Fluvial Geomorphology Assessment and Erosion Mitigation Analysis

Nichol Drain

Elora, Ontario

Prepared for:
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1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained to complete a fluvial geomorphology assessment and erosion mitigation analysis in support of the Elora Sands Development Lands ("subject lands") in Elora, Ontario. The subject lands are generally bounded by Sideroad 15 to the west, Gerrie Road to the north, Irvine Street to the south, and agricultural lands to the east (**Appendix A**). The Nichol Drain flows generally in an east to west orientation through the northern portion of the subject lands. The Nichol Drain is a historically straightened municipal drain constructed in the 1920's. The form and function of the drain were historically maintained by the municipality, limiting the migration potential of the drainage feature.

This fluvial geomorphology assessment is a comprehensive study that includes watercourse characterization and delineation of erosion hazards. This information is crucial to identifying the opportunities and constraints to development. The report also summarizes erosion mitigation targets to address stormwater management requirements for the Nichol Drain.

Specifically, the following activities were completed by GEO Morphix as part of the fluvial geomorphology assessment:

- Review of available background reports and mapping (i.e., watershed/subwatershed studies, geology, topography, conceptual development plans)
- Refine watercourse reaches previously delineated in the SSWS based on a desktop assessment of available data and confirmed through field reconnaissance
- Review recent and historical aerial photographs to understand historical changes in channel form and function, land use and land cover
- Conduct reach-level rapid geomorphological field assessments following standard protocols (e.g., RGA, RSAT) to evaluate instream and riparian conditions
- Complete detailed geomorphological field surveys to support the overall erosion mitigation plan for stormwater management
- Delineate the erosion hazard for the Nichol Drain in support of defining, in part, the limit of development
- Provide support in the development of an erosion mitigation approach for the future stormwater management plan

2 Background Review

The Nichol Drain is a tributary of Irvine Creek, within the Grand River Watershed and is located in Elora Ontario. The Nichol Drain subwatershed originates in the northwestern portion of Fergus and spans approximately 750 ha. The Nichol Drain flows in a generally east to west orientation and drains into Irvine Creek, roughly 150 m west of Irvine Street in Elora. The Nichol Drain subwatershed is largely dominated by agricultural land use with urban development becoming more present in the watershed.

2.1 Nichol Drain Subwatershed Study (Aquafor Beech, 2008)

A Subwatershed Study (SWS) for the Nichol Drain was completed in 2008 by Aquafor Beech Limited, which included information on existing conditions for the Nichol Drain and surrounding lands. The SWS notes that the Nichol Drain had been improved as a municipal drain since the early 1920s and was historically straightened and maintained as a ditch feature. Although in 2008 when the SWS was published, it was evident that the drain had not been recently maintained and was showing signs of adjustment, including more naturalized channel morphology.

The Nichol Drain SWS also included a high-level assessment of the lateral channel migration potential for the Nichol Drain, supporting future constraint delineation. Given the limited sinuosity and historic modifications that have occurred along the drain, the SWS reviewed surrogate reaches with similar geology and drainage area. Meander belt widths of 32 m and 45 m were mapped from surrogate reaches in the nearby Irvine Creek subwatershed to provide context for the migration potential of the Nichol Drain.

A fluvial geomorphological assessment was completed as part of the SWS and included reach delineation and an evaluation of channel stability and sensitivity for the Nichol Drain. Reaches are homogenous segments of channel used in geomorphological investigations and are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach in relation to a proposed activity. Geomorphic reaches were first delineated through desktop assessment and then field-verified in the SWS, where field access was permitted. Six (6) main reaches were delineated for the Nichol Drain, and various sub-reaches were defined to document variability within the main reaches. A reach delineation map is provided in **Appendix A**, which reflects the SWS reach delineation for the Nichol Drain in the context of the subject lands.

Nichol Drain Sub-reach 2a and a portion of sub-reach 2b are located within the Elora Sands subject lands. These reaches drain to Reach 1 and Reach 0 downstream of Sideroad 15. SWS field observations indicate that Reach 2 was a straightened ditch with limited bed morphology. The channel substrate contained gravel and sand but was largely vegetation controlled due to the presence of grasses. Most reaches of the Nichol Drain were considered stable with processes of aggradation occurring. Reach 0 and Reach 1 – downstream of Sideroad 15 and the subject lands – were the exception and were documented as moderately stable with evidence of minor degradation and widening. This is likely due to steeper channel gradients along these reaches. Areas of erosion concern were not specifically documented in the SWS, but it was suggested that Reaches 0 and 1 may be sensitive to future changes in hydrology. Given that the SWS was finalized in 2008, GEO Morphix has completed an updated fluvial geomorphological assessment that is site specific for the subject lands.

3 Desktop Assessment

3.1 Physiography and Surficial Geology

Channel morphodynamics are governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity. Understanding local surficial geology is crucial for determining appropriate erosion thresholds, as the stability of the channel banks and bed depends on the composition of soils, sediment, and underlying parent materials (MNR, 2002).

The subject lands are situated within the Guelph Drumlin Field physiographic region, which is characterized by drumlinized till plains and glacial meltwater channels (Chapman and Putnam, 2007). The SWS (Aquafor Beech, 2008) provides an overview of surficial geology, noting that the area is dominated by glacio-fluvial outwash sand with localized concentrations of outwash gravel to the north and south of the Nichol Drain. This is consistent with the most recent surficial geology mapping published by the Ontario Geological Survey (OGS) (2010) for the subject lands.

3.2 Historical Assessment

A series of historical aerial photographs was reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides insight into the historical factors that have contributed to current channel morphodynamics and potentially how past changes may impact channel planform in the future. Aerial photographs from 1930 (1:20,000), 1964 (1:20,000), 1980 (1:50,000), 1990 (1:50,000) form the National Air Photo Library (NAPL), as well as recent satellite imagery for the years 2006, 2014, and 2024 from Google Earth Pro, were reviewed to understand site history and inform the erosion hazard assessment. Historical aerial photographs are provided in **Appendix B** for reference.

In 1930 the subject lands and surrounding areas' land use was dominated by agricultural practices. The Nichol Drain had been previously straightened throughout the extent of the historical imagery, resulting in a linear planform. Riparian vegetation was limited to small woodlots along the drainage feature and its confluence with Irvine Creek at the downstream extent. Within the subject lands a residential property was present with hedgerows of trees along the driveway.

By 1964 minimal changes to the Nichol Drain and subject lands were observed. Additional treed vegetation was present along the downstream extent. The subject lands and surrounding area to the north, east, and south remained agricultural fields. Residential and commercial developments were established to the west and south of the subject lands along Irvine Creek and the Grand River, creating the Town of Elora.

Between 1964 and 1980 minimal changes to the subject lands and surrounding area were observed. The planform of the Nichol Drain remained linear with no changes to the form observed. Due to the scale of the historical imagery, changes to the riparian buffer of the municipal drain were difficult to discern. By 1990 Elora had further expanded north towards the subject lands. In addition, residential and commercial developments were established in Fergus located at the headwaters of the Nichol Drain. However, the planform and riparian vegetation along the municipal drain remain largely unchanged.

Between 1990 and 2024, a woodlot had formed immediately downstream of 15 Sideroad and the subject lands where the municipal drain flows through before its confluence with Irvine Creek. Ultimately, no changes were observed to the Nichol Drain through the subject lands or downstream.

4 Watercourse Characteristics

4.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method enables a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a reach, for example, as it relates to a proposed activity. Reaches are typically delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004). Reaches are first delineated as a desktop exercise using available data and information such as aerial photography, topographic maps, geological information and physiography maps. The results are then verified in the field.

Reaches within the subject lands were previously delineated as part of the SWS (Aquafor Beech, 2008) and confirmed by GEO Morphix staff during field investigations. Within the subject lands two (2) reaches were delineated along the Nichol Drain. **Reach R2b** initiates upstream of Gerrie Road and ends approximately midway through the subject lands. **Reach R2a** begins at the downstream extent of **Reach** R2b and flows to 15 Sideroad. Reach delineation is graphically presented in **Appendix A**.

4.2 Reach Observations

Field investigations were completed on April 15, 2025, and included the following observations on a reach basis:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Confirmation of valley form (i.e., unconfined, partially confined, confined)
- Observations of erosion, scour, or deposition
- Collection of photographs to document watercourses, riparian areas, adjacent land use, and channel disturbances such as crossing structures

These observations and measurements are summarized in **Table 1**. Field descriptions are supplemented and supported with representative photographs included in **Appendix C**. Field sheets, including those completed for reach characterization and rapid assessments, are provided in **Appendix D**.

Table 1: General reach characteristics

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Bed Substrate	Bank Materials	Valley Type	Dominant Riparian Conditions	Notes
R2a	3.27	0.76	Sand, gravel, and cobble	Sand and gravel	Unconfined	Moderate riparian buffer of grasses	Linear drainage feature with moderate bank erosion
R2b	3.13	0.84	Sand, gravel, and cobble	Sand and gravel	Unconfined	Moderate riparian buffer of grasses	Linear drainage feature with poor sediment sorting

Reach R2a initiates at **Reach R2b** and flows northwest for approximately 315 m to Sideroad 15. The reach was historically straightened to function as a municipal drain, resulting in a linear planform. The riparian buffer was characterized as a continuous coverage of grasses spanning 4 to 10 channel widths. Riffles and runs were the predominant bed morphology observed with bed substrate comprised of sand, gravel and cobbles. Average bankfull width and depth ranged from 2.10 m to 4.50 m and 0.70 m to 0.85 m, respectively. Bank angles were moderately steep, ranging from 30° to 60°, and erosion was observed along 30% to 60% of the banks in the form of undercutting and scour.

Reach R2b begins upstream of the subject lands along a hedgerow adjacent to Gerrie Road and flows northwest for approximately 850 m to **Reach R2a**. As the Nichol Drain is a maintained feature, observations for **Reach R2b** are similar to **Reach R2a**. **Reach R2b** is a linear drainage feature situated in an unconfined floodplain. The riparian buffer was characterized as a continuous coverage of grasses spanning 4 to 10 channel widths. Channel bed morphology was dominated by runs and riffles with substrate ranging from sand to cobbles. Average bankfull width and depth ranged from 2.70 m to 3.80 m and 0.68 m to 1.10 m, respectively.

4.3 Rapid Assessments

Rapid assessments were completed to identify dominant geomorphic processes, document stream health, and to identify any areas of concern regarding erosion or instability. Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (MOE) (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether a channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

The reaches were also classified according to a modified Downs (1995) Channel Evolution Model, which describes the successional stages of a channel resulting from a perturbation, namely hydromodification.

Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve, or respond to an alteration to the system.

Although the RGA and RSAT tools are intended for general use on natural systems with unmodified planform, results are reported below as they still provide an assessment of channel stability and overall stream health. A summary of the reach classifications and rapid assessment scores is provided in **Table 2**.

Table 2: Summary of rapid assessment results

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)			Downs (1995)
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)	
R2a	0.15	In regime	Evidence of Degradation	26	Good	Riparian habitat conditions	e
R2b	0.10	In regime	Evidence of Widening	26	Good	Riparian habitat conditions	e

Reach R2a was assigned an RGA score of 0.15, indicating the reach was in regime. The dominant systematic adjustment was evidence of degradation as indicated by a scour pool immediately downstream of a culvert, and a suspended armour layer visible in the bank. The RSAT resulted in a score of 26, indicating it was in good condition. The limiting factor was riparian habitat conditions due to the lack of canopy cover over the channel. The Downs (1995) classification indicates that this reach was enlarging (e).

Reach R2b was assigned an RGA score of 0.10, indicating the reach was in regime. The dominant process of systematic adjustment was evidence of widening due to the observation of fracture lines along the top of banks and basal scour at the riffles. The RSAT resulted in a score of 26, indicating it was in good condition. The categories scored similarly, but the most limiting factor was riparian habitat conditions due to lack of consistent riparian canopy cover. The Downs (1995) classification indicated that this reach was enlarging (e).

4.4 Detailed Geomorphological Assessment

Following the rapid field assessments, a detailed geomorphological assessment was also completed on **Reach R2a** within the subject lands. The detailed assessment location was selected based on its suitability for analysis from observations of site conditions throughout the watercourse and where access was available. The location of this site is indicated in **Appendix A.**

For the detailed assessment, the following activities were completed along an approximately 50 m length of the reach:

- Topographic survey of channel bed long profile and water level to determine channel bed gradient and water surface slope at the measured discharge
- Topographic survey of 6 detailed channel cross-sections to document average bankfull channel geometry
- Detailed observations at each cross-section location including riparian vegetation type and cover conditions, bank material composition and structure, bank height/angle, bank substrate shear strength, presence of undercutting, and bank root density
- Bed material sampling at each cross-section location following a modified Wolman's (1954) Pebble Count technique and substrate sample for laboratory grain size analysis

The results of the detailed assessment are summarized below in **Table 3**.

Table 3: Detailed Assessment Summary

Channel parameter	R2a
Bankfull Conditions	
Average bankfull width (m)	2.72
Average bankfull depth (m)	0.62
Bankfull gradient (%)	0.48
D_{50} (mm)	1.44
D_{84} (mm)	16.78
Manning's n roughness coefficient	0.048

5 Meander Belt Width Delineation

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform provided there are no topographical or spatial constraints. When defining the limits of an erosion hazard for a watercourse, unconfined and confined systems are assessed differently (TRCA, 2004 and MNR, 2002). Unconfined systems are those with streams in open areas (i.e., valleys not apparent) or with valley walls positioned at a sufficient distance, where the channel cannot reasonably be expected to contact them under existing or future hydrologic scenarios. In this type of setting, the extent of the erosion hazard is delineated by the meander belt width, which is defined as the lateral extent that a channel has historically occupied and will likely occupy in the future.

Following MNR (2002), the meander belt width can be applied, at a minimum, based on 20 times the bankfull channel width. Alternatively, the meander belt width can be determined through a detailed geomorphological study that examines the largest channel meanders, as observed in historical and recent aerial photographs. The meander belt width can then be graphically defined using orthorectified aerial imagery by determining the channel centerline and the channel's central tendency (i.e., meander belt axis). In cases where the channel is not discernible in aerial photographs or the channel has been substantially modified, empirical models can be used to estimate the meander belt width.

Confined systems, in contrast, are those where a watercourse is contained within a defined valley where meander bend migration may be constrained by valley walls. Partially confined systems are those where meander bends are adjacent to only one valley wall and the watercourse is therefore restricted in migration and floodplain occupation on one side of the valley system. In these settings, where the channel is positioned within 15 m of a valley slope, the erosion hazard is generally defined by the toe erosion allowance, stable slope allowance, and erosion access allowance. In some instances, a meander belt width may also apply in partially confined systems (i.e., where the channel is greater than 15 m from the valley slope toe).

Reaches R2a and **R2b** of the Nichol Drain were characterized as unconfined within the subject lands. As the Nichol Drain has been historically straightened to be managed as a municipal drain, natural meanders are not present on the landscape. Aerial imagery was reviewed to locate potential reference reaches to use as surrogates; however, no suitable reference reaches were available for the Nichol Drain. A suite of empirical equations was therefore used to delineate meander belt widths.

The empirical relations from Williams (1986) were modified to include channel area and width, and applied using the bankfull channel dimensions such that:

$$B_w = 18A^{0.65} + W_b \qquad \text{[Eq. 1]}$$

$$B_w = 4.3{W_b}^{1.12} + W_b \qquad \text{[Eq. 2]}$$

where B_w is meander belt width (m), A is bankfull cross-sectional area (m^2), and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values to address issues of underprediction.

The Ward et al. (2002) channel width model was also used to determine a meander belt width (ft):

$$B_w = 6W_b^{1.12} \quad \text{[Eq. 3]}$$

resulting value was then converted to the metric system (m). A 20% factor of safety was not applied to the Ward et al. (2002) channel width value due to the approach used in the modelling (i.e., hazard envelope rather than a linear relationship).

Lastly, meander belt widths were also calculated based on TRCA's (2004) empirical model:

$$B_w = -14.827 + 8.319\ln(\rho g Q S * DA) \quad \text{[Eq. 4]}$$

where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2). Reach gradients were determined using topographic data. The drainage area (7.23 km^2) was provided by MTE (2025) for the downstream extent of **Reach R2a** and was applied to both reaches as a conservative approach. The two-year discharge of 4.60 m^3/s was also provided by MTE (2025).

Empirical modelling results are summarized in **Table 4**, below.

Table 4: Summary of modelled meander belt widths for existing conditions

Reach	Modified Williams (1986) Area*	Modified Williams (1986) Width*	Ward et al. (2002) Width	TRCA (2004)**	Recommended Meander Belt Width (m)
R2a	43	23	25	55	43
R2b	43	23	25	55	43

** Includes 20% factor of safety*
*** Includes one standard error (8.63 m) as factor of safety*

Calculated meander belt widths for **Reaches R2a** and **R2b** ranged from 23 m to 55 m. The 43 m value determined using the Williams (1986) areas equation is recommended as the final meander belt width and includes a 20% factor of safety. The Nichol Drain SWS (Aquafor Beech, 2008) included a high-level assessment of lateral channel migration potential for the Nichol Drain in support of future constraint delineation. Given the limited sinuosity and historic modifications that have occurred along the drain, the SWS reviewed surrogate reaches with similar geology and drainage area. Meander belt widths of 32 m and 45 m were mapped from surrogate reaches in the nearby Irvine Creek subwatershed to provide context for the migration potential of the Nichol Drain. The Williams (1986) area equation produced similar results consistent with the delineation previously completed for the SWS in 2008 by Aquafor Beech. The extent of the meander belt width based is illustrated on the mapping provided in **Appendix A**.

6 Erosion Mitigation Assessment

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank material (Garcia, 2008; Villard and Parish, 2003). As such, they are used to inform erosion mitigation strategies in channels influenced by conceptual flow and stormwater management plans. An erosion threshold was modelled from detailed field observations of **Reach R2a**. Due to site access constraints, a high-resolution digital elevation model (DEM) derived from LiDAR data (OMNRF, 2016) was also used to estimate an erosion threshold for downstream **Reach R1a** in the absence of field-based measurements of channel morphology. This reach was selected for the assessment, as it was determined to be a relatively well-defined, erosion-sensitive reach within the potential zone of impact downstream of the two (2) SWM outlets for the proposed development.

The erosion threshold is a theoretical value, typically expressed as a critical discharge or shear stress, at which entrainment of sediment would occur based on the physical properties of the bed and bank materials. Due to variability between bed and bank composition and structure, erosion thresholds are determined for both bed and bank materials. The lower of the bed and bank erosion thresholds is adopted, as it provides the more conservative and limiting estimate for the subject reach. The results of the erosion threshold assessment are provided in **Table 5** below.

6.1 Methodology

Erosion threshold targets are determined using various methods that depend on the sediment characteristics of the channel. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied (Villard & Parish, 2003). For cohesive materials, a method such as that described by Komar (1987), or empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1994), could be applied. Villard and Parish (2003) emphasize the importance of selecting methods that reflect local sediment conditions and integrating them into site-specific geomorphic assessments.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry, in the form of a critical discharge (Villard & Parish, 2003; TRCA 2012). Theoretically, above this discharge, entrainment and transport of sediment can occur. To determine this discharge, the velocity, *U*, or Shear Stress, τ, is calculated at various depths for a representative cross-section until the average velocity or shear stress slightly exceeds the critical threshold of the bed material. The velocity is determined using Manning's approach, where Manning's *n* value is visually estimated through a method described by Acrement and Schneider (1989) or calculated using the Limerino (1970) approach. A Manning's *n* value of 0.038 for **Reach R2a** and 0.040 for **Reach R1a** were used for the assessment, based on the physical characteristics of the subject reaches. The velocity is mathematically represented as:

$$U = \frac{1}{n} d^{2/3} S^{1/2} \qquad \text{[Eq. 5]}$$

where, *d* is depth of water, *S* is channel bed slope, and *n* is the Manning's roughness.

The shear stress is determined using the depth-slope product, which can be applied to the bed of open channels containing fluid undergoing steady flows. The shear stress is mathematically represented as:

$$\tau_0 = d\rho g S \qquad \text{[Eq. 6]}$$

Where, τ_0 is shear stress, *d* is the water depth, ρ is water density, *g* is acceleration due to gravity, and *S* is the channel slope.

Because only 75% of bed shear stress applies to channel banks in uniform cross sections (Chow, 1959), the erosion threshold is scaled appropriately for these materials.

6.2 Results

Reach R1a along the western portion outside of the subject lands was inaccessible for field assessments, and a high-resolution DEM derived from LiDAR data was used to calculate an erosion threshold. The gradient for this reach was estimated as 1.51%, determined using slope analysis methods applied to the high-resolution DEM. The bed and bank materials within **R1a** were characterized based on roadside observations from the Irvine Street crossing and field data from **R2a**. **Reach R2a** which was classified as an agricultural drainage feature with poorly defined bed and banks.

The banks within **R2a** were characterized as predominantly consisting of silty loam material, while the bed consisted of fine gravels. These soil types were characterized based on the criteria of Fischenich (2001), as they most closely match observations made during field assessments and laboratory grain size analysis results. Roadside observations from **R1a** suggest that bed materials in this reach ranged from graded loam to cobbles, while the banks remained consistent with **R2a**. The Ontario Soil Survey Complex identifies four main soil types within the drainage area of the tributary that flows through the subject lands; Brant fine sandy loam, Harriston loam, Listowel loam, and Parkhill loam (OMAFRA, 2019).

The Brant fine sandy loam developed in lacustrine deposits, while the other soils developed in glacial till environments and generally contain silty loam textures.

Reach R1a is located downstream of **R2a** and drains an area of 797.8 hectares (MTE, 2025). A critical velocity approach was taken using the criteria of Fischenich (2001) for entrainment of the silty loam bank material, where a critical velocity of 0.60 m/s was applied. This yielded a critical discharge of 0.369 m^3/s for the bank materials. The bed materials were composed of graded loam to cobbles, with a corresponding critical velocity of 1.14 m/s based on Fischenich (2001), resulting in a critical discharge of 1.216 m^3/s. As the more conservative value, the critical discharge for the bank materials (0.369 m^3/s) was adopted as the erosion threshold for **Reach R1a**.

Reach R2a, upstream of **R1a**, drains a smaller contributing area of 727.8 hectares (MTE, 2025). The bank materials in this reach consisted of silty loam. Based on Fischenich (2001), a critical velocity of 0.60 m/s was used to evaluate the erosion threshold of the bank materials, resulting in a critical discharge of 0.793 m^3/s. The fine gravel bed materials, with a critical velocity of 0.76 m/s (Fischenich, 2001), yielded a slightly lower critical discharge of 0.485 m^3/s. As the more conservative value, the critical discharge for the bed materials (0.485 m^3/s) was adopted as the erosion threshold for **R2a**.

Channel parameters and erosion threshold results are summarized in **Table 5**.

Table 5: Preliminary erosion threshold results for Reaches R1a and R2a

Channel parameter	R1a		R2a	
Average bankfull channel width (m)	5.72*		2.72	
Average bankfull channel depth (m)	0.49*		0.62	
Channel gradient (%)	1.51*		0.48	
D_{50} (mm)	--		1.44	
D_{84} (mm)	--		16.78	
Manning's n roughness coefficient	0.040		0.038	
Drainage Area (ha)**	797.8		727.8	
Bankfull discharge (m^3/s)***	2.492		1.082	
Average bankfull velocity (m/s)***	1.37		0.83	
Erosion Threshold	**Bed**	**Banks**	**Bed**	**Banks**
Material	Graded Loam to Cobbles	Silty Loam	Fine Gravels	Silty Loam
Reference	Fischenich (2001)	Fischenich (2001)	Fischenich (2001)	Fischenich (2001)
Apparent Shear Stress (N/m^2)	18.19	2.15 – 2.39	3.59	2.15 – 2.39
Critical velocity (m/s)	1.14	0.53 – 0.69	0.76	0.53 – 0.69
Critical depth (m)	0.23	0.14	0.38	0.44
Critical discharge (m^3/s)	1.216	0.369	0.485	0.793
Unitary erosion threshold ($m^3/s/ha$)**	0.00152	0.00046	0.00067	0.00109
Limiting erosion threshold (m^3/s)	**0.369**		**0.485**	
Limiting unitary threshold ($m^3/s/ha$)**	**0.00046**		**0.00067**	

*Derived using LiDAR data
**Drainage area from MTE (2025)
***Based on Manning's equation and select representative cross-sections used in erosion threshold modelling

7 Pre- to Post-Development Erosion Exceedance Analysis

In support of the proposed stormwater management (SWM) plan, an erosion exceedance analysis was completed for the receiving watercourse (CVC, 2015; TRCA, 2012). The application of erosion threshold analysis for evaluating the effectiveness of stormwater management facilities in mitigating changes in downstream erosion potential is a concept developed with support by a co-author of the present report

(P. Villard) and detailed in guidelines prepared for the Credit Valley Conservation Authority and Toronto and Region Conservation Authority and in Villard and Parish (2003).

Our understanding is that under post-development conditions, drainage within the subject lands will be directed through two (2) on-site SWM facilities (MTE, 2025). SWM facility 1 (SWMF1) is proposed to outlet on the downstream side of Sideroad 15 into **Reach R1b**. SWM facility 2 (SWMF2) will outlet upstream of Sideroad 15 into **Reach R2a**, which eventually drains into **R1a** and Irvine Creek (MTE, 2025). **Reach R1a** was selected for analysis, as it is considered an erosion-sensitive reach downstream of the outlets and within the potential zone of impact.

Using the results of the erosion threshold analysis and hydrological simulation modelling provided by MTE (2025) for existing and proposed conditions, erosion exceedance analyses to evaluate the potential for changes in the amount of erosion within the watercourse were completed with our in-house Erosion Exceedance Model. The most relevant erosion exceedance indices are summarized below:

1) Cumulative time of exceedance (t_{ex})
2) Cumulative effective volume (CEV)
3) Cumulative effective work/stream power index (CEWI)

These indices were developed in response to the limitations of traditional peak flow-based stormwater design (Villard & Parish, 2003; Villard & Ness, 2006). They have been applied in various southern Ontario Jurisdictions, including Conservation Halton (CH), Toronto Region Conservation Authority (TRCA), Credit Valley Conservation (CVC). These indices, as a product, provide an evaluation of the number of events, as well as the duration and magnitude of sediment transport (Villard & Ness, 2006). We note that the most relevant indicator is the cumulative effective stream power, as it reflects both the duration and magnitude of erosion exceedance events.

Time of exceedance, average effective discharge, and cumulative effective volume can be calculated from the discharge record and the established critical discharge. The cumulative time of exceedance is simply the summed duration of time where discharge exceeds the established erosion threshold, and the number of exceedances is the count of erosion exceedance events throughout the discharge record. The cumulative time of exceedance quantifies the duration that the threshold is exceeded but does not provide information on the work or erosive force of flows once the thresholds are exceeded (TRCA, 2012). The average effective discharge represents the average magnitude of discharge exceeding the erosion threshold during a given erosion event, whereas the cumulative effective volume represents the total discharge volume that exceeds the erosion threshold throughout the modelled discharge record.

For more relevant indicators, namely the cumulative effective work index (CEWI), hydraulic information is required. Our model applies the discharge to a characteristic cross-section. Using Manning's approach, the discharge at each time step in the continuous hydrological model is converted into a velocity, depth of flow, shear stress, and/or stream power. These parameters are calculated based on field measurements of slope, cross-section, and channel roughness. This provides an analysis that is appropriate to the specific site conditions.

The post- and pre-development hydrological modelling reflects changes to the hydrological regime resulting from implementing SWM measures within the catchment. For each of the modeling nodes, event-based hydrological simulation results were provided by MTE Consultants Inc. Continuous Flow data for **Reaches R1a** and **R2a** along Nichol Drain was provided in the form of continuous annual models for the years 1950-2005 with 15-minute timesteps. The hydrological simulation data for existing and proposed conditions was analyzed to calculate the aforementioned erosion indices. A representative series of post- and pre-development hydrographs, overlain with the respective erosion threshold and bankfull discharge values, are provided in **Appendix E**, for reference.

7.1 Methodology

To calculate erosion indices, both velocity and shear stress were calculated at each time step. Through an iterative process, water depth and velocity were calculated for each discharge passing through a representative cross-section. The cross-section is divided into floodplain and bankfull sections. The cross-section is further broken into panels. Velocity, U, is calculated for each panel using Manning's approach, consistent with practices outlined in Chow (1959) and employed in TRCA (2012). This is a conservative approach as it allows dissipation of flood energy in the floodplain.

The total discharge, Q_T at each time step is based on the summation of the discharge of all panels, Q_i, such that:

$$Q_{T=}\sum Q_i \quad \text{[Eq. 7]}$$

Each Q_i represents discharge through a panel (which is set at 10 percent of the cross-section). Q_i is defined as:

$$Q_i = U_i w_i d_i \quad \text{[Eq. 8]}$$

where, U_i, w_i and d_i are velocity, width and depth for each panel. The discharge for each panel was then summed to give a total discharge. This is more accurate than using average cross-sectional dimensions of a simple trapezoidal channel, as the bed is usually irregular, and a panel approach more accurately represents the true cross-sectional area (Villard and Parish, 2003).

For each event, the discharge is converted into a maximum depth and average velocity. The maximum depth is used to calculate a maximum bed shear stress, $\tau_{o_{\max}}$ based on:

$$\tau_{o_{\max}} = d_{\max}\rho g S \quad \text{[Eq. 9]}$$

where, d_{max} is the maximum water depth, ρ is water density, g is acceleration due to gravity, and S is the channel slope.

Cumulative total work, ϖ_{tot} is defined as:

$$\varpi_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \quad \text{[Eq. 10]}$$

where, U_{avg} is average velocity (Q_{tot}/A_{tot}, where A_{tot} is wetted area), while cumulative effective work index (ϖ_{eff}) is defined by:

$$\varpi_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \varpi < 0 = 0 \quad \text{[Eq. 11]}$$

where, τ_{cr} is the critical shear stress.

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \ \text{ for } (Q_T > Q_{\text{threshold}}) \quad \text{[Eq. 12]}$$

where, $Q_{\text{threshold}}$ is the discharge at the erosion threshold.

The cumulative effective volume (CEV) is defined as:

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \quad \text{[Eq. 13]}$$

7.2 Results

The results of the erosion exceedance analysis indicate that the stormwater management plan for the proposed development effectively mitigates against increasing the erosion potential within the receiving watercourse. The results of the modelling demonstrate a negligible change in key erosion metrics within the receiving watercourse under post-development conditions. Among the metrics assessed, the cumulative effective work index (CEWI) is considered the most representative of erosion potential, as it accounts for both the magnitude and duration of flows exceeding the erosion threshold. Post-development changes in erosion indices within ±5% of existing conditions are deemed negligible, while changes within ±10% are considered minor. Supporting indicators include the cumulative effective volume (CEV) and the cumulative time of exceedance (t_{ex}), which provide additional insight into pre-to-post changes in erosion potential along the subject reach. Representative hydrographs for both existing and proposed conditions are presented in **Appendix E**. A summary of assessment results based on the modeled streamflow data provided by MTE (2025) is included in **Table 6** and **Table 7**.

Table 6: Erosion exceedance assessment results for Reach R1a (1950 - 2005)

Cumulative (All Years)	CEV (m^3)	CEWI (N/m^2)	t_{ex} (hrs)	# Of Exceedances
(PRE)	72,785,290	466,337	14,265	1,610
(POST)	71,426,268	460,786	15,944	1,454
Change (%)	**-1.87**	**-1.19**	**11.77**	**-9.69**

Table 7: Erosion exceedance assessment results for Reach R2a (1950 – 2005)

Cumulative (All Years)	CEV (m^3)	CEWI (N/m^2)	t_{ex} (hrs)	# Of Exceedances
(PRE)	60,332,126	302,105	11,277	1,398
(POST)	59,106,650	301,314	12,270	1,333
Change (%)	**-2.03**	**-0.26**	**8.81**	**-4.65**

The cumulative effective discharge volume (CEV) represents the total volume of flow exceeding the erosion threshold. The CEV for the **R1a** simulation is predicted to decrease by 1.87% and similarly by 2.03% for **R2a**. This indicates a negligible decrease in the total volume of flow exceeding the erosion threshold. Similarly, the CEWI is predicted to decrease by 1.19% for **R1a** and 0.26% for **R2a**, also indicating a negligible decrease in the total effective work. The total time of exceedance is predicted to increase for both reaches as SWM pond release rates are extended under post-development conditions. The systematic reduction in peak flows observed across seasons and years under post-development conditions is expected to result in corresponding decreases in cumulative effective work and the number of exceedances.

Overall, the erosion exceedance modelling results indicate negligible changes in erosion potential within **Reaches R1a** and **R2a** under post-development conditions. Reductions in cumulative effective work (CEWI) and cumulative effective volume (CEV) suggest a slight decrease in total erosive energy and volume of threshold-exceeding flows, while increases in time of exceedance reflect extended, lower-magnitude releases typical of controlled SWM discharge. These results demonstrate that post-development conditions are not expected to increase erosion potential within the receiving watercourse, and that the proposed stormwater management strategy effectively mitigates against changes to the patterns and rates of erosion within the receiving watercourse.

8 Stormwater Management Outfall Recommendations

When assessing the effectiveness of the proposed SWM pond outfalls and spillways, a key consideration is to minimize impacts on natural hazard areas and preserve sensitive natural heritage features. Emergency spillways are generally activated when outfalls are clogged or during extreme storm events, and as such, will not contribute consistent flows with erosive potential to the receiving watercourse. Priority is given to selecting locations near stable watercourses which allows for controlled and stable discharge of stormwater. This approach reduces erosion risks and maintains the natural flow dynamics of watercourses. By incorporating these geomorphological considerations, the chosen outfall locations avoid natural heritage constraints and contribute to the long-term stability and sustainability of the stormwater management facilities.

To ensure that the potential for erosion is mitigated, and channel stability is maintained, erosion protection and flow control methods are recommended for the proposed SWM outlets and spillway. In addition to choosing suitable outfall and spillway locations, erosion protection and flow control methods are recommended to further protect the receiving watercourses and associated floodplains and banks. These methodologies include vegetative bank stabilization, bioengineering techniques, vegetated swales and reinforced pocket wetlands. Additional details including hydraulic stone sizing, phasing, sediment and erosion control plans, and landscape planting plans should be reviewed and provided during the detailed design phase.

9 Erosion Monitoring Recommendations

The erosion mitigation assessment completed in support of the proposed development indicates that instream erosion will not be exacerbated in the receiving Nichol Drain; however, geomorphological instream monitoring is recommended along **Reach R2a** to ensure that erosion mitigation has been adequately addressed in the post-development condition. The following annual post-construction monitoring activities are recommended along **Reaches R2a**:

- Re-survey of monumented cross sections and longitudinal profile established under baseline conditions
- Channel substrate characterization through a modified Wolman (1954) pebble count or sampling at each monumented cross-section
- Collection of monumented photographs
- Re-measurement of erosion pins
- Preparation of an annual report documenting results of the monitoring program, with a summary report provided at the end of the monitoring period

Monumented cross-sections were installed by GEO Morphix along **Reach R2a** in 2025 during the detailed geomorphological assessment. It is recommended that the cross-sections be re-surveyed within one year of the proposed SWM ponds being operational to confirm existing conditions. The post-construction monitoring activities outlined above should be completed on an annual basis for a period of three years, once the SWM ponds are operational. Annual reports and the summary report are to include a comparison of pre- and post-development instream conditions and evaluate any changes in the context of anticipated natural variability. The overall pre- and post-development erosion monitoring program should be finalized at the detailed design stage.

10 Summary

GEO Morphix was retained to complete a fluvial geomorphological assessment and erosion mitigation analysis in support of a residential development at the Elora Sands lands in Elora, Ontario. The assessment included reviewing previously completed reports, examining site history, completing rapid and detailed geomorphological field assessments, delineating the erosion hazard, completing erosion threshold and exceedance modelling, and providing stormwater management outfall recommendations.

The previously completed Nichol Drain Subwatershed Study (Aquafor Beech, 2008) was reviewed along with surficial geology and physiography mapping and an historical assessment with imagery ranging from 1930 to present to understand existing and historical site conditions. Based on the desktop-assessment the land use within the Nichol Drain was straightened prior to 1930 and has since been maintained as a municipal drain, restricting lateral channel migration. The subject lands have remained agricultural throughout the time frame reviewed. Field investigations were completed to characterize watercourse conditions and inform the erosion hazard delineation and erosion mitigation analysis.

An erosion hazard assessment was also completed for the reaches along the Nichol Drain. Within the subject lands, it was determined that **Reach R2a** and **R2b** flow within an unconfined floodplain, requiring meander belt width delineations to address the erosion hazard following MNR (2002) guidelines. Meander belt widths were calculated using empirical modelling due to the historical channel modifications (i.e., absence of natural meanders). The resulting meander belt width of 43 m was recommended for both **Reach R2a** and **R2b**.

Results from the erosion exceedance modelling demonstrate that the proposed SWM strategy is expected to effectively mitigate against increases in erosion potential along **Reach R1a** and **R2a**. Under post-development conditions, negligible changes in erosion potential were exhibited for both reaches in the analysis. Slight reductions in cumulative effective work and effective volume, combined with systematically lower peak flows, suggest that the proposed stormwater management measures will maintain or marginally reduce existing patterns and rates of erosion within the receiving watercourse.

We trust this report satisfies your requirements at this time. Should you have any questions or concerns, please contact the undersigned.

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Director, Principal Geomorphologist

Kat Woodrow M.Sc.
Manager of Watershed Studies, Practice Lead

Jan Franssen, Ph.D.
Senior Watershed Scientist

Christopher Giovino, M.Sc.
Environmental Scientist

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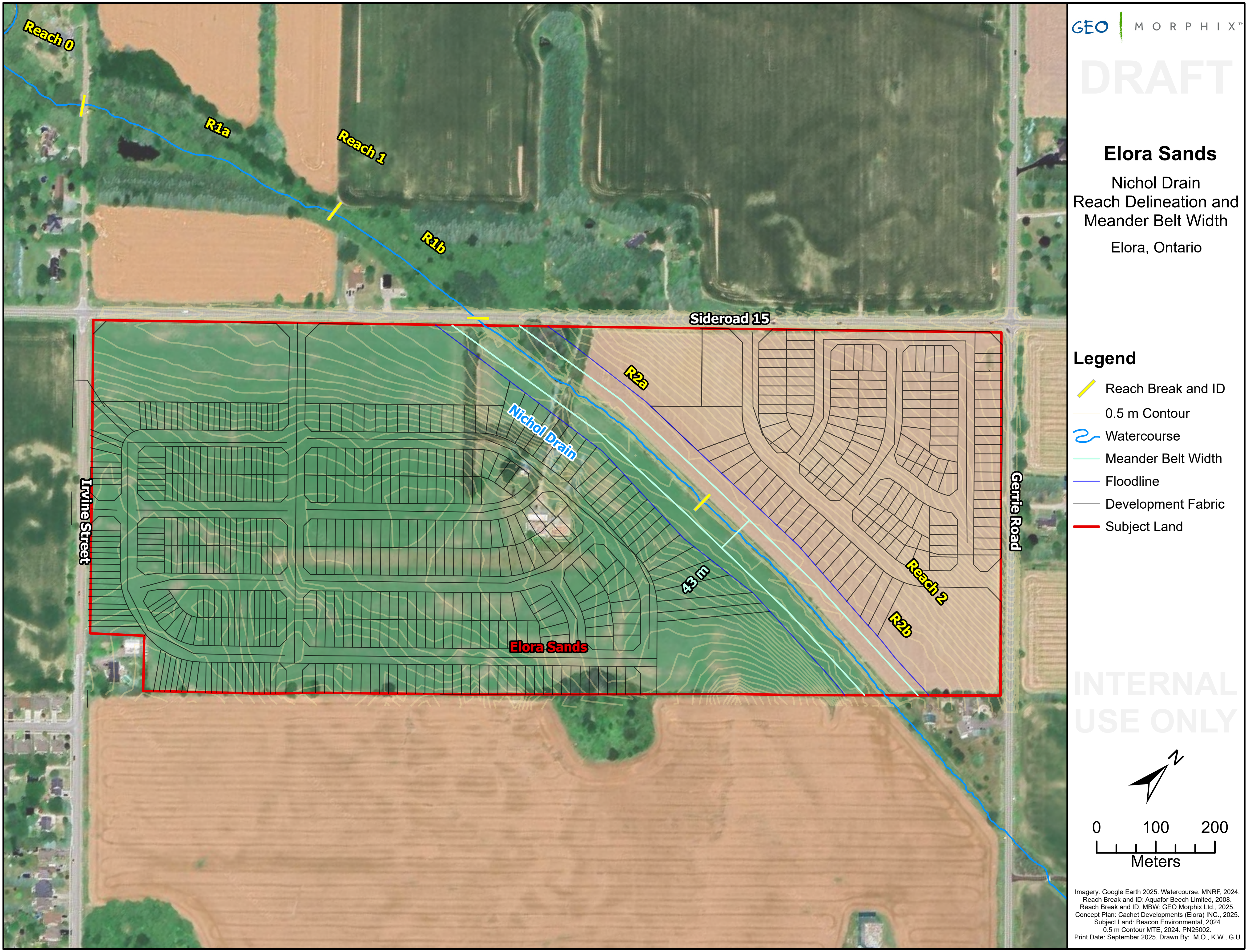
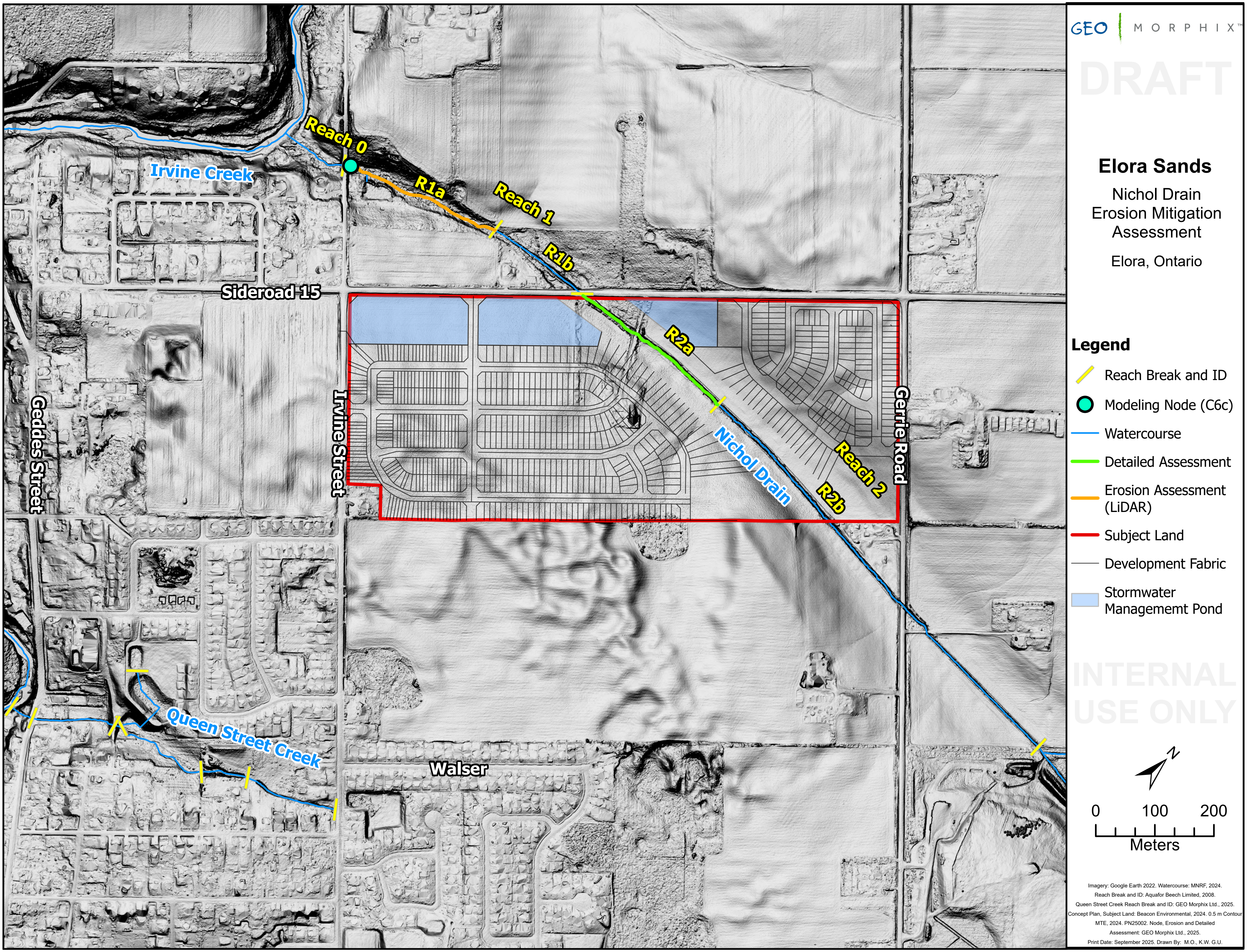
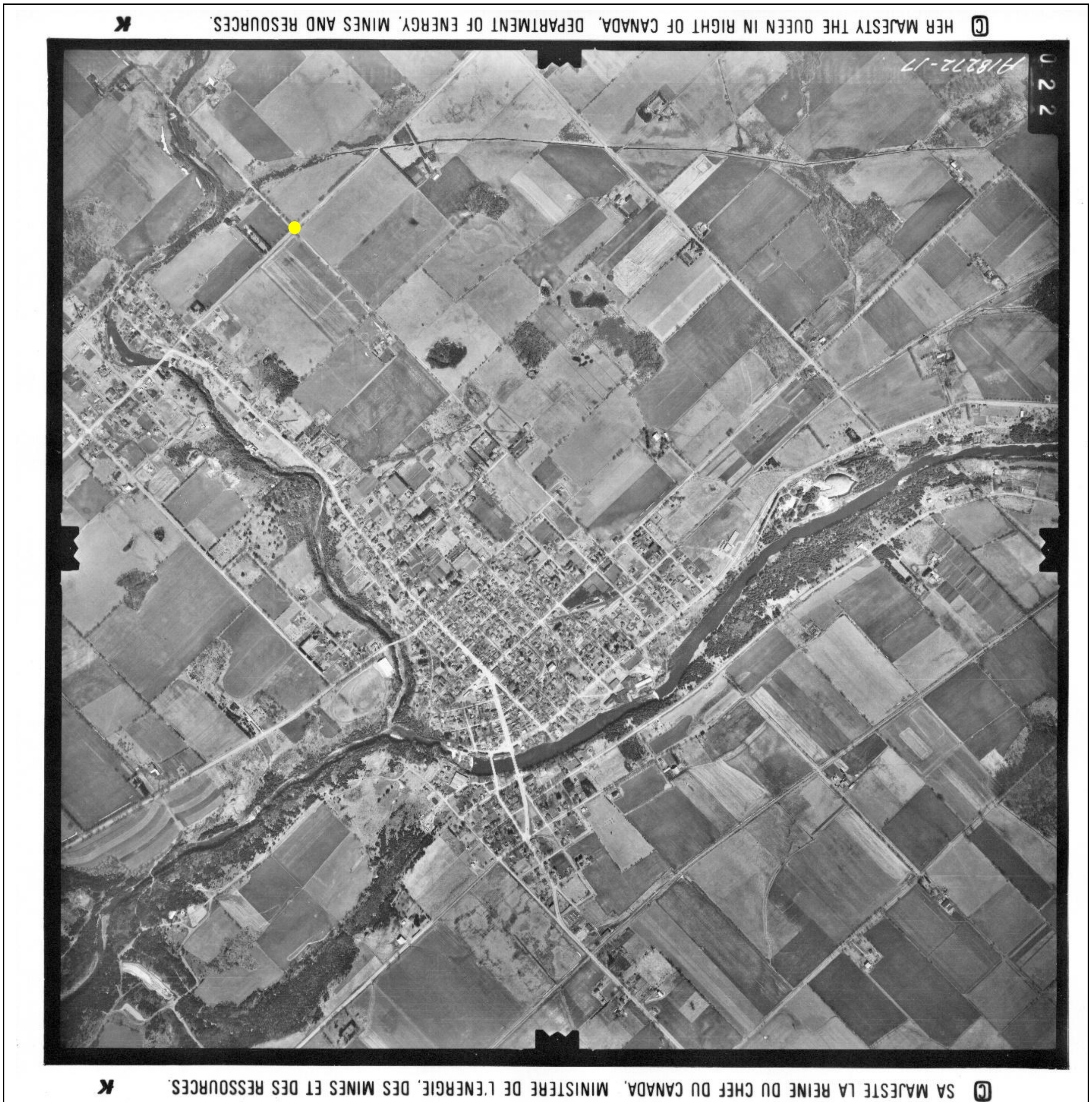
Appendix A:
Study Area Mapping


Reach 0
Reach 1
R1a
R1b
Sideroad 15
R2a
Nichol Drain
Irvine Street
Gerrie Road
43 m
Reach 2
R2b
Elora Sands
GEO MORPHIX™
DRAFT
Elora Sands
Nichol Drain
Reach Delineation and
Meander Belt Width
Elora, Ontario
Legend
Reach Break and ID
0.5 m Contour
Watercourse
Meander Belt Width
Floodline
Development Fabric
Subject Land
INTERNAL USE ONLY
N
0 100 200
Meters
Imagery: Google Earth 2025. Watercourse: MNRF, 2024.
Reach Break and ID: Aquafor Beech Limited, 2008.
Reach Break and ID, MBW: GEO Morphix Ltd., 2025.
Concept Plan: Cachet Developments (Elora) INC., 2025.
Subject Land: Beacon Environmental, 2024.
0.5 m Contour MTE, 2024. PN25002.
Print Date: September 2025. Drawn By: M.O., K.W., G.U

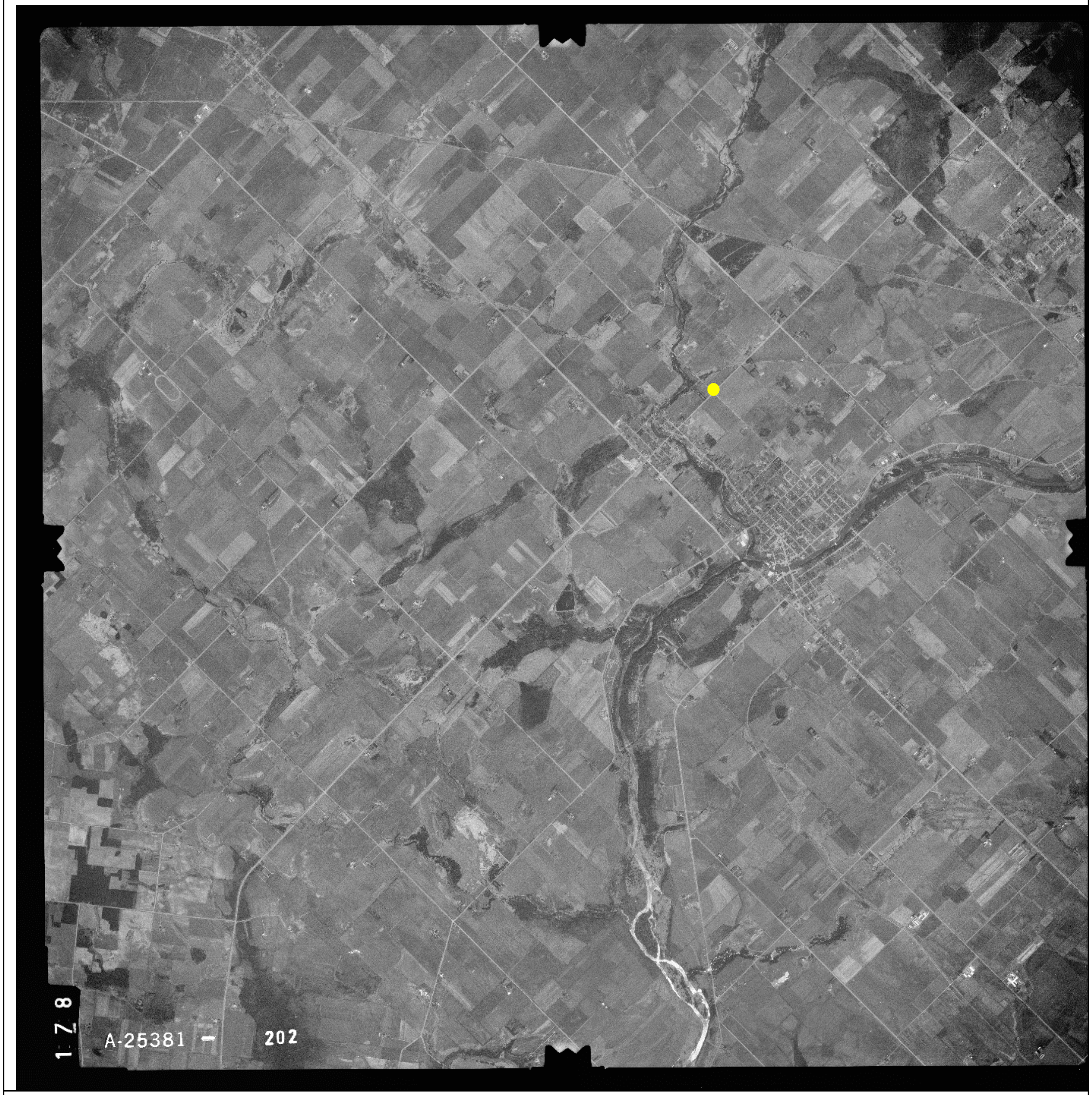

Reach 0
Irvine Creek
R1a
Reach 1
R1b
Sideroad 15
R2a
Geddes Street
Irvine Street
Gerrie Road
Nichol Drain
Reach 2
R2b
Queen Street Creek
Walser
GEO | MORPHIX™
DRAFT
Elora Sands
Nichol Drain
Erosion Mitigation
Assessment
Elora, Ontario
Legend
Reach Break and ID
Modeling Node (C6c)
Watercourse
Detailed Assessment
Erosion Assessment (LiDAR)
Subject Land
Development Fabric
Stormwater Managememt Pond
INTERNAL USE ONLY
N
0
100
200
Meters
Imagery: Google Earth 2022. Watercourse: MNRF, 2024.
Reach Break and ID: Aquafor Beech Limited, 2008.
Queen Street Creek Reach Break and ID: GEO Morphix Ltd., 2025.
Concept Plan, Subject Land: Beacon Environmental, 2024. 0.5 m Contour
MTE, 2024. PN25002. Node, Erosion and Detailed
Assessment: GEO Morphix Ltd., 2025.
Print Date: September 2025. Drawn By: M.O., K.W. G.U.

Appendix B:
Historical Aerial Imagery

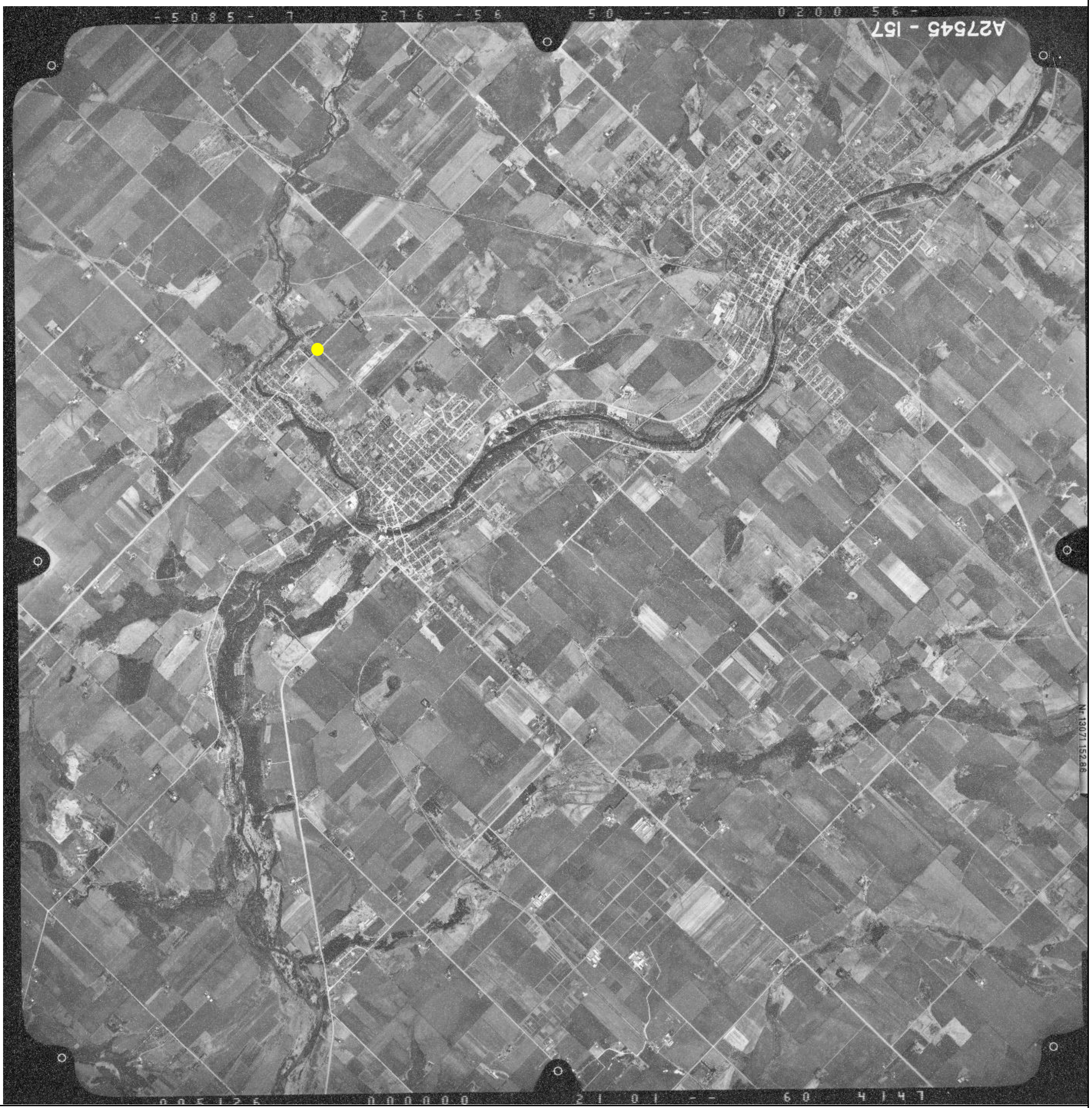
Location: Elora, ON
Year: 1930
Scale: 1:20,000
Source: National Air Photo Library
Yellow Point: Intersection of Irvine Street and Sideroad 15



Location: Elora, ON
Year: 1964
Scale: 1:20,000
Source: National Air Photo Library
Yellow Point: Intersection of Irvine Street and Sideroad 15

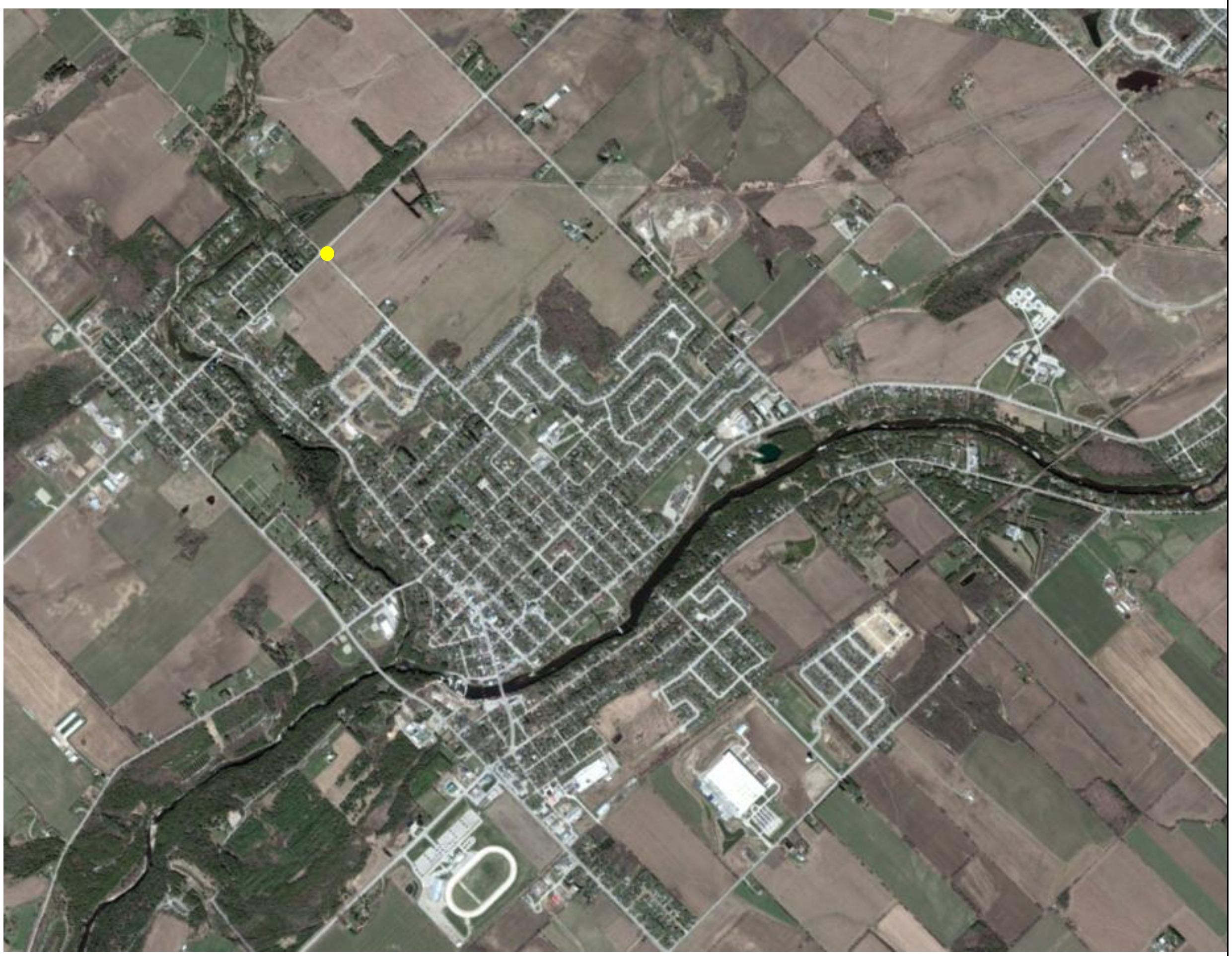


Location: Elora, ON
Year: 1980
Scale: 1:50,000
Source: National Air Photo Library
Yellow Point: Intersection of Irvine Street and Sideroad 15



Location: Elora, ON
Year: 1990
Scale: 1:50,000
Source: National Air Photo Library
Yellow Point: Intersection of Irvine Street and Sideroad 15

Location: Elora, ON
Year: 2006
Scale: Digital Orthoimagery
Source: Google Earth Pro
Yellow Point: Intersection of Irvine Street and Sideroad 15



Location: Elora, ON
Year: 2016
Scale: Digital Orthoimagery
Source: Google Earth Pro
Yellow Point: Intersection of Irvine Street and Sideroad 15

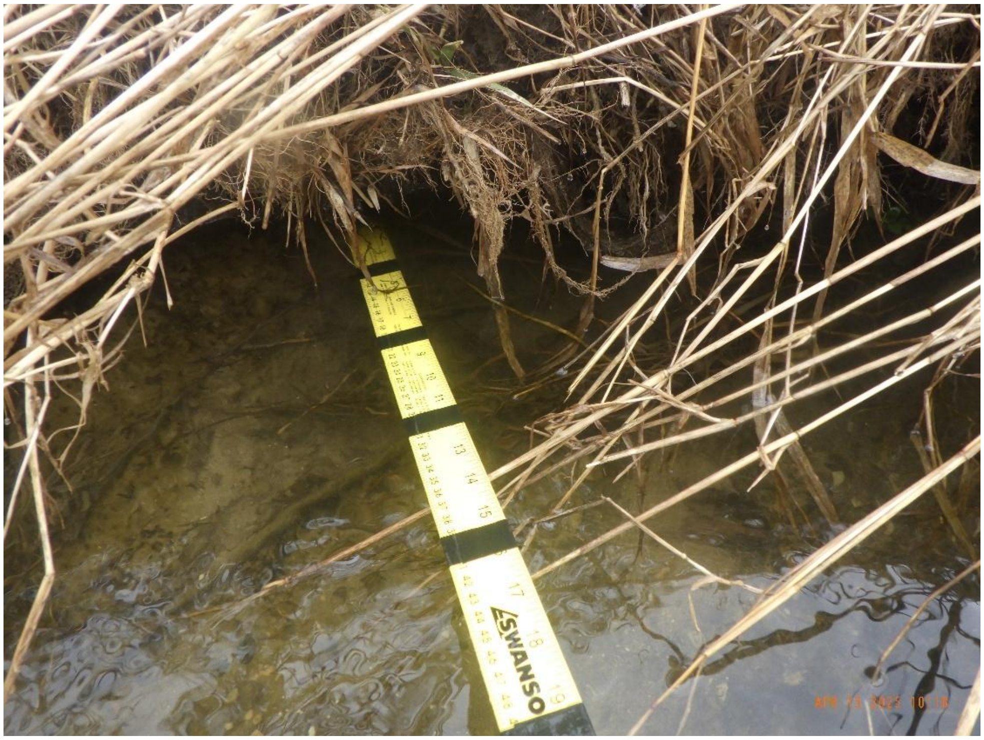
Location: Elora, ON
Year: 2024
Scale: Digital Orthoimagery
Source: Google Earth Pro
Yellow Point: Intersection of Irvine Street and Sideroad 15

Appendix C:
Photographic Record

Reach R2A

Photo 1 Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2A, Elora, Ontario	 Photograph taken facing upstream from culvert at Sideroad 15. Note coarse, cobble substrate. Arrow denotes direction of flow.
Photo 2 Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2A, Elora, Ontario	 Photograph taken facing upstream. Agriculture fields extend close to channel edge on both sides of stream corridor. Arrow denotes direction of flow.

Photo 3
Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2A, Elora, Ontario



Photograph taken of the edge of channel. Slight undercutting 0f 0.23m. Meterstick for scale.

Photo 4
Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2A, Elora, Ontario

Photograph facing above the right bank highlighting a tile drain from adjacent agriculture field. The tile drain diameter was 0.14m.

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Photo 5
Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2A, Elora, Ontario

Photograph taken facing upstream. Note straight, uniform channel condition with dense grass vegetation adjacent to the channel.

Reach R2B

Photo 6 Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2B, Elora, Ontario	 Photograph taken facing upstream as R2A transitions to R2B. Heavy vegetation along the banks. Straight channel with open canopy. Arrow denotes direction of flow.
Photo 7 Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2B, Elora, Ontario	 Photograph facing the right bank flow from tile drain into channel. Tile drain diameter was 0.14m.

Photo 8
Irvine Street & Sideroad 15, Nichol Drain, Irvine Creek, R2B, Elora, Ontario

Photograph taken of bed substrate. Substrate ranges from sand, gravel and cobbles. Water has limited turbidity.

Appendix D:
Rapid Assessment Field Sheets

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General Site Characteristics

Project Number: PN25002

Date:	2025-04-15	**Stream:**	/
Time:	9:20	**Reach:**	R2A
Weather:	4°c, Cloudy	**Location:**	Elora, ON
Field Staff:	MW SHK	**Watershed/Subwatershed:**	Irvine Creek

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Flow Type

H1	Standing water	H1A	Back water
H2	Scarcely perceptible flow		OBD
H3	Smooth surface flow		↳ Overbank deposits (SAND)
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		FAS
H7	Broken standing wave		↳ Floating armorstone
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

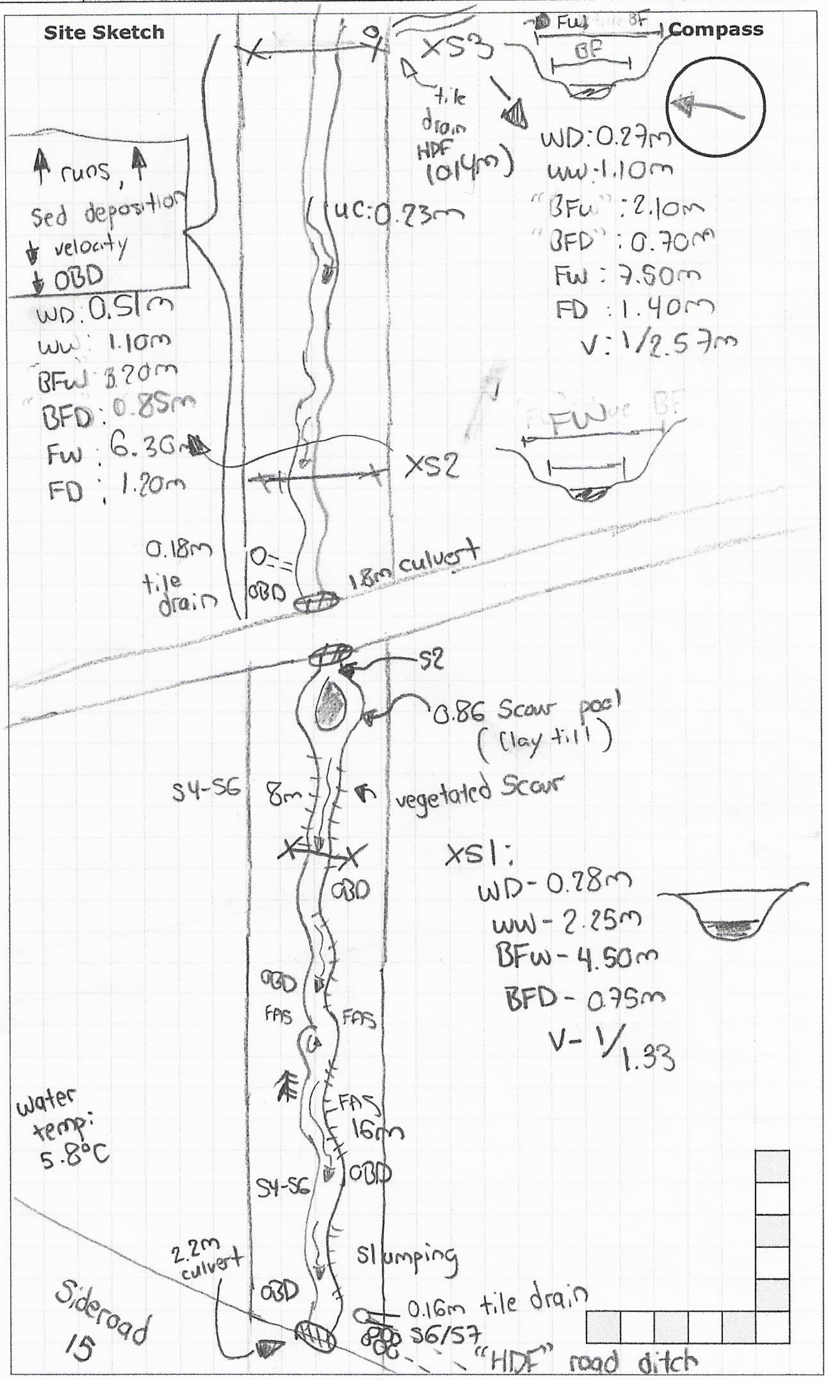
Substrate

S1	Silt	S6	Small boulder
S2	Sand	S7	Large boulder
S3	Gravel	S8	Bimodal
S4	Small cobble	S9	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	EP	Erosion pin
BS	Backsight	RB	Rebar
DS	Downstream	US	Upstream
WDJ	Woody debris jam	TR	Terrace
VWC	Valley wall contact	FC	Flood chute
BOS	Bottom of slope	FP	Flood plain
TOS	Top of slope	KP	Knick point

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MW

Page ____ of ____

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Rapid Geomorphic Assessment

Project Number: PN25002

Date:	2025-04-15	**Stream:**	/
Time:	9:20	**Reach:**	R2a
Weather:	4°C, partly cloudy	**Location:**	Elora, ON
Field Staff:	MW SHK	**Watershed/Subwatershed:**	Irvine Creek

Process	No.	Geomorphological Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	1/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone	X		
		Sum of indices =	1	6	0.143
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		2/6
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s) * culverts	N/A		
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets * 1/1	X		
	6	Cut face on bar forms		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank *	X		
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	2	4	0.333
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		X	1/8
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle *	X		
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach *		X	
	8	Exposed length of previously buried pipe / cable / etc. *		X	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation	N/A		
		Sum of indices =	1	7	0.125
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	7	0.000

Notes: * Cu

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.150
In Regime	**In Transition/Stress**	**In Adjustment**
☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MW

GEO MORPHIX™

Rapid Stream Assessment Technique   Project Number: PN25002

Date:	2025-04-15	**Stream:**	1
Time:	9:20	**Reach:**	R2a
Weather:	4°c, cloudy	**Location:**	Elora, ON
Field Staff:	MW SHK	**Watershed/Subwatershed:**	Irvine Creek

Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☒ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	no/few pools observed * ? • Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MW

GEO MORPHIX™

Date:	2025-04-15	PN:	25002	Location:	Elora, ON

Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
* no/few pools observed	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) =	Poor (<13)	Fair (13-24)	Good (25-34) 26	Excellent (>35)

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: [signature]

Version #2
Last edited: 10/02/2023

GEO MORPHIX™

Reach Characteristics

Project Number: PN25002

Date:	2025-04-15	**Field Staff:**	MW SHK	**Watershed/Subwatershed:**	Irvine Creek
Time:	9:20	**Stream:**	/	**UTM (Upstream):**	/
Weather:	4°C, cloudy	**Reach:**	R2a	**UTM (Downstream):**	/

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)
3	1	7	2	1

~~☐ Evidence of Groundwater~~ Location: ________ ~~Photo:~~ ______

Riparian Vegetation

		Coverage	Channel Widths	Age (yrs)
Dominant Type (Table 6)	3	☐ None	☐ 1 - 4	☒ Immature (<5)
		☐ Fragmented	☒ 4 - 10	☐ Established (5-30)
Encroachment (Table 7)	2	☒ Continuous	☐ > 10	☐ Mature (>30)

Aquatic & Instream Vegetation

		Woody Debris	WD Density	
Type (Table 8)	/	☐ In Cutbank	☒ Low	WDJ/50m: <1
		☒ In Channel	☐ Mod	
Reach Coverage %	/	☐ Not Present	☐ High	

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	1

Channel Characteristics

				Bank Angle	Bank Erosion
Sinuosity Type (Table 9)	1	Sinuosity Degree (Table 10)	1/2	☐ 0 – 30	☐ < 5%
Gradient (Table 11)	1/2	# of Channels (Table 12)	1	☒ 30 – 60	☐ 5 – 30%
Entrenchment (Table 13)	1	Bank Failure (Table 14)	6	☐ 60 – 90	☒ 30 – 60%
				☐ Undercut	☐ 60 – 100%
				* Some 60-90 observed	* alternate meas avail

(Table 19)	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☐	☒	☒	☐	☐	☐	☐
Riffle	☐	☒	☒	☒	☐	☐	☐
~~Pool~~	☐	☐	☐	☐	☐	☐	☐
~~Bed~~ (if no riffle-pool morphology)	☐	☐	☐	☐	☐	☐	☐

Down's Model (Table 15)	m	Bankfull Indicators (Table 18)	3/7	
Sed Sorting (Table 20)	mod	Sediment Transport Observed?	☐ Yes ☒ No ☐ Not Visible	
Transport Mode (Table 21)	2/3	% of Bed Active	0	
Geomorphic Units (Table 22)	6/8	Mass Movement (Table 23)	4	/
Riffle-Pool Spacing (m):	/	% Riffles:	45	% Pools: 5

		*	*
Bankfull Width (m)	4.50	3.20	2.10
Bankfull Depth (m)	0.75	0.85	0.70
Undercuts (m)	0.20	0.23	/
Pool Depth (m)	0.86	/	/
Riffle Length (m)	16.0	8.0	/

Wetted Width (m)	2.25	1.10	1.10
Wetted Depth (m)	0.28	0.51	0.27
Velocity (m/s)	0.752	0.236	0.391
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	/	/	/

Notes:

Photos:

Version #4
Last edited: 04/04/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MW

GEO MORPHIX™

General Site Characteristics

Project Number: PN25002

Date:	2025-04-15	**Stream:**	/
Time:	10:28	**Reach:**	R26
Weather:	4°C, , Cloudy	**Location:**	Elora, ON
Field Staff:	MW SHK	**Watershed/Subwatershed:**	Irvine creek

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Flow Type

H1	Standing water	H1A	Back water
H2	Scarcely perceptible flow		
H3	Smooth surface flow		
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

FAS - Floating armorstone

OBD - Overbank deposits

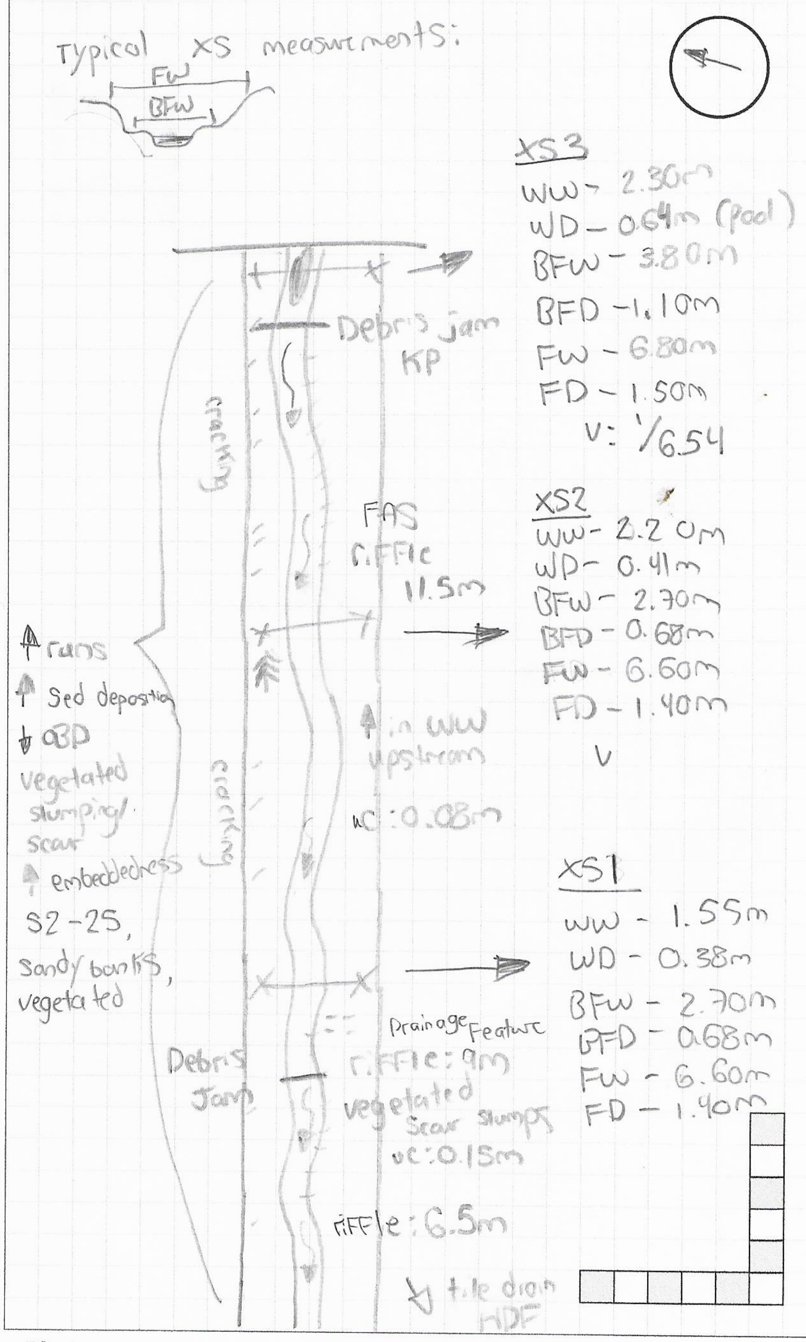
Substrate

S1	Silt	S6	Small boulder
S2	Sand	S7	Large boulder
S3	Gravel	S8	Bimodal
S4	Small cobble	S9	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	EP	Erosion pin
BS	Backsight	RB	Rebar
DS	Downstream	US	Upstream
WDJ	Woody debris jam	TR	Terrace
VWC	Valley wall contact	FC	Flood chute
BOS	Bottom of slope	FP	Flood plain
TOS	Top of slope	KP	Knick point

Site Sketch **Compass**



Photos:

Notes:

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 25002

Date:	2025-04-15	**Stream:**	/
Time:	10:28	**Reach:**	R2b
Weather:	4°c, cloudy	**Location:**	Elora, ON
Field Staff:	MC SHK	**Watershed/Subwatershed:**	Irvine creek

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	1/7
	2	Coarse materials in riffles embedded	X		
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	1	6	0.143
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		0/5
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)	N/A		
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets	N/A		
	6	Cut face on bar forms		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank *		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	0	4	0.000
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		X	2/8
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle	X		
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank	X		
	10	Exposed building foundation	N/A		
		Sum of indices =	2	6	0.250
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	7	0.000

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.098
In Regime	**In Transition/Stress**	**In Adjustment**
☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Version #3
Last edited: 10/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MC

GEO MORPHIX™

Rapid Stream Assessment Technique   Project Number: PN25002

Date:	2025-04-15	**Stream:**	/
Time:	10:28	**Reach:**	R26
Weather:	4°c, cloudy	**Location:**	Elora, ON
Field Staff:	MW SHK	**Watershed/Subwatershed:**	Irvine Creek

Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☒ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
no/few pools observed	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: MW

GEO MORPHIX™

Date:	2025-04-15	PN:	25002	Location:	Elora, ON

Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
* no/Few pools observed	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	X 4.5 ☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) =	Poor (<13)	Fair (13-24)	Good (25-34) 25.5	Excellent (>35)

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: [signature]

GEO MORPHIX™

Reach Characteristics

Project Number: PN25002

Date:	2025-04-15	**Field Staff:**	(MW) SHK	**Watershed/Subwatershed:**	Irving Creek
Time:	10:28	**Stream:**	/	**UTM (Upstream):**	/
Weather:	9°C, cloudy	**Reach:**	R2B	**UTM (Downstream):**	/

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)
1	1	7	2	1

☐ Evidence of Groundwater Location: / Photo: /

Riparian Vegetation

Dominant Type (Table 6)	3
Encroachment (Table 7)	2

- Coverage: ☐ None ☐ Fragmented ☒ Continuous
- Channel Widths: ☐ 1 - 4 ☒ 4 - 10 ☐ > 10
- Age (yrs): ☒ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8)	/
Reach Coverage %	/

- Woody Debris: ☐ In Cutbank ☒ In Channel ☐ Not Present
- WD Density: ☒ Low ☐ Mod ☐ High
- WDJ/50m: <1

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	1

Channel Characteristics

Sinuosity Type (Table 9)	1	Sinuosity Degree (Table 10)	1/2
Gradient (Table 11)	1	# of Channels (Table 12)	1
Entrenchment (Table 13)	1	Bank Failure (Table 14)	6
Down's Model (Table 15)	M	Bankfull Indicators (Table 18)	3/7
Sed Sorting (Table 20)	poor	Sediment Transport Observed?	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	2/3	% of Bed Active	/
Geomorphic Units (Table 22)	6/8	Mass Movement (Table 23)	4 /
Riffle-Pool Spacing (m):	/	% Riffles:	30
		% Pools:	5

- Bank Angle: ☐ 0 – 30 ☒ 30 – 60 * ☐ 60 – 90 ☐ Undercut — 80-90 observed
- Bank Erosion: ☐ < 5% ☐ 5 – 30% ☒ 30 – 60% ☐ 60 – 100% — *alternate available

(Table 19)	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☐	☒	☒	☐	☐	☐	☐
Riffle	☐	☒	☒	☒	☐	☐	☐
Pool	☐	☒	☒	☒	☐	☐	☐
Bed (if no riffle-pool morphology)	☐	☐	☐	☐	☐	☐	☐

Bankfull Width (m)	2.90 *	2.70 *	3.80 *
Bankfull Depth (m)	0.75 *	0.68 *	1.10 *
Undercuts (m)	0.15	0.08	/
Pool Depth (m)	0.64	/	/
Riffle Length (m)	9.0	6.5	11.5

Wetted Width (m)	1.55	2.20	2.30
Wetted Depth (m)	0.38	0.41	0.64
Velocity (m/s)	0.243	0.297	0.153
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	/	/	/

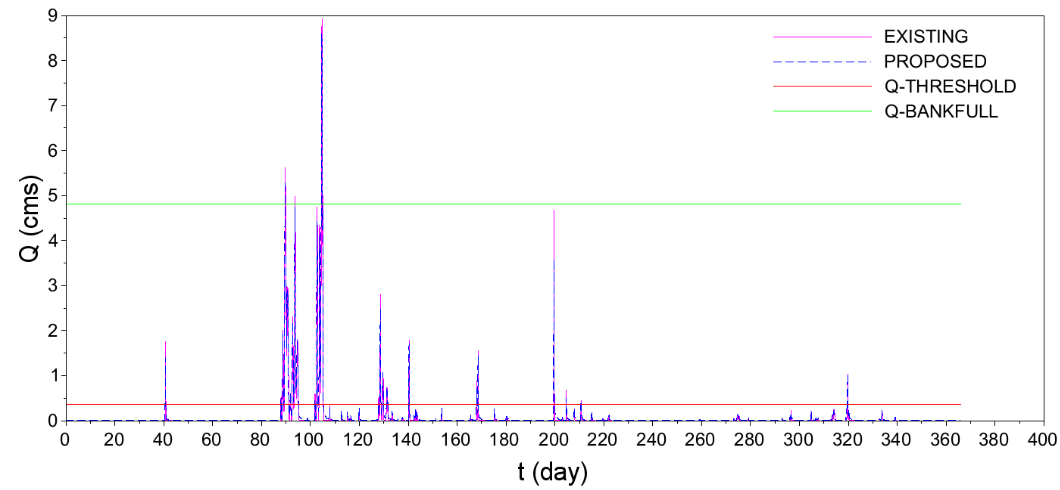
Notes:

Photos:

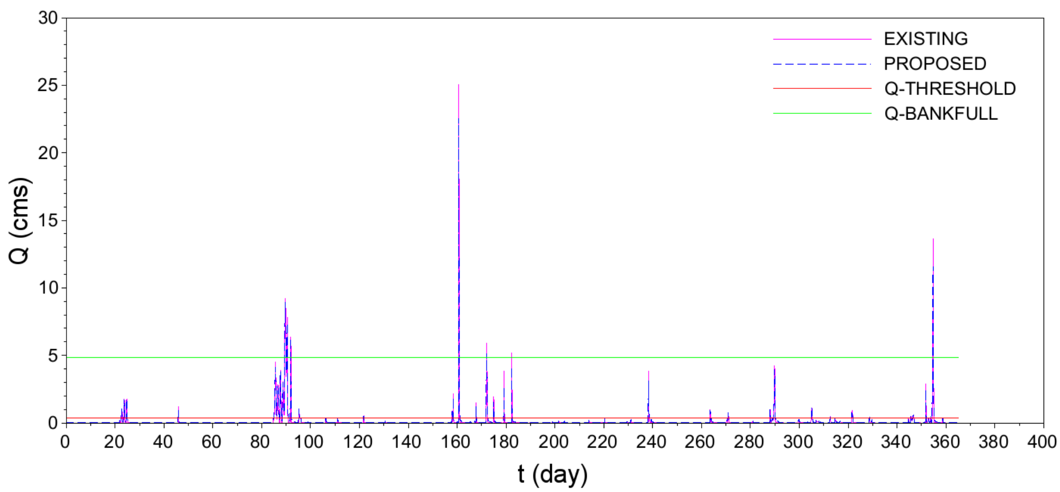
Senior staff sign-off (if required): ________ Checked by: ________ Completed by: ________

Appendix E:
Post- and Pre-Development Hydrographs

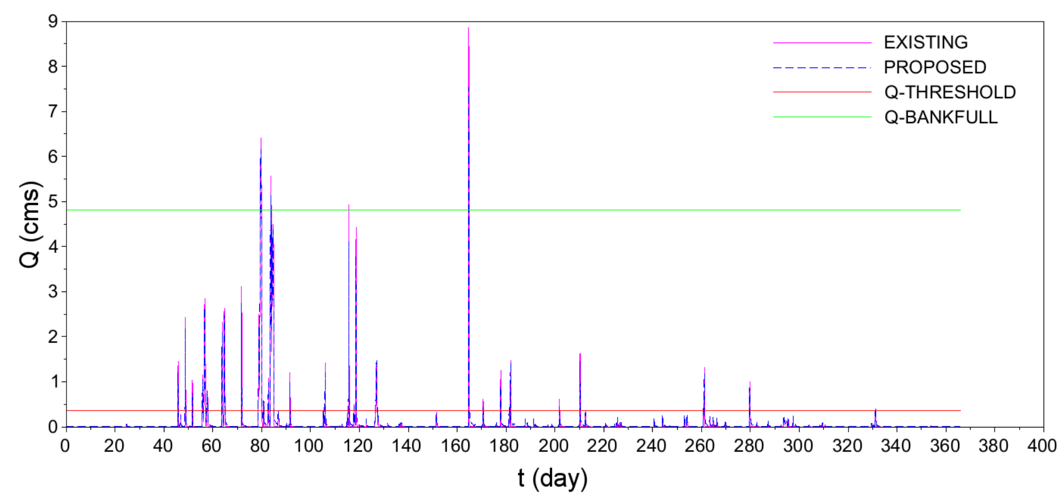
Representative Hydrographs



Reach R1A



Reach R1A



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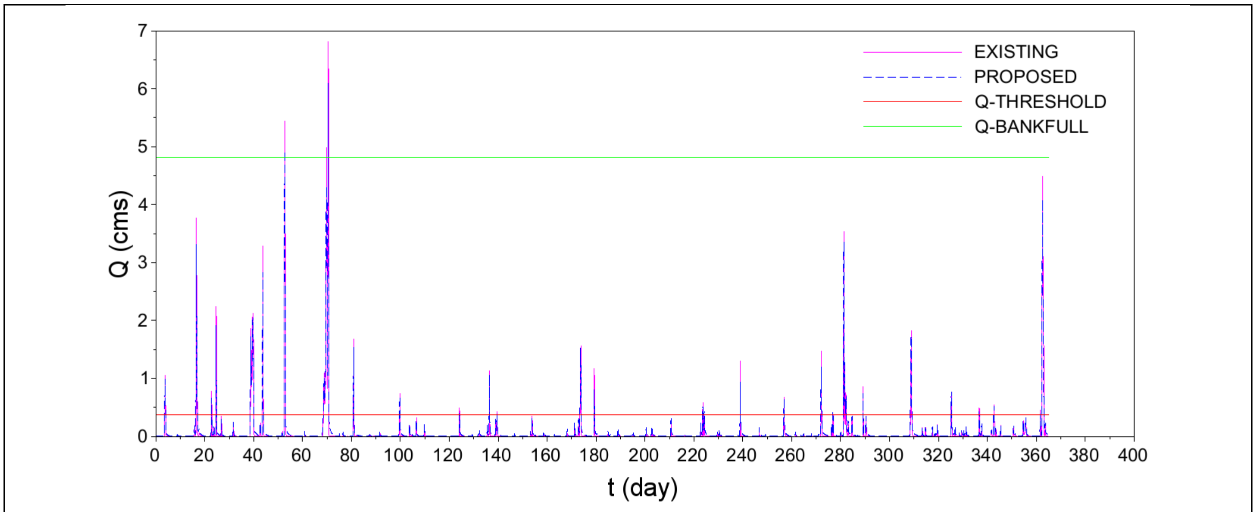
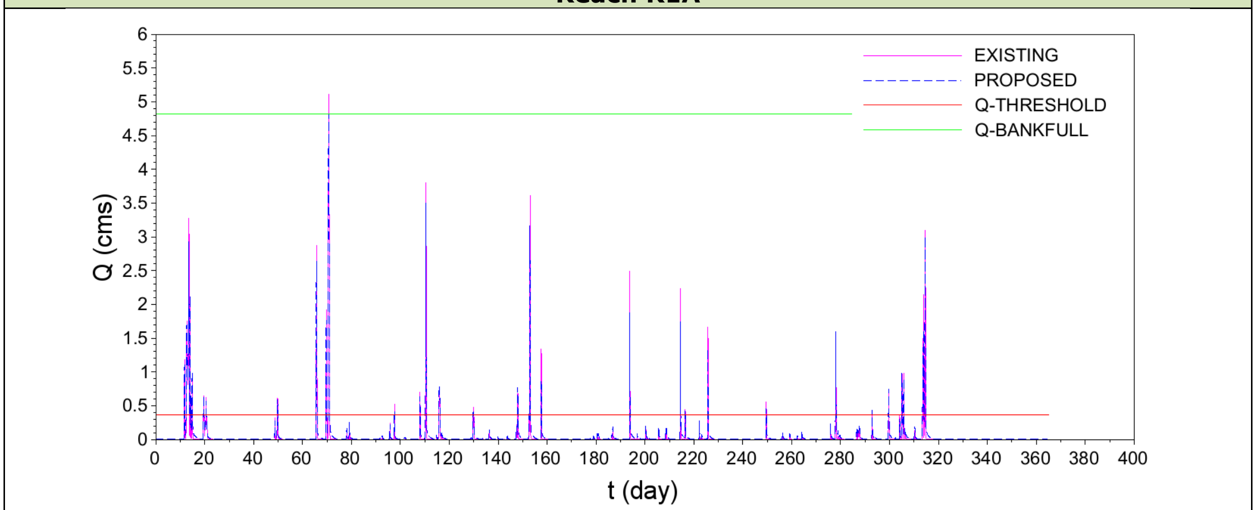


Reach R1A



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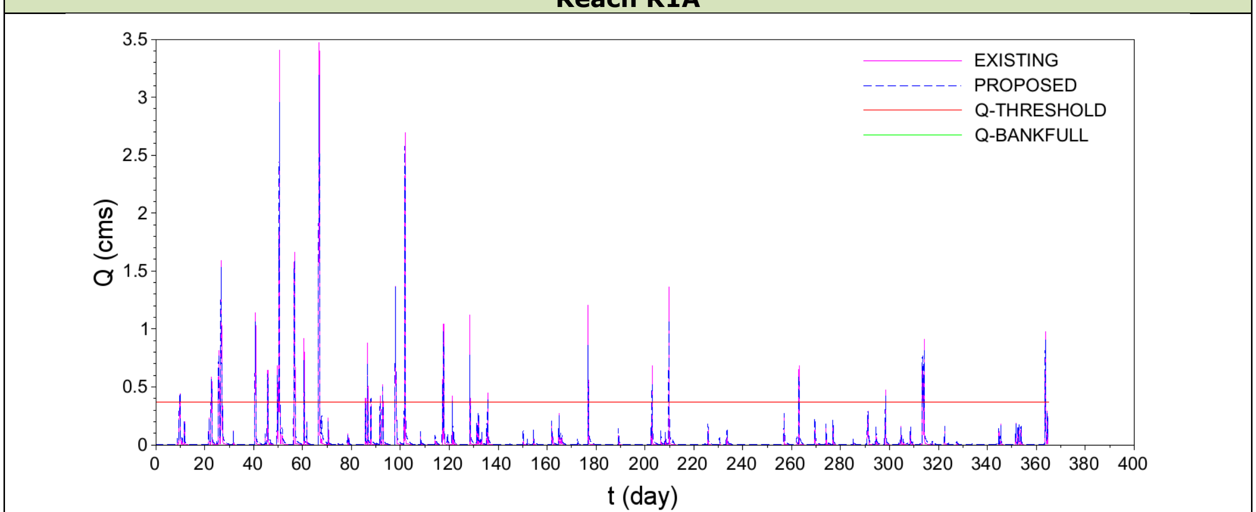
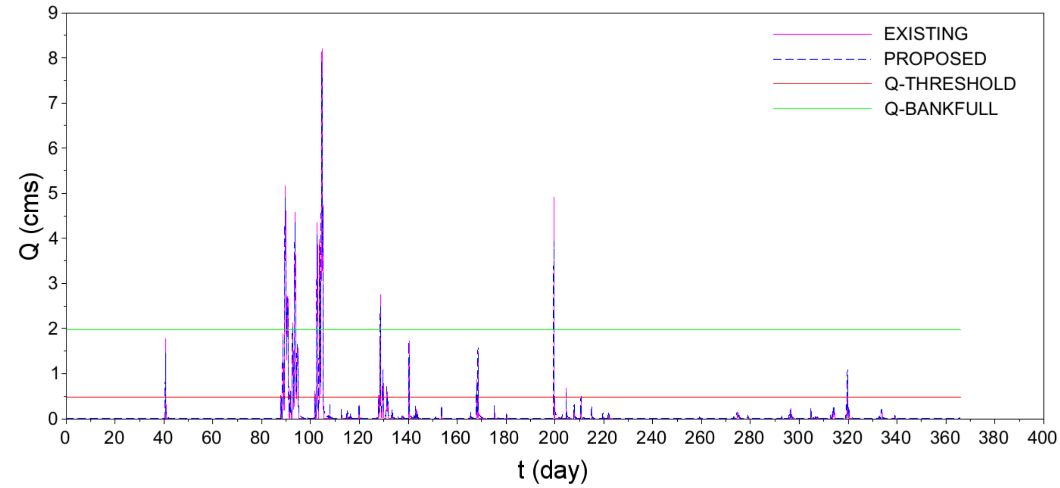
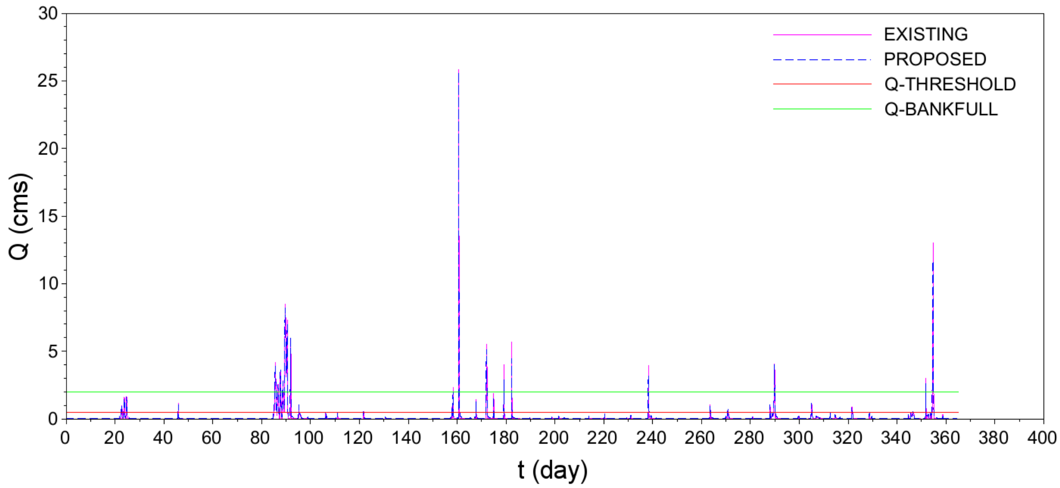


Reach R1A



Reach R2A



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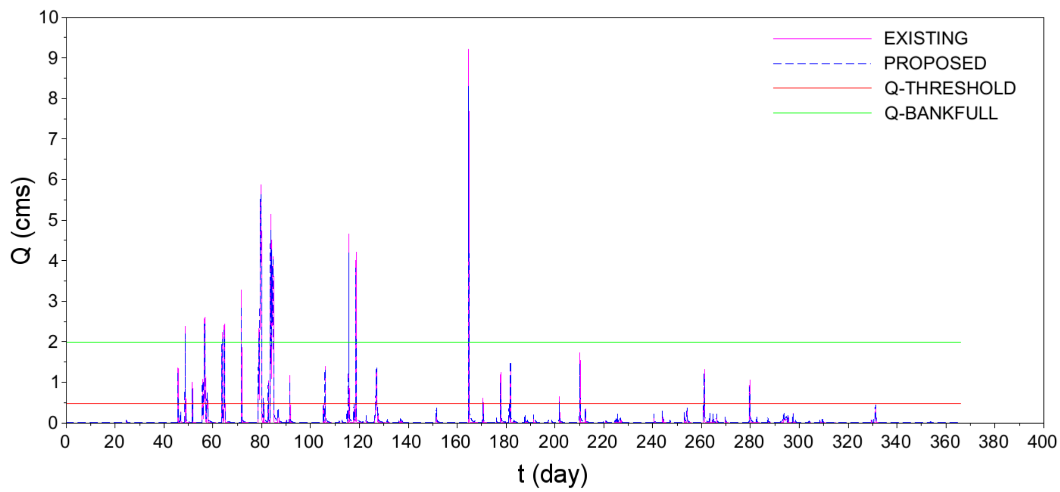

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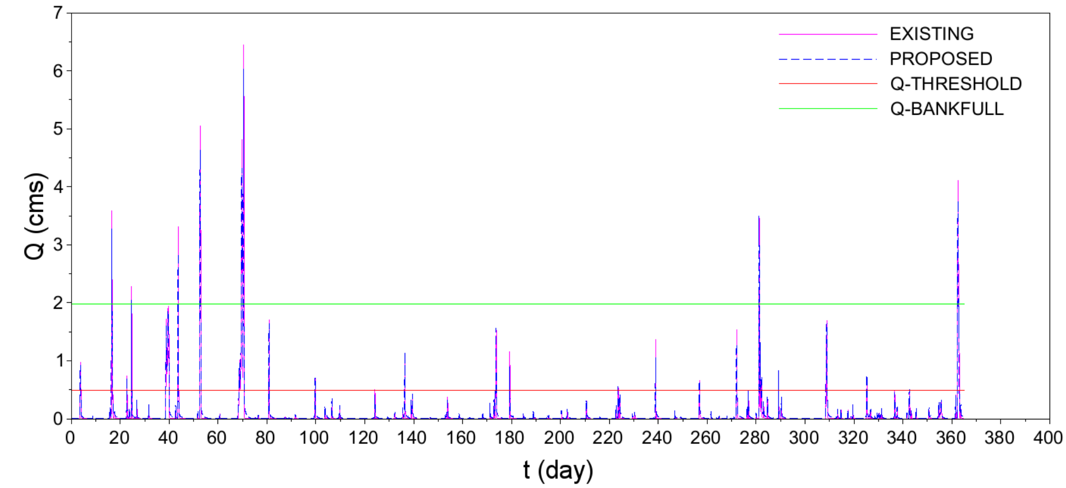

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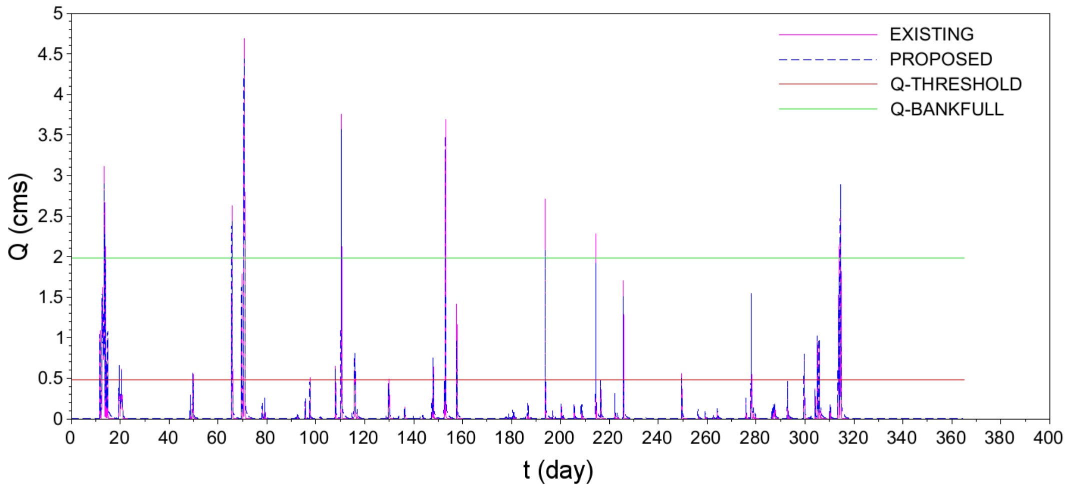

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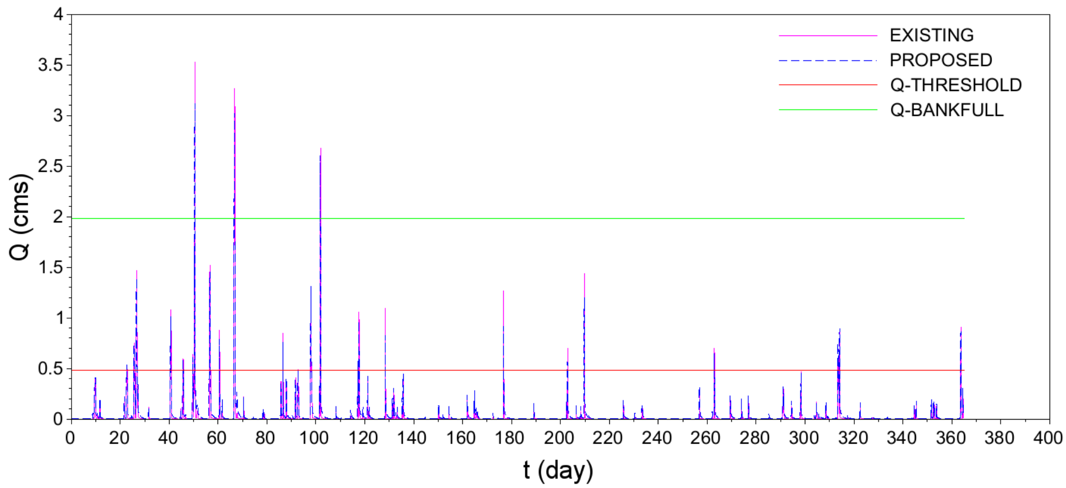

Reach R2A