by Lacey (1931) (NEH and USBR versions), Blench (1970), and Neill (1973). Equations proposed by Lacey (1931) and Blench (1970) (see Equation 8-4) use different constants to predict the shear stress (refer to Table 8-3 and Table 8-4). The equation proposed by Neill (1973) (Equation 8-5) considers maximum scour depth using discharge.

The values are then compared, which is in accordance with the method suggested by Pemberton and Lara (1984), which involves using the regime equations provided by Blench (1970) and Lacey (1931) and averaging the outcome or taking the largest value.

Equation 8-4: Scour Depth (Lacey, 1931 and Blench, 1970)

$$z_t = KQ_d^a W_f^b D_{50}^c$$

Where: z_t = maximum scour depth at the cross − section or reach in question, ft (m)
K = coefficient (table TS14B − 8)
Q_d = design discharge, ft^3/s (m^3/s)
W_f = flow width at design discharge, ft (m)
D_{50} = median size of be material (mm)
a, b, c = exponents (table TS14B − 8)

Table 8-3: Reproduced Constants for Lacey and Blench relations, U.S. units (D_{50} in mm) reproduced from TS14B-8 USDA, 2007

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	C
Straight Reach	0.097	1/3	0	-1/6	0.530	2/3	-2/3	-0.1092
Moderate Bend	0.195	1/3	0	-1/6	0.530	2/3	-2/3	-0.1092
Severe Bend	0.292	1/3	0	-1/6	0.530	2/3	-2/3	-0.1092
Right Angle Bent	0.389	1/3	0	-1/6	1.105	2/3	-2/3	-0.1092
Vertical Rock Wall	0.487	1/3	0	-1/6	/	/	/	/

Table 8-4: Reproduced Constant K for Lacey and Blench relations, SI units (D_{50} in mm) reproduced from TS14B-9 USDA, 2007

Condition	Lacey	Blench
Straight Reach	0.030	0.162
Moderate Bend	0.059	0.162
Severe Bend	0.089	0.162
Right Angle Bend	0.119	0.337
Vertical Rock Wall	0.148	0.000

Equation 8-5: Neill (1973)

$$z_t = z * d_{BF} \left(\frac{Q_d / w_d}{Q_{BF} / w_{BF}} \right)^m$$

Where: $z = 0.5$ if straight, 0.6 if moderate, and 0.7 if severe

z_t = maximum scour depth at the cross – section or reach in question, ft (m)

Q_d = design discharge, $\frac{\text{ft}^3}{\text{s}} \left(\frac{\text{m}^3}{\text{s}} \right)$

w_d = design width (m)

Q_{BF} = bankfull discharge, ft^3/s (m^3/s)

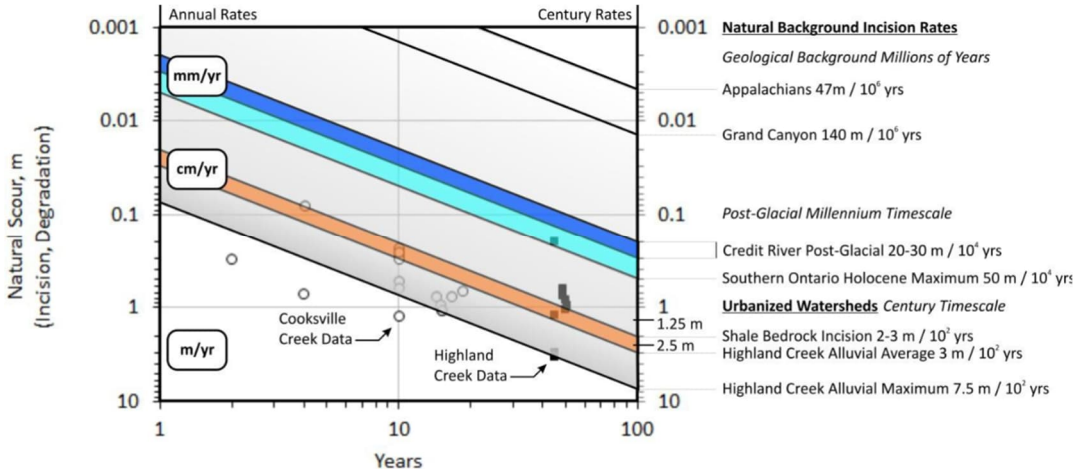
w_{BF} = bankfull width (m)

m = 0.67 for sand, 0.85 for gravel

8.1.2.2 Natural Scour

While local and general scour estimations are based on the autogenic processes between channel dimensions, substrate characteristics, and flow regime, natural scour results from allogenic (regional) processes such as geologic and climatic history, land use changes, and require observation periods spanning multiple decades. Consequently, there are no practical guidelines for establishing natural scour (N_s) in Equation 8-3. Nevertheless, natural channel incision rates over geologic timescales and those resulting from urbanization within Southern Ontario are presented in Figure 8-1.

Figure 8-1: Geological and Historical Rates of Vertical Scour (USDA, 2007)



Based on Figure 4-1, the amount of natural scour expected within WC-04 and WC-08 likely ranges from 0.2 – 0.3 m per 100 years (i.e., 2-3 mm / year) based on the rates provided for the

Credit River post-glacial period. However, a conservative amount of 0.5 m per 100 years should also be considered as a factor of safety, which represents the maximum rate of scour during the Holocene in Southern Ontario.

8.1.2.3 Application of Detailed Methods Results

Measurements and computed channel geometry parameters are presented in Table 8-5, below. The values were extracted from topographic surveys and the field assessment to yield expected rates of scour under bankfull conditions (refer to Section 8.1.1). The highest general/local scour rates are recommended for added safety. Natural scour rates have also been provided and estimate the natural scour that is likely to occur over a 2-year period. Results are provided in Table 8-6 and Table 8-7.

Table 8-5: Measured and Computed Channel Parameters

Channel Parameter	WC-04	WC-08
Average Bankfull Width (m)	11.04	5.93
Average Bankfull Depth (m)	0.67	0.43
Maximum Bankfull Depth (m)	0.87	0.6
Bed Slope (%)	0.16	0.24
Channel Material	Fines and gravels to cobbles and small boulders	Fines and gravels to cobbles and small boulders
Bed Material D_{50} (mm)	6.42	3.38
Bed Material D_{84} (mm)	55.37	39.03
Bankfull Velocity (ms^{-1})	0.78	0.84
Bankfull Discharge (m^3s^{-1})	6.77	2.54
Design Discharge (m^3s^{-1})	6.77	2.54
Stream Power (Wm^{-1})	106.22	59.73
Stream Power per Unit Width (Wm^{-2})	9.76	10.23
Reach Descriptor	Moderate Bend	Moderate Bend

Table 8-6: Predicted Bed Scour Values for WC-04

Method	G_s (m)*	Average Expected N_s (m)	Maximum Expected N_s (m)	FS (m) (as per CVC, 2019) = bankfull depth	Average Expected SHL (m) under bankfull flow	Maximum Expected SHL (m) under bankfull flow
	Calculated Value under bankfull conditions	Expected Scour Over 2 Year-Period			$G_s + N_s + FS$	$G_s + N_s + FS$
Lacey (1931) NEH	0.08	0.004 – 0.006	0.01	0.67	0.75 - 0.76	0.76
Lacey (1931) USBR	0.27	0.004 – 0.006	0.01	0.67	0.94 – 0.95	0.95
Blench (1970) NEH	0.10	0.004 – 0.006	0.01	0.67	0.77 – 0.78	0.78

Method	G_s (m)*	Average Expected N_s (m)	Maximum Expected N_s (m)	FS (m) (as per CVC, 2019) = bankfull depth	Average Expected SHL (m) under bankfull flow	Maximum Expected SHL (m) under bankfull flow
	Calculated Value under bankfull conditions	Expected Scour Over 2 Year-Period			$G_s + N_s + FS$	$G_s + N_s + FS$
Neill (1973)	0.40	0.004 – 0.006	0.01	0.67	1.07 – 1.08	1.08

*Note: * It should be noted that since most scour equations are empirical in nature, they often represent the cumulative effects of local scour (L_s), general scour (G_s), and the safety factor (FS) (CVC, 2019).*

Table 8-7: Predicted Bed Scour Values for WC-08

Method	G_s (m)*	Average Expected N_s (m)	Maximum Expected N_s (m)	FS (m) (as per CVC, 2019) = bankfull depth	Average Expected SHL (m) under bankfull flow	Maximum Expected SHL (m) under bankfull flow
	Calculated Value under bankfull conditions	Expected Scour Over 2 Year-Period			$G_s + N_s + FS$	$G_s + N_s + FS$
Lacey (1931) NEH	0.07	0.004 – 0.006	0.01	0.43	0.50 – 0.51	0.51
Lacey (1931) USBR	0.22	0.004 – 0.006	0.01	0.43	0.65 – 0.66	0.66
Blench (1970) NEH	0.08	0.004 – 0.006	0.01	0.43	0.51 – 0.52	0.52
Neill (1973)	0.26	0.004 – 0.006	0.01	0.43	0.69 – 0.70	0.70

*Note: * It should be noted that since most scour equations are empirical in nature, they often represent the cumulative effects of local scour (L_s), general scour (G_s), and the safety factor (FS) (CVC, 2019).*

8.2 Scour Assessment Results

Results of the scour assessment have been provided in Table 8-8. Values calculated using the simplified and detailed methods have been included in the table for due diligence. Due to the lack of hydraulic modelling data however, it is recommended that the values calculated using the Simplified Standard Method be used, as this represents the amount of scour likely to occur over the next 100 years; the detailed method records the amount of scour likely to occur under bankfull conditions.

Table 8-8: Scour Assessment Results

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Evidence of channel Scour and Erosion	Channel Classification (Table 4 from CVC, 2019)	Simplified Standard Method Predicted Scour of 100-years (m)	Application of Detailed Methods Predicted Scour under Bankfull Conditions (m)*	Recommended Burial Depth for 100-year lifespan (m)**
WC-35	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Muck, Silt, sand, clay, gravel to cobbles	■ Multiple debris jams present. Scour pool and exposed clay along the channel bed were observed downstream of a debris jam near the crossing ■ Exposed clay (bed scour) in the vicinity of the crossing	■ Main Channel ■ Average bankfull depth between 0.5 – 2 m	■ 2.75	■ N/A – Channel survey could not be completed	■ 2.8 ■ Predicted Scour over 100-years. Defined using Simplified Standard Methods as per CVC (2019)
WC-34	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Silt, sand, muck, clay, gravels and cobbles (not natural)	■ The culvert inlet is located at a meander bend. ■ Flow is not centred through the culvert, which is causing erosion adjacent to the culvert inlet along the eastern channel bank ■ Exposed clay (bed scour) in the vicinity of the crossing	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-33	■ Clay to silt-textured till in proximity to modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter	■ Silt, muck, gravel and placed cobbles (not natural)	■ There was minor erosion along the right (south) bank upstream of the crossing behind the culvert. This may be due to the steepness of the ditch wall and not erosion from flows in reach WC-33	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-13	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till	■ Silt, muck, clay	■ Evidence of channel widening was observed from the ROW, including fallen/leaning trees, exposed roots, and basal scour on both sides of the channel through riffles ■ Scour pools present at the culvert outlet. Exposed clay was also noted ■ The left (north) downstream outlet wingwall has collapsed and is now within the channel. This has created a debris jam and is causing flow and sedimentation issues. ■ Channel was channelized prior to 1974 and has been regaining sinuosity since	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-12	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter. Surrounded by clay to silt-textured till and fine-textured glaciolacustrine deposits of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.	■ Clay, silt, sand, muck, cobbles (not natural)	■ The entire feature was straightened by 1999. It has been relatively stable since ■ The watercourse appears to have been dredged, which has exposed clay along the bottom of the channel. This was likely anthropogenic and not due to fluvial geomorphic processes	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-04	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.	■ Fines and gravels to cobbles and small boulders.	■ Abundant evidence of channel widening was observed (leaning and fallen trees, large woody debris, exposed tree roots, basal scour, and fracture lines along the top of the bank) ■ An accumulation of cobbles was present through the crossing structure. No low-flow channel was present ■ Scour pools were noted downstream of the Vodden Street east crossing where stormwater outfalls were located ■ The channel upstream of the Vodden Street East crossing was straightened prior to 1999	■ Main Channel ■ Average bankfull depth between 0.5 – 2 m	■ 3.35	■ 1.08	■ 3.4 ■ Predicted Scour over 100 years. Defined using Simplified Standard Methods as per CVC (2019)
WC-02	■ Clay to silt textured till.	■ N/A	■ No evidence of erosion was observed	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m

Reach ID	Surficial Geology (Ontario Geological Survey, 2010)	Boundary Materials (from field assessment)	Evidence of channel Scour and Erosion	Channel Classification (Table 4 from CVC, 2019)	Simplified Standard Method Predicted Scour of 100-years (m)	Application of Detailed Methods Predicted Scour under Bankfull Conditions (m)*	Recommended Burial Depth for 100-year lifespan (m)**
WC-10	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by clay to silt-textured till. There are also Paleozoic bedrock outcrops in the surrounding area. There are also fine-textured glaciolacustrine deposits nearby of silt and clay with minor sand and gravel. These deposits are interbedded silt and clay with pebbly flow till and rainout deposits.	■ N/A	■ No evidence of erosion was observed	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-08	■ Modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, surrounded by Paleozoic bedrock and clay to silt-textured till.	■ Fines and gravels to cobbles and small boulders	■ Abundant evidence of channel widening was observed (fallen trees, exposed tree roots, large organic debris, basal scour) ■ Aggradation (coarse material embedded in riffles, siltation in pools, and deposition in overbank zone) and degradation (exposed clay, exposed suspended armour layer, and scour pools located downstream of elevated stormwater outfalls) were also observed ■ Live stake restoration was observed at this location and is likely being used to mitigate erosion issues in the reach ■ Channel likely straightened prior to 1974 upstream of Bovaird Drive West	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ 0.70	■ 2.5 ■ Predicted Scour over 100-years. Defined using Simplified Standard Methods as per CVC (2019)
WC-07	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to gravel sized fragments with small boulders	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Evidence of channel widening included basal scour and fracture lines along the top of the bank. ■ Lesser evidence of bed degradation (channel worn into overburden) was also observed	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC–06a	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Abundant evidence of channel widening was observed (fallen/leaning trees, exposed tree roots, and fracture lines on top of the bank, as well as basal scour) ■ Lesser evidence of aggradation (coarse material embedded in riffles and poor sorting of bed materials), and degradation (scour pools located downstream of culvert outfalls) was present	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-06	■ Clay to silt textured till near modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	■ Fines to large boulders	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Abundant evidence of channel widening was observed (fallen/leaning trees, large organic debris, exposed tree roots, and outflanked armourstone, as well as basal scour) ■ Lesser evidence of aggradation was also noted (coarse material embedded in riffles and siltation in pools)	■ Small Channel ■ Average bankfull depth less than or equal to 0.5 m	■ 2.5	■ N/A	■ 2.5 ■ As per Factsheet VI Scour Analysis (2019), a minimum standard of 2.5 m of scour is recommended for all small channels with an average bankfull depth of less than 0.5 m
WC-05a	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	Fines to large boulders	■ Feature is a drainage ditch that was channelized and straightened between 1970 and 1999 ■ Minor evidence of channel widening was observed (basal scour, presence of large organic debris, and outflanked armourstone) ■ Lesser evidence of aggradation (siltation in pools) and degradation (scour pools located downstream of stormwater outfalls) was also observed	Main Channel Average bankfull depth between 0.5 – 2 m	4.0	N/A – Channel survey could not be completed	4.0 Predicted Scour over 100-years. Defined using Simplified Standard Methods as per CVC (2019)
WC-05	■ Clay to silt textured till and modern alluvial deposits of clay, silt, sand, gravel and possibly organic matter, clay to silt-textured till.	Fines to large boulders. Channel lined with concrete.	The entire reach has been lined with concrete. No evidence of erosion was observed.	Main Channel Average bankfull depth between 0.5 – 2 m	Entire channel bed is lined with concrete. No scour analysis performed.	N/A	Entire channel bed is lined with concrete. No scour analysis performed.

Notes: **During preliminary design, should hydraulic modelling for the 100-year flow event become available, the detailed methods should be re-evaluated to determine the predicted scour over the projected lifespan of the buried infrastructure*
*** These values are scour depths and do not include the necessary depth requirement for frost.*

9. Key Findings and Recommendations

The following can be concluded from the fluvial geomorphological assessment and bed scour assessment completed for the project:

- A total of 14 features were investigated. Two features were identified as undefined ephemeral features, eleven were identified as defined permanent or intermittent features, and one was a piped feature.
  - Defined (intermittent or permanent) features were described and photographed in the field and a Reach Characterization, Rapid Geomorphic Assessment (RGA), and a Crossing Assessment (see Section 3.2), were completed as close to the proposed crossing location as possible (where PTE restrictions allowed) to document any evidence of channel instability.
  - Undefined (ephemeral) channels were described in the field and photographed. Ephemeral features typically have a small drainage area and limited seasonal flows. They typically lack the strength to form defined channel boundaries or to cause erosion within the reach.
  - A piped (likely undefined) feature was also documented in the same manner as the ephemeral features.
- Of the eleven defined features investigated, four were found to be “In Regime” with a low erosion risk as per the field investigations and the results of the RGA. The remaining defined reaches investigated (6 in total) were found to be in a “Transitional or Stressed” condition and with a moderate erosion risk (See Section 3.2 and Table 6-6).
- Field surveys were conducted for the two watercourses (WC-04 and WC-08) that could be accessed through public areas. For each watercourse, cross-sections (Section 5.1), bank characterization (Section 5.2), a longitudinal profile (Section 5.3) and a bed characterization analysis (Section 5.4)were completed.
- Preliminary meander belts were delineated for all defined features using the planform mapping approach (where possible) and empirical equations. The empirical approach (Table 6-1) was used for 8 of the 11 defined features due to a narrow channel width, evidence of anthropogenic alteration, or lack of visibility in aerial imagery. The planform mapping approach (see Section 6.1) was used to delineate the preliminary meander belt for the remaining features WC-34, WC-04, and WC-08. Preliminary meander belt width results are summarized in Table 6-2.
- Once the preliminary meander belt width was determined, an erosion allowance was applied to account for the 100-year erosion potential. For defined and unaltered watercourses that could be traced on a map, the erosion rate was defined using

historic meander changes based on aerial imagery. This method was used to delineate the 100-year erosion rate of WC-04 and WC-08 (see Section 6.2.1). For the remaining defined features, the 100-year erosion rate was estimated based on a combination of recommended values from the MNR and based on 10% of the preliminary meander belt width (see Section 6.2.2). The final recommended 100-year erosion rate are summarized in Table 6-6.

- Final meander belt widths results are provided in Table 6-8 and are shown in Appendix D.
- An erosion threshold assessment was completed for WC-04 and WC-08 using the methods outlined in Section 7 to identify the hydraulic conditions (critical discharge) that could cause bed erosion. The results suggest that the bed material is stable for both watercourses at bankfull flows, despite having RGA ratings of Transition or stressed (see Section 7.1). The results are summarized for WC-04 and WC-08 in Table 7-1 and Table 7-2, respectively.
- A bed scour assessment was completed to inform recommended burial depths for buried infrastructure. Results of the scour assessment for each of the 14 features investigated have been provided in Table 8-8. Values calculated using the simplified (see Section 8.1.1) and detailed (see Section 8.1.2) methods have been included in the table for due diligence. The values are scour depths and do not include the necessary depth requirement for frost.
- Based on the results of the assessments completed, the following recommendations can be made for the recommended preferred sanitary trunk sewer route to limit adverse impacts to channel morphology and risk to the proposed trunk sewers:

    1. Recommended pipe burial depth (see Table 8-8) should consider proximity to existing undersized crossing structures (see Section 3.2). Undersized structures constrain flow which can cause additional localized bed erosion. As such, the recommended burial depth in some cases may be an underestimate.
    2. Pipe burial depth considerations should extend laterally past the active channel and ideally should extend to the limit of the Final Meander Belt (see Table 6-8), or at a minimum, the limits of the 100-year erosion rate on either side of the active channel (Table 6-6) to achieve long-term stability.
    3. The erosion threshold assessment (see Section 7.1) suggests the bed material is stable for both WC-04 and WC-08 at bankfull flows. This provides confidence in the recommended burial depth. Before detailed design, it is recommended that field surveys and erosion threshold assessments be considered for any watercourses classified as main channels that were not accessible due to PTE constraints. This includes WC-35 and WC-05a. These assessments should

consider factors such as the reach's energy gradient, bank dimensions, bed substrate and bank composition.

4. It is recommended that additional hydraulic modelling be conducted during more advanced stages of design to confirm the velocities and shear stresses for larger flow events (e.g., 50-year and 100-year flows). Modelling would enable calculation of the estimated scour depths using the Detailed Method, for the projected lifespan of the buried infrastructure which would inform and help refine the recommended burial depths (see Table 8-8).
5. It is well established that large woody debris (LWD) can increase scour depths (Abbe & Montgomery, 1996; Webb & Erskine, 2005; Pagliara & Carnacina, 2011). An ongoing maintenance plan should be developed by a qualified professional to monitor and address LWD, as this debris can cause additional scour beyond the recommended burial depths.

- This study will be used to inform the preliminary design of sanitary trunk sewer water crossings and applicable connections next to subject watercourses (i.e., crossings WC-04 and WC-08). It is recommended that a fluvial geomorphologist be directly involved in the subsequent preliminary and detailed design of the new proposed trunk sewers to specifically address the observed geomorphological issues with the watercourses along the recommended preferred route and to provide further input on channel realignments.

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Building our future, faster.

Central Brampton

Appendix A

Historical Imagery

AECOM

Peel Region


WC-35
1974
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar, Microsoft


WC-35
1999
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar, Microsoft


WC-35
2005
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar, Microsoft


WC-35
2015
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar, Microsoft


WC-35
2023
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar, Microsoft


WC-34
1974
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar


WC-34
1999
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar


WC-34
2005
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar


WC-34
2015
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar


WC-34
2023
Upstream Reach Break
Downstream Reach Break
Peel Region, Maxar


WC-33
1974
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar, Microsoft

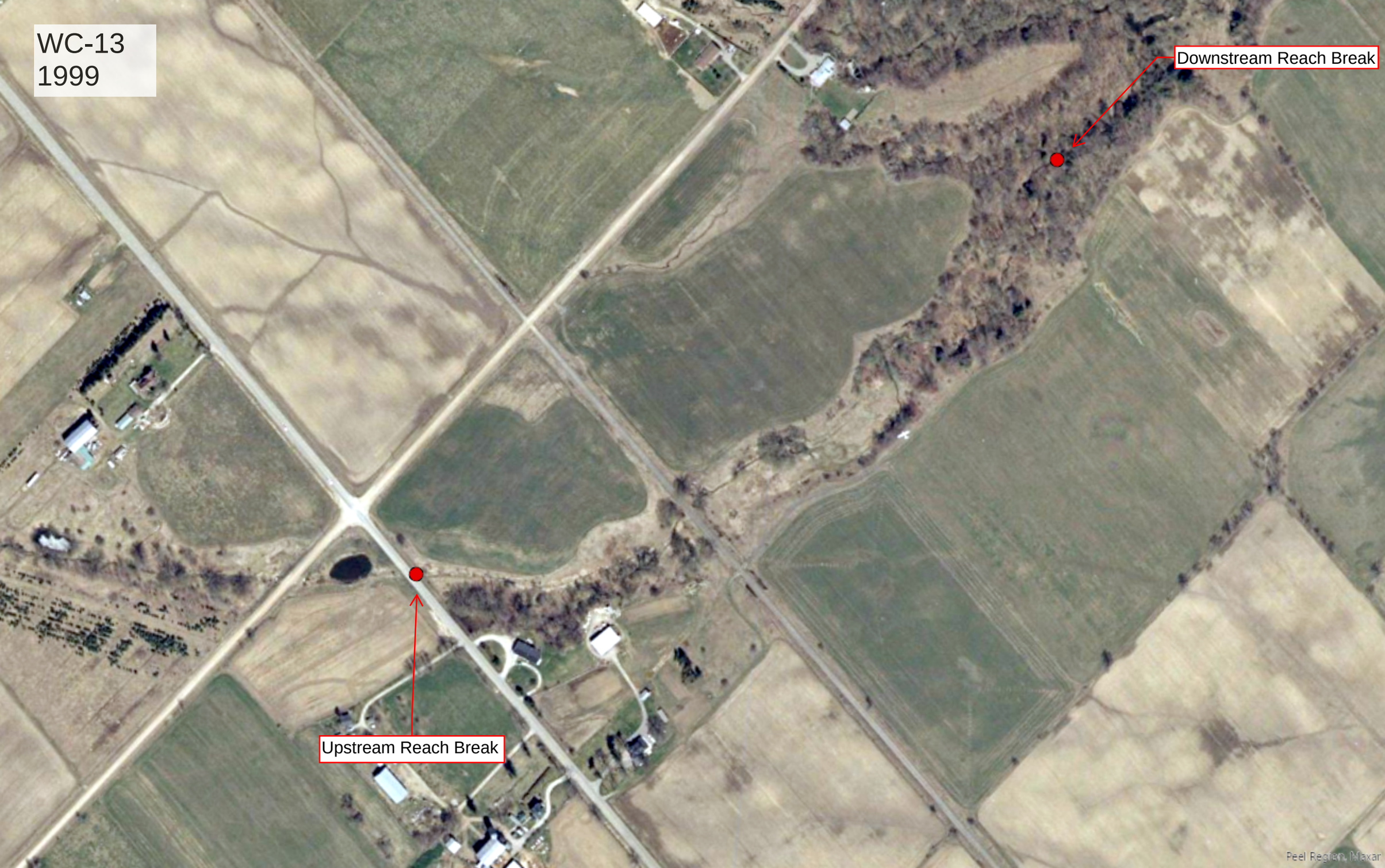

WC-33
1999
Downstream Reach Break
Upstream Reach Break
Esri Region, Maxar, Microsoft


WC-33
2005
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar, Microsoft


WC-33
2015
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar, Microsoft

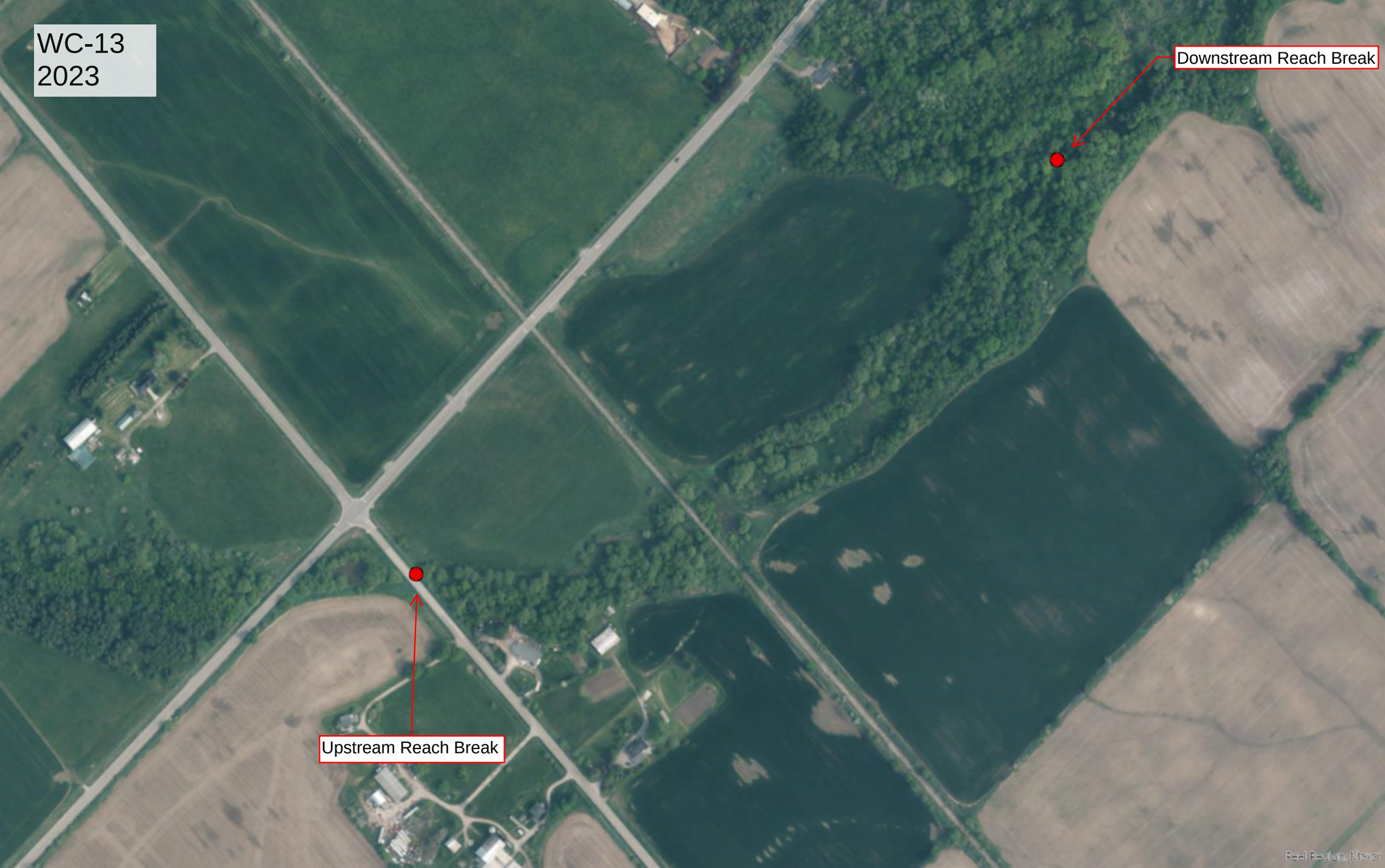

WC-33
2023
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar, Microsoft


WC-13
1974
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar


WC-13
1999
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar


WC-13
2005
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar


WC-13
2015
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar

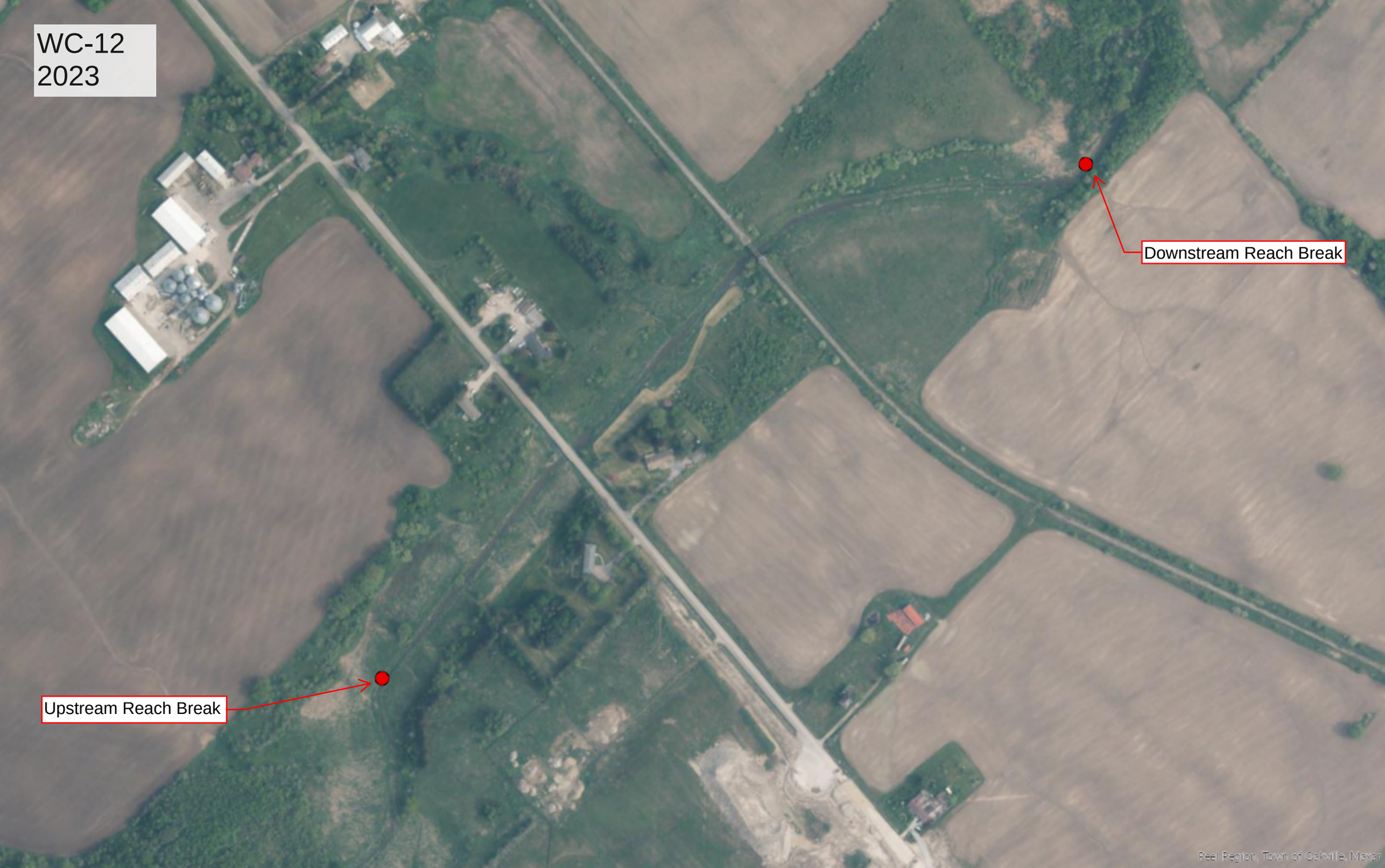

WC-13
2023
Downstream Reach Break
Upstream Reach Break
Peel Region, Maxar


WC-12
1974
Downstream Reach Break
Upstream Reach Break
Peel Region, Town of Oakville, Maxar


WC-12
1999
Downstream Reach Break
Upstream Reach Break
Peel Region, Town of Oakville, Metar


WC-12
2005
Downstream Reach Break
Upstream Reach Break
Peel Region, Town of Caledon, Maxar


WC-12
2015
Downstream Reach Break
Upstream Reach Break
Peel Region, Town of Oakville, Maxar

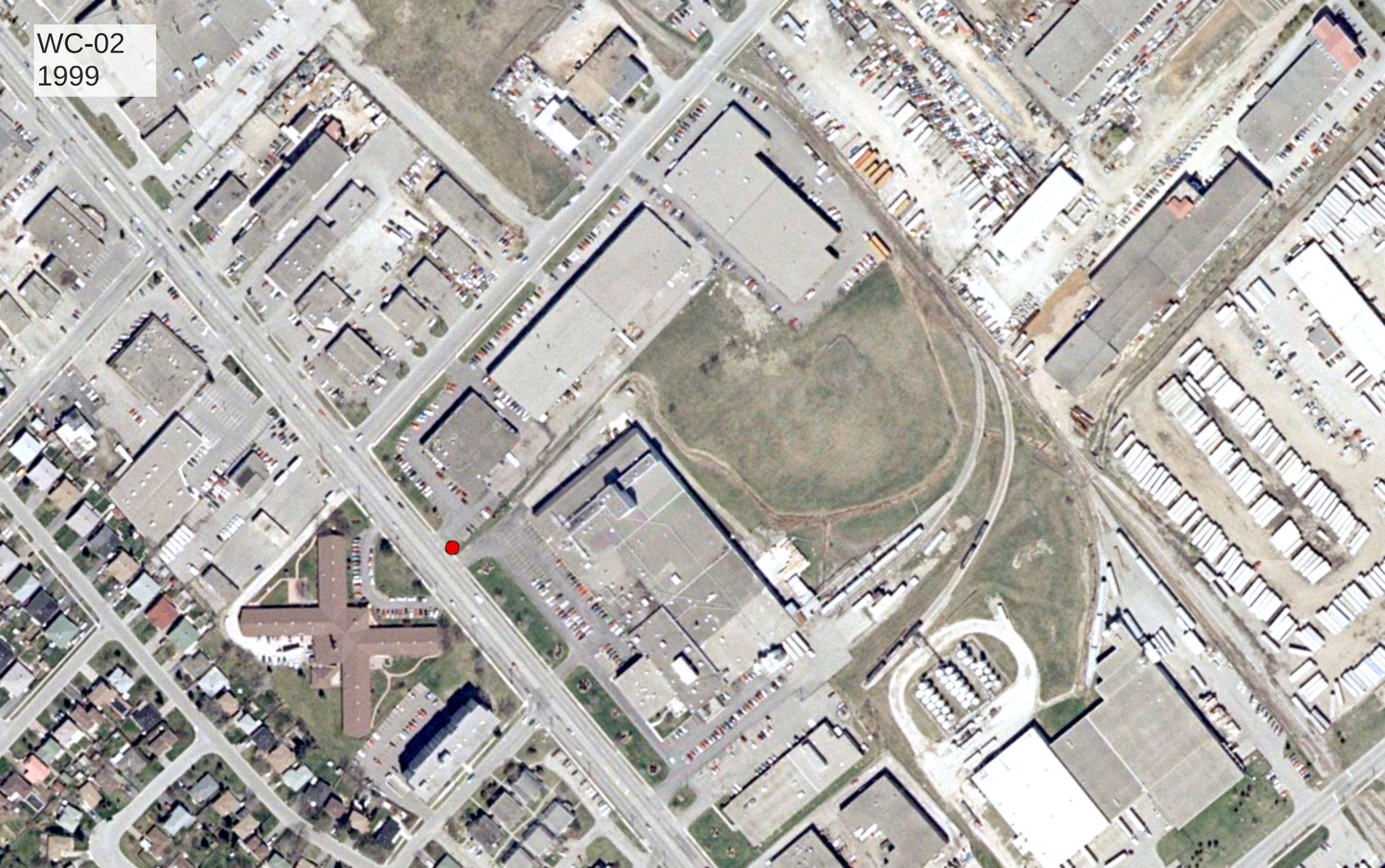

WC-12
2023
Downstream Reach Break
Upstream Reach Break
Peel Region, Town of Oakville, Maxar


WC-04
1999
Upstream Reach Break
Downstream Reach Break


WC-04
2005
Upstream Reach Break
Downstream Reach Break


WC-04
2015
Upstream Reach Break
Downstream Reach Break


WC-04
2024
Upstream Reach Break
Downstream Reach Break


WC-02
1999


WC-02
2005

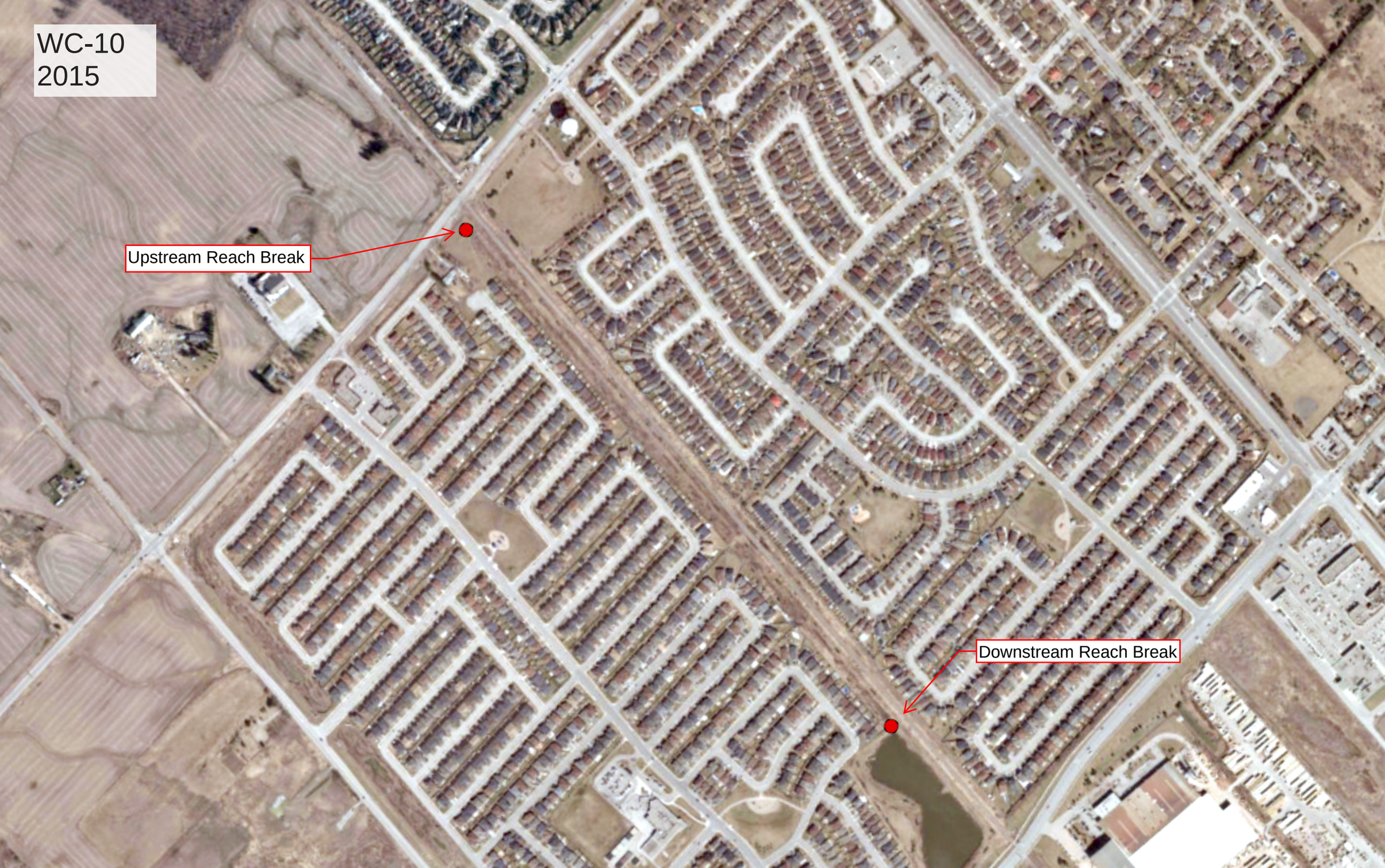

WC-02
2015

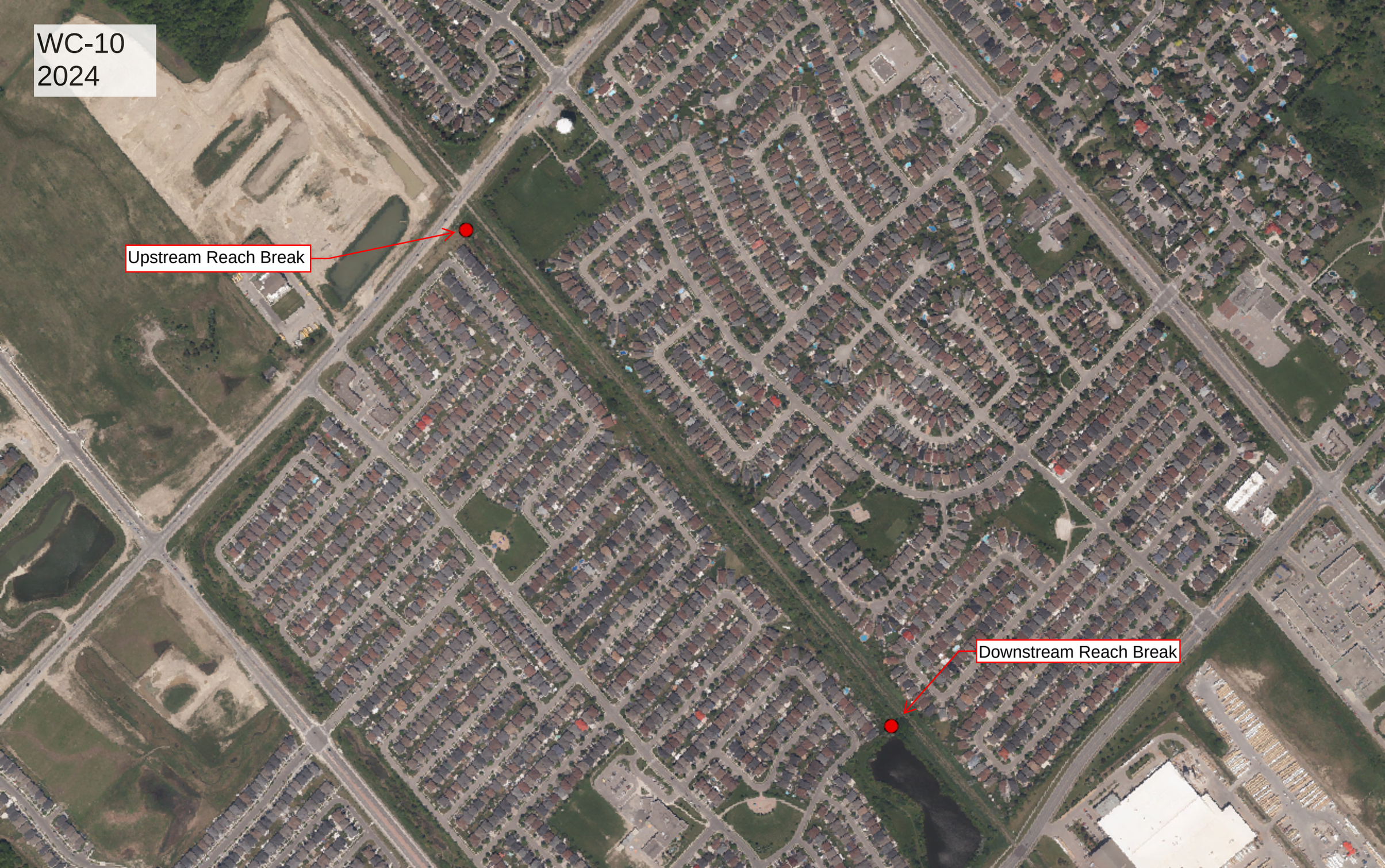

WC-02
2024


WC-10
1970
Upstream Reach Break
Downstream Reach Break


WC-10
1999
Upstream Reach Break
Downstream Reach Break

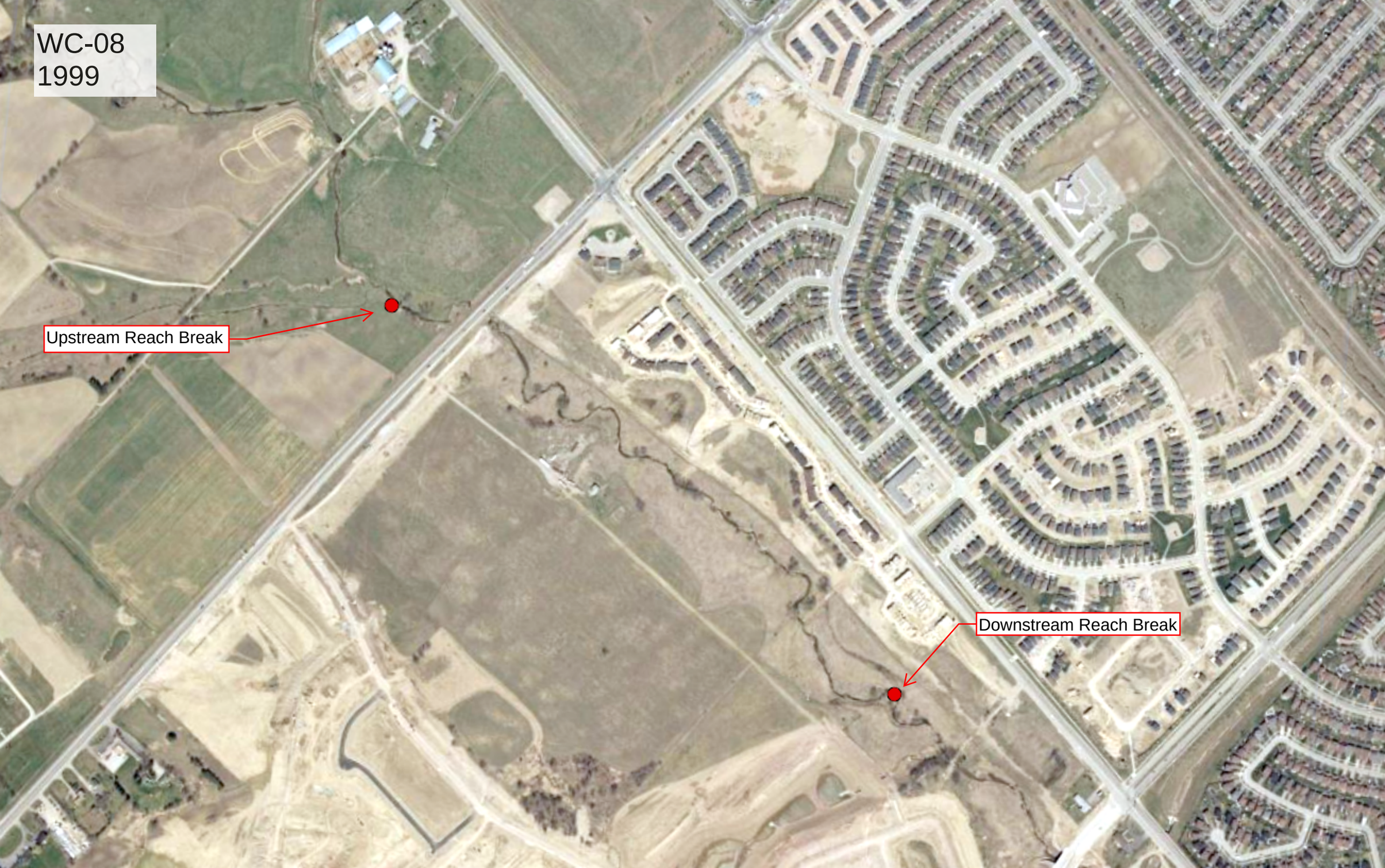

WC-10
2005
Upstream Reach Break
Downstream Reach Break


WC-10
2015
Upstream Reach Break
Downstream Reach Break

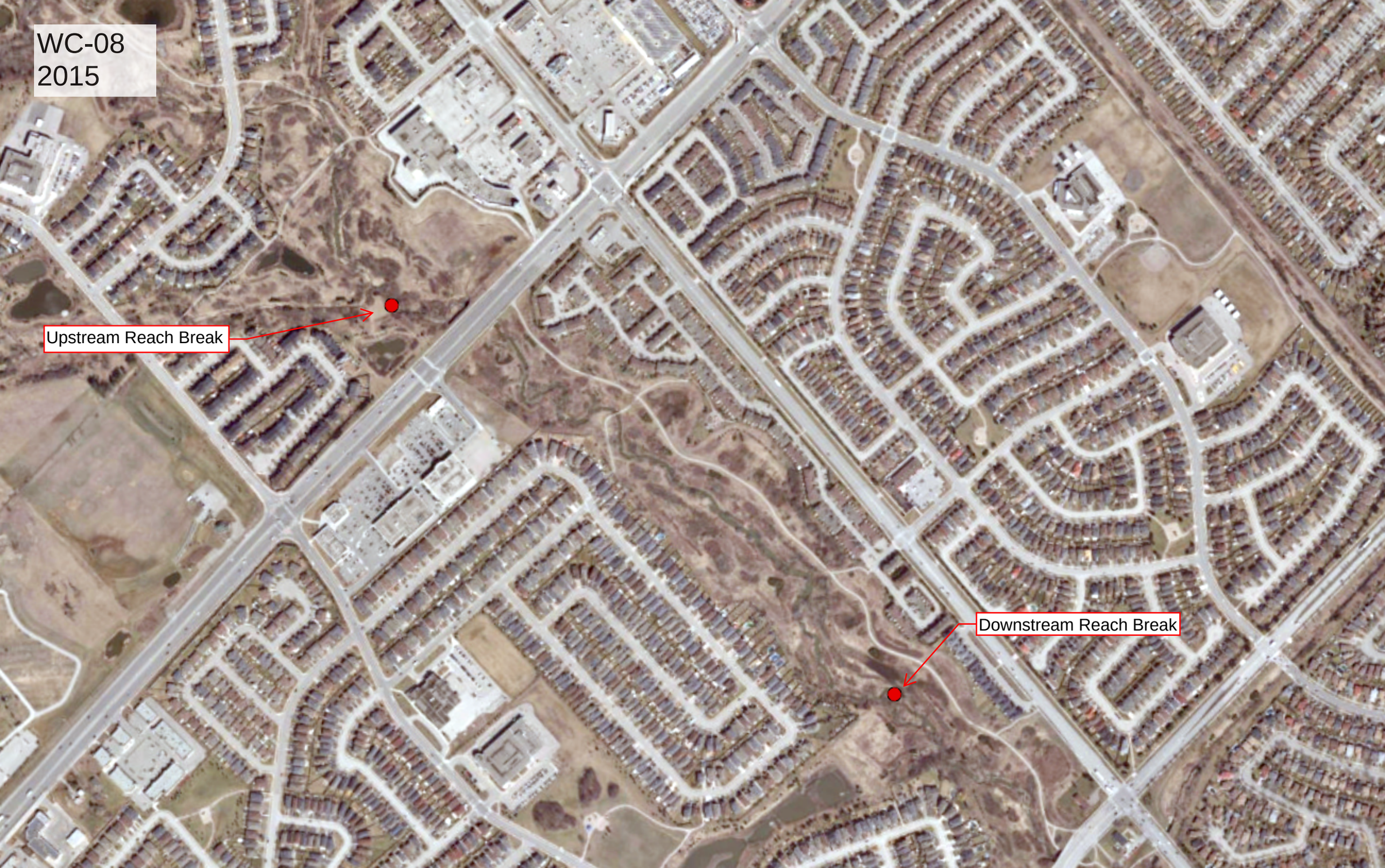

WC-10
2024
Upstream Reach Break
Downstream Reach Break

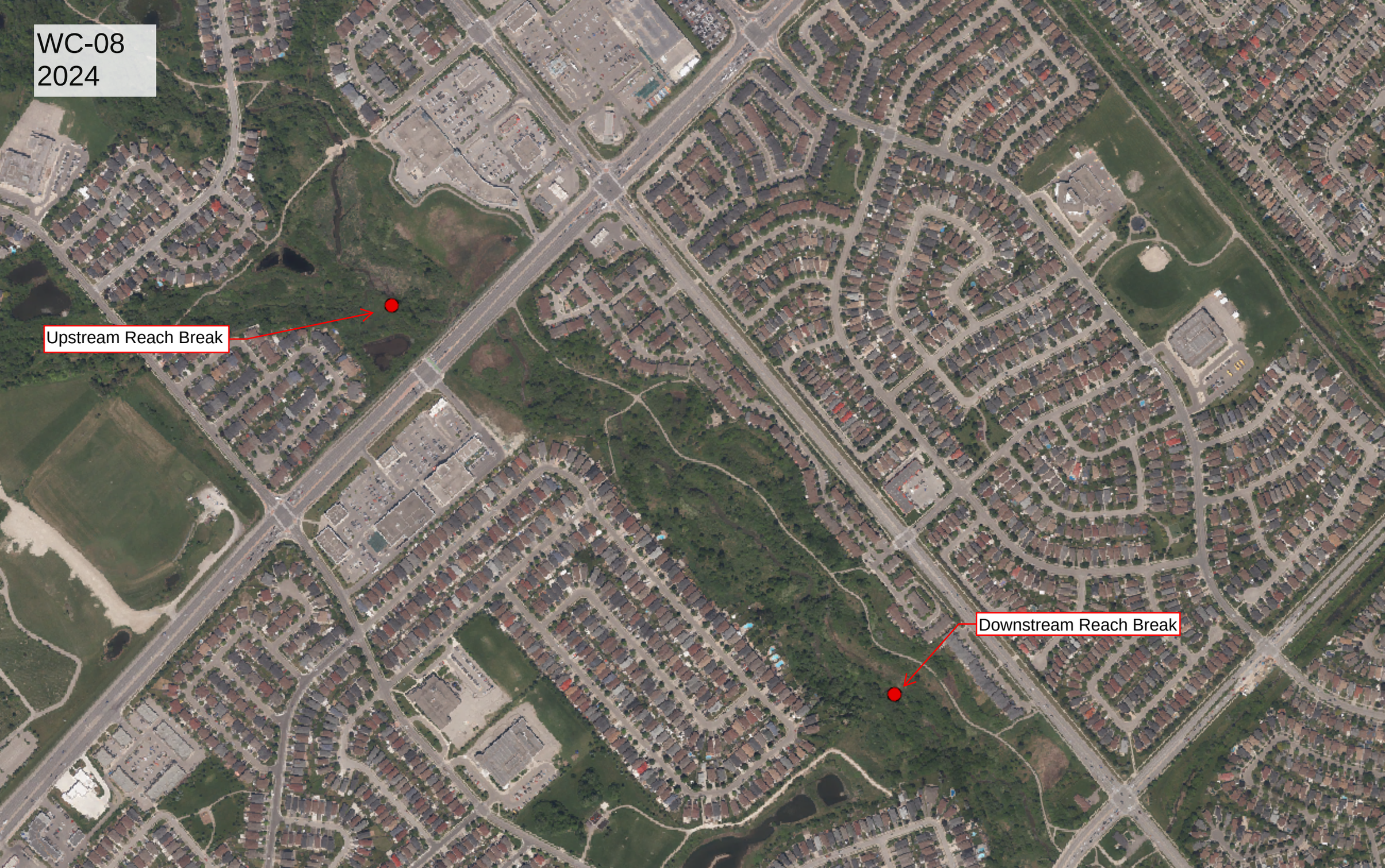


Downstream Reach Break


WC-08
1999
Upstream Reach Break
Downstream Reach Break


WC-08
2005
Upstream Reach Break
Downstream Reach Break


WC-08
2015
Upstream Reach Break
Downstream Reach Break


WC-08
2024
Upstream Reach Break
Downstream Reach Break


WC-07
1970
Upstream Reach Break
Downstream Reach Break

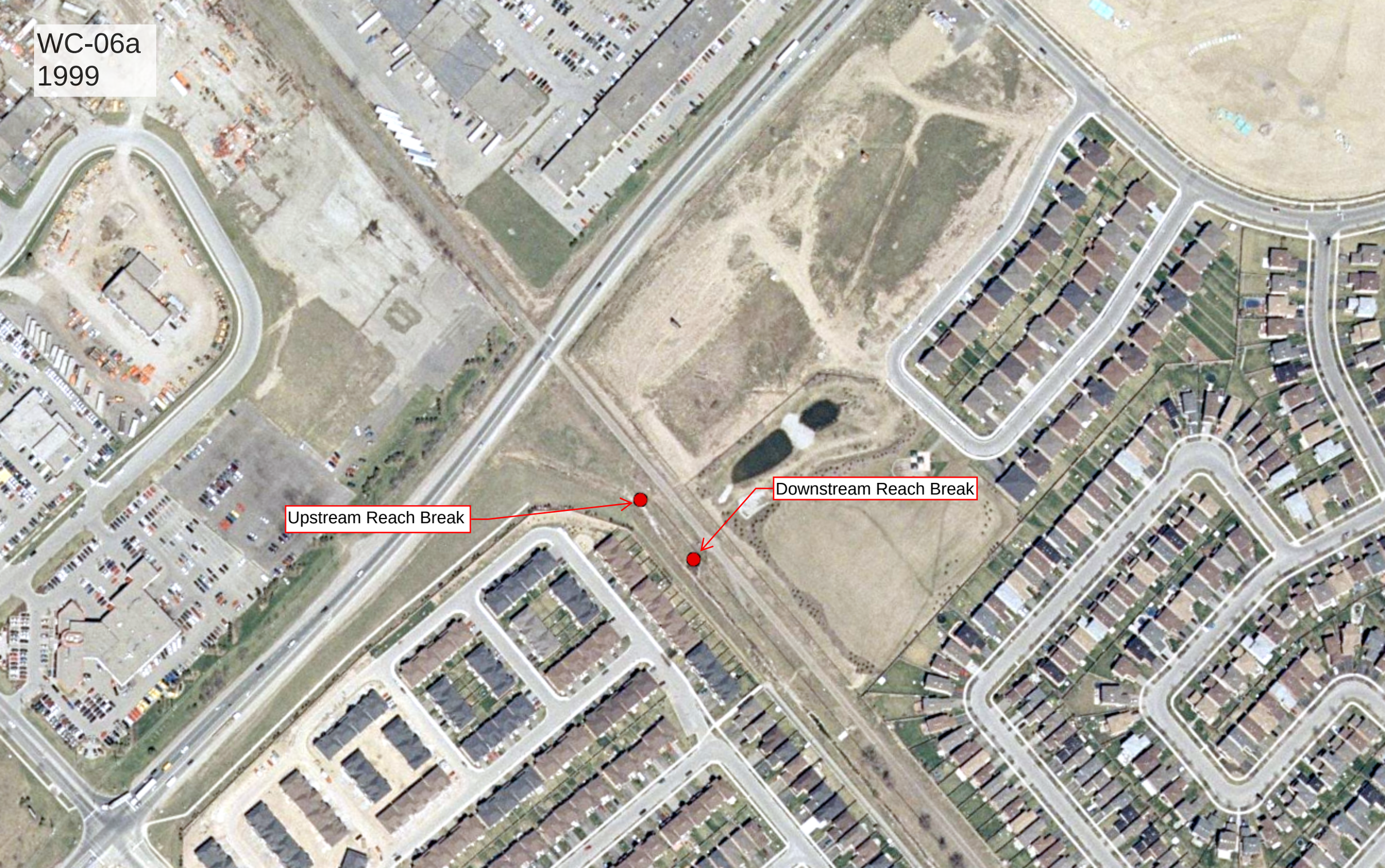

WC-07
1999
Upstream Reach Break
Downstream Reach Break


WC-07
2005
Downstream Reach Break
Upstream Reach Break


WC-07
2015
Downstream Reach Break
Upstream Reach Break


WC-07
2024
Downstream Reach Break
Upstream Reach Break

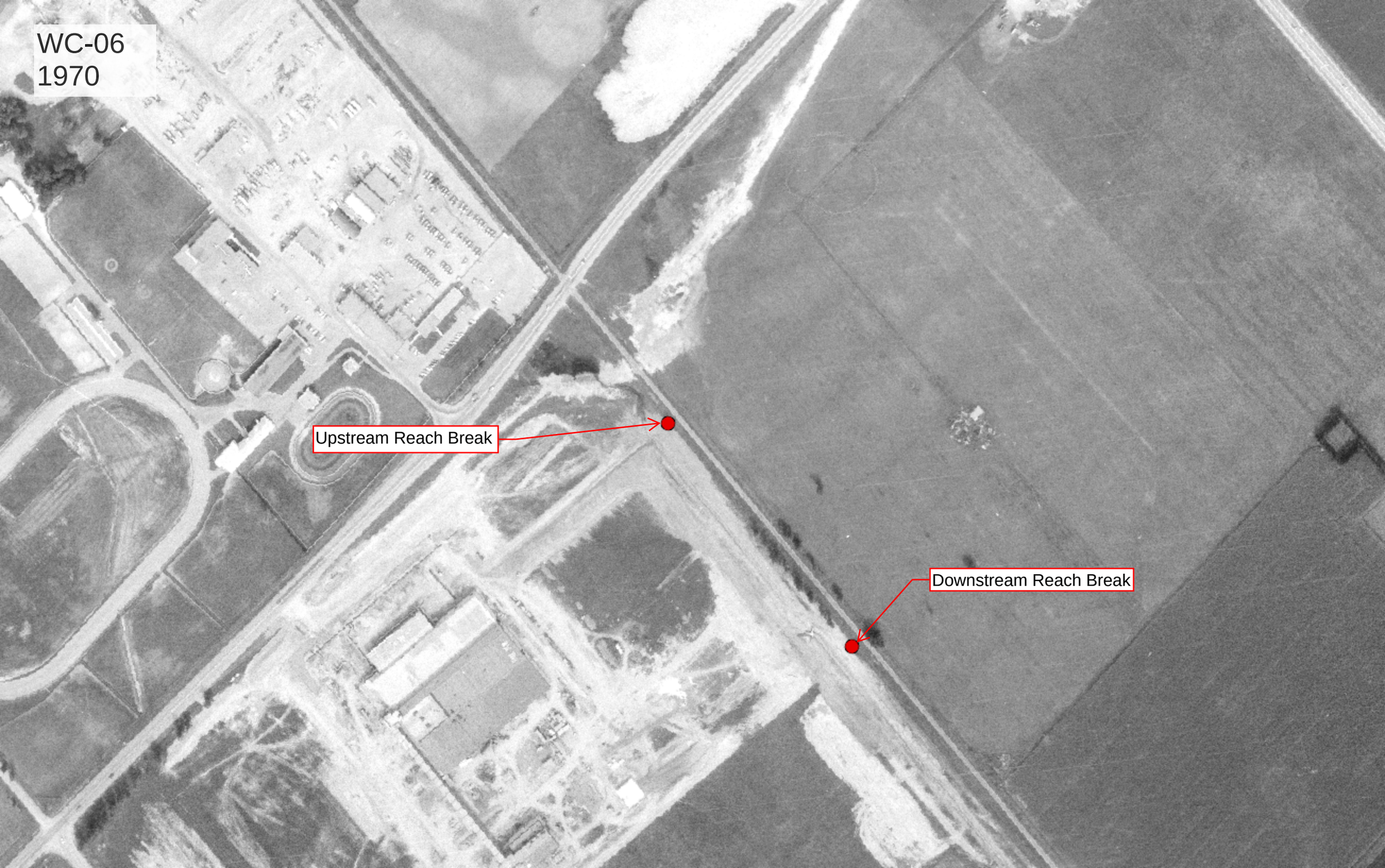

WC-06a
1970
Upstream Reach Break
Downstream Reach Break


WC-06a
1999
Upstream Reach Break
Downstream Reach Break


WC-06a
2005
Upstream Reach Break
Downstream Reach Break


WC-06a
2015
Upstream Reach Break
Downstream Reach Break


WC-06a
2024
Upstream Reach Break
Downstream Reach Break


WC-06
1970
Upstream Reach Break
Downstream Reach Break

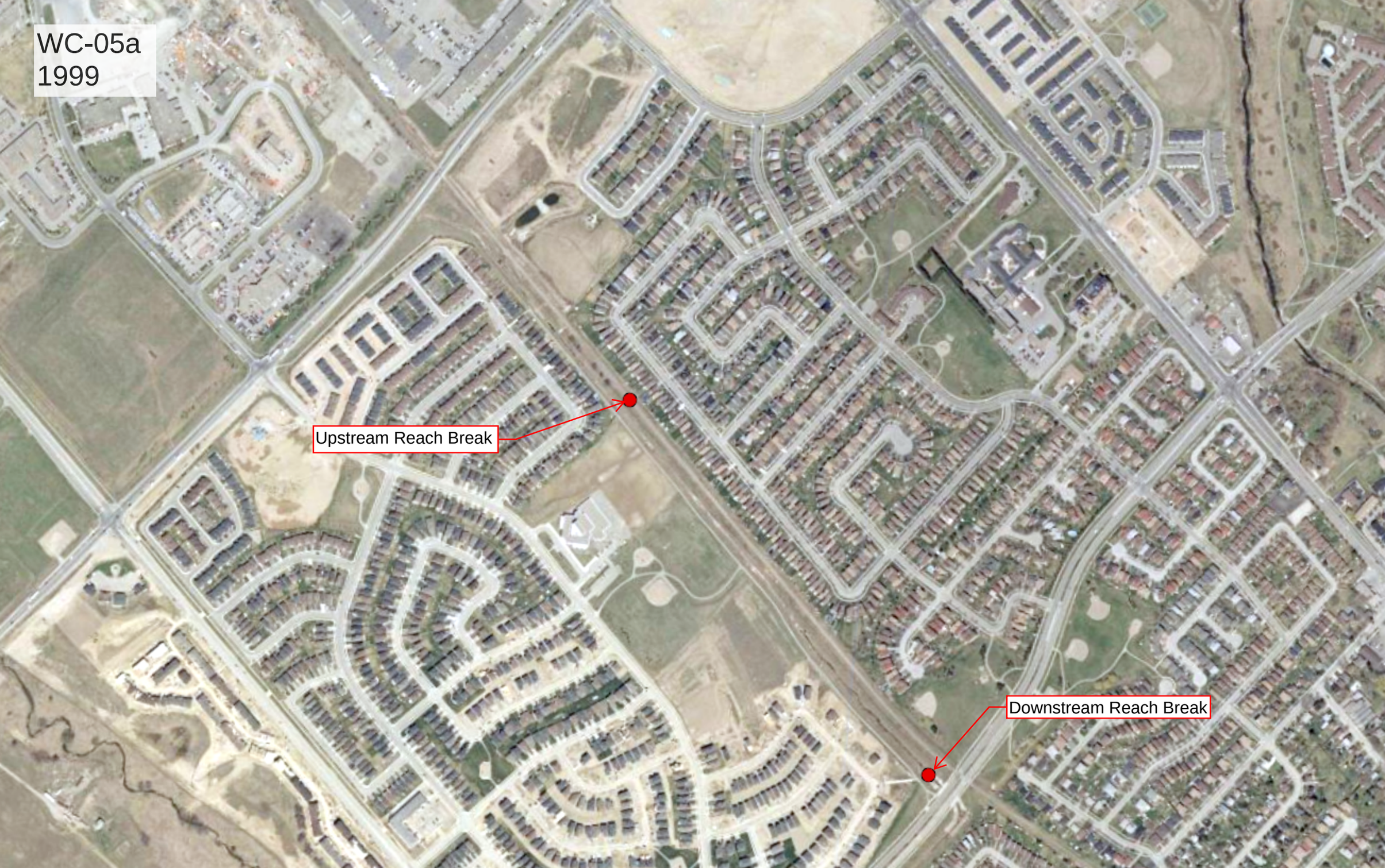

WC-06
1999
Upstream Reach Break
Downstream Reach Break


WC-06
2005
Upstream Reach Break
Downstream Reach Break

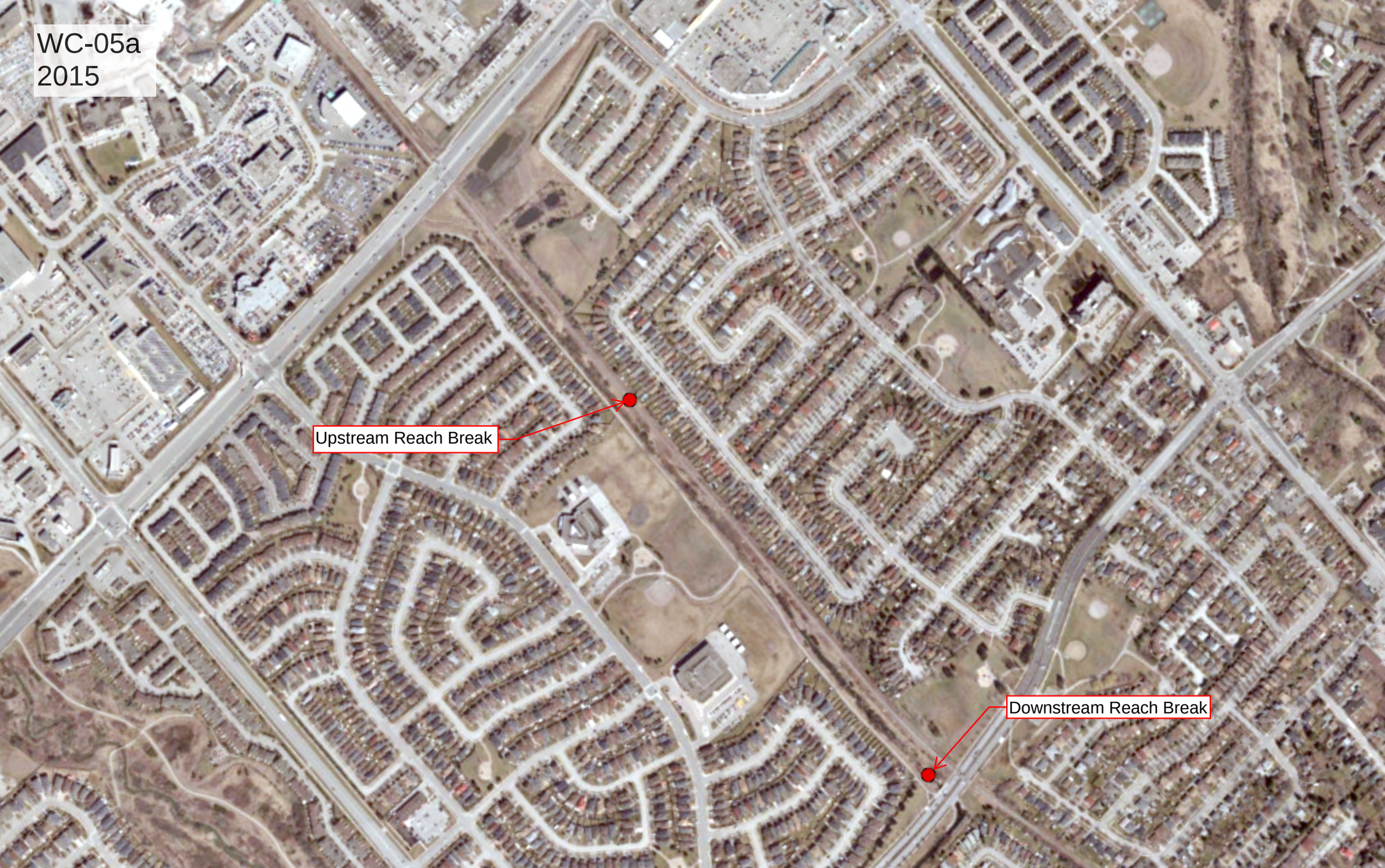

WC-06
2015
Upstream Reach Break
Downstream Reach Break


WC-06
2024
Upstream Reach Break
Downstream Reach Break


WC-05a
1970
Upstream Reach Break
Downstream Reach Break


WC-05a
1999
Upstream Reach Break
Downstream Reach Break


WC-05a
2005
Upstream Reach Break
Downstream Reach Break

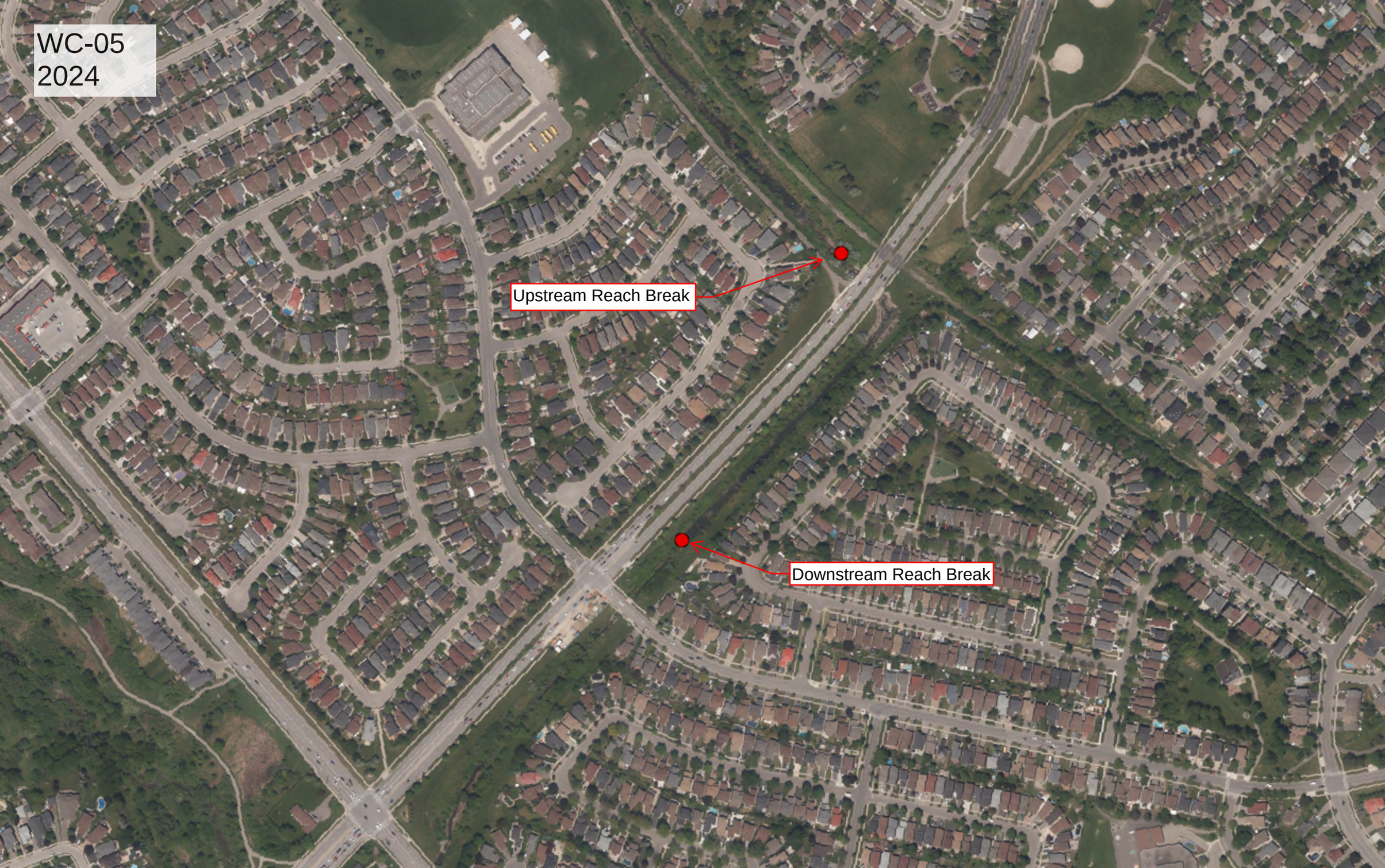

WC-05a
2015
Upstream Reach Break
Downstream Reach Break


WC-05a
2024
Upstream Reach Break
Downstream Reach Break


WC-05
1999
Upstream Reach Break
Downstream Reach Break


WC-05
2005
Upstream Reach Break
Downstream Reach Break


WC-05
2015
Upstream Reach Break
Downstream Reach Break


WC-05
2024
Upstream Reach Break
Downstream Reach Break

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Central Brampton

Appendix B

Photographic Log

AECOM

Peel Region


Reach WC-35
Old School Rd
Old School Rd
Old School Rd
1
2
3
4
N
0.01 0 0 0.01 0.02 0.03 0.04
Kilometers
Peel Region, Maxar, Microsoft, Esri Community Maps Contributors, Province of
Inc, METI/NASA, USGS, EPA, NPS, US
Legend
WC-35 Photo Locations
Watercourse (OHN)

WC-35



Photograph 1. ↑
Looking north towards culvert inlet.



Photograph 2. ↑
Looking upstream (west) from culvert inlet. Meandering channel with bank erosion and large woody debris present.



Photograph 3. ↑
Looking downstream (southeast) at culvert outlet. Leaning and fallen trees present.



Photograph 4. ↑
Looking downstream (southwest). Good access to the floodplain.


Reach WC-34
Old School Rd
Old School Rd
Old School Rd
7
8
6
5
N
0.01 0 0 0.01 0.02 0.02 0.03
Kilometers
Peel Region, Maxar, Microsoft, Esri Community Maps Contributors, Province of
Inc, METI/NASA, USGS, EPA, NPS, US
Legend
WC-34 Photo Locations
Watercourse (OHN)

Photographic Log

Client Name:	Report Name	Project No.
Region of Peel	Fluvial Geomorphic Assessment Memorandum	60736820

WC-34



Photograph 5. ↑
Looking downstream (south) at culvert outlet.



Photograph 6. ↑
Looking downstream (east) at culvert outlet. Woody debris present.



Photograph 7. ↑
Looking upstream (northwest) at culvert inlet. Exposed clay along channel bed.



Photograph 8. ↑
Upstream of culvert inlet. Gravel to cobble substrate present.


Reach WC-33
Old School Rd
Old School Rd
Old School Rd
9
10
11
12
N
0.01 0 0 0.01 0.02 0.02 0.03
Kilometers
Peel Region, Maxar, Microsoft, Esri Community Maps Contributors, Province of
Inc, METI/NASA, USGS, EPA, NPS, US
Legend
WC-33 Photo Locations
Watercourse (OHN)

WC-33



Photograph 9. ↑
Looking upstream (west) at swale channel. Placed rip rap lines the channel bottom.



Photograph 10. ↑
Looking northeast at culvert inlet. No flow present upstream on day of assessment.



Photograph 11. ↑
Looking northeast from culvert outlet. Swale feature becomes defined 20 m downstream of outlet.



Photograph 12. ↑
View of culvert outlet. Sedimentation and stagnant flow present within culvert.


Reach WC-13
Orangeville-Brampton Railway
Orangeville-Brampton Railway
13
14
15
16
N
0.01 0 0 0.01 0.02 0.02 0.03
Kilometers
Peel Region, Maxar, Microsoft, Esri Community Maps Contributors, Province of
Inc, METI/NASA, USGS, EPA, NPS, US
Legend
WC-13 Photo Locations
Watercourse (OHN)

WC-13



Photograph 13. ↑
Looking downstream (northeast) from culvert outlet. Channel poorly defined for short section up to forested area.



Photograph 14. ↑
Looking upstream (west) towards culvert outlet. Left (north) bank wingwall failed and displaced.



Photograph 15. ↑
Looking upstream (west) on upstream side of crossing. Defined channel with low banks.



Photograph 16. ↑
Looking downstream (east) through culvert inlet.


Reach WC-12
Orangeville-Brampton Railway
20
19
18
17
Orangeville-Brampton Railway
N
0.01 0 0 0.01 0.02 0.02 0.03
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
GS, EPA, NPS, US Census Bureau, USDA,
Legend
WC-12 Photo Locations
Watercourse (OHN)

WC-12



Photograph 17. ↑
Looking upstream (southwest) at straightened and dredged channel.



Photograph 18. ↑
West (left bank) embankment with gabion protection.



Photograph 19. ↑
Looking downstream (northeast) from rail crossing, towards right bank.



Photograph 20. ↑
Looking at downstream bed, just downstream of rail crossing. Exposed clay from dredging with placed rip rap along lower banks.


Reach WC-04
21
22
23
27
28
24
29
Vodden St E
25
30
31
Etobicoke Creek
32
26
Ken Whillans Dr
Main St N
Vodden St E
N
0.02 0.01 0 0.02 0.05 0.07 0.09
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
Legend
WC-04 Photo Locations
Watercourse (OHN)

WC-04



Photograph 21. ↑
Looking southeast (downstream) at upstream end of reach.



Photograph 22. ↑
Looking northwest (upstream) at upstream end of reach. Bank erosion along outer bend, with point bar formation along inner bend.



Photograph 23. ↑
Stormwater outfall along left (north) bank. Scour pool present.



Photograph 24. ↑
Looking northeast (downstream) towards Vodden St. E crossing.



Photograph 25. ↑
Looking southwest (upstream) towards Vodden St. E crossing.



Photograph 26. ↑
Looking northeast (downstream) near downstream end of reach.



Photograph 27. ↑
Looking southeast (downstream). Location of XS-1.



Photograph 28. ↑
Looking southeast (downstream). Location of XS-2.



Photograph 29. ↑
Looking southeast (downstream). Location of XS-3.



Photograph 30. ↑
Looking southeast (downstream). Location of XS-4.

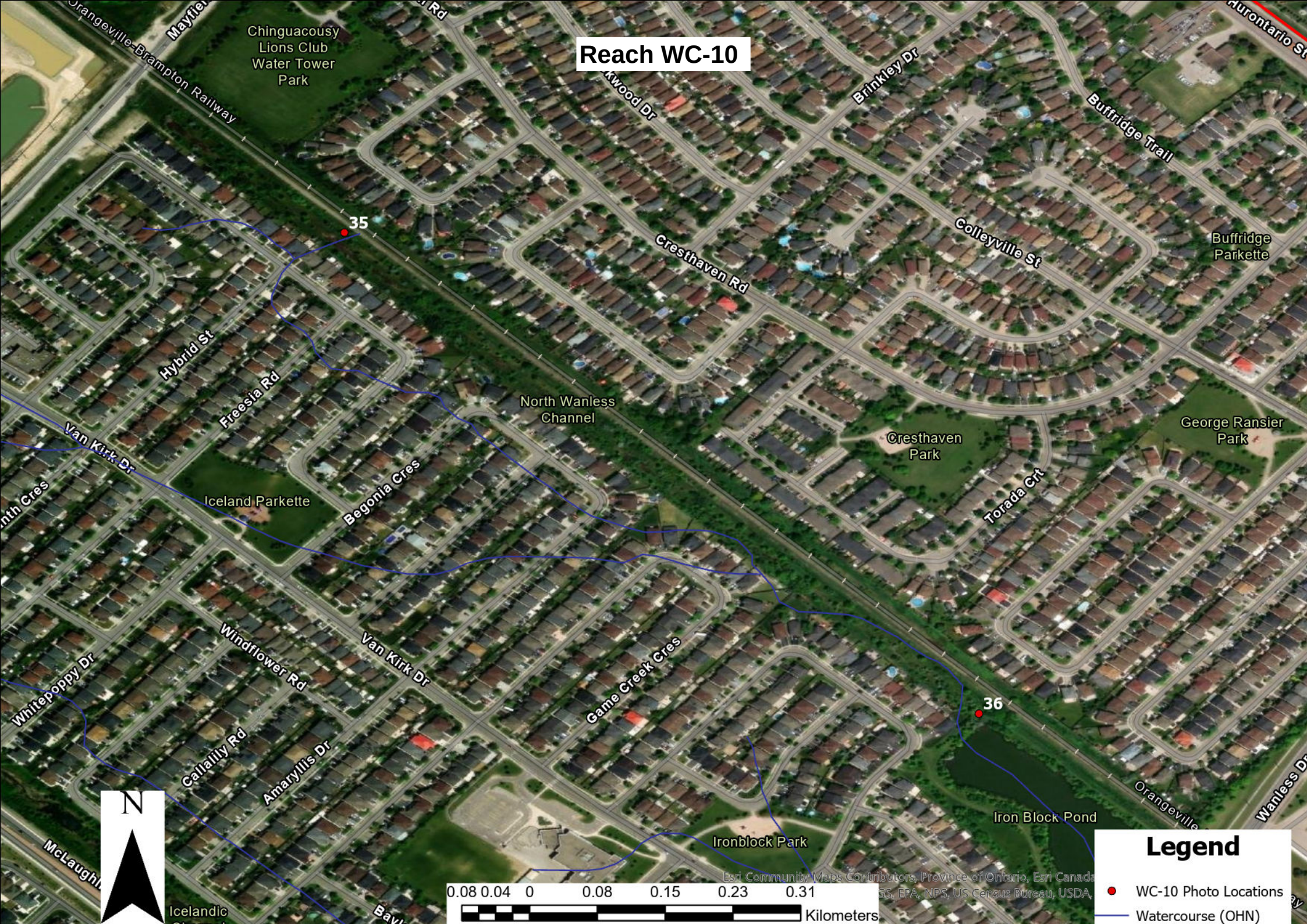


Photograph 31. ↑
Looking southeast (downstream). Location of XS-5.



Photograph 32. ↑
Looking southeast (downstream). Location of XS-6.


Reach WC-02
34
33
Kennedy Rd S
Kennedy Rd S
N
0.01 0 0 0.01 0.02 0.02 0.03
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
Legend
WC-02 Photo Locations
Watercourse (OHN)


Reach WC-10
Chinguacousy Lions Club Water Tower Park
Orangeville-Brampton Railway
Brinkley Dr
Buffridge Trail
Colleyville St
Buffridge Parkette
Cresthaven Rd
35
Hybrid St
Freesia Rd
North Wanless Channel
Van Kirk Dr
Iceland Parkette
Begonia Cres
Cresthaven Park
George Ransier Park
Torada Crt
Windflower Rd
Van Kirk Dr
Game Creek Cres
Whitepoppy Dr
Callalily Rd
Amaryllis Dr
36
Iron Block Pond
Ironblock Park
McLaughlin
Icelandic
Orangeville
Wanless Dr
N
0.08 0.04 0 0.08 0.15 0.23 0.31
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
Legend
WC-10 Photo Locations
Watercourse (OHN)

WC-02



Photograph 33. ↑
Looking west on west side of rail line. Multiple drainage culverts present that connect to WC-10.



Photograph 34. ↑
Looking west on west side of rail line. Multiple drainage culverts present that connect to WC-10.

WC-10



Photograph 35. ↑
Looking west on west side of rail line. Multiple drainage culverts present that connect to WC-10.



Photograph 36. ↑
Looking north (upstream) at downstream end of reach. Intermittent swale feature.


Reach WC-08
Bovaird Dr W
Bovaird Dr W
Bovaird Dr W
Bovaird Dr W
Bovaird Dr W
42
45
41
40
44
43
39
37
38
46
47
48
N
0.02 0.01 0 0.02 0.05 0.07 0.09
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
Legend
WC-08 Photo Locations
Watercourse (OHN)

WC-08



Photograph 37. ↑
Looking northwest towards culvert outlet along Bovaird Drive West. Outfall present along left bank.



Photograph 38. ↑
Looking west at right bank at culvert outlet. Bank erosion present.



Photograph 39. ↑
Looking towards west (right) bank. Christmas tree bank restoration along outer bend downstream of culvert outlet.



Photograph 40. ↑
Looking southwest (upstream) at upstream end of reach. Exposed clay on the bed (arrow).



Photograph 41. ↑
Degradation along bed, with exposed clay present upstream of Bovaird Drive West crossing.



Photograph 42. ↑
Looking southeast (downstream) towards culvert inlet.



Photograph 43. ↑
Looking downstream (northeast). Location of XS-1.



Photograph 44. ↑
Looking downstream (northeast). Location of XS-2.



Photograph 45. ↑
Looking downstream (northeast). Location of XS-3.



Photograph 46. ↑
Looking downstream (southeast). Location of XS-4.



Photograph 47. ↑
Looking downstream (south). Location of XS-5.



Photograph 48. ↑
Looking downstream (southeast). Location of XS-6.


Reach WC-07
Bovaird Dr W
Bovaird Dr W
Bovaird Dr W
Bovaird Dr W
Orangeville-Brampton Railway
Orangeville-Brampton
50
49
52
51
Kenwood Dr
Kenwood Dr
Goldberry Crt
Kenwood Dr
N
0.01 0.01 0 0.01 0.03 0.04 0.06
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
SGS, EPA, NPS, US Census Bureau, USDA,
Legend
WC-07 Photo Locations
Watercourse (OHN)

WC-07



Photograph 49. ↑
Looking West (upstream) at Bovaird Dr W culvert outlet.



Photograph 50. ↑
Looking east (downstream).



Photograph 51. ↑
Looking west (upstream). Feature is entrenched.



Photograph 52. ↑
Bed substrate ranges from silt/clay to small boulders.


Reach WC-06a
Bovaird Dr W
Orangeville-Brampton Railway
Edward And
Harry Dale Pond
53
56
54
55
Kenwood Dr
Kenwood Dr
Orangeville-Brampton Railway
N
0.01 0.01 0 0.01 0.03 0.04 0.06
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
Legend
WC-06a Photo Locations
Watercourse (OHN)

WC-06a



Photograph 53. ↑
Looking northwest at upstream end of reach. Culvert outfall with heavy vegetation encroachment.



Photograph 54. ↑
Looking south (downstream). Bed substrate ranges from silt/clay to large boulders.



Photograph 55. ↑
Looking southeast (downstream) mid reach. Meandering channel with bank erosion observed through the reach.



Photograph 56. ↑
Looking northwest (upstream) at constructed riffle with placed cobbles and boulders near upstream end of reach.


Reach WC-06
Orangeville-Brampton Railway
Koretz Park
57
58
59
60
Kenwood Dr
Kenwood Dr
Richwood Cres
Orangeville-Brampton Railway
Orangeville-Brampton Railway
N
0.01 0.01 0 0.01 0.03 0.04 0.06
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
SGS, EPA, NPS, US Census Bureau, USDA
Legend
WC-06 Photo Locations
Watercourse (OHN)

WC-06



Photograph 57. ↑
Looking upstream (northwest) at upstream end of reach. Woody debris along channel and banks.



Photograph 58. ↑
Looking southeast (downstream). Channel is straightened and entrenched.



Photograph 59. ↑
Placed cobbles on the bed mid-reach.



Photograph 60. ↑
Looking southeast (downstream) at downstream end of reach.


Reach WC-05a
Orangeville-Brampton Railway
Murray St
Murray Street Park
Burnhope Dr
McGraw Ave
Ecclestone Dr
Banner Rd
62
61
Cowan Rd
Harridine
Fred Kee Park
Royal Orchard Dr
Fred Kee Channel
Armbro Park
Beaverhall Rd
Suncrest Dr
Saddletree Trail
64
63
Williams Pky
Dunhill Rd
Trail Ridge Dr
Brampton West
Arjay Trail
N
0.06 0.03 0 0.06 0.12 0.18 0.25
Kilometers
Legend
WC-05a Photo Locations
Watercourse (OHN)

WC-05a



Photograph 61. ↑
Looking southeast (downstream) at upstream end of reach. Armourstone placed along both banks for ~ 100 m.



Photograph 62. ↑
Failed armourstone displaced within channel.



Photograph 63. ↑
Looking towards north bank. Large beaver dam near downstream end of reach.



Photograph 64. ↑
Looking towards north bank. Heavy beaver activity in downstream end of reach creating backwater effects upstream.


Reach WC-05
Orangeville-Brampton Railway
Orangeville-Brampton Railway
Orangeville-Brampton Railway
Williams Pky
Williams Pky
Williams Pky
Williams Pky
Saddletree Trail
66
65
N
0.01 0.01 0 0.01 0.03 0.04 0.06
Kilometers
Esri Community Maps Contributors, Province of Ontario, Esri Canada
SGS, EPA, NPS, US Census Bureau, USDA
Legend
WC-05 Photo Locations
Watercourse (OHN)

WC-5



Photograph 65. ↑
Looking southeast (downstream) at upstream end of reach. Channel bed and banks are concrete.



Photograph 66. ↑
Looking west (downstream). Heavy vegetation encroachment.

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Central Brampton

Appendix C

Crossing Assessment

AECOM

Peel Region

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 17, 2025 **Location:** WC-35

Watercourse Crossing Structure				
Type: Culvert: **Box** Arch Round Ellipse		**Bottom:** Closed Open	**Material:** **Concrete** CSP Metal	
Type: **Concrete**	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**	
Bankfull Width (m): 3-5	**Span Width (m): ~5**	**Diff between Bankfull and Span width (m):**	**Span adequate Size:** **Yes** No	
Impoundment Upstream: Yes **No**		**Impoundment Length (m):**	**Water Depth (m): 0.2 – 0.3**	
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** Yes **No**	**Erosion Protection d/s:** Yes **No**	
Inlet Structure: Wingwalls Projecting Headwall Flow Control		**Outlet Structure:** Wingwalls Projecting Headwalls		
Proximal Infrastructure: Strm Water Outfall Water main Other -				
Notes: **Only observed from ROW**				

Damage			
Degradation or Dredging: Yes **No**		**Aggradation or Deposition:** **Yes*** No	
Perched: Yes No	**Height to Bed (m)**	**Height to Water Level (m):**	
Undercut: Yes No	**Outflanked Structure:** Yes **No**		
Erosion: **Yes** No	**Upstream:** **Yes** No	**Downstream:** **Yes** No	
Scour Damage Yes **No**	**Bed Scour:** **Yes**** No	**Exposed Footing:** Yes **No**	
Notes: ***Sedimentation (aggradation) present along the left bank downstream of the crossing.** ****A scour pool was observed upstream of the crossing immediately downstream of a debris jam** **Bank erosion observed upstream and downstream of the crossing**			

Channel Morphology				
Artificial Reach Break: Yes **No**		**Bed Morphology:** **Meandering**	**Channel Planform:** **Run/ Pools**	
Modified Channel Cross section: Yes **No**		**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) **Natural (u/s d/s)** Nat Channel Design (u/s d/s)		
Bed Material (m)	**Upstream** (~D_{50}): **Clay to cobble sized material with gravel**	**Downstream** (~D_{50}): **Clay to cobble sized material with gravel**	**Channel Gradient:** **Low-moderate**	**Downstream:**
Flow direction at Culvert Inlet: **Straight** Outside bank to edge of crossing: (Left Right)			**Active Bank Erosion:** **yes**	
Notes: **Meandering profile with run/pools** **Heavy amounts of woody debris in channel and along banks upstream and downstream of the crossing** **Exposed clay present in the channel bed** **Banks are relatively low downstream of the crossing**				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking north towards culvert inlet.



Photograph 2. ↑
Looking upstream (west) from culvert inlet. Meandering channel with bank erosion and large woody debris present.



Photograph 3. ↑
Looking downstream (southeast) at culvert outlet. Leaning and fallen trees present.



Photograph 4. ↑
Looking downstream (southwest). Good access to the floodplain.

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 27, 2025 **Location:** WC-34

Watercourse Crossing Structure				
Type: Culvert: **Box** Arch Round Ellipse		**Bottom:** Closed Open	**Material:** **Concrete** CSP Metal	
Type:	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**	
Bankfull Width (m): 3 - 5	**Span Width (m): ~4 - 5**	**Diff between Bankfull and Span width (m):**	**Span adequate Size:** Yes No	
Impoundment Upstream: Yes **No**		**Impoundment Length (m):**	**Water Depth (m):**	
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** Yes **No**	**Erosion Protection d/s:** Yes **No**	
Inlet Structure: Wingwalls Projecting Headwall Flow Control		**Outlet Structure:** Wingwalls Projecting Headwalls		
Proximal Infrastructure: Strm Water Outfall Water main Other **None**				
Notes: **Only from ROW**				

Damage			
Degradation or Dredging: **Yes** No		**Aggradation or Deposition:** Yes **No**	
Perched: Yes No	**Height to Bed (m)**	**Height to Water Level (m):**	
Undercut: Yes No	**Outflanked Structure:** Yes No		
Erosion: **Yes** No	**Upstream:** **Yes** No	**Downstream:** **Yes** No	
Scour Damage Yes No	**Bed Scour:** **Yes** No	**Exposed Footing:** Yes No	
Notes: **Bank erosion observed** **Under cut banks observed upstream of crossing**			

Channel Morphology				
Artificial Reach Break: Yes **No**	**Bed Morphology: Runs**	**Channel Planform: Meandering**		
Modified Channel Cross section: Yes **No**	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) **Natural (u/s d/s)** Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): **Cobbles**	**Downstream** (~D_{50}): **Gravels**	**Channel Gradient:** **Low-moderate**	**Downstream:**
Flow direction at Culvert Inlet: Straight Outside bank to edge of crossing: (Left **Right**)		**Active Bank Erosion: Minor, yes**		
Notes: **Flow is not centered on the culvert inlet. It is directed towards the right (east) bank which is resulting in bank erosion beside the culvert inlet**				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking downstream (south) at culvert outlet.



Photograph 2. ↑
Looking downstream (east) at culvert outlet. Woody debris present.



Photograph 3. ↑
Looking upstream (northwest) at culvert inlet. Exposed clay along channel bed.



Photograph 4. ↑
Upstream of culvert inlet. Gravel to cobble substrate present.

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 27, 2025 **Location:** WC-33

Watercourse Crossing Structure				
Type: Culvert: Box Arch Round Ellipse		**Bottom:** Closed Open	**Material:** Concrete CSP Metal	
Type: CSP	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**	
Bankfull Width (m): NA	**Span Width (m):** 1.3	**Diff between Bankfull and Span width (m):**	**Span adequate Size:** Yes No	
Impoundment Upstream: Yes No		**Impoundment Length (m):**	**Water Depth (m):**	
Sediment Barrier: Yes No		**Floodplain Disconnection:** Yes No	**Erosion Protection d/s:** Yes No	
Inlet Structure: Wingwalls Projecting Headwall Flow Control		**Outlet Structure:** Wingwalls Projecting Headwalls		
Proximal Infrastructure: Strm Water Outfall Water main Other -				
Notes: Ephemeral swale with no flow on day of assessment.				

Damage			
Degradation or Dredging: Yes No		**Aggradation or Deposition:** Yes * No	
Perched: Yes No	**Height to Bed (m)**	**Height to Water Level (m):**	
Undercut: Yes No	**Outflanked Structure:** Yes No		
Erosion: Yes** No	**Upstream:** Yes No	**Downstream:** Yes No	
Scour Damage Yes No	**Bed Scour:** Yes No	**Exposed Footing:** Yes No	
Notes: *Sediment aggradation within culvert **Minor erosion on right bank upstream of culvert behind the culvert Minor deposition of gravel at culvert outlet. Channel is not defined at culvert. There is in-steam vegetation (grasses) Downstream of culvert the channel eventually becomes defined past ROW.			

Channel Morphology				
Artificial Reach Break: Yes No	**Bed Morphology:** NA	**Channel Planform:** Straightened Swale		
Modified Channel Cross section: Yes No	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) Natural (u/s d/s) Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): Placed cobbles	**Downstream** (~D_{50}): Placed cobbles	**Channel Gradient:** Straightened swale feature	**Downstream:**
Flow direction at Culvert Inlet: Straight Outside bank to edge of crossing: (Left Right)		**Active Bank Erosion:**		
Notes: Straightened swale feature with, no defined bed morphology				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking upstream (west) at swale channel. Placed rip rap lines the channel bottom.



Photograph 2. ↑
Looking northeast at culvert inlet. No flow present upstream on day of assessment.



Photograph 3. ↑
Looking northeast from culvert outlet. Swale feature becomes defined 20 m downstream of outlet.



Photograph 4. ↑
View of culvert outlet. Sedimentation and stagnant flow present within culvert.

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 23, 2025 **Location:** WC-13

Watercourse Crossing Structure			
Type: Culvert: Box **Arch** Round Ellipse		**Bottom:** **Closed** Open	**Material:** **Concrete** CSP Metal
Type:	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**
Bankfull Width (m): 1.5	**Span Width (m):** 4	**Diff between Bankfull and Span width (m):**	**Span adequate Size:** **Yes** No
Impoundment Upstream: Yes **No**		**Impoundment Length (m):**	**Water Depth (m):** 0.2
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** Yes **No**	**Erosion Protection d/s:** Yes No
Inlet Structure: **Wingwalls** Projecting Headwall Flow Control		**Outlet Structure:** **Wingwalls** Projecting Headwalls	
Proximal Infrastructure: Strm Water Outfall Water main Other -			
Notes: Bankfull width was 3.5 m at inlet at pool feature Intermittent Poorly defined Arch concrete culvert approximately 4 m in height.			

Damage		
Degradation or Dredging: **Yes** No	**Aggradation or Deposition:** **Yes** No	
Perched: Yes **No**	**Height to Bed (m)**	**Height to Water Level (m):**
Undercut: Yes **No**	**Outflanked Structure:** Yes **No**	
Erosion: Yes **No**	**Upstream:** Yes **No**	**Downstream:** Yes No
Scour Damage Yes **No**	**Bed Scour:** **Yes** No **Clay bed**	**Exposed Footing:** Yes No
Notes: Siltation is present in a pool at the culvert inlet. Downstream of the crossing the left (north) bank wingwall has failed and collapsed within the channel creating a debris jam. Sedimentation in response to the debris jam was observed.		

Channel Morphology				
Artificial Reach Break: Yes **No**	**Bed Morphology:** **Pool-flats**		**Channel Planform:** **Meander**	
Modified Channel Cross section: Yes No	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) **Natural (u/s d/s)** Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): **Silt**	**Downstream** (~D_{50}): **Silt**	**Channel Gradient:** **Low**	**Downstream:**
Flow direction at Culvert Inlet: **Straight** Outside bank to edge of crossing: (Left Right)			**Active Bank Erosion:**	
Notes: Poorly defined downstream				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking downstream (northeast) from culvert outlet. Channel poorly defined for short section up to forested area.



Photograph 2. ↑
Looking upstream (west) towards culvert outlet. Left (north) bank wingwall failed and displaced.



Photograph 3. ↑
Looking upstream (west) on upstream side of crossing. Defined channel with low banks.



Photograph 4. ↑
Looking downstream (east) through culvert inlet.

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 23, 2025 **Location:** WC-12

Watercourse Crossing Structure					
Type: Culvert: Box Arch Round Ellipse **Bridge**		**Bottom:** Closed **Open**		**Material:** Concrete CSP **Metal**	
Type: **open**	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**		**Crossing Length(m): 5**	
Bankfull Width (m):	**Span Width (m): ~10**	**Diff between Bankfull and Span width (m):**		**Span adequate Size:** **Yes** No	
Impoundment Upstream: Yes **No**		**Impoundment Length (m):**		**Water Depth (m):**	
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** Yes **No**		**Erosion Protection d/s:** **Yes*** No	
Inlet Structure: Wingwalls Projecting Headwall Flow Control **None**			**Outlet Structure:** Wingwalls Projecting Headwalls **none**		
Proximal Infrastructure: Strm Water Outfall Water main Other -					
Notes: ***Placed rip-rap erosion protection downstream of the crossing**					

Damage			
Degradation or Dredging: **Yes** No		**Aggradation or Deposition:** Yes **No**	
Perched: Yes **No**	**Height to Bed (m)**	**Height to Water Level (m):**	
Undercut: Yes **No**	**Outflanked Structure:** Yes No		
Erosion: Yes **No**	**Upstream:** Yes No	**Downstream:** Yes **No**	
Scour Damage Yes **No**	**Bed Scour:** **Yes*** No	**Exposed Footing:** Yes **No**	
Notes: **Only accessible from ROW** ***Exposed Clay**			

Channel Morphology				
Artificial Reach Break: Yes **No**	**Bed Morphology:** **Flats**		**Channel Planform:** **Straight**	
Modified Channel Cross section: Yes No	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) Natural (u/s d/s) Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): **Sand**	**Downstream** (~D_{50}): **Sand**	**Channel Gradient:** **Low**	**Downstream:**
Flow direction at Culvert Inlet: **Straight** Outside bank to edge of crossing: (Left Right)			**Active Bank Erosion:**	
Notes: **Realigned/ straightened**				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking upstream (southwest) at straightened and dredged channel.



Photograph 2. ↑
West (left) embankment with gabion protection.



Photograph 3. ↑
Looking downstream (northeast) from rail crossing, towards right bank.



Photograph 4. ↑
Looking at downstream bed, just downstream of rail crossing. Exposed clay from dredging with placed rip rap along lower banks.

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 25, 2025 **Location:** WC-04 (Etobicoke Creek)

Watercourse Crossing Structure			
Type: Culvert: Box Arch Round **Ellipse**		**Bottom:** Closed **Open**	**Material:** **Concrete** CSP Metal
Type: **Concrete**	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**
Bankfull Width (m): 6	**Span Width (m): 10**	**Diff between Bankfull and Span width (m): 4**	**Span adequate Size:** **Yes** No
Impoundment Upstream: Yes No		**Impoundment Length (m):**	**Water Depth (m): 0.05 - 0.02**
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** **Yes** No	**Erosion Protection d/s:** Yes **No**
Inlet Structure: **Wingwalls** Projecting Headwall Flow Control		**Outlet Structure:** **Wingwalls** Projecting Headwalls	
Proximal Infrastructure: **Strm Water Outfall** Water main Other -			
Notes: **Two outfalls (one on each bank) are present directly downstream at the crossing outlet.**			

Damage			
Degradation or Dredging: **Yes** No		**Aggradation or Deposition:** **Yes** No	
Perched: Yes **No**		**Height to Bed (m)**	**Height to Water Level (m):**
Undercut: Yes **No**		**Outflanked Structure:** Yes **No**	
Erosion: **Yes** No		**Upstream:** **Yes** No	**Downstream:** **Yes** No
Scour Damage Yes **No**		**Bed Scour:** Yes **No**	**Exposed Footing:** Yes **No**
Notes: **Heavy bank erosion on both banks upstream and downstream of the crossing structure. There is woody debris accumulation and leaning trees approximately 5 m upstream of the crossing structure. Sedimentation (accumulation of cobbles) was present within the crossing structure.**			

Channel Morphology				
Artificial Reach Break: Yes **No**	**Bed Morphology:** **riffle-pool**		**Channel Planform:** **Meandering**	
Modified Channel Cross section: Yes **No**	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) Natural (**u/s d/s**) Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): **Large gravels, cobbles**	**Downstream** (~D_{50}): **Large gravels, cobbles**	**Channel Gradient:** **Low - moderate**	**Downstream:**
Flow direction at Culvert Inlet: **Straight** Outside bank to edge of crossing: (Left Right)			**Active Bank Erosion:** **Yes**	
Notes: **Run morphology directly upstream, downstream, and through crossing structure.**				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking northeast (downstream) towards Vodden St. E Crossing.



Photograph 2. ↑
Looking southwest (upstream) towards Vodden St. E crossing



Photograph 3. ↑
Looking downstream. Sediment accumulation within culvert crossing.

Watercourse Crossing Assessment Sheet



Photograph 5. ↑
Outfall along left bank, adjacent to crossing outlet. Sedimentation and debris accumulation.



Photograph 6. ↑
Looking upstream towards crossing structure. Outfalls present along both banks. Outfall channel along right bank (see arrow).

Watercourse Crossing Assessment Sheet

Survey Team: MS **Date:** April 16, 2025 **Location:** WC-08 (Fletcher's Creek)

Watercourse Crossing Structure			
Type: Culvert: Box **Arch** Round Ellipse		**Bottom:** Closed **Open**	**Material:** **Concrete** CSP Metal
Type: **Concrete**	**Span Piers (m): piers**	**Distance from Bank to Abutment (m):**	**Crossing Length(m):**
Bankfull Width (m): 6-10	**Span Width (m): 12**	**Diff between Bankfull and Span width (m): 1-4**	**Span adequate Size:** **Yes** No
Impoundment Upstream: Yes **No**		**Impoundment Length (m):**	**Water Depth (m): 0.5**
Sediment Barrier: Yes **No**		**Floodplain Disconnection:** **Yes** No	**Erosion Protection d/s:** Yes **No**
Inlet Structure: Wingwalls Projecting Headwall Flow Control		**Outlet Structure:** **Wingwalls** Projecting Headwalls	
Proximal Infrastructure: **Strm Water Outfall** Water main Other -			
Notes: **Outfall along left bank, scour pool, debris accumulation, sedimentation (bars) along either side**			

Damage		
Degradation or Dredging: **Yes*** No		**Aggradation or Deposition:** **Yes**** No
Perched: Yes **No**	**Height to Bed (m)**	**Height to Water Level (m):**
Undercut: Yes **No**	**Outflanked Structure:** Yes **No**	
Erosion: **Yes** No	**Upstream:** **Yes** No	**Downstream:** **Yes** No
Scour Damage Yes **No**	**Bed Scour:** **Yes** No	**Exposed Footing:** Yes **No**
Notes: ***Scour pool at inlet** ***Scour pool downstream of crossing, most likely from adjacent outfall** ****Sedimentation at inlet** **Bank erosion upstream and downstream**		

Channel Morphology				
Artificial Reach Break: Yes **No**	**Bed Morphology:** **Riffle-Pool**		**Channel Planform:** **Meandering**	
Modified Channel Cross section: Yes **No**	**Cross Section:** Trapezoidal (u/s d/s) 2 Stage (u/s d/s) Natural (u/s **d/s**) Nat Channel Design (u/s d/s)			
Bed Material (m)	**Upstream** (~D_{50}): **Fines, cobbles**	**Downstream** (~D_{50}): **Fines – cobbles, small bounders**	**Channel Gradient:** **Low - moderate**	**Downstream:**
Flow direction at Culvert Inlet: Straight Outside bank to edge of crossing: (Left Right)			**Active Bank Erosion:**	
Notes: **Cobbles** **Sediment (fine) deposition in pools** **Riffle sequences** **Partially embedded sediment at culvert**				

Watercourse Crossing Assessment Sheet

Photographs of Channel Crossing



Photograph 1. ↑
Looking northwest towards culvert outlet along Bovaird Drive West. Outfall present along left bank.



Photograph 2. ↑
Looking west at right bank at culvert outlet. Bank erosion present.



Photograph 3. ↑
Looking towards west (right) bank. Christmas tree bank restoration along outer bend downstream of culvert outlet.



Photograph 4. ↑
Looking southwest (upstream) at upstream end of reach. Exposed clay on the bed (arrow).

Watercourse Crossing Assessment Sheet



Photograph 5. ↑
Degradation along bed, with exposed clay present upstream of Bovaird Drive West crossing.



Photograph 6. ↑
Looking southeast (downstream) towards culvert inlet.

Flow
Building our future, faster.

Central Brampton

Appendix D

Final Meander Belt

AECOM

Peel Region





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Old School Rd
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-35

0 10 20 30 40

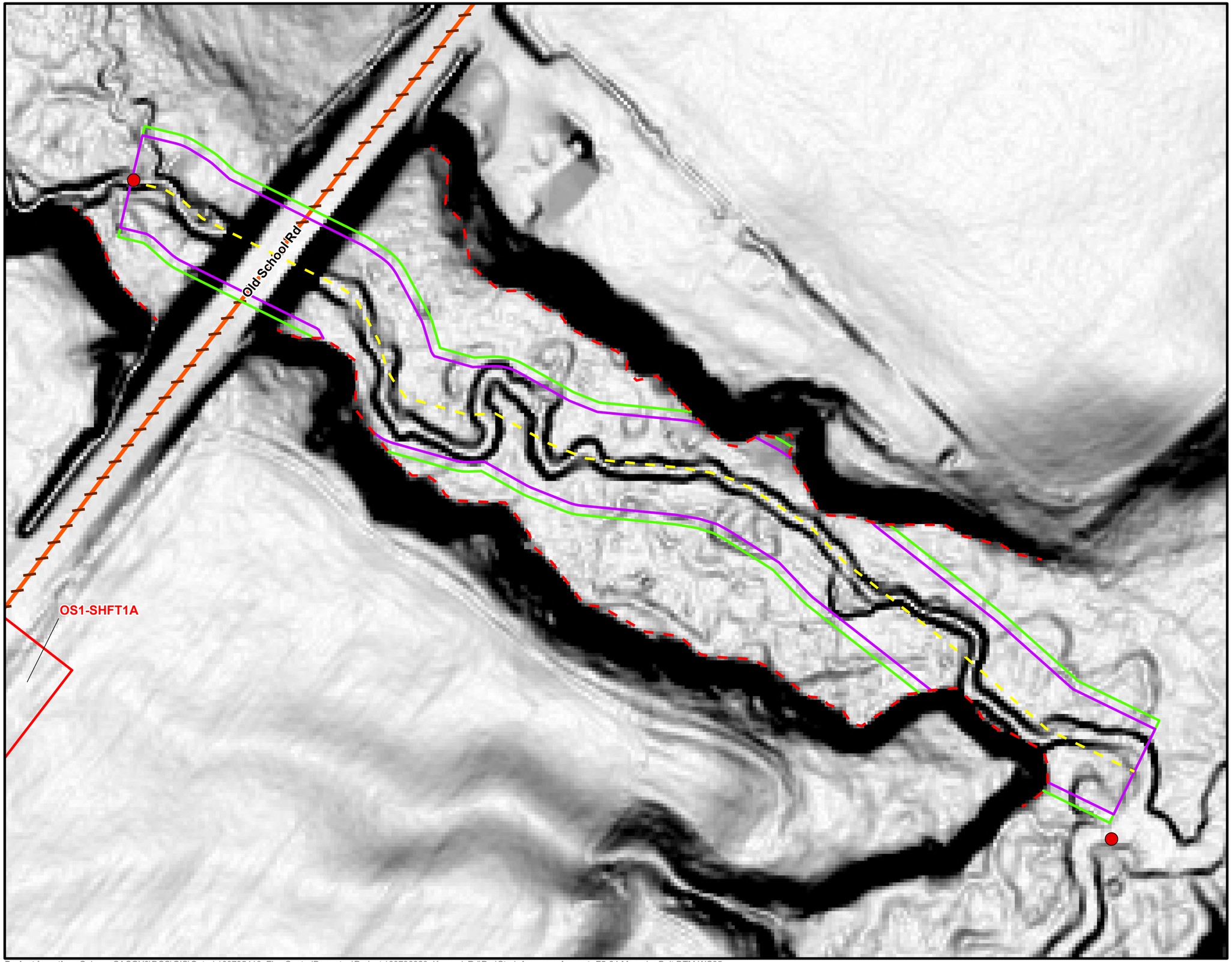
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PN: 60736820	Figure D-1
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-23 Meander Belt Ortho WC35
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Old School Rd
- MTBM Shaft Compound Preferred

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-35

0 10 20 30 40

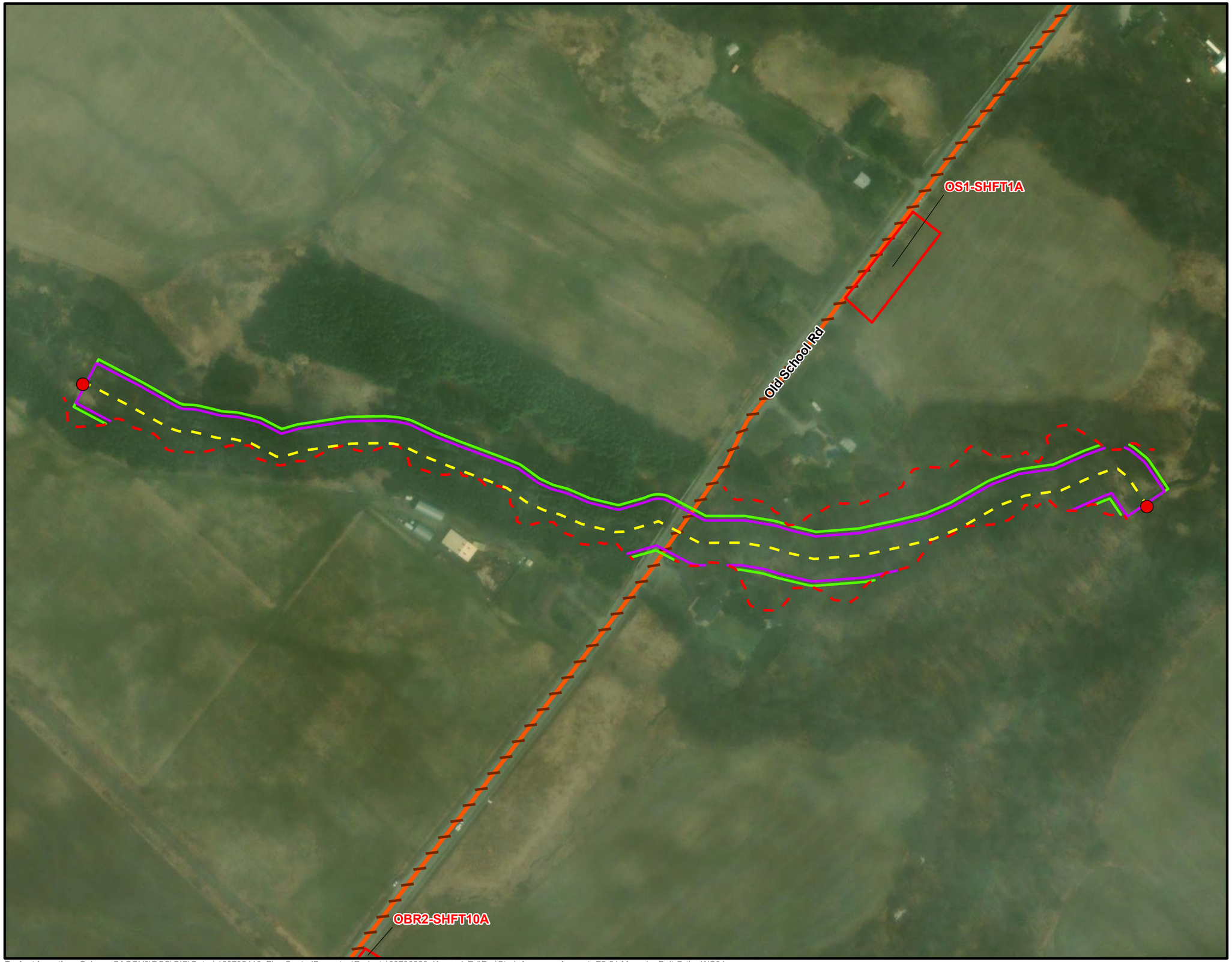
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Scale: 1:1,000

N

PN: 60736820	Figure D-2
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Meander Belt Axis
- Confining Valley Lines
- Preliminary Meander Belt
- Final Meander Belt
- Old School Rd
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-34

0 30 60 90 120

Meters

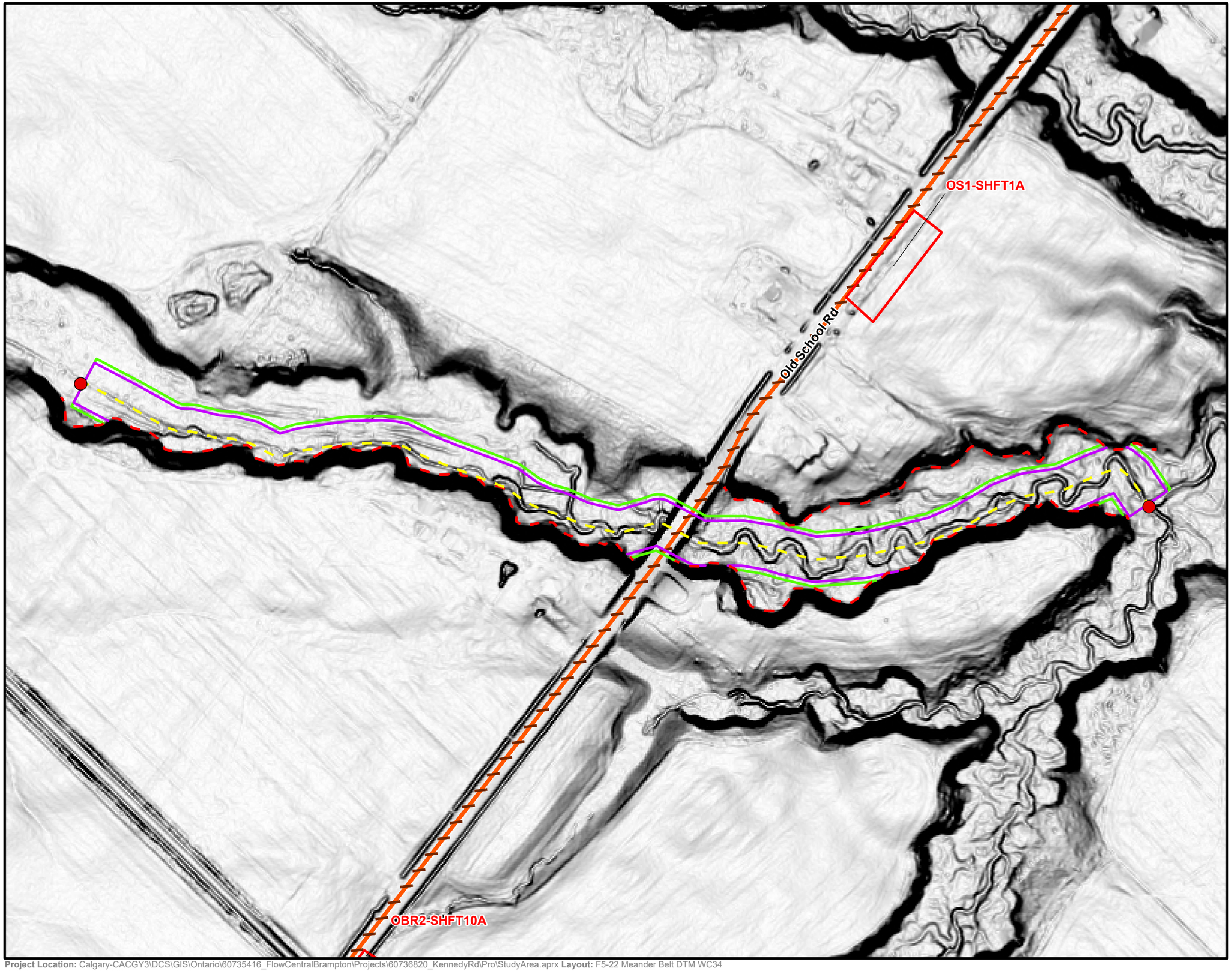
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PN: 60736820	Figure D-3
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-21 Meander Belt Ortho WC34
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Meander Belt Axis
- Confining Valley Lines
- Preliminary Meander Belt
- Final Meander Belt
- Old School Rd
- MTBM Shaft Compound Preferred

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-34

0 30 60 90 120

Meters

Scale: 1:2,391

N

PN: 60736820	Figure D-4
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor
- Old School Rd
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-33

0 10 20 30 40

Meters
Scale: 1:1,000

N

PN: 60736820	Figure D-5
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-19 Meander Belt Ortho WC33
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- MTBM Shaft Compound Preferred
- Orangeville Brampton Railway Corridor
- Old School Rd

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-33

0 10 20 30 40

Meters

Scale: 1:1,000

N

PN: 60736820	Figure D-6
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- McLaughlin Rd
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-13

0 25 50 75 100

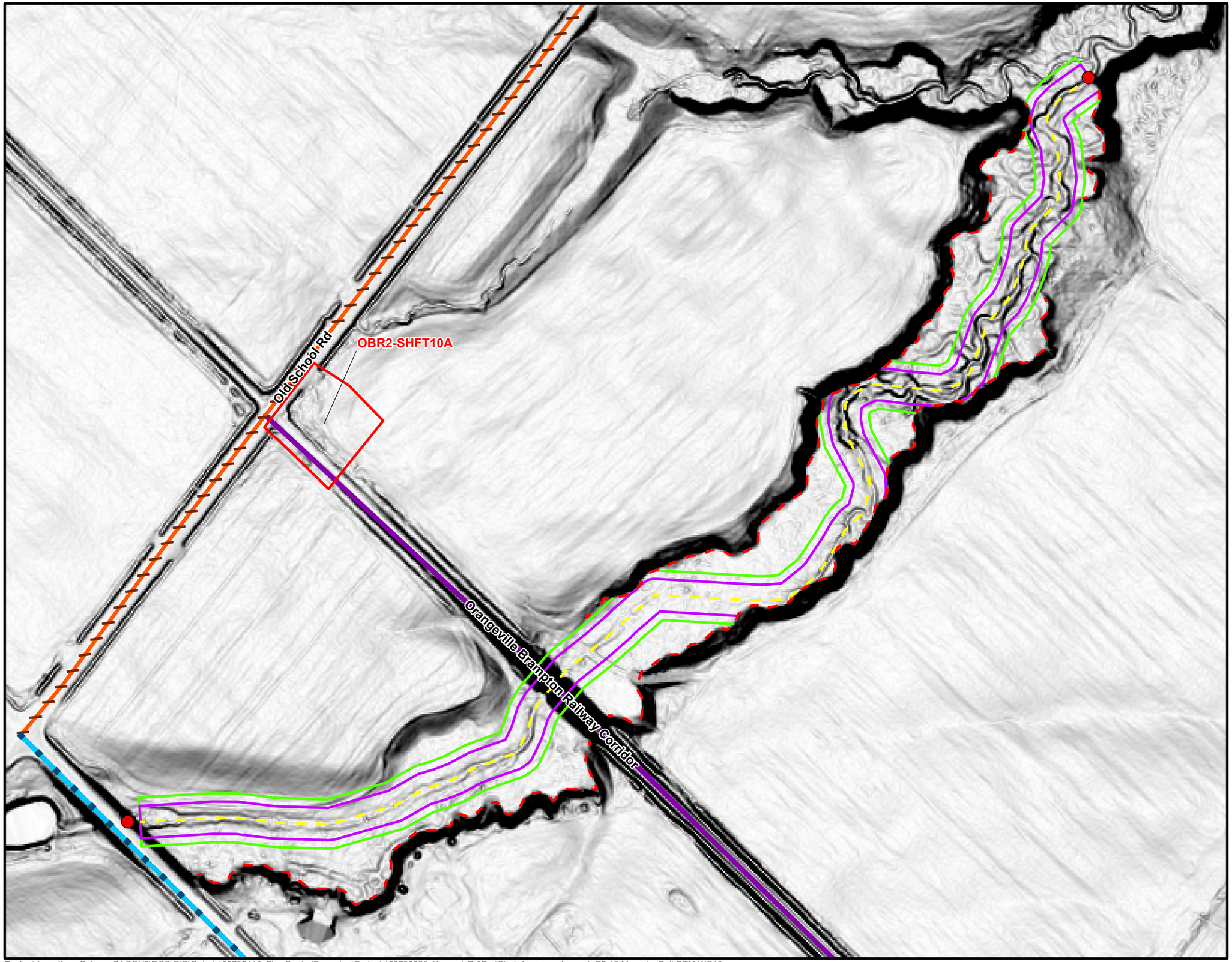
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N

PN: 60736820	Figure D-7
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- McLaughlin Rd
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred
- TBM Shafts
- Connections

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-13

0 25 50 75 100

Meters

Scale: 1:2,122

N

PN: 60736820	Figure D-8
January 27, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- MTBM Shaft Compound Preferred
- Connections
- McLaughlin Rd
- Orangeville Brampton Railway Corridor

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-12

0 30 60 90 120

Meters

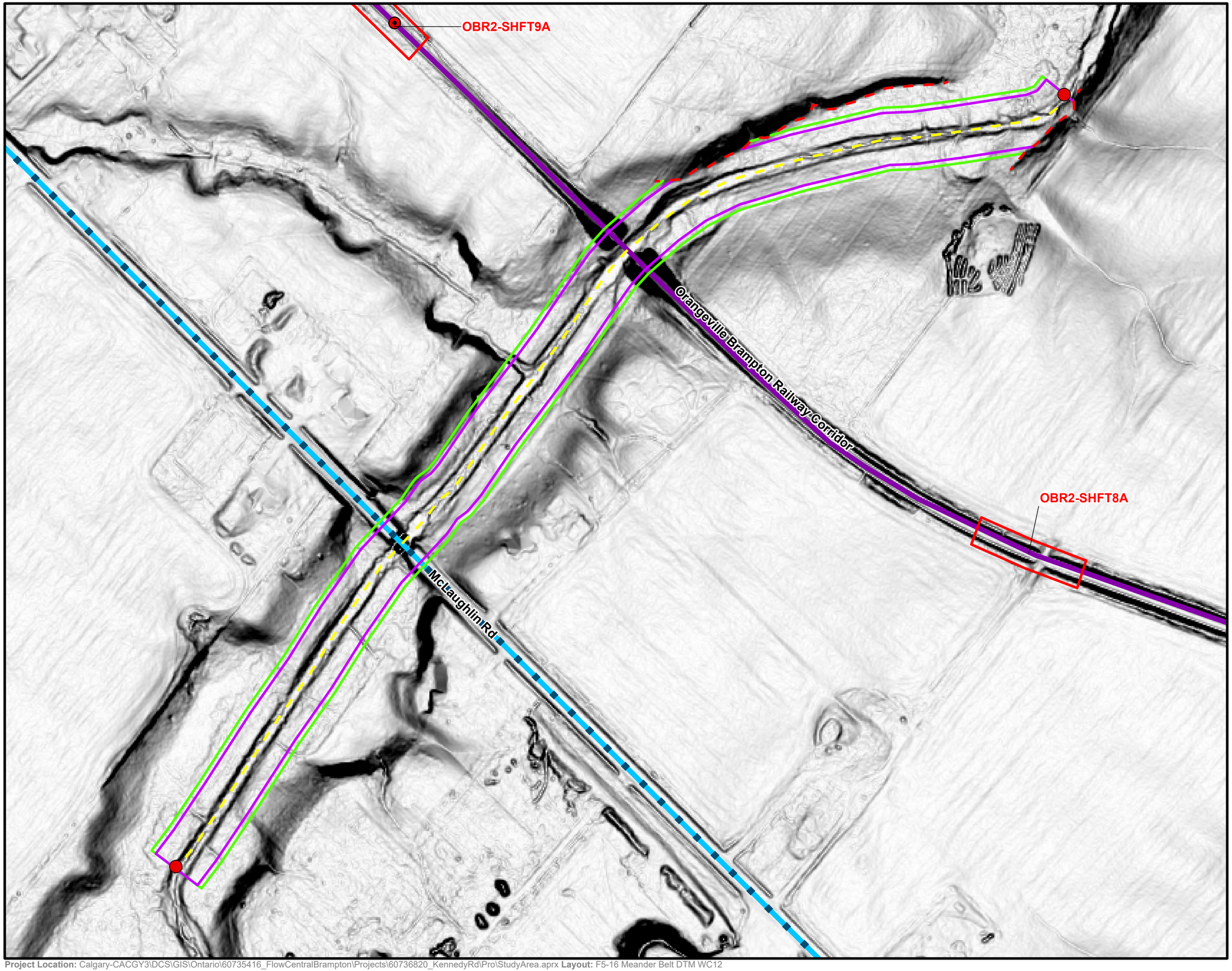
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PN: 60736820	Figure D-9
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-15 Meander Belt Ortho WC12
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- MTBM Shaft Compound Preferred
- Connections
- McLaughlin Rd
- Orangeville Brampton Railway Corridor

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-12

0 30 60 90 120

Meters

Scale: 1:2,500

N

PN: 60736820	Figure D-10
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Bovaird Dr
- Reach Breaks
- MTBM Shaft Compound Preferred
- Connections
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Final Meander Belt 30m Buffer
- ER Fletchers

Existing Trunks

- Fletchers Creek

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-08

0 20 40 60 80 100 120

Meters

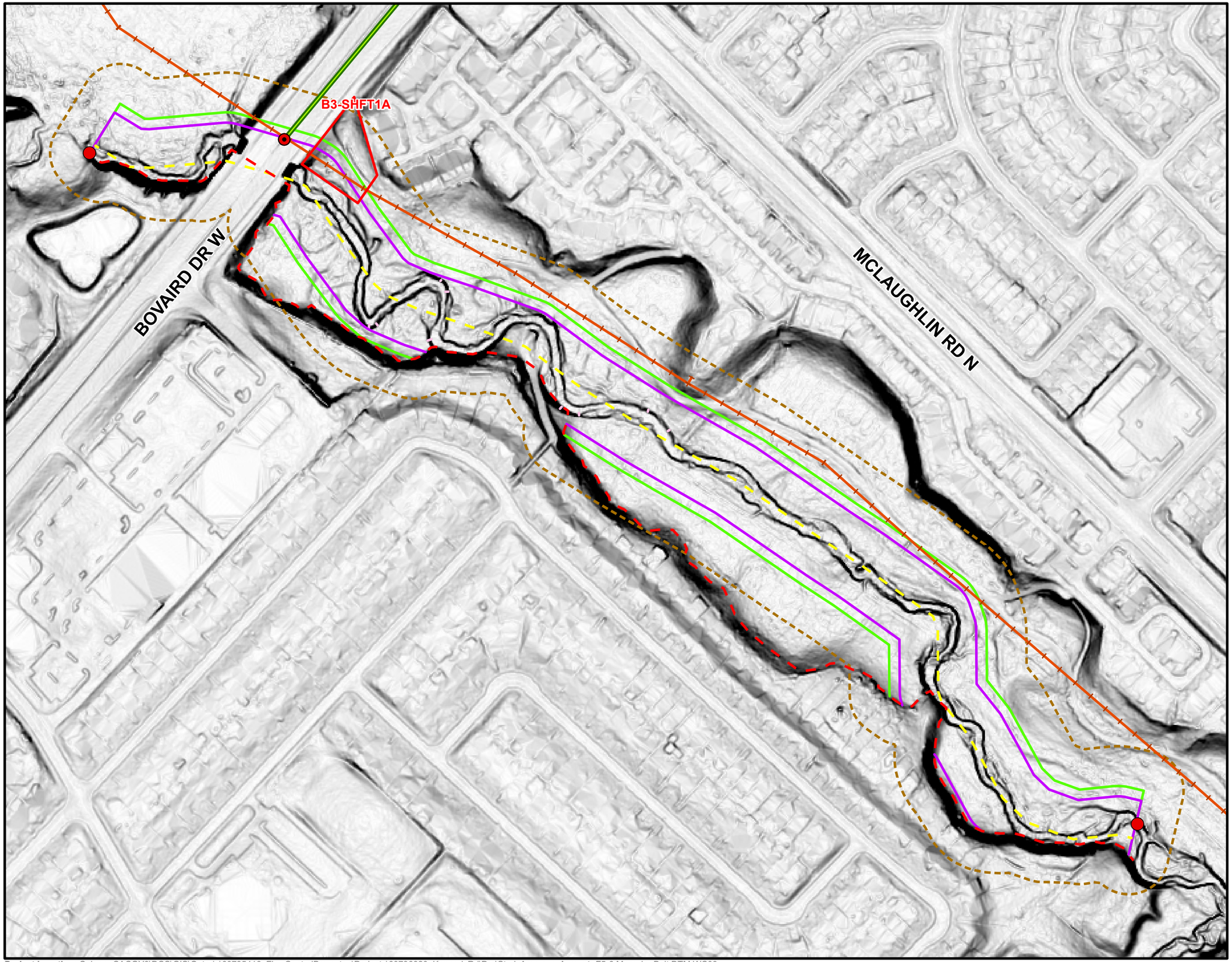
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PN: 60736820	Figure D-11
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-5 Meander Belt Ortho WC08
Date Saved: June 20, 2025 **User:** WangS12





- Bovaird Dr
- Connections
- MTBM Shaft Compound Preferred
- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Final Meander Belt 30m Buffer
- ER Fletchers

Slope Value

20

0

Existing Trunks

- Fletchers Creek

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-08

0 20 40 60 80 100 120

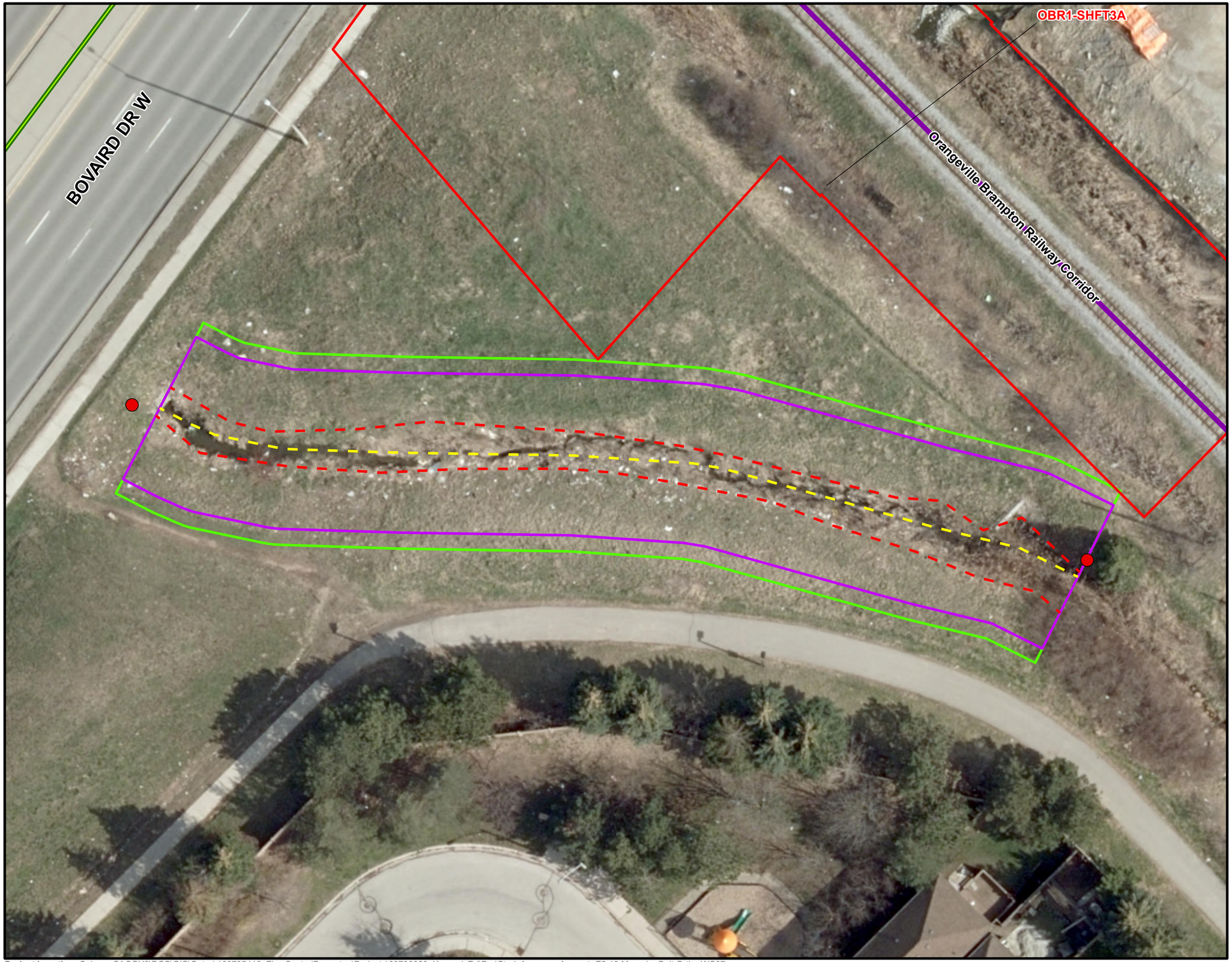
Meters
Scale: 1:2,700

N

PN: 60736820	Figure D-12
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-6 Meander Belt DTM WC08
Date Saved: June 20, 2025 **User:** WangS12





- Reach Breaks
- Meander Belt Axis
- Confining Valley Lines
- Preliminary Meander Belt
- Final Meander Belt
- Bovaird Dr
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-07

0 3.5 7 10.5 14

Meters

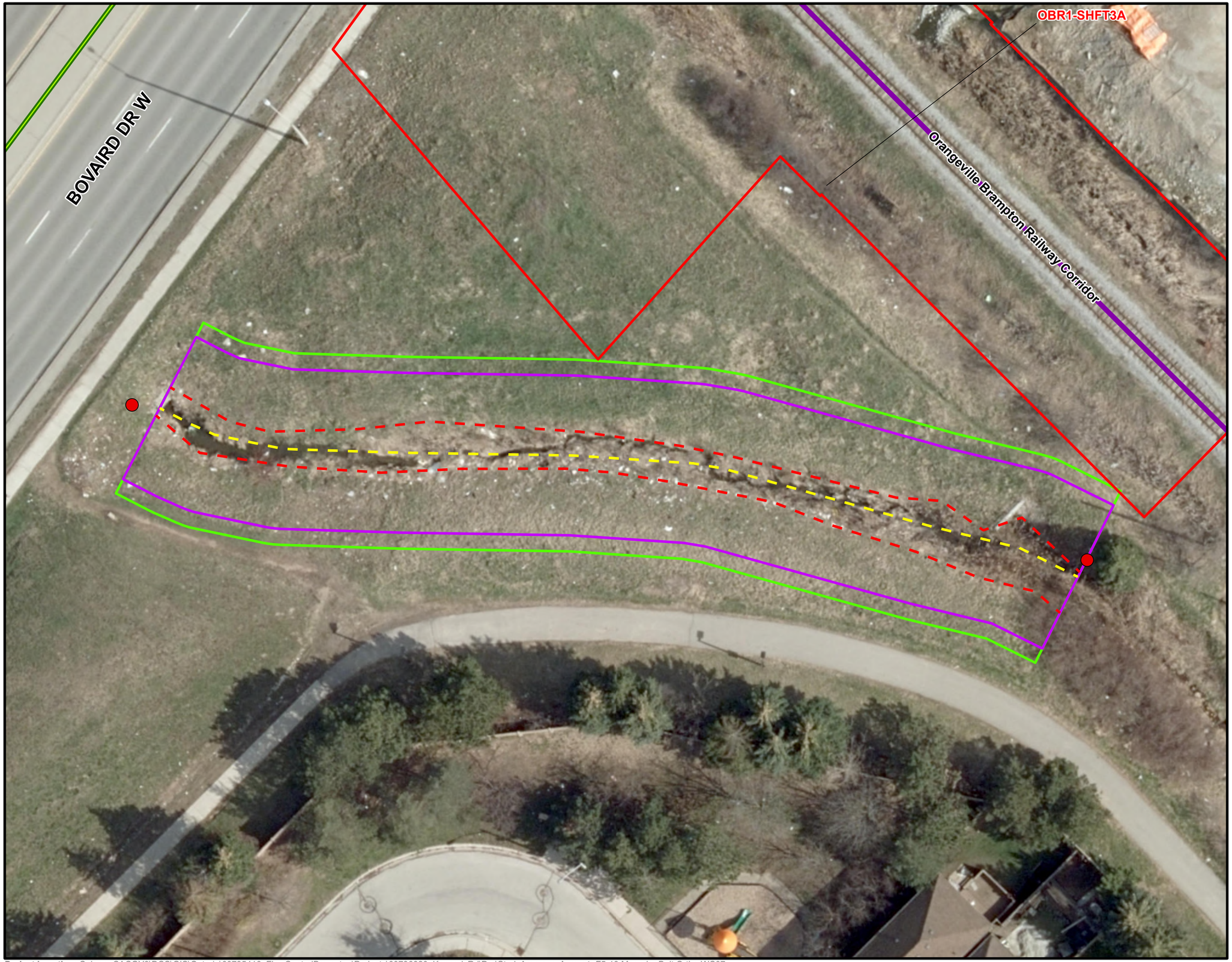
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N

PN: 60736820	Figure D-13
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-13 Meander Belt Ortho WC07
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Meander Belt Axis
- Confining Valley Lines
- Preliminary Meander Belt
- Final Meander Belt
- Bovaird Dr
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-07

0 3.5 7 10.5 14

Meters

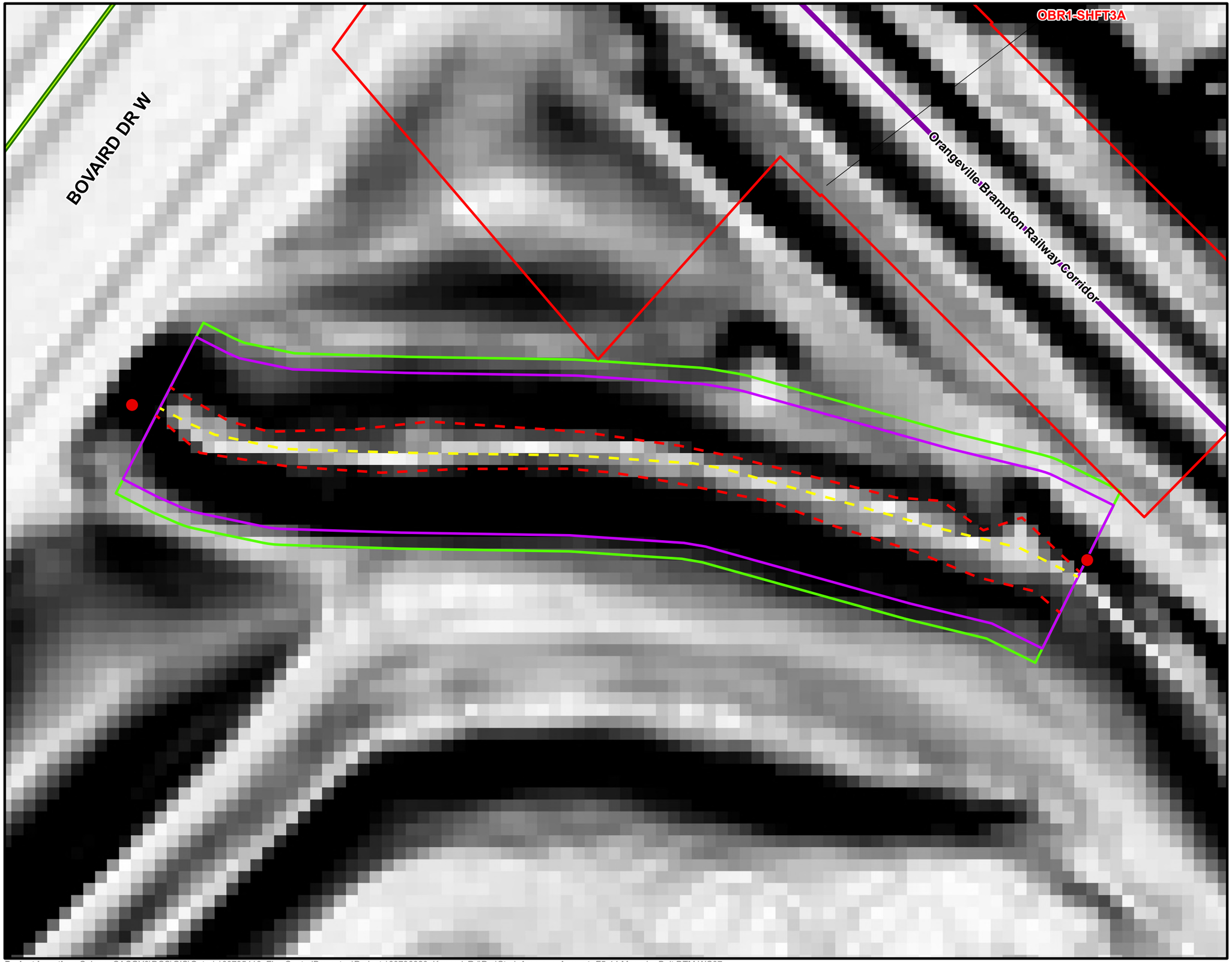
Scale: 1:300

N

PN: 60736820	Figure D-14
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-13 Meander Belt Ortho WC07
Date Saved: January 26, 2026 **User:** WangS12





- Reach Breaks
- Meander Belt Axis
- Confining Valley Lines
- Preliminary Meander Belt
- Final Meander Belt
- MTBM Shaft Compound Preferred
- Orangeville Brampton Railway Corridor
- Bovaird Dr

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-07

0 3.5 7 10.5 14

Meters

Scale: 1:300

N

PN: 60736820	Figure D-15
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-06a

0 3 6 9 12

Meters
Scale: 1:250

N

PN: 60736820	Figure D-16
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-11 Meander Belt Ortho WC06a
Date Saved: June 20, 2025 **User:** WangS12

OBR1-SHFT3A

Orangeville Brampton Railway Corridor



- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- MTBM Shaft Compound Preferred
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-06a

0 3 6 9 12

Meters

Scale: 1:250

N

PN: 60736820 | Figure D-17

January 26, 2026 | AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor
- Connections
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-06

0 10 20 30 40

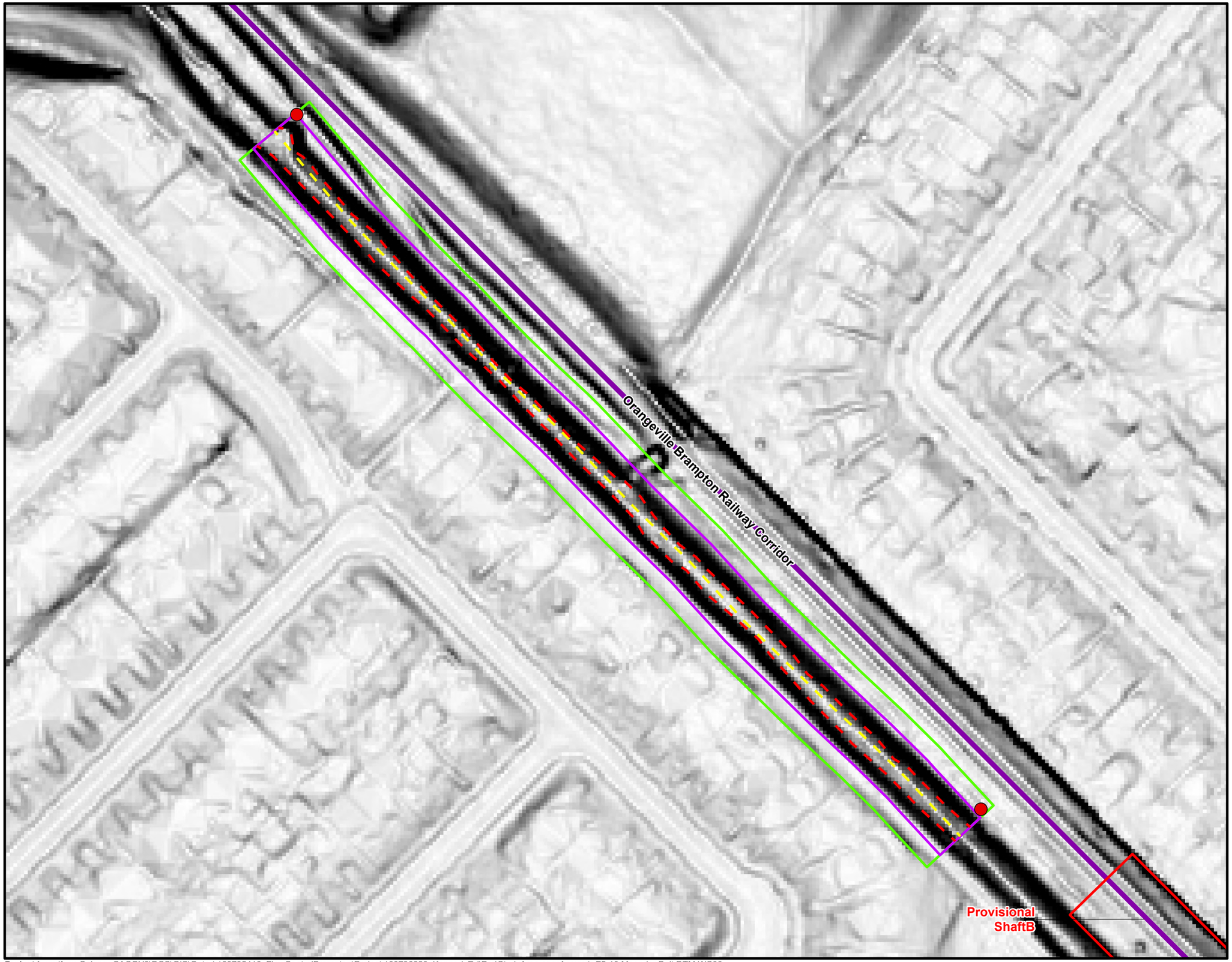
Meters
Scale: 1:1,000

N

PN: 60736820	Figure D-18
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-9 Meander Belt Ortho WC06
Date Saved: June 20, 2025 **User:** WangS12





- Reach Breaks
- Connections
- MTBM Shaft Compound Preferred
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-06

0 10 20 30 40

Meters

Scale: 1:1,000

N

PN: 60736820	Figure D-19
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-10 Meander Belt DTM WC06
Date Saved: June 20, 2025 **User:** WangS12





- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor
- MTBM Shaft Compound Preferred

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-05a

0 30 60 90 120

Meters

Scale: 1:2,500

N

PN: 60736820	Figure D-20
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL





- Reach Breaks
- Confining Valley Lines
- MTBM Shaft Compound Preferred
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Orangeville Brampton Railway Corridor

Slope Value

20

0

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-05a

0 30 60 90 120

Meters

Scale: 1:2,500

N

PN: 60736820	Figure D-21
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-8 Meander Belt DTM WC05a
Date Saved: June 20, 2025 **User:** WangS12





- Vodden St
- MTBM Shaft Compound Preferred
- Connections
- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt

Existing Trunks

- Etobicoke Creek

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with Ortho: WC-04

0 10 20 30 40 50 60

Meters

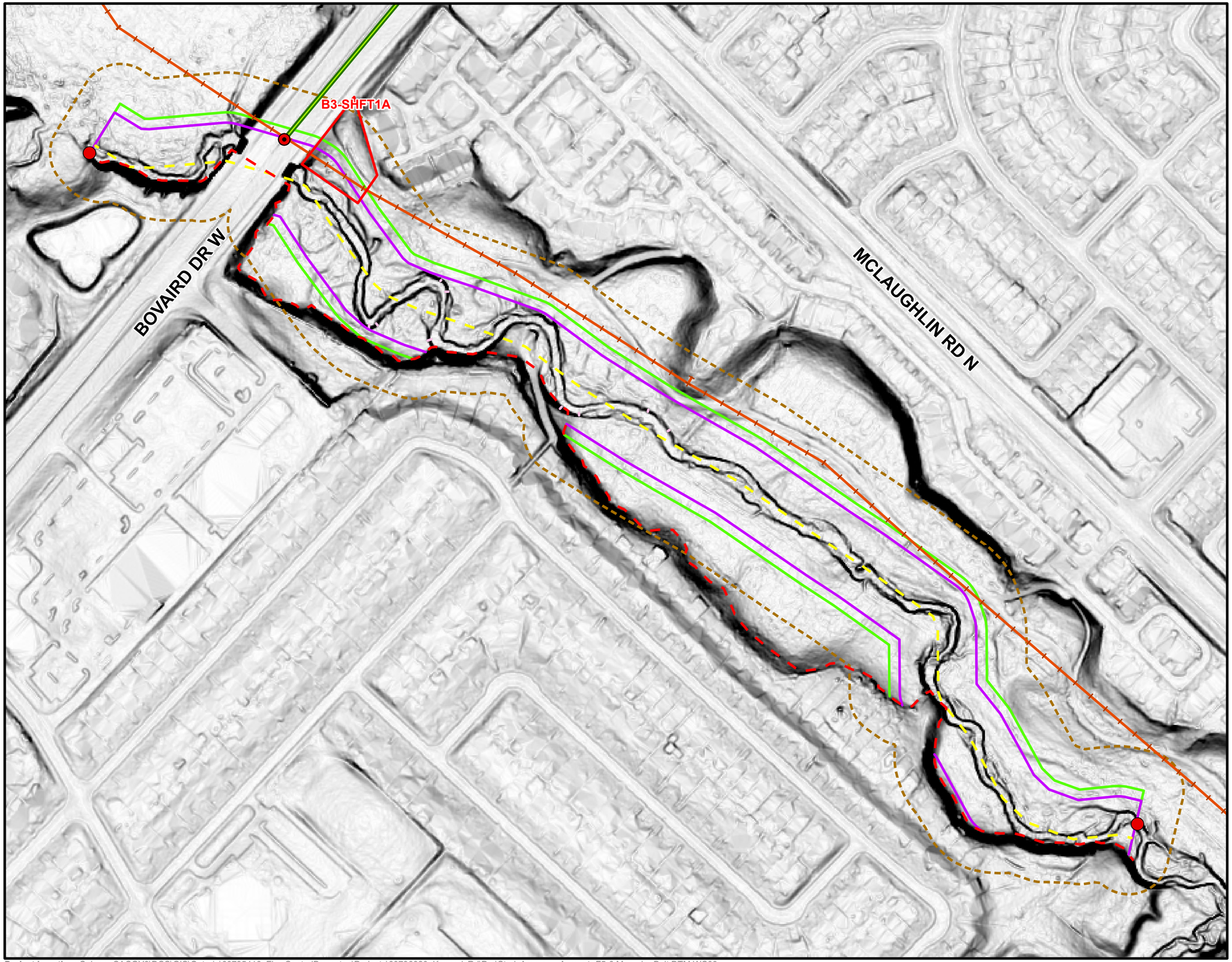
Scale: 1:1,400

N

PN: 60736820	Figure D-22
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-3 Meander Belt Ortho WC04
Date Saved: June 20, 2025 **User:** WangS12





- Bovaird Dr
- Connections
- MTBM Shaft Compound Preferred
- Reach Breaks
- Confining Valley Lines
- Meander Belt Axis
- Preliminary Meander Belt
- Final Meander Belt
- Final Meander Belt 30m Buffer
- ER Fletchers

Slope Value

20

0

Existing Trunks

- Fletchers Creek

Flow | Central Brampton

Kennedy Rd | Meander Belt Width with DTM: WC-08

0 20 40 60 80 100 120

Meters
Scale: 1:2,700

N

PN: 60736820	Figure D-23
January 26, 2026	AECOM

Data Sources:
Government of Ontario, Region of PEEL

Project Location: Calgary-CACGY3\DCS\GIS\Ontario\60735416_FlowCentralBrampton\Projects\60736820_KennedyRd\Pro\StudyArea.aprx **Layout:** F5-6 Meander Belt DTM WC08
Date Saved: June 20, 2025 **User:** WangS12