3054 Homestead Drive
Erosion Threshold Assessment

Hamilton, Ontario

Prepared for:
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GEO MORPHIX
Geomorphology
Earth Science
Observations

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1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained by Fengate Homestead Holdings LP to complete a fluvial geomorphology assessment and erosion threshold analysis in support of the proposed development located at 3054 Homestead Drive ("Subject Property") in the City of Hamilton, Ontario. The subject property is located immediately west of the Hamilton Airport, and east of Homestead Drive within the Airport Employment Growth District (AEGD). The development site is located within the jurisdiction of Niagara Peninsula Conservation Authority (NPCA). It is understood that stormwater management (SWM) outflows from two outlet structures will be discharged into a small headwater channel within the subject property, which eventually flows into Twenty Mile Creek.

The following activities were completed as part of the fluvial geomorphological assessment and erosion threshold analysis:

- Review topographic and geologic maps and previously completed reporting to inform field reconnaissance efforts and provide contextual information for existing conditions characterizations
- Complete a historical site assessment using aerial photograph records to identify changes to the system due to land use and past channel modifications within the primary and extended study areas
- Delineate watercourse reaches along the receiving watercourses through a desktop exercise
- Conduct field reconnaissance to document reach-scale observations of channel substrate, flow behaviour, geomorphological processes, locations of valley wall contacts, and areas of active erosion
- Complete reach-level rapid assessments at each outlet channel using standard accepted techniques for geomorphological assessments to characterize channel conditions, stability, and erosion sensitivity
- Complete a detailed geomorphological field assessment, the primary objective of which is to determine bankfull channel conditions and inform the determination of critical discharge erosion thresholds
- Determine an erosion threshold, expressed as a critical discharge, for the most erosion-sensitive channel reach along the receiving watercourse within the immediate zone of impact associated with the proposed development

The work described above was summarized in version 1.0 of this report and submitted to Fengate Homestead Holdings LP on January 26, 2023. Comments from reviewing agencies were subsequently received requesting preliminary erosion exceedance modelling for the receiving watercourse to evaluate the proposed Stormwater Management (SWM) plan. An outlet is proposed in the northeast corner of the subject property to drain a proposed bioswale and will release flows to the small headwater channel west of Homestead Drive.

The following work was completed to support definition of erosion control criteria for the proposed outlet:

- Erosion exceedance analysis for Reach **H1S1** comparing pre- to post-development conditions for the 25-mm design storm to support erosion mitigation approach for proposed stormwater management on site

2 Background Review

A review of pertinent background material was completed to inform and provide contextual information regarding local hydrology and stream morphology. Material reviewed included site plans, historical aerial photographs, published surficial geological mapping, physiological region and landform mapping, and various relevant background reporting documents.

2.1 Watershed Characteristics

The majority of subject property is located within the headwaters of the Twenty Mile Creek subwatershed, which encompasses a drainage area of approximately 291 km^2. Landuse within this subwatershed is predominantly comprised of rural and agricultural lands (Durley, 2006). The headwaters located on the subject property are associated with Three Mile Creek, a watercourse that drains eastward into Twenty Mile Creek, south of Dickenson Road E, east of Miles Road, approximately 4 kilometres from the subject property.

The remaining portion of the property resides within the Upper Welland River watershed. This watershed drains approximately 480 km^2 of land and contains nearly 3000 km of stream channels (NPCA, 2011). Approximately 55% of this channel length contains some level of riparian vegetation and habitat. Landuse within this watershed is similarly comprised of mostly rural and agricultural lands, with occasional pockets of low-density urban development, such as Mt. Hope.

2.2 Surficial Geology and Physiography

Surficial geology and physiography act as primary controls regarding channel development, as they greatly influence the hydrological and sediment characteristics of a given drainage system. Channel morphodynamics are largely governed by the flow regime and the availability and type of sediments 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.

The study area resides within the Haldimand Clay Plain physiographic region, which extends south from the Niagara escarpment to the north shore of Lake Erie. The region is characterized by a series of parallel recessional moraines comprised of sand and gravel with intervening troughs of silt and clay that control and occasionally impede local drainage. Soils in this region tend to exhibit a heavy texture with poor, uneven drainage (Chapman and Putnam, 1984). Published surficial geology mapping indicates the subject property has fine-textured sediment deposits described as massive-to well laminated and comprised primarily of silt and clays, as well as minor sands and gravels from glaciolacustrine origin (OGS, 2010).

2.3 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics and is used to inform erosion hazard assessments. Aerial photographs for the years 1934, 1950, 1963, 1969, 1978 and 1985 from the National Air Photo Library, and years 2005, 2012, 2014, 2017, 2018 and 2021 from Google Earth Pro, were reviewed. Select imagery is provided in **Appendix A** for reference.

The subject property and surrounding areas were actively cultivated prior to 1934. Landuse consisted primarily of agricultural areas with residential development along the intersection of Homestead Drive and Airport Road. At this time, all main roads were established. Headwater tributaries present within the subject property appear to be draining agricultural fields across Homestead Drive, into Three Mile Creek. No riparian vegetation is evident.

Between 1934 and 1950, the Hamilton Airport began construction adjacent to the subject property. One headwater Tributary of Three Mile Creek, in the northeast portion of the subject property, appears to be more defined while exhibiting low sinuosity. By 1963, the construction of the Hamilton Airport was completed, upper James Street was constructed, and more housing development along Homestead Drive is evident. There are no changes to the headwater features. Between 1969 and 1978, no major changes in landuse or headwater features occur.

By 2005, a subdivision to the south of Airport Road, west of Homestead Drive/Upper James Street was constructed. The Hamilton Airport was expanded towards Homestead Drive by approximately 200 m, encroaching on the subject property. Willow Valley Golf Course was constructed within this time period. The primary landuse continues to remain dominated by agricultural landscapes. Minor riparian vegetation along the headwater drainage features begins to establish itself within the study site.

Between 2005 and 2009 a distinct riparian vegetation buffer (approximately 17 m wide) is evident along all headwater tributaries within, and near by the subject property. With the exception of the beginning stages of an Amazon facility being constructed, minor changes in landuse and headwater features are evident between 2009 and 2013. Between 2018 and 2021, the Amazon facility finished construction. No other changes are noted in landuse and headwater features between 2013 and 2021. No changes in landuse or headwater features draining to Three Mile Creek occur downstream of the subject property during the reviewed time period.

3 Watercourse Characteristics

3.1 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 allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular 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

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), the Toronto and Region Conservation Authority (2004) and others. Several watercourse reaches were delineated within the immediate zone of impact associated with each SWM facility based on a desktop assessment of available data (e.g., MNRF stream layer, surficial geology, historical and recent aerial photographs, topographic data.

Reach delineation was adopted and extrapolated from existing reach mapping provided by GEI Consultants (2022). A total of three reaches were identified within the subject property with an additional two reaches existing downstream along the receiving watercourse. The reaches within the subject property are classified as headwater drainage features, while the two downstream reaches are defined channels. Reach mapping is provided in **Appendix B**, for reference.

3.2 General Reach Observations

A site visit was completed by GEO Morphix Ltd. on July 27, 2022, to document existing channel conditions along the receiving watercourse, downstream of the proposed SWM outlets. Photographs of site conditions are provided in **Appendix C** and field observations are included in **Appendix D**, for reference.

The site visits included the following activities and reach observations:

- Habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation for the extent of each reach assessed
- Descriptions of riparian conditions
- Documentation of culvert crossing conditions
- Estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Observations of erosion, scour or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures
- Completion of rapid channel assessments following the Rapid Geomorphological Assessment (RGA) (MOE, 2003; VANR, 2007) and Rapid Stream Assessment Technique (RSAT) (Galli, 1996) methodologies

General channel characteristics for all assessed reaches are summarized below in **Table 1**. Reaches **H1S1A** and **H2S1** were excluded from the observations, as they are not within the zone of impact associated with the SWM flows and are consequently irrelevant to the erosion assessment.

Table 1: General Reach Observation Summary

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Dominant Riparian Condition	Notes
H1S1	0.91	0.17	Clay/silt, trace sand	Clay/silt, trace sand	Continuous grasses, occasional trees, cattails	○ Grassy swale drainage feature with limited channel definition ○ Minimal geomorphic activity observed ○ Extensive cattail and grass encroachment ○ Flows exit through stable culvert @ d/s end, 0.90 m diameter ○ Channel dry during assessment

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Dominant Riparian Condition	Notes
H1S2	1.53	0.31	Clay/silt, trace sand	Clay/silt, trace sand	Grasses, cattails, fragmented trees	○ Straightened/modified feature – roadside ditch ○ Intermittent channel definition ○ Minimal geomorphic activity ○ Heavy cattail encroachment
H1S3	1.61	0.39	Clay/silt, sand, gravel	Clay/silt, trace sand	Grasses, trees, cattails	○ Bank erosion and exposed bank material prevalent ○ Exposed length of pipe and wiring observed ○ Straightened in upstream extent with some cobble armouring

Reach **H1S1** is an unconfined and relatively poorly defined channel that flows east through the subject lands. Minimal geomorphic activity was observed throughout the entire length of the reach. The riparian zone is characterized by extensive cattails and grasses, which encroach upon the channel bed frequently. The bed and bank materials are generally consistent with one another and are comprised by silt and clay with trace amounts of sand. The average bankfull width and depth are 0.91 m and 0.17 m, respectively. Flows exit the reach through a stable 0.90 m diameter culvert that passes beneath Homestead Dr and Upper James St. The channel was dry during the time of assessment.

Reach **H1S2** begins on the east side of Upper James St and flows north along the side of the road before veering to the east. The channel here is similarly poorly defined in areas but exhibits occasional sections of defined channel. The reach was likely straightened and modified previously as part of the road works. As such, minimal ongoing geomorphic activity was noted throughout the reach. Much of the reach is encroached heavily by cattails, which also occupy the majority of the riparian zone. Minor iron staining was observed and provides evidence of groundwater inputs. The average bankfull width and depth are 1.63 m and 0.31 m, respectively. Flows exit the reach through a small culvert that directs flows beneath a service road associated with the adjacent sod farm.

Reach **H1S3** is an approximately 95 m length of channel that flows northeast towards Willow Valley Golf Course. Flows from **H1S3** exit into an east-flowing lower-order tributary of Twenty Mile Creek. The channel within **H1S3** is constricted by two paved lots associated with the adjacent sod farm and exhibits a meandering planform that frequently contacts and erodes the bounding valley walls. Bed materials range from loose, silty clay deposits within pools to gravels within the riffles. Banks are comprised of a firm silty loam, which is increasingly compact towards the toe of the bank slopes. Riparian vegetation is fairly limited and consists of grasses, cattails, and occasional mature trees. The average bankfull width and depth are 1.61 m and 0.39 m, respectively. Flows during the day of assessment were present, but mostly imperceptible.

3.3 Rapid Field Assessments

Channel stability and susceptibility to erosion were objectively assessed through the application of the Ontario Ministry of the Environment (MOE; 2003) Rapid Geomorphic Assessment (RGA) technique. The RGA evaluates degradation, aggradation, widening, and planimetric form adjustment at the reach scale. The purpose of the RGA is to produce a score, or stability index, which evaluates the degree to which a stream has departed from its equilibrium condition. A stream with a score of less than 0.20 is in regime, indicating minimal changes to its shape or processes over time. A score of 0.21 to 0.40 indicates that a stream is in transition or stress and is experiencing major changes to process and form outside the natural range of variability. A score of greater than 0.41 indicates that a stream is in extreme adjustment, exhibiting a new stream type, or in the process of adjusting to a new equilibrium (MOE, 2003; VANR, 2007).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and consider the ecological functioning 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 the Downs (1995) Model of Channel Evolution and the River Styles Framework (Brierley and Fryirs, 2005). The Downs (1995) model describes successional stages of a channel as a result of 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. The River Styles Framework provides a geomorphological approach to examining river character, behaviour, condition, and recovery potential.

Rapid assessments were completed during the site visit on July 27, 2022. Photographs of channel conditions for all reaches are provided in **Appendix C** and field observations are included in **Appendix D**, for reference. **Table 2**, below, summarizes the results of the rapid field assessments.

Table 2: Reach Classification Summary

Reach Name	RGA Score	Dominant Process	RSAT Score	Downs Model Classification	River Styles Framework
H1S1	0.19 "In Regime"	Planimetric Adjustment	n/a – dry channel	S - Stable	Suspended load meandering/ anastomosing
H1S2	0.19 "In Regime"	Planimetric Adjustment	23 "Fair"	R - Recovering	Suspended load straight
H1S3	0.26 "In Transition/Stress"	Aggradation	25 "Good"	R - Recovering	Mixed load meandering

Reach **H1S1** scored 0.19 on the rapid geomorphic assessment, indicting stable channel conditions. Some level of planimetric adjustment was observed, as evidenced by the multiple threaded channel and presence of chutes. The RSAT was not applicable to reach **H1S1**, as the entire length of channel was dry during the time of assessment. The channel was classified as stable under the Downs (1995) model, and was characterized as a suspended load-dominated meandering and anastomosing channel under the River Styles Framework (Brierley and Fryirs, 2005).

Similar to reach **H1S1**, reach **H1S2** scored 0.19 on the RGA with planimetric adjustment identified as the dominant geomorphic process. The RSAT score was 23, indicating fair conditions of channel stability and physical instream habitat. Riparian conditions were a limiting factor regarding the RSAT score. The channel was classified as a recovering channel under the Downs (1995) model, as the channel was previously straightened and is currently redeveloping a meandering planform. The reach was classified as a suspended load-dominated straight channel.

Reach **H1S3** scored 0.26 on the RGA, indicating a channel currently in transition or stress and consequently experiencing non-natural changes to its forms and processes. The dominant process was identified as aggradation, but evidence of channel widening and degradation was also present. The reach has a good level of stream habitat availability and channel stability, as the RSAT score was 25. Similar to reach **H1S2**, reach **H1S3** was classified as a recovering channel under the Downs (1995) model. The reach was classified as a mixed load meandering channel under the River Styles Framework (Brierley and Fryirs, 2005).

3.4 Detailed Geomorphological Assessment

A detailed geomorphological assessment was completed for reach **H1S3** during the site visit on July 27, 2022. This assessment provided bankfull channel characteristics, including cross-sectional geometry and hydraulics, for the purpose of defining the erosion threshold. Reach **H1S3** was selected based on field observations, as confirmed by both the RGA and RSAT, which showed this channel was most susceptible to erosion. Representative cross sections were surveyed, and a modified Wolman (1954) pebble count was completed, where applicable, to characterize the bed materials. Sediment sampled for bank materials was reviewed and analyzed. A longitudinal survey of the bed was also completed to determine slope. Photographs of channel conditions are provided in **Appendix C** and a comprehensive summary of the channel measurements is included in **Appendix E**, for reference. A tabular summary of channel measurements is also presented in **Table 3**, within **Section 4.2**.

4 Erosion Threshold Assessment

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank material. As such, they are used to inform erosion mitigation strategies in channels influenced by conceptual flow and stormwater management plans. Erosion thresholds were modelled from detailed field observations of reach **H1S3**. This reach was selected for the assessment, as it was determined to be the most erosion-sensitive reach within the immediate zone of impact associated with the SWM outlets within the development. The erosion threshold is the theoretical point, typically expressed as a critical discharge or shear stress, at which entrainment of sediment would occur based on 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.

4.1 Methodology

Threshold targets are determined using different methods that are dependent on channel and sediment characteristics. 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. 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.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry, in the form of a critical discharge. Theoretically, above this discharge, entrainment and transport of sediment can occur. To determine this discharge, the velocity, U, or Shear Stress, t, is calculated at various depths for a representative cross section until the average velocity or shear stress in slightly exceeds the critical threshold of the bed material. The velocity is determined using a Manning's approach, where the 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 0.042 was used for the assessment. The velocity is mathematically represented as:

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

where, d is depth of water, S is channel 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:

$$t = d\rho g S_{bed} \qquad \text{[Eq. 2]}$$

Where, t is shear stress, d is the water depth, ρ is water density, g is acceleration due to gravity, and S_{bed} is the channel bed slope.

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

4.2 Results

Analysis of the bank materials within reach **H1S3** showed they were composed of a compact silty loam using the criteria of Fischenich (2001). Based on the type of material observed, a critical velocity approach was taken using the criteria of Fischenich (2001) for the silty loam bank material, a somewhat cohesive material with high silt and clay content. This material is estimated to have a critical velocity of 0.53 m/s, which was used to determine the material's threshold discharge, the point at which sediment entrainment begins to occur. In this instance, the critical discharge for the bank materials was predicted to be 0.145 m^3/s. A Manning's roughness value of 0.046 was adopted for the critical discharge calculations, based on the framework described by Acrement and Schneider (1989).

The bed material within reach **H1S3** ranged from loose silty clays to large gravels. The D_{84} grain size of the bed materials within reach **H1S3** were determined to be pebble-sized gravels (12.7 mm) according to the Wentworth scale (Wentworth, 1922), and represents the dominant materials found within the riffles. Using the methods described by Miller et al. (1977), this material is predicted to have a permissible velocity of 0.64 m/s. The loose silty clays that occupied the remaining pool and run geomorphic units were classified as alluvial silt under the framework described by Fischenich (2001), as has a permissible velocity of 0.61 m/s. The 0.61 m/s value was selected as the limiting criteria for the bed material and was used to determine the critical discharge, which in this case was 0.078 m^3/s.

The results of the erosion threshold assessment are provided in **Table 3** below. The threshold was modelled from data collected at the receiving reach that is most sensitive to erosion, **H1S3**, and is considered conservative. The final, modelled erosion threshold is the lesser of the bed and bank materials, and in this instance was determined to be 0.078 m^3/s for the bed materials.

Table 3: Reach H1S3 detailed assessment and erosion threshold analysis results

Channel parameter	Results by Reach
	H1S3
Bankfull Conditions	
Average bankfull width (m)	1.61
Average bankfull depth (m)	0.24
Channel gradient (%)	1.58
D_{50} (mm)	<2.0
D_{84} (mm)	12.65
Manning's n roughness coefficient	0.046
Bankfull discharge (m^3/s)	0.35
Bankfull velocity (m/s)	0.92
Channel Bed Erosion Threshold	
Bed Material	Alluvial Silt (Fischenich, 2001)
Critical velocity at the bed (m/s)	0.61
Apparent shear stress acting on bed (N/m^2)	20.87
Critical discharge (m^3/s)	0.078
Channel Banks Erosion Threshold	
Bank Material	Silty Loam (Fischenich, 2001)
Critical velocity at the banks (m/s)	0.53
Apparent shear stress acting on banks (N/m^2)	19.09
Critical discharge (m^3/s)	0.145
Limiting critical discharge (m^3/s)	**0.078**
Unitary erosion threshold* ($m^3/s/ha$)	**0.0016**

* Determined using a 48.2 ha drainage area obtained from the Ontario Watershed Information Tool (OWIT)

5 Preliminary Erosion Exceedance Analysis

In support of the proposed Stormwater Management (SWM) plan, an erosion threshold analysis was completed in association with the Three Mile Creek tributary. An outlet is proposed in the northeast corner of the subject property to drain a proposed bioswale and will release flows to **H1S1** approximately 125 m west of Homestead Drive. Downstream of the subject property, flows from this tributary are conveyed in laterally confined open channels, including reach **H1S1**. Ultimately, flows drain downstream into Three Mile Creek, a headwater tributary to Twenty Mile Creek. To support definition of erosion control criteria for the proposed outlet, an erosion threshold assessment was completed for the receiving tributary (reach **H1S1**).

Using the results of the erosion threshold analysis and hydrological modelling provided by Odan Detech (2023) for pre-development conditions and three (3) successive iterations of post-development conditions, additional analyses regarding the impacts of SWM controls on potential erosion within the watercourse were completed with our in-house Erosion Exceedance Model, based on four erosion exceedance indices:

1) Cumulative time of exceedance

2) Number of exceedance events

3) Cumulative effective discharge and volume

4) Cumulative effective work index (i.e. cumulative effective stream power)

These indices have been applied elsewhere in numerous jurisdictions, such as Conservation Halton and Toronto and Region Conservation Authority and have been widely accepted by Ontario Conservation Authorities. They provide an evaluation of the number, duration, and magnitude of exceedance events. We note that the most relevant indicator is the cumulative effective work index, as this value reflects both the duration and magnitude of erosion exceedance events.

Time of exceedance, number of exceedances, and cumulative effective discharge and volume can be calculated from the discharge record and 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 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, hydraulic information is required. Our model applies the discharge to a characteristic cross-section. Using a 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 analysis that is appropriate to the specific site conditions.

The post- and pre-development hydrological modelling reflects changes to the hydrological regime resulting from SWM measures being implemented within the catchment. Flow data for reach **H1S1** was provided by Odan Detech (2023) in 5-minute increments for the 25 mm design storm. The hydrological modeling was analyzed to calculate the aforementioned erosion indices and identify changes in the erosive potential within **H1S1** following development. The post- and pre-development hydrograph, overlain with the respective erosion threshold and bankfull discharge, is provided in **Appendix F**, for reference.

The simulation used an erosion threshold value of 0.022 m^3/s for reach **H1S1**. This erosion threshold was estimated by scaling that of **H1S3**, determined through the Erosion Threshold Assessment detailed above (**Table 3**). The erosion threshold for **H1S3** is 0.078 m^3/s for a drainage area of 48.2 ha, thus the unitary erosion value is 0.0016 $m^3/s/ha$. Based on a drainage area of 13.80 ha for **H1S1,** taken from the Functional Servicing Report prepared by Odan Detech (2023), multiplied by the previously determined unitary erosion value of 0.0016 $m^3/s/ha$**,** the erosion threshold is estimated to be 0.022 m^3/s.

5.1 Methods

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 the Manning's approach. 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:

$$Q_{T=} \sum Q_i \quad \text{[Eq. 3]}$$

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

$$Q_i = U_i w_i d_i \quad \text{[Eq. 4]}$$

where, w_i and d_i are 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.

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:

$$\tau_{o_{\max}} = d_{\max} \rho g S_{\text{bed}} \quad \text{[Eq. 5]}$$

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

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

$$\varpi_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \quad \text{[Eq. 6]}$$

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:

$$\varpi_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \varpi < 0 = 0 \quad \text{[Eq. 7]}$$

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

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \quad \text{for } (Q_T > Q_{\text{threshold}}) \quad \text{[Eq. 8]}$$

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

The cumulative effective discharge volume (CEV) is defined as:

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \quad \text{[Eq. 9]}$$

Similarly, the cumulative effective discharge (CED) is defined as:

$$\text{CED} = \text{CEV}/t_{ex} \quad \text{[Eq. 10]}$$

5.2 Results

The post- to pre-development hydrograph is included in Appendix F. **Table 4** provides the results of the assessment based on the latest hydrographs for the 25 mm design storm provided by Odan Detech (2023).

Table 4: Reach H1S1 post- to pre-development erosion exceedance analysis results for latest hydrological modelling iteration

Simulation		CED (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
Q_{crit}: $0.022m^3/s$ 25 mm	**(PRE)**	258.90	14.27	2.67	1.00
	(POST)	66.30	5.342	2.50	1.00
	Change (%)	**-74.39%**	**-62.57%**	**-6.25%**	**0.00%**

The cumulative effective discharge (CED) represents the average magnitude of flow exceeding the threshold during a given erosion event. In this instance, the CED decreased by 74.39% by the third iteration of post-development conditions. The cumulative effective work index (ω_{eff}), which reflects both the duration and severity of erosion events, is predicted to decrease by 62.57% in the proposed post-development conditions. The cumulative time of exceedance (t_{ex}), which represents the cumulative time for which flow exceeds the established erosion threshold, is predicted to decrease by 6.25% in the proposed post-development conditions. The number of exceedances within the modelled hydrological record is predicted to remain the same at one (1) exceedance, indicating no change in the frequency of occurrence for erosion events.

Taken as a whole, the results of the post- to pre-development erosion exceedance predict a general reduction in erosion potential for the 25 mm design storm within reach **H1S1** following completion of development activities. The 25 mm design storm captures the majority of rain events and would produce flow conditions near bankfull, or the channel forming flow, thus it is an appropriate event with which to evaluate changes in erosion potential in a receiving watercourse. The expected geomorphic response for the 25 mm design storm within receiving reach **H1S1** is characterized by less severe erosion events. Such reductions in erosion potential are beneficial for streams with urbanizing catchments, as it provides a level of resilience to future developments and their associated hydrological effects. From a fluvial geomorphic perspective, the proposed SWM plans adequately address erosion mitigation concerns.

6 Summary and Conclusions

GEO Morphix Ltd. was retained by Fengate Homestead Holdings LP to complete a fluvial geomorphic and erosion threshold assessment in support of proposed development at 3054 Homestead Dr, Hamilton, Ontario. The assessment included a review of previous studies, completion of a historical assessment, rapid and detailed field reconnaissance, and an erosion threshold assessment and erosion exceedance analysis.

Activities completed for the assessment included a detailed desktop review of available geology, topography, drainage area characteristics, and watercourse reach delineation. General channel observations, rapid stream assessments, and rapid geomorphological assessments for all reaches downstream of the proposed SWM outlet were completed during a site visit on July 27, 2022. These assessments documented existing channel and culvert crossing characteristics and assessed relative erosion-sensitivity of each channel reach. The results of the rapid assessments informed the location of the detailed geomorphological assessment, which was completed at reach **H1S3** during the same field visit.

The results of the detailed geomorphological assessment provided information relevant to the erosion threshold analysis. An erosion threshold, expressed as a critical discharge was determined for both the bed and bank materials within the most erosion-sensitive reach (i.e., **H1S3**). The reach was erosion-limited by the loose silty bed material that occupied most pool and run morphological units within the reach, and the resulting erosion threshold was determined to be 0.078 m^3/s. Using the Ontario Watershed Information Tool, a 48.2 ha pre-development drainage area was determined and used to calculate the unitary erosion threshold of 0.0016 $m^3/s/ha$. This unitary value provides guidance for defining SWM release rates and developing an appropriate erosion mitigation strategy for the 3054 Homestead Drive development.

The results of the erosion threshold analysis provided the input necessary for an erosion exceedance analysis. Hydrographs for a 25 mm design storm were provided for reach **H1S1**. Since the erosion threshold value of 0.078 m^3/s was determined for reach **H1S3**, it was necessary to scale the value to derive an erosion threshold for reach **H1S1** upstream. A drainage area of 13.80 ha for reach **H1S1,** taken from the Functional Servicing Report prepared by Odan Detech (2023), and the unitary erosion threshold of 0.0016$m^3/s/ha$ were used to calculate an erosion threshold of 0.022 m^3/s. The erosion exceedance modelling results indicate that the proposed stormwater management plan adequately mitigates the potential for excess erosion for the 25 mm design storm within the receiving watercourse following development.

We trust this report meets your requirements at the time. Should you have any questions please contact the undersigned.

Respectfully submitted,

Paul Villard Ph.D., P.Geo., CAN-CISEC, EP, CERP
Director, Principal Geomorphologist

Kelsey Serviss, M.Sc.
Environmental Field Technician

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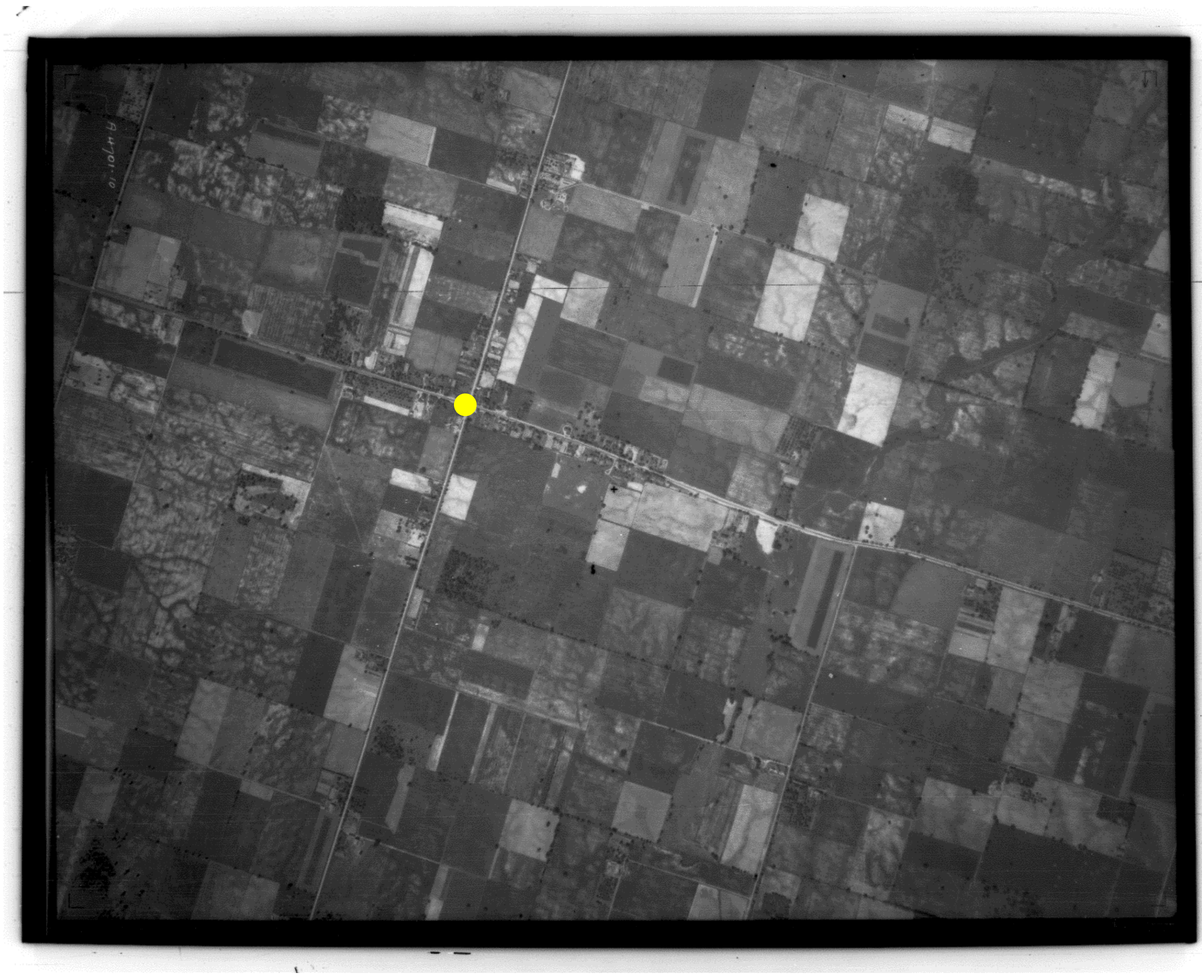
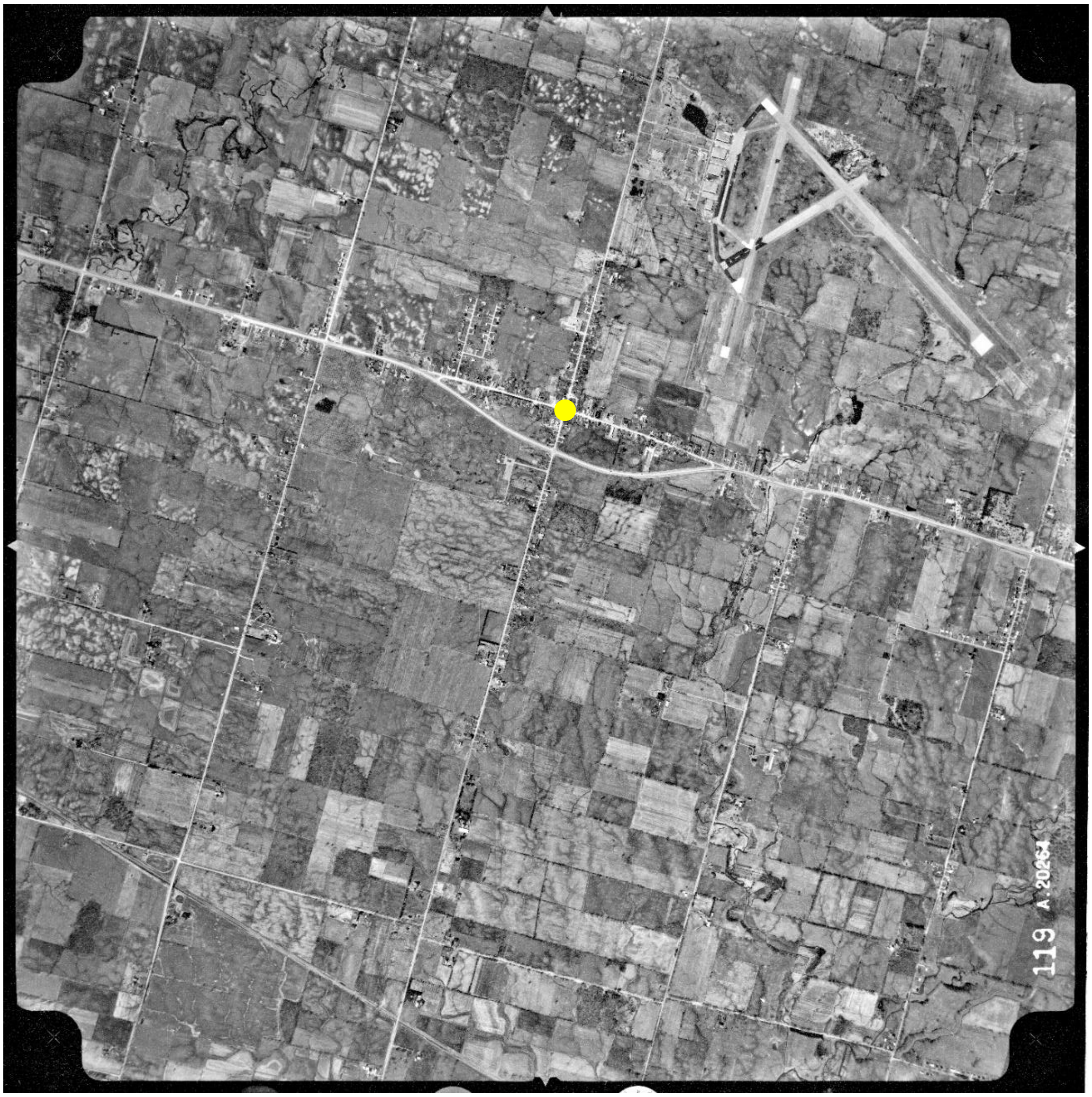
Appendix A
Historical Aerial Photographs



Location: Hamilton, ON
Year: 1934
Scale: 1:20000
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 1950
Scale: 1:12000
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 1963
Scale: 1:15000
Yellow Marker: Intersection of Airport Road and Homestead Drive



Location: Hamilton, ON
Year: 1969
Scale: 1:30000
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 1978
Scale: Approx. 1:15000
Yellow Marker: Intersection of Airport Road and Homestead Drive

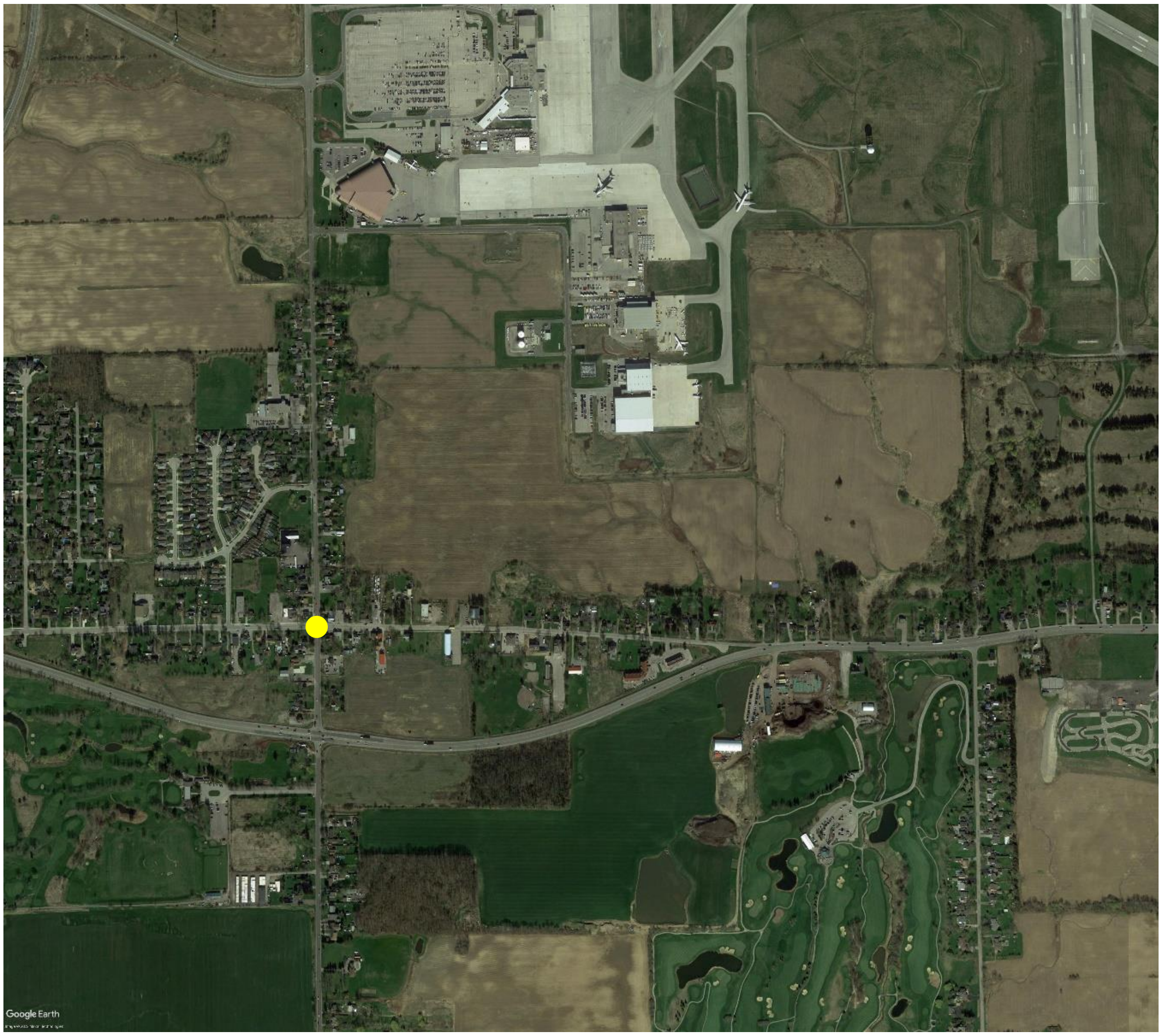
Location: Hamilton, ON
Year: 1985
Scale: 1:12000
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 2005
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 2012
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 2014
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 2017
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive



Location: Hamilton, ON
Year: 2018
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive

Location: Hamilton, ON
Year: 2021
Scale: N/A (orthoimagery)
Yellow Marker: Intersection of Airport Road and Homestead Drive

Appendix B
Reach Delineation

Legend

Reach Break and ID

Watercourse

Detailed Assessment Location

3054 Homestead Drive
Erosion Threshold Assessment

Hamilton, Ontario

GEO MORPHIX™

N

0 75 150
Metres

Imagery: Google Earth, 2021.
Watercourse: MNRF, 2020/GEO Morphix Ltd., 2022.
Reach Break and ID, Detailed Assessment Location: GEO Morphix Ltd.
September 2022. PN22062. Drawn By: M.O., J.T.

Appendix C
Photographic Record

Photo 1
Reach **H1S1**

Reach **H1S1** is a high-order, headwater feature with limited channel definition. Yellow arrow denotes flow direction.

Photo 2
Reach **H1S1**

The channel is intermittently defined, but often exhibits multiple flow-paths. No flows were observed during the time of assessment.

Photo 3
Reach **H1S1**

Riparian conditions are characterized by dense cattails and grasses with occasional mature trees.

Photo 4
Reach **H1S1**

Vegetation encroachment onto the channel bed is common throughout the reach. Indicators of erosion are minimal.

Photo 5 Reach **H1S1**	
	Flows travel through dense cattail marsh features towards Homestead Drive.
Photo 6 Reach **H1S1**	
	Flows exit the reach though a stable 0.90 m PVC pipe culvert passes beneath Homestead Drive and Upper James Street.

Photo 7 Reach **H1S2**	
	Reach **H1S2** flows northeast and adjacent to Upper James Street. The reach is best characterized as a straightened ditch.
Photo 8 Reach **H1S2**	
	Groundwater inputs are evidenced by iron staining observed near the upstream extent of the reach.

Photo 9
Reach **H1S2**

Reach **H1S2** held water during the assessment, but flow velocities were imperceptible. Signs of bank erosion were noted, but were not significant.

Photo 10
Reach **H1S2**

Sections of the reach exhibit multiple and poorly defined channels and flow-paths.

Photo 11 Reach **H1S2**	 Cattail vegetation encroachment is significant throughout the downstream portions of the reach. The channel here is poorly defined.
Photo 12 Reach **H1S2**	 Flows exit reach H1S2 through a stable corrugated plastic pipe culvert that passes beneath a service road associated with the adjacent sod farm.

Photo 13 Reach **H1S3**	
	Reach **H1S3** flows through a constricted corridor between two paved lots.
Photo 14 Reach **H1S3**	
	Bed material ranges from silty clays to medium sized gravels. Banks are comprised of a compact silty clay loam.

Photo 15 Reach **H1S3**	 Riparian vegetation is mostly grasses and cattails, with occasional mature trees near the downstream extent of the reach.
Photo 16 Reach **H1S3**	 The channel exhibits a meandering planform within the constricted corridor. Bank exposure and erosion is common on the outer banks of meander bends.

Photo 17
Reach **H1S3**

Bank erosion has caused several outer banks to become fully exposed and void of any significant vegetation establishment.

Photo 18
Reach **H1S3**

The channel bed was wetted, but flows were minimal and imperceptible during the time of assessment.

Photo 19 Reach **H1S3**	
	The channel typically exhibits a trapezoidal shape with bank angles generally ranging from 60-90 degrees.
Photo 20 Reach **H1S3**	
	Flows exit the reach into an east-flowing tributary of Twenty Mile Creek.

Appendix D
Field Observations

GEO | MORPHIX
Geomorphology
Earth Science
Observations

General Site Characteristics

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	HIS1
Weather:		**Location:**	Mt Hope
Field Staff:	JT MK	**Watershed/Subwatershed:**	20 Mile Crk

Features
- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing 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

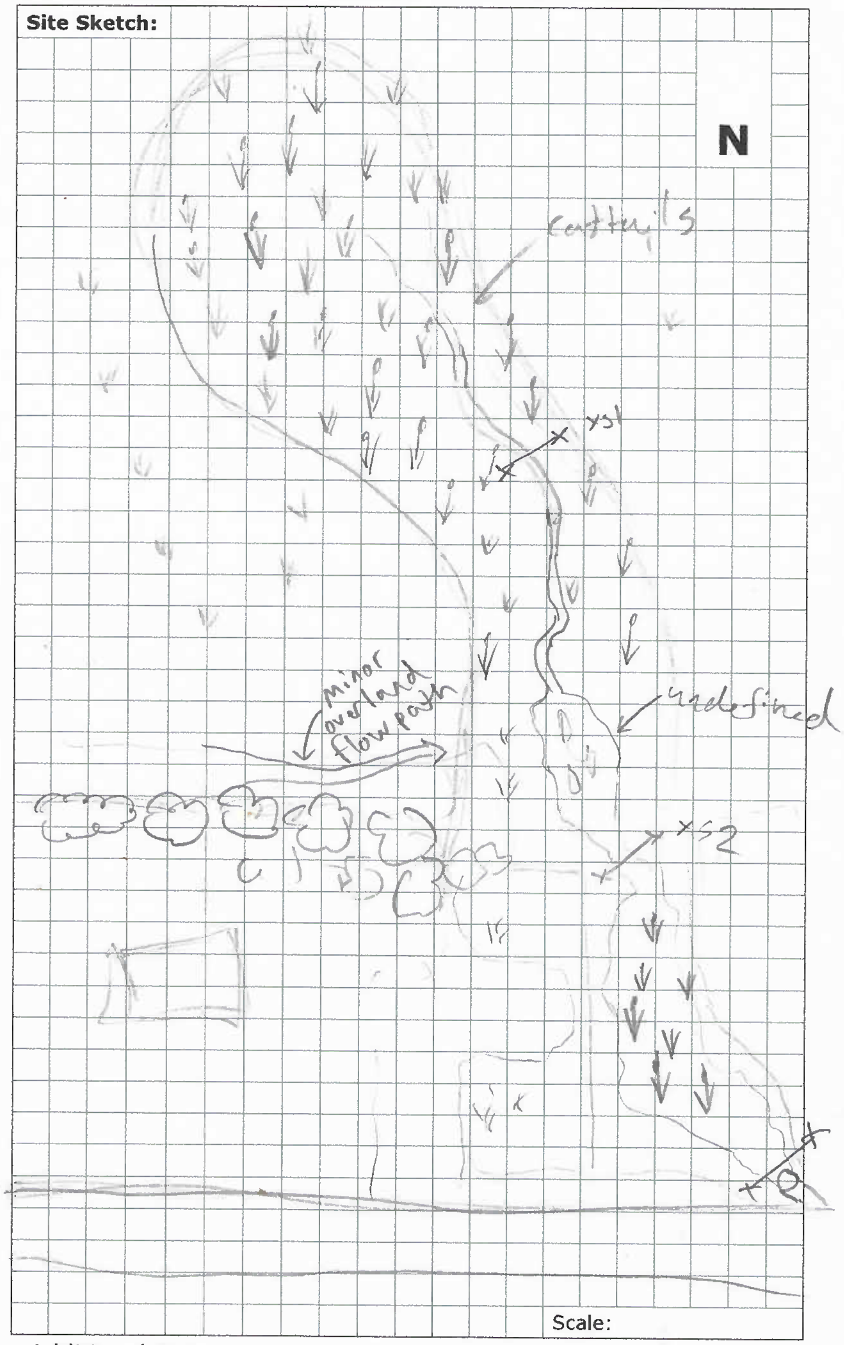
Substrate

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:



Scale:

Additional Notes:

Completed by: ________ Checked by: ________

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code:

Date:	2022-07-27	**Stream/Reach:**	HIS1
Weather:		**Location:**	3054 Homestead Dr
Field Staff:	JT MK	**Watershed/Subwatershed:**	Twenty Mile creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 14 | **Channel Zone** (Table 4): 1/2 | **Flow Type** (Table 5): 3 | ☐ Groundwater | Evidence: ______

Riparian Vegetation

Dominant Type: (Table 6) 3
Species: ______

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths:
- ☐ 1-4
- ☒ 4-10
- ☐ > 10

Age Class (yrs):
- ☒ Immature (<5)
- ☐ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7) 4

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 50

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☒ Not Present

Density of WD:
- ☒ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): N/a
Turbidity (Table 17): N/a

Channel Characteristics

Sinuosity (Type) (Table 9): 1 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 1 | **Number of Channels** (Table 12): 2

Entrenchment (Table 13): / | **Type of Bank Failure** (Table 14): 1 | **Downs's Classification** (Table 15): 5

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☒	☐	☐	☐	☐	☐	☐
Pool Substrate	☒	☐	☐	☐	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☐

Bankfull Width (m)	0.60	1.00	1.12	**Wetted Width (m)**	/		
Bankfull Depth (m)	0.23	0.02	0.25	**Wetted Depth (m)**	/		

Riffle/Pool Spacing (m): n/a | **% Riffles:** n/a | **% Pools:** n/a | **Meander Amplitude:** n/a

Pool Depth (m): n/a | **Riffle Length (m)**: n/a | **Undercuts (m)**: /

Velocity (m/s): / | / | / | **Wiffle ball / ADV / Estimated**

Comments: Multiple, poorly defined channels observed - swale

Bank Angle
- ☒ 0 – 30
- ☐ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☒ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes: - Swale-esque feature, likely an HDF
- Minimal geomorphic activity/adjustment

- Stable outflow culvert ~ 90 cm diameter
- Dry during assessment

Completed by: JT/MK | Checked by: ______

Rapid Stream Assessment Technique **Project Code:** 22063

Date:	2022-07-27	**Stream/Reach:**	H1S1
Weather:		**Location:**	Mt Hope
Field Staff:	JT MK	**Watershed/Subwatershed:**	20 Mile creek

Evaluation 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)
	• 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

Date:		Reach: H151	Project Code:	
Evaluation 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
	• 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	☐ 5 ☐ 6	☐ 7 ☐ 8
n/a Dry 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) =	19	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: ________ Checked by: ________

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code:** 22063

Date:	2022-07-27	**Stream/Reach:**	H1S1
Weather:		**Watershed/Subwatershed:**	20 Mile crk
Field Staff:	JT MK	**Location:**	Mt Hope

Process	No.	Description	Yes	No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	0.333
	2	Coarse materials in riffles embedded	—	—	
	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 =			
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		X	0
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s)		X	
	4	Undermined gabion baskets / concrete aprons / etc.	—	—	
	5	Scour pools downstream of culverts / storm sewer outlets	—	—	
	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 =			
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		X	0
	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.	—	—	
	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	—	—	
		Sum of indices =			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	X		0.429
	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 =			

Additional notes:

Minimal geomorphic activity

Stability Index (SI) = (AI+DI+WI+PI)/4 =	0.19		
Condition	**In Regime**	**In Transition/Stress**	**In Adjustment**
SI score =	☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Completed by: ________ Checked by: ________

General Site Characteristics

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	H152
Weather:		**Location:**	Mt Hope
Field Staff:	JT MK	**Watershed/Subwatershed:**	20 Mile Crk

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing 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

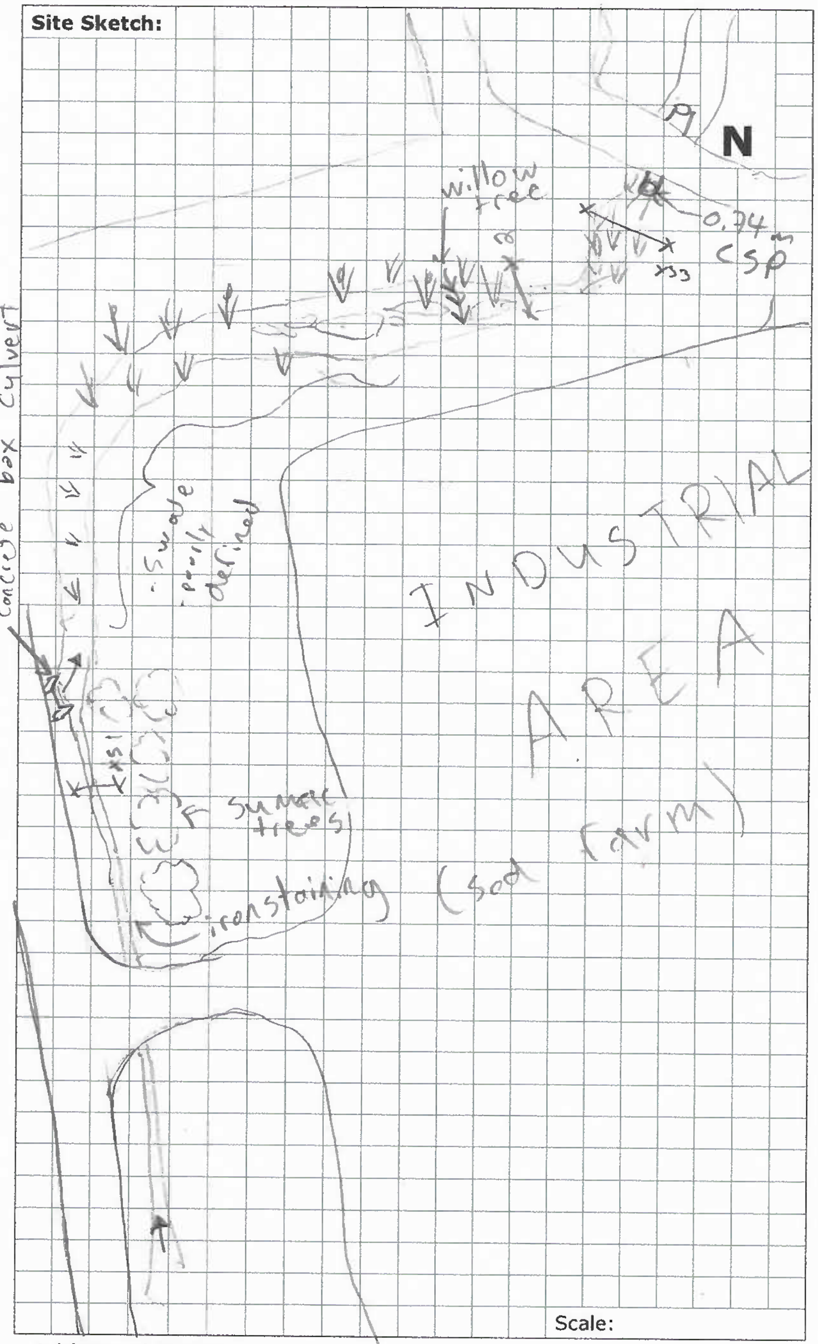
Substrate

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:



Scale:

Additional Notes:

Completed by: ________ Checked by: ________

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Geomorphology Earth Science Observations

Reach Characteristics

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	H152
Weather:		**Location:**	Mt hope
Field Staff:	JT MK	**Watershed/Subwatershed:**	20 Mile Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☒ Groundwater | Evidence: Iron staining

Riparian Vegetation

Dominant Type: (Table 6) 3/4
Species: cattails, sumac

Coverage:
- ☐ None
- ☒ Fragmented
- ☐ Continuous

Channel widths
- ☒ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☒ Immature (<5)
- ☒ Established (5-30) ↳ sumac
- ☐ Mature (>30)

Encroachment: (Table 7) 4

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 35

Woody Debris
- ☒ Present in Cutbank
- ☐ Present in Channel
- ☐ Not Present

Density of WD:
- ☒ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0.25

Water Quality

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

Channel Characteristics

Sinuosity (Type) (Table 9): 1 | **Sinuosity (Degree)** (Table 10): 1 | **Gradient** (Table 11): 1 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 1 | **Downs's Classification** (Table 15): R

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☒	☐	☐	☐	☐	☐	☐
Pool Substrate	☒	☐	☐	☐	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☐

Bankfull Width (m)	1.75	1.32	1.53	**Wetted Width (m)**	0.41	/	0.66
Bankfull Depth (m)	0.25	0.22	0.45	**Wetted Depth (m)**	0.3	/	0.15

Riffle/Pool Spacing (m): n/a | **% Riffles:** 10 | **% Pools:** 90 | **Meander Amplitude:** n/a

Pool Depth (m): 0.3 | **Riffle Length (m)**: n/a | **Undercuts (m)**: /

Velocity (m/s): 0 | 0 | 0 | **Wiffle ball / ADV / Estimated**

Bank Angle
- ☒ 0 – 30
- ☐ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☒ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments: - intermittently poorly defined
- dense cattails throughout
- mostly a roadside ditch

Notes: - Minimal geomorphic activity
- heavily modified and straightened

Completed by: ________ Checked by: ________

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Rapid Stream Assessment Technique **Project Code:** 22063

Date:	2022-07-27	**Stream/Reach:**	H152
Weather:		**Location:**	20 Mile creek
Field Staff:	JT MK	**Watershed/Subwatershed:**	Mt Hope

Evaluation 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

Evaluation Category	Poor	Fair	Good	Excellent
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)
	• 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

Date:		Reach:		Project Code:
Evaluation 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
	• 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	☐ 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) = 23	**Poor (<13)**	**Fair (13-24)**	**Good (25-34)**	**Excellent (>35)**

Completed by: ________ Checked by: ________

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Rapid Geomorphic Assessment

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	H152
Weather:		**Watershed/Subwatershed:**	20 Mile Creek
Field Staff:	JT MK	**Location:**	Mt Hope

Process	No.	Geomorphological Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		x	0.167
	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 =			
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	—	—	0
	2	Exposed sanitary / storm sewer / pipeline / etc.	—	—	
	3	Elevated storm sewer outfall(s)		x	
	4	Undermined gabion baskets / concrete aprons / etc.	—	—	
	5	Scour pools downstream of culverts / storm sewer outlets		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 =			
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	0
	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.	—	~~x~~	
	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	—	—	
		Sum of indices =			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	x		0.571
	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 =			

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.185
Condition	**In Regime**	**In Transition/Stress**	**In Adjustment**
SI score =	☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Completed by: ________ Checked by: ________

GEO | MORPHIX
Geomorphology
Earth Science
Observations

Reach Characteristics

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	H153
Weather:		**Location:**	Mt Hope
Field Staff:	JT MK	**Watershed/Subwatershed:**	20 Mile Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: ____

Riparian Vegetation

Dominant Type: (Table 6) 2

Species: ____

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☒ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☒ Immature (<5)
- ☒ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7) 3

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 15

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☒ Not Present

Density of WD:
- ☒ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 3 | **Sinuosity (Degree)** (Table 10): 3 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): | **Type of Bank Failure** (Table 14): | **Downs's Classification** (Table 15):

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☒	☐	☒	☐	☐	☐	☐
Pool Substrate	☒	☐	☐	☐	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☐

see detailed assessment

Bankfull Width (m)				**Wetted Width (m)**			
Bankfull Depth (m)				**Wetted Depth (m)**			

Riffle/Pool Spacing (m): ~3m | **% Riffles:** ~40 | **% Pools:** ~60 | **Meander Amplitude:**

Pool Depth (m): 0.09 | **Riffle Length (m)**: ~2m | **Undercuts (m)**: 0.02 0.18

Velocity (m/s): / | / | / | **Wiffle ball / ADV / Estimated**

Comments: - outer bank erosion prevalent

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☒ 60 – 90
- ☒ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☒ 60 – 100%

Notes: Constricted/ Straightened in upper portion of reach

- hard clays on bed/toe of bank
~~w~~ loose silty clays

Completed by: ____ Checked by: ____

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Rapid Geomorphic Assessment

Project Code: 22063

Date:	2022-07-27	**Stream/Reach:**	H1S3
Weather:		**Watershed/Subwatershed:**	20 Mile Creek
Field Staff:	JT MK	**Location:**	Mt Hope

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		x	0.429
	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 =			
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	—	—	0.125
	2	Exposed sanitary / storm sewer / pipeline / etc.	x		
	3	Elevated storm sewer outfall(s)		x	
	4	Undermined gabion baskets / concrete aprons / etc.	—	—	
	5	Scour pools downstream of culverts / storm sewer outlets		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 =			
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	0.333
	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.	—	—	
	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		x	
		Sum of indices =			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		x	0.143
	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 =			

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.257

Condition	**In Regime**	**In Transition/Stress**	**In Adjustment**
SI score =	☐ **0.00 - 0.20**	☒ **0.21 - 0.40**	☐ **0.41**

Completed by: ________ Checked by: ________

Rapid Stream Assessment Technique **Project Code:** 22063

Date:	2022-07-27	**Stream/Reach:**	H153
Weather:		**Location:**	20 Mile Creek
Field Staff:	JT MK	**Watershed/Subwatershed:**	Mt Hope

Evaluation 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)
	• 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

Date:		Reach: H153	Project Code:	
Evaluation 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
	• 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	☐ 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) = 25	**Poor (<13)**	**Fair (13-24)**	**Good (25-34)**	**Excellent (>35)**

Completed by: ________ Checked by: ________

Appendix E
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach H1S3

Project Number:	PN22063	**Date:**	2022-07-27
Client:	Fengate	**Length Surveyed (m):**	57.5
Location:	Hamilton - Mount Hope	**# of Cross-Sections:**	7

Reach Characteristics

Drainage Area:	48 ha	**Dominant Riparian Vegetation Type:**	Grasses/Herbaceous Plants
Geology/Soils:	Clay-Silt	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Commerical + Industrial	**Width of Riparian Cover:**	4-10 Channel Widths
Valley Type:	Confined	**Age Class of Riparian Vegetation:**	Immature (<5yrs)
Dominant Instream Vegetation Type:	Cattails	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	15%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	Minimal Flows	**Calculated Bankfull Discharge (m^3/s):**	0.35
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.92
Modelled 2-year Velocity (m/s):	Not modelled		

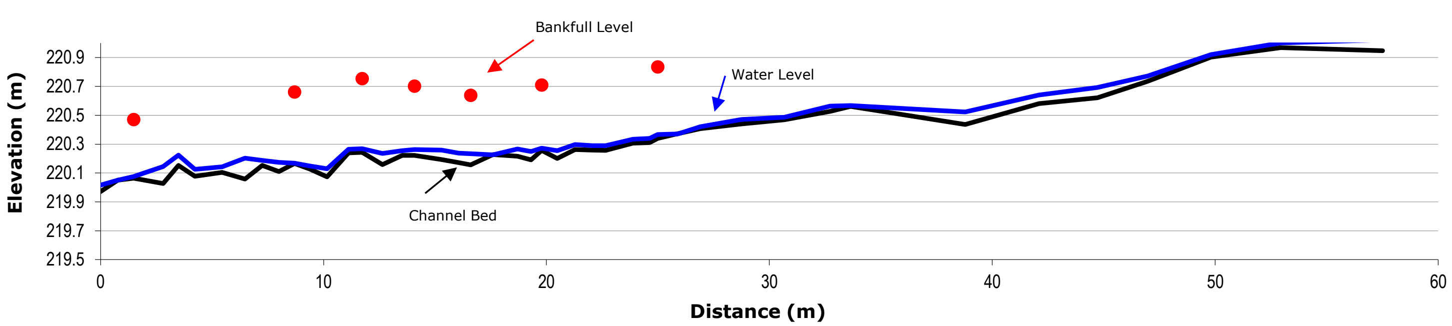
Profile Characteristics

Bankfull Gradient (%):	1.23
Channel Bed Gradient (%):	1.58
Riffle Gradient (%):	Not measured
Riffle Length (m):	Not measured
Riffle-Pool Spacing (m):	Not measured

Planform Characteristics

Sinuosity:	1.15
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.28	1.70	0.62
Bank Angle (deg):	30	90	59
Root Depth (m):	0.05	0.80	0.20
Root Density (%):	5	40	14
Bank Undercut (m):	0.00	0.18	0.05

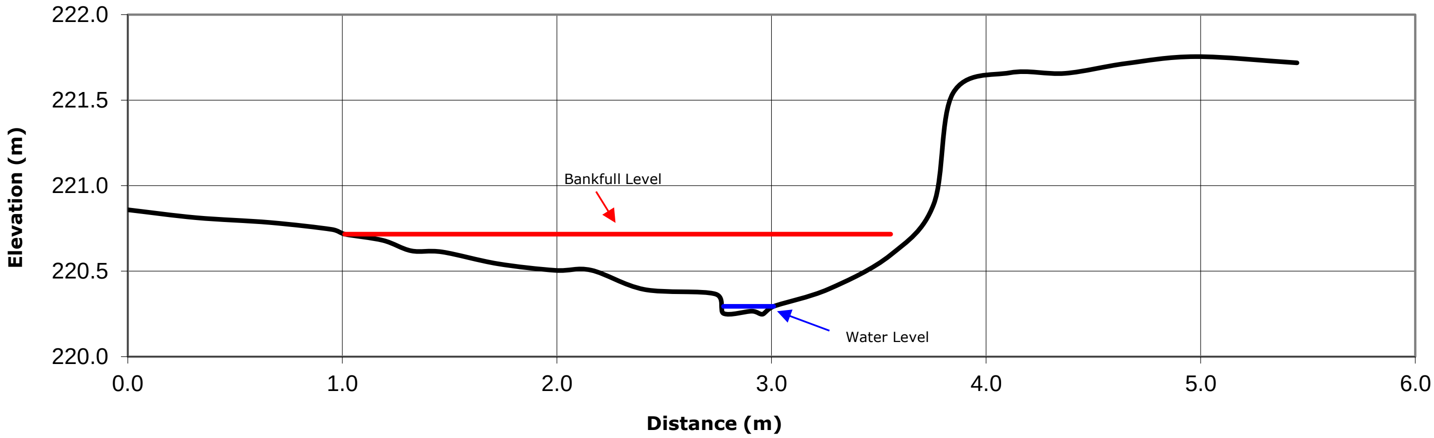
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Silt-Clay	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	1.00	2.54	1.61
Average Bankfull Depth (m):	0.21	0.30	0.24
Bankfull Width/Depth (m/m):	5	10	7
Wetted Width (m):	0.09	0.54	0.34
Average Water Depth (m):	0.01	0.05	0.03
Wetted Width/Depth (m/m):	5	43	14
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.02	0.09	0.06
Manning's *n*:		0.046	

Photograph at cross section 3 (looking upstream)

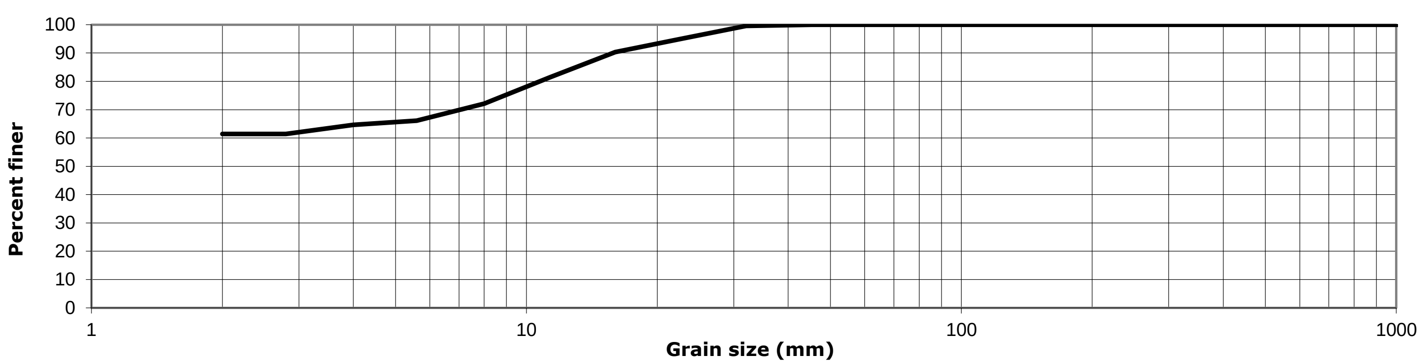
Representative Cross-Section #3



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Till
D_{10} :	<2	**Particle shape:**	Sub-Angular - Sub-Rounded
D_{50} :	<2	**Embeddedness (%):**	60-90
D_{84} :	12.7	**Particle range (riffle):**	Clay-Silt
		Particle Range (pool):	Clay-Silt

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	28.43
for D_{50}:	n/a	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.64	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	26.13		

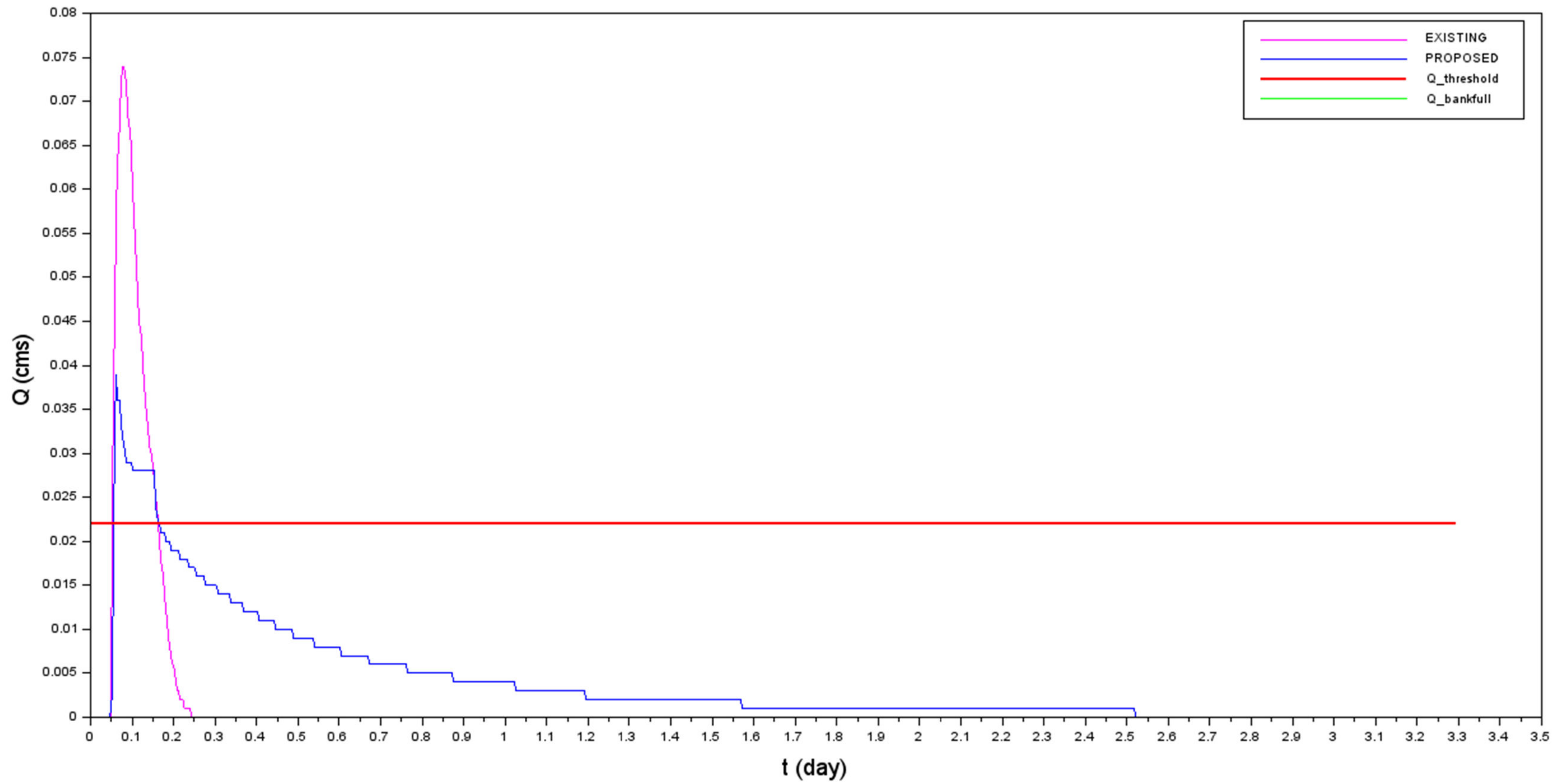
General Field Observations

Channel Description

Reach H1S3 is a short length of channel that flows northeast towards Willow Valley golf course and discharges into a tributary of Twenty Mile Creek. The channel has evidently been modified, straightened and armoured previously, likely as part of the adjacent sod farm activities. A meandering planform is re-developing within the channel corridor, and outer banks are typically eroded and exposed. Riparian vegetation was comprised of grasses, cattails, and occasional mature trees. Channel substrate ranges from silty clays within pools to medium-sized gravels within riffles. Bank materials consist of silty clays which increase in compaction moving down towards the toe of the bank slope. Flows during the day of assessment were imperceptible.

Cross Section 4 - Facing Upstream

Appendix F
Erosion Modelling Hydrograph



Q (cms)
t (day)
EXISTING
PROPOSED
Q_threshold
Q_bankfull
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
0.065
0.07
0.075
0.08
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3 3.1 3.2 3.3 3.4 3.5