Appendix L – Fluvial Geomorphic Assessment

Kennedy Road Environmental Assessment between Steeles Avenue and Major Mackenzie Drive

TECHNICAL MEMORANDUM

DATE January 23, 2019 **PROJECT No.** 1664178

TO HDR Inc.

CC Steven Jagdat

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FLUVIAL GEOMORPHIC ASSESSMENT IN SUPPORT OF THE KENNEDY ROAD MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT, YORK REGION

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by HDR Inc. (HDR) on behalf of the Regional Municipality of York (York Region) to complete a fluvial geomorphic assessment in support of the Schedule C Municipal Class Environmental Assessment (EA) for proposed roadway improvements at Kennedy Road from Steeles Avenue to Major Mackenzie Drive in the City of Markham, Ontario. This technical memorandum outlines the methods and results of the fluvial geomorphic assessment in the vicinity of the study corridor.

1.1 Background

Kennedy Road between Steeles Avenue and Major Mackenzie Drive is currently characterized by a four-lane arterial road that is oriented generally north-south and crosses several environmental features (including wetlands and watercourses), and a number of at-grade and grade separated railway lines and highway infrastructure (including Highway 407). Residential housing is the prominent land use in the areas adjacent to the road; however, there are several other notable development features in the local area, including the York Downs Golf and Country Club, recreational parks, and several industrial and commercial areas (primarily located at the intersection of Kennedy Road and Highway 7, as well as in the areas to the immediate south of this intersection). The study corridor has been targeted for improvements based on York Region's Transportation Master Plan (2016) and 2017 10-Year Roads and Transit Capital Construction Program. The roadway improvements will involve measures to increase the north-south capacity of the roadway in anticipation of growth within the adjacent areas.

As shown on Figures 1 and 2, the project includes two watercourse crossings: the main stem of the Rouge River (5th order stream located 300 m north of the intersection of Kennedy Road and Highway 7); and an unnamed tributary of the Rouge River (1st order stream located 150 m northeast of the intersection of Kennedy Road and Helen Avenue; described herein as the 'unnamed tributary'). The main stem of the Rouge River is presently crossed by a bridge with a span of approximately 30 m, while the unnamed tributary is currently crossed via two corrugated steel pipe (CSP) culverts.

The headwaters of the Rouge River originate in the area of the Oak Ridges Moraine. The river system flows in a generally northwest to southeast direction and ultimately drains to Lake Ontario at a location approximately 16 km downstream of the study area. The watershed of the Rouge River includes a combination of mostly rural and urban land use (40% and 35%, respectively, of the total watershed area) (Toronto and Region Conservation, 2016). Flows from the unnamed tributary join another tributary branch of the Rouge River (2nd order stream and also unnamed) at a location approximately 50 m downstream of the Kennedy Road culvert crossing.

1.2 Purpose and Scope

Modifications to the roadway at Kennedy Road have the potential to influence channel conditions at the Rouge River and unnamed tributary. To that end, a fluvial geomorphic assessment was completed along defined 'reach lengths' (i.e., sections of the watercourse that include similar geomorphic characteristics and controls) to assess meander potential and channel stability. The results of the fluvial geomorphic assessments will be used to support the Class EA process, as well as to assist with the preliminary design of any modifications to the watercourse crossings (e.g., upgrades or replacement of bridges or culverts).

The specific work scope involved the following tasks:

- Background review and field inspections at all reach lengths to characterize channel morphology and assess bed and bank stability (assuming that well defined channel conditions are applicable);
- Meander belt width assessment at select reach lengths to determine the meander potential of the stream in the vicinity of the roadway improvements; and
- 100-year erosion evaluation at select reach lengths to determine the long-term erosion potential of the stream in the vicinity of the roadway improvements.

Each of these tasks is described below in Section 2.0.

2.0 METHODOLOGY

2.1 Background Review and Field Inspections

The following background information was reviewed to assist with the fluvial geomorphic assessment at Kennedy Road:

- Orthoimagery from 1970, 1988 and 2016 that was retrieved from York Region spatial data service (The Regional Municipality of York, Ontario, Canada, 2015a and 2015b);
- Topographic data (contours) from 2016 that was retrieved from York Region spatial data service (The Regional Municipality of York, Ontario, Canada, 2015c);
- Aerial photography for 1954 that was retrieved from the National Air Photo Library; and,
- Rouge River Watershed Plan (Barrett, 2007).

In addition to the background review, a site visit was completed on July 4, 2017. The site reconnaissance included a walk-over at all relevant reach lengths to assess channel morphology and to identify any areas of instability. Further to these general inspections, field activities at reach lengths involved substrate sampling and Rapid Geomorphic Assessments (RGAs). The field data was used to inform the meander belt width and 100-year erosion assessments (Sections 2.2 and 2.3).

2.2 Meander Belt Assessment

A belt width assessment was conducted at select reach lengths based on protocols developed by Toronto and Region Conservation Authority (TRCA, 2004). The belt width assessment included the following activities:

- Background preparation, comprising a detailed analysis of maps and historical aerial photographs/orthoimagery from 1954, 1970, 1988 and 2016, in order to delineate the reach lengths and examine historical land use and channel patterns;
- Field reconnaissance at the identified reach lengths (described in Section 2.1) to evaluate current conditions and obtain measurements of channel geometry; and,
- Delineation/quantification of meander belt widths at select reach lengths to infer the stream corridor that the channel encompassed in the past and could potentially occupy in the future.

2.3 100-Year Erosion Assessment

A 100-year erosion assessment was conducted at select reach lengths in accordance with procedures outlined by Toronto and Region Conservation Authority (TRCA, 2007). The development of the 100-year erosion limit considered the average rate of channel migration in the vicinity of the existing bridge culvert crossings and was based on similar activities described for the meander belt width assessment (Section 2.2), namely an analysis of historical aerial photographs and a field reconnaissance.

3.0 RESULTS

3.1 Background Review and Field Inspections

To account for changes in fluvial geomorphologic characteristics along a channel, watercourses are typically separated into reaches that display similar physical characteristics and controls on channel morphology. With reference to Figures 1 and 2, field observations in combination with a review of available base mapping and air photographs identified one reach length at the Rouge River (described herein as RR-01) and two reach lengths at the unnamed tributary (UT-01 and UT-02). Of note, the delineation of the reach breaks for RR-01 (i.e., upstream and downstream boundaries of the reach length) were based on observed changes in hydrology and valley confinement at the channel, recognizing that the upstream reach break is located immediately downstream of the confluence between the main stem of the Rouge River and a prominent tributary, while the downstream reach break is located in an area where the meander pattern of the channel transitions from confined to unconfined conditions (with consideration of the unaltered channel configuration from the historical air photo record – refer to Section 3.2.2).

The key characteristics of the reach lengths at the Rouge River and unnamed tributary are outlined in Tables 1 and 2. Photographs taken at the site visit of the reach lengths are presented in Attachment A.

Table 1: Key Results from Background Review and Field Inspections at Rouge River (RR-01)

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance

RR-01	- Medium to large sized permanent watercourse with well-defined channel (i.e., incised with visible bed and bank) that includes:
	  - mostly alluvial controls;
	  - variable sinuosity (i.e., channel planform is relatively straight in the vicinity of the existing bridge crossing at Kennedy Road, and meandering at the downstream end of the reach);
	  - limited bed morphology (flat);
	  - slight to moderate entrenchment; and
	  - numerous examples of instream woody debris or overhanging trees.
	
	- Erosion and/or depositional features at the channel that include:
	  - examples of sediment deposition along the bed; and,
	  - instances of bank erosion, recognizing however that the riparian zones and the upper portion of the banks were for the most part well protected against erosion with a dense cover of vegetation.
	
	- The existing meander pattern at the downstream end of the reach is largely confined by the valley walls, while the channel at the Kennedy Road crossing (upstream end of reach) is unconfined.
		13 to 15 m	- Silty fine sand at channel bed (D_{50} = 0.07 mm)
			
			- Medium sand with silt and organics at banks (D_{50} = 1 mm)
				- Riparian areas upstream and downstream of the existing bridge crossing at Kennedy Road include a dense cover of shrubs, grasses and small trees, noting that the downstream overbank zone supports an increased number of larger/mature trees.
				
				- Riparian area under the bridge crossing at Kennedy Road is mostly bare (little to no vegetation cover) and supports pedestrian trails on each side of the river.
					- Channel and riparian zone include evidence of high flood stage (e.g., grasses and other debris accumulated on the branches of trees at the overbank zone, trail closure signs due to flood waters, etc.).
					
					- A prominent tributary joins the main stem channel at a location immediately upstream of the upstream reach break.
					
					- Pedestrian bridge crossings at the Rouge River are maintained at locations approximately 100 m upstream of the Kennedy Road crossing, and approximately 350 m downstream.
					
					- Flow conditions at the time of the field reconnaissance were noticeably turbid.

Table 2: Key Results from Background Review and Field Inspections at Unnamed Tributary (UT-01 to UT-02)

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance
UT-01 (Immediately Upstream of Kennedy Road)	- Roadside ditch that is characterized by a broad trapezoidal channel with a defined trough or notch at the base of the feature (that conveys higher frequency flow events). - The ditch holds a discernible shape and alignment but represents an engineered feature with no natural channel form.	<1 m (at the defined trough)	- Silty clay with fine sand and organics at bed and banks	- Channel margins include mostly low lying vegetation (i.e., manicured grass cover), while channel bed supports cattails and other instream vegetation.	- Upstream end of the reach length (inflow area) includes one concrete box culvert, while the downstream end of the reach length (outflow area) includes two CSP culverts.
UT-02 (Immediately Downstream of Kennedy Road)	- Small intermittent watercourse or drainage feature with a moderately defined channel that includes low sinuosity, limited bed morphology, and relatively stable conditions (i.e., well vegetated bank and/or riparian areas with limited evidence of erosion and sedimentation). - The drainage feature holds a discernible shape and alignment but represents an engineered feature with little to no natural channel form.	4 m	- Silty fine sand with organics and fine gravel at channel bed (D_{50} = 0.07 mm) - Silt with fine sand at banks (D_{50} = 0.06 mm)	- Riparian areas include a dense cover of shrubs, grasses and small and large trees.	- Upstream end of the reach length (inflow area) includes two CSP culverts, while the downstream end of the reach length (outflow area) includes one concrete box culvert. - Various woody and concrete debris was noted at the channel at the time of the field reconnaissance.

Based on the above, evidence of natural channel form and function was limited to RR-01, recognizing that the drainage features at UT-01 and UT-02 are largely engineered. For this reason, detailed field activities, coupled with meander belt width and 100-year erosion assessments, were targeted at RR-01 alone.

The completed RGA forms for RR-01, UT-01 and UT-02 are presented in Attachment B. Grain size results for these reaches are presented in Attachment C. The results of the RGAs suggest that the evaluated reach lengths at the Rouge River and unnamed tributary are relatively stable.

3.2 Meander Belt Assessment

3.2.1 Aerial Photography Analysis

A historical air photograph analysis was completed in support of the meander belt assessment, and relied on aerial photography and orthoimagery from 1954, 1970, 1988, and 2016. These images/photos were used to evaluate changes in channel patterns and surrounding land use over time at the Rouge River (RR-01) and the unnamed tributary (UT-01 and UT-02).

The air photograph analysis (1954-2016) demonstrated that historical land use in the vicinity of RR-01 and UT-01/UT-02, as well as in the upstream catchment areas of these watercourses, was predominated by agriculture up until at least 1970. From there, the air photos/images showed that land use transitioned to primarily residential development in the areas surrounding the Rouge River valley (with the emergence of some commercial and light industry properties at and to the south of the intersection of Kennedy Road and Highway 7), and mostly commercial and industrial development in the vicinity of the unnamed tributary. Further to this, the analysis demonstrated that the construction of Kennedy Road and several other local side roads occurred between 1970 and 1988.

Riparian vegetation within the areas of investigation has been historically moderate in density, consisting of tree, shrub and grass cover. In some instances, this vegetation cover limited direct observation of features on the ground. Nevertheless, the channel at RR-01 was visible on a fairly consistent basis on all of the available aerial photography and orthoimagery (i.e., 1954, 1970, 1988, and 2016), while the channel at UT-01 and UT-02 was discernible in all of the photos/images with the exception of 1954.

The channel at the Rouge River (RR-01) appears to have been significantly altered prior to 1988. For this reason, the observed changes in channel patterns at the study reach are summarized below for the periods before and after 1988:

- Prior to 1988 (captured in the photos/images from 1954 and 1970) and the construction of Kennedy Road, the air photograph analysis showed that the channel followed a strong meandering pattern along the full extent of the study reach, noting a series of five prominent meander bends that trended in a generally east to west direction before transitioning toward the south where the channel becomes confined by the valley wall on the right bank or southern side of the channel. A comparison of the channel planform in 1954 and 1970 demonstrated active migration (i.e., noticeable evidence of lateral movement) of the identified meander bends.

- From 1988 onward (captured in the photos/images from 1988 and 2016), the air photograph analysis showed that the channel planform at the upstream end of the study reach has been noticeably altered (relative to the observed channel pattern in 1954 and 1970). The watercourse now follows a mostly straight alignment in the vicinity of the Kennedy Road crossing (in place of the broad sweeping meander bend that was formerly present in the area – refer to Figure 3). The results suggest that the channel at the upstream section of the reach was re-aligned and straightened before 1988 to accommodate the roadway crossing, while the channel at the downstream portion of the reach was left to adjust naturally. The review of the photos/images from 1988 and 2016 also demonstrated the addition of a stormwater management pond near the downstream end of the study reach, noting that this feature appears to connect to the Rouge River at a location approximately 200 m downstream of the Kennedy Road crossing. A comparison of the channel planform in 1988 and 2016 showed only minor adjustments (i.e., limited evidence of lateral movement) both at the re-aligned/straightened section of channel at the upstream end of the reach, as well as at the meandering section of channel at the downstream end of the reach.

Similar to the observations at the Rouge River (RR-01) but a comparatively smaller scale, the channel at the unnamed tributary (UT-01 and UT-02) appears to have been substantially altered over the period of the historical air photo record. The observed changes in channel patterns at UT-01/UT-02 are summarized below:

- In 1970 and prior to the construction of Kennedy Road, the air photograph analysis showed that the channels at UT-01 and UT-02 were mostly straight and oriented generally south to north. The observed channel planform at these reach lengths likely reflects past re-alignment to accommodate agricultural practices (i.e., straightening of the channel along farm field breaks).

- In the more recent period of the air photo record (1988 and 2016) and following the construction of Kennedy Road, the analysis demonstrated that the channel planform at UT-01 has been significantly modified (relative to the observed channel pattern in 1970). The watercourse remains straight, but is now aligned southwest to northeast along the western side of Kennedy Road before flows from the channel are directed beneath the road via culverts. Further to this, the analysis showed that channel patterns at UT-02 remained relatively unchanged, noting however that the upstream end of the channel at this reach length has been re-located further to the east. The results suggest that portions of the channel at UT-01 and UT-02 were diverted and/or re-aligned before 1988 to accommodate the Kennedy Road crossing. A comparison of the channel patterns at UT-01/UT-02 in 1988 and 2016 showed only nominal adjustments, suggesting that, in the more recent period of the air photo record, the channel has been relatively fixed/stationary from a lateral stability standpoint.

3.2.2 Belt Width Calculations

The meander belt width estimate for the study reach at the Rouge River considered the following:

- The channel in the vicinity of the Kennedy Road crossing was shown to be re-aligned and straightened between 1970 and 1988. Based on TRCA protocols, it is understood that portions of the channel planform that have been previously modified no longer represent the natural meander potential of a watercourse, meaning that these altered sections of the channel prevent reliable measurements of a meander belt width. To that end and in accordance with TRCA guidelines, the meander belt width for the study reach at the Rouge River was determined based on the historical air photographs that recorded the position of the unaltered channel configuration. In other words, the belt width measurements were estimated with consideration for the strong meander pattern that formerly characterized channel conditions along the full extent of the study reach (including the section of channel at the Kennedy Road crossing that has since been re-aligned/straightened).
- The meander pattern at the study reach was observed to be confined by valley walls along both sides of the planform (based on the historical air photographs that recorded the position of the unaltered channel configuration). As such and in accordance with TRCA guidelines, the meander belt width was aligned with the top of the valley wall for the full extent of the study reach. The available topographic data from York Region was used to infer the top of valley wall along both sides of the planform (estimated to be at an average elevation of roughly 172 m asl), recognizing that a detailed topographic survey should be completed to refine this estimate.

Based on the above and with reference to Figure 5, the meander belt width at the Rouge River (RR-01) was estimated to range from approximately 120 m at the Kennedy Road crossing (i.e., the narrowest portion of the valley along the reach length) to approximately 270 m at a location 320 m downstream of the Kennedy Road crossing (i.e., the widest portion of the valley along the reach length).

3.3 100-Year Erosion Limit

In accordance with TRCA protocols, the 100-year erosion limit for the Rouge River (RR-01) was assessed based on the average rate of channel migration at the relevant study reach. Consistent with the approach used for the belt width calculation, the 100-year erosion assessment was determined with consideration for the historical air photographs that recorded the position of the unaltered channel configuration.

The 100-year erosion limit at RR-01 was assessed based on the average rate of channel migration at the following meander bends as shown on Figure 5:

- Meander Bend #1 (located 65 m upstream from Kennedy Road) – average mitigation rate of 50 cm/yr.
- Meander Bend #2 (located 220 m downstream from Kennedy Road) – average mitigation rate of 21 cm/yr.
- Meander Bend #3 (located approximately 500 m downstream of Kennedy Road) – average migration rate of 12 cm/yr.
- Meander Bend #4 (located approximately 760 m downstream of Kennedy Road) – average migration rate of 28 cm/yr.

In general, the estimates at each of the meander bends considered all of the available photos/images (i.e., 1954, 1970, 1988 and 2016). However, the calculations for Meander Bend #1 were based on the aerial photos from 1954 and 1970 alone, given that this meander bend is no longer present from 1988 onward (the channel at this location was re-aligned/straightened).

Based on the historical analysis, the 100-year erosion limit was estimated to be approximately 115 m. This 100-year erosion limit was determined by extending the average rate of migration at the most active meander bend over a 100-year time span (0.50 m/yr * 100 = 50 m), and then applying this distance to either side of the average width of the bankfull channel (50 m * 2 + 15 m = 115 m).

Of note, a closer examination of the erosion estimates identified above demonstrate that the rates of channel migration have been noticeably reduced in the more recent period of the historical air photo record, recognizing that, between 1988 and 2016, the average migration rates at Meander Bends #2 through #4 were shown to vary from 7 cm/yr to 28 cm/yr (equating to a 100-year erosion limit of 71 m).

4.0 SUMMARY AND CONCLUSIONS

A fluvial geomorphic assessment was completed at study reaches of the Rouge River (RR-01) and an unnamed tributary (UT-01 and UT-02) to support a Schedule C Municipal Class EA for the proposed roadway improvements at Kennedy Road from approximately Steeles Avenue to Major Mackenzie Drive. The results of a field reconnaissance at each of the reach lengths demonstrated that natural channel form and function was limited to RR-01, recognizing that the drainage features at UT-01 and UT-02 were shown to be largely engineered. For this reason, detailed field activities, coupled with meander belt width and 100-year erosion assessments, were targeted at RR-01 alone. The key findings of the assessment are summarized below:

- The results of the field studies at the reach length of the Rouge River (RR-01) suggest that the channel is generally stable, noting the following observations:
  - The channel planform is relatively straight and unconfined in the vicinity of the existing bridge crossing at Kennedy Road, and meandering and confined at the downstream end of the reach (the meander bend that formerly characterized channel conditions at the Kennedy Road crossing was re-aligned and straightened between 1970 and 1988, as confirmed by the results of the historical air photo analysis).
  - The channel geometry is moderately entrenched in several sections (i.e., well-incised between steeply sloped banks).
  - The channel included instances of bank erosion in a number of locations, recognizing however that the banks and riparian zones were for the most part well protected against erosion with a dense cover of vegetation.
- Based on the desktop analysis, the meander belt width of the channel ranges from approximately 120 m at the Kennedy Road crossing (i.e., the narrowest portion of the valley along the reach length) to approximately 270 m at a location 320 m downstream of the Kennedy Road crossing (i.e., the widest portion of the valley along the reach length), recognizing that, in accordance with TRCA guidelines, the meander belt width was aligned with the top of the valley wall for the full extent of the study reach.
- Based on the desktop analysis, the 100-year erosion limit of the channel is approximately 115 m.

It is understood that roadway improvements at Kennedy Road may involve upgrades or replacement of the existing bridge crossing at the Rouge River. According to TRCA protocols, crossing structures should be constructed outside of the meander belt width of a watercourse to the extent possible, or, alternatively, the features should be designed to match or exceed the 100-year erosion limit of the channel. However, for the study reach at the Rouge River, it is recognized that spanning a crossing structure the length of the estimated belt width or 100-year erosion limit of the channel would be impractical and cost prohibitive. Furthermore, Golder is of the opinion that the estimated dimensions of the meander belt width and 100-year erosion limit for this particular study are overly conservative, with consideration of the following:

- The meander belt width and 100-year erosion limit are not directly representative of current conditions in the vicinity of the Kennedy Road crossing, recognizing the following:
  - The belt width and 100-year erosion calculations for the study reach were estimated with consideration for historical air photographs from 1954, 1970, 1988 and 2016, noting that the photos/images from 1954 and 1970, in particular, were required to assess meander potential/migration for a formerly unaltered section of the channel configuration in the vicinity of the Kennedy Road crossing.
  - The channel at the Kennedy Road crossing has been heavily modified relative to the period of the historical air photo record that was used to assess the belt width and 100-year erosion limit for this particular location of the study reach (i.e., the meander bend that formerly characterized channel conditions in the vicinity of the Kennedy Road crossing was re-aligned and straightened between 1970 and 1988).
  - The channel at the Kennedy Road crossing is now straight and largely unconfined, noting that this section of channel, in particular, as well as the existing meander pattern at the downstream end of the reach (confined portion of the channel planform), has shown limited evidence of lateral movement over the past 28 years.
  - The valley in the vicinity of the Kennedy Road crossing has been re-configured to accommodate the existing bridge crossing (i.e., earthen embankments extend well into the previous limits of the valley feature), and would inherently reduce the opportunity for lateral channel movement at this location.
- The existing bridge span and adjoining abutments are located within the boundaries of the estimated belt width and 100-year erosion limit of the study reach.
- Any upgrade or replacement of the existing bridge crossing will be designed to convey up to and including the 100-year flow or Regional event; hence, major flows will be directed to the channel and bridge opening, with limited opportunities to outflank the crossing feature and erode a separate flow path.
- The air photograph analysis demonstrated that channel migration in the recent period of record (i.e., 1988 onward) has occurred at a relatively low rate, meaning that, if needed, any repairs or maintenance at the study reach could be readily accommodated within a reasonable timeframe.

For the reasons identified above and from the perspective of fluvial geomorphology, it is suggested, from a preliminary recommendations standpoint, that any upgrade or replacement of the existing bridge at the Rouge River crossing include a width of approximately 30 m, if feasible. This suggested crossing dimension represents two (2) times the average bankfull width of the channel. The suggested span for the proposed bridge is expected to provide sufficient opportunities to maintain channel form and function (e.g., sediment transport and fish passage).

The recommendations described above are based on the results of the fluvial geomorphology assessment alone. Any modification to the crossing spans will also need to consider input from other technical considerations, including the required hydraulic conditions (e.g., flood conveyance for the design event) and the relevant ecological functions (e.g., wildlife passage in the riparian zone).

5.0 CLOSURE

This Report was authored under a Subconsultant Agreement between HDR and Golder for the Regional Municipality of York's ("Owner") projects. The Report is provided to HDR and Regional Municipality of York for their use, utilizing their judgment, in fulfilling a portion of HDR's particular scope of work. No other party may rely upon this report, or any portion thereof, without Golder's express written consent and any reliance of the reports by others will be at that user's sole risk and liability, notwithstanding that they may have received this Report through an appropriate user. In addition, Golder shall not be liable for any use of the Report for any purpose other than that for which the same was originally prepared or provided by Golder, or any improper use of this Report, or to any party other than HDR.

We trust that this technical memorandum meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

GOLDER ASSOCIATES LTD.

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Attachments:

Figures:
Figure 1: Reach Length for Rouge River Crossing at Kennedy Road (RR-01)
Figure 2: Reach Length for Unnamed Tributary Crossing at Kennedy Road (UT-01 and UT-02)
Figure 3: Historical Channel Patterns for Rouge River Crossing at Kennedy Road (RR-01)
Figure 4: Historical Channel Patterns for Unnamed Tributary Crossing at Kennedy Road (UT-01 and UT-02)
Figure 5: Estimated Meander Belt Width for Rouge River Crossing at Kennedy Road (RR-01)

Attachment A – Photographs
Attachment B – Results of Rapid Geomorphic Assessments
Attachment C – Grain Size Distribution Curves

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FIGURES

LEGEND

- Flow Direction
- Watercourse
- Railway
- Estimated Centerline of Channel Beyond the Study Reach
- Reach Break
- Observed Channel Alignment at Study Reach (2016)
- Provincially Significant Wetland (Not Evaluated by OWES)

0 100 200 300

1:4,000 Metres

REFERENCE(S)

1. BASE DATA: MNRF LIO, REGION OF YORK OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
HDR INC

PROJECT
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGION OF YORK

TITLE
REACH LENGTH FOR ROUGE RIVER CROSSING AT KENNEDY ROAD (RR-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-27
DESIGNED	NP
PREPARED	NP/PR
REVIEWED	AF
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
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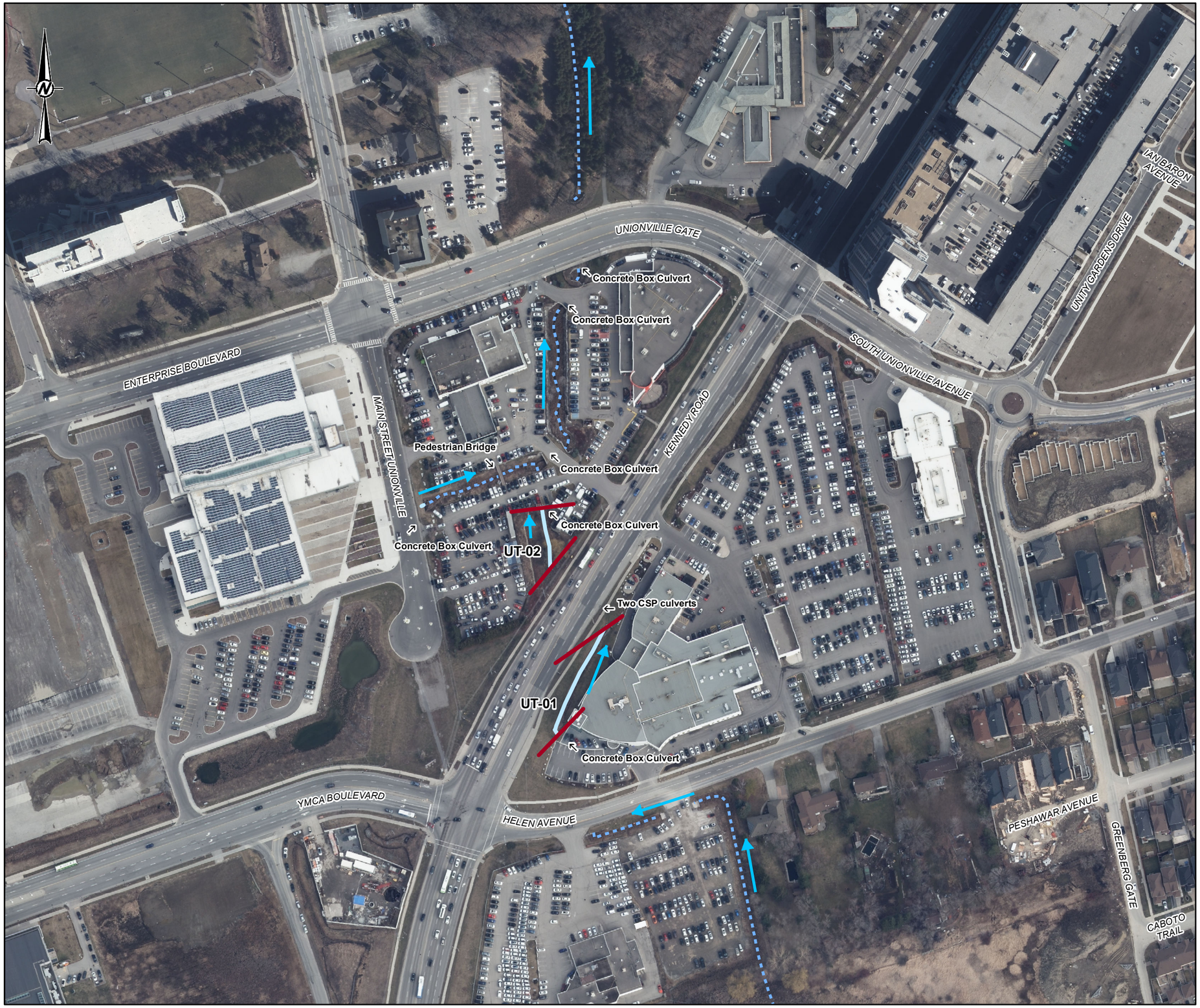

LEGEND

- Reach Break
- Observed Channel Alignment at Study Reach (2016)
- Estimated Centerline of Channel Beyond the Study Reach
- Flow Direction

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1:2,200 Metres

REFERENCE(S)

1. BASE DATA: MNRF LIO, REGION OF YORK OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGION OF YORK

TITLE

REACH LENGTH FOR UNNAMED TRIBUTARY CROSSING AT KENNEDY ROAD (UT-01 AND UT-02)

CONSULTANT

Golder Associates

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PREPARED	NP/PR
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APPROVED	AF

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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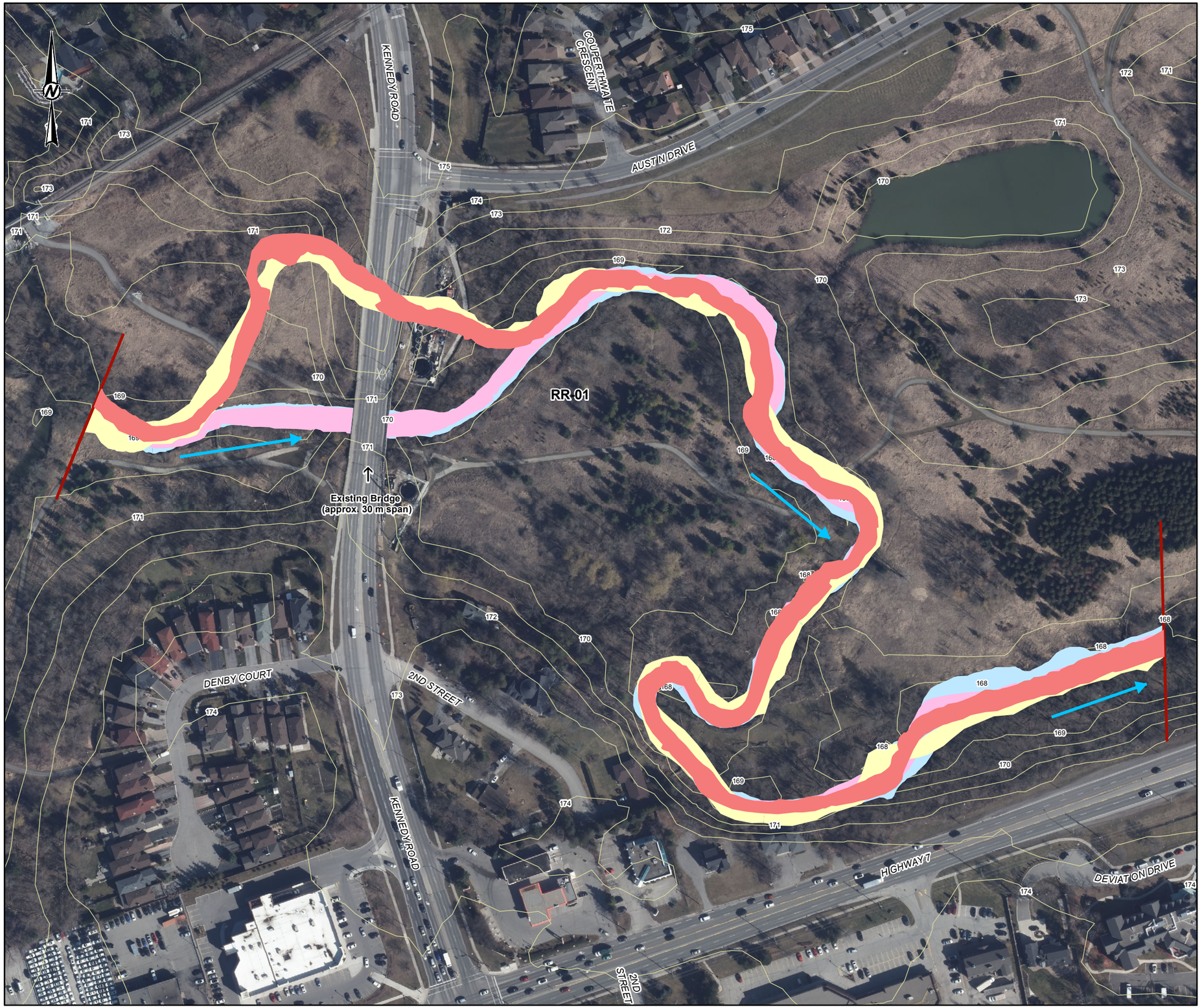


LEGEND

- Flow Direction
- 1m Contour Elevation
- Reach Break
- Observed Channel Alignment in 1954
- Observed Channel Alignment in 1970
- Observed Channel Alignment in 1988
- Observed Channel Alignment in 2016

0 25 50 75 100

1:2,000 Metres

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGION OF YORK

TITLE

HISTORICAL CHANNEL PATTERN FOR ROUGE RIVER CROSSING AT KENNEDY ROAD (RR-01)

CONSULTANT

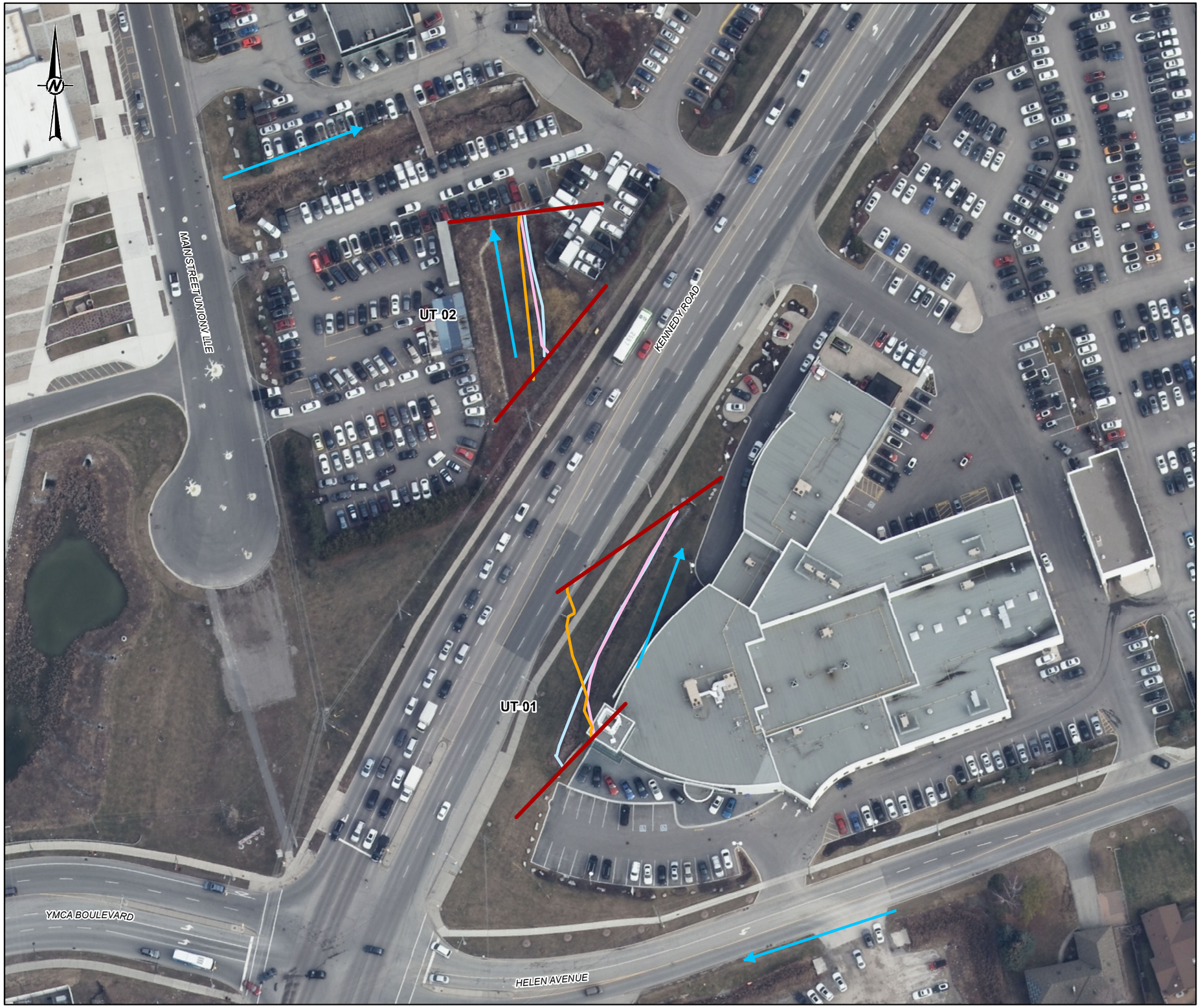
Golder Associates

YYYY-MM-DD	2017-11-23
DESIGNED	NP
PREPARED	NP/PR
REVIEWED	AF
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	0	3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

Path: S:\Clients\Region_of_York\Kennedy_Road\99_PRO\1664178_HDR\40_PRO\D\0004_Fluvial_Geomorphology\1664178-0004-CS-0003.mxd



LEGEND

- Flow Direction
- Reach Break
- Observed Channel Alignment in 1970
- Observed Channel Alignment in 1988
- Observed Channel Alignment in 2016

0 25 50 75

1:900 Metres

REFERENCE(S)

1. BASE DATA: MNRF LIO, REGION OF YORK OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
HDR INC.

PROJECT
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGION OF YORK

TITLE
HISTORICAL CHANNEL PATTERN FOR UNNAMED TRIBUTARY CROSSING AT KENNEDY ROAD (UT-01 AND UT-02)

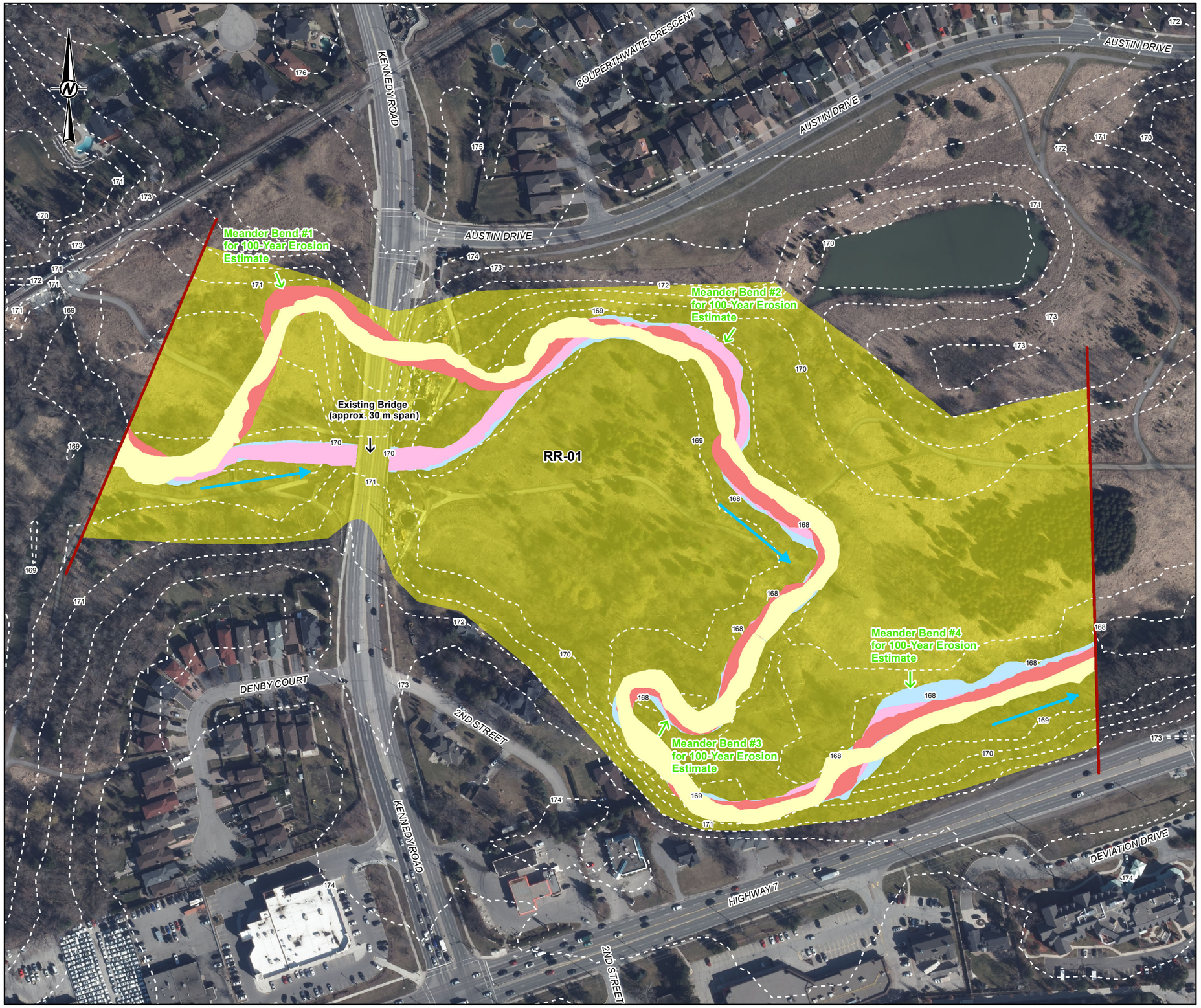
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-23
DESIGNED	NP
PREPARED	NP/PR
REVIEWED	AF
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	0	4

Path: S:\Clients\Region_of_York\Kennedy_Road\99_PRO\1664178_HDR\40_PROD\0004_Fluvial_Geomorphology\1664178-0004-CS-0004.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



LEGEND

- Flow Direction
- 1m Contour Elevation
- Reach Break
- Observed Channel Alignment in 1954
- Observed Channel Alignment in 1970
- Observed Channel Alignment in 1988
- Observed Channel Alignment in 2016
- Estimated Meander Belt Width

0 50 100 150

1:2,200 Metres

REFERENCE(S)

1. BASE DATA: MNRF LIO, REGION OF YORK OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
HDR INC.

PROJECT
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGION OF YORK

TITLE
ESTIMATED MEANDER BELT WIDTH FOR ROUGE RIVER CROSSING AT KENNEDY ROAD (RR-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-27
DESIGNED	NP
PREPARED	NP/PR
REVIEWED	AF
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	0	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

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ATTACHMENT A
Photographs

Photograph 1: Rouge River; view looking cross channel at existing bridge crossing.

Photograph 2: Rouge River; view looking upstream from a location approximately 25 m upstream of the crossing.

Photograph 3: Rouge River; view looking downstream from a location approximately 75 m downstream of the crossing.

Photograph 4: Unnamed Tributary; view looking upstream at a location approximately 25 m upstream of the crossing.

Photograph 5: Unnamed Tributary; view looking upstream at a location approximately 10 m downstream of the crossing.

ATTACHMENT B

Results of Rapid Geomorphic Assessments

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 04-Jul-17 Location: Rouge River (RR-01)

Field Staff: Brian Lingelbach Project #: 1664178

FORM/ PROCESS	GEOMORPHIC INDICATOR #	DESCRIPTION	PRESENT (YES) OR ABSENT (NO)	
Evidence of Aggradation (AI)	1	Lobate bar		No
	2	Coarse material in riffles embedded		No
	3	Siltation in pools	Yes	
	4	Medial bars		No
	5	Accretion on point bars		No
	6	Poor longitudinal sorting of bed materials		No
	7	Deposition in the overbank zone	Yes	
		RATIO OF INDICES [(1)]	2/7 = 0.29	
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		No
	2	Exposed sanitary/storm sewer/pipeline/etc.	N/A	
	3	Elevated storm sewer outfall(s)		No
	4	Undermined gabion baskets/concrete aprons/etc.	N/A	
	5	Scour pools d/s of culverts/stormsewer outlets		No
	6	Cut face on bar forms		No
	7	Head cutting due to knick point migration		No
	8	Terrace cut through older bar material		No
	9	Suspended armor layer visible in bank		No
	10	Channel worn into undisturbed overburden/bedrock		No
		RATIO OF INDICES [(1)]	0/8 = 0	
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	Yes	
	2	Occurrence of large organic debris	Yes	
	3	Exposed tree roots	Yes	
	4	Basal scour on inside meander bends		No
	5	Basal scour on both sides of channel through riffle		No
	6	Gabion baskets/concrete walls/etc. out flanked		No
	7	Length of basal scour > 50% through subject reach		No
	8	Exposed length of previously buried pipe/cable/etc.	N/A	
	9	Fracture lines along top of bank		No
	10	Exposed building foundation	N/A	
		RATIO OF INDICES [(1)]	3/8 = 0.38	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(s)		No
	2	Single thread channel to multiple channel		No
	3	Evolution of pool-riffle form to low bed relief form		No
	4	Cutoff channel(s)		No
	5	Formation of island(s)		No
	6	Thalweg alignment out of phase meander form		No
	7	Bar forms poorly formed/reworked/removed		No
		RATIO OF INDICES [(1)]	0/7 = 0	
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4 [(2)]			0.17	

Notes:

[1] Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices.

[2] Stability Index or SI values inferred as follows: 0.20 or lower = In Regime; 0.21 to 0.40 = Transitional or Stressed; and 0.41 or higher = In Adjustment.

Sourced and adapted from: *Ontario Ministry of the Enviroment, 2003. Stormwater Management Planning and Design Manual.*

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 04-Jul-17 Location: Unnamed Tributary (UT-01)

Field Staff: Brian Lingelbach Project #: 1664178

FORM/ PROCESS	GEOMORPHIC INDICATOR #	DESCRIPTION	PRESENT (YES) OR ABSENT (NO)
Evidence of Aggradation (AI)	1	Lobate bar	No
	2	Coarse material in riffles embedded	N/A
	3	Siltation in pools	No
	4	Medial bars	No
	5	Accretion on point bars	No
	6	Poor longitudinal sorting of bed materials	No
	7	Deposition in the overbank zone	No
		RATIO OF INDICES [(1)]	0/6 = 0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A
	2	Exposed sanitary/storm sewer/pipeline/etc.	N/A
	3	Elevated storm sewer outfall(s)	No
	4	Undermined gabion baskets/concrete aprons/etc.	N/A
	5	Scour pools d/s of culverts/stormsewer outlets	No
	6	Cut face on bar forms	No
	7	Head cutting due to knick point migration	No
	8	Terrace cut through older bar material	No
	9	Suspended armor layer visible in bank	No
	10	Channel worn into undisturbed overburden/bedrock	No
		RATIO OF INDICES [(1)]	0/7 = 0
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	No
	2	Occurrence of large organic debris	No
	3	Exposed tree roots	No
	4	Basal scour on inside meander bends	No
	5	Basal scour on both sides of channel through riffle	No
	6	Gabion baskets/concrete walls/etc. out flanked	No
	7	Length of basal scour > 50% through subject reach	No
	8	Exposed length of previously buried pipe/cable/etc.	N/A
	9	Fracture lines along top of bank	No
	10	Exposed building foundation	N/A
		RATIO OF INDICES [(1)]	0/8 = 0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(s)	No
	2	Single thread channel to multiple channel	No
	3	Evolution of pool-riffle form to low bed relief form	No
	4	Cutoff channel(s)	No
	5	Formation of island(s)	No
	6	Thalweg alignment out of phase meander form	No
	7	Bar forms poorly formed/reworked/removed	Yes
		RATIO OF INDICES [(1)]	1/7 = 0.14
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4 [(2)]			0.04

Notes:

[1] Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices.

[2] Stability Index or SI values inferred as follows: 0.20 or lower = In Regime; 0.21 to 0.40 = Transitional or Stressed; and 0.41 or higher = In Adjustment.

Sourced and adapted from: *Ontario Ministry of the Enviroment, 2003. Stormwater Management Planning and Design Manual.*

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 04-Jul-17 Location: Unnamed Tributary (UT-02)

Field Staff: Brian Lingelbach Project #: 1664178

FORM/ PROCESS	GEOMORPHIC INDICATOR #	DESCRIPTION	PRESENT (YES) OR ABSENT (NO)	
Evidence of Aggradation (AI)	1	Lobate bar		No
	2	Coarse material in riffles embedded	N/A	
	3	Siltation in pools	Yes	
	4	Medial bars		No
	5	Accretion on point bars		No
	6	Poor longitudinal sorting of bed materials	Yes	
	7	Deposition in the overbank zone		No
		RATIO OF INDICES [(1)]	2/6 = 0.33	
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A	
	2	Exposed sanitary/storm sewer/pipeline/etc.	N/A	
	3	Elevated storm sewer outfall(s)		No
	4	Undermined gabion baskets/concrete aprons/etc.	N/A	
	5	Scour pools d/s of culverts/stormsewer outlets		No
	6	Cut face on bar forms		No
	7	Head cutting due to knick point migration		No
	8	Terrace cut through older bar material		No
	9	Suspended armor layer visible in bank		No
	10	Channel worn into undisturbed overburden/bedrock		No
		RATIO OF INDICES [(1)]	0/7 = 0	
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	Yes	
	2	Occurrence of large organic debris	Yes	
	3	Exposed tree roots		No
	4	Basal scour on inside meander bends		No
	5	Basal scour on both sides of channel through riffle		No
	6	Gabion baskets/concrete walls/etc. out flanked		No
	7	Length of basal scour > 50% through subject reach		No
	8	Exposed length of previously buried pipe/cable/etc.	N/A	
	9	Fracture lines along top of bank		No
	10	Exposed building foundation	N/A	
		RATIO OF INDICES [(1)]	2/8 = 0.25	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(s)		No
	2	Single thread channel to multiple channel		No
	3	Evolution of pool-riffle form to low bed relief form		No
	4	Cutoff channel(s)		No
	5	Formation of island(s)		No
	6	Thalweg alignment out of phase meander form		No
	7	Bar forms poorly formed/reworked/removed	Yes	
		RATIO OF INDICES [(1)]	1/7 = 0.14	
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4 [(2)]			0.18	

Notes:

[1] Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices.

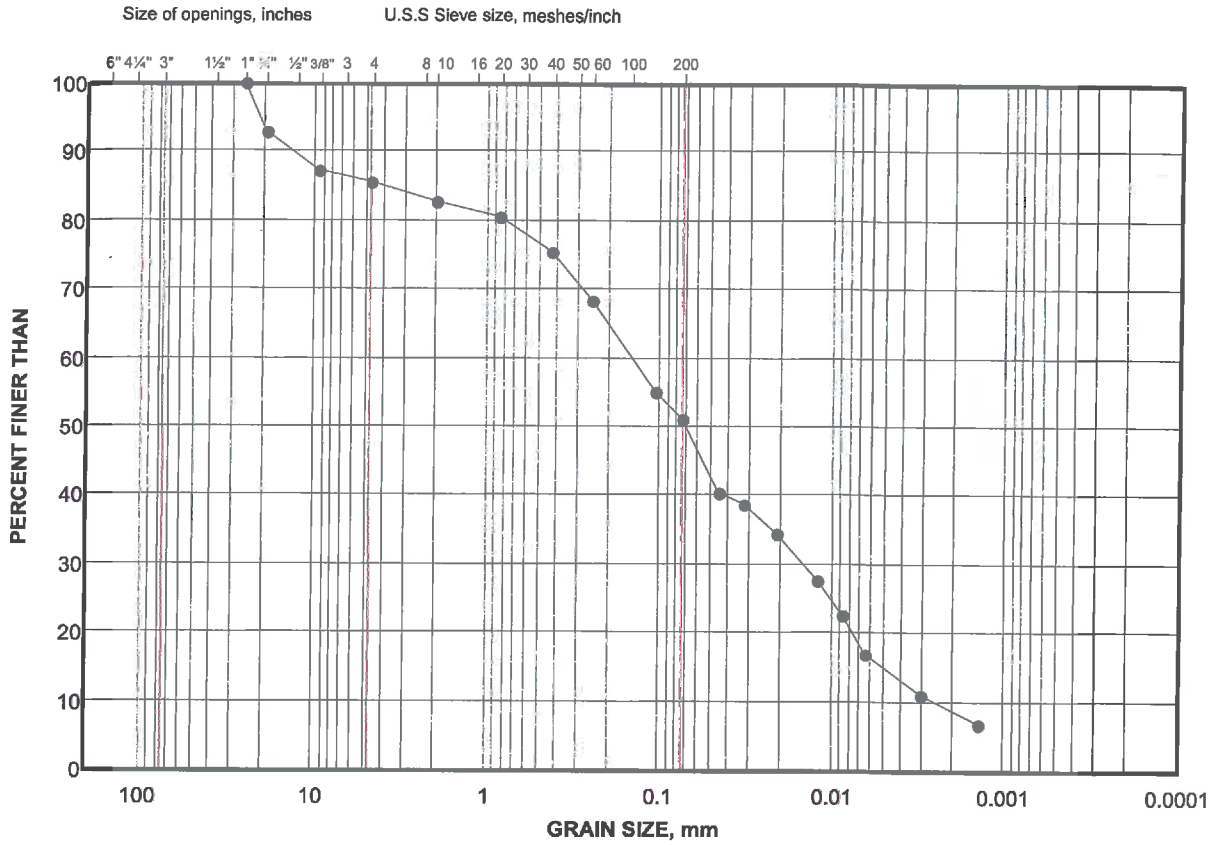
[2] Stability Index or SI values inferred as follows: 0.20 or lower = In Regime; 0.21 to 0.40 = Transitional or Stressed; and 0.41 or higher = In Adjustment.

Sourced and adapted from: *Ontario Ministry of the Enviroment, 2003. Stormwater Management Planning and Design Manual.*

ATTACHMENT C
Grain Size Distribution Curves

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	1

Project Number: 1664178

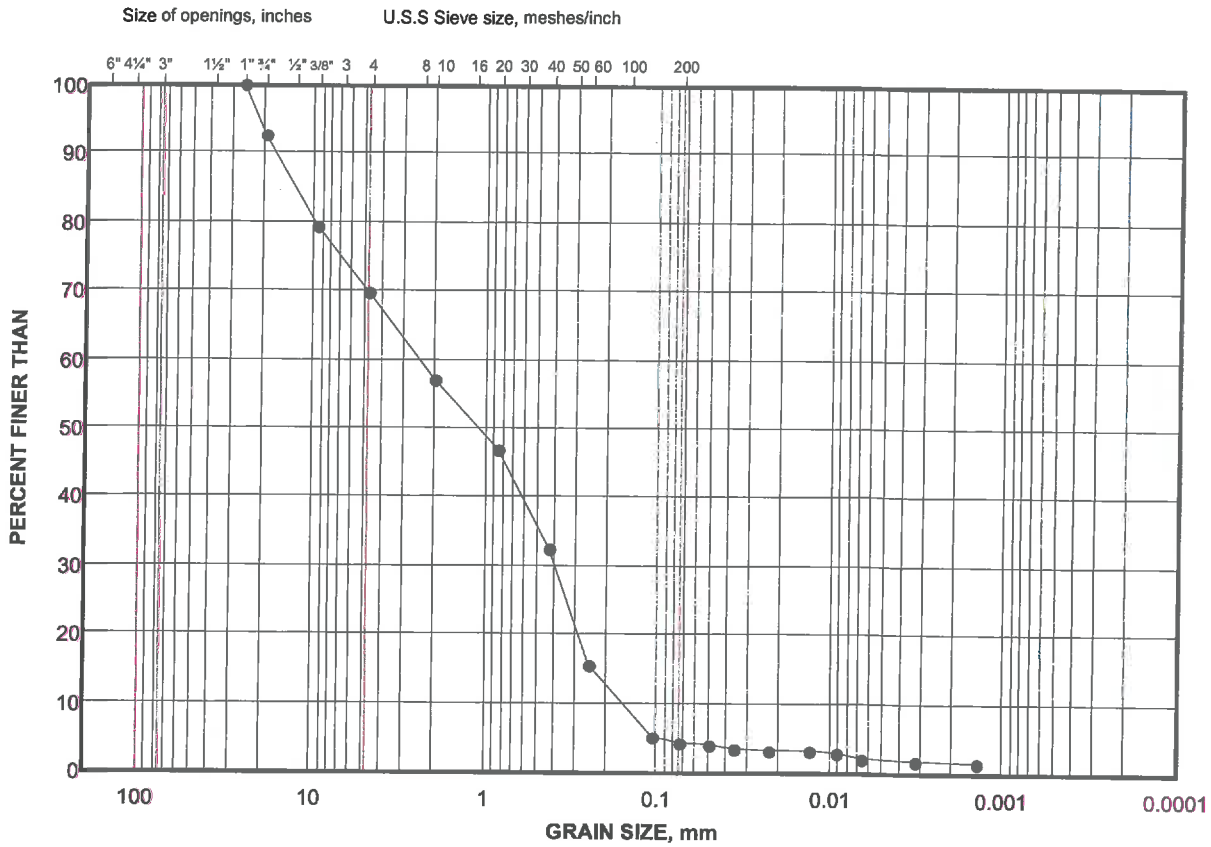
Checked By: _____

Golder Associates

Date: 13-Jul-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	2

Project Number: 1664178

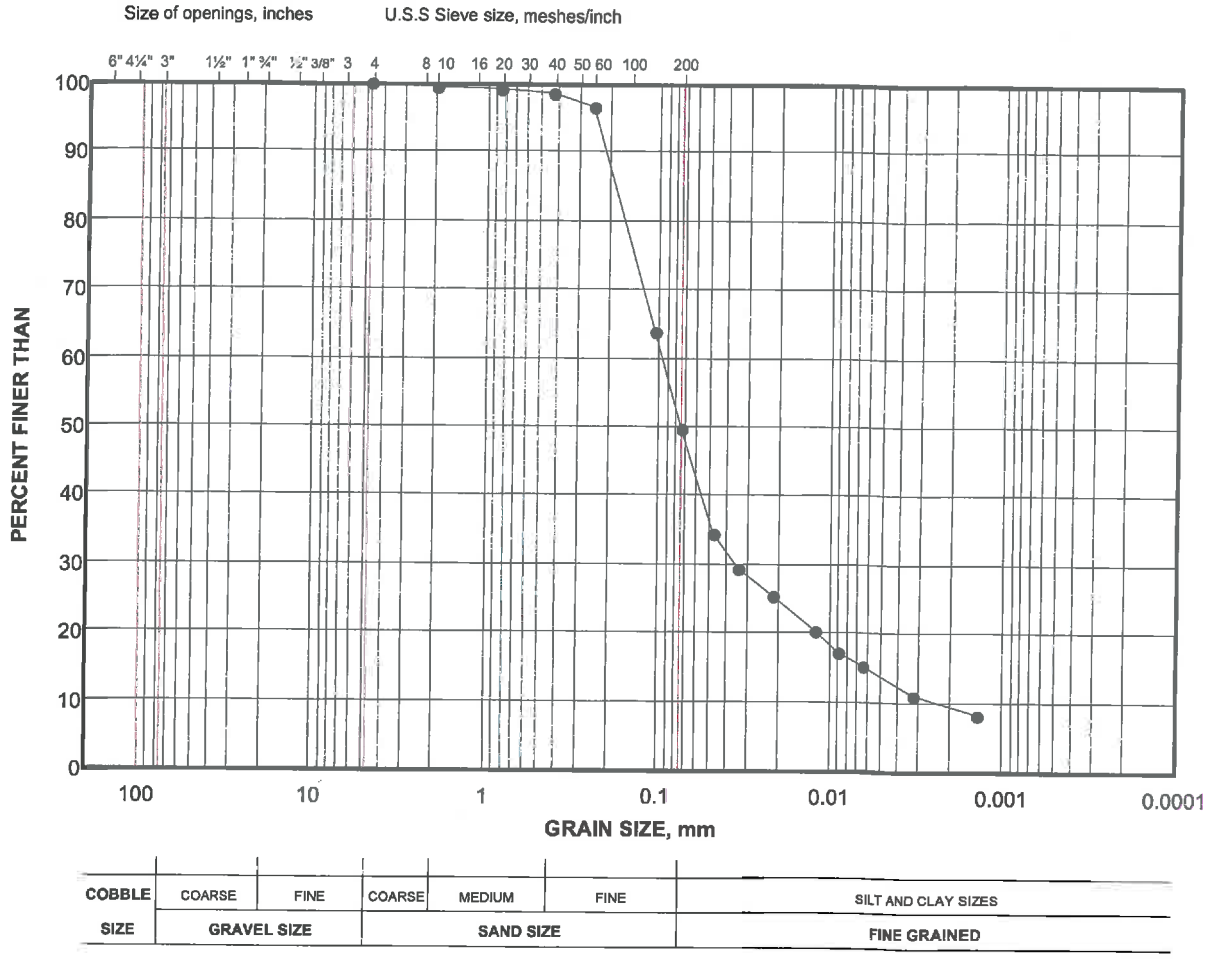
Checked By: _____

Golder Associates

Date: 13-Jul-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	3

Project Number: 1664178

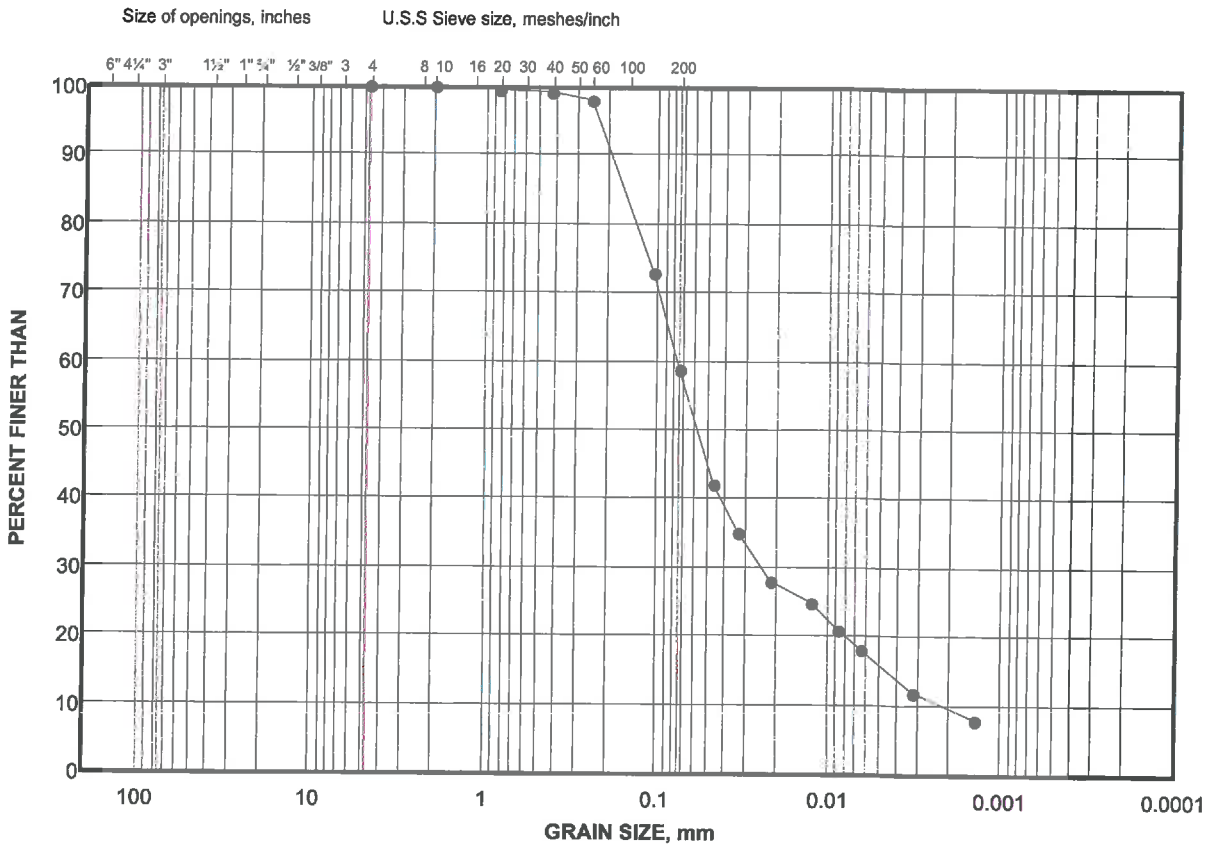
Checked By: _____

Golder Associates

Date: 14-Jul-17

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	SAMPLE
●	4

Project Number: 1664178

Checked By: _____

Golder Associates

Date: 14-Jul-17