Appendix E

Fluvial Geomorphology

Fluvial Geomorphology Study
Fruitland-Winona Block 1 Servicing Strategy
City of Hamilton, Ontario

Prepared for:
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GEO MORPHIX
Geomorphology
Earth Science
Observations

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1 Introduction

GEO Morphix Ltd. was retained by Urbantech Consulting to complete a fluvial geomorphological assessment for the receiving watercourse associated with the proposed Stormwater Management (SWM) facilities within the Block 1 area. Two watercourse features traverse through the Block 1 property and are identified as **Watercourse 5** (**WC5**) and **Watercourse 6** (**WC6**). To support future development plans, it is understood that **WC5** is proposed to be realigned and engineered, while **WC6** is proposed to remain in its natural state. Further, **WC5** is proposed to receive outflows from a SWM pond (Pond 1). An erosion assessment was assessment was complete for **WC5** to to determine if exacerbated rates of erosion could be anticipated within the watercourse as a consequence of development.

The following activities were completed as part of the fluvial geomorphological assessment:

- Review of pertinent background information, including conceptual development plans and previous reporting on the subject watercourse
- Desktop analysis to determine the potential zone of impact, which is the extent of the channel to be addressed
- Delineation and confirmation of stream reaches in the study area
- Rapid geomorphological field assessment to determine the stability of the receiving watercourse
- Completion of a detailed geomorphic assessment downstream of the proposed outlet locations, the primary objective of which is to support the critical flow or erosion threshold
- Determine erosion thresholds for the receiving watercourse
- Complete an erosion exceedance exercise comparing pre- and post-development hydrology provided by Urbantech Consulting (2021)

The following activities were completed in support of the proposed conceptual corridor realignments:

- Calculate bankfull channel dimensions for the proposed corridor alignments
- Channel planform, profile, and detail drawings
- Determine meander belt width for the low flow channel to ensure it can be accommodated within designed corridors
- Provide recommendations for wetland recreation within designed corridors

2 Background Review

2.1 Background Review

The Block 1 property is located in the western end of Stoney Creek, Ontario. The property is bound by Barton Road to the north, Fruitland Road to the west, Highway 8 to the south, and an agricultural property to the east. Existing land use throughout the property includes agricultural, rural residential, and commercial. Agricultural land-use is dominant throughout the interior of the subject property. However, these fields are no longer actively cultivated. Residential and commercial lands are present along the margins of the property.

Two watercourses, **Watercourse 5 (WC5)** and **Watercourse 6 (WC6)**, traverse the property, flowing in a south-to-north direction towards Lake Ontario. **WC5** enters the subject lands through a culvert beneath Fruitland Road and runs parallel to the road on the western edge of the property. **WC5** passes through a short culvert crossing, associated with the existing commercial building in the northwest corner of the property, before exiting the subject property though a culvert under Barton Road. **WC6** flows into the property through a culvert passing under Highway 8. Flows travel north, parallel to Jones Road, and exits the property through a culvert passing beneath Barton Road.

A map of the study area is provided in **Appendix A.**

2.2 Proposed Site Conditions

The proposed development for Block 1 consists mainly of low- and medium-density residential units, with a community park, an elementary school, and some commercial lands. A 40 m wide channel block is proposed for **WC5**, with a portion of the channel set to be realigned within it. Three stormwater management (SWM) ponds are proposed within the property, with outlets discharging into either **WC5** or **WC6**. Of these, Pond 1 will discharge into **WC5** approximately 180 upstream of the Barton Street Culvert. Consequently, the channel section spanning from the Pond 1 outlet to the Barton Street culvert defines the zone of impact for the erosion assessment. The section spanning from Fruitland Road to the approximate outlet location is what is proposed to be realigned.

2.3 Surficial Geology

Channel morphodynamics are largely 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 important for determining appropriate erosion thresholds, as the stability of the channel banks and bed is dependent on the composition of soils, sediment, and underlying parent materials (MNR, 2002).

The Block 1 property resides within Iroquois Plain physiographic region (Chapman and Putnam, 1984). This region extends from the shores of Lake Ontario up to the base of the Niagara escarpment, and is characterized by heavy-textured, low-permeability soil derived from the shales of the underlying Queenston Formation. Broad gravel ridge formations exist from Stoney Creek to Hamilton, in which loams have developed with improved drainage. The surficial geology throughout the site is characterized entirely by the Paleozoic bedrock shales of the Queenston Formation (OGS, 2010).

3 Watercourse Characteristics

3.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are divided as such because they are expected to have similar inputs and outputs in terms of sediments and discharge. They are also expected to react similarly throughout to flow events and other stressors. They are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This 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 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
- Certain types of channel modifications by humans

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, geology information and physiography maps. The results are then verified in the field.

The existing reach delineation was adopted for this assessment, where a single reach (**WC5**) was delineated along **Watercourse 5** within the bounds of the property. This delineation was confirmed during the site visits described Section 3.2, and no additional reach breaks were identified. **Watercourse 6** was not assessed in this report, as it resides outside the zone of impact identified for scope of this assessment.

3.2 Field Observations

Rapid and detailed field assessments were completed as part of this study on August 19th, 2021 and January 31st, 2024. Photographs from the field assessments are provided in **Appendix B**, rapid field observations are provided in **Appendix C**, and the detailed assessment summary is provided in **Appendix D** for reference. A summary of the general observations characterizing the delineated reaches is presented in **Table 1**.

Table 1. Reach characteristics summary

Reach Name	Date Visited	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Dominant Riparian Condition	Notes
WC5	2021-08-19	3.64	0.34	Clay	Clay	Established trees, shrubs	Straight channel with uniform trapezoidal cross-section, minimal geomorphic activity noted

Reach **WC5** is a straight, trapezoidal channel with little to no observable geomorphic activity or geomorphic unit development. The channel was likely straightened as part of the prior agricultural activities within the block. Pooled water was present in the reach during the assessment, but flows were imperceptible due to the low channel gradient. The bed and banks are comprised of a dense, cohesive silty-clay. Banks are well-rooted from the established trees and shrubs that inhabit the riparian corridor.

Rapid Assessments

Rapid field assessments were completed for each of the identified reaches of the receiving watercourse. The rapid assessments were completed to identify the dominant local geomorphic processes, document stream health, and to identify any areas of concern regarding erosion or instability. This included the following observations for each reach:

- Characterization of stream form, process, and evolution using the Rapid Geomorphological Assessment (RGA) (MOE, 2003; VANR, 2007), which evaluates degradation, aggradation, widening, and planimetric form adjustment at the reach scale
- Assessment of the ecological function of the watercourse using the Rapid Stream Assessment Technique (RSAT) (Galli, 1996), which evaluates stream health based on a number of biological indicators
- Stream classification following a modified Downs (1995) and a modified Brierley and Fryirs (2005) River Styles Classification approach which evaluate the magnitude and potential for channel instability and indicate dominant sediment loads, respectively
- Instream estimates of bankfull channel geometry
- Bed and bank material composition and structure
- Georeferenced photographs to document the location of all observed erosion and infrastructure

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 the 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 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 tributary was classified according to a modified Downs (1995) Channel Evolution Model, which 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 (Brierley and Fryirs, 2005) provides a geomorphic approach to examining river character, behaviour, condition, and recovery potential through the identification of the Geomorphic Process Zone. Geomorphic attributes are assessed, larger scale interactions between zones are analyzed, and historical data are studies in order to understand the historical evolution and future trajectories of those reaches. This ultimately provides a physical template for river management. A modified classification approach was applied to the study reaches.

A summary of the reach classifications and rapid assessment scores is provided in **Table 2**.

Table 2: Reach classifications summary

Reach Name	Date Visited	RGA Score	Dominant Process	RSAT Score	Downs Model Classification	River Styles Framework
WC5	2021-08-19	0.14	Widening	28	'm' – Lateral migration (initiating)	11 – Suspended load, straight

Reach **WC5** displayed minimal evidence of instability or erosion. This was reflected by the RGA score of 0.14, indicating a relatively stable channel. The dominant geomorphic process identified was widening, as it scored highest of the four indices in the RGA. **WC5** scored 28 on the RSAT, indicating an acceptable level of stream health. The reach was classified as a suspended load dominated, straight channel under the River Styles Framework (Brierley and Fryirs, 2005). Under the Downs (1995) model, the initiation of lateral migration was identified as the dominant channel forming mechanism.

Detailed Geomorphological Assessments

The detailed assessment, used to inform the erosion threshold analysis, was completed on reach **WC5** on August 19th, 2021. The downstream portion of reach **WC5** was selected for the detailed assessment, as it is situated downstream of the proposed outlet for Pond 1 and will receive discharges originating from the site. Activities completed for the detailed assessment included the following:

- Long-profile survey of the channel centre line
- Eight detailed cross-sectional surveys of the watercourse
- Detailed instream measurements at each cross-section location including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density
- Bed material sampling at each cross-section following a modified Wolman's (1954) Pebble Count Technique or substrate sample
- Velocity and discharge measurements at select representative cross-sections

The resulting measured channel parameters are outlining **Table 3**, and a summary of the detailed assessment results is provided in **Appendix D**.

4 Erosion Threshold Analysis

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 determined from detailed field observations of reach **WC5**. 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.

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, such as that described by Komar (1987). For cohesive materials, empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1998), could be applied.

4.1 Methods

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 is calculated at various depths for a representative cross section until the average velocity in the cross section slightly exceeds the critical velocity 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 Limerino's (1970) approach. 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 coefficient. The visual approach (Acrement and Schneider, 1989) was adopted for determining the Manning's roughness coefficient.

For the bank materials, following Chow (1959) in a simplified cross section, 75% of the bed shear stress acts on the channel banks. In a similar approach, the depth of flow is increased until the shear stress acting on the banks exceeds the resisting shear strength of the bank materials.

4.2 Results

Summarized results of the erosion threshold analysis are provided in **Table 3**. Reach **WC5** contains similar bed and bank materials, differentiated mainly by their level of compactness and water content. Bank material was identified as a non-colloidal silty loam with a corresponding critical velocity of 0.53 m/s. This critical velocity was adopted for the bed materials as well. As the bed material was more compact than the bank material, adopting the bank material critical velocity is a conservative approach with regards to erosion risk. Considering the material's level of cohesiveness, 0.53 m/s is a conservative estimate of the critical velocity itself.

Table 3: Bankfull conditions and erosion threshold calculation parameters for the Watercourse 5 Reach WC5

Channel parameter	Results by Reach
	WC5
Bankfull Conditions	
Average bankfull width (m)	3.64
Average bankfull depth (m)	0.56
Bankfull channel gradient (%)	0.76
D_{50} (mm)	<2
D_{84} (mm)	<2
Manning’s n roughness coefficient	0.038
Bankfull discharge (m^3/s)	1.31
Bankfull velocity (m/s)	1.06
Channel Bed Erosion Threshold	
Bed Material	Silty-clay loam, fairly compact
Apparent shear stress acting on bed (N/m^2)	7.30
Critical velocity at the bed (m/s)*	0.53
Critical discharge (m^3/s)	0.116
Channel Banks Erosion Threshold	
Bank Material	Silty-clay loam, compact
Apparent shear stress acting on banks (N/m^2)	10.59
Critical velocity at the banks (m/s)*	0.53
Critical discharge (m^3/s)	0.290
Limiting Critical discharge (m^3/s)	**0.116**

* Criteria of Fischenich (2001) for non-colloidal silty loam

5 Post- and Pre-Development Erosion Exceedance Analysis

Using the results of the erosion threshold analysis and the provided hydrological modelling for post- and pre-development conditions, additional analyses regarding the impacts of SWM controls on potential erosion within the watercourses were completed with our own in-house model, based on four indices:

1) Cumulative time of exceedance
2) Number of exceedance events

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

These indices have been applied elsewhere in CH, TRCA, CVC, and other jurisdictions. They, as a product, provide an evaluation of the number of events, period of transport, and magnitude. We note that the most relevant indicator is the cumulative effective stream power.

Time of exceedance and number of exceedances can be simply calculated from the discharge record. For more relevant indicators, 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 site appropriate and specific.

The post- and pre-development hydrological modelling reflects changes to the hydrological regime resulting from SWM measures being implemented within the catchment. Continuous flow data was provided by Urbantech Consulting (2021) in 5-minute increments for synthetic 25 mm, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year Chicago storm events. The hydrological modeling was analyzed to calculate the aforementioned erosion indices to identify changes in the erosive potential within **WC5** following development.

5.1 Methods

To calculate work terms, 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:

$$Q_{T=} \sum Q_i \quad \text{[Eq. 2]}$$

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

$$Q_i = U_i w_i d_i \quad \text{[Eq. 3]}$$

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:

$$\tau_{o_{\max}} = d_{\max} \rho g S_{\text{bed}} \quad \text{[Eq. 4]}$$

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:

$$\varpi_{\text{tot}} = \sum \tau_{0_{\text{max}}} . U_{\text{avg}} . \Delta t \qquad \text{[Eq. 5]}$$

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:

$$\varpi_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \varpi < 0 = 0 \qquad \text{[Eq. 6]}$$

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

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \ \ \text{for} \ (Q_T > Q_{\text{threshold}}) \qquad \text{[Eq. 7]}$$

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

5.2 Results

The full series of post- to pre-development hydrographs are included in **Appendix E**, and include the erosion threshold based on discharge, for reference. **Table 4** provides the results of the assessment based on the hydrographs provided by Urbantech Consulting (2021).

Table 4: Results from the post- and pre-development erosion exceedance analysis for Reach WC5

Simulation		CED (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)
25 mm	**(PRE)**	0.95	16.49	3.25
	(POST)	0.98	15.04	3.92
	Change (%)	**3.10%**	**-8.79%**	**20.51%**
2-year	**(PRE)**	6.45	135.52	15.00
	(POST)	7.83	168.78	17.08
	Change (%)	**21.29%**	**24.55%**	**13.89%**
5-year	**(PRE)**	12.18	280.67	18.42
	(POST)	14.46	340.20	20.42
	Change (%)	**18.73%**	**21.21%**	**10.86%**
10-year	**(PRE)**	16.45	376.81	20.25
	(POST)	19.29	454.25	22.17
	Change (%)	**17.28%**	**20.55%**	**9.47%**
25-year	**(PRE)**	22.44	497.47	22.33
	(POST)	25.98	584.02	24.17
	Change (%)	**15.77%**	**17.40%**	**8.21%**
50-year	**(PRE)**	26.77	574.64	23.58
	(POST)	30.75	659.04	25.25
	Change (%)	**14.89%**	**14.69%**	**7.07%**
100-year	**(PRE)**	31.27	648.04	24.67
	(POST)	35.71	724.56	26.33
	Change (%)	**14.19%**	**11.81%**	**6.76%**

It is noted that the cumulative effective discharge (CED) and cumulative effective work index (ω_{eff}) are considered the most relevant erosion indices, as they reflect both the severity and duration of an exceedance event. Further, storms of moderate magnitudes and of relatively frequent recurrence typically exert the most influence on a given channel's geomorphic regime. Results from the 25 mm event and, to a lesser extent, the 2-year event are therefore the most relevant storm simulations in the context of evaluating erosion potential following hydrological regime changes.

For the 25 mm storm, the CED saw a minor increase of 3.10% from pre- to post-development hydrological conditions. The ω_{eff} decreased by 8.79% and the cumulative exceedance duration (t_{ex}) increased by 20.51%. For the 2-year event, the CED, ω_{eff}, and t_{ex} increased by 21.29%, 24.55%, and 13.89%, respectively. Increases in all indices were predicted for the larger storm events. The magnitude of these predicted increases consistently tapers off as storm magnitudes increase, reaching 14.19%, 11.81%, and 3.76% for the 100-year event CED, ω_{eff}, and t_{ex}, respectively.

The notable decrease in erosion potential predicted for the 25 mm event is expected to offset the moderate increases predicted for the larger, less frequent storms. Thus, the modelling results indicate that exacerbated rates of erosion resulting from development will not occur within reach **WC5**.

6 Conceptual Channel Design

As part of the Stoney Creek Urban Boundary Expansion (SCUBE) Phase 3, **WC5** was identified to be restored and realigned, which provides opportunity to replace the existing morphologically-limited channel with a naturalized riffle and pool typology, with cross sectional dimensions closer to that of a naturalized watercourse conveying similar flows. One goal of the natural channel design is to replace the existing degraded channel that has been impacted by past agricultural and development activities. A naturalized watercourse will offer significant improvements to channel form and function, per unit length.

The realignment and naturalization provide opportunities for improved riparian conditions and a well-developed bankfull channel with morphological variability. Improvement in morphology and function will provide additional benefits to sediment balance, floodplain storage, vegetation communities and terrestrial habitat features, aquatic habitat, edge impacts, water balance, fish passage and water quality.

The primary objectives of the design are to:

- Restore the physical form of the channel including planform and in-channel characteristics
- Ensure channel stability and function during low flow periods
- Create low-flow channel that accommodates the bankfull discharge to improve the function of the channel corridor and increase interactions with the floodplain
- Create a floodplain that includes interconnected wet meadow and linear wetland features of variable depth, shape, and hydroperiod
- Provide a mix of coarse and fine sediment sources throughout the low-flow channel and floodplain

- Enhance aquatic habitat for warmwater fish through the provision of a morphologically diverse channel with spatially varied flows
- Improve riparian habitat by installing woody plantings and dynamic floodplain features
- Mitigate potential hazards to the development as well as lands surrounding the development

Technical details are provided in subsequent sections to outline the approach used for channel sizing and habitat restoration.

6.1 Channel Planform

The initial channel planform layout will be created using the modelled radius of curvature value (*Rc*) as a guide. The radius of curvature (*Rc*) of meanders can be used to evaluate channel stability. For example, stable meanders typically exhibit larger *Rc* values as opposed to lower values that indicate increased channel bank erosion and avulsion. Bankfull width is often an appropriate indicator for this instability. Hickin and Nanson (1983) note that channel avulsions are common when meander *Rc* is approximately 1-2 times the channel bankfull width. For larger *Rc* (e.g., >5), the upstream limb of the meander will migrate more rapidly than the downstream limb (Hooke, 1975). Williams (1986) was used to derive values for the channel radius of curvature, using the following equation (Eq. 8):

$$Rc = 2.43 \times w \qquad \text{[Eq. 8]}$$

where *Rc* is the radius of curvature and *w* is the average bankfull width.

Empirical models derived by Hey and Thorne (1986) were followed to determine riffle spacing. Hey and Thorne's (1986) modelled values are often applied in larger watercourses. As such, multiple methods (Eq. 9-11) were considered in order to provide a range of riffle spacing values. These are:

$$Z = 6.31 \times w \qquad \text{[Eq. 9]}$$

$$Z = 9.1186 \times w^{0.8846} \qquad \text{[Eq. 10]}$$

$$Z = 7.36 \times w^{0.896} \times S^{-0.03} \qquad \text{[Eq. 11]}$$

where *Z* represents riffle spacing.

Stream power and unit stream power were calculated as a function of bankfull discharge and channel gradient (Eq. 12-13). Stream power values are important to determine the need for mitigating channel bank and bed erosion. Stream power is given by:

$$\Omega = \rho \times g \times d \times S \qquad \text{[Eq. 12]}$$

where ρ is the density of water (kg/m^3), *g* is the acceleration due to gravity (m/s^2), and *Q* and *S* are discharge (m^3/s) and channel gradient, respectively.

Stream power per unit width (Eq. 13), is given by:

$$\omega = \frac{\Omega}{w} \qquad \text{[Eq. 13]}$$

where as before, Ω and w are stream power and bankfull width, respectively.

The final channel planform will be established through an iterative process. First, a cross section with defined bankfull geometry was developed to calculate parameters for the planform (i.e., radius of curvature). The cross section will then be further refined, and riffle and pool lengths will be determined based on channel gradient.

6.2 Bankfull Channel

The recommended restoration design focuses on a riffle and pool sequences. The riffle and pool sequences will provide significant improvements to not only the channel, as it essentially mimics a natural system, but also to aquatic habitat. In summary, the riffle-pool system offers numerous benefits, namely:

- Channel bed relief for flow variability
- Water aeration in riffle sections
- Relatively quiescent flows in pool sections to provide refuge for fish during high flows
- Increased depths in pools to provide relatively cool water
- In-channel energy dissipation

Channel design dimensions are determined by bankfull discharge, as this represents what is generally referred to as the "*channel-forming discharge*" or the "*dominant discharge*". Several methods can be applied to select an appropriate bankfull discharge. Back calculation of discharge from a reference reach along with support from hydrological modelling is usually the most appropriate. Due to changes in hydrology likely to occur because of the proposed development on site, a discharge based on hydrological modelling was determined for **WC5** and then subsequently used to define channel bankfull geometry. The discharge used to size the bankfull channel was assumed to be equivalent to the modelled 2-year flow. As such, the bankfull discharge was defined as 1.40 m^3/s, based on hydrological modelling provided by Urbantech Consulting Engineers (2021). Bankfull capacity for channels generally have a range from the 1- to 2-year return events. The bankfull channel geometries are provided for guidance for the design concept and can be further refined based on subsequent studies.

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed channel. Since pools are designed to contain ineffective space, this model over-predicts the amount of discharge that they convey. As such, the modelled values for the riffles give a better prediction of the channel's capacity. Average channel geometries, as well as anticipated bankfull conditions for the proposed channel, are provided in **Table 5**.

Table 5: Average bankfull parameters for the proposed channel

Channel parameter	Reach 1	
	Riffle	Pool
Average bankfull width (m)	2.50	3.65
Average bankfull depth (m)	0.32	0.39
Maximum bankfull depth (m)	0.45	0.70
Bankfull width-to-depth ratio	7.89	9.25
Riffle gradient (%)	2.40	0.68
Bankfull gradient (%)	0.68	0.68
Average radius of curvature (m)	22	
Riffle-pool spacing (m)	8	
Manning's roughness coefficient, *n*	0.035	0.04
Mean bankfull velocity (m/s)	1.77	0.97
Bankfull discharge (m^3/s) *	1.40	1.40
Discharge to accommodate (m^3/s)	1.40	1.40
Tractive force at bankfull (N/m^2)	106	47
Stream power (W/m)	330	93
Unit stream power (W/m^2)	132	43
Froude Number (unitless)	1.0	0.50
Maximum grain size entrained (m) **	0.11	0.05
Mean grain size entrained (m)**	0.08	0.03

* Based on Manning's equation; using riffle gradient as pools contain ineffective space, the velocity and discharge conveyed in them are not representative

** Based on a modified Shields equation (Miller et al. 1977), assuming Shields parameter equals 0.06 for gravel

The sizing of proposed substrate materials was guided by a review of hydraulic conditions (i.e., tractive force, flow competency) in the typical cross sections. The channel bed substrate is derived by balancing the average shear stress acting on the bed with the critical shear stress for the material. When the critical shear stress slightly exceeds the average shear stress acting on the bed, sediment transport is initiated.

To provide for a stable bed and level of sorting, 40% 50 mm – 100 mm diameter riverstone, 30% granular 'b' and 30% native material is proposed for the riffles. Granular 'b' consists of a mix of stone where approximately 20% - 50% of the stone is greater than 0.005 m in diameter, but nothing larger than 0.15 m in diameter. These materials will always have a core of sediment that is not entrained under bankfull flow conditions. This material maintains the character of the native material, while providing slightly higher stability and opportunity for sediment sorting. A mix of granular 'B' and native material is proposed for the pools given they experience lower velocities. Hydraulic sizing should be confirmed during detailed design once the channel geometries and flows have been finalized.

6.3 Fish Passage

The near-bed velocity within the channel was modelled to determine whether fish passage is possible under the range of conditions expected for the low-flow channel. The velocity increases logarithmically with height above the bed surface in turbulent flows, through a relationship known as the von Karmen equation, or the Law of the Wall. Based on a knowledge of the bed materials, a theoretical height above the bed where velocity equals zero can be determined. The von Karmen equation is typically used to estimate the shear stress at the bed surface. However, a near-bed velocity can be back calculated using the average shear stress predicted for the low flow channel. The modelled velocities at a 0.01 m depth from the channel bed for the realigned channel was approximately 0.37 m/s in the riffles at the 2-yr return flow.

These values are within the range of velocities tolerated by various species found within the watershed (i.e., brook stickleback, creek chub, etc.; Katopodis and Gervais, 2016). Additionally, channels with gradients less than 5.0% are possible for fish passage, and the realigned channel has gradients that are less than 5.0% (Newbury, 2013). As a result, the gradients and velocities within the realigned channel are not detrimental to fish passage for local species.

6.4 Channel Corridor

6.4.1 Corridor Sizing

Meander belt width delineation was completed in support of defining erosion requirements for the realigned watercourse within the proposed development. With regards to delineating the hazard associated with channel migration, the Ontario Ministry of Natural Resources treats confined and unconfined systems differently. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. In unconfined systems, the hazard is assumed to be from channel migration. Unconfined systems require a meander belt width. Given the size of the existing channel compared to the floodplain, this channel can be considered unconfined.

As part of the design, a meander belt width was calculated based on design bankfull dimensions of the channel to ensure that the planform has a meander belt width that falls within the proposed corridor requirements. Given the scale of the watercourse and limited migration potential for the system, the hazard limits calculated can be considered conservative. The meander belt widths provided are based on a modelled relation from Williams (1986) which were modified to include channel width and a factor of safety, and applied using the bankfull channel dimensions such that:

$$B_w = (4.3{W_b}^{1.12} + W_b) \times 1.2 \quad \text{[Eq. 16]}$$

where *Bw* is meander belt width (m), and *Wb* is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction and provides a factor of safety.

The bankfull channel dimensions of the proposed channel have an average width of 3.10 m. The resulting meander belt width estimates are provided in **Table 6**.

Table 6: Meander belt width estimate for design WC5

Omagh Tributary	Meander Belt Width (m)*	Corridor Bottom Width (m)
Design Reach 1	23	23

* Includes 20% factor of safety

The predicted meander belt width for realigned **WC5** is 23 m based on the proposed flows and corridor gradient. All meander belt width calculations are based on channels where instream energy is greater than potential resistance of the bank materials. As such, they over predict the potential extent of meandering of vegetation-controlled channels and the erosion hazard. The proposed valley bottom width for **WC5** of 23 m adequately addresses the erosion hazard.

6.5 Habitat Restoration

The design incorporates several habitat elements within the channel corridor to improve riparian habitat and promote wildlife biodiversity. To maximize potential for wildlife passage, forage and residency, the habitat design incorporates varying topographies and woody debris. The habitat elements proposed include tortuous meanders, brush mattresses, basking logs, pallet type wood piles, raptor poles, rock piles, and terrestrial mounds.

Potential overwintering deep sections are proposed to provide critical habitat for resident fish. The overwintering deep sections are provided within the tortuous meander pattern, which will increase scour and depth. Overwintering deep sections will be 0.35 m deeper than the typical proposed pools. This habitat feature will provide fish with potential refuge from freezing conditions in the winter, but also provide ideal habitat during low flow periods, and increase habitat heterogeneity within the channel. Due to the size of the proposed channel the pools could freeze completely during the winter.

Brush mattress is proposed along the outside meander bend of the tortuous meanders and at the connection with the conveyance swale at the upstream extent. This treatment consists of live brush cuttings installed parallel to the banks and tied in with coir twine and stakes. The brush mattress will provide bank stability and improve aquatic habitat through shading.

Basking logs consist of a mixture of hardwood and softwood species, place in shallow areas of wetlands and anchored with a mix of stone or limestone blocks. These logs are angled in a way to promote turtle basking.

Pallet type wood piles consist of logs, snags and other wood debris, placed in a way that forms a stable interconnected mound, in the shape of a pallet. Additionally, the wood piles are planted with native fruit bearing vines, which provide forage opportunities for wildlife. Wood piles are placed at various locations along the length of the floodplain.

Raptor poles are constructed from large conifer tree trunks, embedded into the ground and serve to provide perches for larger raptors.

Rock piles consist of a mix of stone of varying sizes, piled up to create small mounds. These features provide hibernation habitat for various terrestrial species. The base of the piles is partially buried to prevent rock falls. Rock piles are installed at various locations along the length of the floodplain.

Terrestrial mounds consist of native material, piled up to create small mounds with a small dimple on the top. The bottom of the mound is seeded with the specified seed mix, while the top has limited soil and seed on it to provide foraging opportunities.

The full channel corridor will be restored using native plant species. This includes appropriate species for the various seed mixes as well as woody vegetation. The plantings are intended to enhance the terrestrial habitat through the provision of species and habitat diversity, increase floodplain soil stability and floodplain roughness, and increase sedimentation. The landscaping plan will be prepared at detailed design.

6.6 Wetland Replication

Offline wetland features will be constructed in addition to the channel. These features enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form. They also provide functional benefits such as short-term water retention and sediment banking. They will be irregularly shaped to maximize the perimeter for a given area, which increases the potential for edge effects. Submerged and dry mounds are proposed within the offline wetlands to provide a topographically complex bottom to increase habitat heterogeneity. The short-term water retention function of these wetland types helps to polish water and moderate the discharge of water into the channel. These features will address the proposed wetland replication due to the removal of the existing wetland feature.

Wetland replication is proposed as part of the development to compensate for the removal of existing wetlands. Within the **WC5** corridor 0.46 ha of wetland is provided, which accounts for approximately 30% of the floodplain. The proposed wetlands have an average depth of 0.60 m. The wetlands were designed with mounds of variable heights to allow for a range of wetland vegetation to establish. We have provided variability to assure that from year-to-year a range of water depths and hydroperiods are provided. The proposed restoration planting plan will be completed at detailed design.

6.7 Stormwater Management Outlet Design

Stormwater management Pond 1 is proposed to outlet to the **WC5** corridor. We recommend a stone core wetland be installed at the proposed outfall. The stone core refers to hydraulically sized rounded stone, which is the subsurface material used to ensure wetland stability. The stone should be hydraulically sized to withstand the pipe capacity or maximum outflow velocity from the SWMP outlet and should include a 20% factor of safety. The wetland should be constructed as an over-excavated depression which is lined with a mix of soil and granular materials, to provide both depressional and subsurface storage (within the interstitial space of the sediment and soil). A layer of topsoil will be installed on top of the stone core to improve vegetation establishment within the feature. Filtration is provided as a result of flow through the soil medium between the pocket wetland a proposed channel.

7 Recommendations for Detailed Design

To support detailed design and ensure proper implementation of the channel corridors, the following activities are recommended at the detailed design stages:

- Confirm valley and channel gradients
- Develop planform and profile for the proposed corridors
- Develop a native planting plan for the proposed corridors
- Confirm hydraulic stone sizing to ensure the channel is stable
- Determine potential locations for additional terrestrial habitat features within each corridor
- Develop recommendations for implementation during construction, including an erosion and sediment control plan
- Develop and finalize a post-construction monitoring plan for the realigned channels

8 Post-Construction Monitoring Recommendations

A post-construction monitoring program is recommended to assess the performance of the implemented channel design. Monitoring observations can also be used to determine the need for remedial works, if required. Monitoring is recommended for three full calendar years after construction and includes annual visual inspections and surveys. The following monitoring and reporting activities are suggested for the realigned channel:

- General observations of the channel works should be documented after construction and after the first large flooding event to identify any potential areas of erosion concern
- Collection of a photographic record of site conditions
- Total station survey of the longitudinal profile and monumented cross sections following construction. This would serve as the as-built reference condition for use in comparing surveys completed in subsequent years
- Re-survey of the longitudinal profile and cross sections in subsequent years after construction
- Installation of erosion pins at monumented cross sections after construction and monitoring of the erosion pins during subsequent years
- Bed material characterization based on Wolman (1954) pebble counts
- General vegetation surveys completed annually after construction, for the duration of the monitoring period to determine survivorship of the plant materials (any dead, diseased or damaged plant materials will be replaced within the warranty period)
- Annual reporting to summarize construction activities (i.e., design implementation), and subsequent year-end reports for the duration of the monitoring period

9 Summary and Recommendations

The purpose of this study was to investigate the potential for excess erosion to occur in the receiving watercourse associated with the SWM outflows from the proposed development within the Block 1 property, Hamilton. Reconnaissance-level field assessments of the receiving watercourse (**WC5**) were completed to characterize the system and identify erosion-sensitive locations within the zone of impact. A detailed geomorphic assessment was completed within the zone of impact along reach **WC5**, from which an erosion threshold was computed and provided as a critical discharge. For reach **WC5**, a critical discharge of 0.116 m^3/s was determined based on a critical velocity of 0.53 m/s acting on the silty-clay bed materials (Fischenich, 2001).

Erosion exceedance modelling results indicate that the proposed stormwater management plan adequately addresses the concerns regarding potential excess erosion within WC5 following development. A reduction in erosion potential was predicted for the 25 mm, and a moderate increase in erosion potential was predicted for the larger, less-frequent storms. Considering the reduction in erosion potential predicted for the highly relevant 25 mm event, we do not foresee the requirement for any changes to the proposed stormwater management plan, or for the requirement of any additionally systemic erosion protection measures, as the assimilative capacity of the receiving watercourse is sufficient for the proposed changes to the hydrological regime.

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

Respectfully submitted,

Lindsay Dav

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Director, Principal Geomorphologist

Lindsay Davis, M.Sc., P.Geo., CAN-CISEC
Geomorphologist

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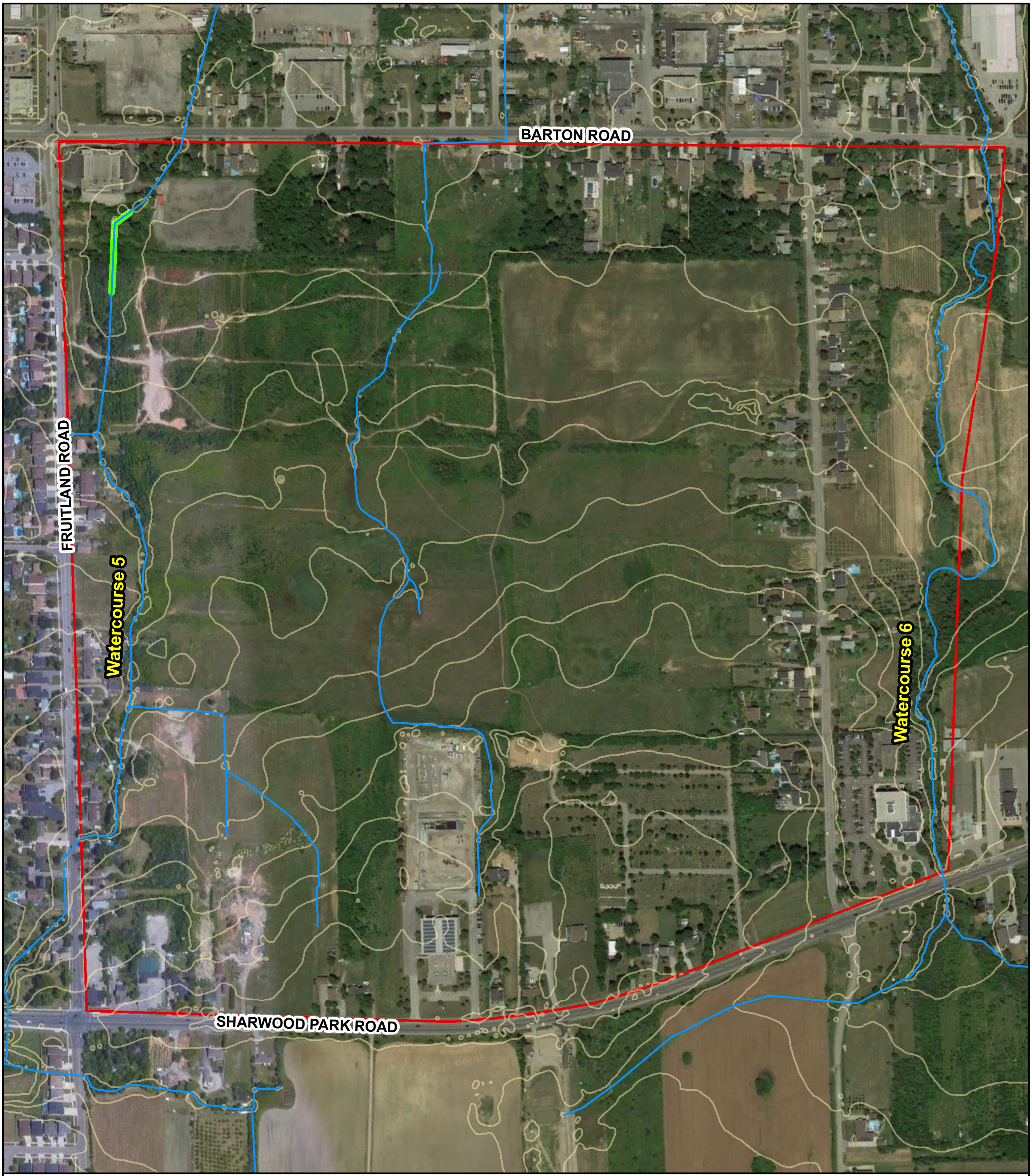
Appendix A
Reach Mapping



Legend

- Watercourse
- Contour (1 m)
- Detailed Assessment
- Subject Property

Reach Delineation

Fruitland-Winona Block 1 Servicing Strategy

Hamilton, Ontario

GEO MORPHIX™

N

0 50 100

Metres

Imagery: Google Earth Pro: 2018
Subject Property: Parish Aquatic Services, 2019.
Watercourse and 1 m Contour: City of Hamilton, 2020.
Detailed Assessment: GEO Morphix Ltd., 2021.
Printed: March 2022. PN21043. Drawn by: J.T., M.O.

Appendix B
Photo Record

Photo 1
Reach **WC5**

Flows enter reach **WC5** through a concrete box culvert passing under Fruitland Road. No erosion concerns were noted. Yellow arrow denotes flow direction.

Photo 2
Reach **WC5**

No bed scour was noted downstream of the Fruitland Road culvert.

Photo 3
Reach **WC5**

Reach **WC5** has a predominantly trapezoidal channel shape throughout the study area. Minimal flow velocities were observed during the assessment.

Photo 4
Reach **WC5**

Bank materials across the entire reach are characterized by silty clay. Occasional tree roots were observed, but the bottom third of the bank is typically exposed.

Photo 5
Reach **WC5**

Bed materials are consistent with the bank materials but are much less compact. Algae is abundant throughout the reach.

Photo 6
Reach **WC5**

Exposed material is common at toe of bank. Riparian vegetation provides some level of stabilization, but roots are typically small and immature.

Photo 7 Reach **WC5**	 Several sections of shallow flow, abundant debris, and loose bed material are present. Debris is largely associated with past agricultural infrastructure.
Photo 8 Reach **WC5**	 A small footbridge is present in **WC5**. A thick debris jam exists immediately upstream and retains a level of flow.

Photo 9
Reach **WC5**

Downstream of the footbridge, debris marks are visible on several flow-impeding trees, indicating the approximate bankfull flow stage.

Photo 10
Reach **WC5**

Bank armouring and a footbridge were observed further downstream. This infrastructure is significantly degraded and has evidently not been maintained for many years.

Photo 11 Reach **WC5**	
	Flows near the downstream extent of the reach are slightly deeper. The channel width expands in this section. The leaning trees indicate a level of channel widening.
Photo 12 Reach **WC5**	
	Evidence of erosion largely subsides near the downstream extent, as the channel exhibits more depositional tendencies, indicated by siltation on the bed.

Appendix C
Field Observations

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Rapid Geomorphic Assessment **Project Code:** 21043

Date:	2021-08-19	**Stream/Reach:**	Watercourse 5
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		X	1/6
	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 =	1	5	0.167
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	—		0/6
	2	Exposed sanitary / storm sewer / pipeline / etc.		—	
	3	Elevated storm sewer outfall(s)		—	
	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 knick point 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	6	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		3/8
	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.		X	
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		—	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation		—	
		Sum of indices =	3	5	0.375
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0
	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

Additional notes: -Min observable geomorphic activity

Stability Index (SI) = (AI+DI+WI+PI)/4 =	0.14		
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: 21043

Date:	2021-08-19	**Stream/Reach:**	Watercourse 5
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

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 n/a	- > 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:	2021-08-19	**Reach:**	Watercourse 5	**Project Code:**	21043

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 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) = 28	**Poor (<13)**	**Fair (13-24)**	[✓ **Good (25-34)**]	**Excellent (>35)**

Completed by: ________ Checked by: ________

GEO | MORPHIX
Geomorphology
Earth Science
Observations

General Site Characteristics

Project Code: 21043

Date:	2021-08-19	**Stream/Reach:**	Watercourse 5
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

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
ΨΨΨ	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

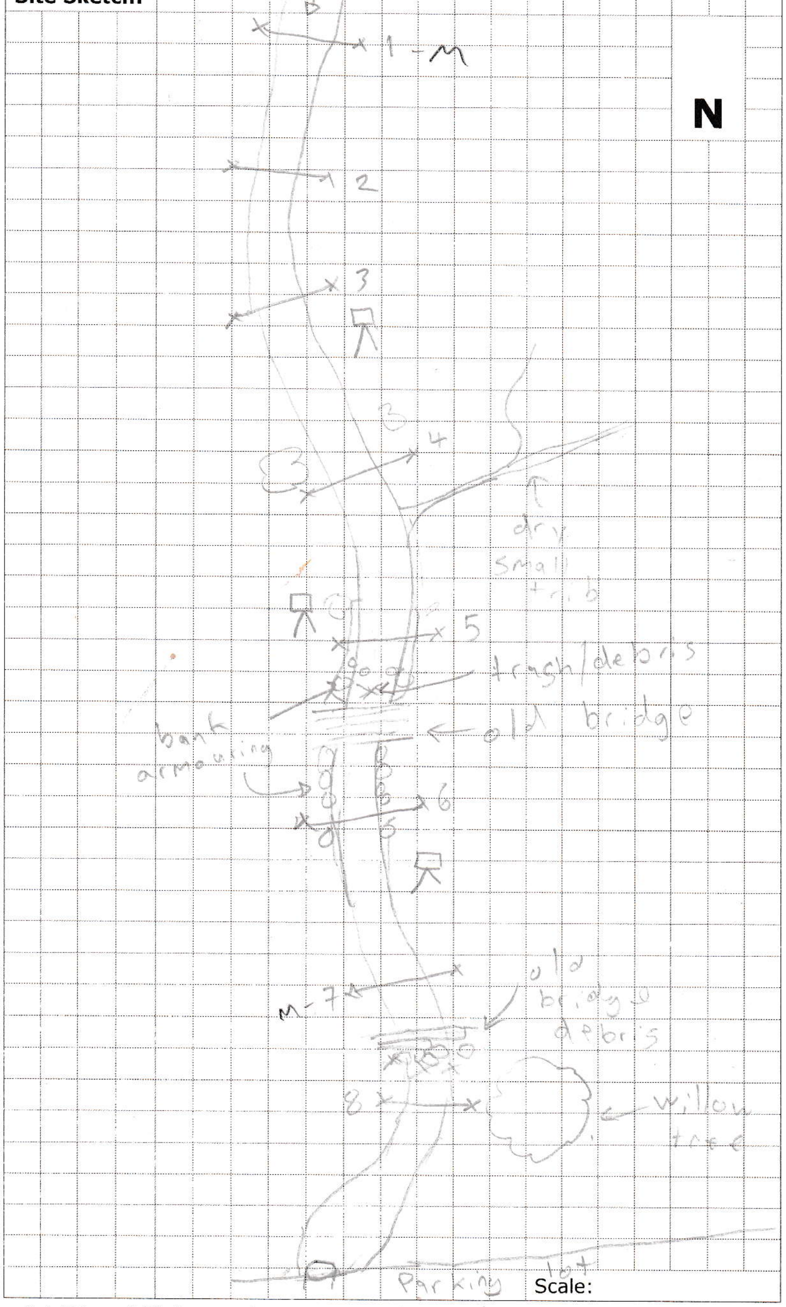
Substrate

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: Clay silt throughout
-Channel more entrenched upstream
-Minimal flow

Completed by: ________ Checked by: ________

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Earth Science
Observations

Detailed Assessment (Total Station)

Project Code: 21043

Date:	2021-08-19	**Reach:**	"Watercourse 5"
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

Point No.		Code	Notes
100	106		1,960 Rod height
			should be 1.600
107			
154	→	BED	
XS3		Reversed	

Survey Direction

☒ Upstream to Downstream
☐ Downstream to Upstream

Cross-sections

No. of Cross-sections: ______
Monitoring Cross-sections:
☐ None
☒ Yes
If yes, which ones: 1 & 7

Rain in last 24 hours

☒ None
☐ Yes: Amount ______ mm

Valley Type:
Confined Partially [✓ Unconfined]

Channel Zone:
Headwater [✓ Transfer] Deposition

Land Use: Residential/Agri

Aquatic Vegetation: algae

Portion of Aquatic Vegetation: 10%

Riparian Vegetation: Trees

Extent of Riparian Cover:
Fragment None [✓ Continuous]

Riparian Cover (channel widths):
1-4 [✓ 4-10] >10

Age Class of Riparian Vegetation:
Immature (<5 yrs) [✓ Established (5-30 yrs)] Mature (>30 yrs)

Extent of Encroachment:
None [✓ Minimal] Moderate
Heavy Extreme

Density of Woody Debris:
[✓ Low] Moderate High

☒ **Overall Photographs Taken**

Blockage(s) in Channel:
[✓ Infrastructure] Dam LWD

Completed by: __________ Checked By: __________

Page ____ of ____

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Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS1 - M
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

x	y				Notes
6.30	1622				
6.70	1611				
7.00	1563				
7.30	1526				
7.60	1498				
7.90	1538				
8.10	1555				
8.30	1601				
8.60	1682				
8.90	1783				
9.20	1838				
9.50	1981	BF			
9.60	2095				
9.80	2302				
9.90	2340	WC			
10.10	2412				
10.30	2448				
10.50	2432				
10.70	2441				
11.00	2441				
11.30	2400				
11.60	2346				
11.80	2321				
11.95	2295				
12.00	2035				
12.15	2015				
12.30	1873				
12.45	1790				
12.65	1701				
12.90	1638				
13.20	1615				
13.60	1623				
14.00	1630				
14.40	1625				
14.60	1602				
14.85	1600				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1. Clay 11. ___ 21. ___ 31. ___
2. + 12. ___ 22. ___ 32. ___
3. silt 13. ___ 23. ___ 33. ___
4. ___ 14. ___ 24. ___ 34. ___
5. ___ 15. ___ 25. ___ 35. ___
6. ___ 16. ___ 26. ___ 36. ___
7. ___ 17. ___ 27. ___ 37. ___
8. ___ 18. ___ 28. ___ 38. ___
9. ___ 19. ___ 29. ___ 39. ___
10. ___ 20. ___ 30. ___ 40. ___

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ___ %

Subpavement: ___

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ___ %

Velocity and Discharge

Velocity:

☑ Estimated 0 m/s
☐ Measured ___ m/s

Discharge:

☐ Estimated ___ m^3/s
☐ Measured ___ m^3/s

Method:

☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: ___ Checked by: ___

Page ___ of ___

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Geomorphology
Earth Science
Observations

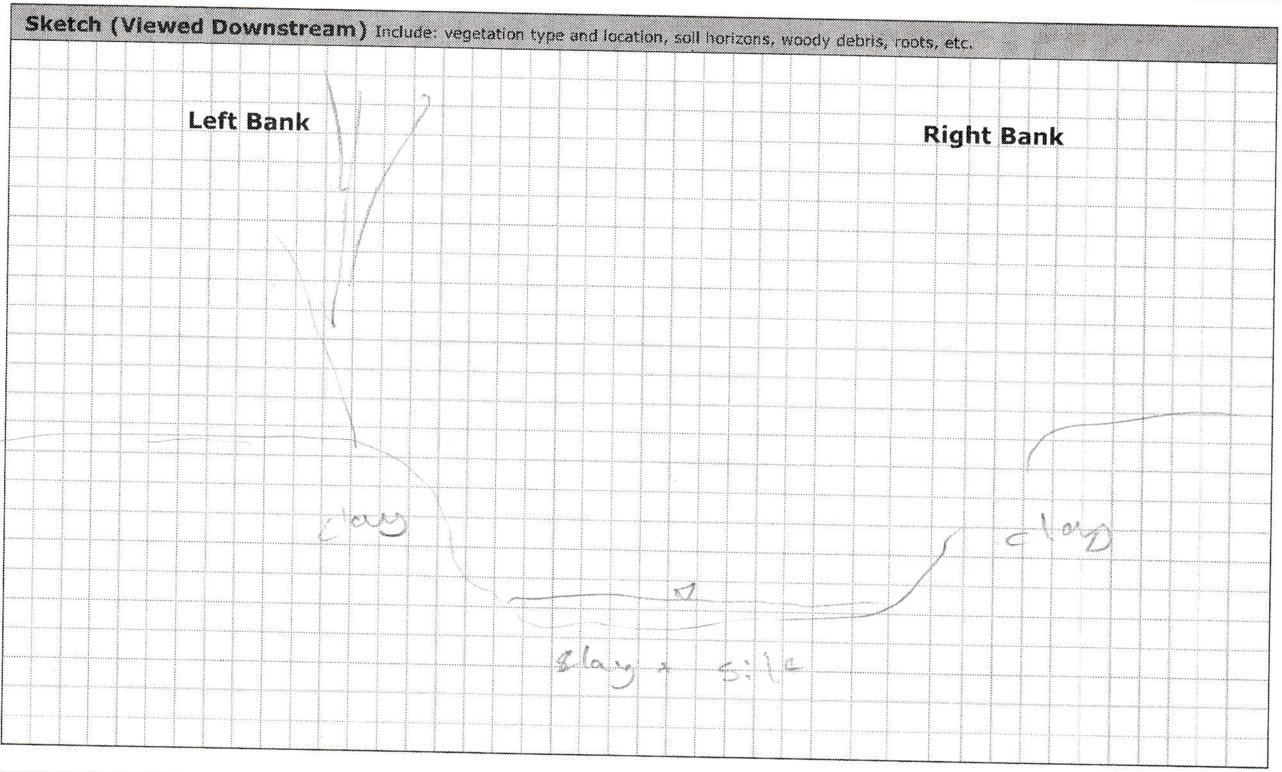
Bank Characteristics

Project Code: 21043

Date:

Reach/XS: XS1

Sketch (Viewed Downstream)
Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☐ Clay
☐ Silt
☐ Sand

☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.76 m
Bank Angle: 75 °
Root Depth: 0.15 m
Root Density: 50 %
Undercut: / m
Erosion Pin: 0.20 m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☐ Clay
☐ Silt
☐ Sand

☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.71 m
Bank Angle: 85 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: 0.20 m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order:

Completed by: ______ Checked by: ______

Page ______ of ______

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Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS2
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

x	y				Notes
6.30	1564				
6.60	1575				
6.90	1585				
7.10	1642				
7.30	1690				
7.60	1740				
7.90	1769				
8.20	1796				
8.40	1892	BF			
8.60	2045				
8.80	2262				
8.95	2326				
9.10	2345				
9.30	2356	2300	→ WL		
9.60	2392				
9.80	2400				
10.00	2402				
10.20	2388				
10.40	2335				
10.60	2264				
10.80	2116				
11.00	1855				
11.20	1705				
11.40	1615				
11.70	1516				
12.00	1437				
12.30	1432				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1.	11.	21.	31.
2. Clay	12.	22.	32.
3. +	13.	23.	33.
4. Silt	14.	24.	34.
5.	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ______ %

Subpavement: ______

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity and Discharge

Velocity:	**Method:**
☒ Estimated 0 m/s	☐ Wiffle ball
☐ Measured ______ m/s	☐ Current Meter
Discharge:	☐ ADV
☐ Estimated ______ m^3/s	☐ Marsh McBirney
☐ Measured ______ m^3/s	☐ Other

Completed by: ______ Checked by: ______

Page ______ of ______

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Geomorphology
Earth Science
Observations

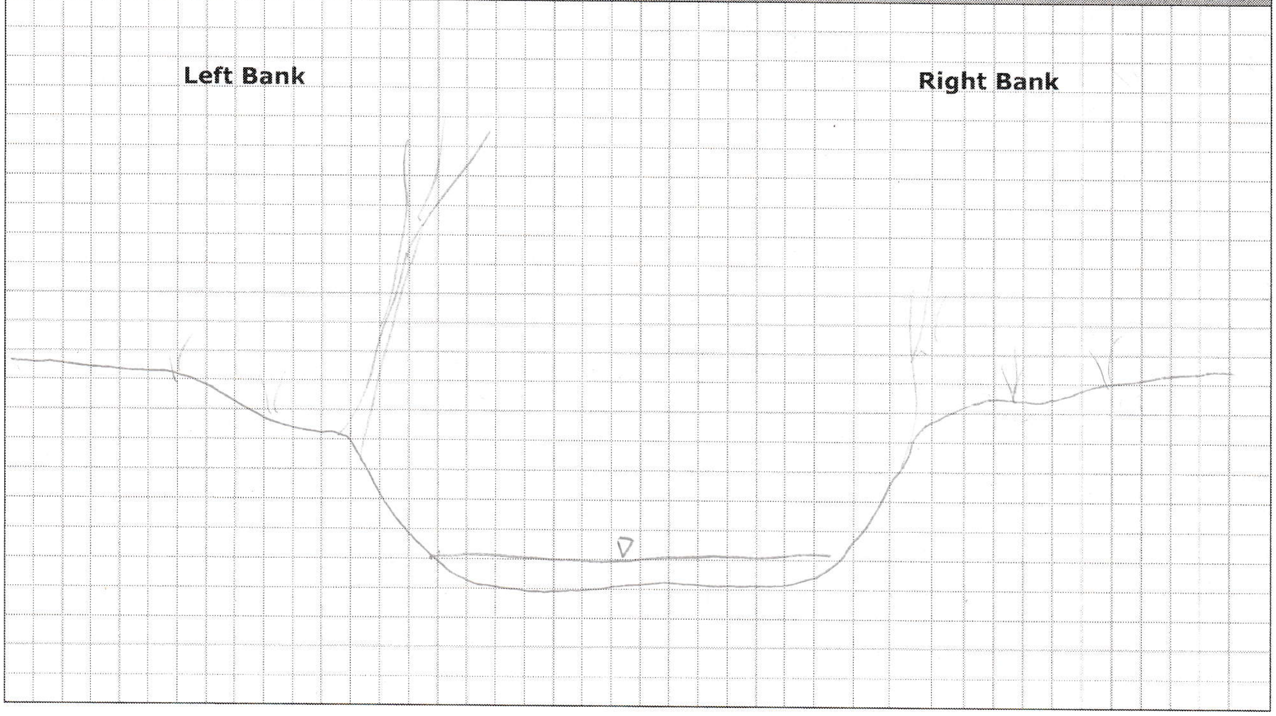
Bank Characteristics

Project Code: 21043

Date: 2021-08-19

Reach/XS: XS2

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand

☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.64 m
Bank Angle: 75 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: ______ m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand

☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.78 m
Bank Angle: 80 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: ______ m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order:

Completed by: ______ Checked by: ______

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Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	X53
Weather:		**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

					Notes
	Total				
	Station				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1. ______
2. ______
3. Clay
4. +
5. Silt
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______
23. ______
24. ______
25. ______
26. ______
27. ______
28. ______
29. ______
30. ______
31. ______
32. ______
33. ______
34. ______
35. ______
36. ______
37. ______
38. ______
39. ______
40. ______

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ____________ %

Subpavement: ____________

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity and Discharge

Velocity:

☒ Estimated 0 m/s
☐ Measured ______ m/s

Discharge:

☐ Estimated ______ m³/s
☐ Measured ______ m³/s

Method:

☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: ________ Checked by: ________

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GEO | MORPHIX
Geomorphology
Earth Science
Observations

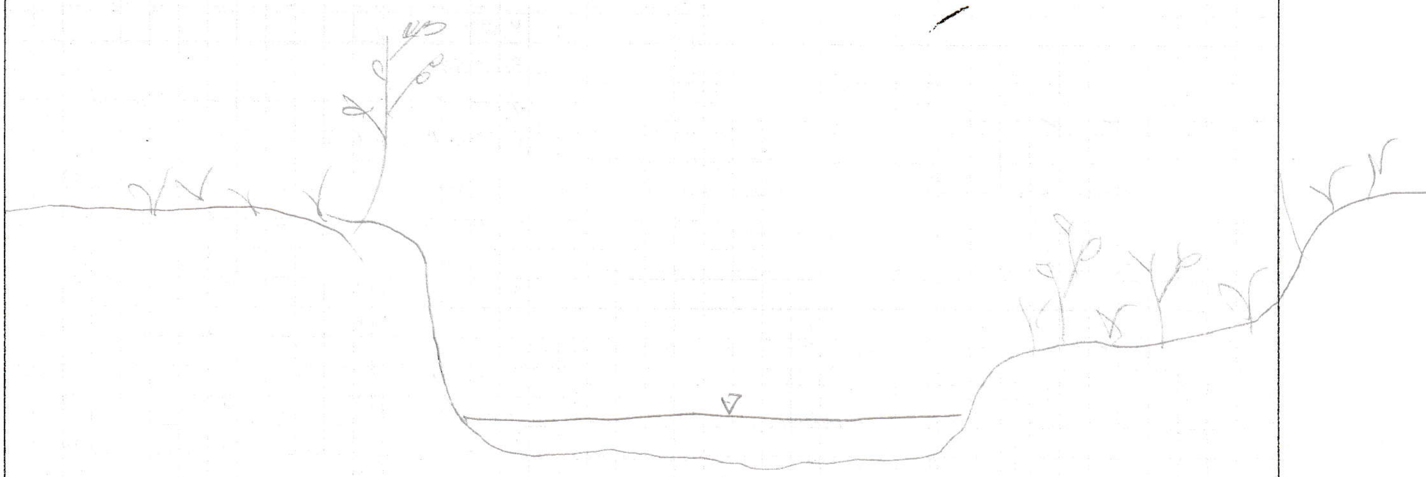
Bank Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/XS:**	XS3

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.

Left Bank **Right Bank**



Left Bank Materials

☐ Bedrock
☐ Till
☑ Clay
☑ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.64 m
Bank Angle: 85 °
Root Depth: 0.15 m
Root Density: 40 %
Undercut: 0.03 m
Erosion Pin: ______ m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☑ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.45 m
Bank Angle: 35 °
Root Depth: 0.15 m
Root Density: 30 %
Undercut: / m
Erosion Pin: ______ m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order: UDLR

Completed by: ______ Checked by: ______

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Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS4
Weather:	26° Sun	**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

x	y				Notes
6.30	1666				
6.60	1684				
6.90	1643				
7.20	1625				
7.50	1614				
7.80	1632				
7.90	1620	BF			
8.10	1679				
8.30	1841				
8.50	2062				
8.60	2156	WL			
8.70	2195	BED			
8.80	2231				
9.10	2251				
9.30	2269				
9.50	2353				
9.75	2278				
10.00	2196				
10.30	2159				
10.45	2125				
10.55	2020				
10.75	1915				
11.00	1825				
11.30	1795				
11.60	1780				
11.90	1712				
12.20	1640				
12.50	1544				
12.70	1518				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1. Clay
2. +
3. silt
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______
23. ______
24. ______
25. ______
26. ______
27. ______
28. ______
29. ______
30. ______
31. ______
32. ______
33. ______
34. ______
35. ______
36. ______
37. ______
38. ______
39. ______
40. ______

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embeddedness: ______________ %

Subpavement: ______________

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______________ %

Velocity and Discharge

Velocity:

☒ Estimated 0 m/s
☐ Measured ______ m/s

Discharge:

☐ Estimated ______ m³/s
☐ Measured ______ m³/s

Method:

☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: ______ Checked by: ______

Page ____ of ____

GEO | MORPHIX
Geomorphology
Earth Science
Observations

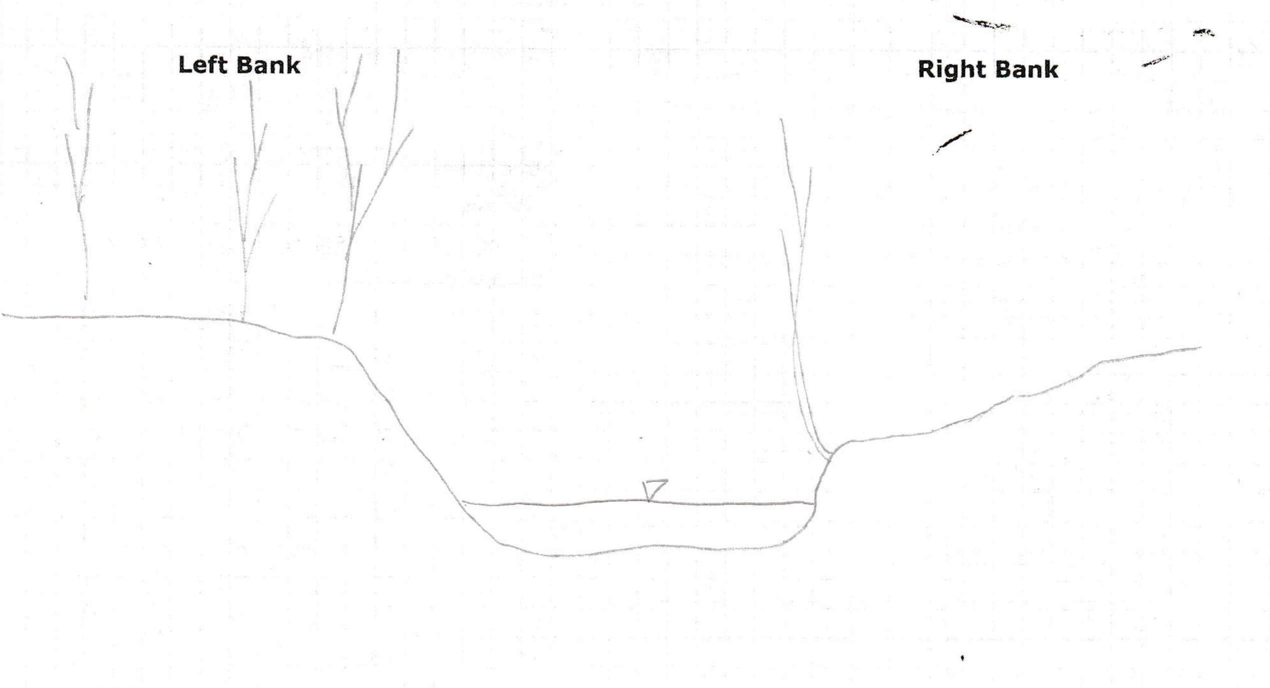
Bank Characteristics

Project Code: 21043

Date: 2021-08-19

Reach/XS: XS4

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.71 m
Bank Angle: 85 °
Root Depth: 0.30 m
Root Density: 30 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ____ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.67 m
Bank Angle: 70 °
Root Depth: 0.20 m
Root Density: 10 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ____ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order:

Completed by: ____ Checked by: ____

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GEO | MORPHIX
Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	X55
Weather:	26°C Sun	**Location:**	Hamilton
Field Staff:	JT PM	**Watershed/Subwatershed:**	

					Notes
	Total				
	station				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1. ______
2. Clay
3. +
4. Silt
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______
23. ______
24. ______
25. ______
26. ______
27. ______
28. ______
29. ______
30. ______
31. ______
32. ______
33. ______
34. ______
35. ______
36. ______
37. ______
38. ______
39. ______
40. ______

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ________________ %

Subpavement: ________________

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity and Discharge

Velocity:

☒ Estimated 0 m/s
☐ Measured ______ m/s

Discharge:

☐ Estimated ______ m^3/s
☐ Measured ______ m^3/s

Method:

☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: ________ Checked by: ________

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GEO | MORPHIX
Geomorphology
Earth Science
Observations

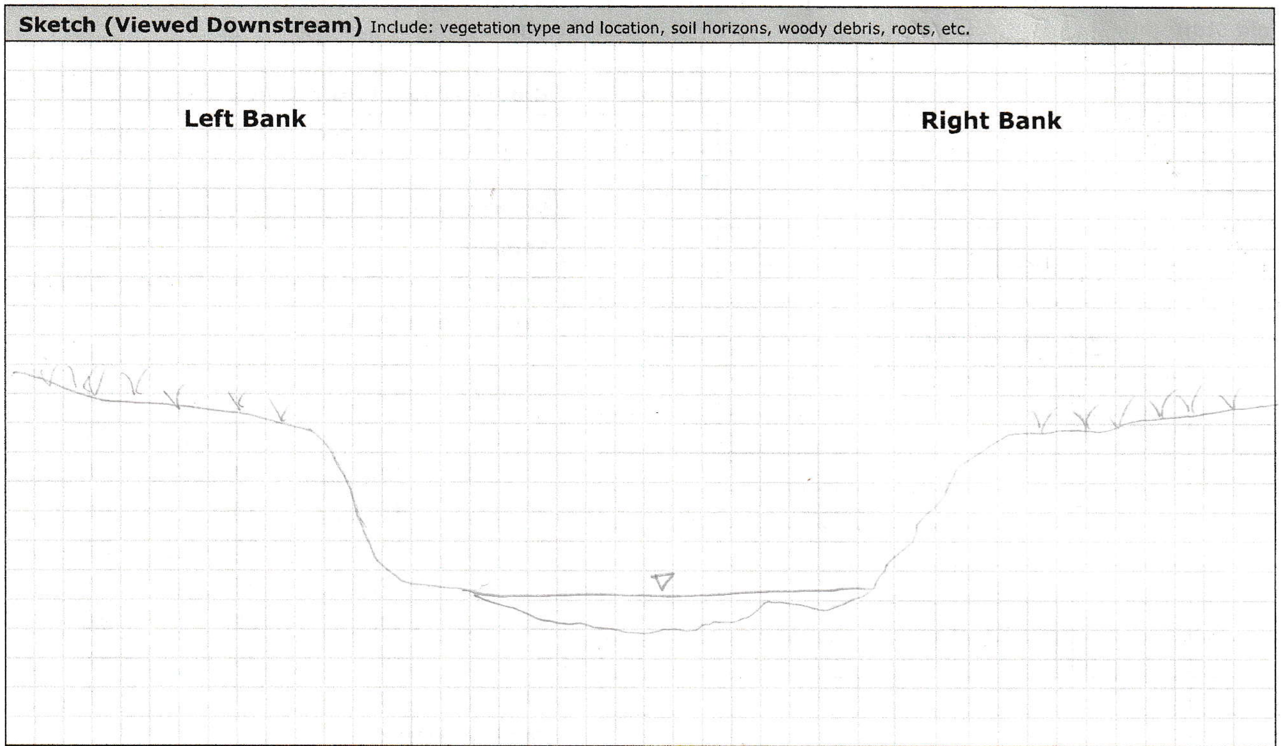
Bank Characteristics

Project Code: 21048

Date:

Reach/XS:

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.40 m
Bank Angle: 30 °
Root Depth: 0.10 m
Root Density: 40 %
Undercut: / m
Erosion Pin: / m

Penetrometer: kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.46 m
Bank Angle: 30 °
Root Depth: 0.20 m
Root Density: 10 %
Undercut: m
Erosion Pin: / m

Penetrometer: kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order:

Completed by: ________ Checked by: ________

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GEO | MORPHIX
Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS6
Weather:	26°C Sun	**Location:**	Hamilton
Field Staff:	J.T. DM	**Watershed/Subwatershed:**	

					Notes
	Total				
	Station				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1. ______
2. ______
3. Clay
4. +
5. Silt
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______
23. ______
24. ______
25. ______
26. ______
27. ______
28. ______
29. ______
30. ______
31. ______
32. ______
33. ______
34. ______
35. ______
36. ______
37. ______
38. ______
39. ______
40. ______

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ________________ %

Subpavement: ________________________

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity and Discharge

Velocity:

☒ Estimated 0 m/s
☐ Measured ________ m/s

Discharge:

☐ Estimated ________ m^3/s
☐ Measured ________ m^3/s

Method:

☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: __________ Checked by: __________

Page _____ of _____

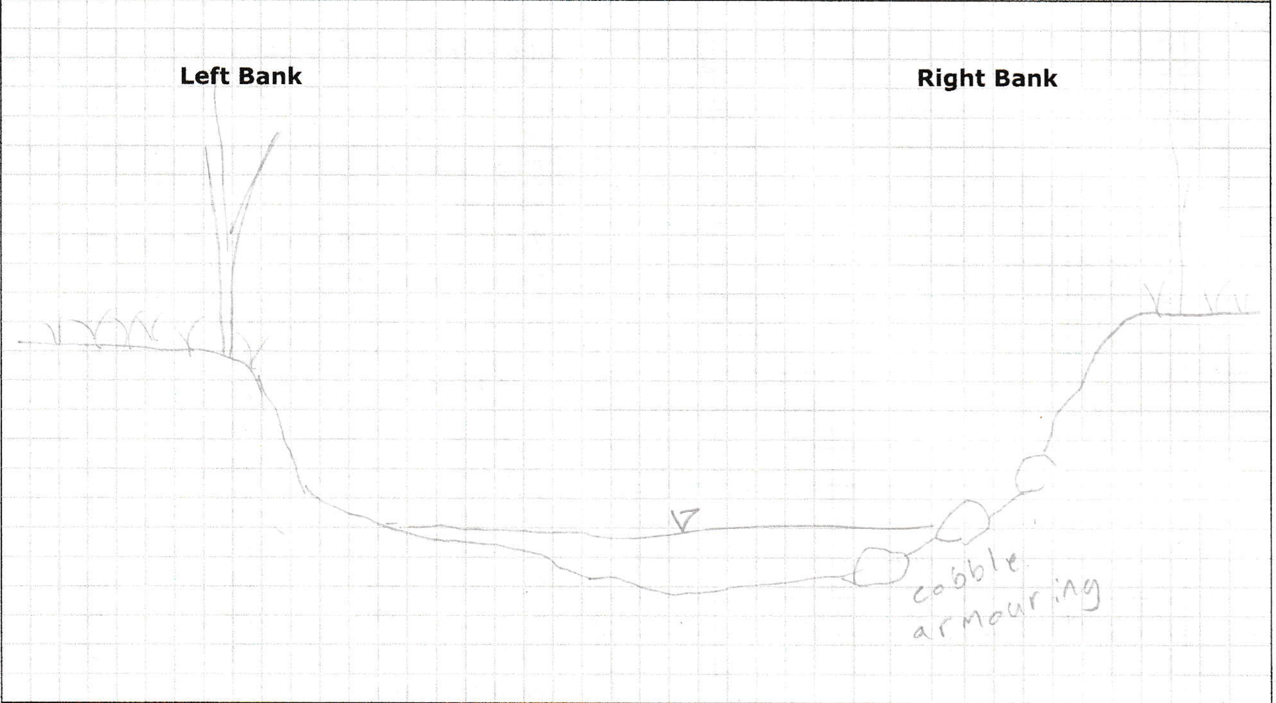
Bank Characteristics

Project Code: 21043

Date: 2021-08-19

Reach/XS: XS6

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.56 m
Bank Angle: 70 °
Root Depth: 0.40 m
Root Density: ______ %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☑ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.78 m
Bank Angle: 75 °
Root Depth: 0.40 m
Root Density: ______ %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order: UDLR

Completed by: ________ Checked by: __________

Page ____ of ____

GEO MORPHIX
Geomorphology
Earth Science
Observations

Cross-Section Characteristics

Project Code: 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS7
Weather:	28° Sun	**Location:**	Hamilton
Field Staff:	JT	**Watershed/Subwatershed:**	

					Notes
	RTK				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1.	11.	21.	31.
2.	12.	22.	32.
3.	13.	23.	33.
4. Clay	14.	24.	34.
5. +	15.	25.	35.
6. silt	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ______ %

Subpavement: ______

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity and Discharge

Velocity:	**Method:**
☒ Estimated 0 m/s	☐ Wiffle ball
☐ Measured ______ m/s	☐ Current Meter
Discharge:	☐ ADV
☐ Estimated ______ m^3/s	☐ Marsh McBirney
☐ Measured ______ m^3/s	☐ Other

Completed by: ______ Checked by: ______

Page ____ of ____

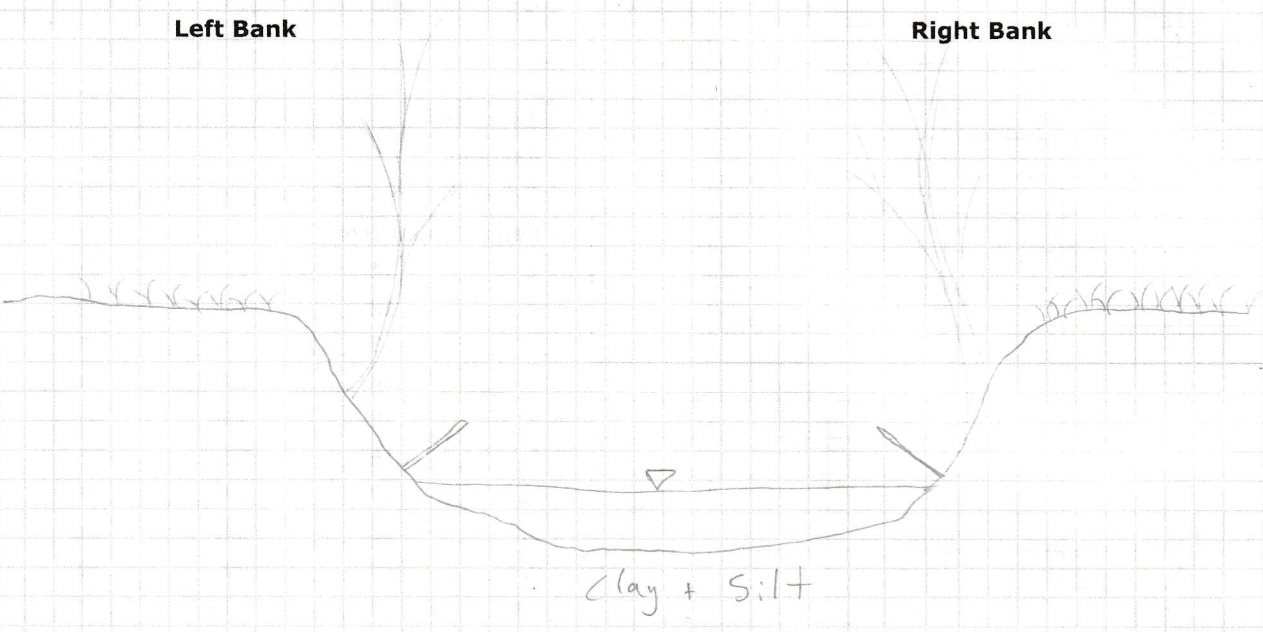
Bank Characteristics

Project Code:

Date:

Reach/XS:

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☑ Clay
- ☑ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height: 0.62 m
Bank Angle: 80 °
Root Depth: 0.40 m
Root Density: 60 %
Undercut: / m
Erosion Pin: 0.20 m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☑ Clay
- ☑ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height: 0.64 m
Bank Angle: 70 °
Root Depth: 0.40 m
Root Density: 15 %
Undercut: / m
Erosion Pin: 0.20 m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order:

Completed by: ________ Checked by: __________

Page _____ of _____

GEO | MORPHIX
Geomorphology
Earth Science
Observations

Cross-Section Characteristics **Project Code:** 21043

Date:	2021-08-19	**Reach/Cross-section:**	XS 8
Weather:	26° Sun	**Location:**	Hamilton
Field Staff:	JT DM	**Watershed/Subwatershed:**	

x	y				**Notes**
6.30	1698				
6.60	1716				
6.95	1771				
7.20	1816				
7.50	1883				
7.70	1967				
7.90	2095				
8.15	2135				
8.40	2151	WL			
8.40	2173				
8.50	2183				
8.70	2232				
9.00	2198				
9.20	2152				
9.50	2133	Rock edge			
9.70	1650	Rock middle			
10.00	1677	Rock			
10.10	1744	Rock	edge		
10.30	1686				
10.50	1605				
10.80	1571				
11.30	1464				

Cross-sectional Morphology

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate

Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count (cm):

1.	11.	21.	31.
2. Clay	12.	22.	32.
3.	13.	23.	33.
4. +	14.	24.	34.
5. Silt	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Particle Shape:

☐ Platy ☐ Sub-angular ☐ Well Rounded
☐ Very Angular ☐ Angular ☐ Sub-Rounded
☐ Rounded

Embededness: ______ %

Subpavement: ______

Sorting: ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Observed ☒ Not Observed

If Observed:

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity and Discharge

Velocity:
☒ Estimated 0 m/s
☐ Measured ______ m/s

Discharge:
☐ Estimated ______ m³/s
☐ Measured ______ m³/s

Method:
☐ Wiffle ball
☐ Current Meter
☐ ADV
☐ Marsh McBirney
☐ Other

Completed by: ______ Checked by: ______

Page ____ of ____

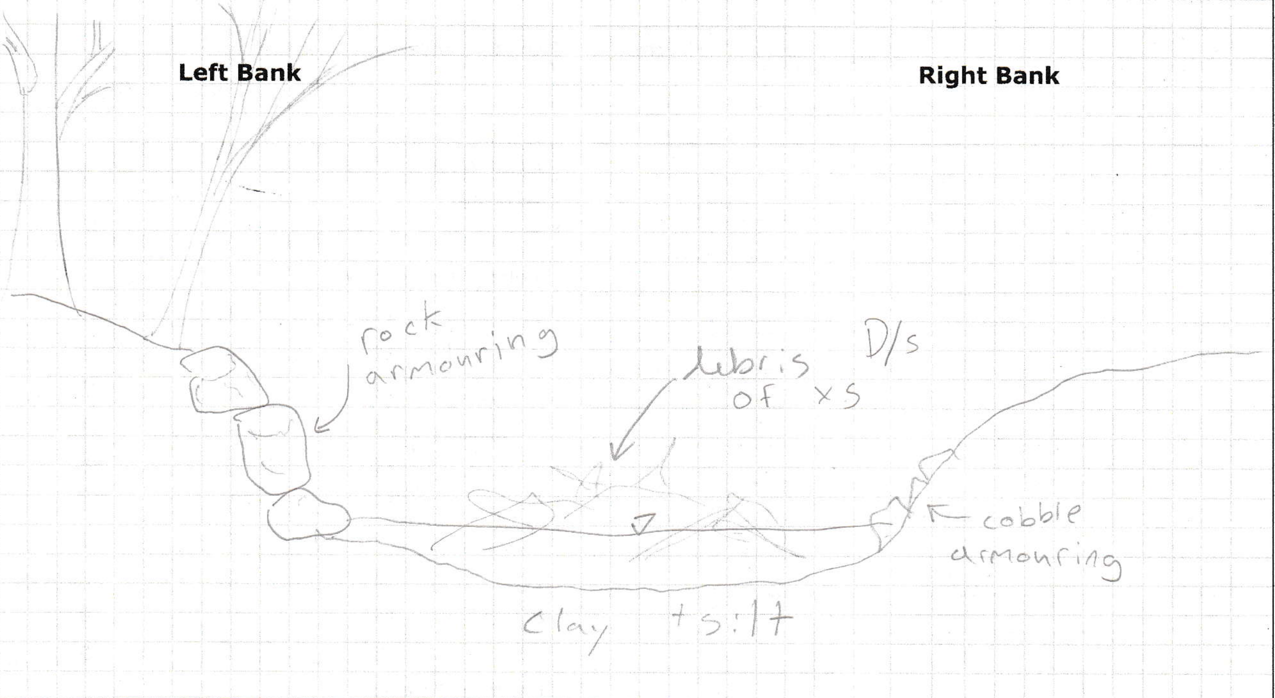
GEO | MORPHIX
Geomorphology
Earth Science
Observations

Bank Characteristics

Project Code: 21043

Date: 2021-08-19
Reach/XS: XS8

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.54 m
Bank Angle: 50 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.51 m
Bank Angle: 30 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order: UDLR

Completed by: ________ Checked by: ________

Page ____ of ____

GEO | MORPHIX
Geomorphology
Earth Science
Observations

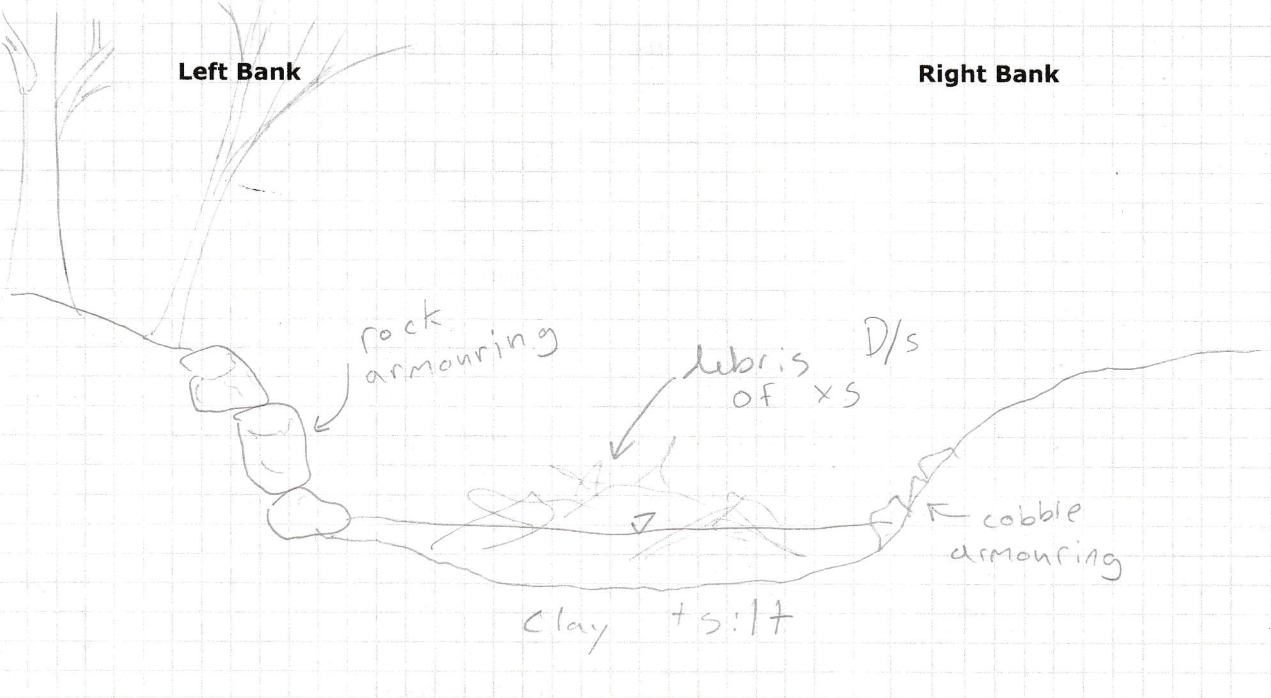
Bank Characteristics

Project Code: 21043

Date: 2021-08-19

Reach/XS: XS8

Sketch (Viewed Downstream) Include: vegetation type and location, soil horizons, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.54 m
Bank Angle: 50 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Right Bank Materials

☐ Bedrock
☐ Till
☒ Clay
☒ Silt
☐ Sand
☐ Gravel
☐ Small Cobble
☐ Large Cobble
☐ Small Boulder
☐ Large Boulder

Bank Height: 0.51 m
Bank Angle: 30 °
Root Depth: 0.30 m
Root Density: 20 %
Undercut: / m
Erosion Pin: / m

Penetrometer: ______ kg/cm²
Foot Used: ☐ Yes ☐ No

Additional Notes

Photo Order: UDLR

Completed by: ______ Checked by: ______

Page ____ of ____

Appendix D
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach: Watercourse 5

Project Number:	PN21043	**Date:**	2021-08-19
Client:	Urbantech Consulting	**Length Surveyed (m):**	86.1
Location:	Hamilton	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	167.1 ha	**Dominant Riparian Vegetation Type:**	Trees
Geology/Soils:	Paleozoic Bedrock	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Residential/Agricultural	**Width of Riparian Cover:**	4-10 Channel Widths
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Established (5-30 Years)
Dominant Instream Vegetation Type:	Algae	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	10%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	Not measured	**Calculated Bankfull Discharge (m^3/s):**	1.31
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	1.06
Modelled 2-year Velocity (m/s):	Not modelled		

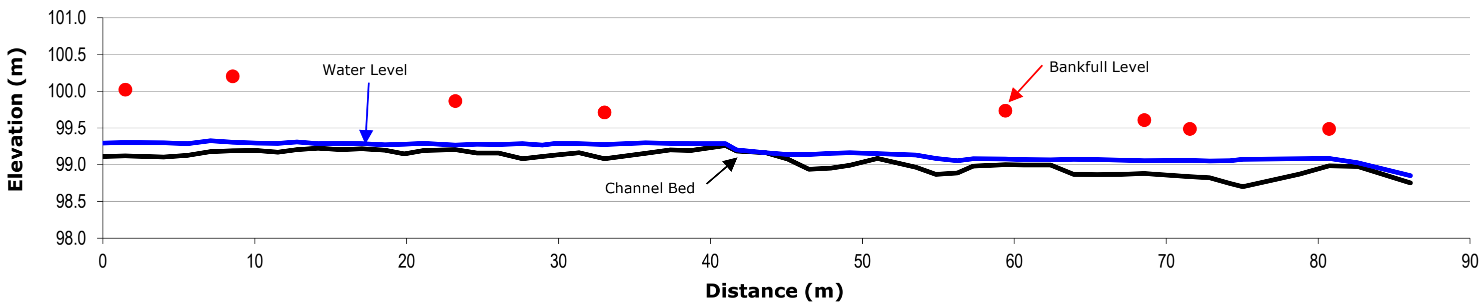
Profile Characteristics

Bankfull Gradient (%):	0.76
Channel Bed Gradient (%):	0.42
Riffle Gradient (%):	n/a
Riffle Length (m):	n/a
Riffle-Pool Spacing (m):	n/a

Planform Characteristics

Sinuosity:	1.29
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

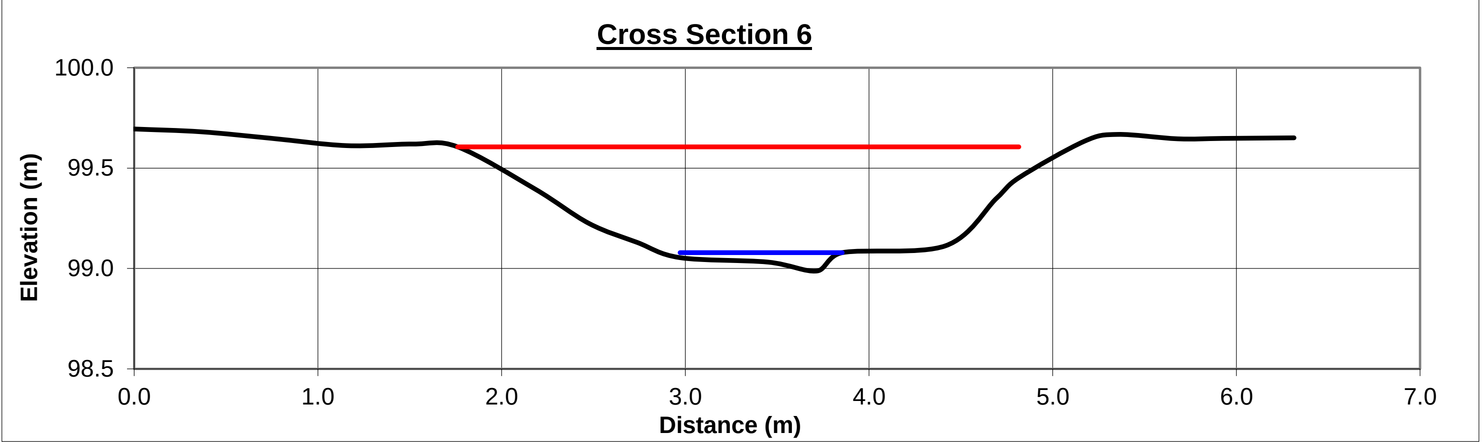
	Minimum	Maximum	Average		Minimum	Maximum	Average
Bank Height (m):	0.40	0.78	0.62				
Bank Angle (deg):	30	85	64	**Torvane Value (kg/cm^2):**		Not measured	
Root Depth (m):	0.10	0.40	0.27	**Penetrometer Value (kg/cm^3):**		Not measured	
Root Density (%):	10	60	28	**Bank Material (range):**		Silty-clay loam (uniform)	
Bank Undercut (m):	0.00	0.03	0.00				

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.60	5.00	3.64
Average Bankfull Depth (m):	0.13	0.42	0.34
Bankfull Width/Depth (m/m):	7	38	13
Wetted Width (m):	0.10	1.80	1.22
Average Water Depth (m):	0.01	0.11	0.05
Wetted Width/Depth (m/m):	4	60	28
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.04	0.20	0.11
Manning's *n* :		0.040	

Photograph at cross section 6 (looking downstream)

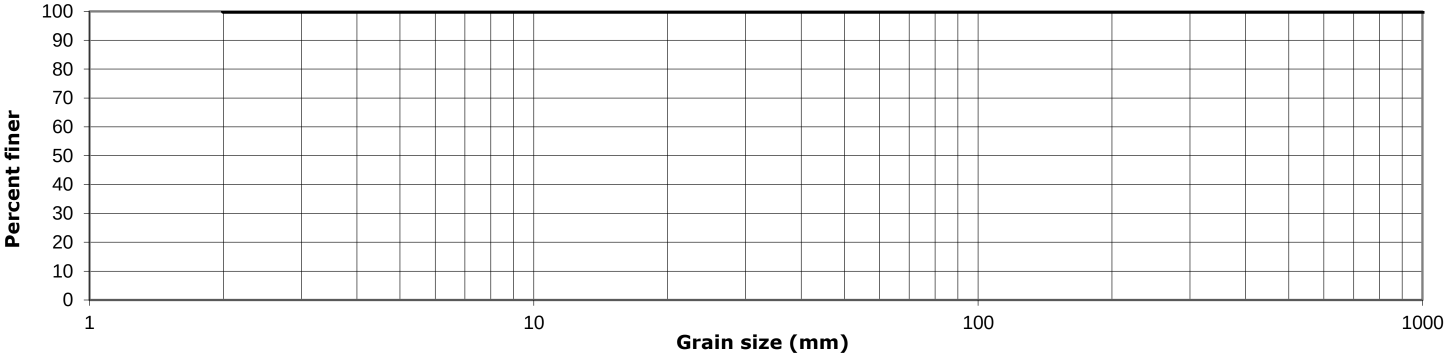
Representative Cross-Section #6



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Shale
D_{10} :	<2	**Particle shape:**	N/A
D_{50} :	<2	**Embeddedness (%):**	N/A
D_{84} :	<2	**Particle range (riffle):**	Silt to clay
		Particle Range (pool):	Silt to clay

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	25.33
for D_{50}:	n/a	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	n/a	**Critical Shear Stress (D_{50}) (N/m^2):**	n/a
Unit Stream Power at Bankfull (W/m^2):	26.86		

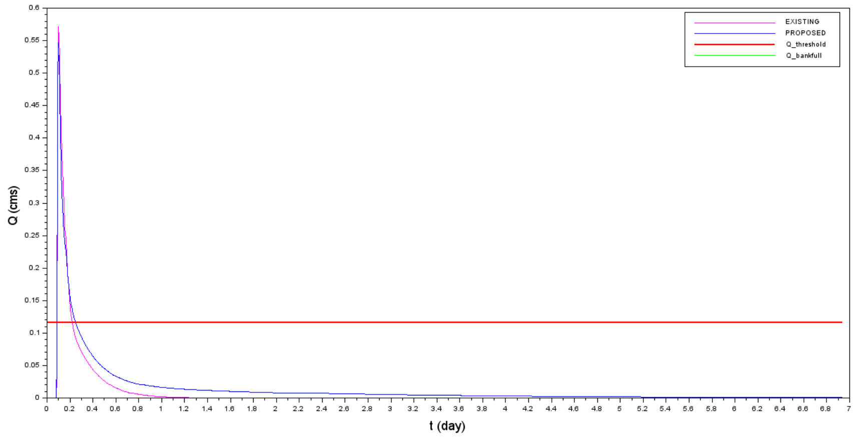
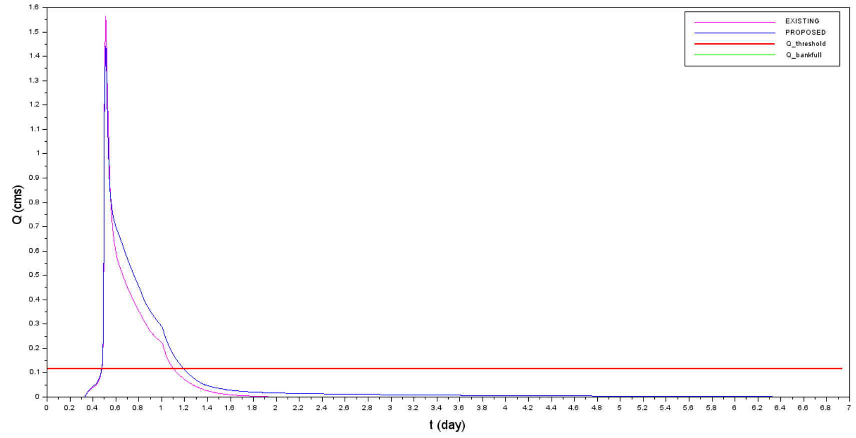
General Field Observations

Channel Description

Watercourse 5 flows through an unconfined valley surrounded by a mix of residential and agricultural areas. The continuous extent of riparian vegetation consists of grasses, herbaceous vegetation, shrubs, and trees. This vegetation is established on the landscape and only minimally encroaches upon the channel. The average bankfull width and depth are 3.64 m and 0.34 m, respectively. Both the bed and bank material is comprised primarily of a compact silty clay loam, with trace amounts of shale pebbles observed. No riffle-pool sequeces are present within the reach. The channel generally exhibits a trapezoidal cross-section shape, with bank angles ranging from 30 to 85. Undercutting and active erosion of the banks was not prevelant. Flow velocities were imperceptible during the assessment.

Photo of typical channel conditions, facing upstream

Appendix E
Erosion Modelling Hydrographs

WC5 25 mm event	
WC5 2-year event	

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WC5
5-year
event

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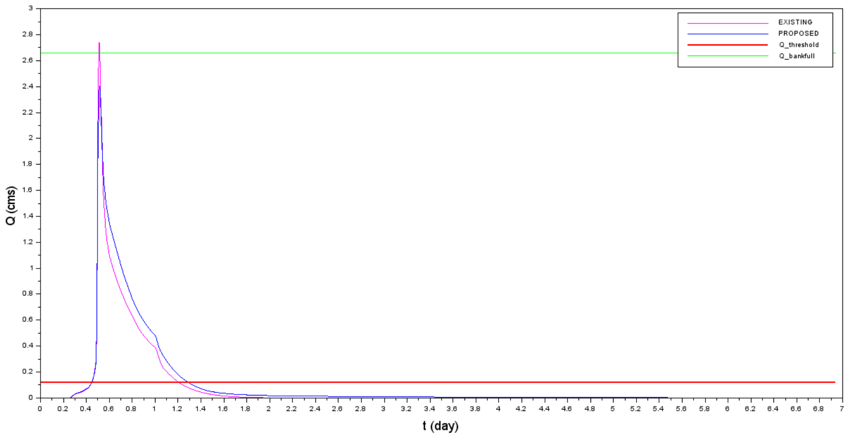

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WC5
10-year
event

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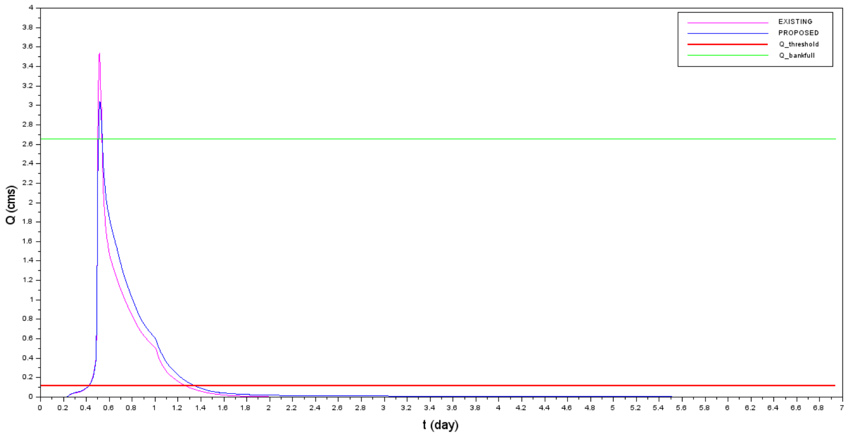

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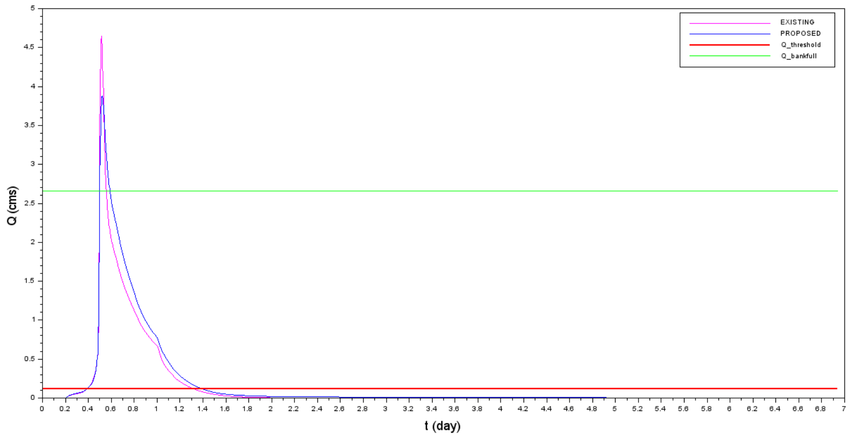
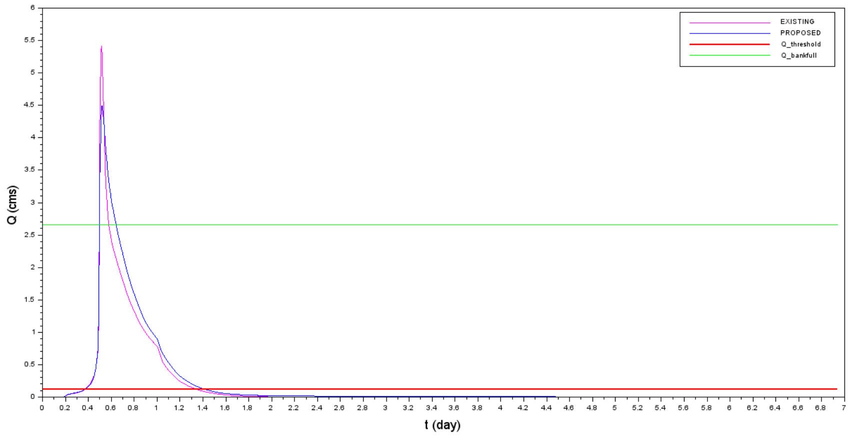
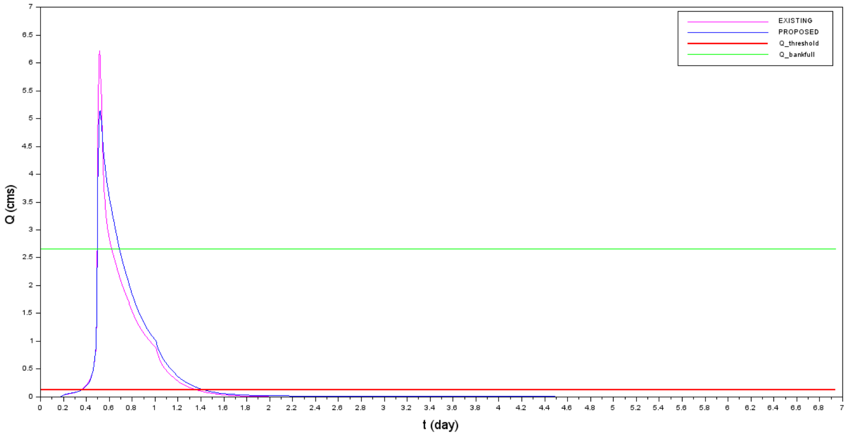
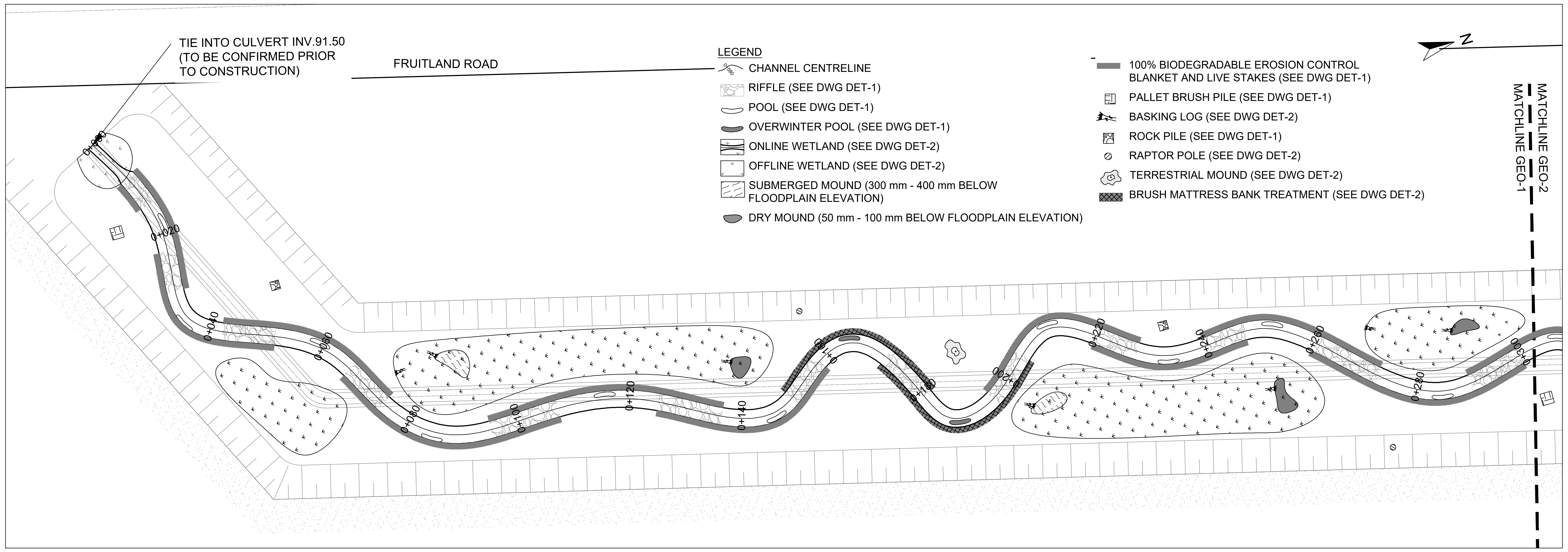
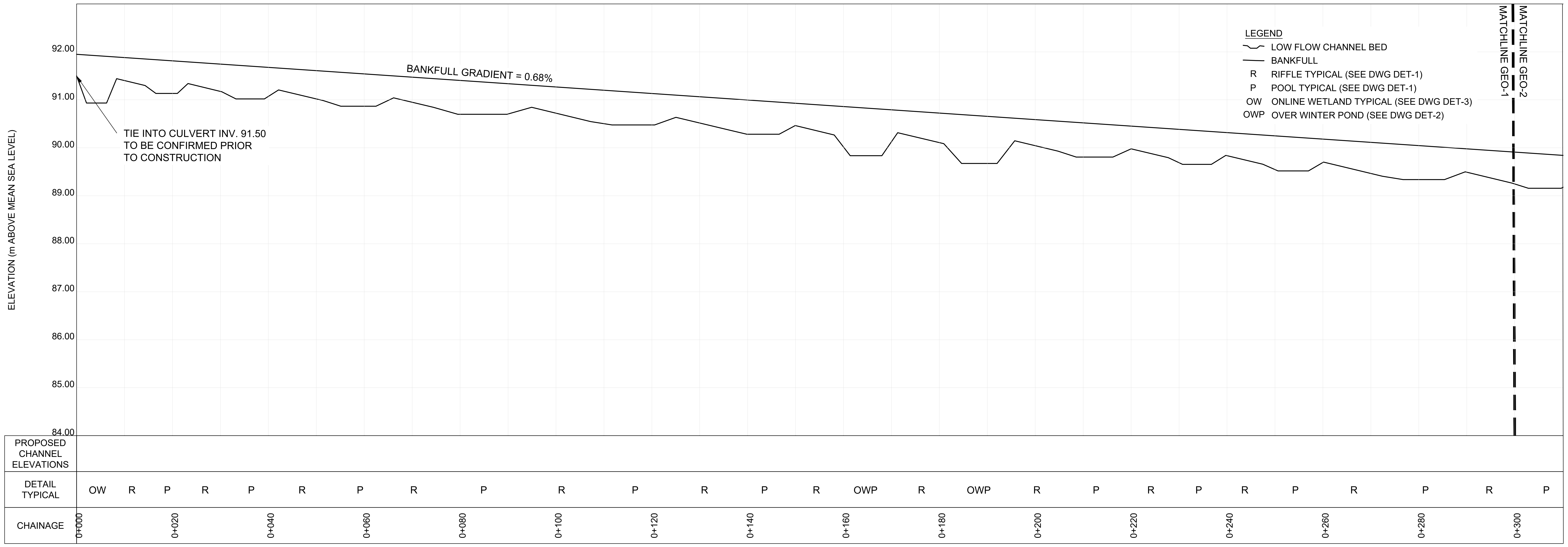
WC5 25-year event	
WC5 50-year event	

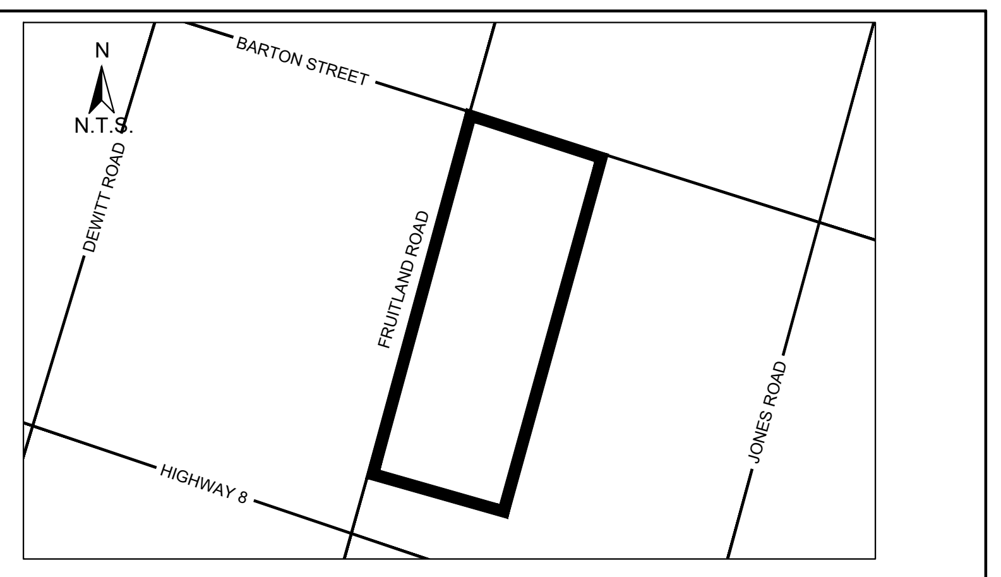
WC5 100-year event	



PLANFORM
1:500



PROFILE
H = 1:500; V=1:50



KEY MAP
N.T.S.

GENERAL NOTES

1. THE ACCOMPANYING CHANNEL REALIGNMENT TECHNICAL DESIGN BRIEF PREPARED BY GEO MORPHIX LTD. (2023) PROVIDES ADDITIONAL DESIGN DETAILS AND DIRECTION FOR IMPLEMENTATION AND IS TO BE REVIEWED IN CONJUNCTION WITH THIS DRAWING SET.
2. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
3. THE CONTRACTOR MUST NOTIFY THE DESIGNER AND CONTRACT ADMINISTRATOR OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
4. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
5. LAYOUT MUST BE REVIEWED AND APPROVED BY THE DESIGNER / DESIGNER REPRESENTATIVE, DESIGNATED ENGINEER, AND THE CONTRACT ADMINISTRATOR.
6. CONSTRUCTION OBSERVATION IS TO BE PERFORMED BY A CERTIFIED FLUVIAL GEOMORPHOLOGIST OR EXPERIENCED ENVIRONMENTAL INSPECTOR UNDER DIRECTION FROM THE DESIGNER.
7. ON-SITE SUPPORT FROM PROJECT ENGINEER (E.G., GEOTECHNICAL, HYDROGEOLOGICAL, AND/OR WATER RESOURCES ENGINEER) REQUIRED TO ASSESS AND ENSURE FAVOURABLE SURFICIAL AND SUBSURFACE CONDITIONS TO SUPPORT CHANNEL REALIGNMENT CONSTRUCTION.
8. BE ADVISED THAT THE LOCAL REGULATORY BODY MAY, AT ANY TIME, WITHDRAW THIS PERMISSION, IF, IN THE OPINION OF THE AUTHORITY, THE CONDITIONS OF THE PERMIT ARE NOT BEING COMPLIED WITH. THIS APPROVAL DOES NOT EXEMPT THE PROPERTY OWNER/APPLICANT/AGENT FROM THE PROVISIONS OF ANY OTHER FEDERAL, PROVINCIAL OR MUNICIPAL STATUTES, REGULATIONS OR BY-LAWS, OR ANY RIGHTS UNDER COMMON LAW.

TIMING OF WORKS

1. WORKS SHALL BE COMPLETED DURING THE DESIGNATED IN-WATER WORKS WINDOW SET OUT BY MNRF/DFO.
2. TREE CLEARING IS TO BE COMPLETED OUTSIDE THE BIRD NESTING SEASON (APRIL 1ST TO AUGUST 1ST) TO COMPLY WITH THE FEDERAL MIGRATORY BIRDS CONVENTION ACT. ANY TREES THAT REQUIRE REMOVAL OUTSIDE OF THIS TIMING WINDOW MUST FIRST BE INSPECTED BY A QUALIFIED BIOLOGIST TO DETERMINE THE PRESENCE OF NESTING BIRDS.
3. THE WEATHER FORECAST SHOULD BE CONTINUALLY MONITORED TO ENSURE THAT WORKS ARE UNDERTAKEN ONLY DURING FAVOURABLE WEATHER CONDITIONS.
4. COMPLETE THE WORKS WITH MINIMAL AVOIDABLE INTERRUPTIONS ONCE THEY COMMENCE.

SITE AND MATERIAL MANAGEMENT

1. ALL CONSTRUCTION EQUIPMENT AND MATERIALS (IMPORTED OR EXCAVATED) MUST BE STORED AT LEAST 30 m AWAY FROM ANY WATERBODY IN A STABLE AREA ABOVE THE ACTIVE FLOODPLAIN, OR IN A DESIGNATED STAGING/STORAGE AREA.
2. IN THE EVENT OF AN UNEXPECTED STORM, ALL UNFIXED ITEMS THAT HAVE THE POTENTIAL TO CAUSE A SPILL OR AN OBSTRUCTION TO FLOW MUST BE MOVED A STABLE AREA ABOVE ACTIVE FLOODPLAIN.
3. STOCKPILES MUST BE LOCATED OUTSIDE THE ISOLATED WORK AREAS.
4. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW.
5. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE. ALL DISTURBED GROUND LEFT INACTIVE FOR MORE THAN 30 DAYS SHALL BE STABILIZED USING APPROPRIATE EROSION CONTROL MEASURES AND AN APPROPRIATE SEED MIX AS NOTED WITHIN THE FINAL APPROVED RESTORATION PLAN.
6. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
7. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.
8. AN AFTER-HOURS CONTACT NUMBER IS TO BE VISIBLY POSTED ONSITE FOR EMERGENCIES. ALL THE PLANS SHOULD HAVE NAME AND CONTACT INFO OF THE PERSON RESPONSIBLE FOR ESC MEASURES.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. FOLLOWING INSTALLATION OF THE PROPOSED ESC MEASURES, A QUALIFIED AGENT OF THE PROPONENT (E.G. CAN-CISEC CERTIFIED MONITOR) WILL CONDUCT REGULAR SITE VISITS TO MONITOR ALL WORKS, PARTICULARLY THE CONDITION OF THE ESC MEASURES, DEWATERING, AND IN- OR NEAR-WATER WORKS. SHOULD CONCERNS ARISE; THE ENVIRONMENTAL MONITOR WILL CONTACT THE PROPONENT, THE CONSERVATION AUTHORITY, AND ANY OTHER APPROPRIATE PARTIES.
3. EROSION AND SEDIMENT CONTROLS MUST BE MAINTAINED DURING CONSTRUCTION, AND ANY REQUIRED REPAIRS OR REPLACEMENTS MUST BE COMPLETED WITHIN 24 HOURS AFTER THEY HAVE BEEN IDENTIFIED DURING THE MONITORING.
4. EROSION AND SEDIMENT CONTROLS MAY REQUIRE PERIODIC ADJUSTMENTS TO REFLECT CHANGING SITE CONDITIONS. THE CONTRACTOR WILL BE RESPONSIBLE FOR THESE ADJUSTMENTS TO ENSURE PROPER FUNCTION.
5. ANY CHANGES TO THE EROSION AND SEDIMENT CONTROL PLAN BEYOND MINOR ADJUSTMENTS MUST BE APPROVED BY THE CONTRACT ADMINISTRATOR.
6. ADDITIONAL EROSION AND SEDIMENT CONTROL SUPPLIES MUST BE KEPT ON SITE IN ORDER TO FACILITATE IMMEDIATE REPAIRS AND/OR UPGRADES AS NEEDED.
7. ALL TEMPORARY SEDIMENT CONTROLS MUST BE REMOVED AFTER THE CONTRACT ADMINISTRATOR DEEMS THE SITE TO BE STABLE.
8. THE PROJECT PROPONENT OR THEIR REPRESENTATIVE IS ULTIMATELY RESPONSIBLE FOR CONTROLLING SEDIMENT AND EROSION WITHIN THE CONSTRUCTION SITE FOR THE TOTAL PERIOD OF THE CONSTRUCTION.
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	DATE	BY	REVISIONS

DESIGNED BY: LD
CHECKED BY: PV
DRAWN BY: AS / SG
DATE: APRIL 2024

**NOT FOR CONSTRUCTION
SCALED FOR PLOT
ON 'ARCH D'**

24/03/15

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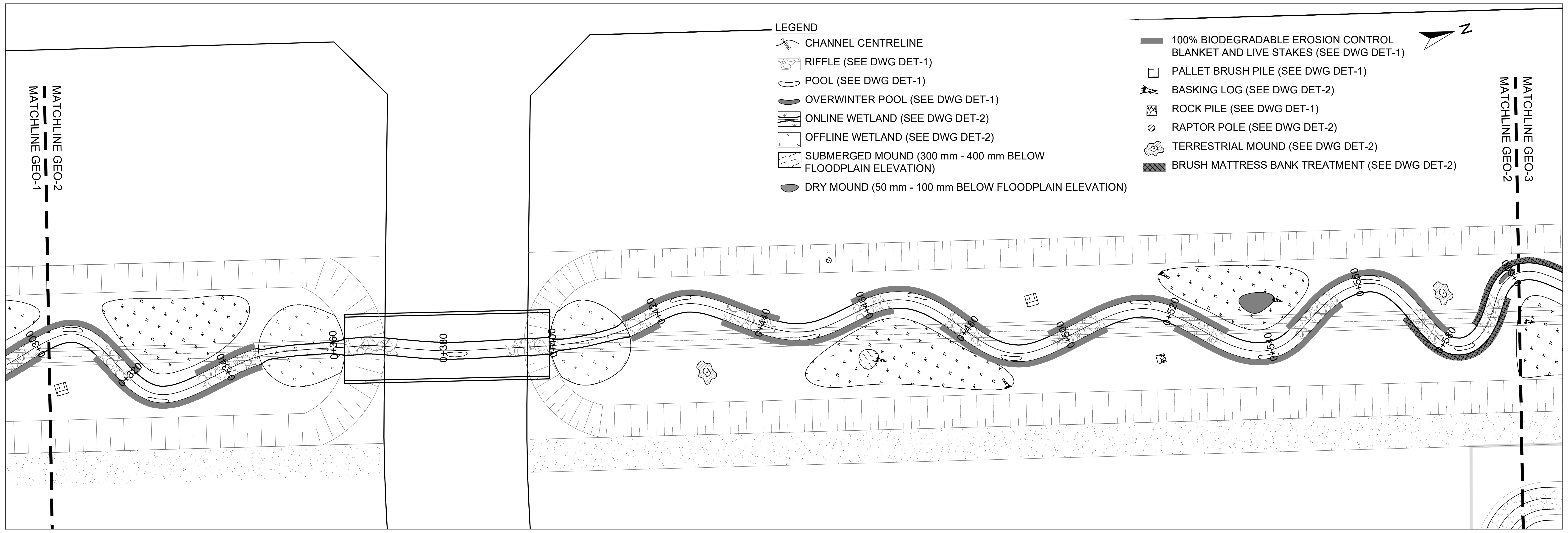
WATERCOURSE 5
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21043
DRAWING No.: GEO-1
SCALE: AS NOTED
SHEET 1 OF 5



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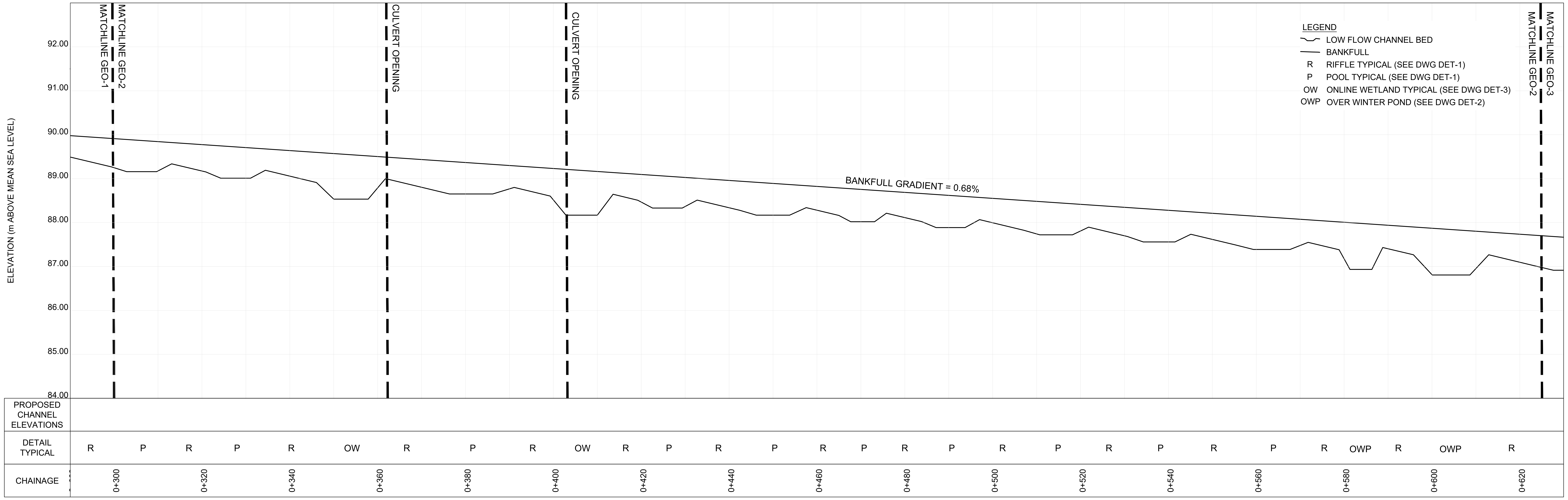

PROFILE
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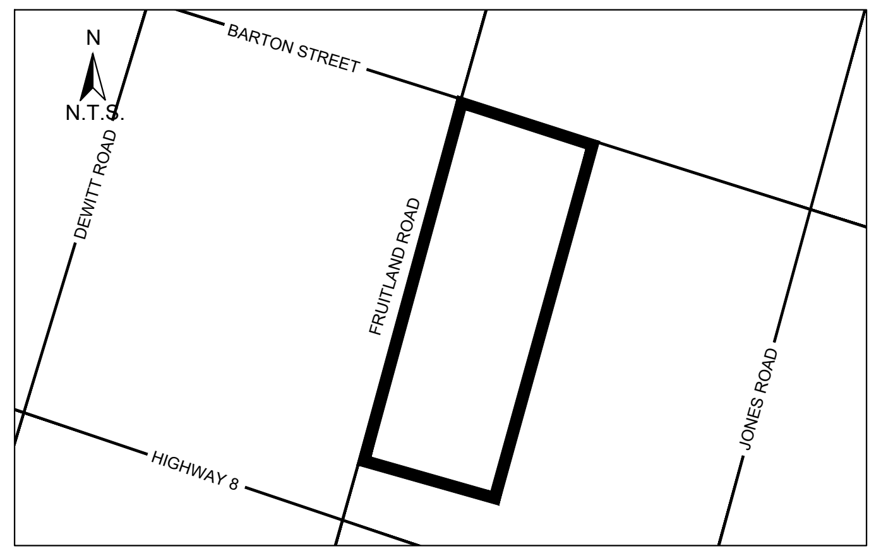

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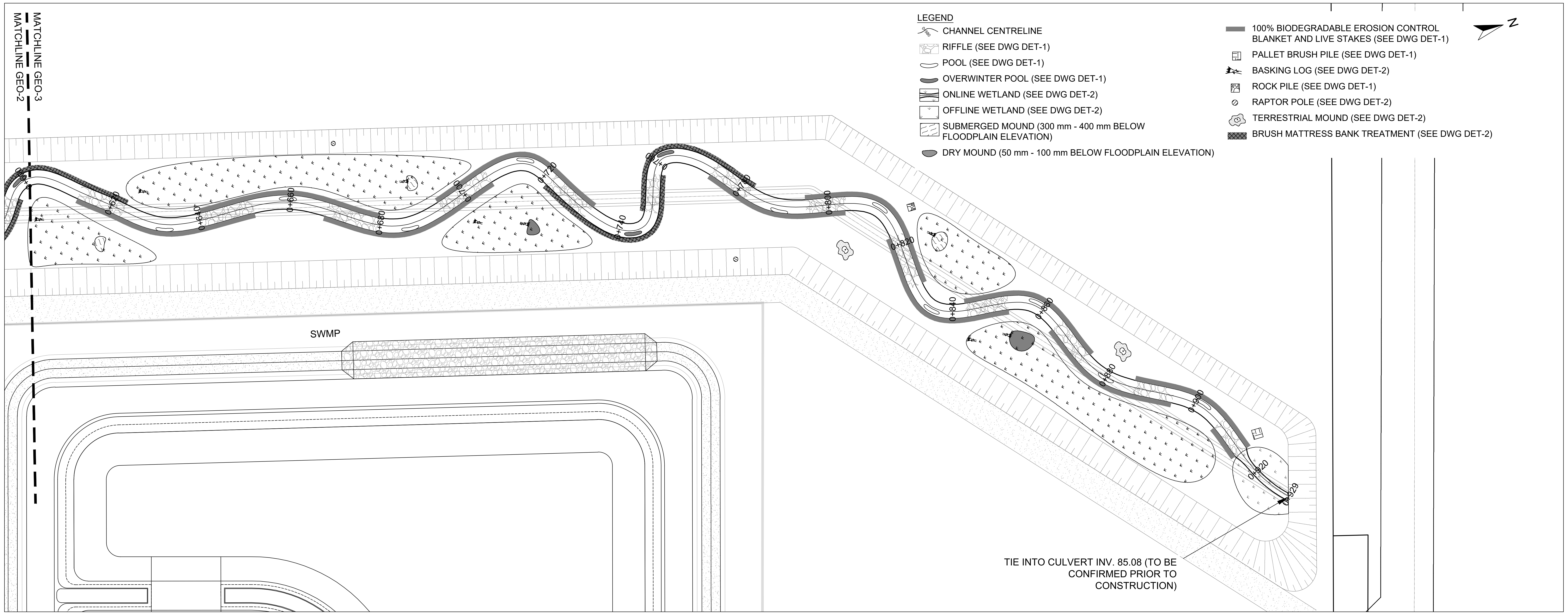
WATERCOURSE 5
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21043
DRAWING No.: GEO-2
SCALE: AS NOTED
SHEET 2 OF 5



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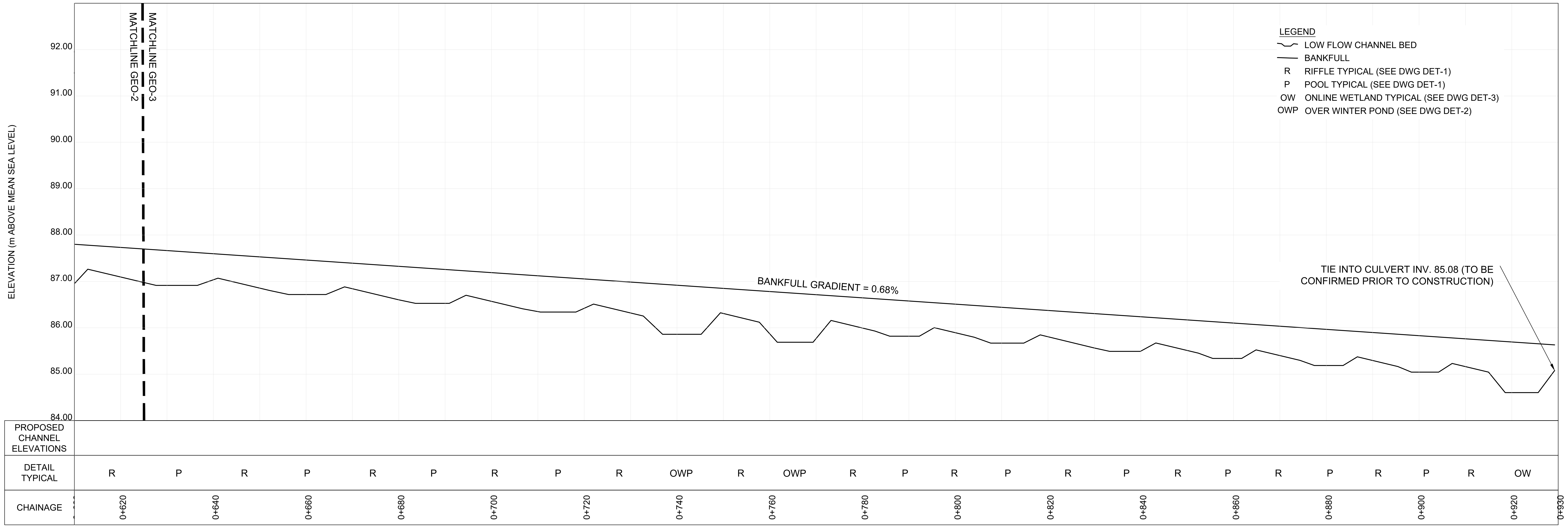

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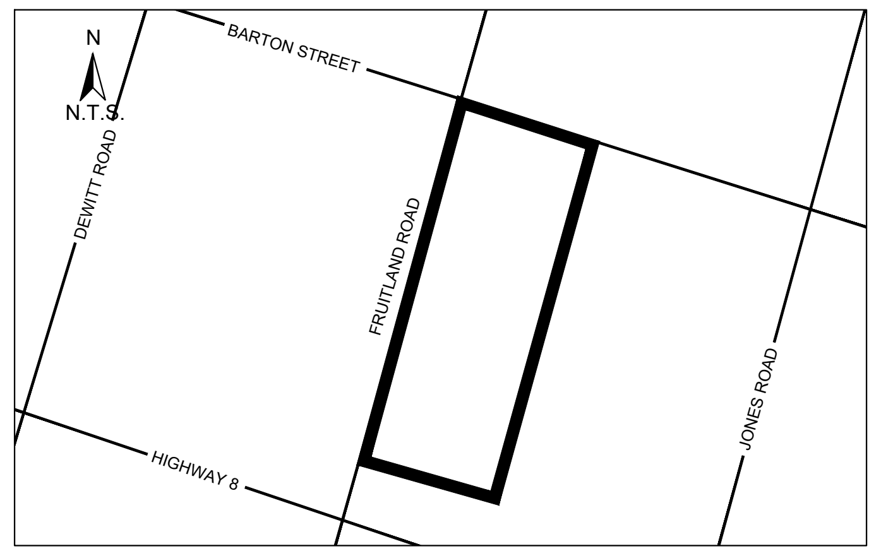

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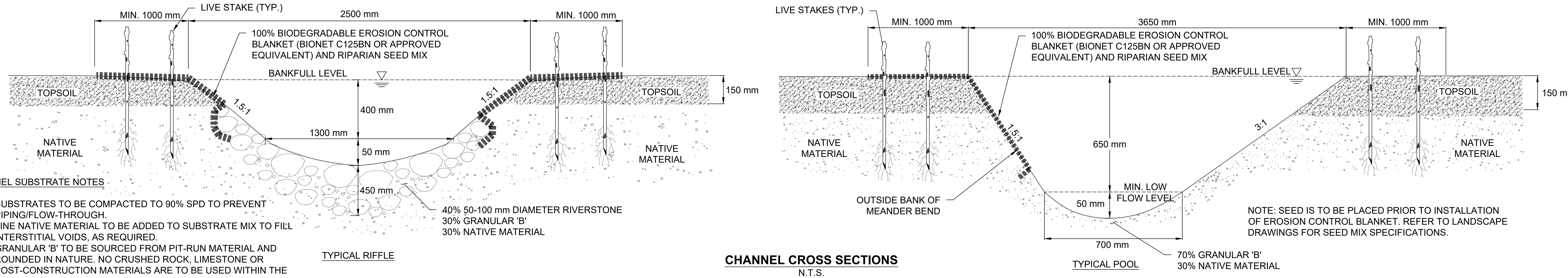
WATERCOURSE 5
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21043
DRAWING No.: GEO-3
SCALE: AS NOTED
SHEET 3 OF 5



TYPICAL RIFFLE

TYPICAL POOL

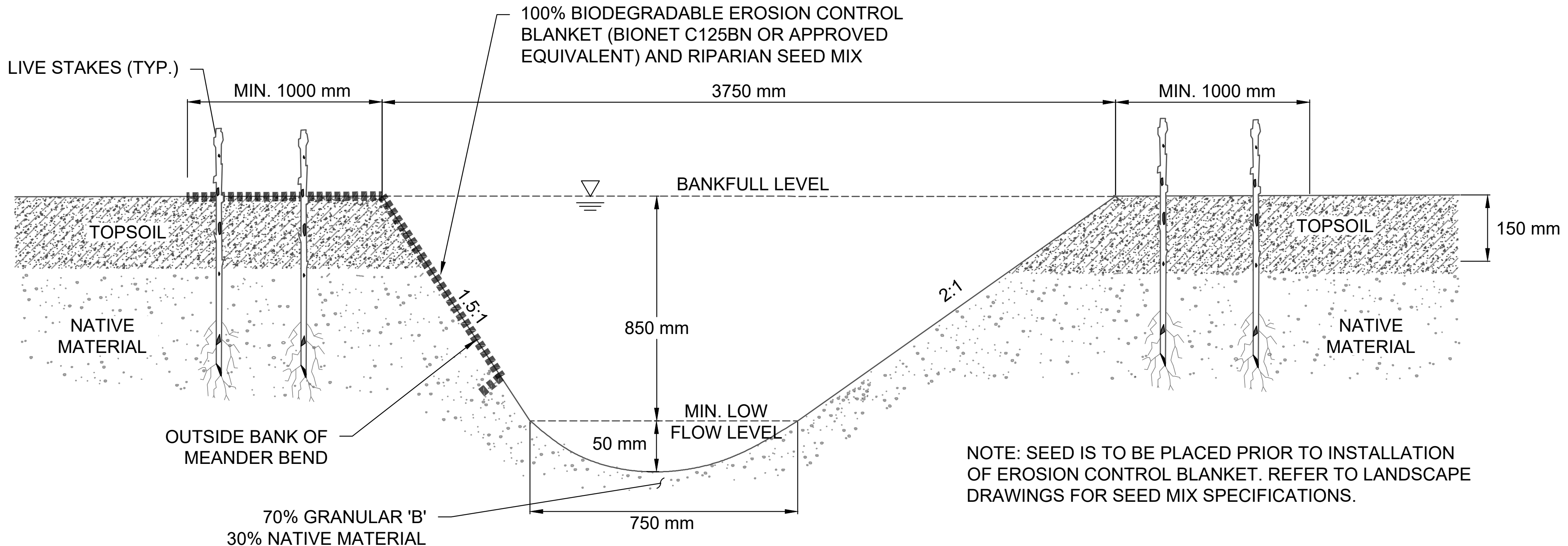
NOTE: SEED IS TO BE PLACED PRIOR TO INSTALLATION OF EROSION CONTROL BLANKET. REFER TO LANDSCAPE DRAWINGS FOR SEED MIX SPECIFICATIONS.

CHANNEL SUBSTRATE NOTES

1. SUBSTRATES TO BE COMPACTED TO 90% SPD TO PREVENT PIPING/FLOW-THROUGH.
2. FINE NATIVE MATERIAL TO BE ADDED TO SUBSTRATE MIX TO FILL INTERSTITIAL VOIDS, AS REQUIRED.
3. GRANULAR 'B' TO BE SOURCED FROM PIT-RUN MATERIAL AND ROUNDED IN NATURE. NO CRUSHED ROCK, LIMESTONE OR POST-CONSTRUCTION MATERIALS ARE TO BE USED WITHIN THE CHANNEL. MATERIAL TO BE REVIEWED BY THE DESIGNER OR REPRESENTATIVE PRIOR TO INSTALLATION.

CHANNEL CROSS SECTIONS

N.T.S.



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OVERWINTER POOL TYPICAL SECTION

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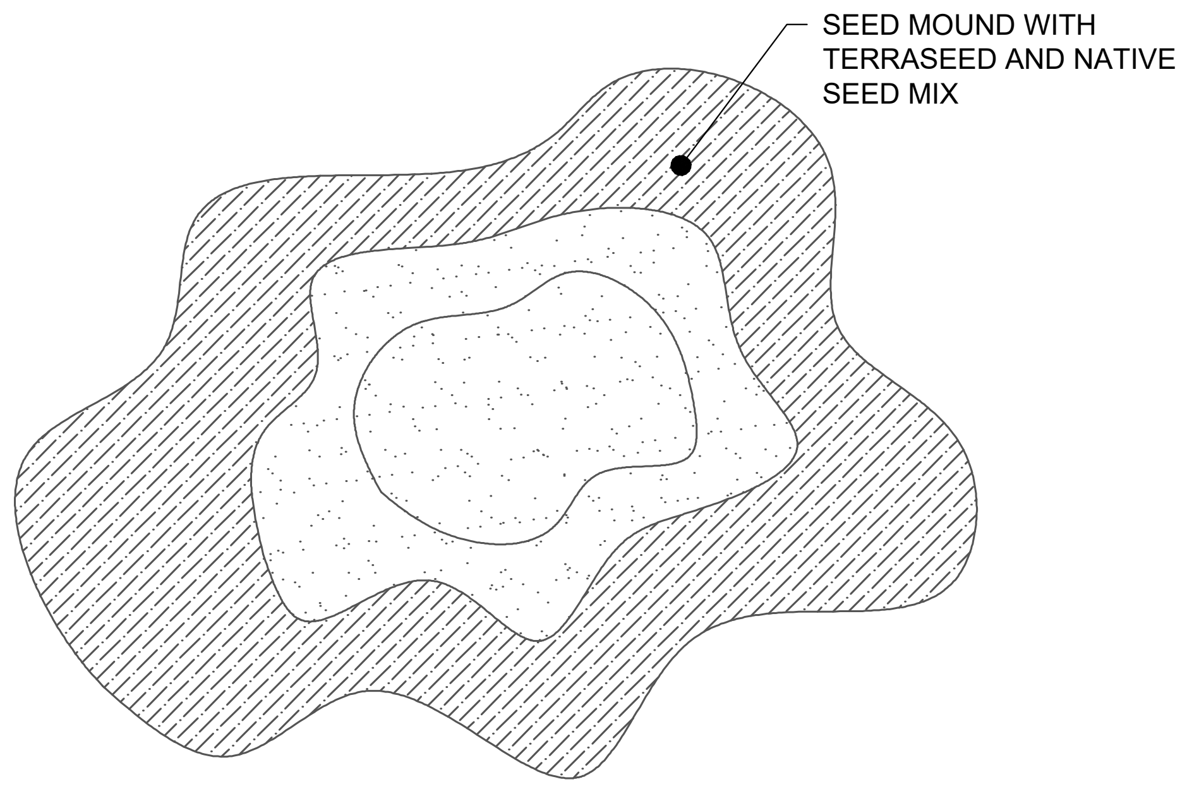
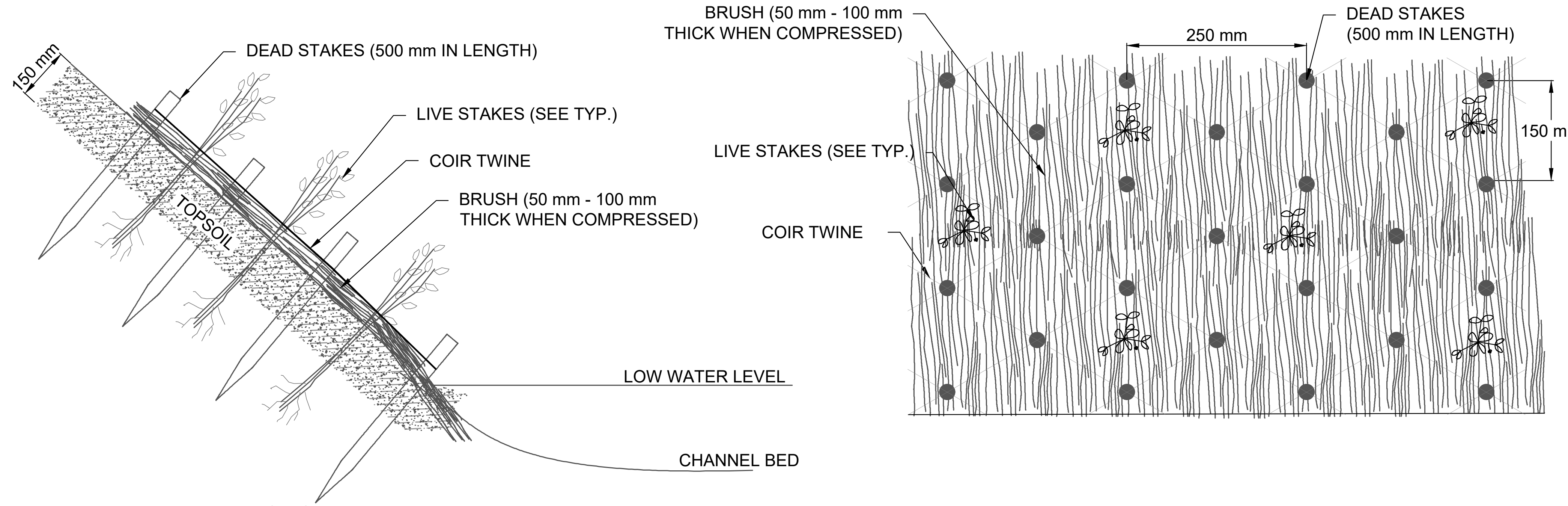


NOTES
1. HEIGHT OF TERRESTRIAL MOUND SHALL BE 1000 mm TO 2000 mm.
2. PLACEMENT OF VEGETATED TERRESTRIAL MOUND TO BE AS PER PLAN, IN DRY AREAS ONLY.
3. CONSTRUCTION OF MOUND TO BE COMPLETED IN CONJUNCTION WITH SITE GRADING ACTIVITIES AS TERRESTRIAL MOUNDS TO BE GRADED TO MATCH EXISTING GROUND AND/OR TIE INTO EXISTING SLOPES.
4. TERRESTRIAL MOUND TO BE SLIGHTLY CONCAVE/DIMPLED ON TOP.
5. SEED MIX TO BE COMPRISED OF RIPARIAN / UPLAND SPECIES AS PER PLANTING PLAN.

TERRESTRIAL MOUND

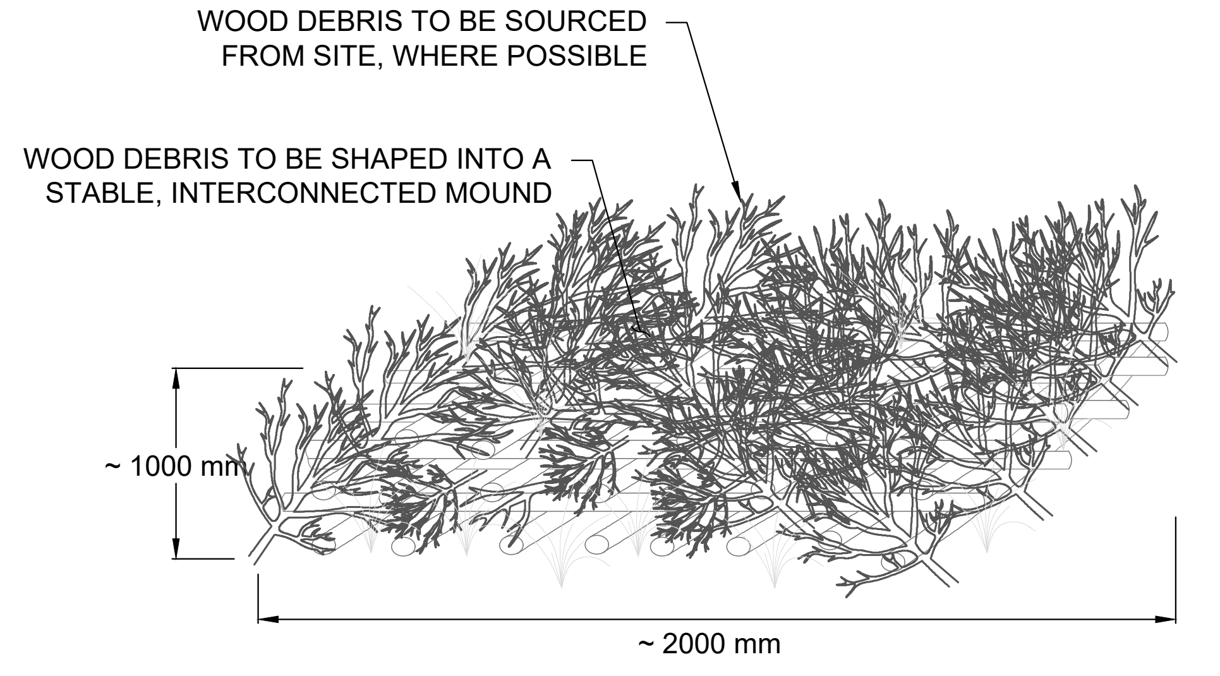
N.T.S



NOTES
1. LIVE BRANCHES TO CONSIST OF WILLOW AND DOGWOOD SPECIES, APPROXIMATELY 1 m IN LENGTH AND 50 mm - 100 mm IN WIDTH.
2. SOURCE MATERIAL FOR BRUSH MATTRESS SHOULD BE CONFIRMED BY THE DESIGNER OR REPRESENTATIVE.
3. BRANCHES TO BE KEPT IN MOIST AND COLD UNTIL INSTALLATION.
4. BRUSH MATTRESS TO BE INSTALLED WHILE BRANCHES ARE DORMANT.
5. BRANCHES TO BE PLACED ON SLOPE WITH BUTT END TOWARDS VALLEY FLOOR AND PUSHED INTO SOIL.
6. BRANCHES MUST BE FLEXIBLE ENOUGH TO CONFORM TO THE SLOPE SURFACE IRREGULARITIES.
7. POUND DEAD STAKES TO HALF THEIR LENGTH INTO SOIL BETWEEN BRANCHES. TIE COIR TWINE AROUND DEAD STAKES AND TIGHTLY OVER BRANCHES. USE A CLOVE HITCH TO SECURE STAKES. POUND STAKES INTO SLOPE TO COMPRESS BRANCHES AGAINST GROUND.
8. TAMP LIVE STAKES BETWEEN DEAD STAKES.
9. FILL VOIDS BETWEEN BRANCHES OF THE BRUSH MATTRESS WITH SOIL TO PROMOTE ROOTING.

BRUSH MATTRESS

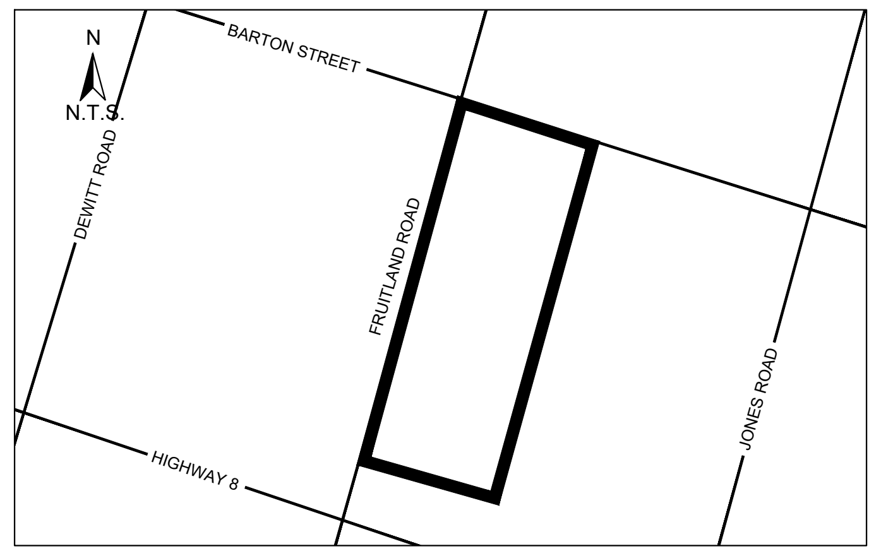
N.T.S.



NOTES
1. LARGEST AND HEAVIEST LOG MATERIAL SHOULD BE PLACED ON THE BASE OF THE BRUSH PILE. THE SMALLEST BRUSH MATERIAL SHOULD BE PLACED AT THE TOP.
2. LOGS SHOULD BE FORMED INTO A PALLET SHAPE.
3. HEIGHT OF BRUSH PILE IS NOT TO EXCEED 1.0 M.
4. A MIX OF HARDWOOD AND SOFTWOOD SHOULD BE USED.
5. PLANT WITH NATIVE FRUIT BEARING VINES.

PALLET TYPE WOOD PILE

N.T.S



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1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. FOLLOWING INSTALLATION OF THE PROPOSED ESC MEASURES, A QUALIFIED AGENT OF THE PROPONENT (E.G. CAN-CISEC CERTIFIED MONITOR) WILL CONDUCT REGULAR SITE VISITS TO MONITOR ALL WORKS, PARTICULARLY THE CONDITION OF THE ESC MEASURES, DEWATERING, AND IN- OR NEAR-WATER WORKS. SHOULD CONCERNS ARISE; THE ENVIRONMENTAL MONITOR WILL CONTACT THE PROPONENT, THE CONSERVATION AUTHORITY, AND ANY OTHER APPROPRIATE PARTIES.
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2. ENSURE EQUIPMENT AND MACHINERY ARE IN GOOD OPERATING CONDITION (POWER WASHED), FREE OF LEAKS, EXCESS OIL, AND GREASE.
3. NO EQUIPMENT REFUELLING OR SERVICING SHOULD BE UNDERTAKEN WITHIN 30 m OF ANY WATERCOURSE OR SURFACE WATER DRAINAGE.
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WORK AREA ISOLATION

1. ALL WORK IN ISOLATED WORK AREAS MUST BE COMPLETED IN THE DRY. AN ADEQUATE NUMBER OF PUMPS MUST BE USED FOR UNWATERING.
2. CROSSING AN ACTIVE WATERCOURSE OR WETLAND BY EQUIPMENT, VEHICLES, PERSONNEL, ETC. IS NOT PERMITTED UNLESS APPROVED BY THE CONSERVATION AUTHORITY. ALL ACCESS TO WORK SITES SHALL BE FROM EITHER SIDES OF THE WATERCOURSE OR WETLAND.
3. THE UNWATERING DISCHARGE LOCATION MUST BE LOCATED AT LEAST 30 M FROM ANY WATERCOURSE OR WETLAND IN AN AREA WITH DENSE VEGETATIVE GROUNDCOVER, AND WHERE THE DISCHARGE CAN RETURN TO THE WATERBODY DOWNSTREAM OF THE WORK AREA OVER THE GROUNDCOVER.
4. FISH MUST BE REMOVED FROM THE WORK AREA ONCE ISOLATED. FISH SALVAGE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.

1.	24/03/15	LD	FIRST CONCEPTUAL DESIGN SUBMISSION
	DATE	BY	REVISIONS

DESIGNED BY: LD
CHECKED BY: PV
DRAWN BY: AS / SG
DATE: APRIL 2024

NOT FOR CONSTRUCTION
SCALED FOR PLOT ON 'ARCH D'

24/03/15

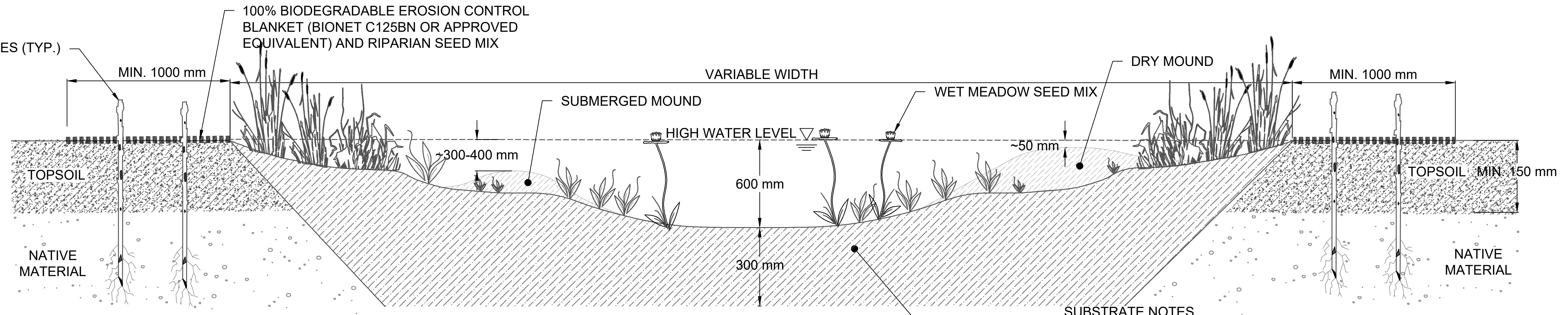
GEO
MORPHIX™
36 Main St N., P.O. Box 205
Campbellville, Ontario L0P 1B0

T: 416.920.0926
www.geomorphix.com

BLOCK 1 BSS
FRUITLAND-WINONA BLOCK 1 OWNERS GROUP, HAMILTON

WATERCOURSE 5
CONCEPTUAL CHANNEL DESIGN
DETAILS

PROJECT No.: 21043
DRAWING No.: DET-1
SCALE: AS NOTED
SHEET 4 OF 5



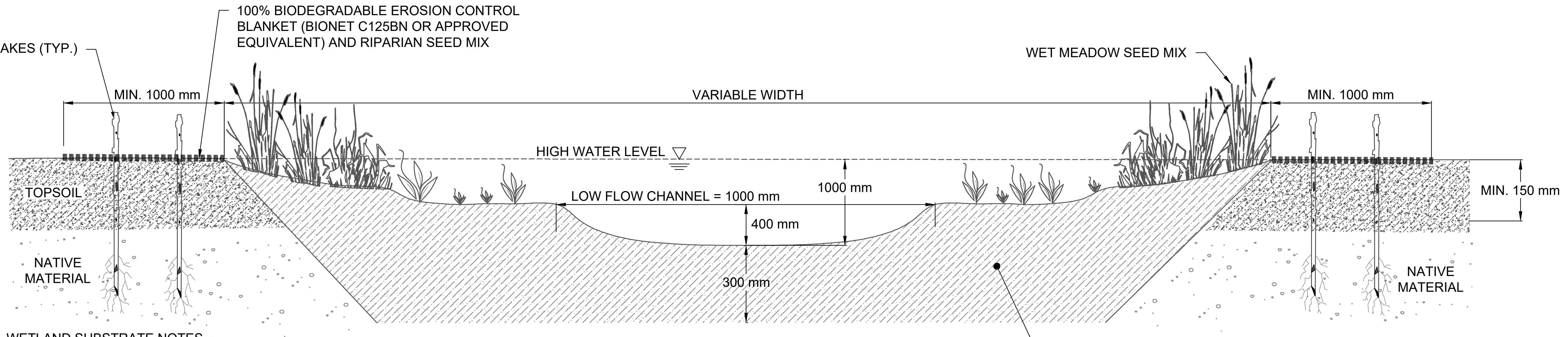
NOTE: SEED IS TO BE PLACED PRIOR TO INSTALLATION OF EROSION CONTROL BLANKET. REFER TO LANDSCAPE DRAWINGS FOR SEED MIX SPECIFICATIONS.

WETLAND CROSS SECTION

N.T.S.

SUBSTRATE NOTES

1. SUBSTRATES TO BE COMPACTED TO 90% SPD TO PREVENT PIPING/FLOW-THROUGH.
2. FINE NATIVE MATERIAL TO BE ADDED TO SUBSTRATE MIX TO FILL INTERSTITIAL VOIDS, AS REQUIRED.
3. GRANULAR 'B' TO BE SOURCED FROM PIT-RUN MATERIAL AND ROUNDED IN NATURE. NO CRUSHED ROCK, LIMESTONE OR POST-CONSTRUCTION MATERIALS ARE TO BE USED WITHIN THE CHANNEL. MATERIAL TO BE REVIEWED BY THE DESIGNER OR REPRESENTATIVE PRIOR TO INSTALLATION.



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ONLINE WETLAND CROSS SECTION

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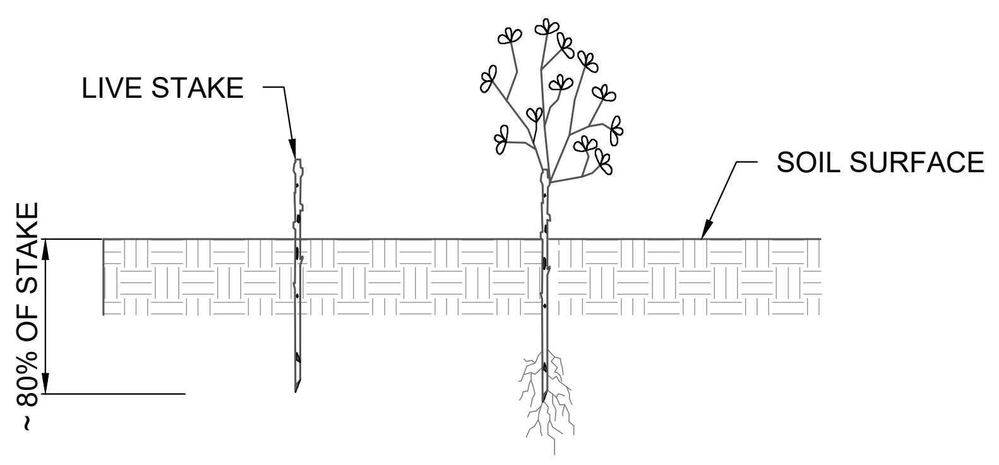


SPECIES AND QUANTITIES

COMMON NAME	SCIENTIFIC NAME	SIZE
RED OSIER DOGWOOD	*Cornus stolonifera*	1 m
PUSSY WILLOW	*Salix discolor*	1 m
SANDBAR WILLOW	*Salix exigua*	1 m

NOTES

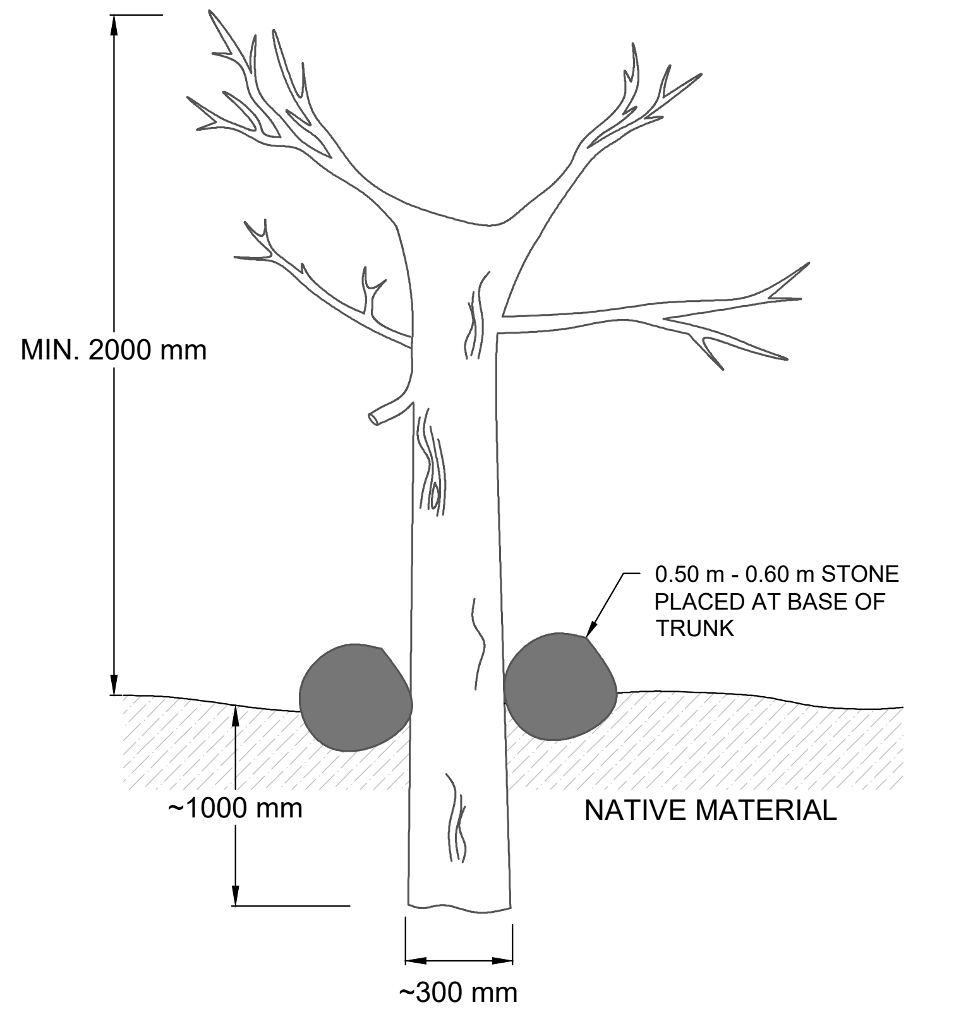
1. QUANTITY TO BE DETERMINED BASED ON AREA OF DISTURBANCE TO BE RESTORED
2. LIVE STAKES SHOULD BE FROM AT MINIMUM 2-YEAR OLD STOCK.
3. LIVE STAKES ARE TO BE INSTALLED AT A DENSITY OF 3 STAKES PER SQUARE METRE.
4. LIVE STAKES SHOULD BE PRE-SOAKED (SUBMERGED IN WATER) FOR AT LEAST 24 HOURS AFTER HARVESTING AND IMMEDIATELY BEFORE INSTALLATION.
5. LIVE STAKES SHOULD NOT BE STORED FOR A PERIOD LONGER THAN 2 DAYS, UNLESS THEY ARE BEING SOAKED.
6. THE CONTRACTOR SHALL PROTECT PLANT MATERIALS FROM DRYING FROM THE TIME OF HARVEST UNTIL INSTALLED.
7. LIVE STAKES ARE TO BE A MINIMUM OF 25 mm IN DIAMETER AND CUT TO A LENGTH OF 1000 mm.
8. CUT ANGLE AT THE BOTTOM OF THE STAKE AND FLAT ON THE TOP.
9. TRIM ALL SIDE BRANCHES WHILE TAKING CARE NOT TO DAMAGE THE BARK.
10. INSTALL STAKES WITH BUDS POINTING UPWARDS AND THICKER STEM IN THE BED.
11. LIVE STAKES SHOULD BE INSTALLED USING A LARGE RUBBER MALLET.
12. 80% OF THE STAKE IS TO BE BELOW SURFACE.
13. TAMP THE LIVE STAKE INTO THE GROUND AT RIGHT ANGLE TO THE SURFACE.
14. IN COMPACT SOIL A PILOT HOLE SHOULD BE USED TO LIMIT DAMAGE TO THE STAKES.
15. IF USING A PILOT HOLE REPACK SOIL AROUND THE LIVE STAKE.
16. LIVE STAKES SHOULD STAND FIRM FROM THE SOIL FOLLOWING INSTALLATION.
17. ALL STAKES NOT PLANTED TO THE SPECIFICATIONS ABOVE WILL BE REPLACED AT THE CONTRACTOR'S EXPENSE.

LIVE STAKE

N.T.S.

EROSION CONTROL BLANKET SPECIFICATIONS

1. A BIODEGRADABLE EROSION CONTROL BLANKET (ECB) SHALL BE INSTALLED ON ALL DISTURBED NATURAL SURFACES FOLLOWING THE PLACEMENT OF TOPSOIL AND APPLICATION OF THE NATIVE SEED MIX.
2. THE ECB MUST BE CONSTRUCTED OF 100% WOVEN COCONUT FIBRE (E.G., COIR) OR STRAW MAT WITHIN A GEOJUTE NETTING (TOP AND BOTTOM) WITH BIODEGRADABLE THREAD. NON-BIODEGRADABLE MATERIAL INCLUDING POLYPROPELENE OR PLASTICS WITH A BIODEGRADABLE RATING ARE NOT ACCEPTABLE. THE MINIMUM WEIGHT OF THE ECB MUST BE 400 g/m^2 (12 oz./yd^2).
3. TO INSTALL, THE ECB MUST BE UNROLLED DOWNSLOPE OR IN DIRECTION OF WATER FLOW. ADJACENT ECBS SHOULD OVERLAP A MINIMUM OF 150 mm ALONG THE EDGES. AT THE END OF EACH ROLL, FOLD BACK 100 mm TO 200 mm OF THE ECB. OVERLAP THIS 100 mm TO 200 mm OVER THE START OF THE NEXT ROLL. SECURE THE TWO LAYERS TO THE GROUND SECURELY.
4. BIODEGRADABLE OR TAPERED WOODEN STAKES SHALL BE USED TO SECURE THE BLANKET. STAKES SHALL BE INSTALLED AT THE SPACING RECOMMENDED BY THE ECB MANUFACTURER TO PREVENT SURFACE RUNOFF FROM ERODING THE UNDERLYING SOIL.

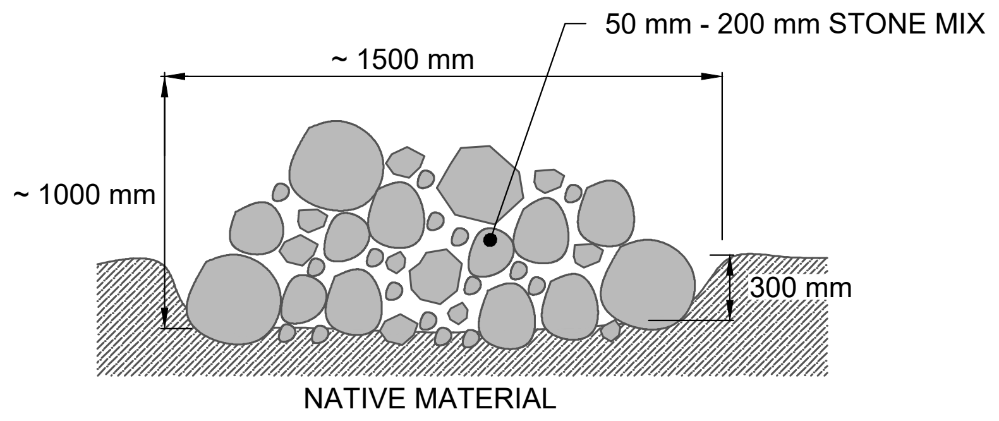


NOTES

1. CONSTRUCT WITH CONIFER TRUNKS WITH TWO OR MORE NATURAL BRANCHES.
2. AT LEAST 75% OF THE BARK SHOULD BE INTACT.
3. AUGER HOLE TO A DEPTH OF ~1.0 m INSTALL TRUNK AND TAMP IN SAND AROUND BASE.
4. ~1.0 m OF TRUNK IS TO BE BURIED.
5. PLACE 0.50 m - 0.60 m STONE AROUND BASE FOR ADDITIONAL SUPPORT.
6. IF ROOT WAD IS USED PLACE ROOT AT TOP.
7. LOGS SHOULD BE SOURCED ON SITE (WHERE POSSIBLE).
8. AT LEAST 4 RAPTOR POLES ARE TO BE 5 m IN HEIGHT.

RAPTOR POLE

N.T.S.

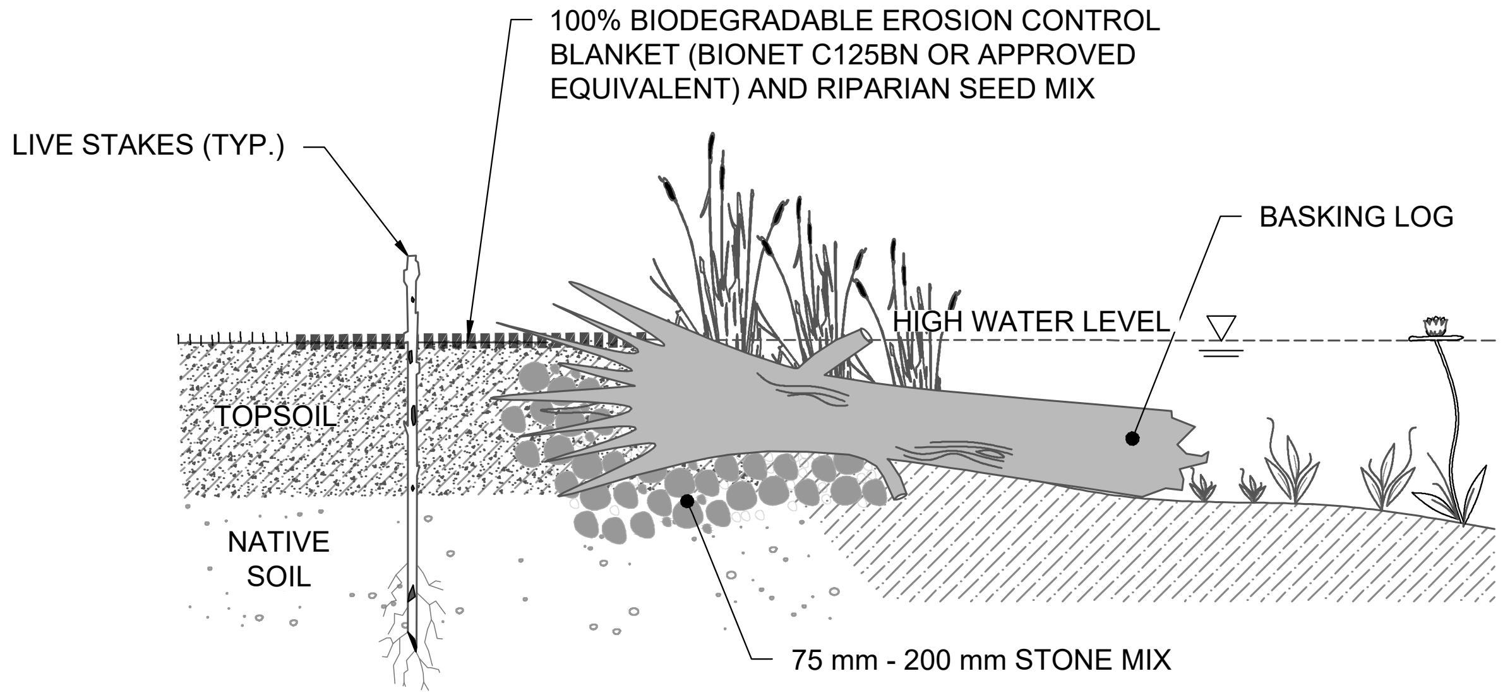


NOTES

1. 50 mm - 200 mm STONE MIX WITH SOME ANGULAR STONES.
2. THE STONE MIX SHOULD PROVIDE A VARIETY OF INTERSTITIAL SPACES.
3. PILES ARE AT LEAST 1500 mm IN DIAMETER AND ~1000 mm HIGH.
4. PARTIALLY BURY PILES 300 - 400 mm TO AVOID ROCKFALL.

ROCK PILE

N.T.S



NOTES

1. ANCHOR AND SUPPORT BASKING LOGS WITH 75 mm - 200 mm STONE MIX.
2. FIRMLY COMPACT STONE MIX TO PREVENT THROUGH FLOW.
3. BURY 1/3 OF LOG INTO SOIL.
4. LENGTH OF BASKING LOGS ARE TO BE INSTALLED 1000 - 1500 mm INTO WET AREA.
5. BASKING LOGS TO BE A MINIMUM 500 mm IN DIAMETER AND 2000 - 2500 mm IN LENGTH.
6. BASKING LOGS SHOULD BE ANGLED TO PROMOTE TURTLE BASKING.
7. BASKING LOGS SHOULD BE A MIXTURE OF SUITABLE HARDWOOD AND SOFTWOOD SPECIES.
8. BASKING LOGS SHOULD BE DOUBLED UP IN SPECIFIED LOCATIONS

BASKING LOG

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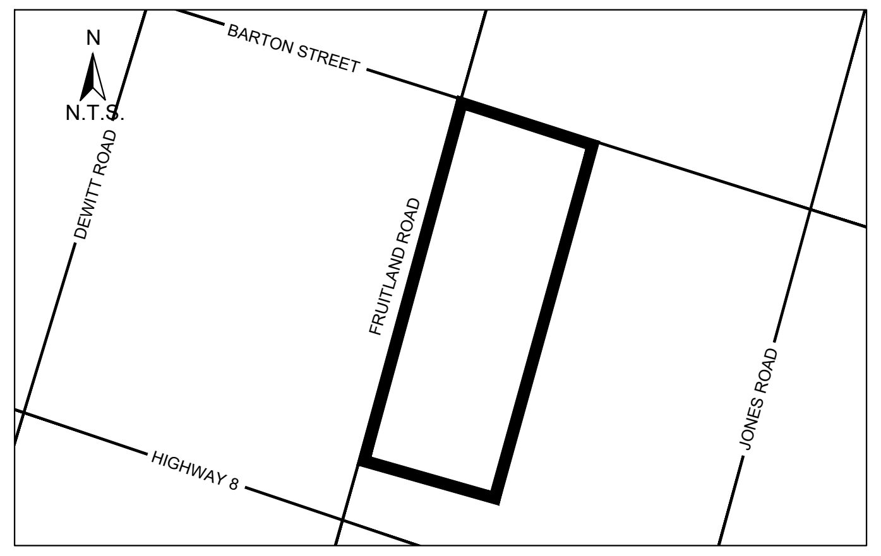

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WORK AREA ISOLATION

1. ALL WORK IN ISOLATED WORK AREAS MUST BE COMPLETED IN THE DRY. AN ADEQUATE NUMBER OF PUMPS MUST BE USED FOR UNWATERING.
2. CROSSING AN ACTIVE WATERCOURSE OR WETLAND BY EQUIPMENT, VEHICLES, PERSONNEL, ETC. IS NOT PERMITTED UNLESS APPROVED BY THE CONSERVATION AUTHORITY. ALL ACCESS TO WORK SITES SHALL BE FROM EITHER SIDES OF THE WATERCOURSE OR WETLAND.
3. THE UNWATERING DISCHARGE LOCATION MUST BE LOCATED AT LEAST 30 M FROM ANY WATERCOURSE OR WETLAND IN AN AREA WITH DENSE VEGETATIVE GROUNDCOVER, AND WHERE THE DISCHARGE CAN RETURN TO THE WATERBODY DOWNSTREAM OF THE WORK AREA OVER THE GROUNDCOVER.
4. FISH MUST BE REMOVED FROM THE WORK AREA ONCE ISOLATED. FISH SALVAGE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.

1.	24/03/15	LD	FIRST CONCEPTUAL DESIGN SUBMISSION
	DATE	BY	REVISIONS

DESIGNED BY: LD
CHECKED BY: PV
DRAWN BY: AS / SG
DATE: APRIL 2024

NOT FOR CONSTRUCTION
SCALED FOR PLOT ON 'ARCH D'

24/03/15

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FRUITLAND-WINONA BLOCK 1 OWNERS GROUP, HAMILTON

WATERCOURSE 5
CONCEPTUAL CHANNEL DESIGN DETAILS

PROJECT No.: 21043
DRAWING No.: DET-2
SCALE: AS NOTED
SHEET 5 OF 5