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PROFESSIONAL ENGINEERS

City of Guelph

Ward to Downtown Bridges

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FINAL REPORT

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Table of Contents

List of Figures

List of Tables

Appendices

Appendix A	HEC-RAS Model Output Data
Appendix B	Existing Conditions Photographs

1. Introduction

The City of Guelph initiated a Class Environmental Assessment for two pedestrian bridges that would link St. Patrick's Ward with Downtown Guelph. Council had previously approved a bridge adjacent to the Guelph Junction Railway Bridge; the Downtown Secondary Plan identifies two new additional pedestrian bridges over the Speed River, between Macdonell Street and Neeve Street (**Figure 1-1**).

Ecosystem Recovery Inc. in collaboration with GM BluePlan and Aboud and Associates, was retained to conduct a fluvial geomorphic assessment of the Speed River within the study area. The assessment was intended to document existing conditions, to inform the selection of proposed pedestrian crossing locations that would minimize impact on fluvial processes, and to assess the implication of the proposed crossing on fluvial geomorphic processes and hydraulic conditions that define aquatic habitat and enable fish migration.

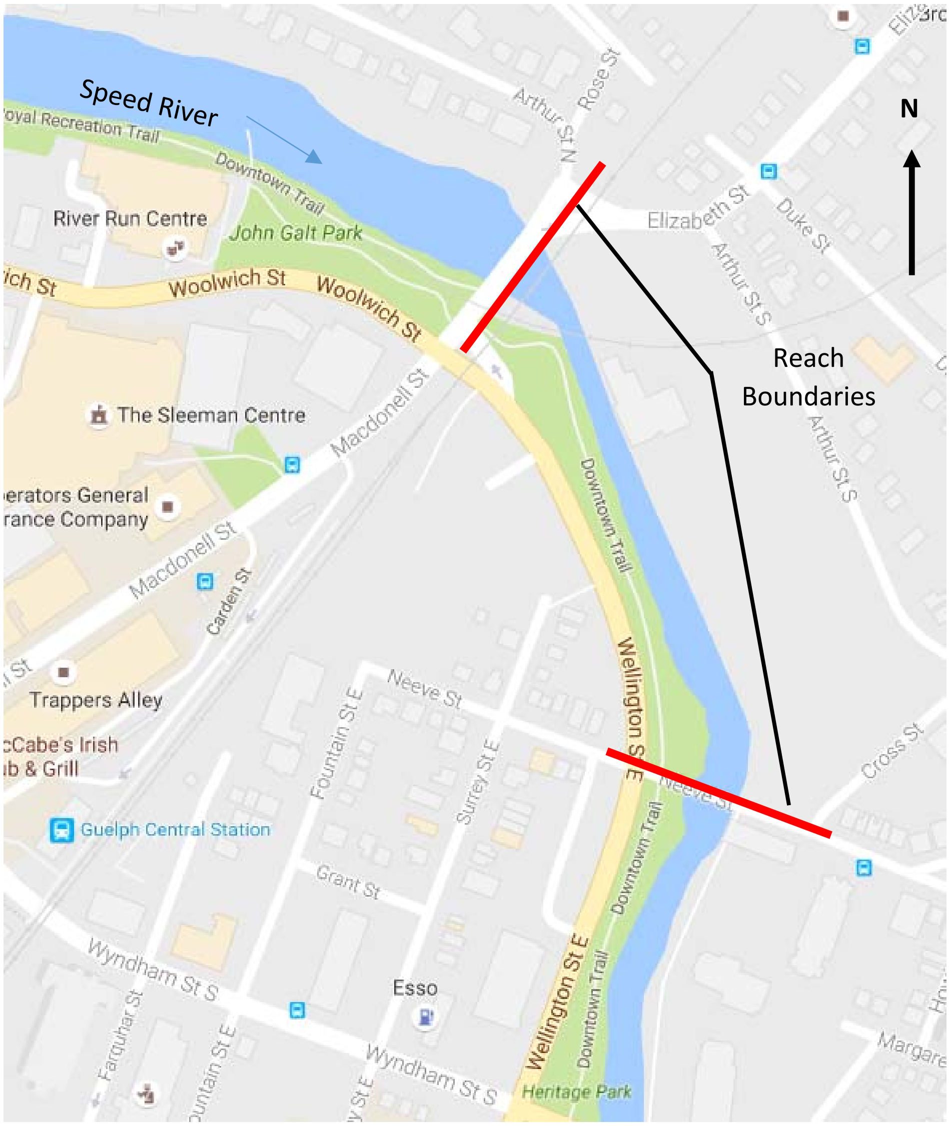


Figure 1-1. Overview of Study Area (source: Google Maps, 2015)

2. Study Approach

The geomorphic assessment was focused specifically on documenting channel processes and conditions that could affect, or be affected by, the proposed pedestrian crossing. As part of a multi-disciplinary team, results of geomorphically based analyses are intended to provide input into various aspects of the EA study, including the environmental assessment and identification of alternatives for the proposed pedestrian crossing location.

The workplan that was proposed for this study included the following tasks:

- Review available background information regarding the Speed River in proximity to the study area;
- Delineate a study reach(es);
- Complete both a synoptic and detailed level field investigation;
- Review and update the existing hydraulic model;
- Complete an historic airphoto/mapping assessment; and
- Prepare report to document study process and findings.

3. Site Description

The Speed River, which originates from Orton, ON, is impounded by a dam in the Guelph Lake Conservation Area. From the dam, the river flows approximately 7,100 m to Macdonell Street in the City of Guelph. The focus of this study is on the ~ 320 m long channel section that extends from Macdonell Street to Neeve Street (**Figure 1-1**). Here, the river separates the Ward and Downtown neighbourhoods. High intensity (high rise) residential development is currently underway along the north side of the river. Heritage Trail Park separates Wellington Street from the river by a minimum width of 20 m. Two railway lines cross over the Speed River near Macdonell Street.

3.1 Reach Delineation

Characteristics of a watercourse vary spatially in response to changes in the controls that define channel form (i.e., flows, geology, slope, riparian vegetation). Delineation of reaches along a watercourse is an appropriate means of defining channel lengths that are similar in physical and flow characteristics. Given the relative consistency in channel form within a reach, a relative uniformity in channel processes can then be inferred. This forms a sound basis for analyses.

Reach delineation for this study was guided primarily by field observations of channel conditions and processes. The upstream reach limit was defined as the concrete spillway at the CN railway crossing (i.e., ~ 20m downstream of Macdonell Street) and the downstream limit was defined as Neeve Street. The concrete spillway separates the impounded portion of the Speed River from the actively flowing channel near Macdonell Street and appeared to separate a cobble-gravel stream bed channel from a bedrock controlled channel bed downstream of Neeve Street. Reach boundaries are illustrated on **Figure 1-1**.

3.2 Geology and Physiography

Review of surficial geology mapping of the study area indicates that the Speed River is situated in an area of exposed bedrock (Karrow et al., 1979). The Ontario Geological Survey (2010) defines the bedrock as being of Paleozoic origin. Chapman and Putnam (2007) indicate that, through the study area, the physiography corresponds to a glacial spillway in which glaciofluvial gravels occur (i.e., adjacent to any exposed bedrock).

3.3 Historical Assessment

3.3.1 Landuse

A sequence of historical airphotos was obtained from the National Airphoto library and the City of Guelph. Due to the resolution and scale of the images, only the 1930, 1964, 1995, and 2015 photos were examined to identify historical changes to landuse and channel planform configuration within the study area. Historical images of the study area are included in **Figure 3-1** for reference.

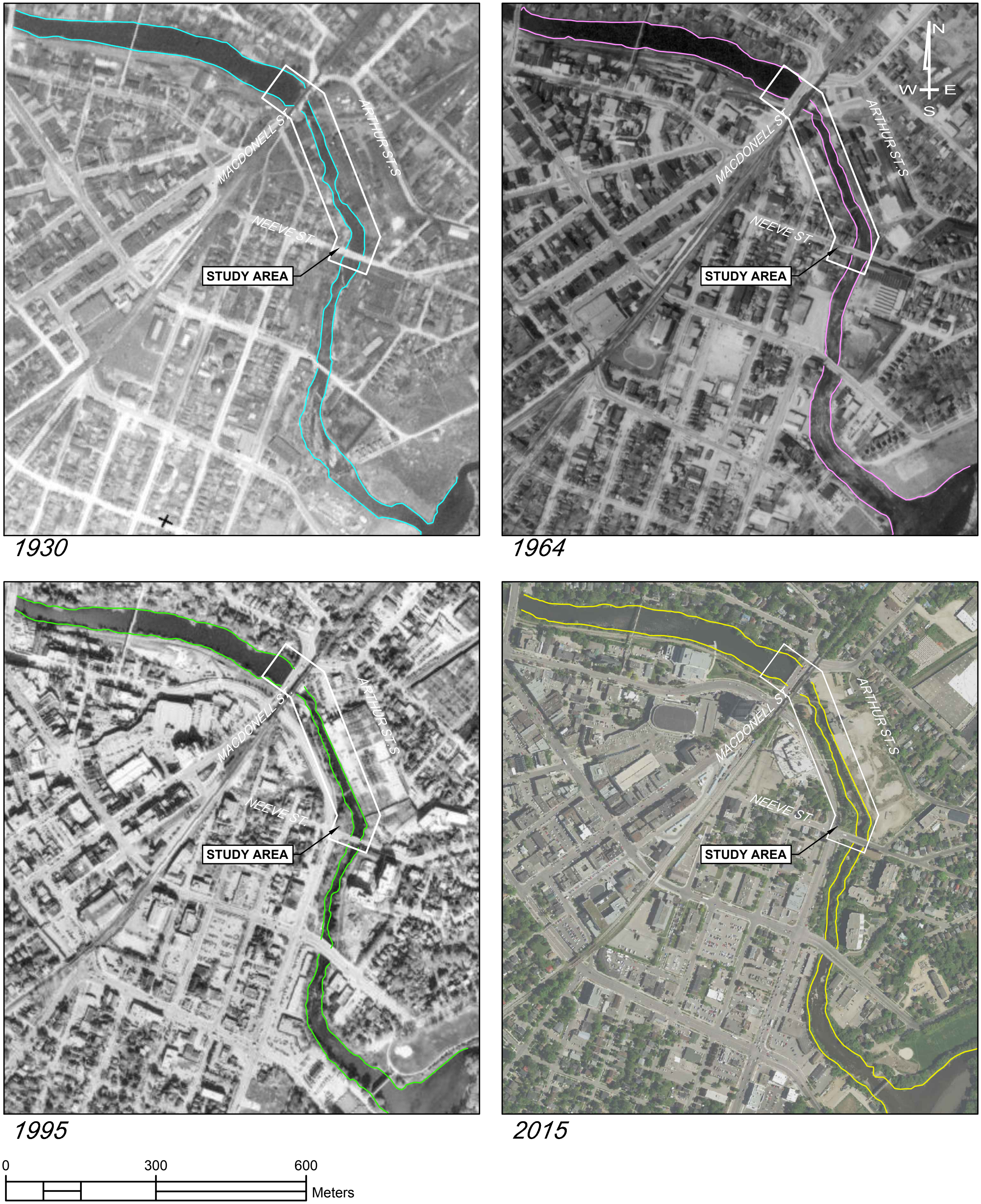
Review of the aerial photography reveals that landuse surrounding the study area was already established as residential by the time of the 1930 aerial photo. A majority of the transportation (road and rail) network was also already in place by 1930; this included Macdonell Street, Neeve Street, and the two railroad crossings. Between 1930 and 1964, the factory located adjacent to the east bank of the river (between Macdonell and Neeve Streets) had become established and the residential landuse surrounding the area had increased in density; the Macdonell Street road crossing appears to have been upgraded adjacent to the CN/CP railway bridge.

The 1995 aerial photo shows that the density of residential landuse had further increased since 1964 and that the footprint of the factory adjacent to the east bank of the Speed River had expanded. By 2015, the factory appeared to have been torn down and only a few small buildings remained in its former footprint. No significant changes to landuse from 1995 to 2015 occurred in the surrounding area.

3.3.2 Channel

An overlay of the historic creek planform configurations was completed to provide insight into channel changes and modes of channel evolution that have occurred in the study area (See **Figure 3-2**). The digital aerial photographs were geo-referenced using common elements visible on all photos (e.g., buildings, road). Given the distortion that occurs from the centre of a photo to the outside edges of the image, there is some inherent difficulty in precise geo-referencing the photos. Nevertheless, the overlay provides insight into changes within the study area and provides a usable base for subsequent analyses.

Observations made from **Figure 3-1** and **Figure 3-2** suggest that the Speed River was within its current alignment since 1930. A slight constriction occurred upstream of Neeve Street near the location of the existing sanitary sewer crossing (demonstrated by the 1930 overlay); the constriction was subsequently widened as of the 1964 overlay likely to accommodate development along the floodplain and installation of the sanitary sewer crossing. The confluence of the Speed River with the Eramosa River appears to have been modified between 1930 and 1964; the confluence was shifted north and the surface area at the confluence was increased. **Figure 3-2** indicates that minimal changes to the planform configuration occurred between 1964 and 2015 in the study reach. A weir-like structure that was perpendicular to the river (i.e., likely the sanitary sewer, See **Section 3.5**) was first evident in the 1964 airphoto.



1930

1964

1995

2015

HISTORICAL COMPARISON OF THE STUDY AREA

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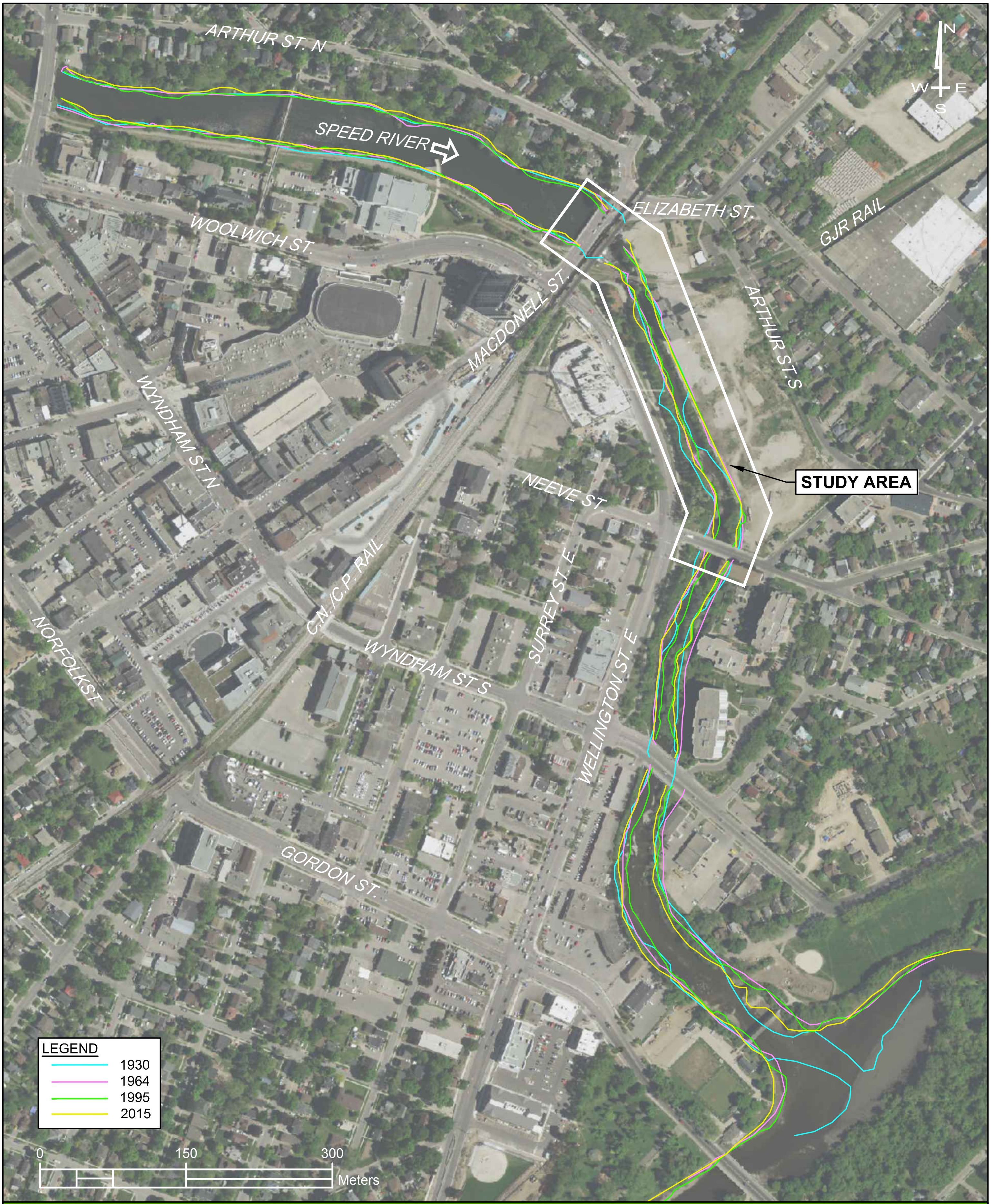
Figure
3-1



HISTORICAL OVERLAY OF THE SPEED RIVER IN THE STUDY AREA

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Figure 3-2

3.4 Hydrology and Hydraulics

Flow rates for the Speed River were obtained from the HEC RAS model that was provided by the Grand River Conservation Authority. The flow rates are summarized in Error! Reference source not found..

Table 3-1. Peak flow rates for study area

Return Period (yrs)	Flow Rates (m^3s^{-1})
2	81.9
5	114
10	134
20	155
50	181
100	200
Regional - Original	512
Regional - GRHS	480

The model was updated with field surveyed cross-sections to gain an understanding of the hydraulic conditions that occur in the study area and to serve as the basis for further analyses pertaining to the proposed pedestrian bridge crossings. The cross-sections representing the Macdonell Street crossing, the railway bridge, the GJR Bridge and the Neeve Street crossing were not updated in the model since field site conditions at, or in proximity to the crossings appeared to be well represented by the model. **Figure 3-3** illustrates the location of the existing and updated cross sections through the study area.

Review of the flood elevations through each of the cross-sections indicates that, through the study reach, the 100 year flow event is contained within the defined channel (**Figure 3-4**). At the upstream end of the reach (HEC RAS sections 24233.57 to 24169.23), the west bank is overtopped by the Regional event From HEC RAS section 24144.82 to Neeve Street, the Regional event typically spills over both banks. The change in water level elevations between the existing and updated model that is evident in **Figure 3-4** is due to the increased resolution of the updated model (i.e., increase in number of cross-sections).

Model output data from the updated HEC-RAS model are presented in **Table 3-2.** For the purpose of this study, it was assumed that the bankfull flow event was equivalent to 60% of the 2 year flow. Data presented in **Table 3-2** provides an overview of the minimum, maximum, and average hydraulic parameters for each flow series; section specific data is provided in **Appendix A**.

Evident through review of **Table 3-2** is the substantial increase in maximum shear stress and stream power that occurs within the study reach during the 10 year and larger flows; this increase is attributable to the increase in Froude number of flows into the supercritical regime. The maximum shear stress and stream power occur at HEC RAS section 24233.57 for flow events from the 10-year to the 100-year; the maximum occurs at HEC RAS section 24110.45 for the Regional (Original) event. The substantial increase in maximum shear stress and stream power occurs for more sections downstream of the spillway as the flow stage increase. During the 10-year event, only HEC RAS section 24233.57 demonstrates this increase; whereas for the Regional (Original) event, HEC RAS sections 24233.57 to 24110.45 demonstrate the increase.

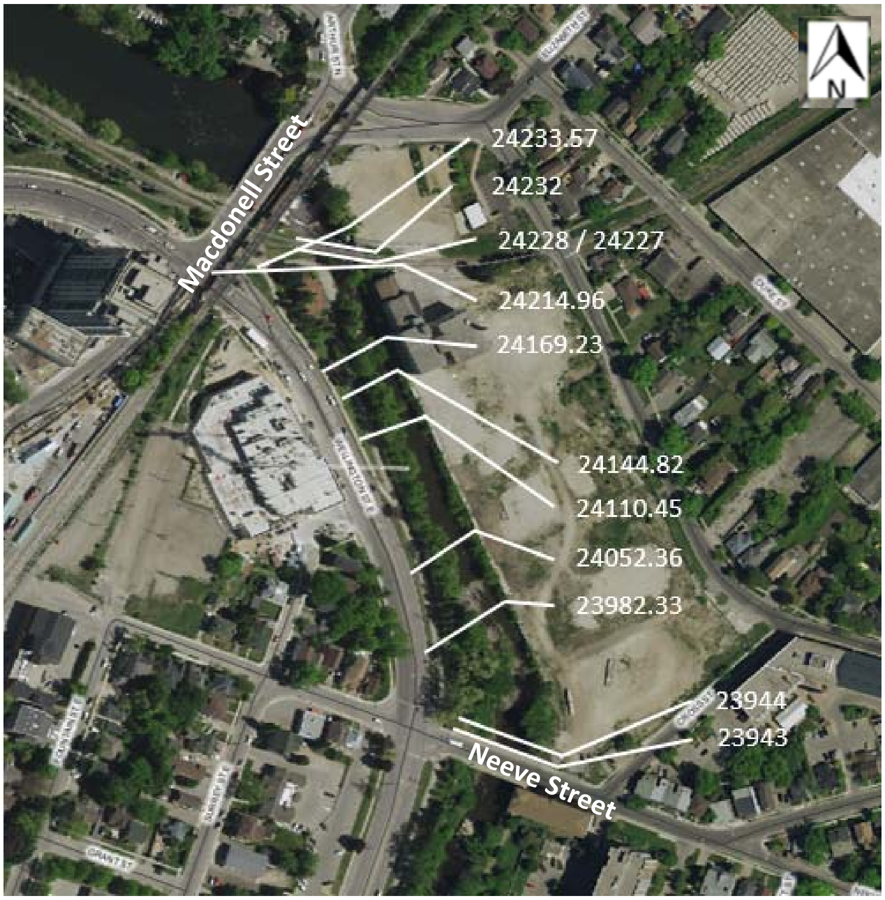

Figure 3-3. Location of HEC-RAS sections (airphoto from Google Maps extracted 2017)

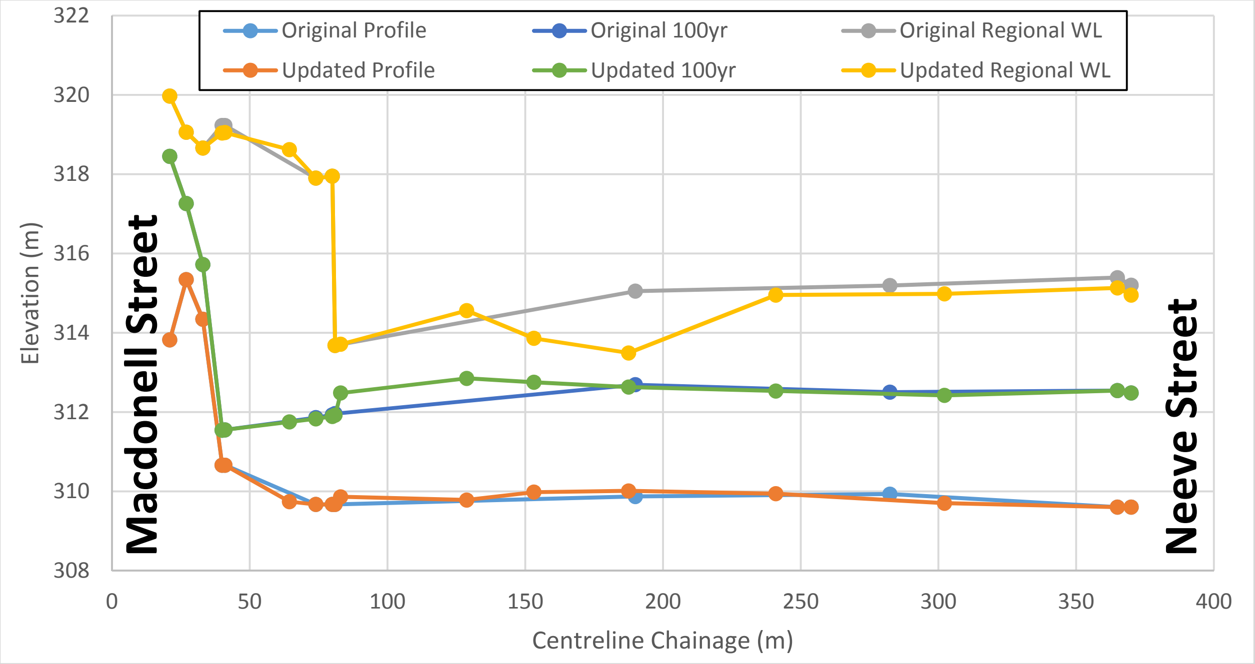

Figure 3-4. Water surface elevations through study area based from existing and updated HEC-RAS model.

Table 3-2. Summary of HEC-RAS model results for the study area.

	Water Surface Elevation (m)	Flow Width (m)	Froude Number	Velocity (m/s)	Shear Stress (N/m2)	Stream Power (N/m*s)	Entrainable Grain Size (m)	Transportable Grain Size (m)
Bankfull (Q = 49.14 m3/s)								
Min	311.18	13.86	0.42	1.33	24.97	45.42	0.03	0.06
Max	311.94	37.38	0.62	2.23	40.81	91.12	0.06	0.19
Average	311.67	20.64	0.50	1.83	29.76	54.32	0.04	0.13
2-year (Q = 81.90 m3/s)								
Min	311.55	14.09	0.44	1.61	38.71	84.6	0.05	0.10
Max	312.38	37.43	0.7	2.8	60.08	168.21	0.08	0.32
Average	312.08	21.28	0.57	2.34	45.05	105.52	0.06	0.22
5-year (Q = 114 m3/s)								
Min	311.86	14.26	0.45	1.82	49.02	117.02	0.07	0.12
Max	312.72	37.48	0.75	3.24	77.06	249.97	0.11	0.44
Average	312.39	21.58	0.62	2.76	59.54	165.10	0.08	0.31
10-year (Q = 134 m3/s)								
Min	311.45	13.6	0.46	1.94	53.97	136.66	0.07	0.14
Max	312.9	37.5	1.73	6.6	354.36	2339.59	0.49	2.05
Average	312.44	21.64	0.74	3.28	93.55	395.31	0.13	0.52
20-year (Q = 155 m3/s)								
Min	311.63	13.7	0.46	2.05	57.6	156.82	0.08	0.16
Max	313.04	37.53	1.68	6.8	364.7	2480.42	0.50	2.19
Average	312.49	21.84	0.85	3.77	124.90	613.38	0.17	0.72
50-year (Q = 181 m3/s)								
Min	311.87	13.82	0.47	2.18	61.83	182.35	0.08	0.18
Max	313.22	37.56	1.64	6.93	365.76	2535.34	0.50	2.28
Average	312.67	22.07	0.86	4.01	135.02	681.71	0.19	0.80
100-year (Q = 200 m3/s)								
Min	312.05	13.92	0.47	2.27	64.34	195.31	0.09	0.20
Max	313.22	37.57	1.62	7	364.2	2548.1	0.50	2.33
Average	312.62	22.14	0.98	4.55	172.69	959.21	0.24	1.06
Regional (Q = 480 m3/s)								
Min	313.75	16.3	0.33	2.27	51.03	153.92	0.07	0.20
Max	315.49	110	1.21	6.95	303.23	2107.48	0.42	2.30
Average	314.93	52.29	0.76	5.03	175.52	1018.46	0.24	1.27
Regional (Q = 512 m3/s)								
Min	313.48	16.42	0.33	2.3	51.77	158.11	0.07	0.21
Max	315.68	110	1.34	7.13	322.89	2280.47	0.44	2.43
Average	314.94	51.92	0.83	5.44	205.81	1283.26	0.28	1.51

3.5 Existing Conditions

A reconnaissance level field investigation was undertaken of the study area, beginning upstream of Macdonell Street and extending downstream of Neeve Street. The site visit occurred on August 19, 2016. Photographs illustrating site conditions are in **Appendix B,** an annotated map showing key site characteristics is provided in **Figure 3-5**, and a summary of field measured parameters is presented in **Table 3-3**.

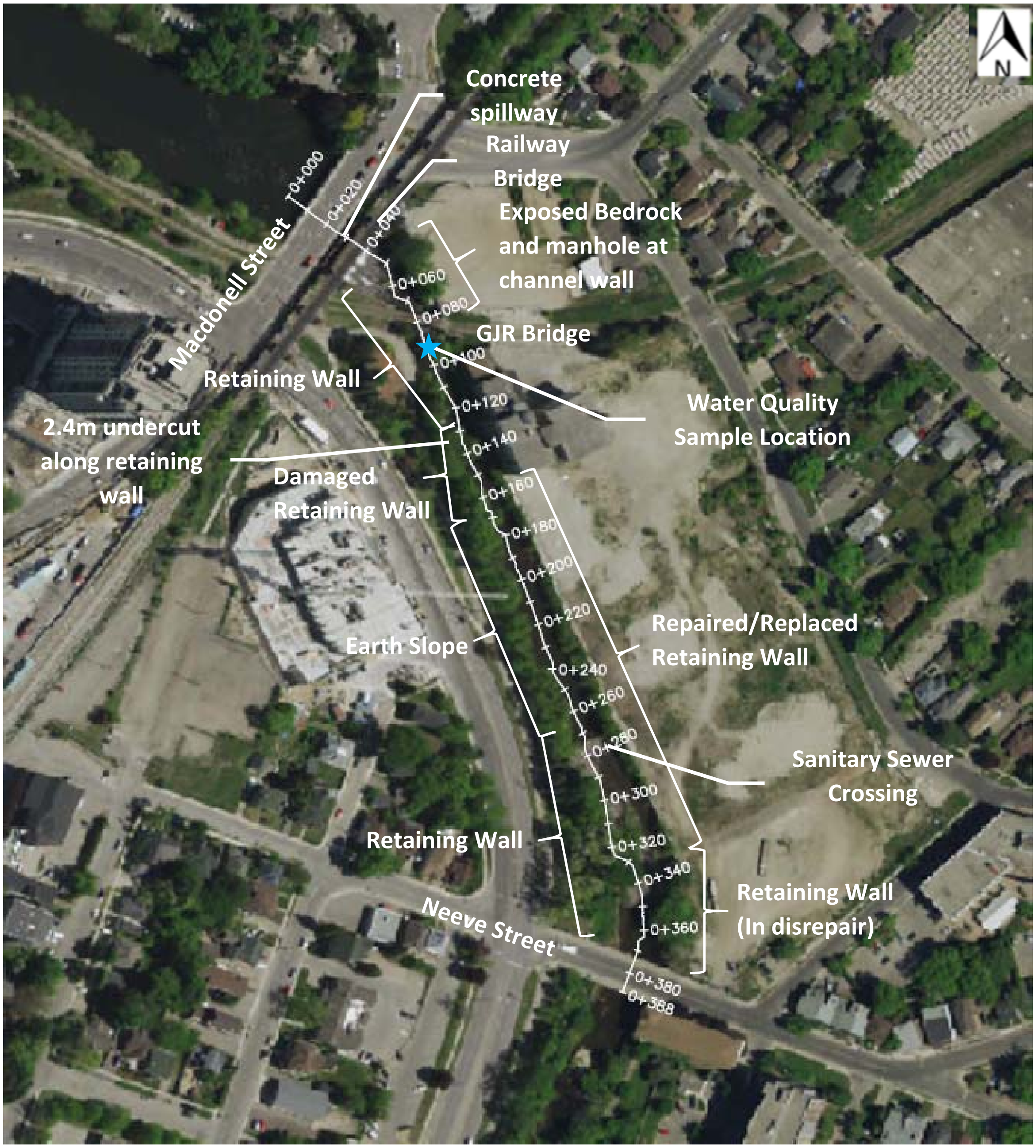

Figure 3-5. Overview of Site Conditions

Table 3-3. Overview of field measured channel parameters.

	Minimum	Maximum	Average
Channel			
Channel Width (m)	19.51	46.01	30.63
Channel Depth (m)	2.27	5.68	3.41
Cross-section Area (m^2)	69.06	155.85	99.28
Bankfull			
Channel Width (m)	15.36	26.65	20.88
Channel Depth (m)	1.14	4.55	2.58
Cross-section Area (m^2)	27.30	69.89	51.75
low conditions			
Wetted width (August 31, 2016)	12.42	22.88	16.07
Water Depth	0.17	0.77	0.47
Water area	3.89	10.10	7.05
Wetted perimeter	16.26	25.55	19.73
Substrate (mm)			D5 - 5 D16 - 10 D35 - 30 D50 - 65 D65 - 90 D84 - 140 D95 - 200

Key site characteristics are as follows:

- **Riparian area** – along the north bank of the Speed River, the riparian area was occupied by remnant and new development. Along the south river bank, the riparian area consisted of green space associated with the Heritage Trail Park (minimum width of 20 m) which included herbaceous, shrub, and tree vegetation to the top of bank. Trees overhung the bank and extended into the channel cross-section; this occurred predominantly along the upstream end of the study area (e.g., upstream of 0+180, **Figure 3-5**). Several trees appeared to have become established on the face of the retaining walls.
- **Planform** – The reach appeared to have been previously straightened/hardened and was considered to be nearly straight between MacDonnell and Neeve Streets. The hardened channel banks restrict natural channel planform and width adjustment processes.
- **Channel cross-section** – the cross sectional configuration tended to be nearly symmetrical and relatively uniform throughout the reach (i.e., U-shaped) with vertical (concrete wall or grouted masonry wall), or near vertical (earthen) banks. Based on the topographic survey, the channel width (from top of bank to top of bank) ranged from 19.51 to 46.01m. The channel cross-section was narrower in the upstream than downstream portion of the study reach (i.e., close to the railway bridges and Macdonell Street).
- **Low flow channel** – during low flow conditions, the average flow depths ranged from 0.17m (riffle) to 0.77m (pool and backwater). The low flow cross-sectional area ranged from 3.89 to 10.10 m^2.

- **Bed morphology** – little variation in bed morphology was observed throughout the study reach. The bed morphology and water level elevation was controlled by the sanitary sewer (0+280, **Figure 3-5** and **Figure 3-6**). Upstream of the sanitary sewer, the water depth gradually increased in the upstream direction and included localized, somewhat deeper pools (i.e., water depth attained 70 m, in comparison to average depth of 0.44 m). Downstream of the sanitary sewer, the channel bed has a riffle form with micro-pools occurring along the bed (water depth of 0.42 m and adjacent riffle water depths of 0.26 m).
- **Bed materials** – the substrate material was characterized by coarse particles typically ranging from 5 mm to 300 mm (D_{50} of 65 mm); larger particles (500+ mm) were present at the upstream limit of the reach. Small pockets of medium to coarse sands were present on the channel bed between larger clasts/rocks. The channel bed is classified as a cobble bed (Bunte and Abt, 2001).
- **Bank materials (east bank)** – Immediately upstream of Neeve Street, the (stone and mortar) retaining wall along the east bank was in disrepair (undercut, fractured, stone in places with minimal mortar remaining). Near the sanitary sewer crossing (See **Figure 3-4**), the east bank wall appeared to have been recently replaced/repaired with a concrete wall; small gravel extended from the concrete wall to the river's edge.
- **Bank materials (west bank)** - The west bank consisted of alternating sections of retaining wall and earthen slopes. The retaining wall persisted from Neeve Street until immediately upstream of the sewer crossing. This was followed by an earthen slope that steepened in the upstream direction. A short section of retaining wall was in disrepair in the area across from the existing building (**Conditions Figure**) here, a void appeared behind the wall, and retroactive stabilization works appeared to have been implemented. Approximately 90 m downstream of the railway bridge crossing, the retaining wall began again and continued upstream until the Macdonell Street crossing.
- **Depositional features –** accumulation and stabilization of sediment deposits occurred within the channel as lateral and medial bar forms. A lateral bar had formed along the west river bank, upstream of Neeve Street; this bar was vegetated with herbaceous plants and shrubs. A medial bar had formed downstream of the sanitary sewer crossing and was stabilizing into a vegetated island (0+305 to 0+317). Along the west bank, in the upper portion of the study reach, overhanging riparian vegetation and fallen trees contributed to local deposition and scour conditions within the channel cross-section.
- **Concrete Spillway** – at the upstream end of the study reach, a 4.68 m high concrete spillway conveyed water from upstream to downstream of the CN railway bridge. The pool depth downstream of the concrete spillway ranges from 1.1 to 1.7 m; the deepest portion of the pool occurs along the east bank. The concrete spillway seems intact; woody debris was present along the crest of the spillway. This structure provides grade control to the upstream portion of the Speed River and also protects a bedrock knickpoint that occurs along the channel bed profile (i.e., near vertical drop).
- **Exposed Sanitary Sewer –** a metal sanitary sewer pipe was observed on the channel bed. This pipe was secured to the channel bed with poured concrete (0+280). In three (3) locations, the sanitary sewer was unsupported/unprotected by concrete and water flow occurred under the pipe. In general, the sanitary sewer contributed to backwater conditions in the upstream portion of the reach.

- **Stormwater –** two stormwater outfalls (0+090 and 0+330) were present along the retaining walls in addition to numerous drains on both banks that convey runoff from the floodplain to the Speed River.
- **Manhole** – along the east bank, upstream of the GJR bridge, there is an exposed sewer manhole at 0+070. The manhole structure protrudes from the east bank and is within the section of the study reach where exposed bedrock is present along the channel bank.

A topographic survey was completed along the study reach to enable quantification of channel parameters and to serve as a basis for hydraulic modeling in support of alternative identification and evaluation. A summary of cross-sectional dimensions is provided in **Table 3-3**. The topographic survey profile is provided in **Figure 3-6**.

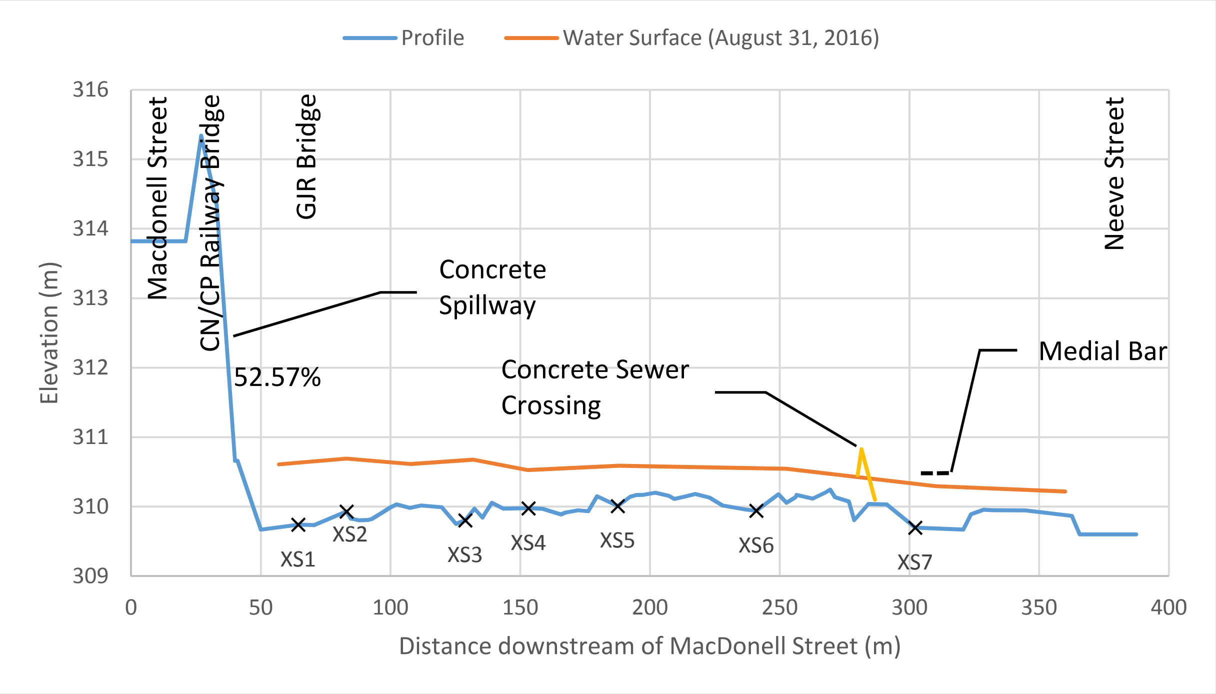

Figure 3-6. Channel Profile

Review of the profile clearly demonstrates the grade control effect of the sanitary sewer (0+280); the water surface gradually increases upstream to the concrete spillway. The spillway is set at a steep gradient of 52.5 % with a large plunge pool at the base. The profile demonstrates an overall adverse channel slope towards the sanitary crossing which could increase the backwater effect within the upstream section of the study area. The channel bed from the profile does not show distinct features such as pools and riffles upstream of the sanitary sewer crossing. However, downstream of the crossing, there appears to be a pool followed by a riffle that extends downstream towards Neeve Street.

3.6 Water Quality

A surface water quality collection program has been established to characterize the water quality within the study area during four seasons. A separate report outlining the water sampling program is being prepared under separate cover. In summary, ten (10) samples will be collected in the study area, including one (1) dry weather sample in summer and one (1) dry weather sample and two (2) wet weather samples in each of the autumn, winter and spring seasons; the sampling location is shown on **Figure 3-4**. Water quality parameters that are being assessed include the following:

- Total phosphorous in water,
- Anions: Chloride, Nitrate,
- Metals: Copper, Lead, Zinc,
- Total Suspended Solids,
- E.Coli in Water, and
- Dissolved Oxygen

The dry weather samples were collected following the protocol from Section 6.2.6 of the Canadian Council of Ministers of the Environment (CCME) "Protocols Manual for Water Quality Sampling in Canada" (2011) for "Sampling by Wading". The dry weather samples will be taken once sufficient time has lapsed following a previous significant rain event to reduce water levels to approximately baseline conditions. Based on a review of Water Survey of Canada gauge data ("Speed River Below Guelph", 02GA015), a minimum wait time of 8 days since the last rainfall event recorded at the Shand Dam, appears to be sufficient for baseflow conditions to be re-established in the study area.

The wet weather samples were collected following the procedures outlined by the Northern Ecological Monitoring and Assessment Network's (EMAN-North) "A Guide to Designing and Conducting Water Quality Monitoring in Northern Canada" (2005) in addition to Sections 6.2.2 and 6.2.5 from CCME's protocols (2011).

Table 3-4. Overview of surface water quality sampling

Sample	Date	Time	Water Temperature (°C)	Air Temperature (°C)	Water Depth (m)	Sample Type
1	Sept 7/16	8:55 AM	22.75	25.8	1.0	Dry
2	Oct 20/16	1:25 PM	14	13.3	1.05	Wet
3	Nov 7/16	12:45 PM	9	15.2	1	Dry
4	Nov 29/16	8:40 AM	4	8.8	1	Wet
5	Jan 3/17	12:10 PM	2	3	1.5	Wet

A summary of the water quality assessment results from the completed water quality sampling events is provided in **Table 3-5** and includes comparison to Provincial Water Quality Objectives (PWQO)/Standards and Canadian Environmental Quality Guidelines for Fresh Water Aquatic Life (CCME, 2008). Review of the data indicates that sample 2 (E. Coli) and sample 5 (Total Phosphorous, Copper, Lead and E. Coli) exceed the guideline values. It is noteworthy that, in Sample 5 (January 3, 2017), while the copper and lead concentrations exceeded the CCME (2008) guidelines, the concentrations did not exceed the PWQO values. The high E.Coli concentrations (Samples 2 and 5) both occurred during wet weather events.

Water quality parameters that are particularly relevant to aquatic biota include dissolved oxygen (DO) and water temperature. The Canadian Environmental Quality Guidelines (CCME, 2008) reports a lowest acceptable minimum concentration of dissolved oxygen for coldwater (6.5 to 9.5 mg/L) and warmwater (5.5 to 6.0 mg/L) biota. Aboud and Associates (2016) define the study area as supporting a coolwater fisheries for which no criteria were identified. Review of the data presented in **Table 3-5** indicates that all samples satisfy the minimum DO limits for warmwater biota and exceed or are within the range for coldwater biota (note: sample 1 and 2 do not meet the guideline for early life stages of coldwater biota: 9.5 mg/L).

Table 3-5. Surface water quality sampling results and regulation limits (note: values that do not satisfy guidelines/standards are shown in bold red text)

	Total Phosphorus (mg/L)	Anions (mg/L)		Metals (mg/L)			Total Suspended Solids (mg/L)	E. Coli (CFU / 100mL)	Dissolved Oxygen (mg/L)
		Chloride	Nitrate	Copper	Lead	Zinc			
Regulation	**0.03[2]**	**120[1]**	**13[1]**	**0.002[1]** **0.005[2]**	**0.001[1]** **0.005[2]**	**0.03[1]** **0.02[2]**	**-**	**400[3]**	**5.5-6.0[4]** **6.5-9.5[5]**
Sample 1	0.03	40.8	<0.05	<0.002	<0.001	<0.005	<10	330	8.4
Sample 2	0.03	45.5	0.29	<0.002	<0.001	0.009	<10	**1500**	9
Sample 3	0.02	52.9	0.53	<0.002	<0.001	<0.005	<10	122	11
Sample 4	0.03	52.9	0.64	<0.002	<0.001	<0.005	<10	200	12
Sample 5	**0.06**	79.1	0.91	**0.003**	**0.002**	0.019	35	**500**	12.7

References: [1] CCME. 2008. Canadian Environmental Quality Guidelines for Fresh Water Aquatic Life, [4] warmwater, [5] coldwater

[2] PWQO. 1994. Water Management. *Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy.*

[3] CRWQ. 2012. Guidelines for Canadian Recreational Water Quality. *Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch*

3.7 General Recommendations

Through the existing conditions characterization, recommendations with respect to location and configuration of any potential bridge crossing within the study area were identified. These recommendations were provided to GMBluePlan to support the alternative selection process and included the following:

Hydraulic/Water level

- Minimize interference with in-channel flows. Placement of the bridge deck above the top of banks would be preferred to reduce interference with flows
- No change in flood elevations should occur, as a result of the bridge placement, to avoid flooding of the adjacent private properties.

Geomorphology

- Avoid placing abutments in the creek, if possible, to reduce interference with flow (i.e., creation of scouring eddies, redirection of thalweg etc.) and to minimize implications to water surface elevations.

- Where possible, place crossing abutments in areas where the channel banks are already hardened rather than in areas of naturalized west banks. This avoids removal of well-established vegetation that enhances bank integrity and stability and provides in-stream flow roughness to reduce flow velocities.

- Where possible, enhance naturalized condition of banks adjacent to proposed crossing abutments where hardened bank materials are removed. Similarly, where opportunities exist to incorporate vegetation into any abutment protection materials, this will enhance bank conditions.

Water Quality

- Opportunities to enhance water quality should be explored in conjunction with any of the potential alternatives. This could include:
    - Enhance riparian vegetation plantings to provide shade and organic inputs into the river.
    - Enhance riparian vegetation to capture sediment and associated pollutants.

4. Review of Proposed Crossing Alternatives

Through the Environmental Assessment process, six alternatives for the proposed pedestrian bridge crossing were identified (**Figure 4-1**):

- Alternative 1: Bridge Immediately south of GJR Bridge (±40 m south of Macdonell Street) (0+080)
- Alternative 2 : Bridge ±200 m north of Neeve Street (0+155)
- Alternative 3: Bridge ±140 m north of Neeve Street (0+235)
- Alternative 4: Bridge ±90 m north of Neeve Street (0+275)
- Alternative 5: Bridge ±50 m north of Neeve Street (0+325)
- Alternative 6: Do Nothing

It is understood that, based on recommendations of the Downtown Guelph Secondary Plan, two bridge sites are being evaluated as part of this process and thus two of the alternatives will be identified as 'preferred'. Each of the alternatives was reviewed with respect to the implications for hydraulic flow conditions, in-stream channel processes, and potential effect on aquatic habitat and fish passage. Potential implications and considerations pertaining to each crossing are summarized in the following sub-sections.

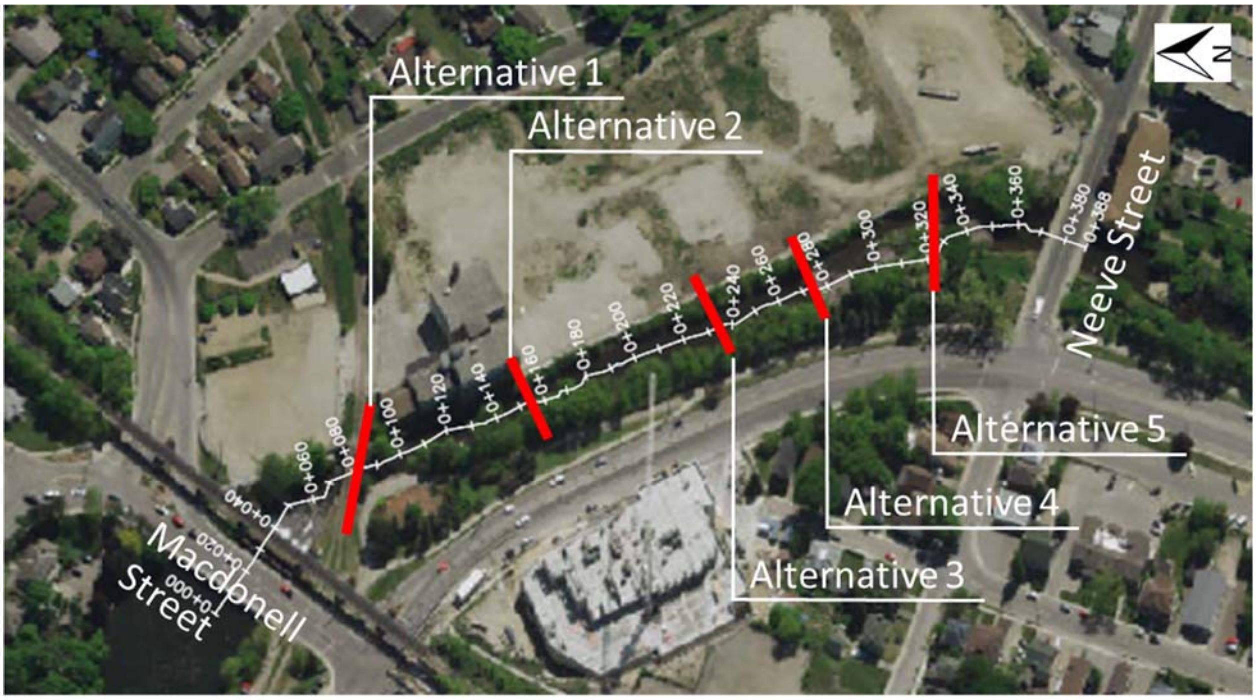

Figure 4-1. Location of Bridge Alternatives

4.1 Regional Water Level

A key concern for the study area is the potential implication of any crossing structure on the regional water level. Any increase in flood level could pose a risk to the development area, currently under construction, on the east side of the river. The updated HEC-RAS model was reviewed to examine the relation between the alternative bridge deck soffit (underside) elevations and flood lines.

As noted in **Section 3.4**, all flow events up to, and including, the 100 year flow event, are contained entirely within the channel cross-section and are thus not impacted by any of the proposed bridge alternatives. The Regional event flows spill onto the floodplain throughout the entire study area (i.e., either the west bank or both banks, see **Section 3.4**).

Given that Alternative 3 occurred in a transition zone from supercritical to subcritical flow (based on existing conditions modelling), this alternative was modeled to better examine implications for the 100 year and regional flood elevation and the corresponding hydraulic conditions. (**Figure 4-2**). More specifically, the potential of Alternative 3 to increase regional flood elevations to the east of the river was examined through modeling. The implication of all other proposed alternatives on regional flood elevations and hydraulic conditions was inferred through review of data only and is presented in **Table 4-1.**

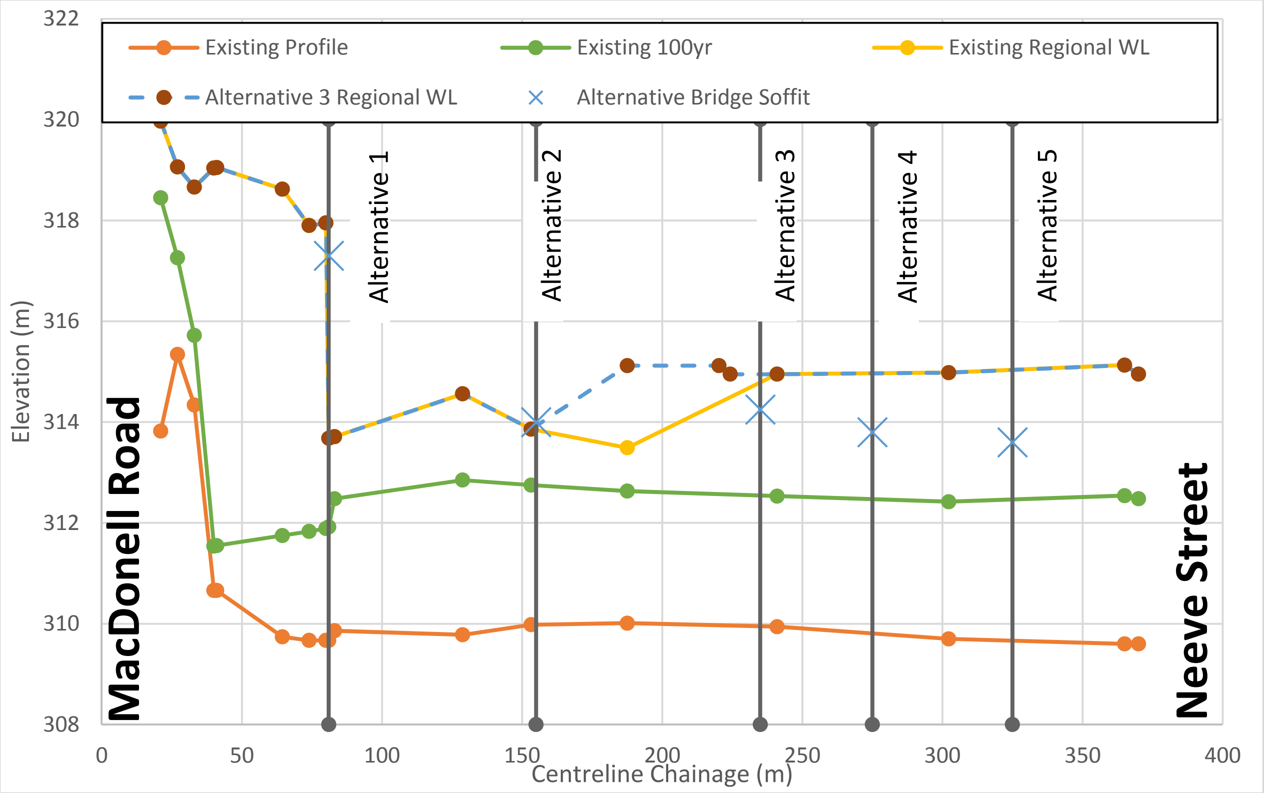

Figure 4-2. Comparison of regional water level between existing conditions and the proposed Alternative 3 bridge crossing. The location of all other alternatives is for general spatial reference only. The proposed bridge soffit for all alternatives is shown in relation to the existing regional flood levels.

Table 4-1. Overview of alternative implications on regional water levels and instream hydraulic conditions.

Alternative	Regional Water Level (m)	Soffit Elevation (m)	Implications
1	313.68	317.30	• The existing regional water level is below the proposed soffit elevation. • Under existing conditions, supercritical flow occurs at the GJR Bridge and persists for approximately 115m downstream. • The instream hydraulic conditions are unlikely to be impacted by this alternative
2	313.84	314.00	• The existing regional water level is below the proposed soffit elevation. • Alternative 2 is within the zone of supercritical flow, which continues for approximately 40m downstream. • The instream hydraulic conditions are unlikely to be impacted by this alternative.
3	314.79	314.25	• This alternative is situated in a transition zone in which the flow regime goes from supercritical to subcritical. • The existing regional water level would overtop the bridge deck. • This alternative could impact the location of the hydraulic jump that occurs during the regional flood (i.e., it is expected to move upstream from its current location)
4	314.97	313.80	• The existing regional water level would overtop the deck of Alternative 4 • The potential for regional flood levels to increase, as a result of the bridge, exists and should be further assessed through modelling • This alternative is situated within a zone of subcritical flow
5	315.03	313.60	• The existing regional water level would overtop the bridge deck. • The potential for regional flood levels to increase, as a result of the bridge, exists and should be further assessed through modelling • This alternative is situated within a zone of subcritical flow
6			• No change to existing conditions

4.2 Fluvial Processes

The Speed River cross-section, through the study area, is oversized from a geomorphic perspective and is more accurately defined as a flood control channel. Consequently, the channel forming flows (i.e., bankfull) that are typically responsible for maintaining and defining the river morphology, are unaffected by all alternatives.

A change in hydraulic conditions, is anticipated during the regional flood events for some alternatives, as described in **Section 4.1** and summarized in ¢l·ōfŜ пπнΦ While ǎdzŎK ŜǾŜyǘǎ ǘŜyŘ ǘƻ ƻŎŎdzǊ infrequently, they can cause substantial channel change. Within the study area, review of hydraulic modeling completed for Alternative 3 suggests that implementation of this alternative affects the location of the hydraulic jump; a decrease in the spatial extent of supercritical flows (i.e., that occur upstream of the hydraulic jump) is considered to be beneficial from an erosion and scour potential perspective (i.e., Alternative 3).

In addition to hydraulic effects, alterations to channel boundary materials (banks) may be required to enable implementation of the alternatives. In general, the effect of an alternative will be less in areas where the bank and/or bed was previously disturbed/hardened. Opportunities to enhance failing bank materials with bioengineered materials may occur with several alternatives.

A summary of the geomorphic implications from each alternative is provided in **Table 4-2**.

4.3 Fish Habitat and Passage

Since the bridge alternatives do not interfere with the flow events most commonly associated with fish migration (i.e., less than 2 year event), the effect of the alternatives on fish passage is expected to be negligible. Hydraulic factors which affect the integrity of aquatic habitat are similar to those which define geomorphic channel parameters and processes. The physical changes to channel form that must occur to enable implementation of any of the alternatives affect aquatic habitat conditions. Changes that would affect aquatic habitat include removal of vegetation and reinforcement of naturalized slopes with stone to protect abutments. Opportunities to enhance failing bank materials may occur in conjunction with implementation of several alternatives.

A summary of the aquatic habitat and fish passage implications from each alternative is provided in **Table 4-2**.

4.4 Summary

The implications (advantage and disadvantage) of each potential alternative on hydraulic conditions, geomorphic processes, and fish passage was examined; a summary is provided in **Table 4-2**. Overall, the interference with existing conditions increases in the downstream direction (i.e., as the bridge deck elevation becomes lower than the regional flood level and alters hydraulic conditions). Opportunities for enhancement of existing conditions is limited to the area in the immediate vicinity of the proposed crossings.

Table 4-2. Overview of positive and negative implications for each proposed alternative.

Alternative	Advantage	Disadvantage
1	• No impact to floodlines, channel processes or fish movement potential	• No enhancement of existing conditions
2	• No impact to floodlines, channel processes or fish movement potential • Opportunity to restore damaged retaining wall (west side) and incorporate vegetation	• Requires vegetation removal on the west side of the river
3	• Reduction in length of supercritical flow during the regional flood event • No change to fish movement potential	• East abutment would be within the Regional flood elevation • Naturalized slope would be affected • Increase in flood elevation for the Regional event flow event.
4	• No impact to channel processes or fish movement potential • Opportunity to restore damaged retaining wall and incorporate bioengineering materials into the recently placed east side toe protection • Area has been previously disturbed due to the sanitary sewer and thus footprint of disturbance remains limited	• Bridge soffit and abutments would be within the floodplain • The potential for regional flood levels to increase, and local flow hydraulics to change, as a result of the bridge exists and should be further assessed through modelling •
5	• No impact to channel processes of fish movement potential • Opportunity to restore damaged retaining wall	• Bridge soffit and abutments would be within the floodplain • The potential for regional flood levels to increase, and local flow hydraulics to change, as a result of the bridge exists and should be further assessed through modelling
6	No change to existing conditions and no opportunities to enhance existing conditions	

5. Preferred Alternative

Through the EA study process (GM Blueplan, 2017), and evaluation of the 6 original bridge options, the two preferred alternatives for bridge locations across the Speed River between Macdonell Street and Neeve Street were identified as Alternative 1: Bridge Immediately south of GJR Bridge (0+080) and Alternative 2 : Bridge ±200 m north of Neeve Street (0+155).

The soffit elevation (317.3m) for Alternative 1 is above the regional flood elevation and is thus not expected to have significant impacts to the instream hydraulic conditions of the Speed River through the study area. Given that this section of the Speed River is currently impacted by existing structures, it may be a beneficial location to construct the proposed pedestrian crossing. The fluvial processes are already impacted by the concrete spillway, Macdonell Street crossing and the GRJ bridge crossing and thus

Alternative 1 should not impose further modifications. Similarly, fish passage is already impacted by the concrete spillway upstream of Alternative 1 and the proposed soffit elevation should not impact instream hydraulic conditions thus no further implications for fish passage are expected.

Alternative 2 occurs through a portion of supercritical flow along the Speed River. The proposed soffit elevation (314m) is not expected to impact the existing instream hydraulic conditions of the Speed River. Since no change in hydraulic condition is expected, then no change to fluvial processes or fish passage potential are anticipated. Further, no change to the channel boundary materials are anticipated (i.e., a retaining wall occurs along both the east and west banks).

6. Conclusions and Recommendations

A geomorphic and hydraulic assessment of the Speed River was completed between Macdonell Street and Neeve Street in the City of Guelph. The intent of the assessment was to gain insight into existing conditions and processes so that opportunities and constraints for potential bridge crossing alternatives could be identified. Once the alternatives were identified by GMBluePlan, the effect of implementing the alternatives on Regional event water level elevations, instream hydraulic conditions, geomorphic channel form and functions, and on aquatic habitat characteristics and fish passage potential was assessed and included in the alternative evaluation process completed by GMBluePlan. The preferred alternatives (Alternatives 1 and 2) are not expected to adversely affect the hydraulic, geomorphic or fish passage and habitat characteristics of the study area and provide limited opportunities for enhancement of existing conditions.

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Appendix A

HEC- RAS Model Output Data

Appendix B

Speed River HEC-RAS Model Output

Existing Conditions Model - Plan Name: ERI 2016 Update

River Sta		Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Power Chan (N/m s)
24297		2-year	81.9	317.1	0	0.73	111.99	54.81	0.13	1.56	1.14
24297		5-year	114	317.56	0	0.89	128.06	70.57	0.15	2.21	1.96
24297		10-year	134	317.83	0	0.94	167.26	80.04	0.15	2.38	2.23
24297		20-year	155	318.08	0	1	188.14	88.54	0.16	2.68	2.69
24297		50-year	181	318.33	0	1.09	212.26	109.51	0.17	3.11	3.39
24297		100-year	200	318.5	0	1.15	232.88	126.13	0.17	3.39	3.88
24297		Reg - Orig	512	319.99	0	1.83	444.9	146.9	0.24	7.87	14.4
24297		Reg - GRHS	480	319.89	0	1.77	429.56	146.9	0.23	7.39	13.07
24297		Reg GRHS w. spli	480	319.89	0	1.77	429.56	146.9	0.23	7.39	13.07
24297		60% of 2year	49.14	316.58	0	0.52	93.95	37.11	0.1	0.84	0.44
24287	MacDonell Rd		Bridge								
24277		2-year	81.9	317.06	0	0.74	110.8	53.63	0.13	1.6	1.18
24277		5-year	114	317.48	0	0.91	125.31	67.86	0.15	2.32	2.11
24277		10-year	134	317.72	0	0.97	158.66	76.26	0.16	2.58	2.5
24277		20-year	155	317.96	0	1.04	178.01	84.52	0.16	2.91	3.02
24277		50-year	181	318.25	0	1.11	203.36	95.02	0.17	3.26	3.63
24277		100-year	200	318.45	0	1.17	225.78	124.18	0.17	3.53	4.12
24277		Reg - Orig	512	319.97	0	1.84	441.48	146.9	0.24	7.98	14.71
24277		Reg - GRHS	480	319.87	0	1.78	426.73	146.9	0.23	7.48	13.31
24277		Reg GRHS w. spli	480	319.87	0	1.78	426.73	146.9	0.23	7.48	13.31
24277		60% of 2year	49.14	316.57	0	0.52	93.66	36.82	0.1	0.85	0.45
24271	Allan's Dam	2-year	81.9	316.4	0	3.24	25.26	23.8	1	41.6	134.89
24271	Allan's Dam	5-year	114	316.66	0	3.62	31.53	23.8	1	48.36	174.85
24271	Allan's Dam	10-year	134	316.81	0	3.82	35.06	23.8	1.01	52.36	200.13
24271	Allan's Dam	20-year	155	316.96	0	4.01	38.63	23.8	1.01	56.07	224.98
24271	Allan's Dam	50-year	181	317.14	0	4.22	42.9	23.8	1	60.14	253.75
24271	Allan's Dam	100-year	200	317.26	0	4.38	45.63	23.8	1.01	63.77	279.5
24271	Allan's Dam	Reg - Orig	512	319.06	0	4.53	191.89	132.05	0.75	56.67	256.79
24271	Allan's Dam	Reg - GRHS	480	318.98	0	4.43	181.25	132.05	0.74	54.53	241.47
24271	Allan's Dam	Reg GRHS w. spli	480	318.98	0	4.43	181.25	132.05	0.74	54.53	241.47
24271	Allan's Dam	60% of 2year	49.14	316.09	0	2.74	17.96	23.8	1.01	32.91	90.04
24265		2-year	81.9	315	0.03	5.57	14.71	22.45	2.19	145.16	808.02
24265		5-year	114	315.21	0.02	5.86	19.46	22.45	2.01	148.14	867.93
24265		10-year	134	315.33	0.02	6.01	22.29	22.45	1.93	150	901.64
24265		20-year	155	315.46	0.02	6.18	25.07	22.45	1.87	153.58	949.65
24265		50-year	181	315.61	0.02	6.35	28.5	22.45	1.8	156.42	993.51
24265		100-year	200	315.72	0.01	6.47	30.91	22.45	1.76	158.8	1027.45
24265		Reg - Orig	512	318.66	0.01	5.25	133.75	128.27	0.72	110.41	579.44
24265		Reg - GRHS	480	318.62	0.01	5.09	128.12	127.8	0.71	104.2	530.13
24265		Reg GRHS w. spli	480	318.62	0.01	5.09	128.12	127.8	0.71	104.2	530.13
24265		60% of 2year	49.14	314.76	0.04	5.17	9.5	22.45	2.54	143.09	739.84
24258		2-year	81.9	311.06	0.13	9.24	8.87	22.45	4.69	466.77	4312.1
24258		5-year	114	311.19	0.1	9.54	11.95	22.45	4.17	453.58	4325.39
24258		10-year	134	311.28	0.08	9.69	13.83	22.45	3.94	447.77	4337.19
24258		20-year	155	311.36	0.07	9.83	15.76	22.45	3.75	443.85	4364.47
24258		50-year	181	311.47	0.06	10	18.1	22.45	3.55	440.51	4404.16
24258		100-year	200	311.54	0.06	10.11	19.79	22.45	3.44	438.9	4436.67
24258		Reg - Orig	512	317.51	0	3.9	132.6	14.29	0.48	48.05	187.48
24258		Reg - GRHS	480	317.25	0	3.66	131.11		0.46	42.3	154.86
24258		Reg GRHS w. spli	480	317.25	0	3.66	131.11		0.46	42.3	154.86
24258		60% of 2year	49.14	310.91	0.21	8.78	5.59	22.45	5.62	487.88	4285.16

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Power Chan (N/m s)
24257	2-year	81.9	311.07	0.12	8.95	9.15	22.45	4.47	433.55	3879.32
24257	5-year	114	311.2	0.09	9.32	12.23	22.45	4.03	430.31	4010.65
24257	10-year	134	311.29	0.08	9.5	14.1	22.45	3.83	428.37	4070.16
24257	20-year	155	311.37	0.07	9.67	16.03	22.45	3.65	427.01	4128.81
24257	50-year	181	311.48	0.06	9.85	18.37	22.45	3.48	425.97	4196.77
24257	100-year	200	311.55	0.06	9.97	20.05	22.45	3.37	425.63	4245.18
24257	Reg - Orig	512	317.63	0	3.24	161.55	41.9	0.4	27.87	90.16
24257	Reg - GRHS	480	317.33	0	3.18	150.95	26.02	0.4	27.24	86.64
24257	Reg GRHS w. spli	480	317.33	0	3.18	150.95	26.02	0.4	27.24	86.64
24257	60% of 2year	49.14	310.92	0.18	8.33	5.9	22.45	5.19	431.97	3600.02
24233.57	2-year	81.9	312.37	0	2.47	33.1	14.09	0.52	43.96	108.78
24233.57	5-year	114	312.69	0	3.03	37.66	14.26	0.59	63.79	193.09
24233.57	10-year	134	311.45	0.03	6.6	20.3	13.6	1.73	354.36	2339.59
24233.57	20-year	155	311.63	0.03	6.8	22.79	13.7	1.68	364.7	2480.42
24233.57	50-year	181	311.87	0.02	6.93	26.11	13.82	1.61	365.76	2535.34
24233.57	100-year	200	312.05	0.02	7	28.59	13.92	1.56	364.2	2548.1
24233.57	Reg - Orig	512	315.21	0.01	6.8	75.58	16.42	0.99	276.51	1880.72
24233.57	Reg - GRHS	480	314.97	0.01	6.71	71.67	16.3	1	272.69	1829.92
24233.57	Reg GRHS w. spli	480	314.97	0.01	6.71	71.67	16.3	1	272.69	1829.92
24233.57	60% of 2year	49.14	311.94	0	1.82	27.02	13.86	0.42	24.97	45.42
24232	2-year	81.9	312.38	0	2.42	33.83	16.2	0.53	42.66	103.27
24232	5-year	114	312.72	0	2.9	39.34	16.31	0.6	58.85	170.54
24232	10-year	134	312.9	0	3.17	42.3	16.38	0.63	69.06	218.78
24232	20-year	155	311.78	0.02	6.41	24.18	15.99	1.66	327.18	2096.9
24232	50-year	181	311.96	0.02	6.67	27.14	16.05	1.64	343.32	2289.67
24232	100-year	200	312.09	0.02	6.84	29.24	16.1	1.62	353.84	2419.86
24232	Reg - Orig	512	315.31	0.02	6.57	80.4		0.88	305.25	2005.94
24232	Reg - GRHS	480	315.22	0.01	6.16	80.4		0.83	268.28	1652.84
24232	Reg GRHS w. spli	480	315.22	0.01	6.16	80.4		0.83	268.28	1652.84
24232	60% of 2year	49.14	311.93	0	1.85	26.58	16.04	0.46	26.53	49.04
24228	2-year	81.9	312.36	0	2.44	33.61	16.19	0.54	43.3	105.5
24228	5-year	114	312.7	0	2.92	39.05	16.31	0.6	59.85	174.73
24228	10-year	134	312.88	0	3.19	41.96	16.37	0.64	70.32	224.57
24228	20-year	155	313.04	0	3.47	44.67	16.43	0.67	81.78	283.79
24228	50-year	181	313.22	0	3.8	47.64	16.49	0.71	96.52	366.7
24228	100-year	200	312.31	0.02	6.12	32.68	16.17	1.37	275.19	1684.18
24228	Reg - Orig	512	315.25	0.02	6.57	80.4		0.88	305.25	2005.94
24228	Reg - GRHS	480	315.16	0.01	6.16	80.4		0.84	268.28	1652.84
24228	Reg GRHS w. spli	480	315.16	0.01	6.16	80.4		0.84	268.28	1652.84
24228	60% of 2year	49.14	311.92	0	1.86	26.43	16.04	0.46	26.88	49.97
24227	2-year	81.9	312.36	0	2.44	33.55	16.19	0.54	43.47	106.11
24227	5-year	114	312.69	0	2.93	38.97	16.31	0.6	60.12	175.88
24227	10-year	134	312.87	0	3.2	41.87	16.37	0.64	70.67	226.17
24227	20-year	155	313.04	0	3.48	44.56	16.43	0.67	82.21	285.95
24227	50-year	181	313.21	0	3.81	47.52	16.49	0.72	97.08	369.8
24227	100-year	200	312.3	0.02	6.14	32.55	16.17	1.38	277.7	1706.42
24227	Reg - Orig	512	315.55	0.01	5.66	107.01	40.17	0.8	183.2	1037.27
24227	Reg - GRHS	480	315.34	0.01	5.59	99.06	37.31	0.8	180.17	1006.32
24227	Reg GRHS w. spli	480	315.34	0.01	5.59	99.06	37.31	0.8	180.17	1006.32
24227	60% of 2year	49.14	311.92	0	1.86	26.39	16.04	0.46	26.97	50.23

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Power Chan (N/m s)
24214.96	2-year	81.9	312.22	0	2.8	29.25	18.07	0.7	60.08	168.21
24214.96	5-year	114	312.54	0	3.24	35.14	18.59	0.75	77.06	249.97
24214.96	10-year	134	312.72	0	3.48	38.48	18.88	0.78	86.89	302.58
24214.96	20-year	155	312.89	0.01	3.72	41.71	19.16	0.8	97.09	360.8
24214.96	50-year	181	313.09	0.01	3.97	45.58	19.48	0.83	108.6	431.21
24214.96	100-year	200	313.22	0.01	4.14	48.26	19.71	0.85	116.75	483.81
24214.96	Reg - Orig	512	315.68	0	5.07	107.34	32	0.75	145.28	736.04
24214.96	Reg - GRHS	480	315.49	0	4.97	101.3	30.3	0.75	141.47	703.14
24214.96	Reg GRHS w. spli	480	315.49	0	4.97	101.3	30.3	0.75	141.47	703.14
24214.96	60% of 2year	49.14	311.8	0	2.23	22	16.65	0.62	40.79	91.12
24169.23	2-year	81.9	312.13	0	2.46	33.29	18.11	0.58	45.22	111.24
24169.23	5-year	114	312.43	0	2.95	38.74	18.5	0.64	62.14	183.02
24169.23	10-year	134	312.59	0	3.22	41.75	18.51	0.68	72.5	233.23
24169.23	20-year	155	312.74	0	3.49	44.55	18.86	0.71	83.7	292.19
24169.23	50-year	181	312.91	0	3.81	47.79	19.32	0.75	97.54	371.72
24169.23	100-year	200	313.02	0	4.03	50.03	19.64	0.78	107.62	433.94
24169.23	Reg - Orig	512	314.74	0.01	6.24	89.01	28.55	0.95	219.21	1368.31
24169.23	Reg - GRHS	480	314.5	0.01	6.21	82.38	26.66	0.97	221.18	1374.09
24169.23	Reg GRHS w. spli	480	314.5	0.01	6.21	82.38	26.66	0.97	221.18	1374.09
24169.23	60% of 2year	49.14	311.73	0	1.88	26.13	18.04	0.5	28.27	53.16
24144.82	2-year	81.9	312.07	0	2.38	34.4	19.91	0.58	43.12	102.68
24144.82	5-year	114	312.37	0	2.83	40.26	20.42	0.64	58.77	166.4
24144.82	10-year	134	312.53	0	3.07	43.58	20.44	0.67	67.8	208.47
24144.82	20-year	155	312.69	0	3.31	46.83	21.35	0.7	77.17	255.61
24144.82	50-year	181	312.86	0	3.59	50.68	21.87	0.73	88.58	317.91
24144.82	100-year	200	312.98	0	3.78	53.37	21.99	0.75	96.64	364.9
24144.82	Reg - Orig	512	313.87	0.01	7.13	75.18	39.39	1.22	315.59	2250.78
24144.82	Reg - GRHS	480	313.75	0.01	6.95	70.96	30.48	1.21	303.23	2107.48
24144.82	Reg GRHS w. spli	480	313.75	0.01	6.95	70.96	30.48	1.21	303.23	2107.48
24144.82	60% of 2year	49.14	311.68	0	1.84	26.68	19.81	0.51	27.75	51.12
24110.45	2-year	81.9	312	0	2.24	36.49	23.18	0.57	38.88	87.27
24110.45	5-year	114	312.29	0	2.63	43.37	23.65	0.62	50.91	133.84
24110.45	10-year	134	312.46	0	2.83	47.33	23.91	0.64	57.72	163.41
24110.45	20-year	155	312.63	0	3.02	51.27	24.17	0.66	64.46	194.87
24110.45	50-year	181	312.81	0	3.24	55.84	24.47	0.68	72.51	235.04
24110.45	100-year	200	312.95	0	3.38	59.1	24.68	0.7	77.92	263.67
24110.45	Reg - Orig	512	313.48	0.01	7.06	72.49	25.53	1.34	322.89	2280.47
24110.45	Reg - GRHS	480	314.93	0	3.91	133.68	44.27	0.63	89.16	348.49
24110.45	Reg GRHS w. spli	480	314.93	0	3.91	133.68	44.27	0.63	89.16	348.49
24110.45	60% of 2year	49.14	311.61	0	1.78	27.62	22.57	0.51	26.38	46.93
24052.36	2-year	81.9	311.82	0	2.27	36.01	28.23	0.64	42.39	96.41
24052.36	5-year	114	312.12	0	2.55	44.75	29.07	0.66	50.12	127.7
24052.36	10-year	134	312.3	0	2.68	49.95	29.56	0.66	53.97	144.77
24052.36	20-year	155	312.48	0	2.81	55.2	30.04	0.66	57.6	161.74
24052.36	50-year	181	312.68	0	2.95	61.37	30.6	0.66	61.83	182.35
24052.36	100-year	200	312.83	0	3.04	65.88	31.01	0.66	64.34	195.31
24052.36	Reg - Orig	512	315.07	0	3.41	172.82	77.5	0.54	65.49	223.04
24052.36	Reg - GRHS	480	314.93	0	3.33	162.62	77.5	0.53	63.27	210.66
24052.36	Reg GRHS w. spli	480	314.93	0	3.33	162.62	77.5	0.53	63.27	210.66
24052.36	60% of 2year	49.14	311.44	0	1.9	25.82	24.14	0.59	31.42	59.8

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Power Chan (N/m s)
23982.33	2-year	81.9	311.6	0	2.19	37.47	26.49	0.59	38.71	84.6
23982.33	5-year	114	311.89	0	2.53	45.09	26.53	0.62	49.02	123.94
23982.33	10-year	134	312.05	0	2.72	49.28	26.55	0.64	55.23	150.15
23982.33	20-year	155	312.21	0	2.9	53.44	26.57	0.65	61.39	178.06
23982.33	50-year	181	312.38	0	3.12	58.09	26.6	0.67	69.17	215.54
23982.33	100-year	200	312.49	0	3.27	61.12	26.61	0.69	75.19	246.06
23982.33	Reg - Orig	512	315.08	0	3.05	241.85	97.76	0.44	51.77	158.11
23982.33	Reg - GRHS	480	314.94	0	3.02	227.73	97.76	0.44	51.03	153.92
23982.33	Reg GRHS w. spli	480	314.94	0	3.02	227.73	97.76	0.44	51.03	153.92
23982.33	60% of 2year	49.14	311.26	0	1.74	28.29	26.44	0.54	26.64	46.27
23944	2-year	81.9	311.55	0	1.61	50.81	37.43	0.44	53.78	86.68
23944	5-year	114	311.86	0	1.82	62.62	37.48	0.45	64.28	117.02
23944	10-year	134	312.04	0	1.94	69.18	37.5	0.46	70.55	136.66
23944	20-year	155	312.21	0	2.05	75.72	37.53	0.46	76.61	156.82
23944	50-year	181	312.41	0	2.18	83.11	37.56	0.47	84.28	183.53
23944	100-year	200	312.54	0	2.27	88	37.57	0.47	90.21	205.02
23944	Reg - Orig	512	315.13	0	2.3	283.01	110	0.33	73.45	169.24
23944	Reg - GRHS	480	314.99	0	2.27	267.04	110	0.33	71.98	163.37
23944	Reg GRHS w. spli	480	314.99	0	2.27	267.04	110	0.33	71.98	163.37
23944	60% of 2year	49.14	311.18	0	1.33	36.84	37.38	0.43	40.81	54.44
23943	2-year	81.9	311.52	0	1.71	48.03	35.5	0.47	10.54	17.97
23943	5-year	114	311.83	0	1.94	58.83	35.5	0.48	12.78	24.77
23943	10-year	134	312	0	2.07	64.86	35.5	0.49	14.11	29.14
23943	20-year	155	312.17	0	2.19	70.88	35.5	0.49	15.39	33.66
23943	50-year	181	312.36	0	2.33	77.62	35.5	0.5	17.03	39.72
23943	100-year	200	312.48	0	2.44	82.04	35.5	0.51	18.32	44.66
23943	Reg - Orig	512	314.95	0	2.81	280.02	132.21	0.41	19.38	54.47
23943	Reg - GRHS	480	314.82	0	2.73	263.1	132.21	0.4	18.5	50.58
23943	Reg GRHS w. spli	480	314.82	0	2.73	263.1	132.21	0.4	18.5	50.58
23943	60% of 2year	49.14	311.16	0	1.4	35.01	35.5	0.45	7.88	11.06
23935 Neeve St		Bridge								
23930	2-year	81.9	311.52	0	1.71	47.92	35.5	0.47	10.59	18.1
23930	5-year	114	311.83	0	1.94	58.71	35.5	0.48	12.84	24.94
23930	10-year	134	311.99	0	2.07	64.74	35.5	0.49	14.17	29.33
23930	20-year	155	312.16	0	2.19	70.74	35.5	0.5	15.46	33.88
23930	50-year	181	312.35	0	2.34	77.47	35.5	0.5	17.11	39.98
23930	100-year	200	312.48	0	2.44	81.87	35.5	0.51	18.41	44.96
23930	Reg - Orig	512	314.44	0	3.25	217.58	126.26	0.5	26.86	87.26
23930	Reg - GRHS	480	314.18	0	3.29	186.11	119.83	0.52	28.09	92.33
23930	Reg GRHS w. spli	480	314.18	0	3.29	186.11	119.83	0.52	28.09	92.33
23930	60% of 2year	49.14	311.16	0	1.41	34.92	35.5	0.45	7.93	11.16

Appendix B

Existing Conditions Photographs

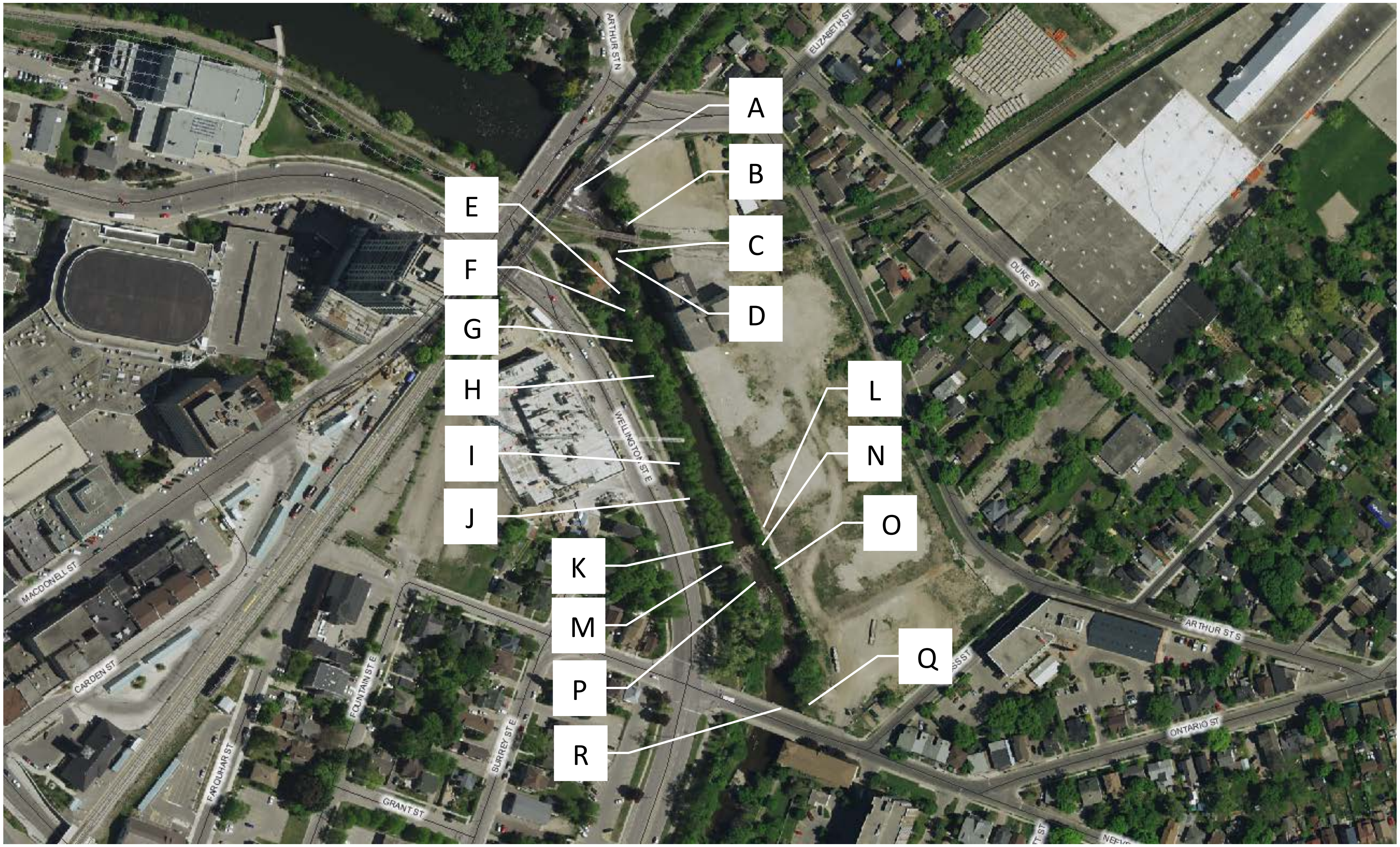
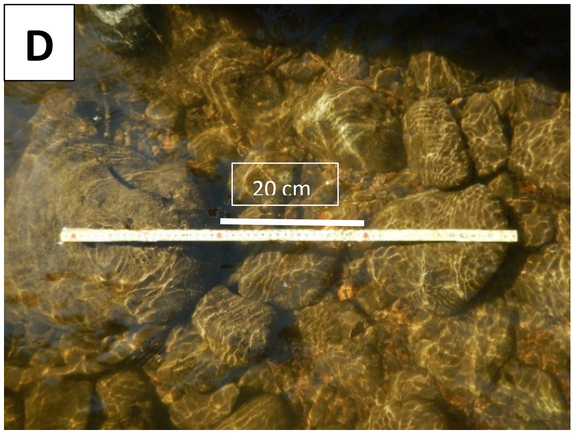


Figure A-1. Location of photos shown in Appendix A.

Looking upstream at the GJR railway bridge to the CNR bridge, concrete spillway and Macdonell Street.

Sewer manhole structure situated along the east bank, between the CNR and GJR railway bridges; note the exposed bedrock surrounding the structure (interbedded shale and limestone/siltstone formations)

Looking upstream at the GJR railway bridge crossing.



Bed material at the GJR railway bridge crossing consisted of cobble and gravels

Recently fallen tree downstream of GJR railway bridge crossing (west bank).

Looking at west bank where a tree was growing out of the retaining wall; this coincides with an approximately 2.4 m deep undercut.

G

Section of failed retaining wall and some potential retroactive structural stabilization (west bank)

H

Fallen trees along west bank provide in-channel roughness and potential fish habitat

I

Section of steep earthen banks upstream of sewer crossing (west bank). Overhanging trees provide shade and shelter to the river.

J

Fallen trees along west bank provide in-channel roughness and potential fish habitat

K

Photo of bed material immediately upstream of sewer crossing

L

Transition between old (repaired) and new (replaced) retaining wall on east bank upstream of sewer crossing.

Looking east along sewer crossing; exposed pipe.

Sewer manhole at location of sewer crossing; note the manhole lid had been displaced. The lid was subsequently replaced by City staff.

Section of east bank at sewer crossing. Gravel appears to have been placed at the toe of the recently constructed concrete wall.

Looking upstream at the existing sewer crossing and pointing to the gaps between the concrete.

Condition of the existing east bank retaining wall upstream of Neeve Street

Looking downstream at the Neeve Street bridge crossing.