Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

LAKESHORE TRANSPORATION STUDIES - NEW CREDIT RIVER ACTIVE TRANSPORTATION (AT) BRIDGE STUDY

FLUVIAL GEOMORPHOLOGY ASSESSMENT REPORT
MISSISSAUGA, ONTARIO

Prepared for:
HDR CORPORATION

Prepared by:
MATRIX SOLUTIONS INC.

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Mississauga, Ontario

Suite 3001, 6865 Century Ave.
Mississauga, ON, Canada L5N 7K2
T 905.877.9531 F 289.323.3785
www.matrix-solutions.com

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Prepared for HDR Corporation, January 2023

Amy Nicoll, M.Sc., P.Geo. (Limited)
Fluvial Geomorphologist January 30, 2023

reviewed by
Roger Phillips, Ph.D., P.Geo.
Senior Geomorphologist January 30, 2023

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1 INTRODUCTION

HDR Corporation retained Matrix Solutions Inc. to complete a fluvial geomorphology assessment report as part of the Lakeshore Transportation Studies. The studies include three infrastructure projects in the Lakeview, Port Credit, and Clarkson communities that build from the 2019 Lakeshore Connecting Communities Transportation Master Plan. These studies include the Lakeshore Bus Rapid Transit (BRT) Study, Lakeshore Complete Street Study, and the New Credit River Active Transportation (AT) Bridge Study.

This report will focus on the geomorphic assessment associated within the New Credit River AT Bridge Study, with the remaining two studies to be discussed in separate reports.

As part of the Lakeshore Transportation Studies, HDR is developing the preliminary design and completing the Schedule B Class Environmental Assessment for a new AT bridge over the Credit River north of Lakeshore Road. The new span bridge will connect the existing multi-use path on Mississauga Road to existing multi-use path on the east side of Credit River. This bridge will enhance mobility across the river for pedestrians.

1.1 Scope

The geomorphic assessment included the following tasks:

- background review
- historical characterization of the Credit River
- field reconnaissance and rapid geomorphic assessment
- erosion hazard assessment
- geomorphic impacts and mitigation strategies for the preliminary design of the preferred AT bridge

This fluvial geomorphology assessment report summarizes the findings and recommendations of the geomorphic assessment of the Credit River within the New Credit River AT Bridge study area (the study area). The Credit River is under the jurisdiction of Credit Valley Conservation (CVC).

2 STUDY AREA AND HISTORICAL ASSESSMENT

Matrix carried out a historical characterization of the Credit River in the vicinity of Lakeshore Road, which included a review of surficial geology and physiography mapping; a literature review of local glacial history; and a review of documented historical land uses, historic maps and photographs, available historical photographs, topographic survey information, and bathymetric data. While engineering controls are currently in place along the riverbanks, the historical review provides insight into the range of channel dynamics that can be expected along the lower reach of the river at the outlet to Lake Ontario.

2.1 Physiography and Surficial Geology

The surficial geology of the southern Ontario region is shaped by a legacy of bedrock erosion and sediment deposition following continental glaciations over geological timescales and post-glacial incision by fluvial processes over the last 10,000 years. The resulting stream and river drainage networks—including their sediments and slope profiles—are conditioned by this glacial and post-glacial history. The physiography and surficial geology of the Lakeshore Transportation Studies area is presented on Figure 1. Local topography, valleylands, watercourses, and crossing locations within the New Credit River AT Bridge study area are presented on Figure 2.

2.1.1 Lakeshore Transportation Studies Area

Along the Lake Ontario shoreline, the Lakeshore Transportation Studies area is located within the Iroquois Plain physiographic region, which is a region that was submerged by Glacial Lake Iroquois following the Wisconsinan ice age roughly 11,000 years ago (Chapman and Putnam 1984). As a result, the surficial geology is dominated by sand and gravel lake deposits and localized silt, clay, and till deposits blanketing the scoured bedrock surface. The underlying bedrock of the area is primarily shale and limestone of the Georgian Bay Formation. This consists of interbedded grey-green to dark grey shale and fossiliferous calcareous siltstone to limestone (Armstrong and Dodge 2007). This shale is exposed in areas along the riverbed and valley walls of the Credit River. North of the area, contacts with the overlying Queenston Formation (red shale interbedded with limestone) can also be seen on the valley walls.

North of the Glacial Lake Iroquois Shoreline are more extensive glacial till and fine-grained glacial lacustrine deposits that cover the gradually varying topography of the South Slope physiographic region, ultimately trending upwards in elevation to the Oak Ridges Moraine (north) and Niagara Escarpment (west) that are the topographic highs in the region.

2.1.2 New Credit River Active Transportation Bridge Study Area

The New Credit River AT Bridge study area is situated within the lower reaches of the Credit River valley, which drains a moderately sized watershed in the region of about 1,000 km^2 from the uplands above the Niagara Escarpment, down the South Slope and over the Lake Iroquois Plain, to empty into Lake Ontario. The focused study area of this report is essentially the Credit River valley and estuary at Lake Ontario, and as such, the surficial geology is characterized by recent river deposits of silt, sand, and gravel alluvium within the topographically well-defined valley landform (Figure 2). However, the lower reaches of the Credit River have been significantly modified and infilled, associated with the Port Credit settlement as described further in the historical assessment (Section 2.2). In this context, the natural fluvial process of flooding and erosion have been modified within the valleylands, and thus, the geomorphic erosion hazard (Section 6) is highly managed and constrained by the engineered bank protection, existing transportation crossings, harbour facilities, and other urban land uses within the former floodplain and estuary marshlands.

2.2 Historical Assessment

Matrix carried out a historical characterization of the Credit River in the vicinity of Lakeshore Road, which included a review of scientific literature, documented historical land uses, and historic maps and photographs. The review provides insight into the range of channel dynamics that can be expected along the lower reach of the river at the outlet to Lake Ontario and the river's history of modification.

2.2.1 Pre-historical Lake Ontario Shoreline

Scientific literature on the geological evolution of Lake Ontario was reviewed to further inform the geomorphological context of the lower Credit River valleylands and coastal estuary environment. The existing valley topography and river channel landforms are the result of large fluctuations in lake water levels following deglaciation of the Lake Ontario basin. Initially, about 12,000 years ago, water levels in the lake were about 40 m higher than today, forming the Lake Iroquois shoreline bluff north of the study area (Anderson and Lewis 2012, Coakley and Karrow 1994, Hladyniuk 2014). The lake levels then dropped to about 40 m below present water level (Figure A), resulting in downcutting (i.e., incision) of the pre-historic Credit River into the Iroquois Plain and underlying bedrock, thus creating a well-defined valley landform. The evidence of this lower water level and base level for Lake Ontario tributaries includes barrier beach deposits within the lake bottom sediments (Lewis and Todd 2019). From this low, water levels have steadily risen over the last 10,000 years to present day lake levels, resulting in inundation of the incised valley landforms and aggradation of fine sediments within the estuaries (Weninger and McAndrews 1989). The aggradational environment of the study area is supported by mapping of stream power for the Credit River, as the high energy of upstream reaches drops off dramatically in the lower reaches from greater than 100 W/m^2 upstream of the Queen Elizabeth Way to less than 10 W/m^2 downstream (Desloges et al. 2020). Like most Lake Ontario tributaries prior to European settlement, the Credit River estuary had a barrier beach bar and associated estuary marshlands within the lower reaches of the valley, but much of the marshlands have been lost with the history of port land developments along the shoreline (Whillans 1982).

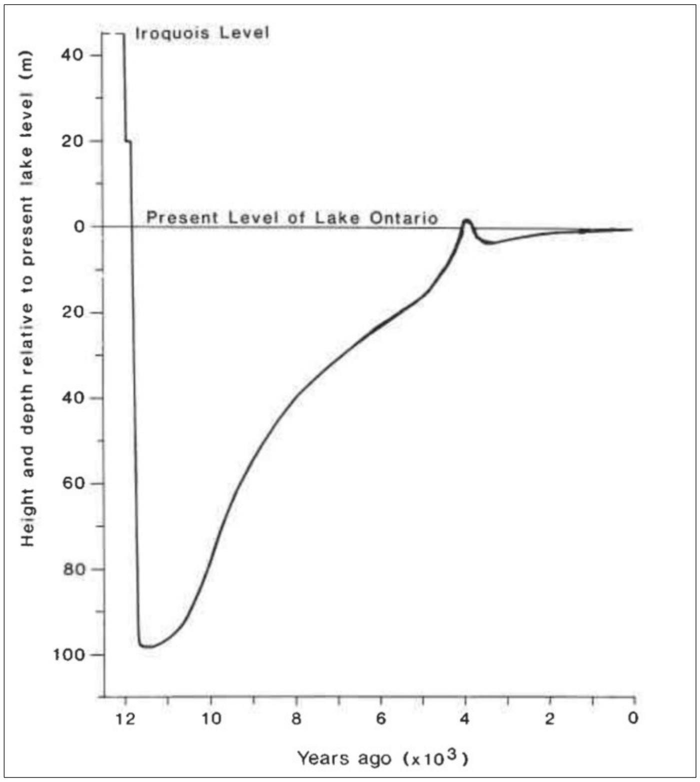


FIGURE A Lake Ontario Water-level curve Since Deglaciation (Source: Weninger & McAndrews [1989], Redrawn from Anderson and Lewis [1985])

2.2.2 Historical Land Use and Port Credit Development

Given that the Credit River within the study area has a long history of development, relevant background documents were reviewed to provide further context regarding the modifications to the shoreline, estuary, and floodplain with associated engineering of the river and transportation crossings.

Displacing the Mississaugas of the New Credit First Nation in the area, the expansion and intensification of British colonial settlements around the lower Credit River occurred in the early 1800s (MNCFN n.d.). With the intensified settlement came major deforestation in the late 1800s and extraction of stone material from the Credit River channel for construction (e.g., “stonehooking”; CVC 2014). An 1846 map with plans for expanding the Town of Port Credit shows that while much of the Credit River valleylands were still naturally vegetated marshlands at the time, the Toronto Street bridge is mapped crossing the river (coincident with the current location of Lakeshore Road bridge) and shoreline barrier beach and bars are mapped with a canal cut through for access to the harbour (Figure B; Heritage Mississauga 2018).

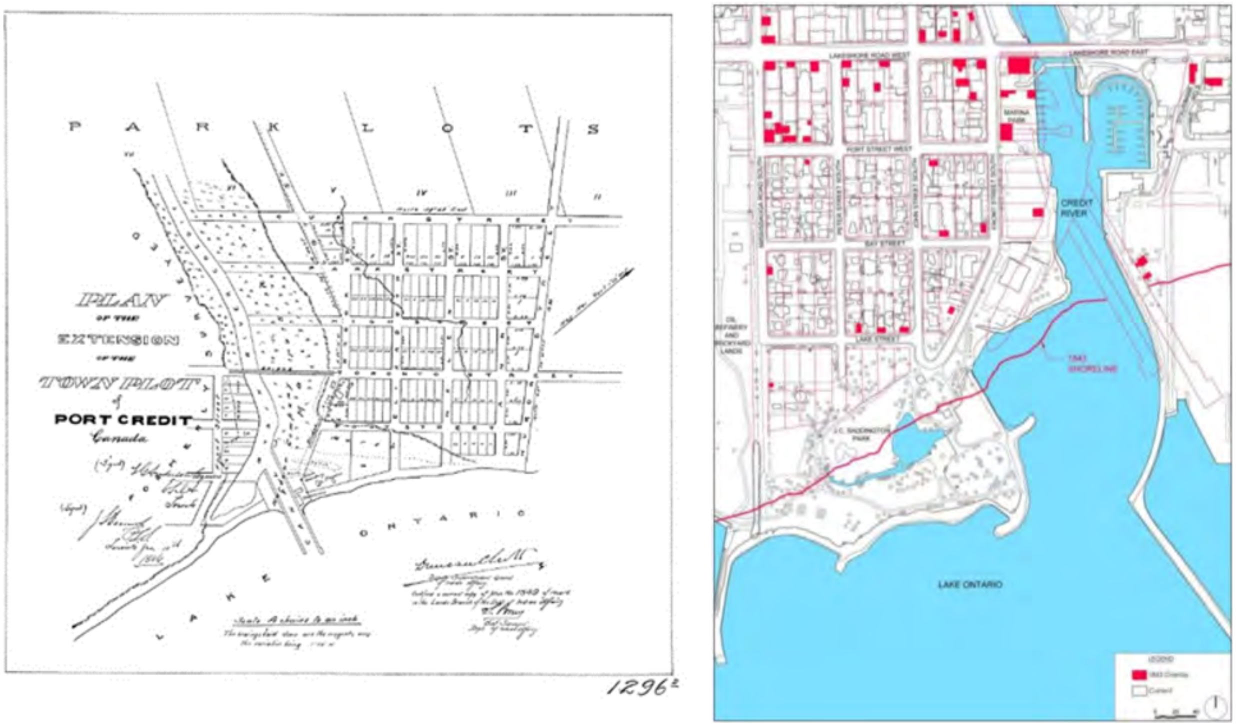


FIGURE B Expansion Plan for the Town of Port Credit in 1846 (Heritage Mississauga 2018)

Continued expansion of the Town of Port Credit and harbour occurred throughout the 1900s, with significant alterations to the shoreline of the Credit River channel, removal of the barrier bar, and widening of the river mouth at the lake shore from the original canal used in the 1800s (Figure C; GRA 2019, Heritage Mississauga 2018). Widespread loss of shoreline marshlands and barrier bars has been commonly documented for Lake Ontario (Whillans 1982; Evergreen 2021). The original iron bridge over the Credit River for Toronto Street was replaced in 1919 with two-lane concrete bowstring bridge (Figure C, Part A), which was subsequently replaced in 1960 with the current three-span concrete deck, four-lane bridge with sidewalks on either side (GRA 2019). The railway bridge over the Credit River was constructed about 400 m upstream of the Toronto Street bridge in 1903 (Figure C, Part B) and was recently twinned in 2008 (ASI 2017).

Further modifications to the Credit River floodplain and estuary marshes occurred in the 1950s and 1960s, with construction of the marina at the lake shore, with associated infilling and extension of parkland (Figure C, Parts C and D). Memorial Park was built in the mid-1950s upon fill that eliminated Faulkner Marsh, which was the wetland on the north floodplain of the Credit River between the railway bridge and Lakeshore Road (CVC 2014). During this period post 1950, most of the Credit River channel downstream of the railway bridge was engineered with stone and/or concrete block structures to protect the adjacent lands from erosion and flooding (CVC 2014). As sedimentation is an ongoing process in the estuary environment (Section 2.1), periodic dredging of the Credit River channel and harbour has occurred over the historical period and, mostly recently, in 2014 (CVC 2014).

<table>
<tr><td></td><td></td></tr>
<tr><td>A. Construction of a two-lane bowstring bridge in 1919 that was replaced with the current four-lane bridge in 1960 (GRA 2019)</td><td>B. Old Port Credit Village (Heritage Mississauga 2018)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>C. Port Credit in 1965 (post card steamship lines; Modern Mississauga 2020)</td><td>D. Port Credit Harbour Marina in 1971 (insauga 2014)</td></tr>
</table>

FIGURE C Select Historic Photographs of the Credit River; Background Review of Recent Studies and Designs

Recent studies pertaining to the fluvial geomorphology of the Credit River within the study area were reviewed to provide further context within the urbanized setting. These included the Lake Ontario Integrated Shoreline Strategy (LOISS; Aquafor Beech 2011), the 1 Port Street East Proposed Marina Environmental Assessment Terms of Reference (Shoreplan 2020), and the Lakeshore Transportation Master Plan (HDR 2019). These studies present collected information on the geomorphic character of the Credit River near Lakeshore Road, which support the findings of the historical assessment (Section 2.2).

The Credit River is the primary source of sediment to the lakeshore in the LOISS study area, contributing over 174,000 tonnes per year (Aquafor Beech 2011). Due to low channel slope and backwatering, the Credit River is turbid and aggradational near Lakeshore Road, and its substrate is fine (silts and mud; Aquafor Beech 2011). Nearshore lakebed materials mainly include shale bedrock overlain with erodible cohesive tills. The riverbed and port are periodically dredged to remove excess sediment to restore navigability. The most recent dredging occurred in 2014 (Aquafor Beech 2011, Shoreplan 2020). Bathymetry mapping from 1971 indicates that the river is typically 5 to 9 feet deep, with a shallower area near Saddington Park. Depths increase to over 20 feet beyond the breakwater (Figure D).

FIGURE D Bathymetry in the Project Study Area (Source: from: Ontario Hydrographic Chart No. 2070 - Harbours in Lake Ontario, 1971 [Excerpted from Figure 6-9, Shoreplan 2020])

The proposed new AT bridge crossing of the Credit River was evaluated as part of the Lakeshore Transportation Master Plan (HDR 2019). Six crossing alternatives were identified in addition to a "Do Nothing" alternative (Figure E). The bridge location options included crossings near Mineola Road, Queen Street, Park Street, High Street, north of the existing Lakeshore Road bridge, and an Inspiration Port Credit Bridge. Potential impacts for all options—except the "Do Nothing" option—included impacts to Credit River (CVC regulated) lands and potential impacts to aquatic habitat due to construction of the crossing.

The Port Credit Harbour Marina north of the estuary is proposed to be redeveloped, which will result in the extension of the existing land base (Shoreplan 2020). This project does not impact Lakeshore Road, but it illustrates the ongoing process of urbanization and lake shore change near the Credit River.

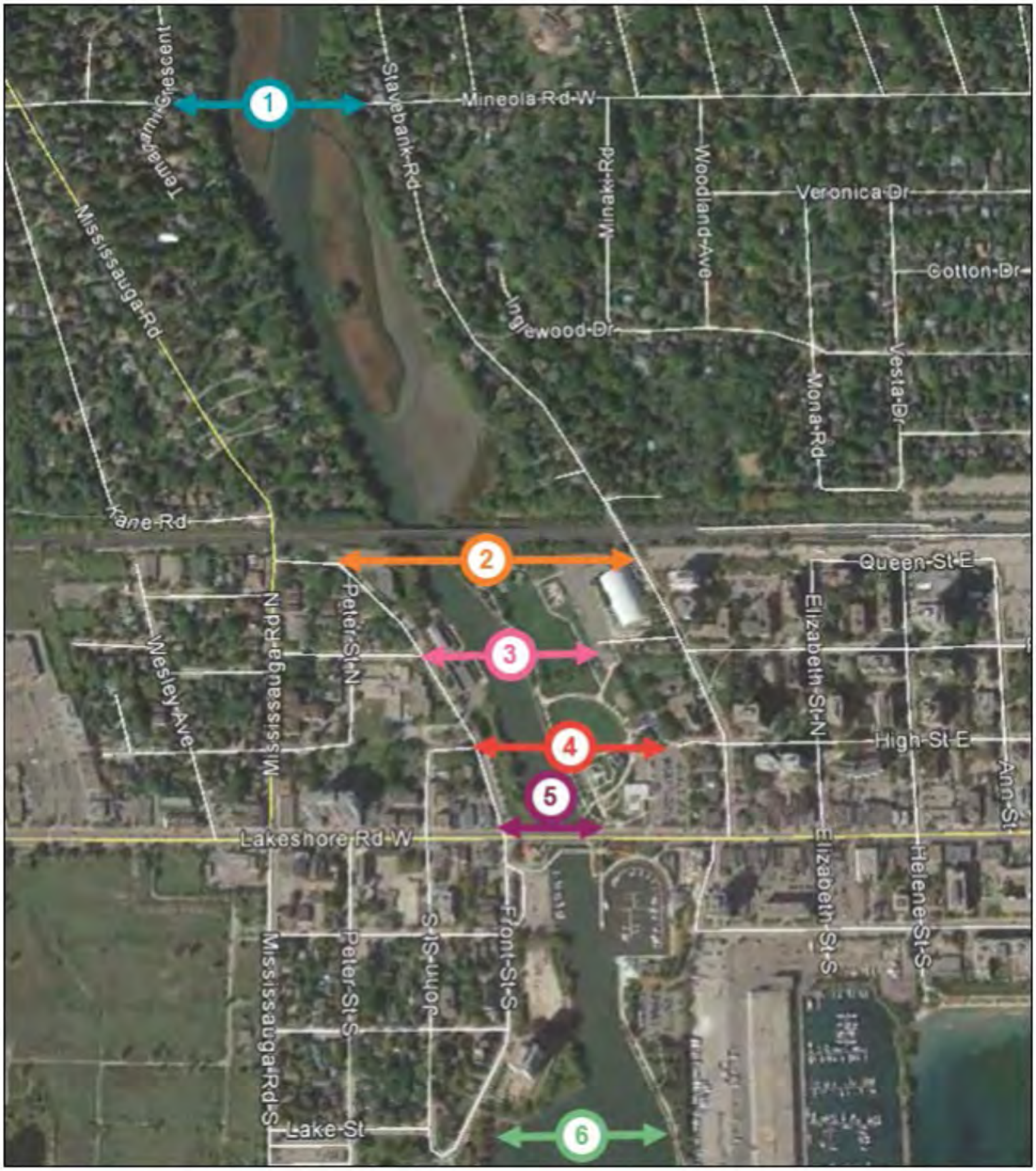


FIGURE E **Lakeshore Transportation Master Plan, Exhibit 5-57 Location of Active Transportation Crossing Alternatives (HDR 2019)**

2.2.3 Summary of Historical Assessment

The lower Credit River within the study area was originally the product of its physiographic context as a flooded, low-energy estuary environment following post-glacial valley formation and rising water levels in Lake Ontario over millennia. Through its subsequent historical development, the Credit River valleylands and Lake Ontario shoreline have been gradually converted from low-lying marshlands and barrier beaches to port lands supporting a variety of early settlement economic activities and then, more recently, to marina and park lands accommodating intensified urban and recreational land uses. With two major transportation crossings for rail and road that have been maintained and upgraded for the last 100 to 150 years, this history of development has been accompanied by extensive modifications to the Credit River channel to manage the associated erosion and flooding hazards. As a result, the fluvial geomorphology of the river within the Port Credit study area is highly engineered, and the risks of natural river processes have been substantively mitigated under current conditions. Sedimentation within the study reaches of the river remains the dominant fluvial process of the low-energy estuary environment, which will likely require continued management by periodic dredging.

Given the highly modified river environment within the study area, standard fluvial geomorphic assessment practices were adapted for the specific urban environment and focused on the requirements of the New Credit River AT Bridge Study and the Lakeshore Transportation Studies. This adapted study includes further background review of recent studies (Section 3); documentation of existing hydrologic, hydraulic; and geomorphic conditions (Section 4); and the resulting erosion risks and recommendations for the proposed new AT bridge crossing (Sections 5 and 6).

2.2.4 Historic Aerial Photograph Assessment

Further confirming the Credit River history summarized in the previous sections, aerial photographs from 1931, 1946, and 1968 were acquired from the National Air Photo Library (NAPL) and geo-rectified for use in the historic channel and erosion hazard risk assessment. Publicly available satellite imagery from 2020 was also reviewed. Historic photographs and recent satellite imagery are included in Appendix A. An overlay of historic channel traces from each photograph year are presented on Figure 3.

2.2.4.1 1931 Historic Aerial Photograph Interpretation

In 1931, land use included large residential lots and agricultural lands upstream of the train bridge and was more urbanized downstream in Port Credit Village. Many of the Port Credit roads still present today had already been constructed. Front Street North ran within 30 m of the riverbank. The Lakeshore Road crossing was a two-lane bowstring bridge as discussed in Section 2.2.2. A secondary bridge also conveyed water from the north floodplain (Faulkner Marsh) to the open water downstream of Lakeshore Road, in the area that was later developed into a marina.

At this time, the river catchment had already undergone many decades of deforestation. Sediment supply to the river would have been high due to the replacement of natural vegetation with farmland. A plume of sediment extends into the lake in the 1931 air photograph.

The banks of the Credit River were natural 1931. The river upstream of the train bridge was narrower than present (within photograph extent) and was lined with a large wetland along the north floodplain. The wetland extended along the valley toe of slope and was connected to the river by multiple small drainage channels. The island that currently lies 0.5 km upstream of the train bridge extended further downstream in 1931. Downstream of the train bridge, the original marsh wetland on the north floodplain was still present, and a narrow floodplain was present on the south bank. The river entered the lake through a narrow (roughly 20 m wide) opening between sand bars, which may be a remnant of the earlier nineteenth century canal. In 1931, the lake shore was sandy and had not been artificially extended into the lake.

2.2.4.2 1946 Historic Aerial Photograph Interpretation

In 1946, the same bowstring bridge was present as was the secondary bridge crossing (Faulkner Marsh) on Lakeshore Road. The upstream land use remained residential and agricultural, but additional residences had been constructed. The island 0.5 km upstream of the train bridge had receded by several meters, possibly in response to reduced rates of sedimentation as land use changed, or to increased bed slope and flow velocities upstream of dredging activities, or to lake water level change. The north floodplain remained a wetland, with pockets of open water. The distribution of areas of open water on the floodplain differed somewhat from the 1931 photograph, perhaps due in part to different water levels at the time of the photographs. Downstream of Lakeshore Road, the riverbanks and lake shoreline at the mouth of the river remained natural in general, with the addition of more boat docks along the north riverbank. The sand bars at the mouth of the river had either receded or were further inundated in the 1946 photograph, and the wetted opening to the lake between the bars was 37 m wide.

2.2.4.3 1968 Historic Aerial Photograph Interpretation

By 1968, the lands upstream of the train bridge had been dramatically urbanized up to Highway 403. The wetland upstream of the train bridge had changed into a wetland peninsula and side channel. Downstream, the floodplain had been infilled, and the riverbanks had been hardened. The Lakeshore Road bridge had been recently replaced to the current structure, and the secondary bridge that had drained the wetland was removed (Faulkner Marsh). The marina downstream of Lakeshore Road had been built, including docks and an engineered shoreline, and the shoreline on the north side river had been built out by 350 m. Breakwaters had also been constructed, jutting out up to 650 m into Lake Ontario. The remnant barrier beach was removed, and the mouth of the river had been widened.

2.2.4.4 2020 Satellite Imagery Interpretation

By 2020, the peninsula upstream of the train bridge had cut off to become an island. The island 0.5 km upstream of the train bridge had receded by several meters further upstream. At Lakeshore Road, a pedestrian bridge has been built just downstream of the Lakeshore Road bridge. The marina just downstream of Lakeshore Road had been updated, and there were no major changes to the lake shore on the north bank. On the south side, the shore had been built out further into Lake Ontario and housed a high-rise building east of Front Street as well as a park (J.C. Saddington Park) and waterfront trail.

3 EXISTING GEOMORPHIC CONDITIONS

To evaluate the existing geomorphic conditions, the hydrological context is first summarized (Section 4.1) followed by the results of the field assessment (Section 4.2).

3.1 Hydrological Context

The hydrological context of the lower Credit River in the study area is characterized by both Lake Ontario water levels (Section 4.1.1) and potential river flooding events generated from the watershed that have been assessed in the existing hydraulic modeling (Section 4.1.2).

3.1.1 Lake Ontario Water Levels

The base level of the Credit River is set by water levels in Lake Ontario. Contemporary water levels in Lake Ontario are primarily controlled by natural hydrological processes and are also affected by outflow regulation in the St. Lawrence Seaway. The hydrologic effect on Lake Ontario is mainly the outflow of Lake Erie (which supplies about 85% of the inflow into Lake Ontario and is uncontrolled), the precipitation and evaporation over Lake Ontario, and the runoff from Lake Ontario's local drainage basin (International Joint Commission 2020). The Lake Ontario system contains three major cycles (International Joint Commission 2020):

- persistently high or low precipitation over several years, which is the main natural cause of extreme high or low water levels
- annual cycles of snowmelt and evaporation that cause higher levels in spring and lower levels in the fall
- wind effects that cause rapid, short-lived change in water levels.

In the last century (1918-2019), mean monthly water levels have fluctuated over a range of approximately 2.1 m or 73.8 to 75.9 m elevation (DFO 2021). The annual cycle in Lake Ontario water levels has been fairly consistent from the mid-1990s to 2016. The maximum mean monthly flow in the record occurred in 2019 at approximately 75.9 m elevation (DFO 2021).

In the long term, changes in lake water levels will have an impact on erosion rates along the lake shore and on backwatered riverbanks. In the future, isostatic rebound will continue to occur, which will cause a gradual rise in lake levels on the order of 20 cm per 100 years. Climate change presents the possibility of more extreme water supply conditions (both wet and dry), storms and wind events that are more severe, and increased erosion impacts in winters when there is less ice along the shoreline (International Joint Commission 2020).

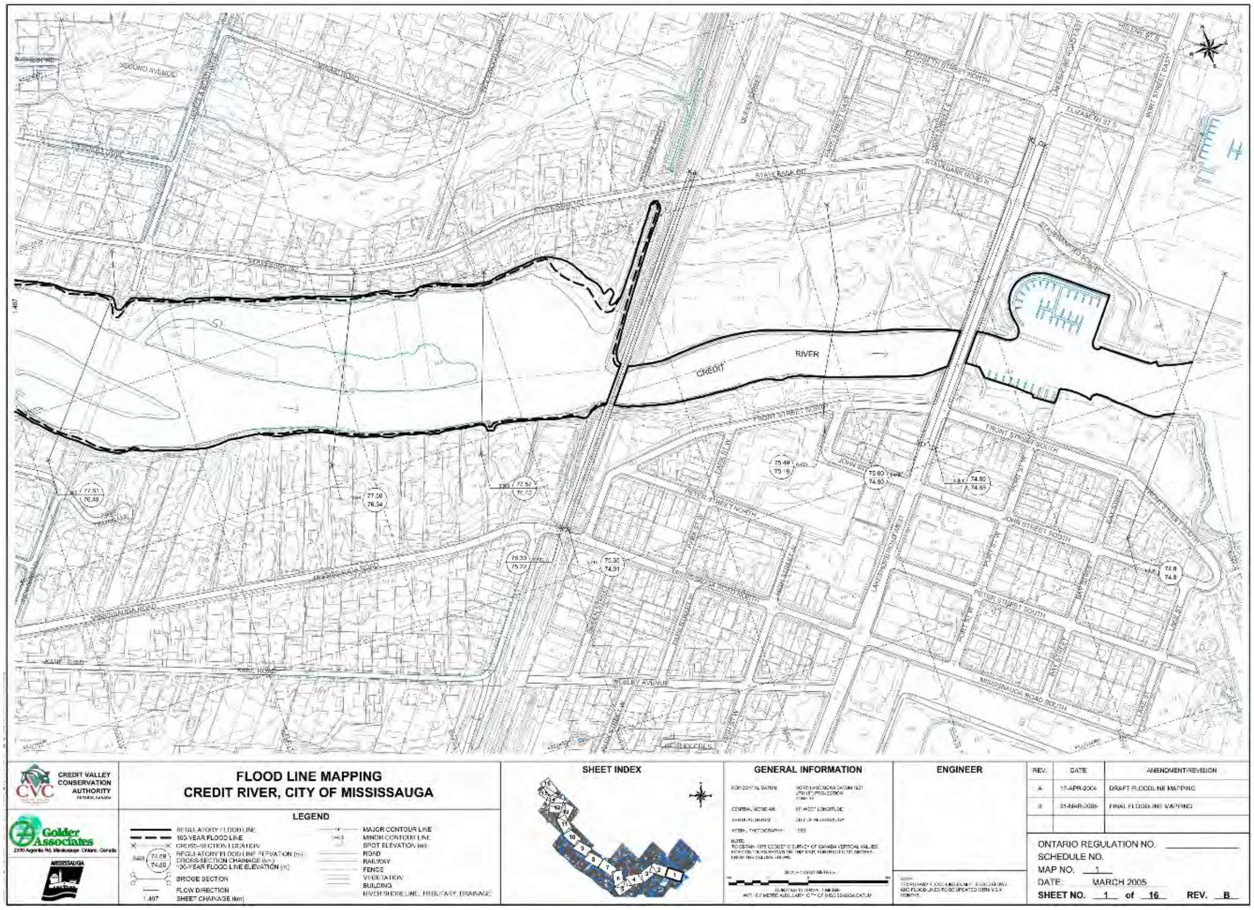
3.1.2 Hydraulic Modelling

CVC provided HEC-RAS models of the Credit River for existing and proposed conditions. Existing peak flow rates in the vicinity of the Lakeshore Road were summarized from these models in Table A. CVC also provided Regulatory floodline mapping for the Credit River in the vicinity of Lakeshore Road dated March 2005 (Figure F). The mapping indicates that the regulatory floodline is contained within the main river channel south of the train bridge to Lake Ontario. Upstream of the train bridge, the Regulatory floodline is contained within the river valley and differs slightly from the 100-year floodline.

TABLE A Credit River Existing Peak Flow Rates

Watercourse	2-year m^3/s	5-year m^3/s	10-year m^3/s	25-year m^3/s	50-year m^3/s	100-year m^3/s	Regional m^3/s
Credit River	120.00	222.90	290.50	368.60	468.20	557.10	732.60

Source: Credit River HEC-RAS model (CVC 2009)



The bold solid line and dotted line indicate the regulatory and 100-year floodlines, respectively.

FIGURE F Floodline Mapping of the Credit River near Lakeshore Road (CVC 2015)

The New Credit River AT Bridge study area lies downstream of a hydraulic transition from the steep reaches of the main Credit River valley into a low-gradient estuary at Lake Ontario. Changes in stream power along the Credit River profile are discussed further in Section 3.1. Within the estuary reach, the historical port lands development, floodplain infilling, and extensive engineering of riverbanks discussed in Section 2 have confined the Regional flood event into a narrower channel compared to the pre-development floodplain marshlands and barrier beaches. The highly controlled hydraulics of the reach significantly limit ongoing fluvial processes and thus, also limit geomorphic hazards/risks within the reach.

The New Credit River AT Bridge will just span the Regional water level, based on the general arrangement drawing provided by HDR (refer to Appendix C) and available hydraulic modeling information. Bank treatments are proposed to extend to the shoreline or the 50-year flow elevation. The addition of new cross-sections at the proposed AT Bridge in the updated HEC-RAS model resulted in slight variation in nearby water levels and velocities (refer to Table B). Water levels and velocities should be confirmed at detailed design and changes may require approval by CVC and other stakeholders.

TABLE B Credit River Existing and Updated Velocities

Crossing	Station	Location	Condition	Velocity (m/s)						
				2-yr	5-yr	10-yr	20-yr	50-yr	100-yr	Regional
Proposed AT Bridge	0.715	Upstream (CN Rail crossing outlet)	Existing	3.08	3.71	4	4.26	4.53	4.72	5.05
			Updated	3.04	3.64	3.91	4.14	4.39	4.56	4.9
			Difference	-0.04	-0.07	-0.09	-0.12	-0.14	-0.16	-0.15
	0.69	Inlet	Existing	-	-	-	-	-	-	-
			Updated	2.63	3.2	3.45	3.69	3.93	4.1	4.44
			Difference	-	-	-	-	-	-	-
	0.679	Outlet	Existing	-	-	-	-	-	-	-
			Updated	2.46	3.01	3.26	3.49	3.73	3.9	4.24
			Difference	-	-	-	-	-	-	-
	0.453	Downstream	Existing	1.17	1.49	1.65	1.8	1.96	2.09	2.32
			Updated	1.18	1.5	1.66	1.81	1.98	2.1	2.33
			Difference	0.01	0.01	0.01	0.01	0.02	0.01	0.01

Note:
Stations 0.69 and 0.679 were not included in the existing conditions HEC-RAS model

TABLE C Credit River Updated Water Levels

Location	Sta	100-year Water Level	Regular Water Level
Upstream	0.715	75.39	76.19
Inlet	0.69	75.38	76.2
Outlet	0.679	75.39	76.2
Downstream	0.453	74.92	75.79

3.2 Geomorphic Field Assessment

Matrix completed a geomorphic field assessment on August 20, 2021. A reach break was delineated at the train bridge due to upstream and downstream differences in channel planform, valley form, and backwatering. Reach breaks are presented on Figure 3.

The purpose of the geomorphic field assessment was to characterize channel form and processes and identify any erosion hazards occurring in the study area. The field assessment was tailored to the site conditions based on the findings of the historical assessment.

The mouth of the Credit River is influenced by estuarine processes: the interaction of fluvial and coastal processes. Lake water level acts as the base level, which is the lower limit for erosion within the river. This is because water slows and loses its eroding power as it enters the relatively still lake waters. Consequently, changes in lake levels cause changes in geomorphic processes within the river upstream. As well, the morphology of riverbanks at the mouth of a watercourse may be shaped by coastal processes, which, like fluvial systems, are governed by the interaction between erosive forces (e.g., wave action) and resisting forces. Within the active channel, the reduction in flow speed in the estuary creates an aggradational environment. The historical context of the river also encourages aggradation due to deep incision of the river valley followed by millennia of lake level rise (Section 2.2.1).

Given its setting, the standard Rapid Geomorphic Assessment and Rapid Stream Assessment Technique that are normally completed were not applicable to the Credit River within the study area. Instead, general site observations were made to confirm interpretations from the background review and historical assessments (Sections 2 and 3). A stream crossing assessment was also completed to describe existing bridges from a geomorphic perspective. The results of the field study are summarized in the following subsections, and site photographs are presented in Appendix B.

3.2.1 Results

3.2.1.1 General Observations

The geomorphic assessment took place from the Canadian National Railway (CN) rail bridge to the mouth of the Credit River, which is a stretch approximately 1 km in length. The banks of the Credit River are armoured through most of the study area. As much of the near-riverbank land has been artificially modified for park, marina, road, and other uses, floodplain and shoreline materials are generally artificial structures engineered to manage flooding and erosion for the adjacent land uses.

Observed evidence of aggradation included silt deposition at the toe of the banks and the presence of the marsh upstream of the train bridge. Other historic aggradational features, such as the historical barrier beach at the river’s mouth and the former marsh upstream of Lakeshore Road, have been lost. The water was turbid during the assessment, which illustrated the important process of sediment delivery from the river catchment to the lake. The history of periodic dredging has also been noted in Section 2.

Due to the water’s turbidity and the depth, bed morphology and bankfull depths were not measured. The average channel width was 55 m (±8 m). No signs of out of bank flows were observed. Above lake levels, the riverbanks and valleylands are generally stable.

3.2.1.2 Upstream of Lakeshore Road

The riverbanks are well-vegetated surrounding the CN rail bridge, with marsh habitat located upstream of the rail bridge along the east side. Both banks are continuously armoured with various types of bank protection except for the forested part of the south bank, which is not armoured (Appendix B, photographs 3 to 5). Types of bank protection include armourstone, boulders, gabion basket, and concrete. Photographs of armoured banks are provided in Appendix B (photographs 6 to 8, 11 [north bank], 2, 9, 10, and 12 to 14 [south bank]).

3.2.1.3 Downstream of Lakeshore Road

Downstream of Lakeshore Road are many bank structures including marinas, an old pier with wood pilings, scrubby vegetation, and stone bank protection. In J.C. Saddington Park, which is constructed beyond the original shoreline limits, the south bank is protected with concrete blocks and armourstone. The north bank has also been artificially extended and is composed of sheet pile. A breakwater extends from the north shore into the lake.

3.2.1.4 Existing Conditions in the Vicinity of the Proposed Active Transportation Bridge

The new Credit River AT bridge is proposed to be located immediately downstream of the CN rail bridge (Figure 4).

In this location, the south bank is steep, approximately 7 m high, and has a simple profile. Downstream of the proposed crossing footprint to the canoe club, the bank has a similar total height but has a two-stage profile, with a steeper 2 to 3 m high segment at the bottom and a gentler slope above. Erosion and exposed bank materials were noted on the lower 2 to 3 m of the bank. The bank material was sandy and silty and is likely composed in part of artificial fill related to the rail bridge and surrounding developments. The bank is also well-vegetated with shrubs and trees and has an open understory. The bed at the bank toe contained over 10 cm of loose silt, and tree root mats were noted to have grown at the water surface. A concrete stormwater outfall is located on the south bank approximately 10 m downstream of the train bridge (Appendix B, photograph 4). This outfall is in moderate condition, with bank slumping above and deposited fines at its base.

Near the proposed east abutment of the new Credit River AT bridge, the north riverbank is approximately 2 to 3 m high. The toe of the north bank is protected with armourstone. Bank materials were not visible due to bank armouring and riparian vegetation; however, it is likely that the bank is composed of fill. The north bank is also well-vegetated with shrubs and trees before entering Memorial Park.

3.2.2 Existing Stream Crossing Assessment

The stream crossing assessment collects data specific to the channel and crossing structure within the vicinity of the road and rail crossings. Information recorded includes crossing type, material, shape, dimensions, structural condition, as well as an assessment of potential issues relating to the channel near the crossing (e.g., bank erosion, bed scour, debris trapping, and fish passage).

Table D summarizes the characteristics of the existing Lakeshore Road Credit River bridge and CN railway bridge.

3.2.3 Results

The Lakeshore Road bridge is skewed in relation to the river axis upstream of the bridge and is aligned with the river axis downstream. The river is wide with a low gradient near the bridge and passes through three cells. Due to water depth and turbidity, the riverbed was not visible through the bridge. The riverbanks are protected upstream, through, and downstream of the bridge, and no signs of instability were observed apart from local rilling related to overland flow. A pedestrian walkway crosses below the bridge on the north bank.

The CN rail bridge abutments jut into the active channel and floodplain and are protected by concrete slabs. The profile of the rail bridge girders is low, with only a few meters of clearance from the water surface at the time of the site assessment.

TABLE D Credit River Bridge at Lakeshore Road Crossing Assessment

Structure				Local Bankfull Dimensions		Channel Width : Opening Width	Gradient	Flow Restriction	Appendix B Photos
Crossing	Type	Opening Width (m)	Skew Angle (degrees)	Width (m)	Depth (m)				
Lakeshore Road Bridge	Three-span bridge	56 m	24° upstream 2° downstream	55 to 60 m	4.2 m[(1)]	Similar	0.027%[(2)]	None	6, 7, 8, 9, 10, 11
CN Rail Bridge	Single-span iron bridge	60 m	15° upstream 22° downstream	55 to 160 m	4.2 m[(1)]	Opening narrower than upstream channel	0.027%[(2)]	None	1, 2, 5

Note: Skew angles measured between alignment of the crossing structures and Lakeshore Road centreline. The skew angle is 0° where the crossing structuring is perpendicular to the Lakeshore Road centreline.
Sources:
(1) Matrix Natural Environment 2021 field study
(2) Reach slope, Credit River HEC-RAS model (CVC 2009)

4 EROSION RISK ASSESSMENT

Due to the geomorphic setting of the study reach, lateral migration and meandering is not the dominant process and is quite unlikely to occur. The backwatering effect of Lake Ontario and the low gradient of the reach river results in a dramatic loss of stream power within the study area. Specific stream power plummets from highs of 100 to 400 W/m^2 in the confined reaches of the Credit River through Mississauga to less than 10 W/m^2 at the lake. Given these factors, and the extensive hard engineering structures along the riverbanks, lateral migration is not considered to be an active process on river morphology in the study reach. This is supported by studies of other large river systems in the area such as Weninger (1986) who noted that the planform of the Humber River did not change between 1834 and 1978 as well as the limited natural changes observed for the Credit River in the historic air photograph assessment (Section 2.2.4).

The study reach flows through an almost 200 m wide valley. Originally, the river accessed the entire valley bottom. As discussed, the floodplain was infilled in the mid-twentieth century to eliminate a natural wetland (Faulkner Marsh). Floodlines are now contained within the channel (Section 3.1.2).

As such, a meander belt assessment was not considered applicable. In practical management terms, the river is being managed as a port, and engineering controls on bank erosion are being maintained through the great majority of the study reach. Excessive sedimentation on the riverbed is being managed with periodic dredging for navigability. Near the lake, the banks and shoreline are artificial. The historic photograph assessment showed that most of the riverbank changes observed between the train bridge and the lake since 1931 have been anthropogenic changes (Section 2.2.4).

Local erosion risk can still exist in this context for areas hydraulically impacted by existing crossings, particularly if banks are not armoured. Based on the field assessment, the south bank immediately downstream of the train bridge lacks bank protection. To estimate a local erosion hazard limit for the unprotected portion of the south bank, a procedure adapted from the Ontario Ministry of Natural Resources *Technical Guide - River and Stream Systems: Flooding Hazard Limit* (currently the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry; MNR 2002) for confined watercourses was used for this study. The local erosion limit was defined by a 3:1 stable slope allowance plus a toe erosion allowance. For this location, a 2 m toe erosion allowance is recommended as a reasonable setback in the context of the low-energy reach and surrounding artificial bank structures (Table 3 of MNR [2002]). Although evidence of bank instability was noted at this location, the local bank conditions were not classified as "actively eroding," again based on the low energy in the reach and lack of channel change observed over the historic period (Section 2.2.4).

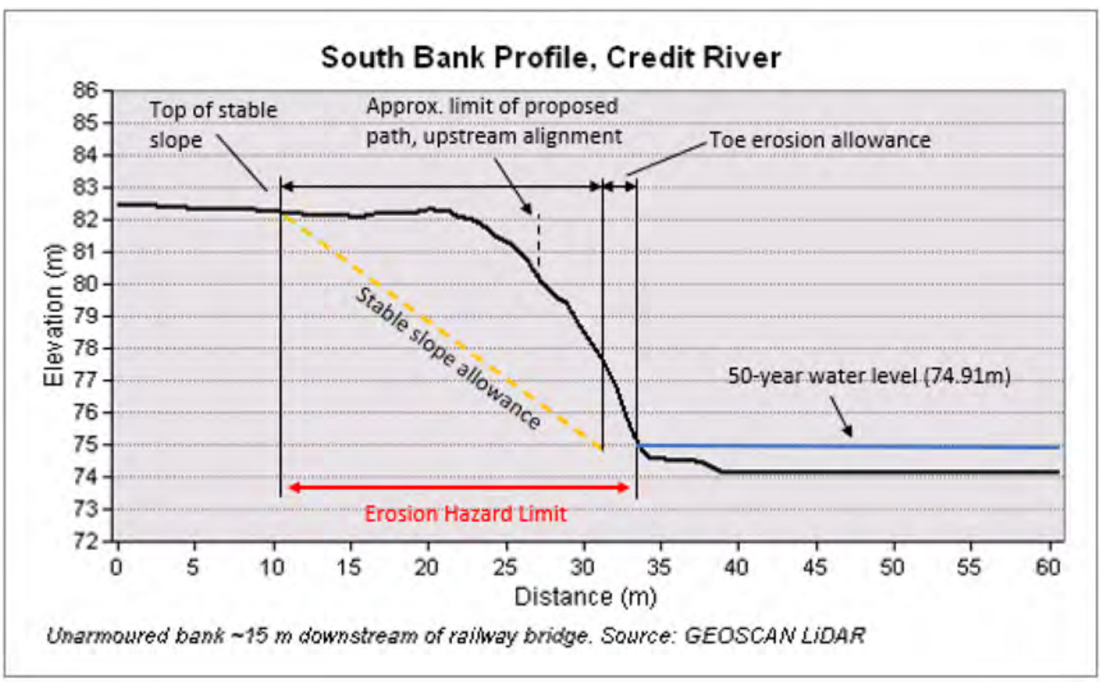
From the train bridge to roughly 25 m downstream, the unarmoured bank was approximately 7 m high in relation to the water level at the time of the field assessment and, based on available LiDAR, has an angle of approximately 1 horizontal (H):1.5 vertical (V). From roughly 25 to 100 m downstream of the rail bridge, the bank has a similar total height but has a two-stage profile, with a steeper (~2H:1V), 2 to

3 m high segment at the bottom and a gentler (>3:1) slope above. Evidence of erosion was observed on the lower 2 to 3 m bank face. The local erosion risk hazard limits were calculated to reflect the change in slope and profile. Sample calculations for the area at the train bridge are provided in Equations 1 and 2.

Equation 1 Stable slope allowance = 3 × bank height
= 3 × 7 m
= 21 m

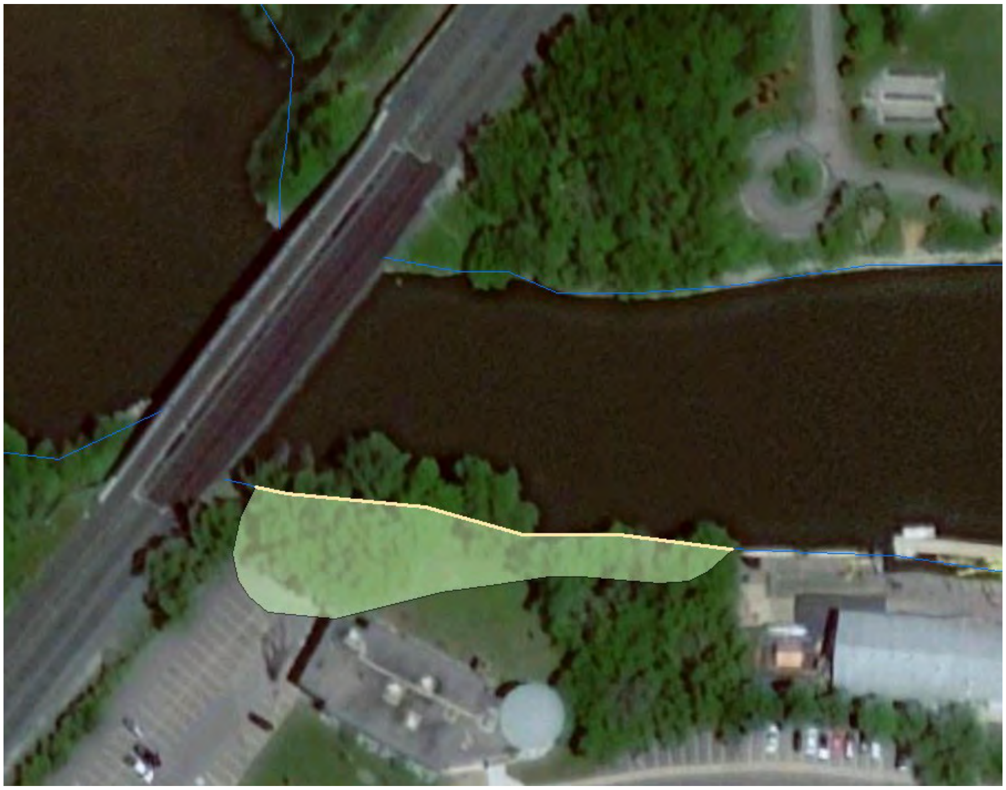
Equation 2 Local erosion hazard limit = stable slope allowance + toe erosion allowance
= 21 m + 2 m
= 23 m

The local erosion hazard limit ranged from 8 to 23 m from the toe of bank. Figure G presents the south bank profile and a schematic depiction of the local erosion hazard limit at a section near the rail bridge. Figure H presents a plan view of the extent of the unprotected bank and the local erosion hazard limits. As part of the detailed design for the AT bridge crossing, a detailed geotechnical study is recommended for this location to confirm or refine the erosion hazard limit and to inform the design and construction of the bridge abutment foundation, local grading, and potential erosion control works.



Notes: Blue line = water level, orange line = 3:1 slope, red line = Local erosion hazard limit (3:1 setback + 2 m toe erosion allowance); erosion limit linework shown is schematic

FIGURE G Local Erosion Hazard of Unarmoured South Riverbank ~15 m Downstream of Train Bridge



Notes: light green polygon = local erosion hazard limit, light yellow line = unarmoured bank

FIGURE H Local Erosion Hazard Limits and Extent of Unarmoured Portion of the South Riverbank

4.1 Scour Assessment

The CVC (2019a) *Fluvial Geomorphic Guidelines: Factsheet VI: Scour Analysis* provides guidelines for scour assessment studies. CVC defines scour assessment as the technical and professional evaluation of the long-term risks due to potential vertical erosion and/or degradation of stream and river channels. Vertical scour associated with a watercourse is not well defined and there is a lack of consistent guidance for practitioners. A variety of rational and empirical methods are available to quantify the potential scour of a watercourse in anticipation of new infrastructure and hazard delineation. CVC (2019a) aims to guide such evaluations.

Following the completion of the Lakeshore Transportation Studies Environmental Assessment, the following additional assessment is recommended based on CVC guidelines:

- Scour assessment to identify the scour hazard limit (SHL) at each watercourse crossing for which alterations to the crossing structure or watercourse are proposed. For the Lakeshore Bus Rapid Transit (BRT) Study, this would include the proposed New Credit River AT bridge.

- Where engineering to the 100-year scour hazard limit is not practical or feasible with respect to impacting adjacent land uses and/or habitats, hazard mitigation and management plans will be required to the satisfaction of CVC and other stakeholders.

It is recommended that this assessment be completed by a qualified engineer and/or geoscientist at detailed design.

5 CROSSING RECOMMENDATIONS

5.1 Principles of Crossing Design and Crossing Design Guidance

Fluvial geomorphic recommendations regarding the proposed New Credit River AT bridge construction have been developed based on the results of the desktop assessment, field investigation results, and geomorphic analysis to provide a geomorphic review of the preliminary bridge design. A review of the proposed crossing location, span, skew, and abutment placement is provided to address risks associated with erosion hazards surrounding the channel. The fluvial geomorphic review involved the evaluation of the following criteria:

- **Meander belt width, meander geometry and 100-year migration rate:** crossings are typically evaluated in terms of their relationship to these parameters. These do not generally apply to the current study area under existing conditions as a managed urban watercourse. However, a local erosion hazard area was delineated (Section 4) in the footprint of the proposed works.

- **Channel size and location in stream network:** the potential for lateral channel movement and erosion generally increases with channel size. However, in estuaries, stream power dramatically decreases, and thus sedimentation and aggradation tend to dominate fluvial process and drive geomorphic changes. Bank erosion and lateral channel dynamics can occur in backwater estuary associated with bar formation and flow deflection, but this is not the case in under the current artificially confined conditions of the lower Credit River where sedimentation managed with periodic dredging (Section 2).

- **Valley setting:** the Credit River has a wide valley but has been disconnected to the floodplain by infilling; therefore, standard approaches to crossing design for the Credit River with respect to valley setting are of limited application.

Where a new crossing is proposed, a collective evaluation of all these factors is used to direct the development of new structural design parameters (span, length, and skew) that are appropriate from a fluvial geomorphic perspective. This process is also informed by local conservation authority guidelines. The CVC's *Fluvial Geomorphic Guidelines* (CVC 2015) states that a well-designed crossing:

- spans the stream and banks
- does not change water velocity
- has natural substrate
- creates no noticeable change in river form
- preferably structures include bridges, open bottom arches, or culverts that span and are embedded in the streambed

The CVC's *Technical Guidelines for Watercourse Crossings* (CVC 2019b) provides the following additional geomorphic guidance under Section 6: Design Principles:

- *The crossing design should respect the fluvial geomorphic process in the watercourse in order to minimize the negative impacts on the aquatic and terrestrial environment.*

- *The span of crossings should be selected based on detailed fluvial geomorphic analyses. Abutments, piers and other bridge components should be located outside of the 100-year local erosion hazard. Determination of the local erosion hazard is separate from the procedure of determining meander belt and scour potential at a specific site. The 100-year local erosion hazard will determine the extent at which the crossing infrastructure should be placed in order to avoid future channel realignment or unnecessary hardening of the channel or banks.*

- *Where the existing bridge abutments interfere with the erosion hazard, a fluvial geomorphic assessment must be completed in order to identify if the abutment needs removal or relocation.*

- *It is recognized that larger crossings may require piers in the watercourse. This must be specified early in the process. In some cases, as early as during the environmental assessment.*

- *For new crossings, the footing depths are based on the scour depth (see Section 6.3.1) as identified by a fluvial geomorphologist. Provide the method used, results of the analyses and the input parameters used to determine the type and depth of footings.*

- *The replacement or new construction of a crossing must be an open footing culvert or bridge, unless there is a compelling reason why a closed bottom culvert would provide greater social, economic and environmental benefits.*

The New Credit River AT bridge pedestrian crossing design should consider the same design principles (CVC 2019b), but may require some adaptation for the low-energy estuary and highly modified urban environment, with consultation with and approval by CVC and other stakeholders.

The Toronto and Region Conservation Authority (TRCA) also provides guidance for crossing design, which is provided here for context, as the proposed bridge is within CVC jurisdiction. The TRCA's *Crossing Guideline for Valley Stream Corridors* (TRCA 2015) states that:

Crossings should be located away from geomorphically active and unstable areas and be designed to span the zone of potential future channel migration, as defined by the meander belt or 100-year erosion limit, to reduce risks from channel migration over time. However, it is recognized in some instances this may not be practical, particularly for modifications to existing crossings or for new crossings of small, stable watercourses.

The current study for the Credit River is for a large watercourse but may be considered in association with nearby existing crossings and in the context of low stream energy and proximity to the lake with respect to the geomorphic risks.

5.2 Geomorphic Impact Assessment of the Preliminary Design

5.2.1 Description of Proposed Works

As part of planned improvements to active transport options and connectivity, a New Credit River AT bridge is proposed to be built across the Credit River. The new span bridge will connect the existing multi-use path on Mississauga Road to the existing multi-use path on the east side of Credit River. This bridge will feature a 2.5 m sidewalk and a 3.6 m two-way cycling facility. Four alternative alignments of the proposed bridge, adjacent paths, and other impacted areas (such as parking) have been proposed. The impact assessment includes all four options as a preferred solution had not been selected at the time of writing this report.

Matrix reviewed the following design materials provided by HDR:

- general arrangement drawing titled *Bridge Option Analysis – Through Truss Option (Nov. 2021)*
- PDF plan view of "All Cases" (all four alternatives)
- shapefile of the footprint of the proposed works for all alternatives
- Google Earth .kmz of the footprint of the proposed works for all alternatives

An annotated map of the Credit River and the proposed New Credit River AT bridge works are presented on Figure 4.

The proposed pedestrian bridge is a clear-span structure with a span of 66.0 m. The opening width is approximately 61 m. The crossing is proposed to be located approximately 20 m downstream of the existing train bridge and approximately 400 m upstream of the existing Lakeshore Road bridge, following the river's centerline. The length of the bridge (upstream to downstream) will be approximately 8.0 m. The bridge crosses the river at a skew of approximately 120 degrees from the channel centerline (a perpendicular crossing would cross at a 90-degree angles). Construction access routes will use existing paths and roads. Construction laydown areas include a small area on the south bank and a larger area west of the existing path on the north bank. Tree removals will be required on both banks to accommodate the proposed works.

The surveyed shoreline elevation shown on the general arrangement drawing is approximately 75.25 m on the north bank. This appears to correspond to the elevation of the existing armourstone bank protection observed on site. LiDAR mapping indicates that the top of bank elevations on the north and south banks at the proposed bridge are 77.5 m and 82.0 m, respectively. The 50-year water level indicated on the general arrangement drawing is 74.91 m through the crossing.

The proposed bridge abutments lie within several metres of the existing channel shoreline. The south bridge abutment is approximately 3.9 to 7.9 m from the 50-year water level, with the upstream end of the abutment close to the shoreline due to an existing notch in the bank and the skew of the abutment. The proposed north abutment is 3.4 to 7.0 m from the 50-year water level, with its south end closest to the water.

The proposed bridge location is one of the few areas encountered during the field reconnaissance where banks were not completely armoured. The south bank in the proposed crossing location is a steep, 7 m high earth bank, which generally lacks bank protection. Some trees on the bank had J-shaped trunks, which is an indicator of gradual hillslope creep processes, and some tree roots were exposed indicating surface erosion, but generally were not undercut. Some localized bank erosion was observed; however, tree roots appear to be helping to stabilize this bank. Bank material was sandy and silty and is likely composed, in part, of fill related to the train bridge. A stormwater outfall with a concrete headwall is located less than 5 m north of the proposed south abutment.

The east bank at the proposed crossing location is protected by a continuous band of armourstone and boulders, which were generally considered to be in good condition during the 2021 field assessment. The riverbank slopes up from the high-water level by 2 to 3 m and flattens out into the floodplain (Memorial Park). The floodplain between the bank and the existing pathway is forested.

5.2.2 Review of Design in Relation to Toronto and Region Conservation Authority and Credit Valley Conservation Requirements

The proposed AT bridge is a clear-span bridge, which is a preferred structure type per CVC's 2015 and 2019 guidelines. The proposed span of 66 m is approximately 10 m wider than the existing Lakeshore Road bridge (56 m span), and 6 m wider than the opening width of the rail bridge upstream, which has an opening width of approximately 60 m between its piers per the CVC HEC-RAS model. The alignment of the bridge over the river is not perpendicular, which results in a longer structure. The bridge abutments are located 3.4 to 7.9 m from the edge of water at the 50-year water level. As the abutments are also not aligned with the riverbanks, a parallel skew to the banks would provide more distance from the water.

The bridge is located within a reach that is not geomorphically active overall; the reach is actively managed with bank armouring and is controlled by lake backwatering rather than active lateral migration processes. However, some localized bank erosion was noted on the south bank through the bridge footprint, which has been documented and mapped as part of the local erosion hazard area (refer to Figure G). The mapped erosion hazard is related to the expansion of flows downstream of the train bridge, which acts as a pinch point; the lack of bank protection in that location; and oversteepening of the bank.

Based on this mapping (Figure = G), the western abutment of the concept design bridge would be expected to be within this erosion hazard area. The proposed bridge does not span the top of the south bank, which is steep and shows some signs of instability. The south abutment will be constructed on the face of the south bank within the local erosion hazard area. To address potential erosion risks in this location, river and geotechnical engineering will be required at detailed design (refer to Section 5.2.3) to ensure that the south bank is stable and that it ties in with the rail bridge upstream and existing erosion control works downstream. This will be particularly important under future conditions when the stabilizing influence of tree roots are lost due to tree removals.

While it is preferable per CVC guidelines (refer to Section 5.1) to design new structures outside the erosion hazard limit such that hardening is not required, it is appropriate in this context to mitigate the erosion hazard with bank protection works, informed by a geotechnical and further engineering studies, due to the specific characteristics of the sites:

- The riverbanks within this reach are entirely armoured outside of the local erosion hazard area. In practical management terms, the river is being managed as a port, and engineering controls on bank erosion are being maintained through the great majority of the study reach. Erosion protection works near the proposed western bridge abutment will tie into and provide a consistent bank management approach throughout the reach.

- Bank protection will protect the upstream train bridge from erosion, as well as the adjacent private properties inland and downstream, including the existing downstream bank armouring.

- Bank protection may be integrated with the replacement or rehabilitation of the existing stormwater outfall near the proposed western abutment, which is in poor condition.

- Given the context of the bridge abutment within an actively managed, low energy reach, the erosion risk to the AT bridge structure can be managed by bank protection works. After installation of appropriate erosion mitigation measures, the bridge abutment will no longer be considered within the erosion hazard limit assuming continued maintenance of the bank.

The current general arrangement drawing depicts the abutments outside of the 50-year water level (74.91 m), and notes that existing shorelines are to be retained below this water level. The banks above the 50-year water level are proposed to be lined with riprap to provide stability per the current general arrangement drawing.

The design of the bank protection on the embankments below the abutments must be confirmed at detailed design with input from CVC. The following preliminary recommendations are provided as initial guidance for the erosion protection design:

- It is recommended that a stable rounded riverstone gradation be used as a more natural riprap material, which is consistent with CVC guidelines for restoration of natural watercourses. Other materials, such as armourstone, may be considered as appropriate based on the results of updated hydraulic modeling. Bioengineering or vegetated of the upper slope may also be considered.

- The west unprotected bank is anticipated to require some regrading to provide a stable and protected slope.

- The design should tie into the bridge upstream and the bank armouring downstream.

- The installation of riprap or other stone erosion protection measures may require in-water or near water works, which will require additional technical analysis and submissions for CVC permitting. A more detailed analysis to be done during the detailed design phase.

- The depth of the proposed bridge abutments will be determined at detailed design with input from a scour assessment, geotechnical study, and input from CVC.

- The foundational depth of the abutments will impact the staging and equipment required for their construction. This will also impact whether construction will occur within the high-water level. The work is anticipated to require some impact within the high-water level. Any adjustments to the abutment foundation depth based on the scour assessment could impact the construction footprint and may require a marine assessment (i.e., a bathymetric survey and geotechnical/geophysical substrate characterization).

- It is expected that the City will acquire land rights through purchase or easements where necessary to construct and maintain and bank protection works associated with the AT bridge and abutments.

Several options for the proposed path west of the bridge are under consideration. Under at least one alignment option, the path veers upstream along the south riverbank before turning to follow the existing fence line along the CN railway corridor. Figure G depicts this path option in relation to the existing slope. The jog upstream of the path in this option would occur on the upper portion of the bank within the erosion hazard area. As noted above, this portion of the bank is over steepened and is potentially impacted by hydraulic expansion from the railway bridge confinement of the channel. The configuration of this path alignment relative to the existing slope and storm outfall, if selected as the preferred alternative, should be confirmed at detailed design and erosion risks and mitigation techniques will potentially need to be considered.

The preliminary bridge design is not anticipated to have direct permanent impacts on the form of the channel through the crossing. Indirect effects could result from changes in hydraulics during flows above the 50-year water level due to bank protection works, however these are anticipated to be minor. As well, potential changes in lake levels over the design life of the bridge should be considered at detailed design.

5.2.3 Recommendations for Detailed Design

To mitigate potential impacts of the proposed works, the following considerations should be made at detailed design:

- confirm water levels and velocities near the proposed AT Bridge
- confirm hydraulic conveyance is met under all flood conditions and lake water levels
- complete river and geotechnical engineering of the south bank through the bridge to ensure that it is stable, and that it ties in with the train bridge upstream and existing erosion control works downstream
- identify the scour hazard limit at the proposed bridge through completion of a scour assessment to determine appropriate bridge footing depths, acceptable based on geotechnical criteria in the engineering design, and erosion hazard policy criteria by CVC and stakeholders
- confirm the extent and type of bank protection below the proposed bridge and along the unprotected part of the bank based on the results of the geotechnical engineering study, consultation with CVC, and updated hydraulic information
- confirm land ownership of the bank work area. It is expected that the City will acquire land rights through purchase or easements where necessary to construct and maintain and bank protection works associated with the AT bridge and abutments
- confirm the alignment of the bridge abutments, path, and the disturbance limits of construction
    - Additional assessment and planning will be required to isolate the work area and mitigate impacts if installation of the bank protection and/or the construction of the abutments require in-water work.
    - The configuration of the path along the south bank should be confirmed, and the associated slope stability, bank erosion risks, and mitigation techniques will need to be considered, with potential works reviewed and approved by CVC and impacted stakeholders.

- Drainage in the area of the existing parking lot and storm outfall on the south bank will also need to be considered at detailed design with respect to the alignment of the path, bridge abutment and associated works to ensure stability of the channel bank and slope.

5.3 Conclusion

This fluvial geomorphology assessment report summarizes the findings and recommendations of the geomorphic assessment of the Credit River within the New Credit River AT Bridge study area. The geomorphic assessment includes background review and historical characterization of the Credit River, field reconnaissance, erosion hazard risk assessment, and provides a geomorphic review of the preliminary design of the preferred AT bridge over the Credit River and recommendations for detailed design.

Geomorphic processes in the Credit River estuary are influenced by the glacial history of area and recent anthropogenic modifications. The estuary is aggradational and at a reach-scale poses little risk of erosion under existing conditions. A clear span AT bridge has been proposed located downstream of the existing train bridge. The proposed bridge appears to span the high-water level of the river, but hydraulic model conditions require further confirmation as the design progresses. The south abutment of the proposed bridge is situated on a portion of the riverbank that locally exhibits evidence of instability and erosion, without existing erosion control structures, and possibly due to hydraulic impacts of the train bridge upstream. The abutment lies within the calculated local erosion hazard area, as assessed in Section 5 of this report. At least one path alignment under consideration also intersects the bank within the erosion hazard area (Figure G). As such, river and geotechnical engineering will be required at detailed design to ensure stability of the bank and 7 m high slope. The abutment and path alignments may be refined, and limits of construction should be determined to confirm no in-water work. A scour assessment and detailed hydraulic conveyance study are also recommended to be completed at detailed design or at earlier stages as the design progress.

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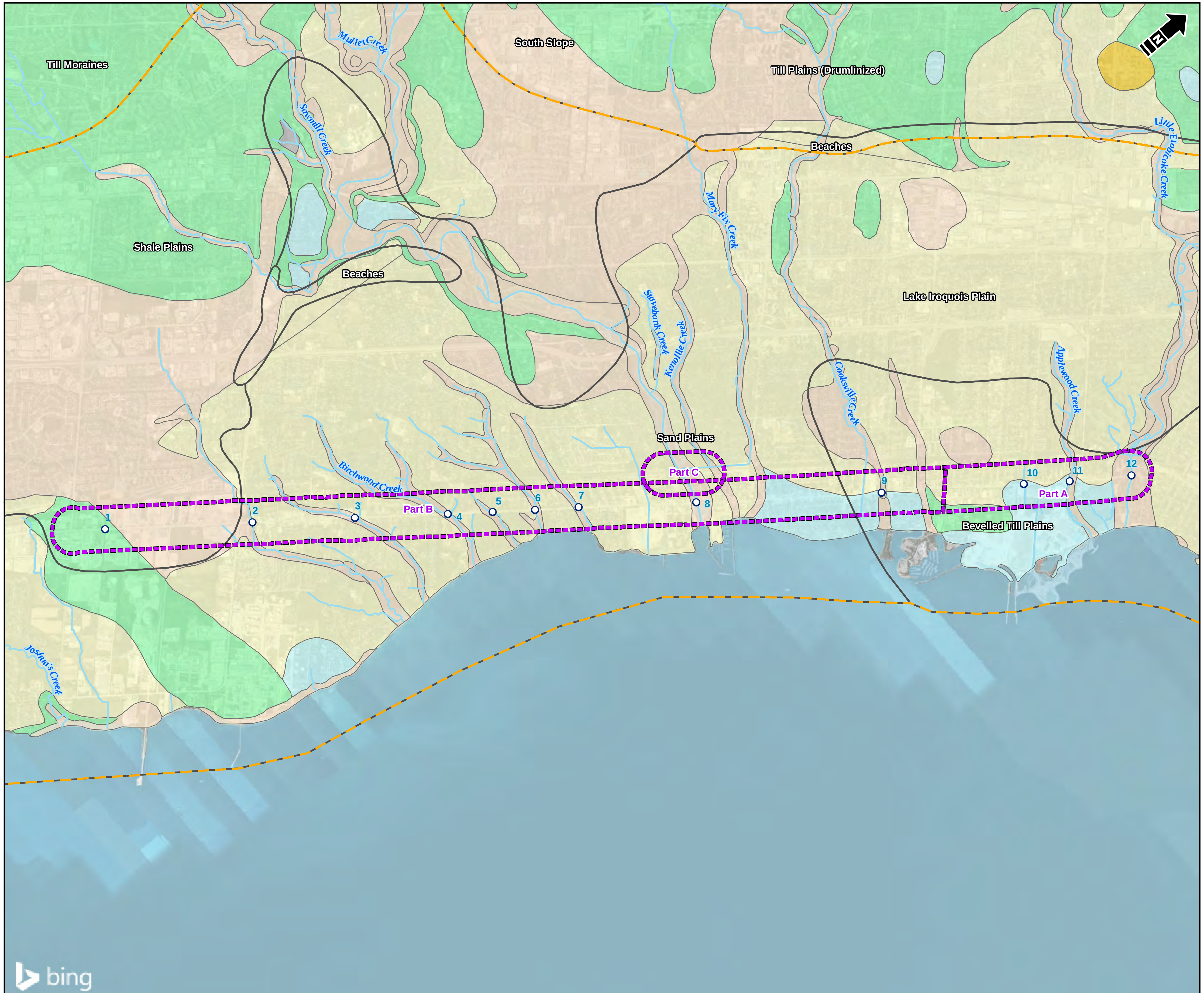

Study Area
Physiographic Landforms
Physiographic Region - Boundary between South Slope and Iroquois Plain
Water Body
Watercourse
Watercourse Crossing

Surficial Geology Unit

1 - Bedrock: limy mudrock and clastic sedimentary rock
4 - Glacial Deposits (till): clayey silt to silt
5 - Moraine Deposits: fine sand to gravel
7 - Glacial Lake Deposits: sand and clay
8 - Glacial Lake Deposits: sand and gravel
9 - Organic Deposits: peat, muck, and marl
10 - River Deposits: sand and gravel

Study Areas

Part A: Lakeshore Bus Rapid Transit (BRT) Study
Part B: Lakeshore Complete Streets Study
Part C: New Credit River Active Transportation (AT) Bridge Study

Watercourse Crossings

1: Avonhead Creek Crossing
2: Sheridan Creek Crossing
3: Turtle Creek Crossing
4: Birchwood Creek Crossing
5: Moore Creek Crossing
6: Lornewood Creek Crossing
7: Tecumseh Creek Crossing
8: Credit River Crossing
9: Cooksville Creek Crossing
10: Serson Creek Crossing
11: Applewood Creek Crossing
12: Etobicoke Creek Crossing

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1:50,000 Kilometers
0.5 0 0.5 1
NAD 1983 UTM Zone 17N

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ENVIRONMENT & ENGINEERING

HDR Corporation
New Credit River Active Transportation Bridge

Surficial Geology and Physiography Lakeshore Transportation Studies

Date: November 2021	Project: 33023	Submitter: A. Nicoll	Reviewer: R. Phillips

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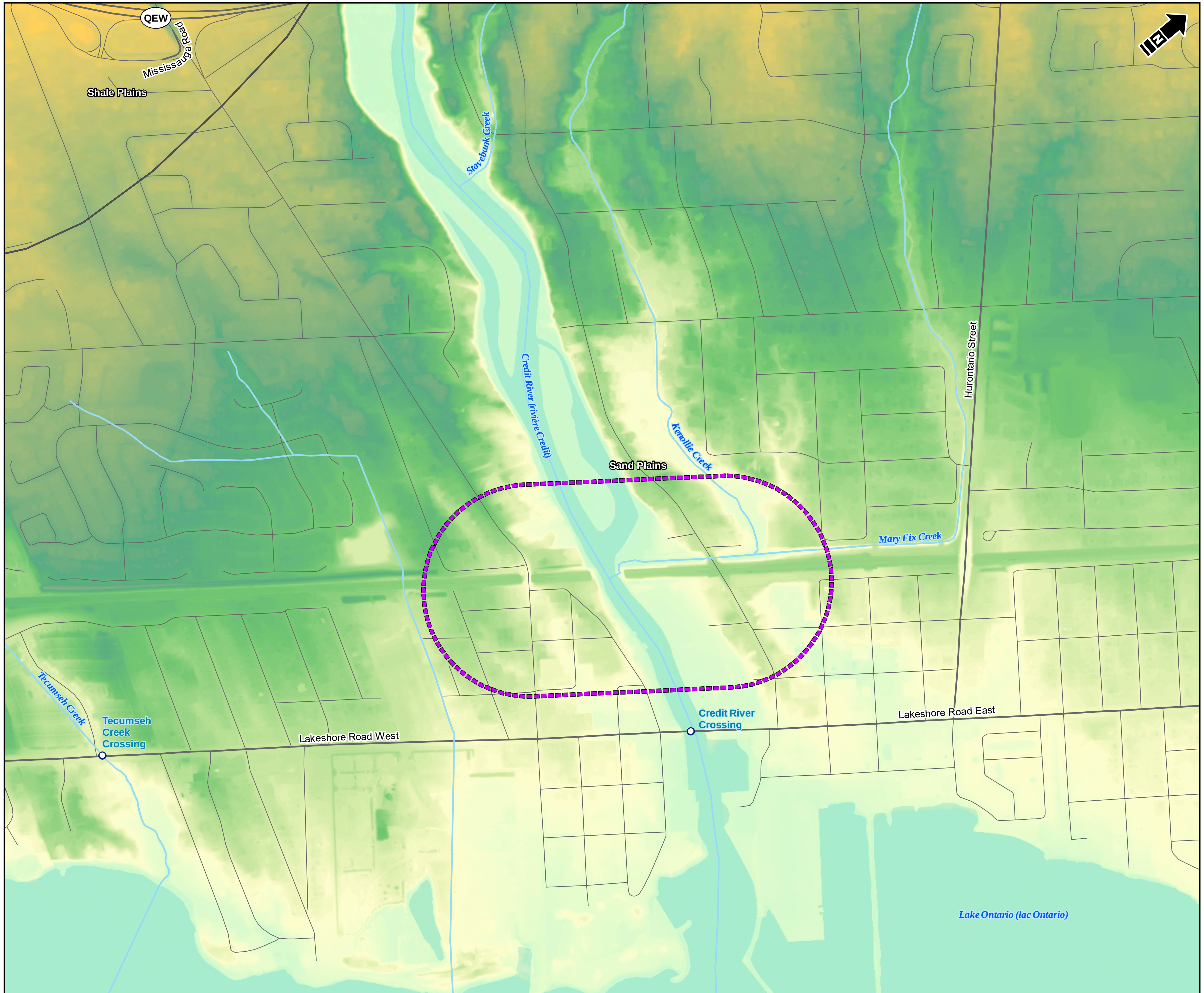
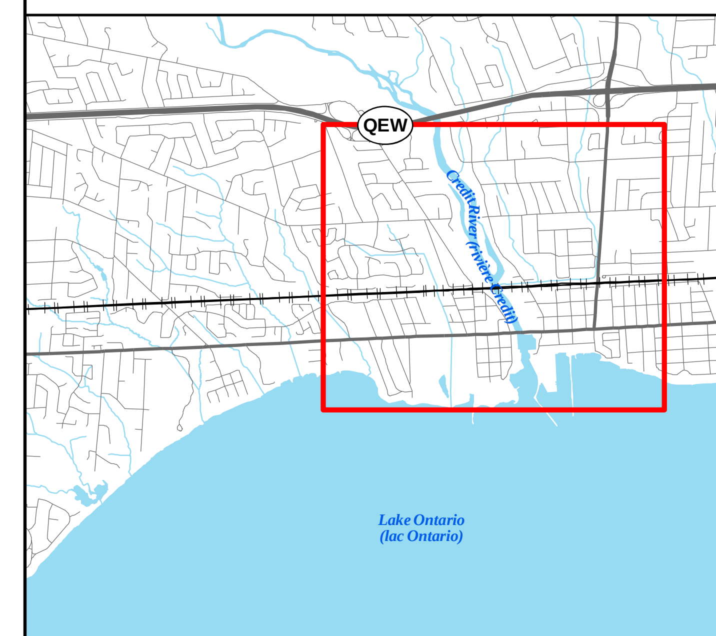
Figure 1



- Study Area
- Physiographic Landforms
- Water Body
- Watercourse
- Highway
- Road
- Watercourse Crossing

Digital Elevation Model (masl)
High : 140
Low : 70



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NAD 1983 UTM Zone 17N

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New Credit River Active Transportation Bridge

Topography

Date:	Project:	Submitter:	Reviewer:
November 2021	33023	A. Nicoll	R. Phillips

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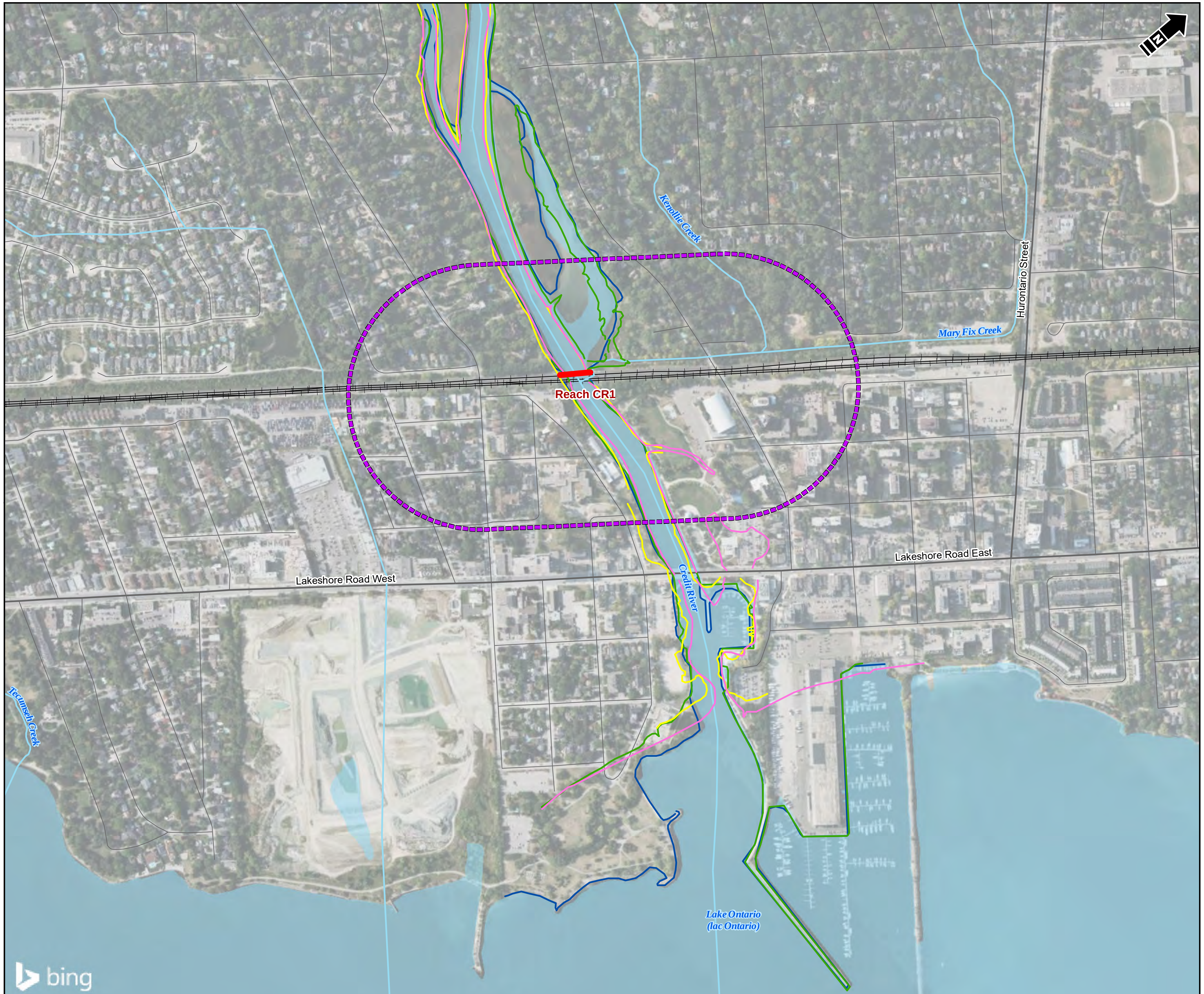
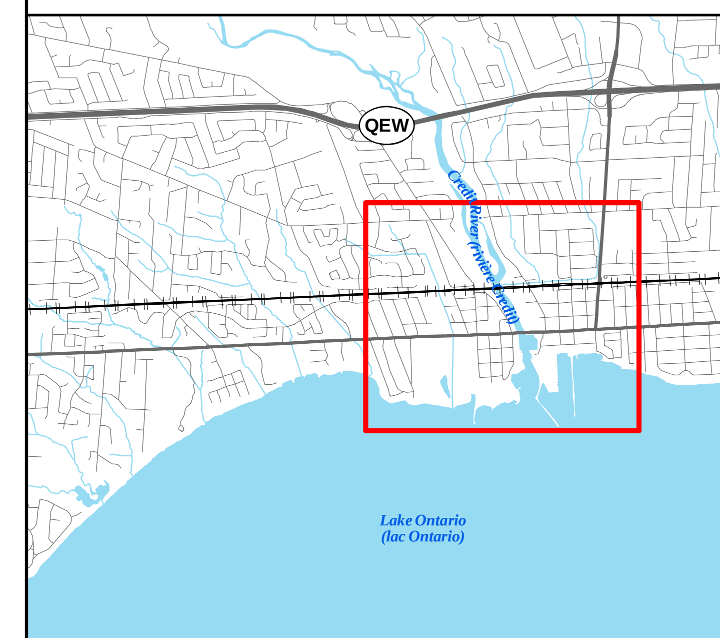
Figure 2



Study Area
Water Body
Watercourse
Railway
Highway
Road
Reach Break

Historic Traces

1931
1946
1968
2020



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1:8,000 Meters
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NAD 1983 UTM Zone 17N

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ENVIRONMENT & ENGINEERING

HDR Corporation
New Credit River Active Transportation Bridge

Reach Breaks & Historic Traces

Date:	Project:	Submitter:	Reviewer:
November 2021	33023	A. Nicoll	R. Phillips

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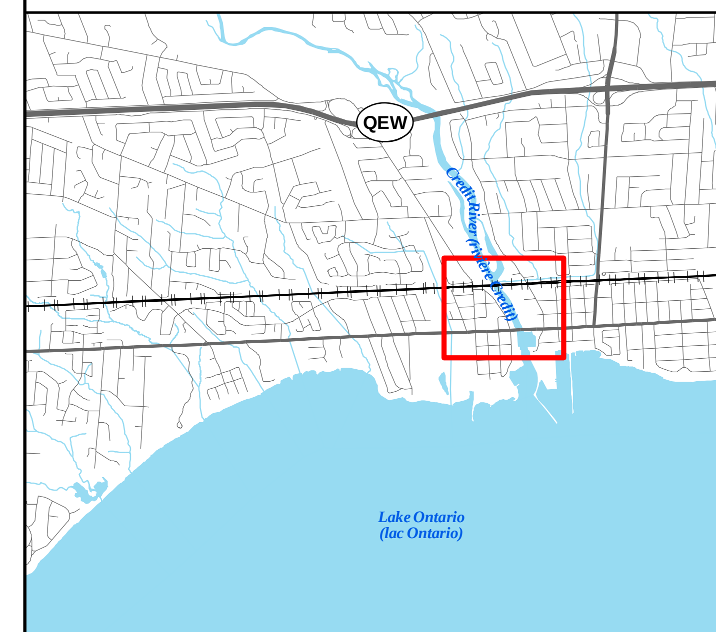
Figure
3

I:\HDRCorporation\33023\FiguresAndTables\GMY\2021\Report\Part_C\Figure-3-Reach_Breaks_and_Historic_Traces.mxd - Tabloid_L - 12-Nov-21, 10:49 AM - lmwright - TID005

AT Bridge Footprint
Local Erosion Hazard Area
Unprotected Bank
Watercourse
Railway
Highway
Road

Historic Traces

2020



1:3,500 Meters
35 0 35 70
NAD 1983 UTM Zone 17N

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HDR Corporation
New Credit River Active Transportation Bridge

Proposed Works

Date: June 2022	Project: 33023	Submitter: A. Nicoll	Reviewer: R. Phillips

Figure 4

APPENDIX A
Historic Aerial Photographs

1931 Aerial Photograph

Roll Number: A3249 Photo: 41 Scale: 15,000

Disclaimer:
The photographs as shown are not georectified.
Photograph source:: National Air Photo Library (NAPL). Satellite imagery source: Bing Maps, 2020.

1946 Aerial Photograph

Roll Number: A9669 Photo: 72 Scale: 20,000

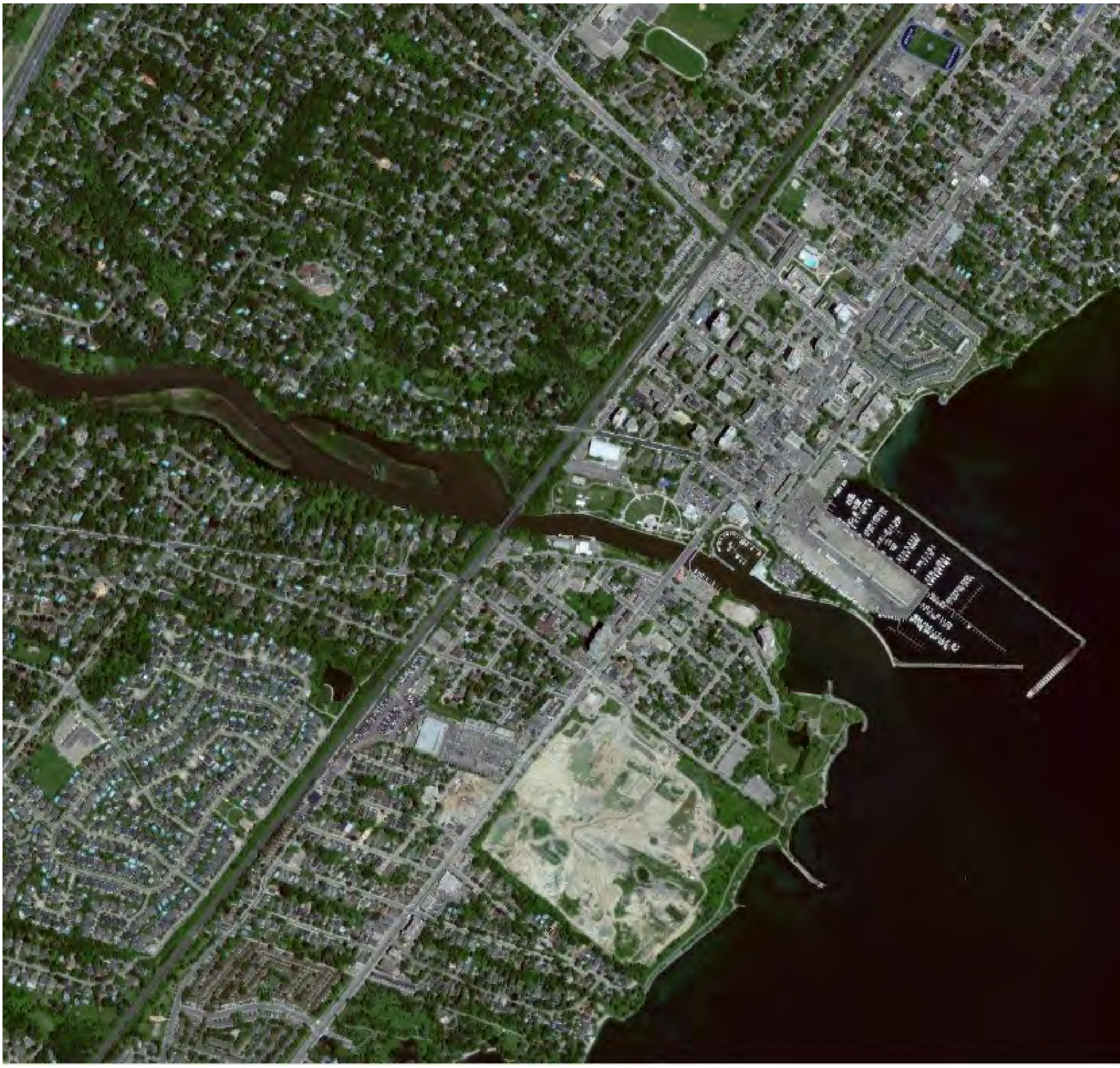
Disclaimer:
The photographs as shown are not georectified.
Photograph source:: National Air Photo Library (NAPL). Satellite imagery source: Bing Maps, 2020.

1968 Aerial Photograph

Roll Number: A20347 Photo: 42 Scale: 25,000

Disclaimer:
The photographs as shown are not georectified.
Photograph source:: National Air Photo Library (NAPL). Satellite imagery source: Bing Maps, 2020.

2020 Satellite Imagery



Disclaimer:
The photographs as shown are not georectified.
Photograph source:: National Air Photo Library (NAPL). Satellite imagery source: Bing Maps, 2020.

APPENDIX B
Site Photographs

Matrix Solutions Inc.
August 20, 2021

1. Railway bridge – Looking upstream toward the north bank.

Matrix Solutions Inc.
August 20, 2021

1. North bank downstream of railway bridge. Floodplain is forested and bank is armoured.

Matrix Solutions Inc.
August 20, 2021

3. South bank in vicinity of proposed Active Transport Bridge (ATB) - bank is forested, lacks consistent bank protection (occasional concrete pieces at toe) and some evidence of erosion was observed.

Matrix Solutions Inc.
August 20, 2021

4. South bank in vicinity of proposed ATB - outfall several meters upstream of proposed ATB.

Matrix Solutions Inc.
August 20, 2021

5. Railway Bridge – Looking toward the south bank. South bank near railway bridge is approximately 7 m high, lacks bank protection.

Matrix Solutions Inc.
August 20, 2021

6. Lakeshore Road Bridge – Looking downstream from the south bank.

Matrix Solutions Inc.
August 20, 2021

7. Lakeshore Road Bridge – bridge footing and gabion cages on the south bank.

Matrix Solutions Inc.
August 20, 2021

8. Lakeshore Road Pedestrian Bridge – looking downstream from the south bank.

Matrix Solutions Inc.
August 20, 2021

9. Lakeshore Road Pedestrian Underpass – looking upstream at the north bank.

Matrix Solutions Inc.
August 20, 2021

10. Lakeshore Road Bridges – looking upstream towards the north bank.

Matrix Solutions Inc.
August 20, 2021

11. Lakeshore Road Bridge – from the north bank, looking at the south bank.

Matrix Solutions Inc.
August 20, 2021

12. Credit River with Railway Bridge in distance – looking upstream from the north bank.

Matrix Solutions Inc.
August 20, 2021

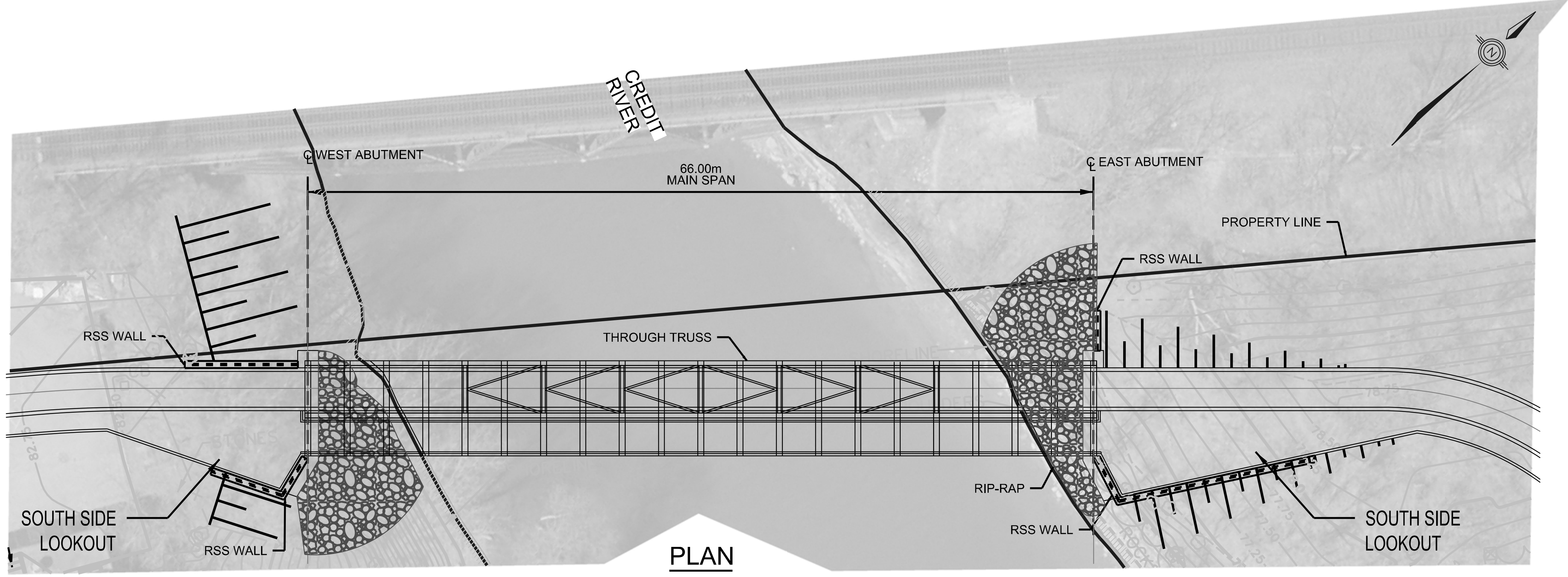
13. Credit River with Lakeshore Road Bridge in distance - looking downstream from the north bank.

Matrix Solutions Inc.
August 20, 2021

14. Credit River with Railway Bridge – looking upstream from the north bank.

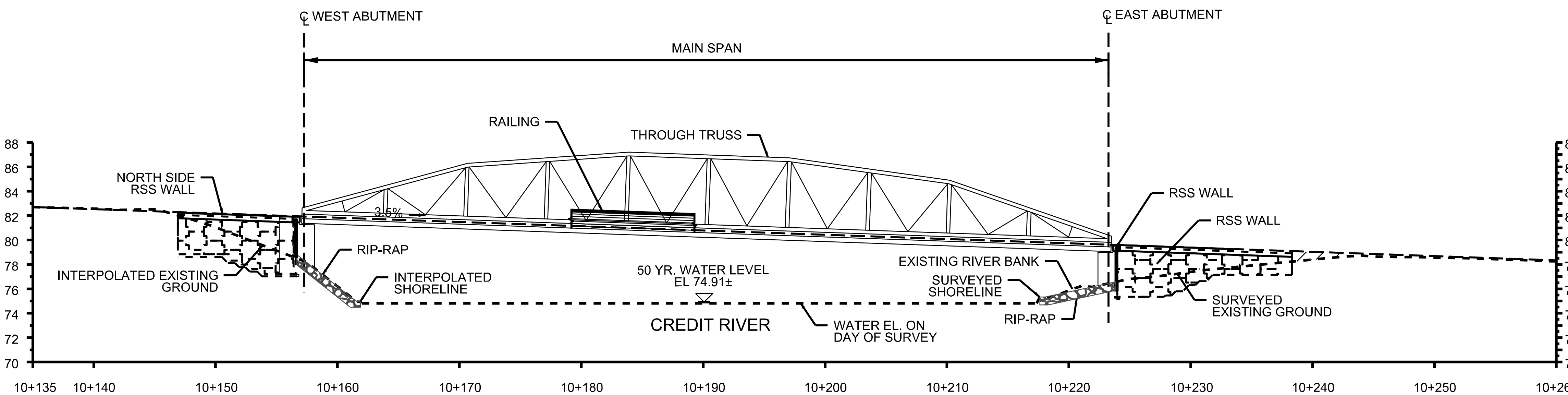
APPENDIX C
Credit River AT Bridge General Arrangement Drawing and Conceptual Alternatives

APPENDIX C1
Credit River AT Bridge General Arrangement Drawing



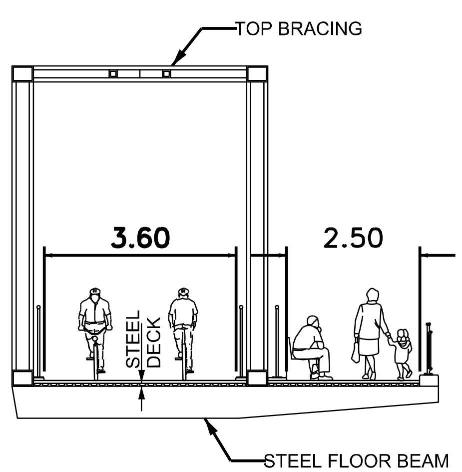
PLAN

SCALE 1:200



PROFILE ALONG PROPOSED BRIDGE CENTERLINE

SCALE 1:200



TYPICAL SUPERSTRUCTURE

PRELIMINARY NOT FOR CONSTRUCTION

HDR | MISSISSAUGA

LAKESHORE ROAD
(PART C)
TRANSPORTATION STUDY
BRIDGE OPTION ANALYSIS
THROUGH TRUSS OPTION
GENERAL ARRANGEMENT

PLAN NO.

SCALE

DATE
NOV. 2021

APPENDIX C2
Conceptual Alternatives, All Cases

Conceptual Design Alternatives, Credit River AT Bridge
Received from HDR May 30, 2022