APPENDIX C

Fluvial Geomorphology

C1: Fluvial Geomorphological Assessment and Natural Channel Design

C2: 2021 Water Quantity and Quality Monitoring

Appendix C1

Fluvial Geomorphological Assessment and Natural Channel Design

North Milton Business Park
Town of Milton, Ontario

Fluvial Geomorphological Assessment and Natural Channel Design

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1 Introduction

This report provides a summary of the fluvial geomorphological assessment completed for the North Milton Business Park area ("Study Area") in the Town of Milton, Ontario. As part of the development plan on site, a channel realignment and several conveyance swales have been proposed. As such, the geomorphological assessment was used to inform stormwater and servicing requirements on site, as well as the classification and management of existing watercourse features. A large portion of the Study Area was accessible to our study team, including all lands owned by Orlando Corporation ("Orlando Lands"); however, access was not available for several land parcels that are not currently participating in the development process. Features on the inaccessible, non-participating lands were only examined at a desktop level.

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

- Background review of existing documents related to the development lands, including topography, physiography, and geology maps of the study area
- Reach delineation for all watercourses and headwater drainage features (HDF) on Orlando property
- Historical assessment of changes in channel adjustment and human modification using historical aerial photographs
- Site reconnaissance, including rapid geomorphological or headwater drainage feature assessments for reaches identified on Orlando property
- Detailed geomorphological assessments to inform the proposed natural channel design on site and determine a local erosion threshold in support of the SWM erosion mitigation strategy
- Review of downstream watercourses to support erosion mitigation approach for proposed stormwater management on site
- Development of conceptual channel designs, including planform, profile, cross-sections and associated details

2 Background Review and Desktop Assessment

2.1 Existing Site Conditions

The Study Area is part of the larger Sixteen Mile Creek watershed and predominantly drains to a section of the Upper Middle Branch of Sixteen Mile Creek (MSMC). A section of the Upper Middle Branch briefly overlaps the northeastern corner of the Study Area along Esquesing Line. Several tributaries of the Upper Middle Branch also cross the site. Tributary/Reach **R3S1** bisects the entire site, originating near Boston Church Road and 5th Sideroad and discharging flows at Esquesing Line, approximately 600 m north of James Snow Parkway. Tributary R1/R2 flows from an existing woodlot east of Boston Church Road and joins with additional drainage from onsite agricultural fields to flow south and cross James Snow Parkway. The third tributary on the property (R5) drains south from 5th Side Road to James Snow Parkway west of Boston Church Road. All drainage features in the Study Area are graphically displayed in **Appendix A**.

According to the Ontario Geologic Survey (OGS, 2003), the Study Area is located on the Peel Plain physiographic region and contains surficial deposits of fine-textured till derived from glaciolacustrine deposits, containing predominantly clay and silt. Based on a review of recent aerial photographs (Google Earth Pro) the land is actively used for agricultural activities. Forest cover is limited to the northeastern corner of the site containing the Middle Branch of Sixteen Mile Creek.

The local topography is generally flat. Several straight drainage pathways or ditches are evident in recent aerial photographs, suggesting recent anthropogenic modifications in support of agricultural activities. Given the agricultural activity on site and the low-grade topography, several headwater drainage features have formed. These features are also mapped in **Appendix A**.

Realignment or modifications have been proposed for each tributary to support development plans for the site. For example, a channel realignment based on natural channel design principles has been proposed for Tributary/Reach **R3S1**. Several headwater channels have been proposed for removal, but instead, we have proposed to retain these features as conveyance swales. The proposed watercourse management plan is further outlined in **Section 5**.

2.2 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channels and surrounding land use and land cover over time. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics.

Aerial photographs and satellite images from 1946 to 2017 were reviewed as part of the historical assessment. Specifically, aerial photographs from 1946, 1969, 1974, 1985, 2004, and 2017 were reviewed and are provided in **Appendix B**, for reference.

In 1946, land use was dominated by agricultural practices, with a patch of forested area directly north of the property. The Middle Branch of Sixteen Mile Creek flows within the forested area and across the northern corner of the Study Area in a southeast direction. Headwater drainage features were observed across several agricultural fields and are intermittently visible on subsequent aerial photographs following 1946.

In 1969, two major land use changes were observed. On the Orlando land parcel west of Boston Church Road, an oval-shaped racetrack had been constructed. Also, Highway 401 had been constructed to the south. Between 1969 and 1985, land use remained consistent (i.e., agricultural) and there were no observable differences associated with watercourses and drainage features on site.

In 2004, areas north of Highway 401 and south of the Study Area were being developed into an industrial complex. By 2017, areas to the south and west of the subject property were fully developed for industrial uses. However, both the watercourses and land use remained unchanged within the Study Area.

2.3 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. 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 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

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. This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others.

Preliminary reach delineation resulted in two defined reaches on the Orlando properties: a section of the Upper Middle Branch of Sixteen Mile Creek (Reach **SM1**) and the downstream section of the Sixteen Mile Creek tributary that bisects the site (Reach **R3S1**). The two reaches were defined using existing watercourse linework available through the MNRF Ontario Base Mapping. The reaches were also defined based on land use, riparian cover, and defined drainage patterns visible in recent aerial photographs. The two main reaches were also field verified during the site assessment outlined in **Section 3**.

Reach **SM1** is a main section of Upper Middle Sixteen Mile Creek. Reach **R3S1** is a poorly defined tributary that crosses an agricultural field. Additional reaches classified as headwater drainage features were also identified during site reconnaissance on the Orland lands. Defining smaller headwater drainage features through desktop assessment can be difficult given their annual variation in exact location or extent. As such, the location and extent of all headwater drainage features required confirmation during site observation. A reach map showing the main **SM1** and **R3S1** watercourses and various headwater drainage features is provided in **Appendix A**.

Downstream of the Orlando properties, an additional reach along the Sixteen Mile Creek tributary was delineated as Reach **R3S0**. **R3S0** was subdivided into 3 sub-reaches: Reaches **R3S0A**, **R3S0B**, and **R3S0C**. Reach **R3S0A** receives flows from **R3S1** through a culvert crossing beneath Esquesing Line. The channel flows straight and southeast through agricultural fields, eventually reaching James Snow Parkway, which defines the break with sub-reach **R3S0B**. **R3S0B** is a meandering, realigned section of **R3S0** that was constructed between 2009 and 2013 as part of the James Snow Parkway development. Reach **R3S0C** extends from the terminus of the realigned section (**R3S0B**) to the bridge crossing at 5th Line. The channel here flows though a grassy valley and exhibits small, frequent meanders. Due to property access constraints, field confirmation for **R3S0** was limited to the sub-reach **R3S0C** and right of way observations at Esquesing Line.

It should be noted that additional stream reaches were observed on non-participating properties in the Study Area. These features were either documented in the MNRF Ontario Base Mapping product or observed in recent aerial photographs. Given that access was not permitted to these sites, field confirmation could not be completed.

3 Field Assessment

Several field assessments were completed to characterize all main watercourses and headwater drainage features on Orlando properties. Photographs of site conditions are provided under **Appendix C** and field observations are provided in **Appendix D**.

3.1 Headwater Drainage Feature Assessment

Headwater Drainage Feature Assessments (HDFA) were completed within the Orlando properties in conjunction with Savanta Inc. staff. HDFAs were completed in accordance with the *Ontario Stream Assessment Protocol* (OSAP) (TRCA, 2017) and the Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation's (CVC) *Evaluation, Classification, and Management of Headwater Drainage Features Guidelines* (2014). This approach includes three (3) separate site visits to assess the aquatic, hydrologic, and geomorphic attributes of each headwater drainage reach.

In accordance with OSAP and TRCA/CVC's Guidelines, the first HDFA site visit was completed over the days of April 13 and 27, 2018 during spring freshet conditions. The second site visit was completed on May 30, 2018 following a period of 48 consecutive hours without rainfall. The third and final site visit was completed on August 15, 2018 following a period of 72 consecutive hours without rainfall. The information and observations collected during the HDF assessment were used to inform management approaches for each feature. The management classification exercise was completed by Savanta Inc.

This information is provided under Savanta's Environment Impact Study report. A general summary of headwater drainage features is provided below.

Numerous headwater drainage features were identified on Orlando properties within the Study Area. Nearly half of the headwater drainage features were only documented during the first HDFA site visit. From a management perspective these features had limited hydrological, ecological, or geomorphological function. These features were classified as *No Management Required*.

Several headwater drainage features were identified as having contributing functions with regards to hydrology resulting in a management classification of *Mitigation*. Mitigation features can be eliminated on the landscape, but their existing functions should be replicated through stormwater management. This may be in the form of conveyance swales, online wet vegetation pockets, or replication through constructed wetland features.

One headwater drainage feature was shown to have valued hydrology and habitat function and was therefore classified as *Conservation*. *Conservation* features must be maintained on the landscape through relocation or enhancement in-situ. This included **R1S2**, which is in a protected woodlot at the northern extent of the Orlando property east of Boston Church Road. This feature has been proposed to remain in-situ.

3.2 Rapid Geomorphological Assessment

A rapid geomorphological assessment was completed for main watercourses on Orlando lands. Given the extent of headwater drainage features on site, the rapid geomorphological assessment was limited to reach **SM1** and **R3S1** within the Orlando lands. An additional rapid assessment was completed for reach **R3S0C**, downstream of **R3S1** and the Orlando lands. A rapid geomorphological assessment was completed following standard field protocols:

- Characterization of stream form, process, and evolution using the Rapid Geomorphological Assessment (RGA) (MOE, 2003; VANR, 2007)
- Assessment of the ecological function of the watercourse using the Rapid Stream Assessment Technique (RSAT) (Galli, 1996)
- Instream estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation

The Rapid Geomorphic Assessment (RGA) tool evaluates degradation, aggradation, widening, and planimetric form adjustment at the reach scale (MOE, 2003; VANR, 2007). Systematic adjustments typically result in changes to the floodplain, channel condition or valley characteristics. The RGA produces a score, or stability index, which evaluates the degree to which a stream has departed from the equilibrium condition. Reach **SM1** had a score of 0.32, identified as *in transition* meaning the channel is undergoing changes in process and form outside of the channel's natural variability. The dominant process of change was identified as aggradation, supported by observations of siltation in pools, accretion on point bars, and coarse riffle materials embedded in finer sands and silts. Reach **R3S1** had a significantly low score of 0.04, identified as *in regime* meaning the channel is stable in its current state. No dominant process of change was identified. Given the limited variability in morphology along the reach, many components of the RGA were not present. Reach **R3S0C** yielded an RGA score of 0.22, placing it near the lower bound of the '*in transition'* category. The dominant process was identified as planimetric adjustment, evidenced by the formation of chutes, frequent undercutting, and formation of small islands within the channel.

The Rapid Stream Assessment Tool (RSAT) evaluates stream health, based on an inclusion of biological indicators. This technique relies on a scale ranging from 'poor' to 'excellent' for observations concerning channel stability, channel scouring/sediment deposition, physical instream habitat, water quality, and riparian habitat conditions, to provide a qualitative assessment of stream health (Galli, 1996). Reach **SM1** had a score of 21 identified as *Fair* stream health, with the only limiting factor being evident of increase sediment deposition. **R3S1** and **R3S0C** had scores of 17 and 24, respectively, both also identified as *Fair*. The limiting factors for both were largely associated with a lack of quality instream and riparian habitat conditions. A portion of the RSAT was also difficult to complete given that the channel was dry and ephemeral in nature. This influences the degree of available instream habitat.

Reach **SM1** flows in a southeastern direction across the northern corner of the property. Reach **SM1** is a mixed-load meandering channel, with a low gradient that sits within a wide valley system. The channel flows through an established and continuous riparian buffer zone that extends greater than 10 times the channel width and contains predominately grasses and deciduous trees. The average bankfull width and depth were 7.9 m and 0.83 m, respectively. The average wetted width and depth were 6.1 m and 0.49 m, respectively. Bank angles ranged from 30 to 60 degrees. Bank materials consisted of clay and silt. Bed materials in pools ranged from sand to cobble, while bed materials in riffles ranged from sand to boulder. A high density of woody debris was also observed in the channel. General channel characteristics are summarized below in **Table 1**.

Reach **R3S1** flows in a southeastern direction across the large central parcel from a woodlot at the top end and down to the Esquesing Line. The channel is relatively straight with a low gradient that sits within an unconfined valley setting. The channel flows through an established agricultural field with heavily fragmented riparian grasses. Along most of the reach, cropland extends to the edge of the channel. The average bankfull width and depth were 3.7 m and 0.19 m, respectively. It should be noted that the feature has been historically channelized. As such, bankfull dimensions are likely an overestimate of the natural low-flow channel size. In some locations, there appears to be a smaller, nested channel within the larger feature. Water was not present in the channel on the day. Bank materials consisted of clay and silt. Channel substrate was mostly uniform and contains silt, clay, sand, and pockets of small gravels. General channel characteristics are summarized below in **Table 1**.

Reach **R3S0C** flows eastwards through a grassy valley corridor. The reach is best described as a low-gradient, meandering, suspended-load dominated channel. Riparian conditions are characterized by grasses with patches of mature trees on the northern banks. The average bankfull width and depth are 1.75 m and 0.27 m, respectively. The bank materials throughout the reach are a cohesive silty-clay, and bed materials range from compact, cohesive silty-clay to small gravel. Bank angles are generally near-vertical, and undercutting is common throughout the reach. Flow was absent during the time of assessment. General channel characteristics are summarized below in **Table 1**.

Table 1: General channel characteristics for reach SM1 and R3S1

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Riffle	Pool		
SM1	7.9	0.8	Sand to boulder	Sand to cobble Coarse materials embedded	Continuous, wide, trees and grasses	Meandering, undercutting at outer banks, deposition at inner banks.
R3S1	3.7	0.19	Uniform substrate throughout; predominantly silt/clay/sand; some small gravels		Fragmented grasses; crops up to end of channel in several areas	Straight channel, limited erosion, heavy vegetation encroachment; evidence of historical channelization; lack of geomorphic units
R3S0C	1.75	0.46	Uniform substrate throughout; predominantly clay; some small gravels		Continuous, wide, grasses and occasional trees	Fairly entrenched, frequent meandering, undercutting common, poorly defined geomorphic units

3.3 Detailed Assessment

To accommodate the proposed development on site, a channel realignment has been proposed for Reach **R3S1**. Reach **R3S1** has been classified as a blue watercourse feature, meaning that the feature must be maintained on the landscape but may also be considered as a candidate feature for restoration and realignment. As such, a detailed geomorphological assessment was completed in support of the proposed realignment. Downstream of the Orlando lands, an additional detailed geomorphological assessment was completed on reach **R3S0C**. This purpose of the additional assessment was to inform an erosion assessment in support of the SWM and erosion control plans associated with the development.

Obtaining detailed geomorphological measurements and observations allows for a more complete characterization of channel geometry, flow, and sediment characteristics. The data obtained are used to make well informed decisions with regards to channel characteristics applied in natural channel design in the interest of maintaining or improving channel conditions with regards to stability and fluvial function. The assessment completed for reach **R3S1** supports both channel realignment and erosion sensitivity analysis. The assessment completed for reach **R3S0C** supports the erosion threshold and exceedance analyses.

The detailed geomorphological assessment for **R3S1** was completed on August 21, 2015, and included a substantial portion of the reach. It should be noted that the site was visited again July 2021 to verify that conditions had not changed. The detailed geomorphological assessment for **R3S0C** was completed on August 25, 2021. The results of the detailed assessments are provided in **Table 2**, and a summary is included in **Appendix D**. The following activities were completed as part of the detailed assessment:

- Longitudinal profile along the channel bed to determine slope
- Eight representative cross-sectional surveys of the watercourse to determine average channel dimensions
- Detailed instream measurements at each cross-section including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density
- Bed material characterization at each cross-section following a modified Wolman's (1954) Pebble Count Technique or substrate sample

- Geo-referenced photographs taken at each cross-section

Table 2: Detailed assessment results for reach R3S1 and R3S0C

Channel Parameter	Results by Reach	
	R3S1	R3S0C
Measured		
Average bankfull channel width (m)	3.77	1.75
Average bankfull channel depth (m)	0.20	0.46
Average bankfull cross-sectional area (m^2)	0.75	0.46
Bankfull channel gradient (%)	0.47	0.67
D_{50} (mm)	<2.0	<2.0
D_{84} (mm)	16.0	18.8
Manning's n roughness coefficient	0.037	0.038
Computed		
Bankfull discharge (m^3/s) *	0.35	0.43
Average bankfull velocity (m/s)	0.47	0.90
Unit stream power at bankfull discharge (W/m^2)	4.32	16.01
Tractive force at bankfull (N/m^2)	9.22	17.78
Critical shear stress (N/m^2) **	1.46	1.46
Flow competency for D_{50} (m/s) ***	0.27	0.27
Flow competency for D_{84} (m/s) ***	0.71	0.76

* Based on Manning's equation
** Based on Shields diagram from Miller et al. (1997)
*** Based on Komar (1987)

4 Meander Belt Width Assessment

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no topographical constraints. A meander belt width assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a stream.

When defining the meander belt width for a creek system, the TRCA (2004) and Ministry of Natural Resources and Forestry (MNRF) protocol treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or slopes well-outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where a valley wall contact is possible.

Based on the field observations and a review of the historical and recent aerial images, Middle Sixteen Mile Creek (**SM1**) is situated within a densely vegetated and wide floodplain. Defined valley walls were not observed in the vicinity of the creek, which indicates that the system is unconfined and free to migrate across the floodplain. Similarly, the tributary of Sixteen Mile Creek (**R3S1**) is also situated within an unconfined valley. As such, the erosion hazard for both features can be defined by the channel's meander belt width. We understand that development activities are not proposed in the vicinity of Reach **SM1**. As such, the meander belt width assessment outlined here is provided for characterization purposes. Erosion hazards associated with the proposed realigned **R3S1** are also addressed as part of the conceptual channel design outlined in **Section 6**. An existing meander belt width for **R3S1** is outlined here for characterization purposes only.

There are several methods to estimate meander belt width for unconfined systems. Georeferenced historic and recent aerial imagery can be used to examine past positions and current configurations of the channel planform and to delineate the channel centreline, and its central tendency (i.e. meander belt axis). The meander belt width can also be estimated using empirical models such as those defined by Williams (1986) and TRCA (2004).

Overall, the historical assessment suggested limited channel migration for **SM1**, but given the dense tree cover on site, confirmation of channel planform conditions was difficult using aerial photographs. Although, two meander amplitudes were discernable north of the property near Southcott Drive in the 2016 aerial imagery (Google Earth Pro). The meander amplitudes measured for these features were 33 m and 23 m.

The historical assessment for **R3S1** was also difficult given the lack of defined channel meanders associated with the tributary. **R3S1** has also undergone significant historical modifications (i.e., straightening) due to past agricultural activities on site. Given the difficulty in defining channel extent through aerial photograph interpretation for both features, the Williams (1986) and TRCA (2004) models were also applied to estimate the meander belt width.

The Williams (1986) was modified to include channel width, and applied using field measured bankfull channel dimensions such that:

$$B_w = 4.3W_b^{1.12} + W_b \quad \text{[Eq. 1.]}$$

Where B_w is the meander belt width (m) and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width value.

The TRCA (2004) model was also used to calculate a meander belt width (B_w) such that:

$$Bw = -14.827 + 8.31\ In(pgQS*DA) \quad \text{[Eq. 2.]}$$

where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2).

One standard error (~8m) was added to the TRCA calculations to account for variability in the empirical relation. The TRCA guidelines recommend one standard error be applied in scenarios where hydrological conditions are expected to remain constant. Based on the concept plan, changes to the hydrological regime are not proposed or anticipated. Results of the meander belt width analyses are provided in **Table 3**.

Table 3: Meander belt widths for Reach SM1 and Reach R3S1

Reach	Meander Belt Width (m)			Proposed Meander Belt Width (m)
	*Largest Meander Amplitude (m)	**Williams - Width (1986)	ᵀTRCA (2004)	
SM1	33	62	45	62
R3S1	No visible meanders	22	24	24

* Largest meander amplitude measured upstream of Reach SM1 in 2016 imagery
**Includes 20% factor of safety
ᵀ 1 standard error (~8 m) for factor of safety assuming no changes in post-development hydrology

For reach **SM1**, the largest meander measured was 33 m, including the width of the channel. The Williams (1986) approach resulted in a meander belt width of 62 m, and the TRCA (2004) method resulted in a meander belt width of 45 m. We propose a meander belt width of 62 m for Reach **SM1**. This is a conservative estimate given that the largest meander amplitude measured upstream was 33 m.

For reach **R3S1**, there were no visible meanders in the historical period of record. Therefore, a modelling approach was used to determine the meander belt width. The Williams (1986) approach resulted in a meander belt width of 22 m, and the TRCA (2004) method resulted in a meander belt width of 24 m. As such, we propose a meander belt width of 24 m for Reach **R3S1**. Although, it should be noted that an existing meander belt width for **R3S1** is outlined here for characterization purposes only. Erosion hazards associated with the proposed realigned **R3S1** are addressed as part of the conceptual channel design outlined in **Section 6**.

The meander belt widths are graphically presented in **Appendix A**, for reference.

5 Erosion Threshold Analysis

In support of the proposed Stormwater Management (SWM) plan, an erosion threshold analysis was completed in association with the Sixteen Mile Creek tributary. 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.

The proposed SWM plan includes two (2) SWM facilities on Orlando Lands. A SWM pond is proposed on the west side of the Study Area adjacent to the CN Rail Line. The pond will provide flows to a conveyance swale proposed along the western boundary of the site. Ultimately, flows from this facility and the associated conveyance swale will drain south of James Snow Parkway to an existing catch basin and stormwater sewer. Given the existing SWM south of the Study Area, there are no concerns with regards to erosion impacts downstream.

A second SWM Pond is proposed near James Snow Parkway and Esquesing Line and will release flows to the farthest downstream extent of the realigned section of **R3S1**. Downstream of the Study Area, flows from this tributary are conveyed in open channels that cross agricultural lands, including reach **R3SC0C**. Ultimately, flows drain downstream to the Main Branch of Sixteen Mile Creek. To support definition of erosion control criteria for the proposed SWM facility, an erosion threshold assessment was completed for the receiving tributary (Reach **R3S0C**).

5.1 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:

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

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.

5.2 Results

Summarized bankfull channel conditions and results from the erosion threshold analysis are provided in **Table 4**. Reach **R3S0C** contains relatively similar bed and bank materials, differentiated mainly by their level of compactness. Bank material was identified as a cohesive, non-colloidal silty loam with a corresponding critical velocity of 0.53 m/s (Fischenich, 2001). The more-compact bed material was identified as a cohesive clayey silt with a corresponding critical velocity of 0.61 m/s (Julien, 1998). Considering the bed and bank material's level of cohesiveness, the critical velocities adopted for this analysis are considered conservative estimates.

We note that the bed material was not entirely comprised of the cohesive clayey silt material. While the finer, cohesive material was the dominant material, the remaining unconsolidated material was considered as a limiting factor in the analysis. The unconsolidated material within the reach had a median grain size of 14.4 mm. Under Komar (1987), a critical velocity of 0.67 m/s is required to entrain materials of this size. Thus, the unconsolidated material was not a limiting factor with respect to the channel bed erosion threshold.

Table 4: Bankfull channel conditions and erosion threshold calculations for R3S0C

Channel Parameter	Results by Reach
	Reach R3S0C
Average bankfull width (m)	1.75
Average bankfull depth (m)	0.46
Channel gradient (%)	0.67
D_{50} (mm)	<2
D_{84} (mm)	18.8
Manning's n roughness coefficient	0.038
Bankfull discharge (m^3/s)	0.43
Bankfull velocity (m/s)	0.90
Bed Material Erosion Threshold	
Bed Material	Alluvial clayey silt
Critical Velocity (m/s)	0.61*
Apparent shear stress acting on bed (N/m)	11.58
Critical discharge (m^3/s)	0.118
Bank Material Erosion Threshold	
Bed Material	Silty clay loam
Critical Velocity (m/s)	0.53**
Apparent shear stress acting on banks (N/m)	11.40
Critical discharge (m^3/s)	0.261
Limiting critical discharge (m^3/s)	**0.118**
Unitary erosion threshold ($m^3/s/ha$)* **	**0.00068**

**Criteria adopted for Alluvial Silt (Julien, 1998)*
***Criteria adopted for Silty Loam (Fischenich, 2001)*
****Determined using drainage area of 173.4 ha*

The erosion threshold established for reach **R3S0C** is 0.118 m^3/s, based on a critical velocity of 0.61 m/s acting on the alluvial clayey-silt bed material (Julien, 1998). Using a drainage area of 173.4 ha obtained from the Ontario Flow Assessment Tool, the unitary erosion threshold for **R3S0C** is 0.00068 $m^3/s/ha$. These values are in close agreement with the unitary erosion threshold previously established for **R3S1** upstream, as well as the average unitary erosion threshold of 0.00050 $m^3/s/ha$ from the Town of Halton Hills 401 Corridor Integrated Planning Project (Dillon, 2000).

6 Post- and Pre-Development Erosion Exceedance Analysis

Using the results of the erosion threshold analysis and hydrological modelling provided by TYLin (2022) 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 and volume
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, as it reflects both the duration and magnitude of erosion exceedance events.

Time of exceedance, number of exceedances, and cumulative effective discharge and volume can be simply calculated from the discharge record and established critical discharge. The cumulative time of exceedance is simply the summed duration of time where discharge exceeds the established erosion threshold, and the number of exceedances is the count of erosion exceedance events throughout the discharge record. The cumulative effective discharge represents the average magnitude of discharge exceeding the erosion threshold during a given erosion event, whereas the cumulative effective volume represents the total discharge volume that exceeds the erosion threshold throughout the modelled discharge record.

For more relevant indicators, namely the cumulative effective work index, hydraulic information is required. Our model applies the discharge to a characteristic cross-section. Using a Manning's approach, the discharge at each time step in the continuous hydrological model is converted into a velocity, depth of flow, shear stress, and/or stream power. These parameters are calculated based on field measurements of slope, cross-section and channel roughness. This provides analysis that is 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 TYLin (2022) in 15-minute increments spanning from 1962 to 2004. The hydrological modeling was analyzed to calculate the aforementioned erosion indices and identify changes in the erosive potential within **R3S0C** following development. A full series of post- and pre-development hydrographs, overlain with the respective erosion threshold and bankfull discharge, are provided in **Appendix G**, for reference.

6.1 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:

$$Q_{T=} \sum Q_i \qquad \text{[Eq. 4.]}$$

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

$$Q_i = U_i w_i d_i \qquad \text{[Eq. 5.]}$$

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:

$$\tau_{o_{\max}} = d_{\max}\rho g S_{\text{bed}} \quad \text{[Eq. 6.]}$$

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

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

$$\varpi_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \quad \text{[Eq. 7.]}$$

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

$$\varpi_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \varpi < 0 = 0 \quad \text{[Eq. 8.]}$$

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

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \quad \text{for } (Q_T > Q_{\text{threshold}}) \quad \text{[Eq. 9.]}$$

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

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

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \quad \text{[Eq. 10.]}$$

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

$$\text{CED} = \text{CEV}/t_{ex} \quad \text{[Eq. 11.]}$$

6.2 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 5** provides the results of the assessment based on the hydrographs provided by TYLin (2021).

Table 5: Results of the post- to pre-development erosion exceedance analysis for Reach R3S0C

Simulation			CED (m^3/s)	CEV (m^3)	Ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
Reach R3S0C	Qcrit: 0.118 m^3/s	(PRE)	0.18153	203730.50	1625.49	311.75	50.00
		(POST)	0.07687	99963.85	758.97	361.25	27.00
		Change (%)	**-57.63**	**-50.93**	**-53.31**	**15.88**	**-46.00**

The cumulative effective volume (CEV) simply represents the total volume of flow above the threshold level throughout the modelled time period, whereas the cumulative effective discharge (CED) represents the average magnitude of flow exceeding the threshold during a given erosion event. In this instance, the CED and CEV decreased by 57.63% and 50.93%, respectively. Given the increase in t_{ex}, erosion events in the post-development scenario are expected to have a longer duration, which will be offset by the expected decrease in the magnitude of exceedance flows. The cumulative effective work index, which reflects both the duration and severity of erosion events, is predicted to decrease by 53.31% in the post-development conditions. The number of exceedances within the modelled hydrological record is predicted to decrease by 46%, indicating a reduction in the frequency of occurrence for erosion events.

Taken as a whole, the results of the post- to pre-development erosion exceedance predict a general reduction in erosion potential within reach **R3S0C** following completion of development activities. The majority of the erosion indices show reductions between 46 and 58%, with the exception of the exceedance duration, which increased by 15.88%. The expected geomorphic regime within receiving reach **R3S0C** is characterized by longer duration but less severe and less frequent erosion events. Such reductions in erosion potential are beneficial for streams with urbanizing catchments, as it provides a level of resilience to future developments and their associated hydrological effects. From a fluvial geomorphic perspective, the proposed SWM plans adequately address erosion mitigation concerns.

7 Natural Channel Design for Stream Reach R3S1

7.1 Design Objectives

Reach **R3S1** has been proposed for realignment based on natural channel design principles. This provides an opportunity to replace the existing morphologically-limited channel with a naturalized shallow and deep undulating typology, with cross sectional dimensions closer to that of a naturalized watercourse conveying similar flows. One goal of natural channel design is to replace existing degraded channels, particularly those impacted by past agricultural activities. In the case of Reach **R3S1**, a naturalized watercourse will offer significant improvements to channel form and function, per unit length. Conceptual design drawings for the **R3S1** realignment are provided in **Appendix F** for reference.

Small, low order watercourses such as **R3S1** provide detention and retention functions with regards to both flow and sediment. To maintain and enhance these functions, the design needs to provide good communication with the floodplain as well as diversity in channel and floodplain morphology. Floodplain enhancement features in the form of offline wetlands are proposed for the channel corridor. These features enhance aquatic and terrestrial habitat by increasing diversity and providing a more natural floodplain form. They also provide functional benefits by storing and discharging water over long attenuated periods.

The proposed realignment and naturalization provide opportunities for improved riparian conditions and a well-developed bankfull channel with morphological variability. Improvement in morphology and function would provide additional benefits to sediment balance, floodplain storage, vegetation communities and terrestrial habitat features, edge impacts and restoration requirements, water balance, fish passage and water quality. In its existing form, Reach **R3S1** is a degraded feature heavily impacted by historical agricultural practices. The proposed channel design outlined here provides an overall improvement to existing conditions.

The primary objectives of the design are to:

- Restore the physical form of the channel including planform and in-channel characteristics
- Improve the function of the channel as well as its interactions with the floodplain
- Improve retention and detention of flows upstream of the proposed stormwater management ponds
- Enhance aquatic habitat through the provision of a morphologically diverse channel with spatially varied flows
- Improve riparian habitat by installing woody plantings and floodplain features
- Mitigate potential hazards to the development as well as lands surrounding the development

In the development of a natural channel design, the length of the watercourse proposed to be realigned is typically replicated or exceeded, to provide an overall gain in habitat. The length of the existing Reach **R3S1** to be realigned is 1,110m. The corridor for Reach **R3S1** will provide a total realigned channel length of 1,364 m. The increase in channel length will result in a significant increase to the total area of restored and enhanced habitat.

7.2 Channel Planform

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:

$$Rc = 2.43 \times w \qquad \text{[Eq. 12.]}$$

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 shallow undulation section spacing (equations 5-8). Hey and Thorne's (1986) modelled values are intended for application in larger watercourses. As such, multiple methods were considered in order to provide a range of shallow undulation section spacing values.

$$Z = 6.31 \times w \qquad \text{[Eq. 13.]}$$

$$Z = 9.1186 \times w^{0.8846} \qquad \text{[Eq. 14.]}$$

$$Z = 7.36 \times w^{0.896} \times S^{-0.03} \qquad \text{[Eq. 15.]}$$

where *Z* represents shallow section spacing.

Stream power and unit stream power were calculated as a function of bankfull discharge and channel gradient (equations 5-6). Stream power values are important to determine the need for mitigating channel bank and bed erosion. Stream power is given by:

$$\Omega = \rho \times g \times d \times S \qquad \text{[Eq. 16.]}$$

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, is given by:

$$\omega = \frac{\Omega}{w} \qquad \text{[Eq. 17.]}$$

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

The initial planform layout for **R3S1** was created using the modelled radius of curvature value as a guide. The final channel planform was established through an iterative process. First, a cross section was developed to calculate parameters for the planform and then the cross section was refined. Then, given the channel gradient, shallow and deep undulation section lengths were refined. The radius of curvature and shallow and deep undulation spacings are provided in **Table** .

The applied planform is appropriate for the proposed cross-sectional geometry. Further details on the bankfull channel are outlined in **Section 7.3**. The planform also falls within the theoretical meander belt width determined for the realigned channel as outlined in **Section 7.4.1**. Given that the planform has been shown to be suitable through the modelling exercise outlined above, it is anticipated that the meander belt width determined for the channel is also appropriate.

7.3 Bankfull Channel

The recommended restoration design focuses on a shallow and deep undulation typology. This typology will provide significant improvements to not only the channel, as it essentially mimics a natural system, but also to aquatic habitat. When it is assessed to be an appropriate channel type, a shallow and deep undulating system offers numerous benefits, namely:

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

Channel dimensions are determined by bankfull discharge, as this represents what is generally considered 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. However, due to the historic impacts to the watercourse as a result of agricultural activities, the computed discharge could not be considered accurate or reliable. Additionally, due to changes in hydrology likely to occur as a result of the development, a more appropriate discharge, based on hydrological modelling was determined for this reach. The bankfull discharge used to model the channel was assumed to be equivalent to the modelled 1.25-year return post-development flow. The bankfull discharge based on hydraulic modelling is 0.23 m^3/s and 0.08 m^3/s respectively for Reach **R3S1**, as provided by The Municipal Infrastructure Group Ltd. Given that groundwater inputs to the system are substantially lower than the bankfull discharge, no significant impacts to the channel are anticipated from a groundwater perspective.

Shallow and deep cross section geometries, as well as anticipated bankfull conditions, are provided in **Table 6**. A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed channels. Since deep sections are designed to contain ineffective space, this model over-predicts the amount of discharge that they convey. However, the modelled values for the shallow sections give a better prediction of the channel capacity. The proposed realigned section of Reach **R3S1** has an overall gradient of 0.31 % for 1,364 m. Bankfull width and depth range between 1.50 m to 2.25 m and 0.20 m to 0.40 m, for shallow and deep sections, respectively. Average gradient for the shallow sections is 0.97%.

Low gradient channels tend to have more sinuous planforms. This natural occurrence increases roughness and resistance and extracts or increases shear locally within the channel. Although the channel slope decreases from the existing condition, the increased sinuosity and steeper faces of the proposed shallow bed features will result in localized increases in shear stress during lower flows and higher shear stresses in the deeper bed sections during higher flows. This approach will allow for maintenance of channel form. In addition to the increased sinuosity and steeper faces of the shallow bed features, the lower width to depth ratio for the channel is closer to that of a natural meadow channel that will maintain sediment transport processes. Proposed channel parameters are outlined in **Table 6**.

Table 6: Bankfull parameters of the proposed realignment for reach R3S1

Channel parameters	Reach R3S1			
	Reach 1 Shallow	Reach 1 Deep	Reach 2 Shallow	Reach 2 Deep
Bankfull width (m)	1.80	2.25	1.45	1.33
Average bankfull depth (m)	0.18	0.23	0.14	0.21
Maximum bankfull depth (m)	0.25	0.40	0.20	0.35
Bankfull width-to-depth ratio	7.20	5.61	7.25	5.71
Channel gradient (%)	1.00	0.31	0.93	0.31
Radius of curvature (m)*	4		3	
Shallow and deep undulation section spacing (m)**	11		10	
Manning's roughness coefficient, *n*	0.04	0.03	0.04	0.03
Mean bankfull velocity (m/s) †	0.71	0.62	0.59	0.57
Bankfull discharge (m^3/s) †	0.23	0.33	0.12	0.24
Discharge to accommodate (m^3/s)	0.23	0.23	0.08	0.08
Tractive force at bankfull (N/m^2)	25	12	18	11
Stream power (W/m)	23	10	11	7
Unit stream power (W/m^2)	15	7	9	5
Maximum grain size entrained (m) ††	0.03	0.01	0.02	0.01
Mean grain size entrained††	0.02	0.01	0.01	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (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, a mix of granular 'b' and native material is proposed for the shallow sections in the realigned sections of channel. Recent research has shown that even a minimal increase to the D_{84} within the system can have an impact on the overall channel stability and reduce potential erosion (MacKenzie and Eaton, 2017). The channel design includes granular 'b' within the shallow sections to provide greater substrate variability and complexity within the system as well as improve channel stability. Granular 'b' is proposed as a grain size distribution. Specific stone size distributions would reduce the degrees of freedom by limiting grain size classes. Granular 'B' or pit run stone is proposed given there is a higher diversity in sources and less prescription compared to specific grain size distributions. 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 is particularly important as the supply of natural sediment from upstream will be limited due to development.

7.4 Channel Corridor

7.4.1 Corridor Sizing

Meander belt width delineation is also completed to define corridor sizing requirements for a hydrological feature (i.e., the watercourse) within the proposed development. Given the small scale of the watercourse and the limited meander potential, it is noted that the delineated floodplain would likely be larger than the theoretical meander belt width. Given the small scale and low order of the channel, there is little to no erosion hazard.

As noted in **Section 4**, the TRCA and MNRF protocols for defining erosion hazard treat confined and unconfined systems differently. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. Given the size of the channel compared to the floodplain, this channel can be considered unconfined. As such, a meander belt width was calculated for the realigned tributary based on design bankfull dimensions to ensure that the planform has a meander belt width that falls within the proposed corridor requirements. Given the limited channel definition, the hazard limits calculated can be considered conservative. The meander belt width provided here is based on the modelled results.

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

$$B_w = (4.3{W_b}^{1.12} + W_b) \times 1.2 \qquad \text{[Eq. 10]}$$

where *Bw* is meander belt width (m), *A* is bankfull cross-sectional area (m^2), 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 1.87 m. The resulting meander belt width estimate for the channel is provided in **Table 7.**

Table 7: Meander belt width estimates for proposed realigned reach R3S1

Channel Section	Williams (1986) Meander Belt Width (m)
Reach R3S1	13

The proposed valley bottom width for reach **R3S1** is 24 m. It is anticipated that the channel will be stable given the low gradient and proposed vegetation control. The predicted meander belt width is 12 m. As such, the meander belt width for the proposed realigned channel fits well within the proposed valley bottom width.

We note that the meander belt width outlined here is theoretical. Given the limited energy and vegetation control, the channel is unlikely to migrate or adjust its planform within the bounds calculated. All meander belt width calculations are based on channels where instream energy is greater than the potential resistance of bank materials. As such, they over predict the potential extent of meandering and erosion hazard. It is our opinion that the proposed corridor arrangement addresses the theoretical meander belt width and more than adequately addresses any potential erosion hazard.

7.4.2 Corridor Wetland Features

Offline and online wetland features will also be constructed along 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 potential for edge effects. Submerged and dry mounds are proposed within the wetland to provide a topographically complex bottom that will increase habitat heterogeneity.

Stone-core wetlands are proposed at all SWMP outfalls and serve to accept discharge from the associated outlets. The stone core refers to hydraulically-sized rounded stone, which is the subsurface material used to ensure wetland stability. Submerged and dry mounds are proposed within the stone-core wetland to provide a topographically complex bottom that will increase habitat heterogeneity. The short-term water retention function of these wetlands also helps to polish the water and moderate the discharge of water into the channel (in addition to the functions provided by the SWM pond).

The 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 increase floodplain roughness and sedimentation. The landscaping plans will be prepared by others during detailed design.

7.4.3 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 include tortuous meanders, brush mattresses, basking logs, brush piles, raptor poles, rock piles and terrestrial mounds. The accompanying drawings provide design details and direction for the implementation of the proposed habitat features.

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. 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. 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.

Brush 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 brush piles are planted with native fruit bearing vines, which provide forage opportunities for wildlife. Brush piles are placed at various location 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.

7.5 Natural Erosion Control

Newly constructed features can be vulnerable to erosion. This is particularly true before vegetation has established along the channel banks. While low-flow events should not intensify erosion, the concern for erosion occurs when there are high flows or precipitation events during construction.

For immediate erosion protection, mechanical stabilization in the form of biodegradable erosion control blankets (i.e., coir cloth, jute mat, etc.) should be used. As the blankets will biodegrade over time, this serves as a short-term stabilization measure.

For long-term stability, implementation of a planting plan is recommended. This includes deep rooting native grasses and other herbaceous species seeded along and within bioswale sections, prescription of flood tolerant native shrub and tree species, and use of seed banks within the local soil. Shrubs should be planted close to the bioswale margins to provided maximum benefit with respect to stabilization and bioswale cover.

Potential erosion locations (i.e., along the outside meander bends, immediately downstream of wet meadow features, etc.) should be anticipated, and should be reflected in the planting plan. Live staking and shrub stock should be used adjacent to the bioswale bank to provide immediate benefit as well as long-term infilling. If appropriate live staking methods are followed, this method should provide greater benefits than simple potted or bare root shrub plating. This is because of the potential for higher densities with live staking.

7.6 Interim and Long-Term Channel Conditions

After construction, it is anticipated that the channel will go through a period of adjustment. This is related to the growth rate of vegetation and long-term succession. In the short-term (< 5 years) we anticipate a level of vegetation encroachment into the channel given the proposed planting plan. When the channel is first landscaped, the vegetation will be immature with minimal canopy cover resulting in a higher percentage of grasses establishing and encroaching into the channel. As the vegetation matures and the canopy cover increases (10 – 25 years) we anticipate less grass encroachment into the channel due to reduced light penetration. The increased canopy cover will also benefit the system by reducing light penetration and increasing shading which results in a cooler channel. During this phase there will likely be limited change in channel morphology.

In the long term (> 25 years) the canopy cover will increase, and we anticipate riparian vegetation to consist of less grasses and more shrubs, herbaceous, and tree species. This will likely result in greater habitat diversity due to increased woody debris. Willow and dogwood species are proposed along the channel banks which will increase woody debris within the channel. As the vegetation matures it will increase organic inputs and habitat diversity. The vegetation change over time will influence channel function. The proposed meandering channel is an appropriate planform design as the vegetation encroachment in the channel decreases.

8 Bioswale Design for Tributary R5

8.1 Design Objectives

Reach **R5S1** and **R5S0** are headwater features located west of Boston Church Road that have been classified as mitigation. The mitigation designation means that the feature can be removed from the landscape but that its hydrological function must be maintained through stormwater management. Although these features could have been removed and their hydrological function replicated, we have proposed a treatment train approach. The features are proposed to be realigned as conveyance swales along the western boundary of the Study Area to convey flows from upstream as well as discharged water from SWM Pond 1. The proposed realignment provides opportunity to replace the existing morphologically-limited feature with an enhanced bioswale that offers numerous benefits to the system, including retention and detention of flows, on site infiltration, and polishing effects. One goal of a bioswale design approach is to replace existing degraded channels, particularly those impacted by past agricultural activities. We have proposed a bioswale feature with shallow and deep undulating typology. It is anticipated that this approach will provide significant improvements to the existing headwater drainage features, as it will essentially replicate a natural system. Conceptual design drawings for the R5 tributary are provided in **Appendix F** for reference.

Headwater features like Reach **R5S1** and **R5S0** provide detention and retention functions with regards to both flow and sediment. To maintain and enhance these functions, the design needs to provide diversity in morphology. The primary objectives of the design, therefore, are to:

- Convey flows from upstream and the proposed SWM ponds to the downstream channel
- Improve the function of the existing headwater drainage features
- Improve water quality by extending detention of water through shallow and deep undulations
- Improve riparian habitat by installing woody plantings

8.2 Bioswale Design

Shallow and deep undulation cross section geometries, as well as anticipated swale conditions, are provided in **Table 8**. A simple Manning's approach was used to iteratively back-calculate dimensions for the proposed swale. Since deep sections are designed to contain ineffective space, this model over-predicts the amount of discharge that they convey. However, the modelled values for the shallow sections give a better prediction of the swale capacity. The discharge used to model the low-flow channel in this section was assumed to be equivalent to the modelled 1.25-year return post-development flow. The conveyed discharge based on hydraulic modelling provided by The Municipal Infrastructure Group Ltd. is 0.10 m^3/s along reach **R5S1** and 0.14 m^3/s along reach **R5S0**. The proposed realigned section of **R5S1** has an overall gradient of 0.29% for 400 m. Swale width and depth range between 1.25 m to 1.55 m and 0.25 m to 0.35 m, for shallow and deep sections, respectively. Average gradient for the shallow sections is 1.45%. The proposed realigned section of **R5S0** has an overall gradient of 0.29%

for 380 m. Swale width and depth range between 2.00 m to 2.30 m and 0.25 m to 0.35 m, for shallow and deep sections, respectively. Average gradient for the shallow sections is 0.83%. Given the anticipated flow characteristics, it is expected that the conveyance swale will become fully vegetated.

Table 8: Bankfull parameters of the proposed realignment for reach R5S1 and reach R5S0

Bioswale parameters	Reach R5S1		Reach R5S0	
	Shallow	Deep	Shallow	Deep
Swale width (m)	1.25	1.55	2.00	2.30
Average swale depth (m)	0.15	0.17	0.17	0.21
Maximum swale depth (m)	0.25	0.35	0.25	0.35
Swale width-to-depth ratio	5.00	4.41	8.00	6.56
Swale gradient (%)	1.45	0.29	0.83	0.29
Shallow and deep section spacing (m)**	10		16	
Manning's roughness coefficient, *n*	0.06	0.06	0.06	0.06
Mean velocity (m/s) †	0.50	0.49	0.42	0.57
Swale capacity (m^3/s) †	0.10	0.13	0.14	0.28
Discharge to accommodate (m^3/s)	0.10	0.10	0.14	0.14
Tractive force at swale capacity (N/m^2)	36	10	20	10
Stream power (W/m)	14	4	12	8
Unit stream power (W/m^2)	14	4	7	5
Vegetation erosion velocity (m/s)	<1.0 m/s persistent			

** Based on Hey and Thorne (1986)
† Based on Manning's equation

The bioswale consists of a 300 mm base layer of 70% granular 'b' and 30% native material, providing both depressional and subsurface storage within the interstitial spaces. A 150 mm layer of topsoil will cover the base layer and will be Terraseeded with the proposed wet meadow seed mix.

Given the limited energy and vegetation control, the proposed conveyance swale is unlikely to migrate or adjust its planform resulting in no erosion hazard associated with the feature.

The swale 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 increase floodplain roughness.

9 Post-Construction Channel Design and Erosion Monitoring

A post-construction monitoring program is recommended to assess the performance of the implemented channel design and to identify any instances of excess erosion in sensitive downstream stream reaches. Monitoring observations can also be used to determine the need for remedial works. The following monitoring and reporting activities are suggested for the realigned channels:

- 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 for the subsequent years
- Bed material characterization using pebble counts
- General vegetation surveys completed annually after construction, for the duration of the monitoring period
- Year-end report summarizing construction activities (i.e., design implementation), and subsequent year-end reports for the duration of the monitoring period

The following monitoring and reporting activities are suggested for the sensitive receiving reach **R3S0C**:

- Installation of erosion pins at monumented cross sections after construction and monitoring of the erosion pins and cross-sectional geometry for the subsequent years
- Bed material characterization using pebble counts and sampling techniques
- General observations of the channel conditions pertaining to evidence of recent erosion

10 Summary

This report details the fluvial geomorphological assessment and conceptual corridor design completed in support of the North Milton Business Park at James Snow Parkway and Esquesing Line in the Town of Milton, Ontario. The fluvial assessment included a review of previous studies, completion of a historical assessment, rapid and detailed field reconnaissance, and erosion threshold assessment, and development of a conceptual corridor design.

Two main watercourse features were identified in the Study Area: a section of the main branch of Middle Sixteen Mile Creek (**SM1**) and a tributary of the Main Branch of Sixteen Mile Creek (**R3S1**). Several other tributaries were identified in the Study Area and were identified as headwater drainage features. Where access was permitted, the extent and location of headwater drainage feature and watercourse reaches were confirmed.

An erosion assessment was completed to inform erosion control criteria for proposed SWM ponds. Specifically, a detailed geomorphological field assessment was completed on the most erosion-sensitive receiving reach (Reach **R3S0C**), from which an erosion threshold was computed and provided as a critical discharge. For reach **R3S0C**, a critical discharge of 0.118 m^3/s was determined based on a critical velocity of 0.61 m/s acting on the silty-clay bed material (Julien, 1998). Erosion exceedance modelling results indicate that the proposed stormwater management plan adequately mitigates the potential for excess erosion within **R3S0C** following development.

A conceptual corridor design was developed for the tributary of Sixteen Mile Creek defined as Reach **R3S1**. Further, bioswale designs have also been proposed for headwater drainage features. The proposed designs will enhance seasonal aquatic habitat and provide a diverse channel and floodplain morphology.

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

Respectfully submitted,

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Environmental Scientist

Lindsay Davis, M.Sc., P.Geo., CAN-CISEC
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River Scientist

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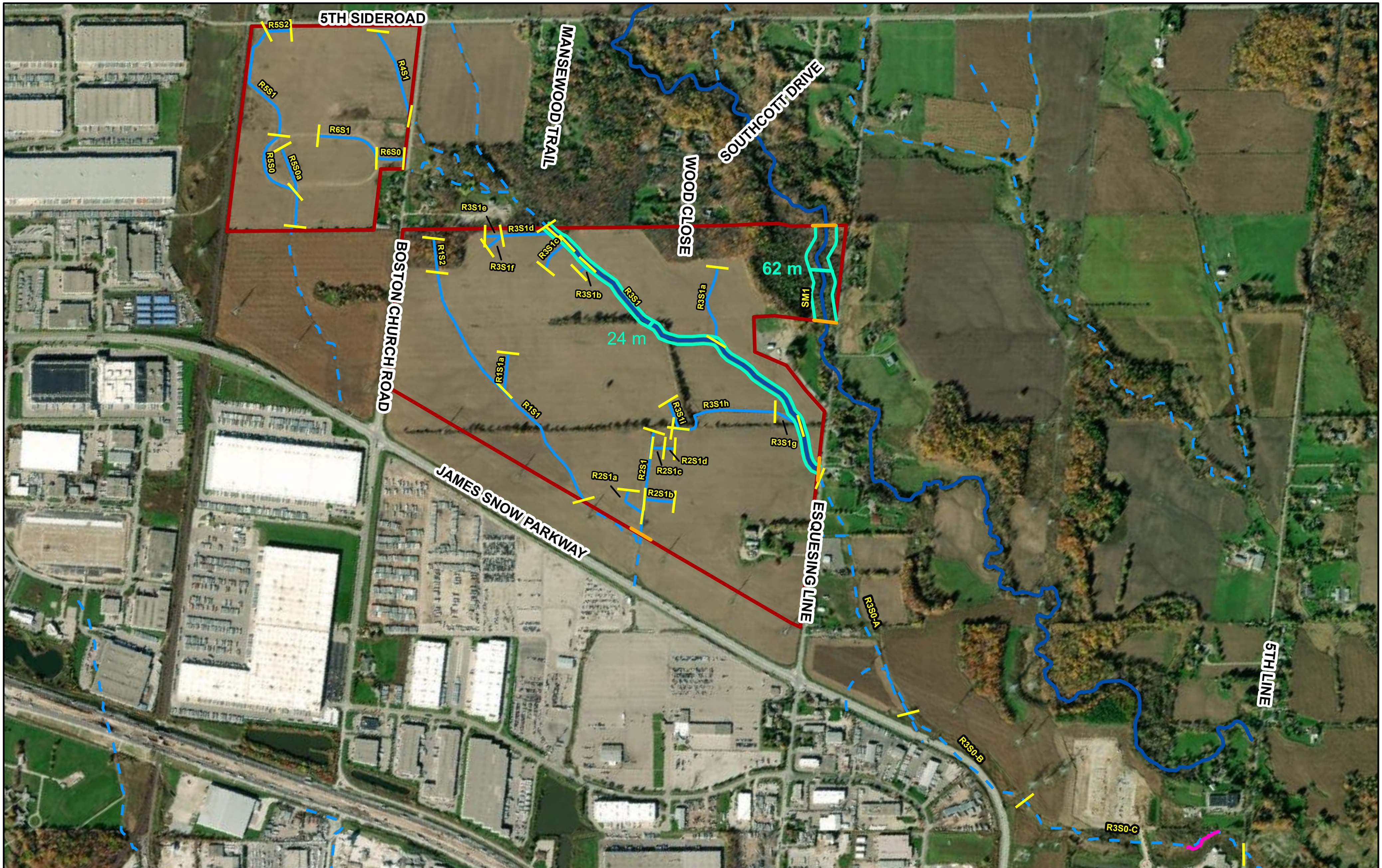
Appendix A
Study Area Mapping



Legend

- Reach Break and ID
- Headwater Drainage Feature
- Assumed Drainage Outside of Accessible Property
- Watercourse
- Detailed Assessment Location
- Meander Belt Width (m)
- Orlando Lands
- Extent Assessed

North Milton Business Park

Detailed Assessment

Milton, Ontario

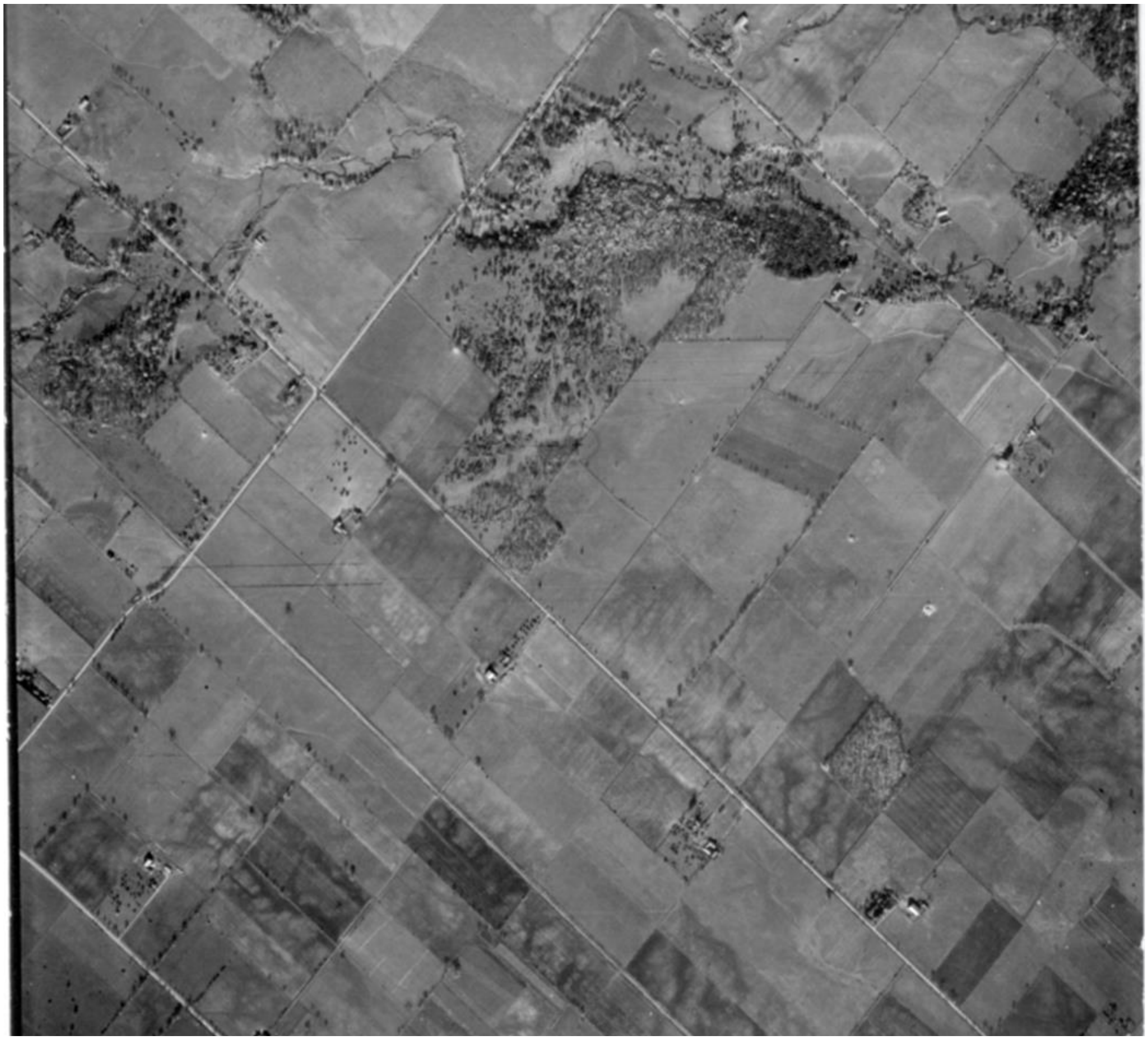
0 150 300

Metres

GEO MORPHIX™

Imagery: Google Earth, 2018.
Reach Break and ID and HDF: Savanta and GEO Morphix Ltd., 2018. Watercourse: GEO Morphix Ltd., and MNRF, 2019. Orlando Property and Proposed Development Plan: TMIG, 2018.
Extent Assessed: GEO Morphix Ltd., 2019.
Meander Belt Width: GEO Morphix Ltd., 2019, 2021.
Print Date: March 2022. PN21059. Drawn By: M.O., J.T.

Appendix B
Historical Aerial Photographs



Location: Milton, Ontario
Year: 1946
Scale: 1:20,000
Source: NAPL

Location: Milton, Ontario
Year: 1969
Scale: 1:30,000
Source: NAPL

Location: Milton, Ontario
Year: 1974
Scale: 1:25,000
Source: NAPL

Location: Milton, Ontario
Year: 1985
Scale: 1:40,000
Source: NAPL

Location: Milton, Ontario
Year: 2004
Scale: N/A
Source: Google Earth Pro

Location: Milton, Ontario
Year: 2017
Scale: N/A
Source: Google Earth Pro

Appendix C
Photographic Record

Photo 1
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Riparian vegetation consisted mainly of trees and grasses. Yellow arrow indicates flow direction.

Photo 2
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Woody debris jams were common throughout the reach.

Photo 3
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Photograph taken of the right (west) bank. Groundwater seepage was observed in a few locations along the banks.

Photo 4
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Photograph showing mature, leaning trees. This is evidence for channel widening.

Photo 5
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Photograph of a beaver dam. Water behind the dam was approximately 0.40 m deep.

Photo 6
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Photograph of the right bank (southwest) displaying wide undercutting and exposed roots. Measured undercuts ranged from 0.26 to 1.25 m.

Photo 7
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Photograph of the deepest pool observed. Pools and runs made up the majority of the geomorphic units in this channel.

Photo 8
Reach **SM1**: Sixteen Mile Creek, northeastern corner of subject property, Milton

Bed and bank materials ranged from clay to cobbles.

Photo 9
Reach **R3S1**: Sixteen Mile Creek Tributary, central portion of subject property, Milton

General overview of tributary through subject property. Note extensive vegetation encroachment and farm crop planted to edge of feature.

Photo 10
Reach **R3S1**: Sixteen Mile Creek Tributary, central portion of subject property, Milton

General overview of tributary through subject property. Note vegetation encroachment and farm crop planted to edge of feature.

Photo 11 Reach **R3S1**: Sixteen Mile Creek Tributary, central portion of subject property, Milton	 Area with less instream vegetation. Note small flow path area within larger excavated feature contains uniform substrate. No flow or water on the day.
Photo 12 Reach **R3S1**: Sixteen Mile Creek Tributary, central portion of subject property, Milton	 Area with less instream vegetation. feature contains uniform substrate. No flow or water on the day. No observed geomorphic units.

Photo 13 Reach **R3S0C**: Sixteen Mile Creek Tributary, downstream of subject property, Milton	
	General overview of tributary. Riparian vegetation is characterized by grasses and occasional trees. Encroachment into the channel was relatively high.
Photo 14 Reach **R3S0C**: Sixteen Mile Creek Tributary, downstream of subject property, Milton	
	A moderately outflanked and degraded crossing was observed at the upstream extent of the sub-reach, indicating some level of planform adjustment.

Photo 15 Reach **R3S0C**: Sixteen Mile Creek Tributary, downstream of subject property, Milton	 Bed materials in **R3SC0** is predominantly clay and silt. Trace amounts of gravel are present in patches throughout.
Photo 16 Reach **R3S0C**: Sixteen Mile Creek Tributary, downstream of subject property, Milton	 The channel generally exhibits a U-shaped geometry with moderate entrenchment. Geomorphic units are often poorly defined.

Appendix D
Field Observations

General Site Characteristics

Project Code/Phase: 15027

Date:	July 8/15	Stream/Reach:	SM1
Weather:	overcast + 24°C	Location:	Esquesing Ln, Milton
Field Staff:	CH + AW	Watershed/Subwatershed:	Sixteen Mile Crk

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Island/bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization
- Instream log/tree
- Fence
- Culvert
- Swamp
- Grasses
- Tree

j-trunk tree

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

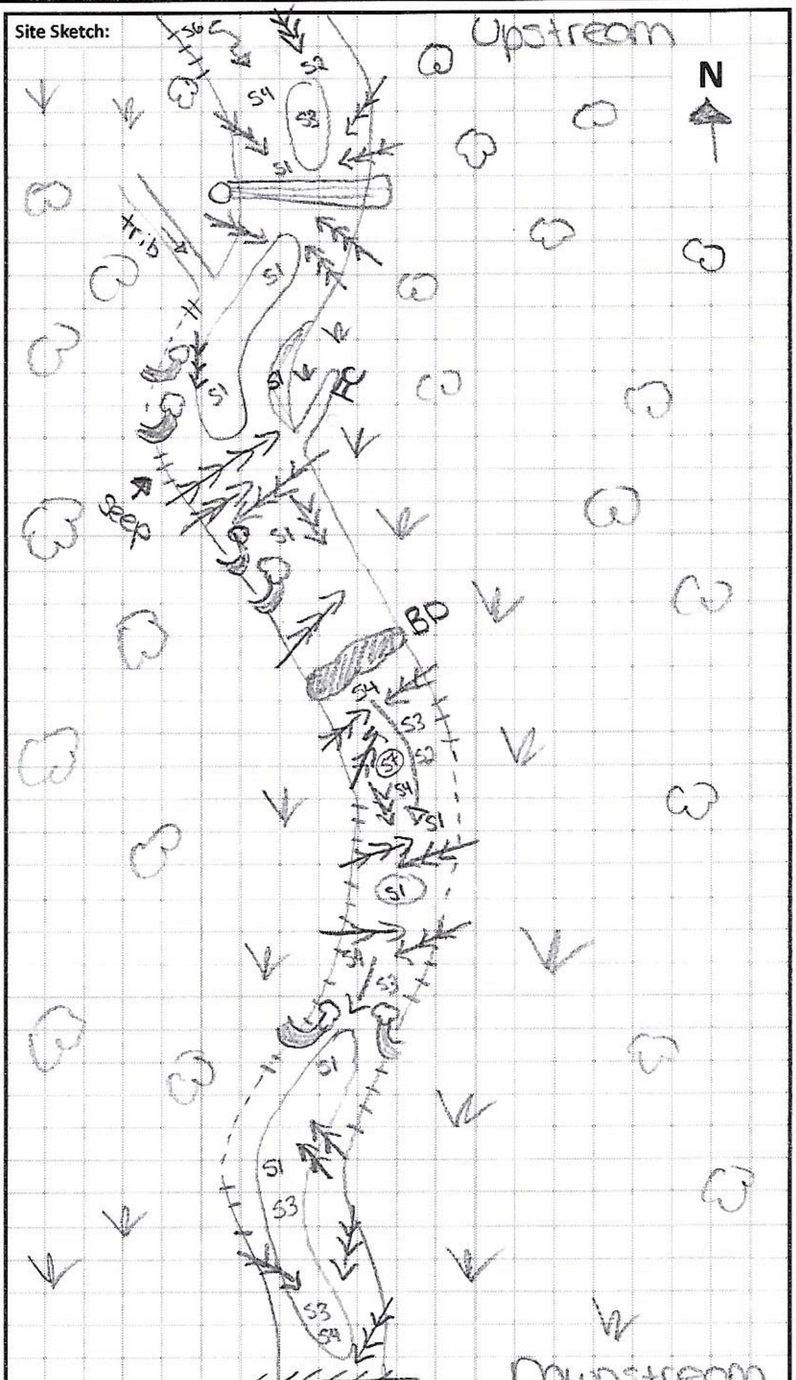
Substrate

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

Other BD - Beaverdam

BM	Benchmark	TR	Terrace
FC	Flood chute	BOS	Bottom of slope
FP	Floodplain	TOS	Top of slope
GC	Grade control	VWC	Valley wall contact
KP	Knick point	WDJ	Woody debris jam

Site Sketch:



Additional notes:

High Embeddedness
seepage throughout from banks

GEO | MORPHIX
Geomorphology
Earth Science
Observations

Completed by: CH Checked by: ________

...ch Characteristics

GEO | MORPHIX
Geomorphology Earth Science Observations

Project Code/Phase: 15027

Date:	July 8/15	**Stream/Reach:**	SM1
Weather:	overcast + 24°C	**Location:**	Esquesing Line, Milton
Field staff:	AW + CH	**Watershed/Subwatershed:**	16 Mile Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 7 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☒ Groundwater | Evidence: iron staining + seepage

Riparian Vegetation

Dominant Type: (Table 6) 1/3
Species: Mixed

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths (m): ☐ 1-4 ☐ 4-10 ☒ > 10

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

Encroachment: (Table 7) 2

Aquatic/Instream Vegetation

Type (Table8): / | Coverage of Reach (%): /

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

Density of WD: ☐ Low ☐ Moderate ☒ High | WDJ/50m: 5

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

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

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): M

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

	U/S		D/S		U/S		D/S
Bankfull Width (m)	7.7	8.9	7.2	**Wetted Width (m)**	5.5	6.9	5.9
Bankfull Depth (m)	0.8	0.78	0.91	**Max Wetted Depth (m)**	0.49	0.31	0.67

Riffle/Pool Spacing (m): NA too few Riffles | **% Riffles:** <5 | **% Pools:** 80 | **Meander Amplitude:** NA

Pool Depth (m): 1.25 | **Riffle Length (m):** 2 | **Undercuts (m):** 0.26 1.25

Velocity (m/s): / | / | 0.3 | Wiffle ball / ADV / Estimated

Comments: Only Riffle @ U/S. Mostly Pools w/ few Runs

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

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

Notes:

Completed by: CH   Checked by: ________

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: 15027

Date:	July 8/10	Stream/Reach:	SM1
Weather:	overcast 24°C	Location:	Esquesing Ln, Milton
Field Staff:	CH + AW	Watershed/Subwatershed:	16 Mile Crk

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	4/7
	2	Coarse materials in riffles embedded	✓		
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone		✓	
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA		0/5
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA		
	3	Elevated storm sewer outfall(s)	NA		
	4	Undermined gabion baskets / concrete aprons / etc.	NA		
	5	Scour pools downstream of culverts / storm sewer outlets	NA		
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	5	0.00
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		3/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.	NA		
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.	NA		
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation	NA		
		Sum of indices =	3	4	0.43
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	✓		2/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form	✓		
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	2	5	0.29

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.32

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

Completed by: CH Checked by: ________

Rapid Stream Assessment Technique **Project Number:** 15027

Date:	July 8/15	Stream/Reach:	SM 1
Weather:	overcast 24°C	Location:	Esquesing Ln: Milton
Field Staff:	CH + AW	Watershed/Subwatershed:	Sixteen Mile Crk

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 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☒ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☒ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

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 percentage 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 NA
Point range	☐ 0 ☐ 1 ☐ 2	☒ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m 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

Additional notes:

Total overall score (0 - 42) = 21

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
		✓		

Completed by: CH Checked by: ________

Reach Characteristics

Project Code/Phase: pn17136

GEO MORPHIX Geomorphology Earth Science Observations

Date:	August 15, 2018	**Stream/Reach:**	R3S1
Weather:	sun, clear conditions	**Location:**	James Snow and Esquesing
Field staff:	CHutton + Savanta staff	**Watershed/Subwatershed:**	16 MC
UTM (Upstream)	refer to U/S wetland boundary	**UTM (Downstream)**	refer to Esquesing location

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 1/2 | **Flow Type** (Table 5): 3 | ☐ Groundwater | Evidence: n/a

Riparian Vegetation

Dominant Type: (Table 6) 3

Species: ____________

Coverage: ☒ None ☒ Fragmented ☐ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

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

Encroachment: (Table 7) 4

limited riparian vegetation; cropland to edge of channel

Aquatic/Instream Vegetation same as riparian vegetation

Type (Table8) n/a | Coverage of Reach (%) 90

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

Density of WD: ☐ Low ☐ Moderate ☐ High

WDJ/50m: n/a

Water Quality

n/a no water; feature dry

Odour (Table 16):

Turbidity (Table 17):

Channel Characteristics

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

Entrenchment (Table 13): 2 | **Type of Bank Failure** (Table 14): 5 | **Downs's Classification** (Table 15): E - artificial from past excavation

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

Bankfull Width (m) 3.7

Bankfull Depth (m) 0.19

Wetted Width (m) n/a no water

Wetted Depth (m)

~~**Riffle/Pool Spacing (m)** **% Riffles:** **% Pools:**~~

Meander Amplitude: n/a

~~**Pool Depth (m)** **Riffle Length (m)**~~

Undercuts (m)

~~**Veloctity (m/s)** Wiffle ball / ADV / Estimated~~ n/a no water

Bank Angle: ☐ 0 – 30 ☒ 30 – 60 ☐ 60 – 90 ☐ Undercut n/a n/a

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

Comments: no morphological features (i.e. riffles/pools) clay/silt substrate throughout entire feature

Notes: historical excavation evident along feature; heavily vegetated; limited erosion; impacts from agriculture

Completed by: CH

Checked by: PV

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code:** pn17136

Date:	August 15, 2018	**Stream/Reach:**	R3S1
Weather:	sun, clear conditions	**Location:**	James Snow and Esquesing
Field Staff:	CHutton + Savanta staff	**Watershed/Subwatershed:**	16 MC

Process	No.	Description	Yes	No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	1/6
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools	X		
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	1	6	0.17
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	n/a		
	2	Exposed sanitary / storm sewer / pipeline / etc.	n/a		
	3	Elevated storm sewer outfall(s)	n/a		
	4	Undermined gabion baskets / concrete aprons / etc.	n/a		
	5	Scour pools downstream of culverts / storm sewer outlets	n/a		
	6	Cut face on bar forms		X	
	7	Head cutting due to 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	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	n/a		
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots	n/a		
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc.	n/a		
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.	n/a		
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation			
		Sum of indices =	0	5	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	7	0

Additional notes:	**Stability Index (SI) = (AI+DI+WI+PI)/4 =**			0.04
	Condition	**In Regime**	**In Transition/Stress**	**In Adjustment**
	SI score =	☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Completed by: CH Checked by: PV

Rapid Stream Assessment Technique **Project Code:** pn17136

Date:	August 15, 2018	**Stream/Reach:**	R3S1
Weather:	sun, clear conditions	**Location:**	James Snow and Esquesing
Field Staff:	CHutton + Savanta staff	**Watershed/Subwatershed:**	16 MC

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 No trees along reach	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☒ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas) No formal riffles along reach	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

Date:		Reach:		Project Code:	

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble No formal riffles along reach	• 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~~
	No water present • ~~Summer afternoon water temperature > 27°C~~	• ~~Summer afternoon water temperature 24-27°C~~	• ~~Summer afternoon water temperature 20-24°C~~	• ~~Summer afternoon water temperature < 20°C~~
Point range	☐ 0 ☐ 1 ☒ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality No water present; ephemeral stream	• 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) = 17	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: CH Checked by: PV

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code:** 21059

Date:	2021-08-25	**Stream/Reach:**	D/S of R351
Weather:	32°C	**Location:**	Milton
Field Staff:	JT DV	**Watershed/Subwatershed:**	16MC

Process	No.	Description	Yes	No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	0
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =			
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		X	0
	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	—		
	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 =			
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		X	0.286
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc.	—		
	7	Length of basal scour >50% through subject reach	X		
	8	Exposed length of previously buried pipe / cable / etc.	—		
	9	Fracture lines along top of bank	X		
	10	Exposed building foundation	—		
		Sum of indices =			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	X		0.6
	2	Single thread channel to multiple channel	—		
	3	Evolution of pool-riffle form to low bed relief form	—		
	4	Cut-off channel(s)		X	
	5	Formation of island(s)	X		
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed	X		
		Sum of indices =			

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.22
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:

Date:	2021-08-25	**Stream/Reach:**	D/S of R3S1
Weather:	32°C	**Location:**	Milton
Field Staff:	JT DV	**Watershed/Subwatershed:**	16MC

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☒ 8	☐ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8

Date:		Reach:		Project Code:	

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☑ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality Dry	• 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) = 24	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: ________ Checked by: ________

Appendix E
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach R3S1

Project Number:	PN17136	**Date:**	August 21, 2015
Client:	Orlando Corporation	**Length Surveyed (m):**	116.8
Location:	Sixteen Mile Creek, Esquesing Ln, Milton	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	112 ha	**Dominant Riparian Vegetation Type:**	Grasses
Geology/Soils:	Halton Till	**Extent of Riparian Cover:**	None
Surrounding Land Use:	Agricultural	**Width of Riparian Cover:**	Continuous
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Immature
Dominant Instream Vegetation Type:	None	**Extent of Encroachment into Channel:**	Heavy
Portion of Reach with Instream Veg:	None	**Density of Woody Debris:**	None

Hydrology

Measured Discharge (m^3/s):	Dry	**Calculated Bankfull Discharge (m^3/s):**	0.35
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.47
Modelled 2-year Velocity (m/s):	Not modelled		

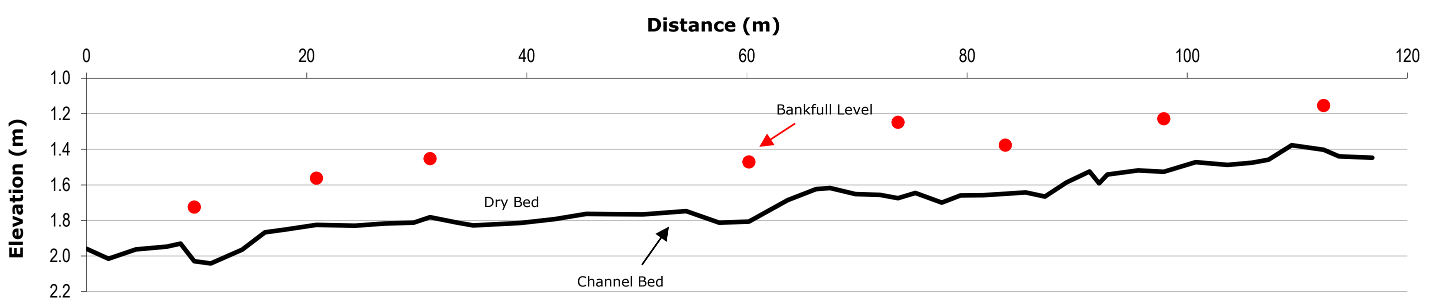
Profile Characteristics

Bankfull Gradient (%):	0.47
Channel Bed Gradient (%):	0.47
Riffle Gradient (%):	N/A: poor riffle development
Riffle Length (m):	N/A: poor riffle development
Riffle-Pool Spacing (m):	N/A: no riffle-pool development

Planform Characteristics

Sinuosity:	1.04
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

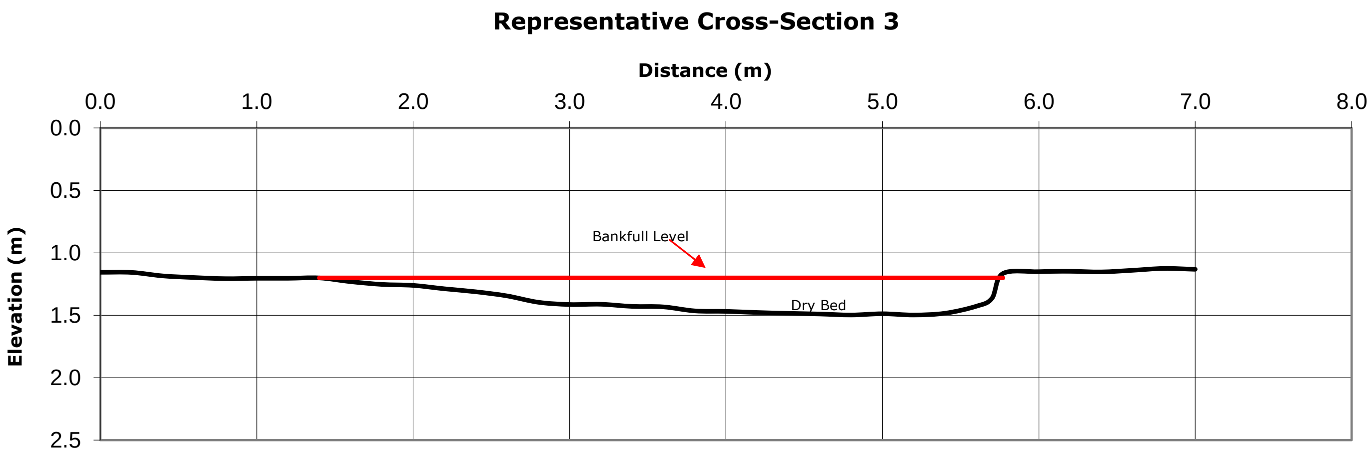
	Minimum	Maximum	Average
Bank Height (m):	0.2	0.50	0.32
Bank Angle (deg):	10	90	40
Root Depth (m):	0.04	0.20	0.13
Root Density (%):	5	90	62
Bank Undercut (m):	0.00	0.05	0.03

	Minimum	Maximum	Average
Torvane Value (kg/cm^2):	Not measured		
Penetrometer Value (kg/cm^3):	Not measured		
Bank Material (range):	Clay, silt, gravel and cobbles		

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.70	4.60	3.77
Average Bankfull Depth (m):	0.13	0.28	0.20
Bankfull Width/Depth (m/m):	14	24	19
Wetted Width (m):	N/A: dry at the time of assessment		
Average Water Depth (m):	N/A: dry at the time of assessment		
Wetted Width/Depth (m/m):	N/A: dry at the time of assessment		
Entrenchment (m):	Not measured		
Entrenchment Ratio (m/m):	Not measured		
Maximum Water Depth (m):	N/A: dry at the time of assessment		
Manning's *n*:	0.050		

Photograph at cross section 3 (looking upstream)

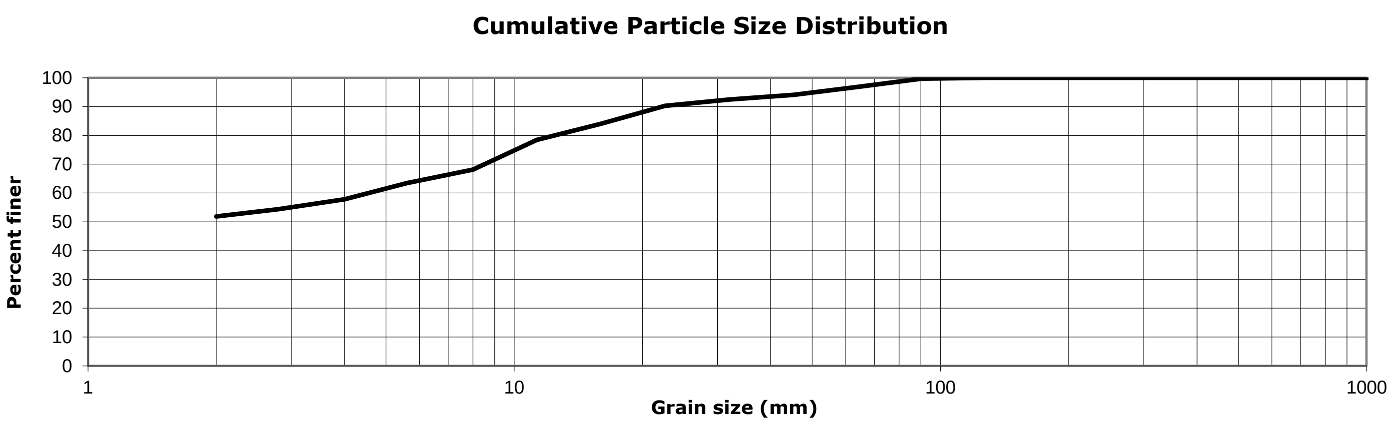


Substrate Characteristics

Particle Size (mm)

D_{10} :	<2
D_{50} :	2.0
D_{90} :	22.0

Subpavement:	Clay
Particle shape:	Platy, angular to sub-rounded
Embeddedness (%):	10 to 60
Particle range (riffle):	Clay to cobbles
Particle Range (pool):	Clay to cobbles



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	9.22
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.71	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	4.32		

General Field Observations

Channel Description

The channel was dry during the time of assessment. This headwater drainage feature conveys flow through an active agricultural field. Planted crops extend to the tops of banks. The channel was heavily vegetated within the banks with grasses and meadow vegetation including cattail reeds. During low flow conditions, streamflow follows a single, clearly marked path with little encroachment from vegetation. Bed material is mainly composed of silt and clay with gravel and cobbles in isolated areas. The average bankfull width and depth are 3.84 m and 0.20 m, respectively. Steep banks and minor undercutting were noted along very limited sections of the reach.

Cross Section 6 - Looking Upstream

Detailed Geomorphological Assessment Summary

Reach R3S0

Project Number:	PN21059	**Date:**	2021-08-25
Client:	Orlando Development Corp.	**Length Surveyed (m):**	138.9
Location:	Milton, ON	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	173.4 ha	**Dominant Riparian Vegetation Type:**	Grasses
Geology/Soils:	Till	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Industrial	**Width of Riparian Cover:**	>10 channel widths
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Immature
Dominant Instream Vegetation Type:	n/a	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	0%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.00	**Calculated Bankfull Discharge (m^3/s):**	0.43
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.90
Modelled 2-year Velocity (m/s):	Not modelled		

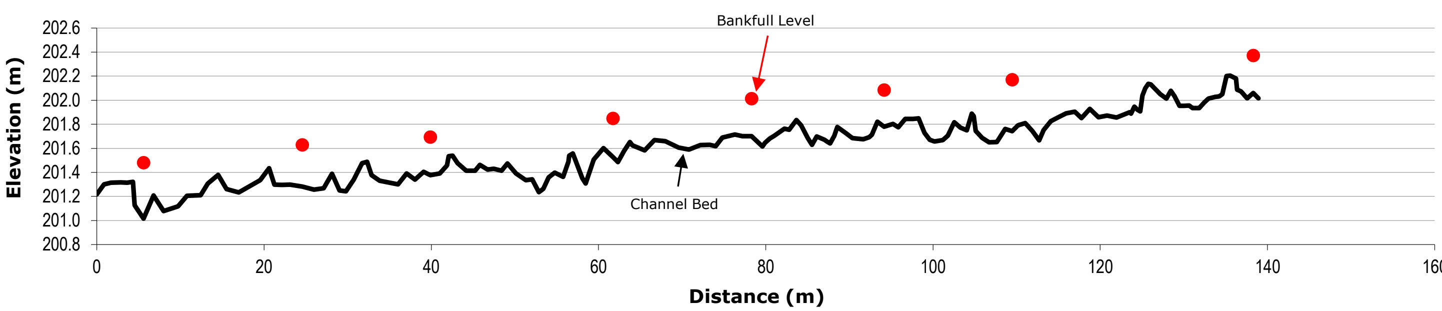
Profile Characteristics

Bankfull Gradient (%):	0.67
Channel Bed Gradient (%):	0.63
Riffle Gradient (%):	2.83
Riffle Length (m):	15.74
Riffle-Pool Spacing (m):	not measured

Planform Characteristics

Sinuosity:	1.24
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.27	0.55	0.47
Bank Angle (deg):	50	90	82
Root Depth (m):	0.25	0.50	0.31
Root Density (%):	10	30	27
Bank Undercut (m):	0.03	0.15	0.08

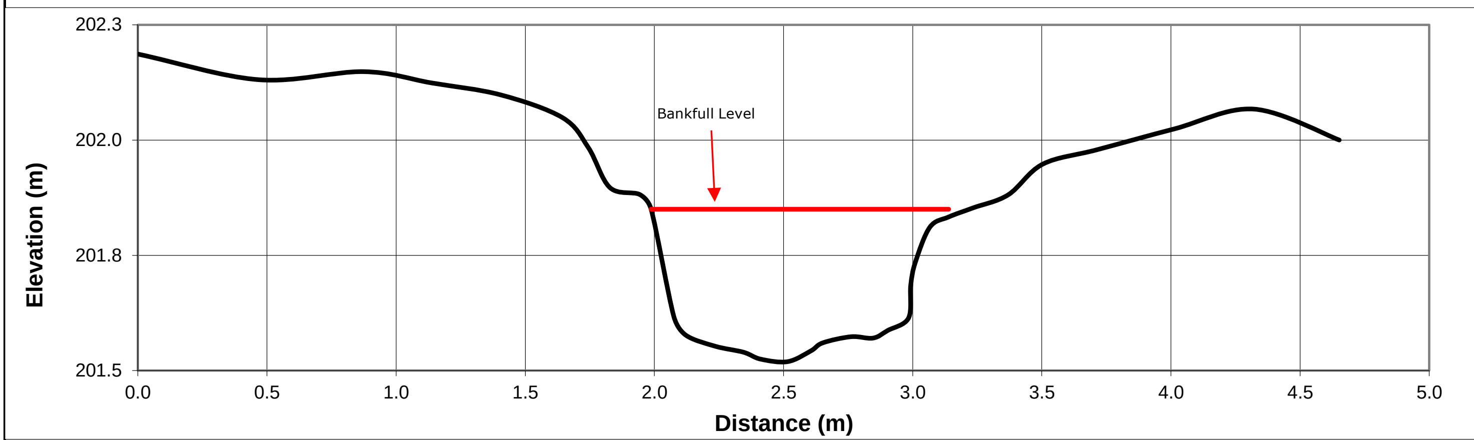
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):			

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	0.71	3.98	1.75
Average Bankfull Depth (m):	0.21	0.34	0.27
Bankfull Width/Depth (m/m):	3	13	6
Wetted Width (m):	0.00	0.00	0.00
Average Water Depth (m):	0.00	0.00	0.00
Wetted Width/Depth (m/m):	#DIV/0!	#DIV/0!	#DIV/0!
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.00	0.00	0.00
Manning's *n*:		0.038	

Photograph at cross section 4 (facing upstream)

Representative Cross-Section #4



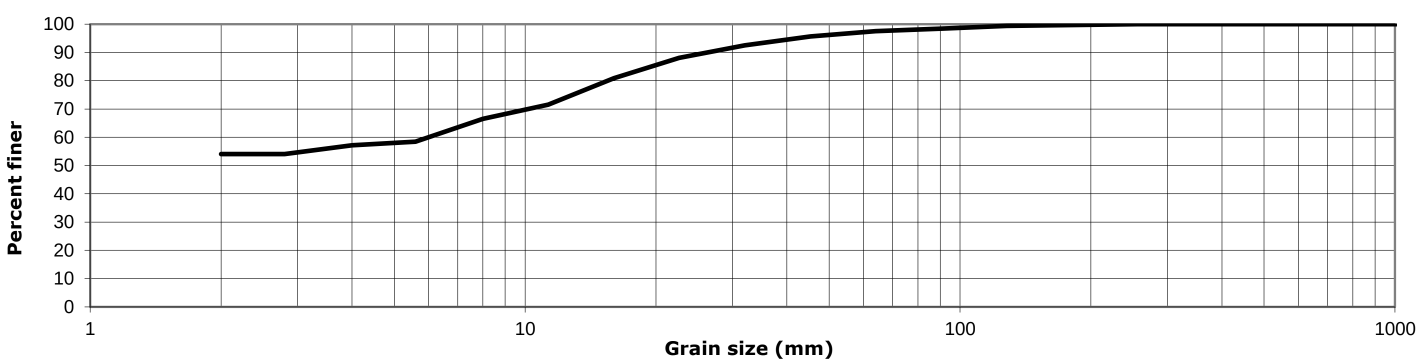
Substrate Characteristics

Particle Size (mm)

D_{10} :	2.0
D_{50} :	2.0
D_{84} :	18.8

Subpavement:	Till
Particle shape:	Sub-rounded
Embeddedness (%):	40-60
Particle range (riffle):	Clay to gravel
Particle Range (pool):	Clay to gravel

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	17.78
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.76	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	16.01		

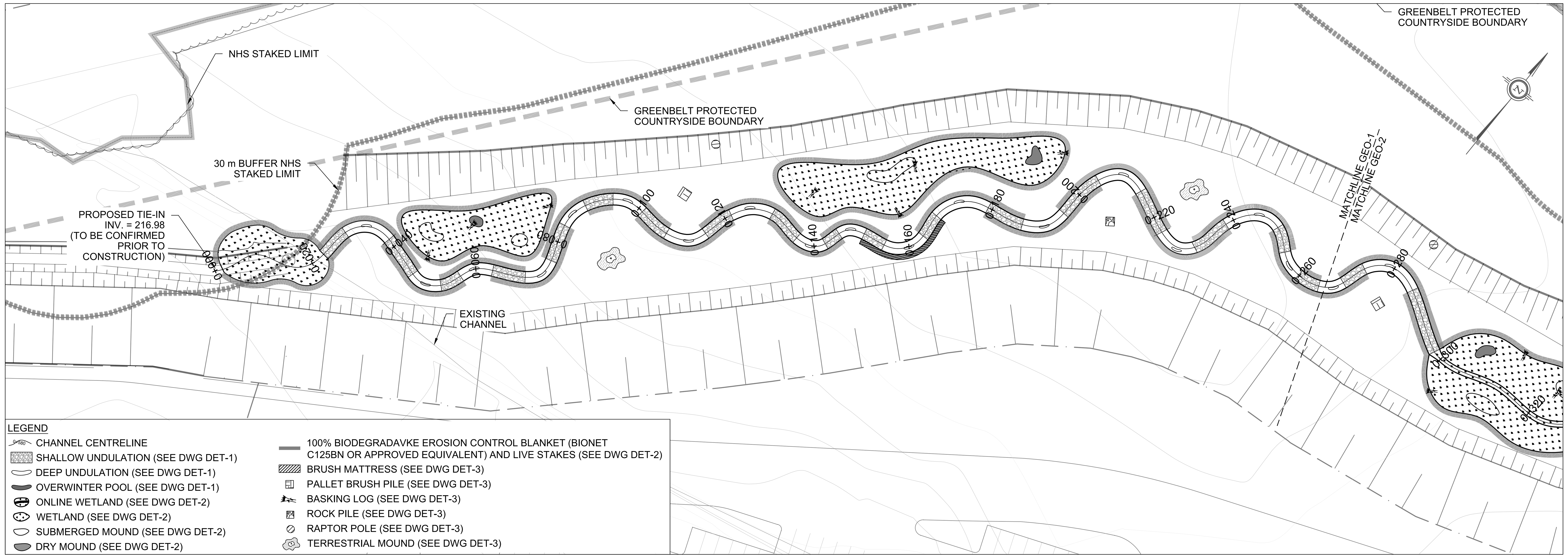
General Field Observations

Channel Description

Reach R3S0 is a low-gradient channel that flows eastwards through an unconfined, grassy valley corridor. Riparian conditions are dominated by grasses with occasional mature trees. Large woody debris and exposed tree roots in the banks were not observed. Bank materials thoughout the reach are a cohesive silty-clay. Bed materials range from compact, cohesive silty-clay to small gravel. The median grain size of the unconsolidated bed material is 14.04 mm. Bank undercutting, up to 0.15 m, was frequently observed throughout the reach. The average bankfull width and depth are 1.75 m and 0.27 m, respectively. Flow was absent during the time of assessment.

Cross Section 6 - Facing Downstream

Appendix F
Conceptual Design Drawings



PLANFORM
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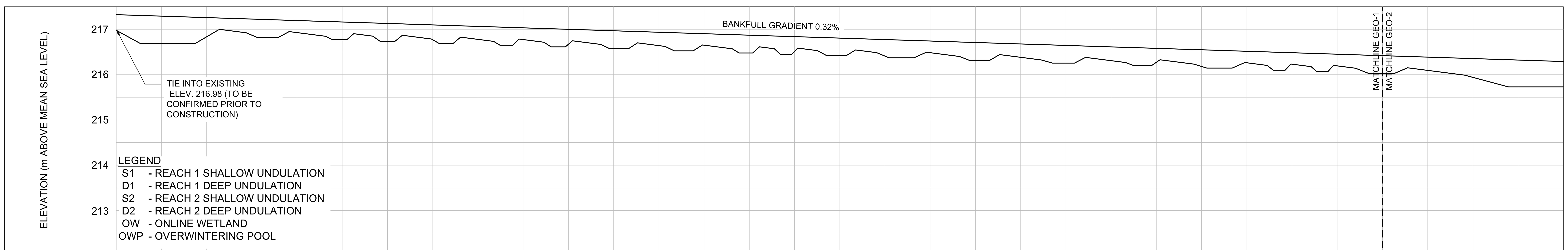
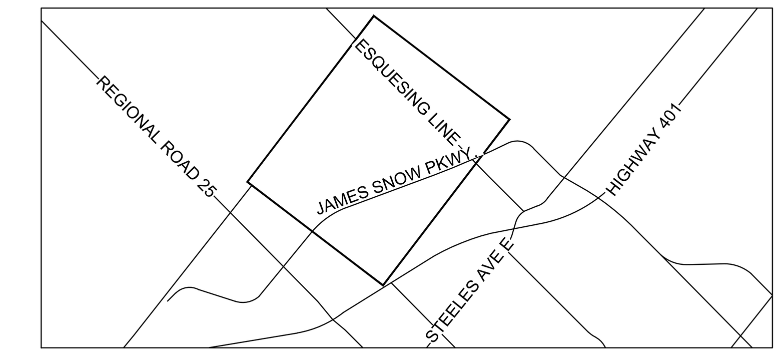


PROPOSED LOW FLOW ELEVATION	217.00, 216.92, 216.82, 216.95, 216.85, 216.77, 216.90, 216.85, 216.74, 216.87, 216.79, 216.69, 216.83, 216.73, 216.65, 216.79, 216.72, 216.61, 216.75, 216.67, 216.57, 216.70, 216.62, 216.52, 216.65, 216.57, 216.48, 216.61, 216.57, 216.45, 216.59, 216.53, 216.42, 216.55, 216.49, 216.37, 216.49, 216.40, 216.31, 216.44, 216.32, 216.25, 216.38, 216.27, 216.20, 216.33, 216.23, 216.14, 216.27, 216.20, 216.10, 216.23, 216.18, 216.07, 216.20, 216.14, 216.03, 216.15, 215.99, 215.73
DISTANCE	0+000, 0+020, 0+040, 0+060, 0+080, 0+100, 0+120, 0+140, 0+160, 0+180, 0+200, 0+220, 0+240, 0+260, 0+280, 0+300, 0+320
DETAIL TYPICAL	OW, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, D, S, OW

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

SCALED FOR PLOT ON 'ARCH D'



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KEY MAP
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3. STOCKPILES MUST BE LOCATED OUTSIDE THE ISOLATED WORK AREAS.
4. STABILIZE STOCKPILED SOILS THAT ARE STORED FOR PROLONGED PERIODS WITH THE APPLICATION OF A NURSE CROP AT A RATE OF 60 kg/ha.
5. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW. ON SOILS THAT WILL BE EXPOSED FOR PROLONG PERIODS, TEMPORARILY INSTALL A BIODEGRADABLE EROSION CONTROL BLANKET ON EXPOSED SOILS, OR APPLY A NURSE CROP AT A RATE OF 60 KG/HA.
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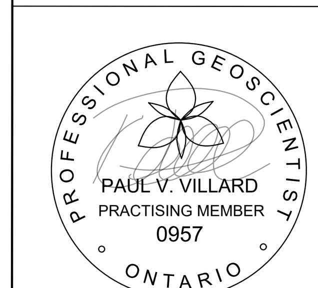
2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD | CHECKED BY: PV

DRAWN BY: AS | DATE: APRIL 2022



22.04.14

GEO MORPHIX
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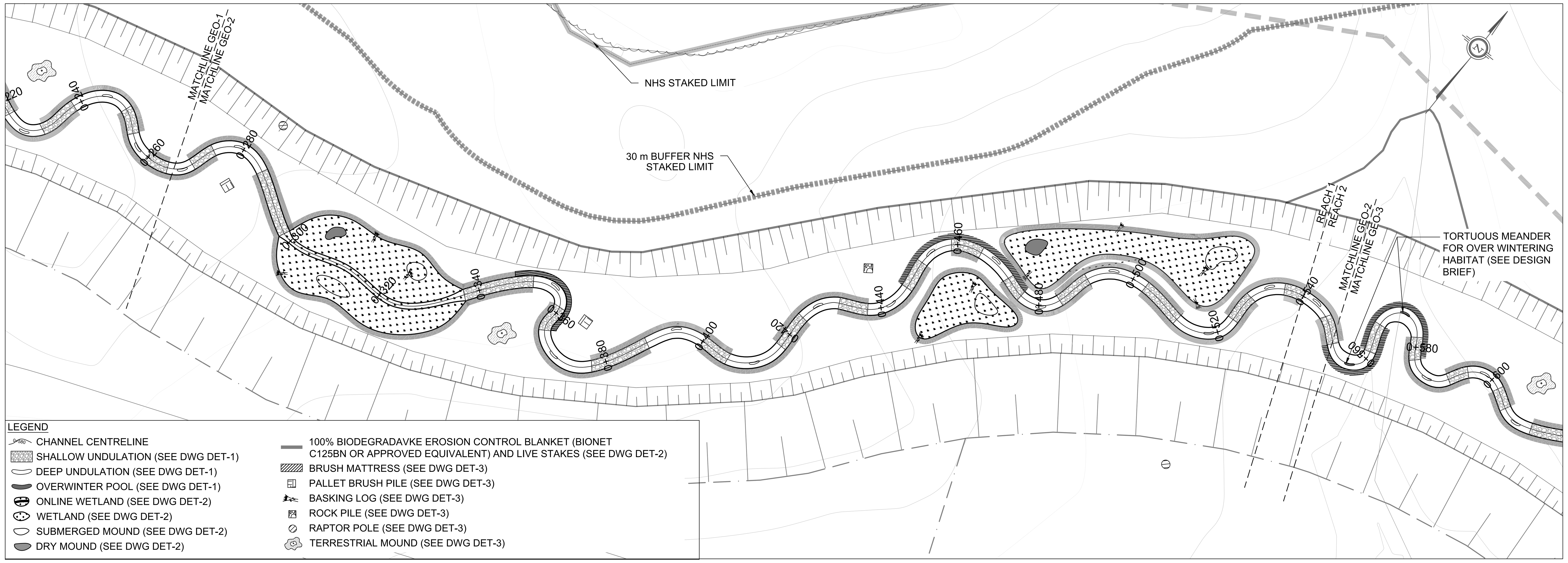
T: 416.920.0926
www.geomorphix.com

NORTH PORTA LANDS
ORLANDO CORPORATION

MSMC - TRIB - 01 DS (REACH R3S1) CONCEPTUAL CHANNEL DESIGN PLANFORM AND PROFILE

PROJECT No.: 21059 | DRAWING No.: GEO-1

SCALE: AS NOTED | SHEET 1 OF 12



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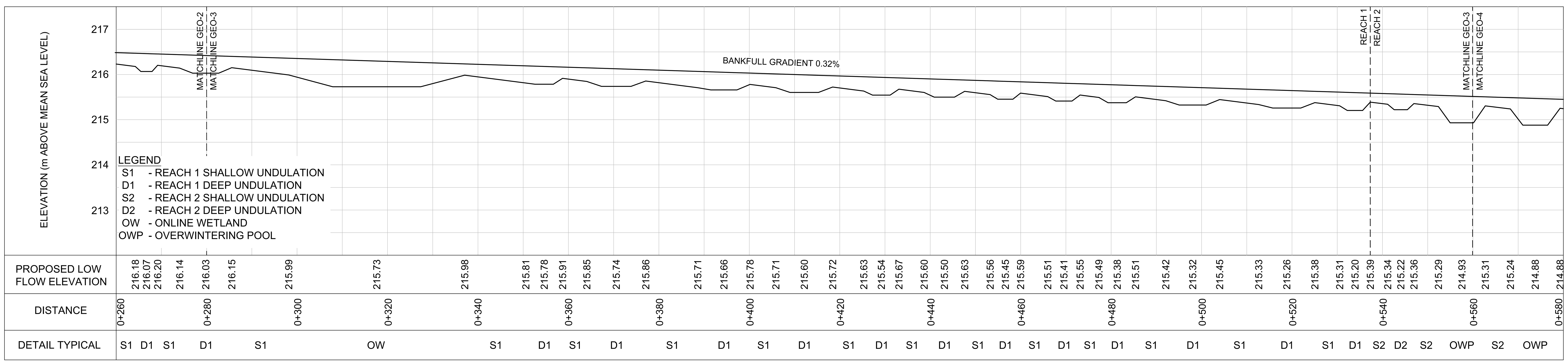

PROFILE
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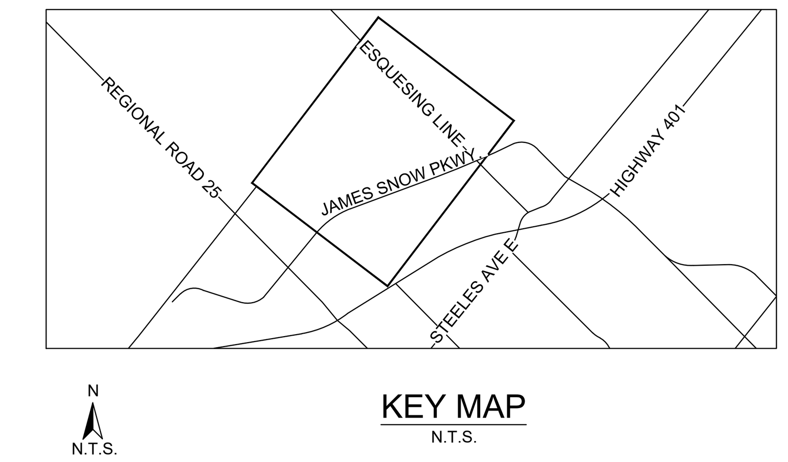

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KEY MAP
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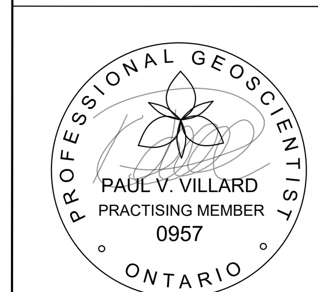
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD	CHECKED BY: PV
DRAWN BY: AS	DATE: APRIL 2022



22.04.14

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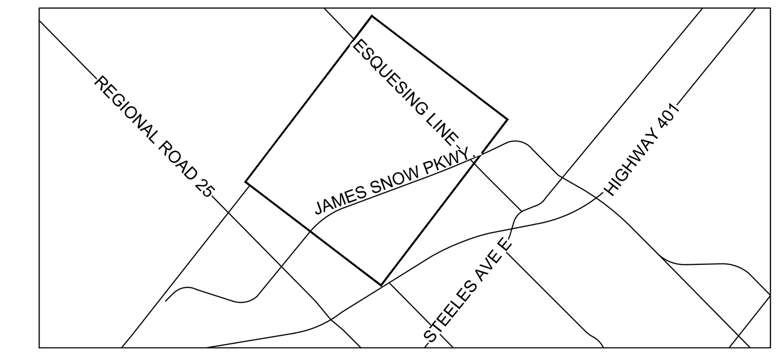
NORTH PORTA LANDS
ORLANDO CORPORATION

MSMC - TRIB - 01 DS (REACH R3S1)
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21059	DRAWING No.: GEO-2
SCALE: AS NOTED	SHEET 2 OF 12

SCALED FOR PLOT ON 'ARCH D'



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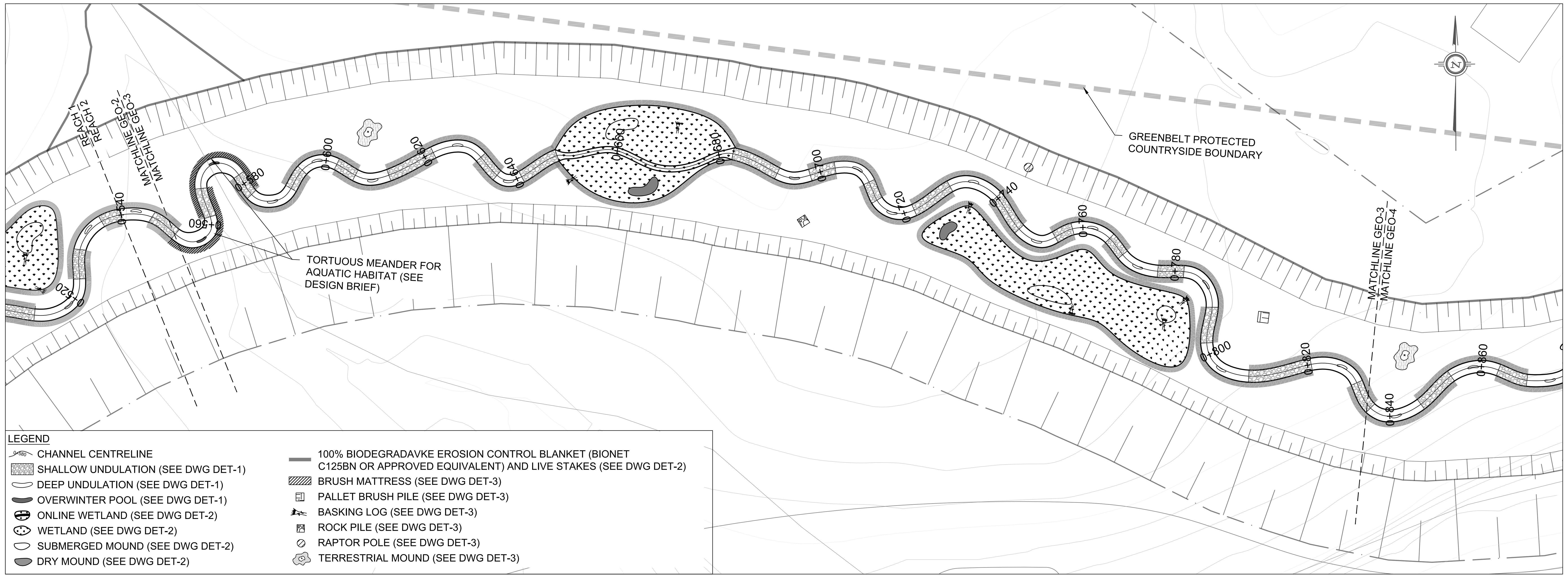

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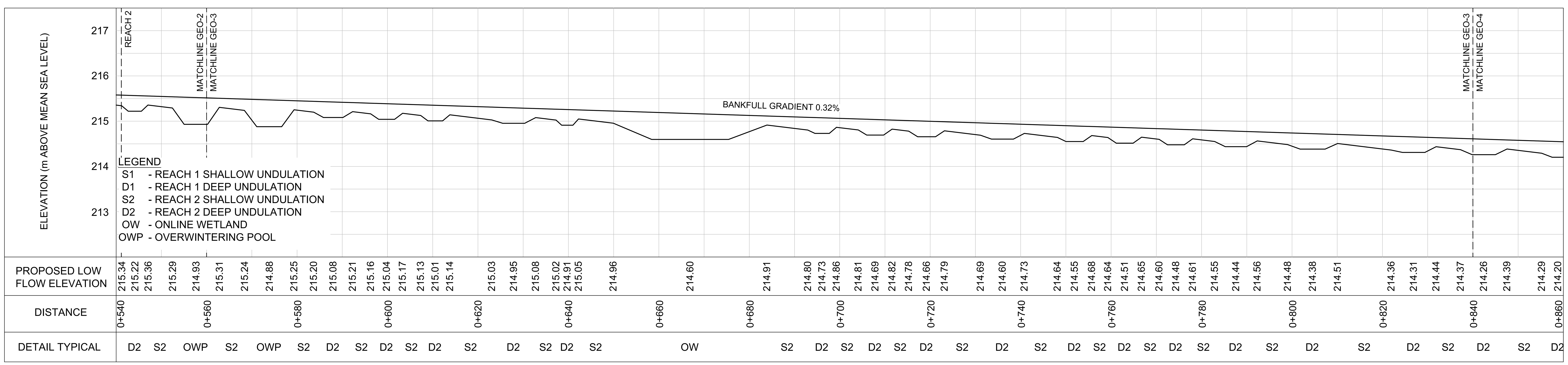

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2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD | CHECKED BY: PV

DRAWN BY: AS | DATE: APRIL 2022

PROFESSIONAL GEOSCIENTISTS ONTARIO
PAUL V. VILLARD
PRACTISING MEMBER
0957
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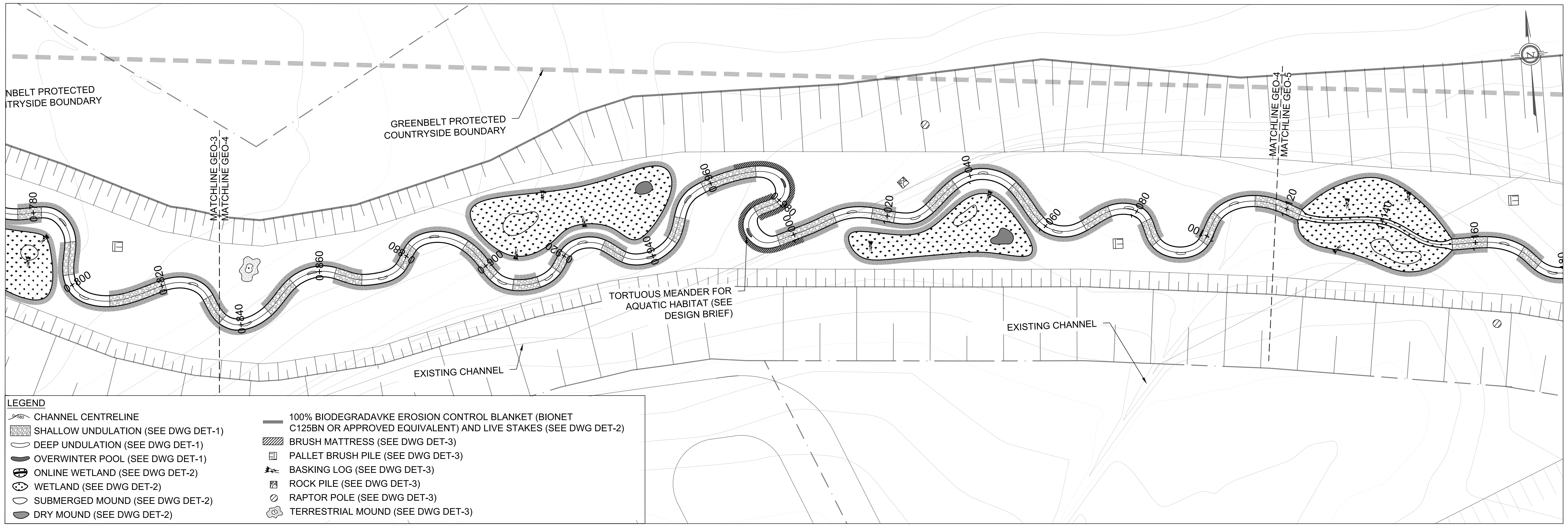
ORLANDO CORPORATION

MSMC - TRIB - 01 DS (REACH R3S1)
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21059 | DRAWING No.: GEO-3

SCALE: AS NOTED | SHEET 3 OF 12

SCALED FOR PLOT ON 'ARCH D'



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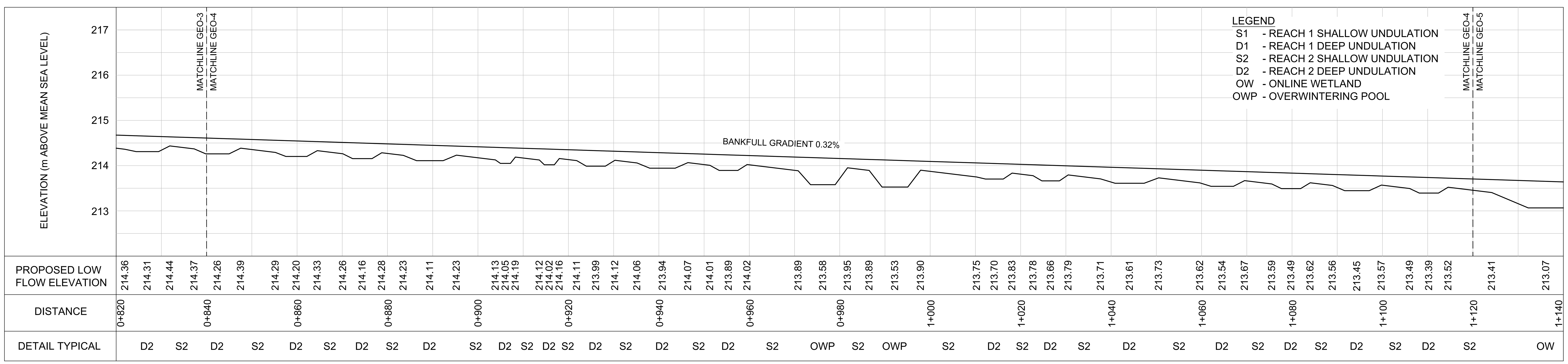

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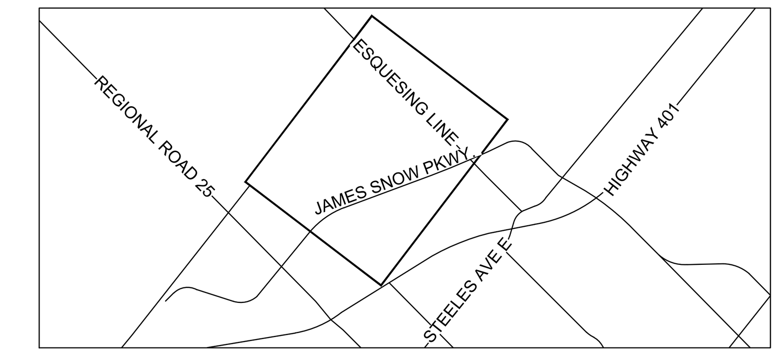

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KEY MAP
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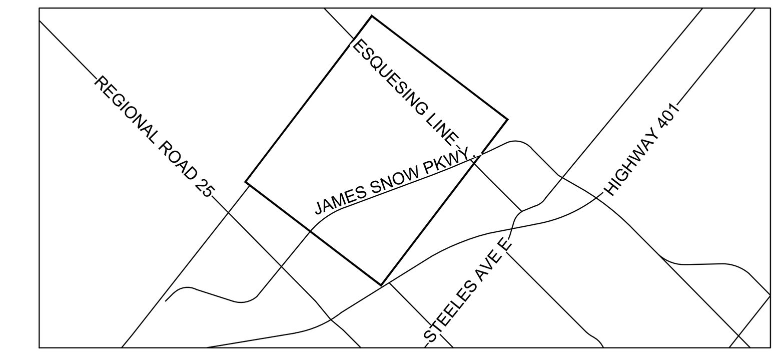
MSMC - TRIB - 01 DS (REACH R3S1)
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21059	DRAWING No.: GEO-4
SCALE: AS NOTED	SHEET 4 OF 12

SCALED FOR PLOT ON 'ARCH D'



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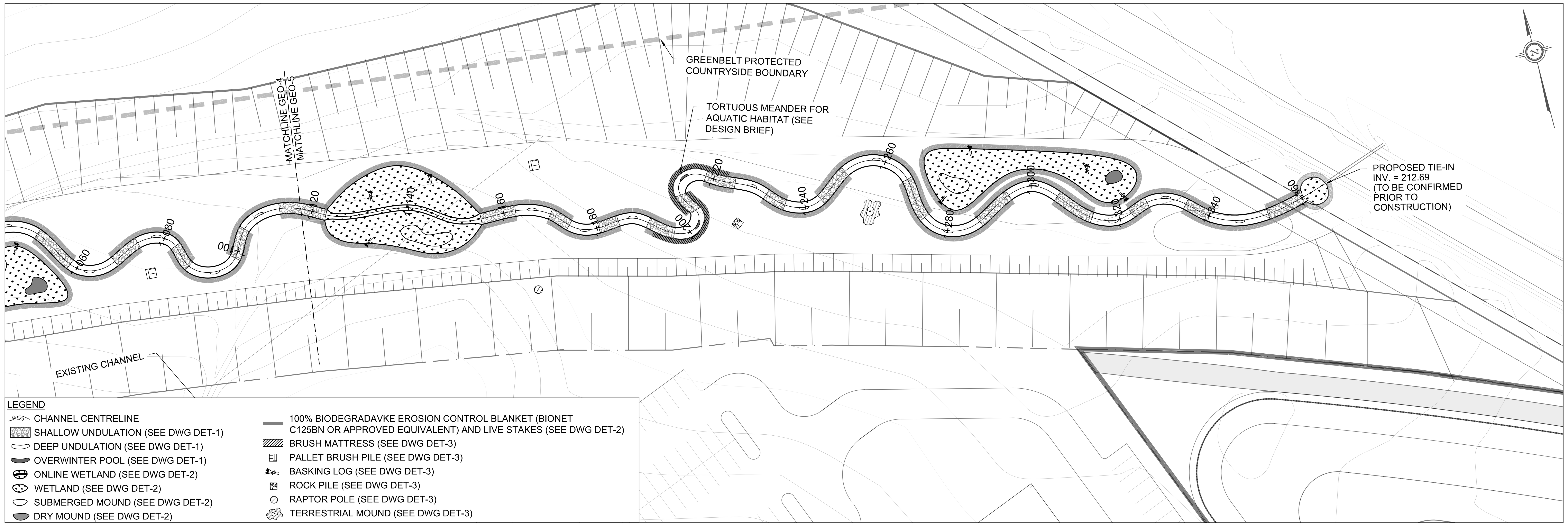

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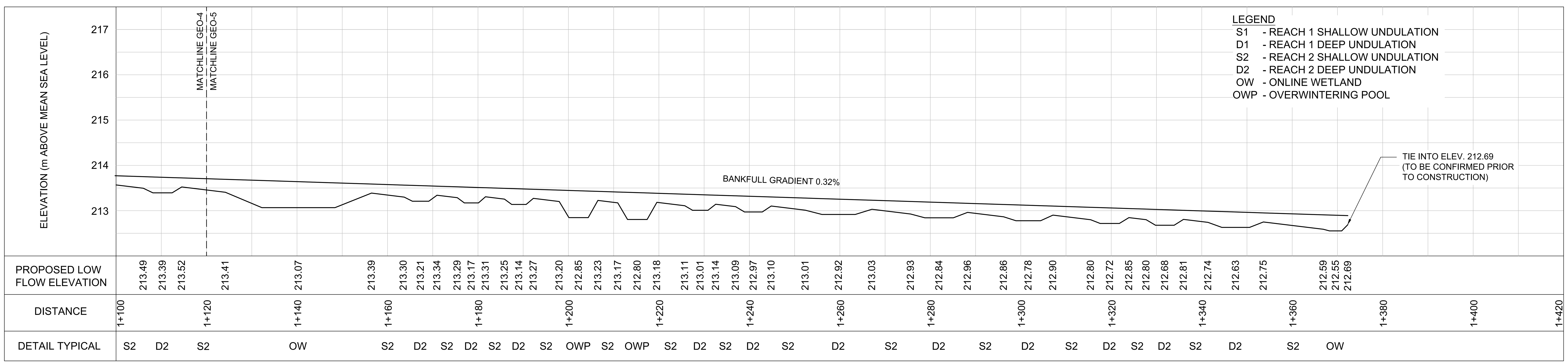

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CONCEPTUAL CHANNEL DESIGN
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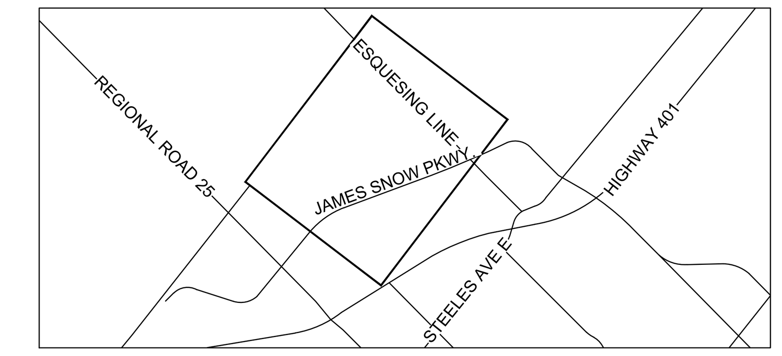
PROJECT No.: 21059
DRAWING No.: GEO-5
SCALE: AS NOTED
SHEET 5 OF 12

SCALED FOR PLOT ON 'ARCH D'



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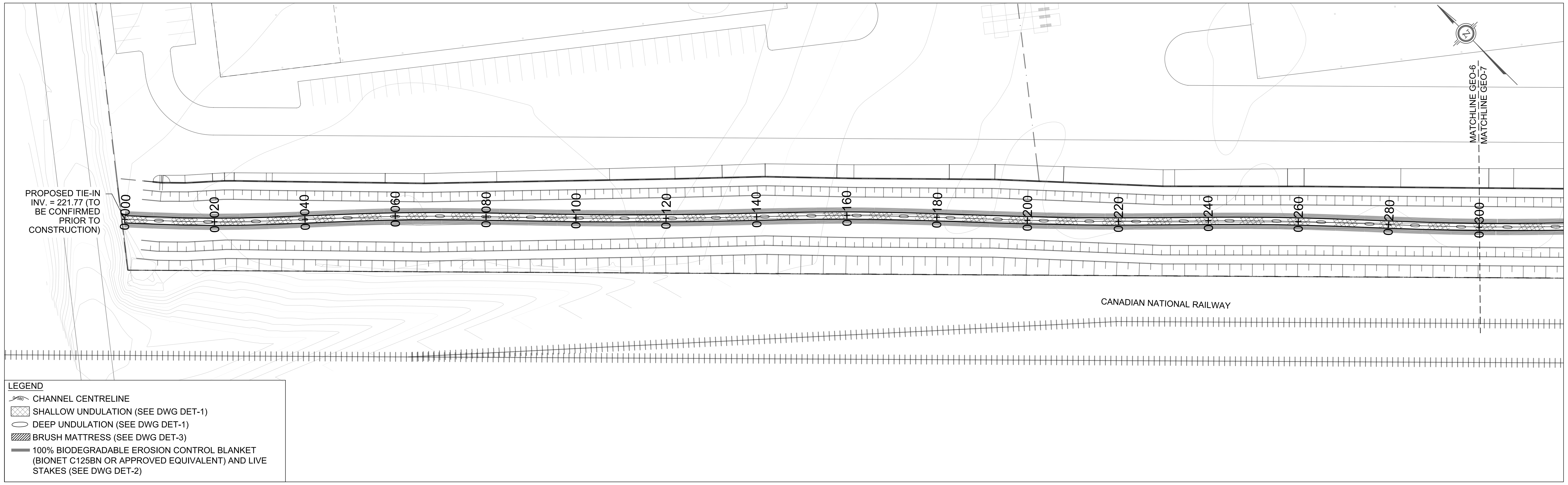
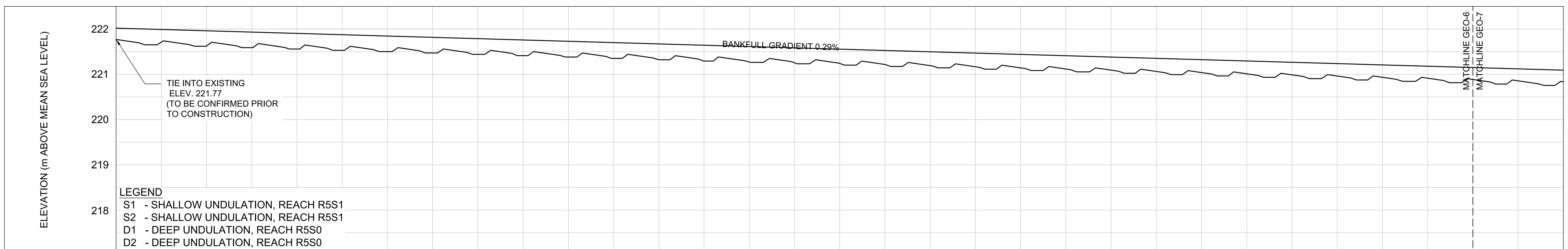


PLANFORM
1:500



PROPOSED LOW FLOW ELEVATION	221.77; 221.70 221.65 221.74; 221.66 221.62 221.71; 221.63 221.59 221.68; 221.60 221.56 221.65; 221.58 221.53 221.62; 221.55 221.50 221.59; 221.52 221.47 221.56; 221.49 221.44 221.53; 221.46 221.41 221.50; 221.42 221.38 221.47; 221.40 221.35 221.44; 221.36 221.32 221.41; 221.34 221.29 221.38; 221.30 221.26 221.35; 221.28 221.23 221.32; 221.25 221.20 221.29; 221.22 221.17 221.26; 221.18 221.14 221.23; 221.15 221.11 221.20; 221.13 221.08 221.17; 221.10 221.05 221.14; 221.07 221.02 221.11; 221.03 220.99 221.08; 221.01 220.96 221.05; 220.98 220.93 221.02; 220.95 220.90 220.99; 220.92 220.87 220.96; 220.89 220.85 220.93; 220.86 220.81 220.90; 220.83 220.79 220.87; 220.79 220.75 220.84
DISTANCE	0+000 0+020 0+040 0+060 0+080 0+100 0+120 0+140 0+160 0+180 0+200 0+220 0+240 0+260 0+280 0+300 0+320
DETAIL TYPICAL	S1 D1 S1 D1

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

No.	DATE	BY	REVISIONS
2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES

DESIGNED BY: PV/LD
CHECKED BY: PV
DRAWN BY: AS
DATE: APRIL 2022

PROFESSIONAL GEOSCIENTISTS ONTARIO
PAUL V. VILLARD
PRACTISING MEMBER
0957
22.04.14

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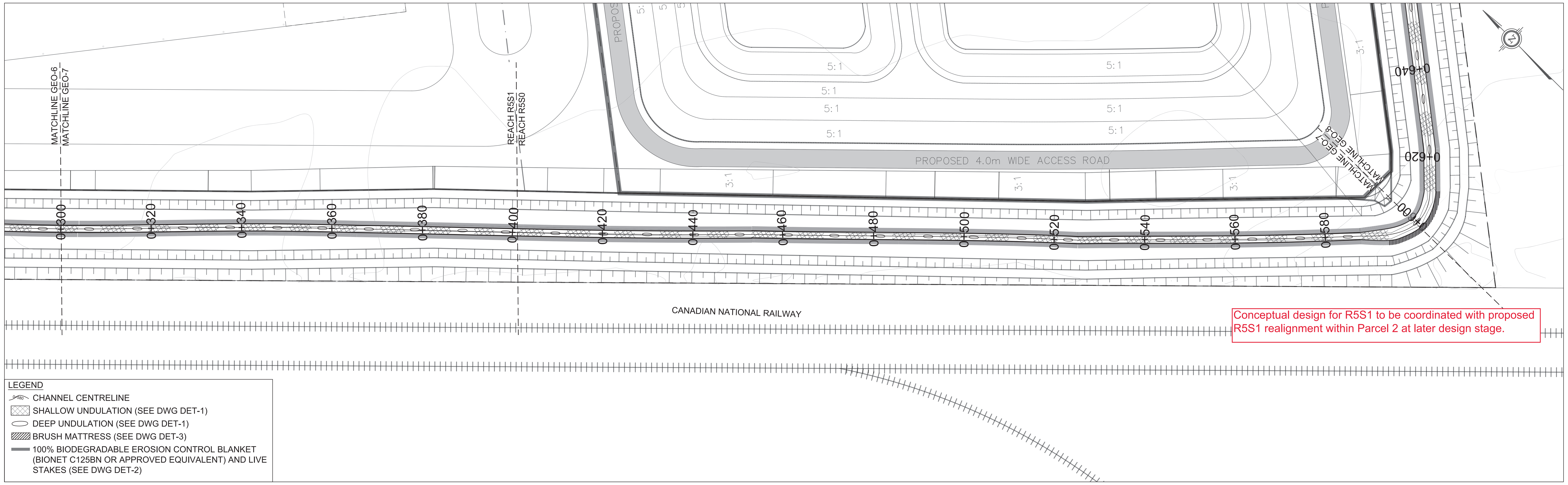
NORTH PORTA LANDS
ORLANDO CORPORATION

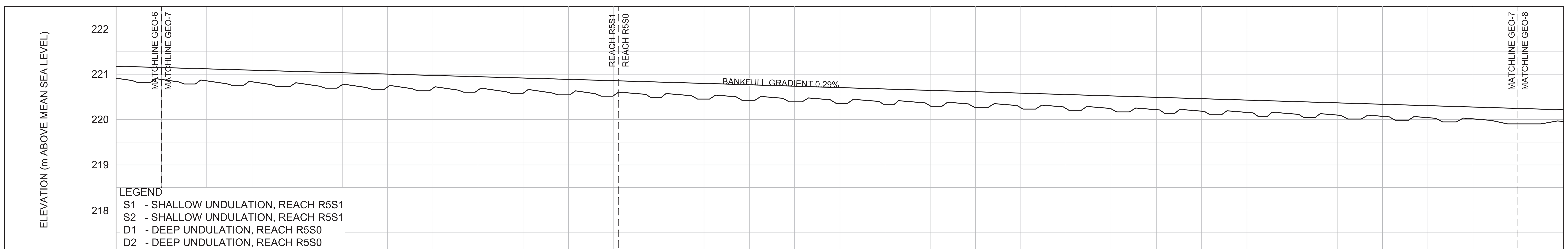
MSMC - TRIB - 03 US (REACH R5S1)
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21059
DRAWING No.: GEO-6
SCALE: AS NOTED
SHEET 6 OF 12

SCALED FOR PLOT ON 'ARCH D'

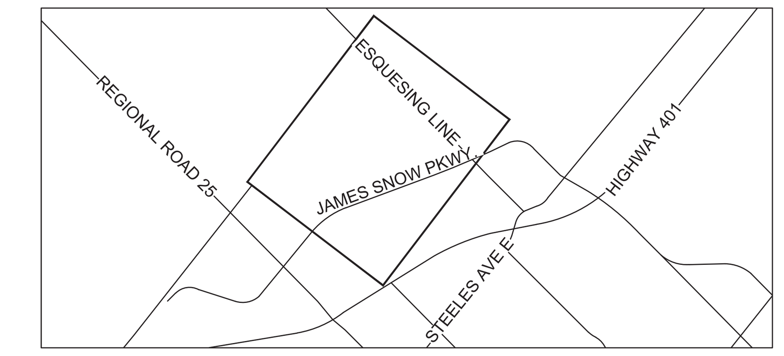


PLANFORM
1:500



PROPOSED LOW FLOW ELEVATION	220.86 220.81 220.90 · 220.83 220.79 220.87 · 220.79 220.75 220.84 · 220.77 220.73 220.81 · 220.74 220.69 220.78 · 220.71 220.66 220.75 · 220.68 220.64 220.72 · 220.65 220.61 220.70 · 220.61 220.58 220.66 · 220.59 220.55 220.63 · 220.57 220.52 220.61 · 220.56 220.48 220.57 · 220.53 220.45 220.54 · 220.50 220.42 220.51 · 220.47 220.39 220.48 · 220.44 220.36 220.45 · 220.40 220.33 220.42 · 220.37 220.30 220.38 · 220.35 220.27 220.35 · 220.31 220.23 220.32 · 220.28 220.20 220.29 · 220.25 220.17 220.26 · 220.21 220.14 220.23 · 220.18 220.11 220.19 · 220.15 220.07 220.16 · 220.11 220.04 220.13 · 220.09 220.01 220.10 · 220.06 219.98 220.07 · 220.03 219.95 220.03 · 219.98 · 219.90 · 219.97
DISTANCE	0+300 · 0+320 · 0+340 · 0+360 · 0+380 · 0+400 · 0+420 · 0+440 · 0+460 · 0+480 · 0+500 · 0+520 · 0+540 · 0+560 · 0+580 · 0+600
DETAIL TYPICAL	D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S1 D1 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 S2 D2 D2

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



N
N.T.S.

KEY MAP
N.T.S.

GENERAL NOTES

1. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
2. THE CONTRACTOR MUST NOTIFY THE CONTRACT ADMINISTRATOR AND CONSERVATION AUTHORITY OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
3. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
4. LAYOUT MUST BE REVIEWED AND APPROVED BY THE CONTRACT ADMINISTRATOR.

TIMING OF WORKS

1. WORKS SHALL BE COMPLETED BETWEEN JULY 1ST TO MARCH 31ST.
2. TREE CLEARING SHOULD BE COMPLETED OUTSIDE THE BIRD NESTING SEASON 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 STOCKPILED SOILS THAT ARE STORED FOR PROLONGED PERIODS WITH THE APPLICATION OF A NURSE CROP AT A RATE OF 60 kg/ha.
5. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW. ON SOILS THAT WILL BE EXPOSED FOR PROLONG PERIODS, TEMPORARILY INSTALL A BIODEGRADABLE EROSION CONTROL BLANKET ON EXPOSED SOILS, OR APPLY A NURSE CROP AT A RATE OF 60 KG/HA.
6. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE.
7. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
8. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. SEDIMENT CONTROLS MUST BE INSPECTED DAILY TO ENSURE THAT THEY ARE IN GOOD REPAIR AND FUNCTIONING AS INTENDED.
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.
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7. ALL TEMPORARY SEDIMENT CONTROLS MUST BE REMOVED AFTER THE CONTRACT ADMINISTRATOR DEEMS THE SITE TO BE STABLE.

DELETERIOUS SUBSTANCE CONTROL/SPILL MANAGEMENT

1. PREVENT THE RELEASE OF SEDIMENT, SEDIMENT-LADEN WATER, RAW CONCRETE, CONCRETE LEACHATE OR ANY OTHER DELETERIOUS SUBSTANCES INTO ANY WATERBODY, RAVINE OR STORM SEWER SYSTEM.
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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	DATE	BY	REVISIONS
2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES

DESIGNED BY: PV/LD | CHECKED BY: PV

DRAWN BY: AS | DATE: APRIL 2022

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
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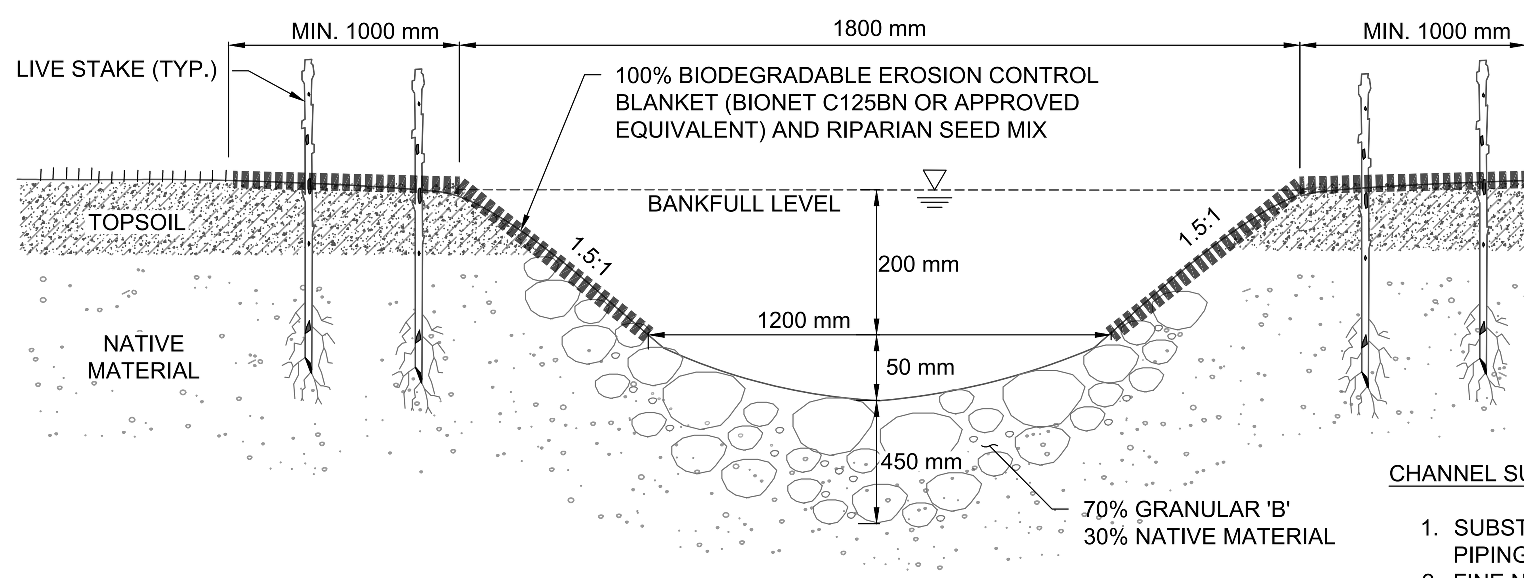
ORLANDO CORPORATION

MSMC - TRIB - 03 US (REACH R5S1)
CONCEPTUAL CHANNEL DESIGN
PLANFORM AND PROFILE

PROJECT No.: 21059 | DRAWING No.: GEO-7

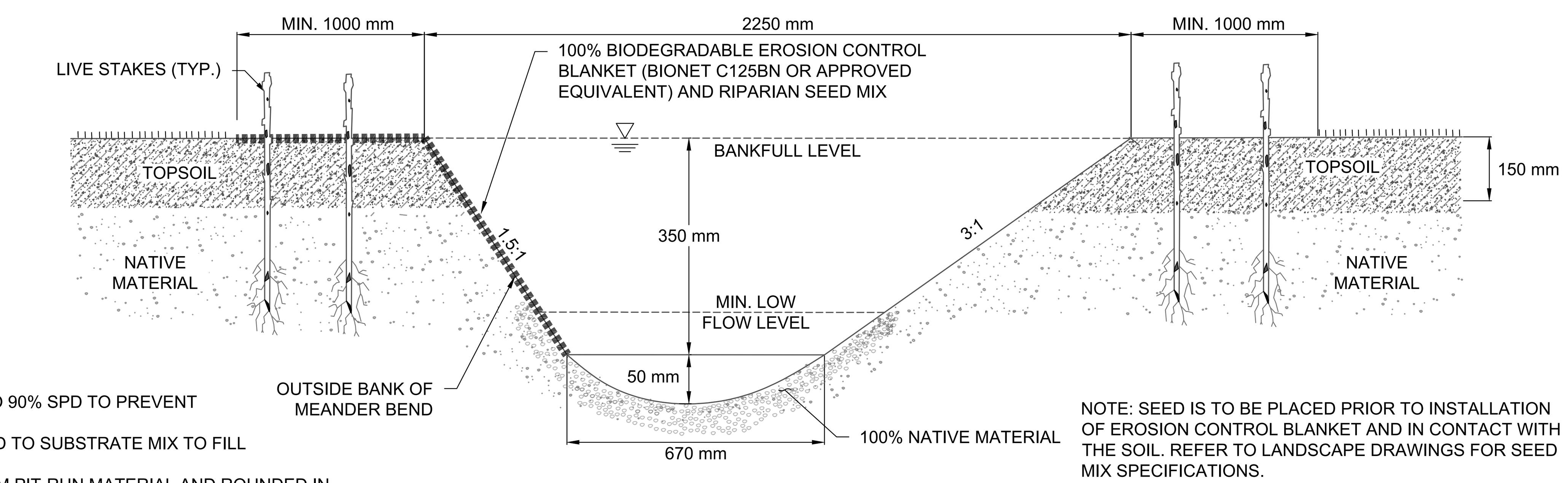
SCALED FOR PLOT ON 'ARCH D' | SCALE: AS NOTED | SHEET 7 OF 12



CHANNEL SUBSTRATE NOTES

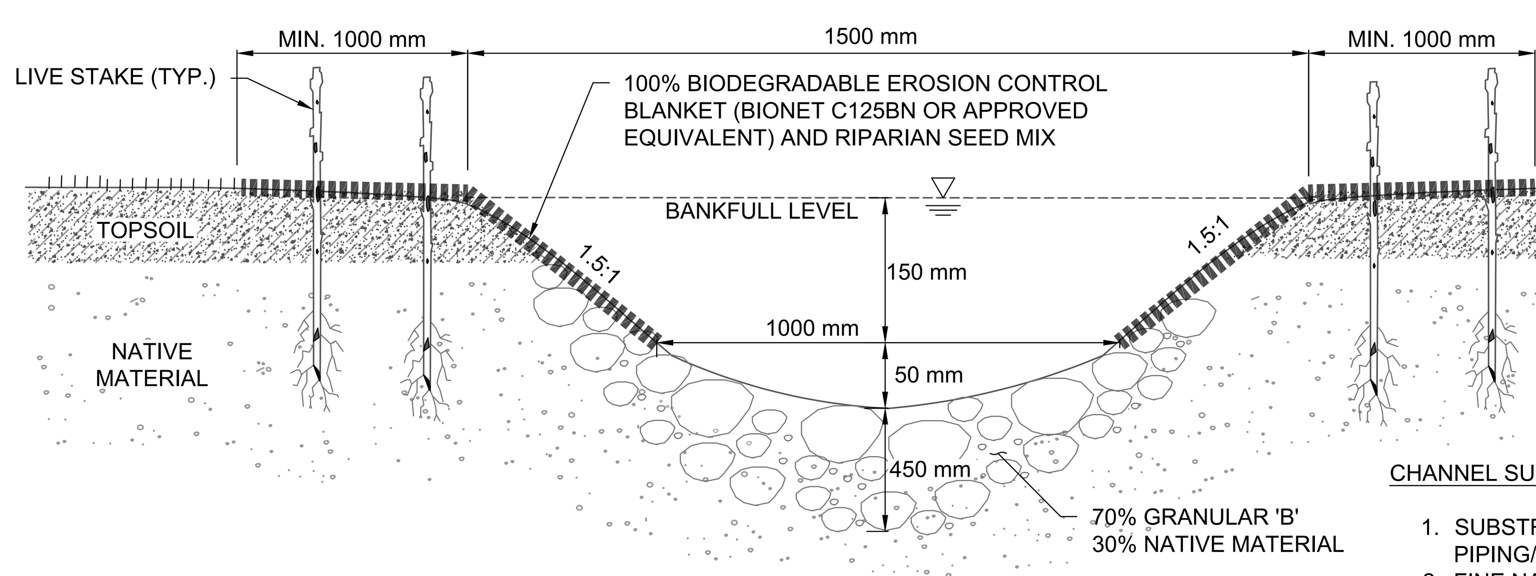
1. SUBSTRATES TO BE COMPACTED TO 90% SPD TO PREVENT PIPING/FLOW-THROUGH.
2. FINE NATIVE MATERIAL TO BE ADDED TO SUBSTRATE MIX TO FILL INTERSTITIAL VOIDS, AS REQUIRED.
3. GRANULAR 'B' TO BE SOURCED FROM PIT-RUN MATERIAL AND ROUNDED IN NATURE. NO CRUSHED ROCK, LIMESTONE OR POST-CONSTRUCTION MATERIALS ARE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

TYPICAL SHALLOW UNDULATION - MSMC-TRIB-01 DS
REACH R3S1 (REACH 1)
N.T.S.



NOTE: SEED IS TO BE PLACED PRIOR TO INSTALLATION OF EROSION CONTROL BLANKET AND IN CONTACT WITH THE SOIL. REFER TO LANDSCAPE DRAWINGS FOR SEED MIX SPECIFICATIONS.

TYPICAL DEEP UNDULATION - MSMC-TRIB-01 DS
REACH R3S1 (REACH 1)
N.T.S.



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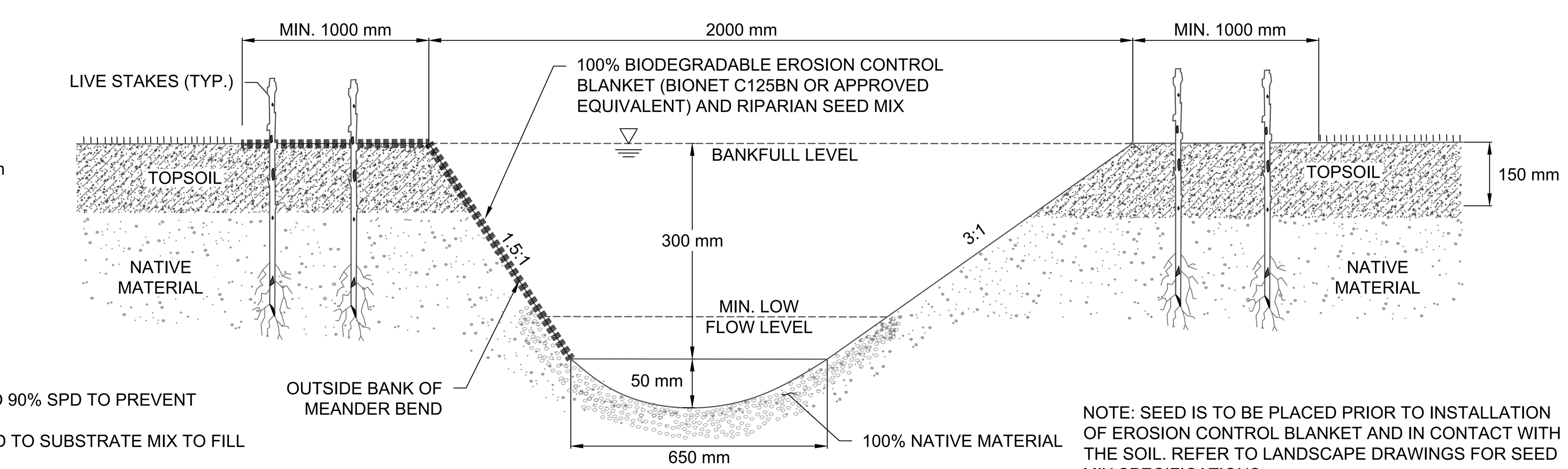
TYPICAL SHALLOW UNDULATION - MSMC-TRIB-01 DS
REACH R3S1 (REACH 2)
N.T.S.



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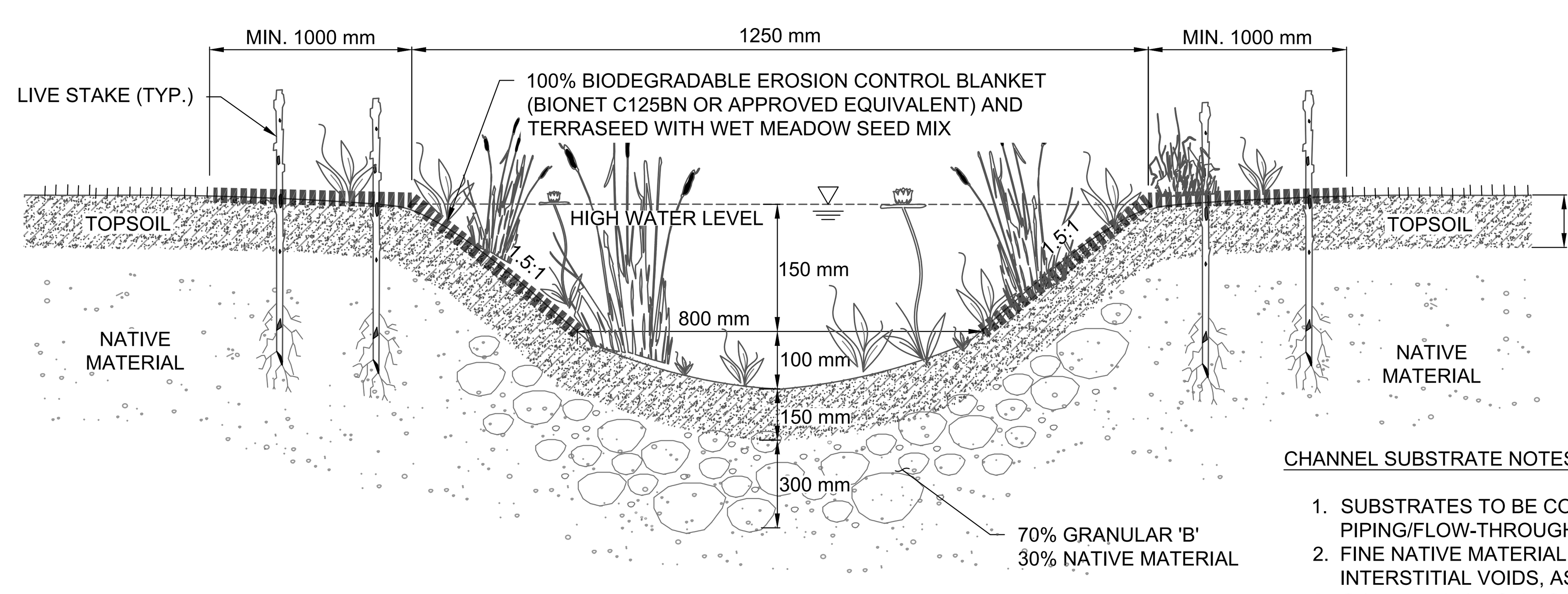
TYPICAL DEEP UNDULATION - MSMC-TRIB-01 DS
REACH R3S1 (REACH 2)
N.T.S.



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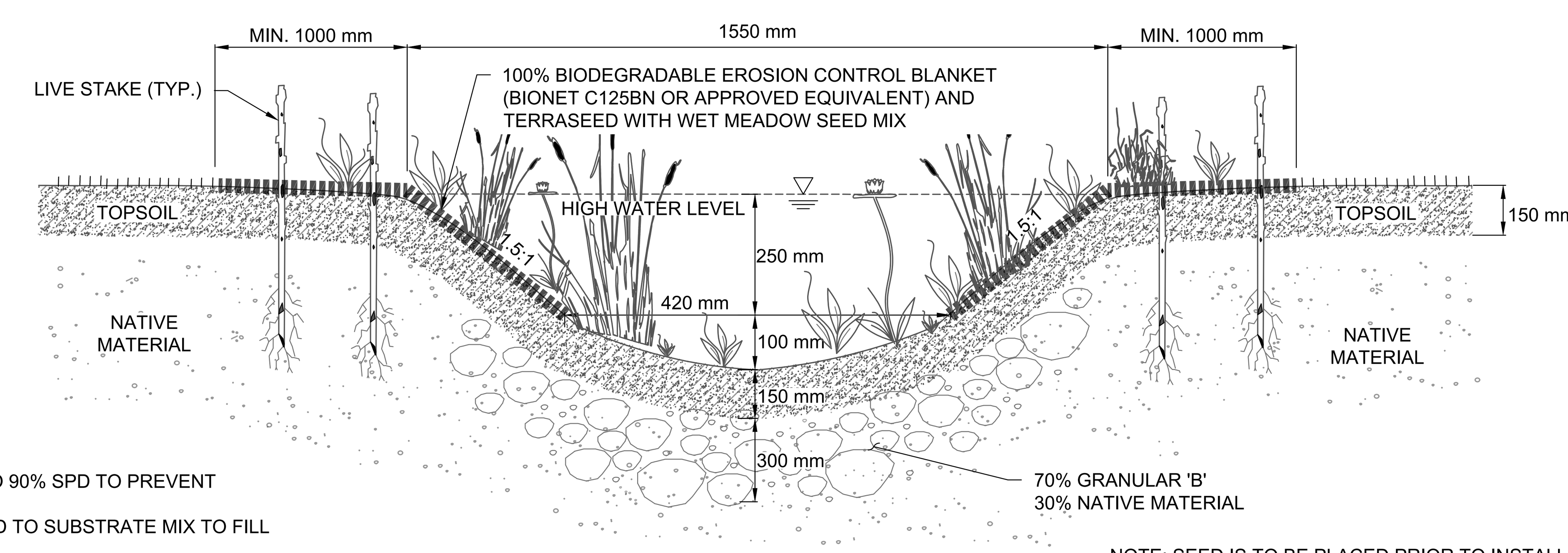
TYPICAL SHALLOW UNDULATION - MSMC-TRIB-03 US (REACH R5S1)
N.T.S.



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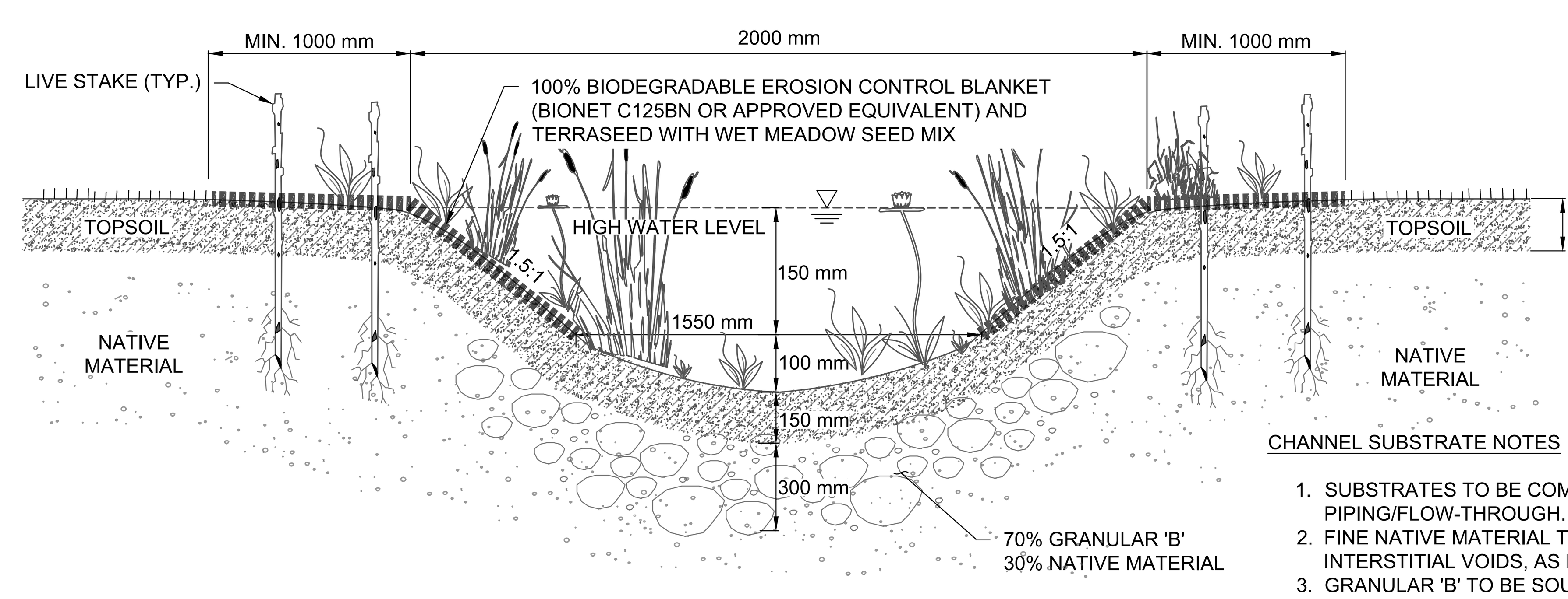
TYPICAL DEEP UNDULATION - MSMC-TRIB-03 US (REACH R5S1)
N.T.S.



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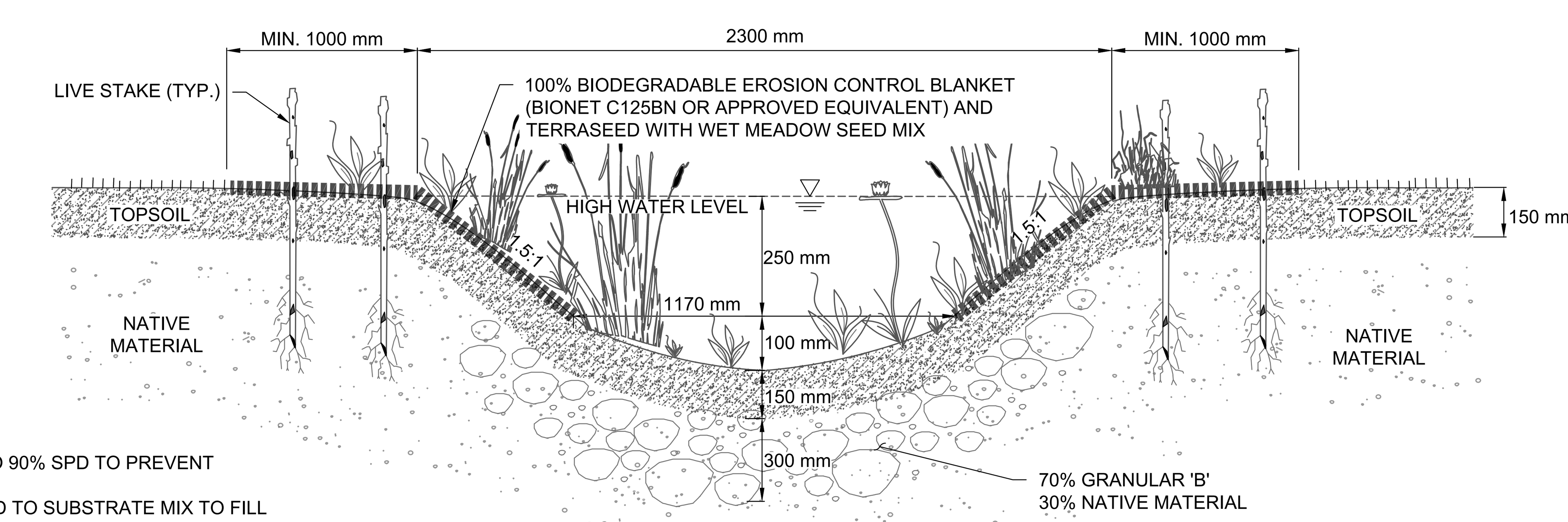
TYPICAL SHALLOW UNDULATION - MSMC-TRIB-03 DS (REACH R5S0)
N.T.S.



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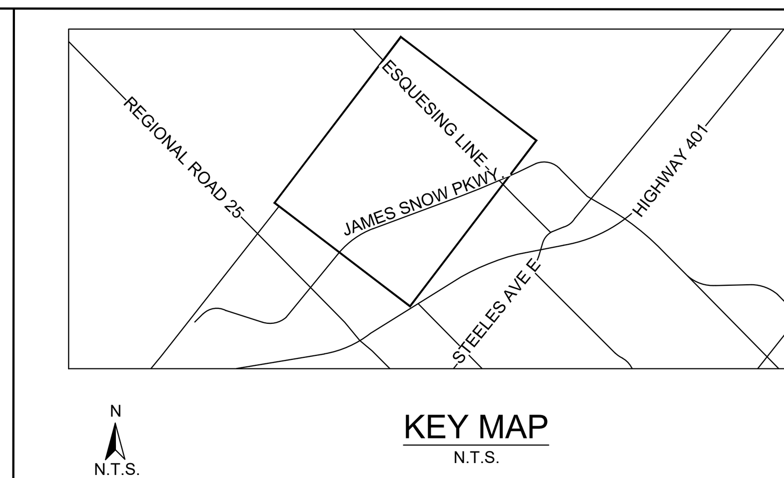
TYPICAL DEEP UNDULATION - MSMC-TRIB-03 DS (REACH R5S0)
N.T.S.

DRAFT FOR DISCUSSION



KEY MAP
N.T.S.

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1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD | CHECKED BY: PV
DRAWN BY: AS | DATE: APRIL 2022

PROFESSIONAL GEOSCIENTISTS ONTARIO
PAUL V. VILLARD
PRACTISING MEMBER
0957
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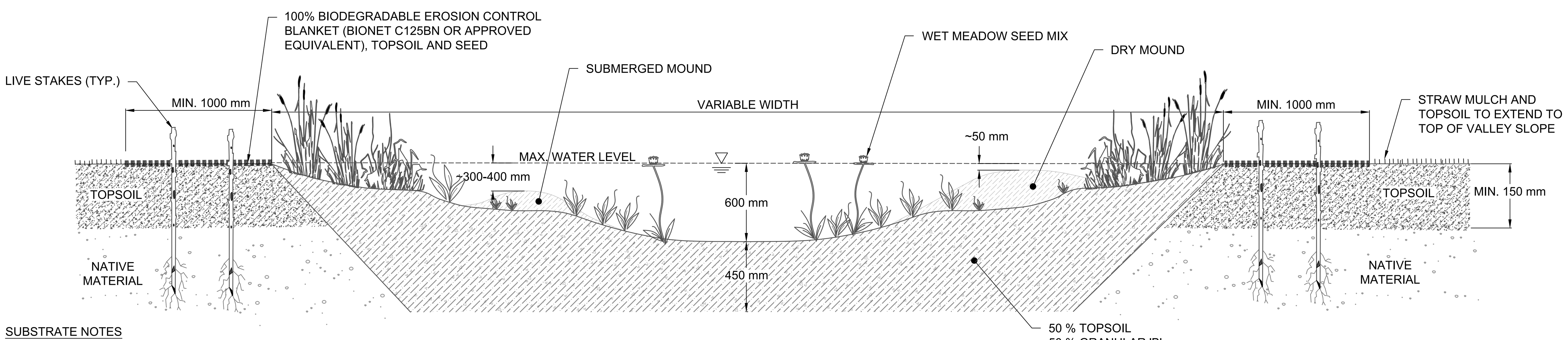
NORTH PORTA LANDS
ORLANDO CORPORATION

CONCEPTUAL CHANNEL DESIGN
RESTORATION DETAILS

PROJECT No.: 21059 | DRAWING No.: DET-1
SCALE: AS NOTED | SHEET 9 OF 12

SCALED FOR PLOT ON 'ARCH D'



SUBSTRATE NOTES

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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.

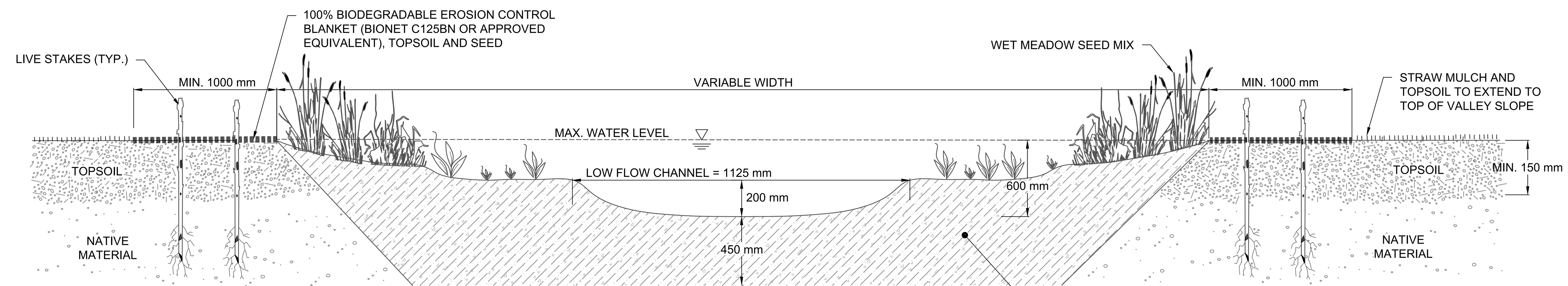
NOTE: SEED IS TO BE PLACED PRIOR TO INSTALLATION OF EROSION CONTROL BLANKET AND IN CONTACT WITH THE SOIL. REFER TO LANDSCAPE DRAWINGS FOR SEED MIX SPECIFICATIONS.

WETLAND CROSS SECTION
N.T.S.

WET MEADOW SEED MIX

COMMON NAME	SPECIES	PERCENTAGE
AWL FRUITED SEDGE	*Carex stipata*	2
BEBB'S SEDGE	*Carex bebbii*	5
BONESET	*Eupatorium perfoliatum*	2
FOX SEDGE	*Carex vulpinoidea*	25
COMMON BUR REED	*Sparganium eurycarpum*	5
BLADDER SEDGE	*Carex intumescens*	5
NODDING BUR-MARIGOLD	*Bidens cernua*	2
SWAMP ASTER	*Aster puniceus*	1
JOINTED RUSH	*Juncus articulatus*	5
SPOTTED JOE PYE WEED	*Eupatorium maculatum*	1
MONKEY FLOWER	*Mimulus ringens*	1
SWAMP MILKWEED	*Asclepias incarnata*	10
TUSSOCK SEDGE	*Carex stricta*	5
VIRGINIA WILD RYE	*Elymus virginicus*	25
WOOL GRASS BULRUSH	*Scirpus cyperinus*	1

NOTES
1. APPLY SEED MIX AT A RATE OF 30 kg PER HECTARE.
2. SEEDING SHALL OVERLAP ADJACENT GROUND COVER BY 300 mm.
3. SIMULTANEOUSLY APPLY A NURSE CROP OF VIRGINIA WILD RYE (*Elmus virginicus*) AT A RATE OF 22 kg PER HECTARE.
4. WATER SOIL AFTER SEED APPLICATION.



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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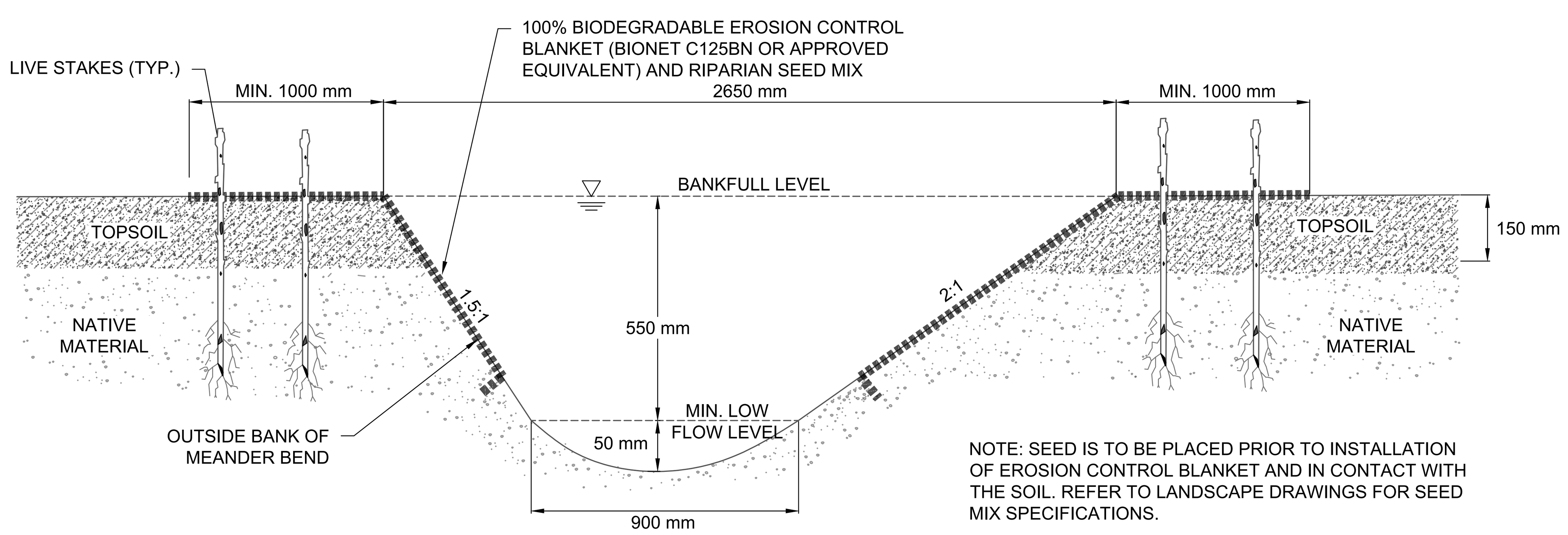
ONLINE WETLAND CROSS SECTION - MSMC-TRIB-01 DS
N.T.S.

RIPARIAN SEED MIX

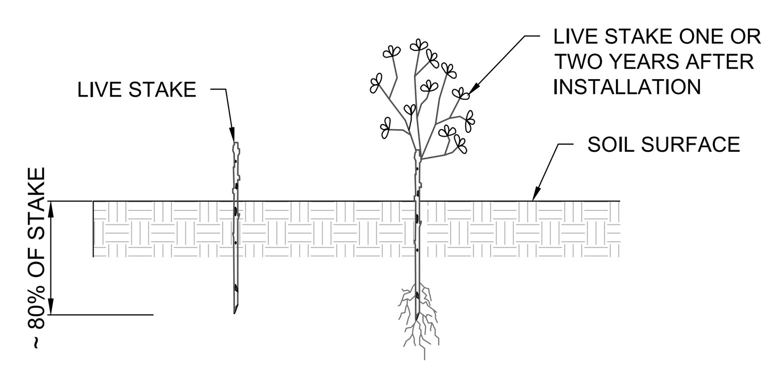
COMMON NAME	SPECIES	PERCENTAGE
BIG BLUESTEM	*Andropogon gerardii*	30
BLACK EYED SUSAN	*Rudbeckia hirta*	6
BOTTLEBRUSH GRASS	*Elymus hystrix*	5
FOWL BLUEGRASS	*Poa palustris*	30
FOWL MEADOW GRASS	*Glyceria striata*	2
FOX SEDGE	*Carex vulpinoidea*	25
NEW ENGLAND ASTER	*Aster novae-angliae*	2

NOTES
1. APPLY SEED MIX AT A RATE OF 30 kg PER HECTARE.
2. SEEDING SHALL OVERLAP ADJACENT GROUND COVER BY 300 mm.
3. APPLY A NURSE CROP OF ANNUAL OATS (Avena Sativa) AT A RATE OF 60 kg PER HECTARE.
4. WATER SOIL AFTER SEED APPLICATION.



NOTE: SEED IS TO BE PLACED PRIOR TO INSTALLATION OF EROSION CONTROL BLANKET AND IN CONTACT WITH THE SOIL. REFER TO LANDSCAPE DRAWINGS FOR SEED MIX SPECIFICATIONS.

OVERWINTER POOL TYPICAL SECTION
N.T.S.

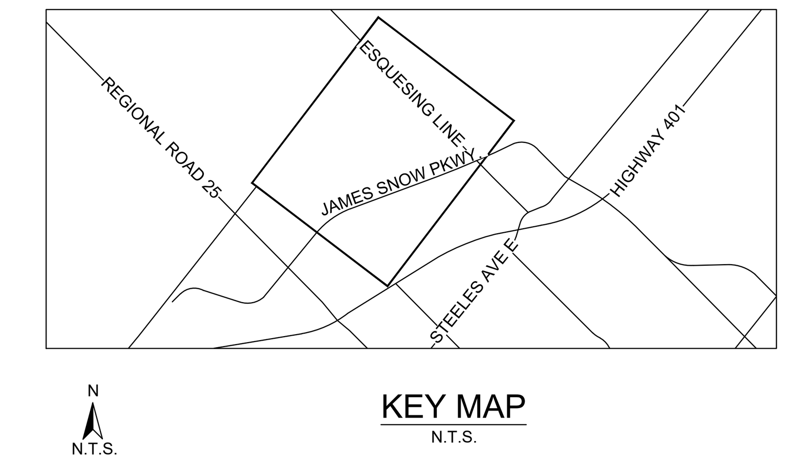


SPECIES AND QUANTITIES

COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
RED OSIER DOGWOOD	*Cornus stolonifera*	6690	1 m, BARE ROOT
PUSSY WILLOW	*Salix discolor*	6690	1 m, BARE ROOT
SANDBAR WILLOW	*Salix exigua*	6690	1 m, BARE ROOT

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.



KEY MAP
N.T.S.

GENERAL NOTES

1. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
2. THE CONTRACTOR MUST NOTIFY THE CONTRACT ADMINISTRATOR AND CONSERVATION AUTHORITY OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
3. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
4. LAYOUT MUST BE REVIEWED AND APPROVED BY THE CONTRACT ADMINISTRATOR.

TIMING OF WORKS

1. WORKS SHALL BE COMPLETED BETWEEN JULY 1ST TO MARCH 31ST.
2. TREE CLEARING SHOULD BE COMPLETED OUTSIDE THE BIRD NESTING SEASON 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 STOCKPILED SOILS THAT ARE STORED FOR PROLONGED PERIODS WITH THE APPLICATION OF A NURSE CROP AT A RATE OF 60 kg/ha.
5. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW. ON SOILS THAT WILL BE EXPOSED FOR PROLONG PERIODS, TEMPORARILY INSTALL A BIODEGRADABLE EROSION CONTROL BLANKET ON EXPOSED SOILS, OR APPLY A NURSE CROP AT A RATE OF 60 KG/HA.
6. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE.
7. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
8. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. SEDIMENT CONTROLS MUST BE INSPECTED DAILY TO ENSURE THAT THEY ARE IN GOOD REPAIR AND FUNCTIONING AS INTENDED.
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.
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7. ALL TEMPORARY SEDIMENT CONTROLS MUST BE REMOVED AFTER THE CONTRACT ADMINISTRATOR DEEMS THE SITE TO BE STABLE.

DELETERIOUS SUBSTANCE CONTROL/SPILL MANAGEMENT

1. PREVENT THE RELEASE OF SEDIMENT, SEDIMENT-LADEN WATER, RAW CONCRETE, CONCRETE LEACHATE OR ANY OTHER DELETERIOUS SUBSTANCES INTO ANY WATERBODY, RAVINE OR STORM SEWER SYSTEM.
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.
4. A SPILL CONTAINMENT KIT MUST BE READILY ACCESSIBLE ON SITE IN THE EVENT OF A RELEASE OF A DELETERIOUS SUBSTANCE TO THE ENVIRONMENT. ONSITE STAFF MUST BE TRAINED IN ITS USE.
5. THE CONTRACT ADMINISTRATOR MUST BE NOTIFIED IMMEDIATELY IN THE EVENT OF A SPILL OF DELETERIOUS SUBSTANCE.

WORK AREA ISOLATION

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2. 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.
3. 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.

	DATE	BY	REVISIONS
2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES

DESIGNED BY: PV/LD | CHECKED BY: PV
DRAWN BY: AS | DATE: APRIL 2022

PROFESSIONAL GEOSCIENTISTS ONTARIO
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PRACTISING MEMBER
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22.04.14

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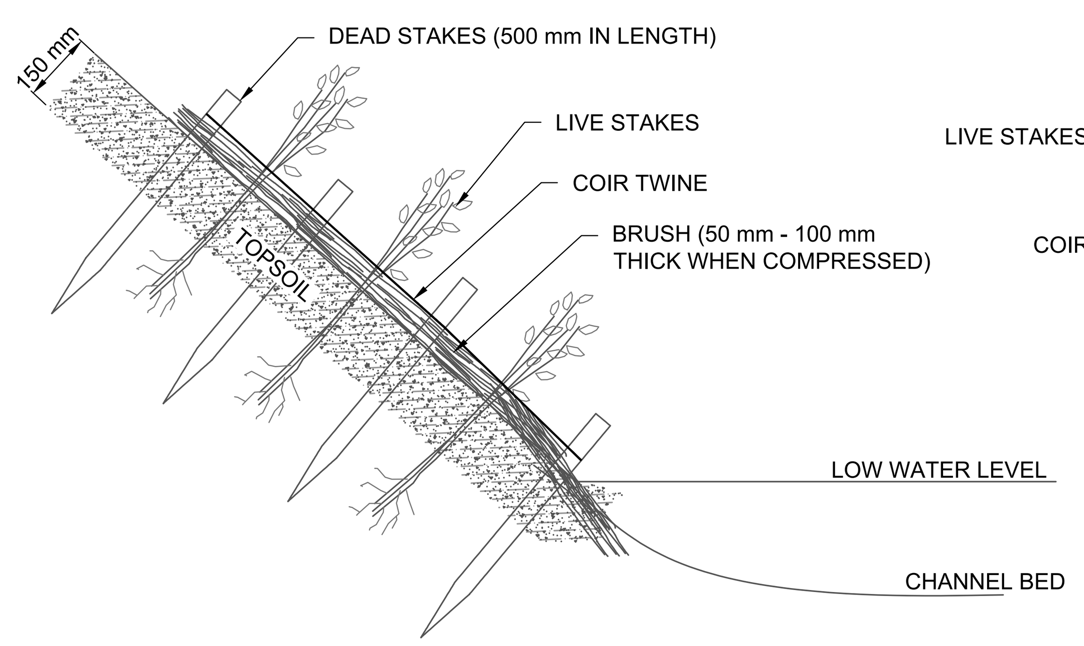
NORTH PORTA LANDS
ORLANDO CORPORATION

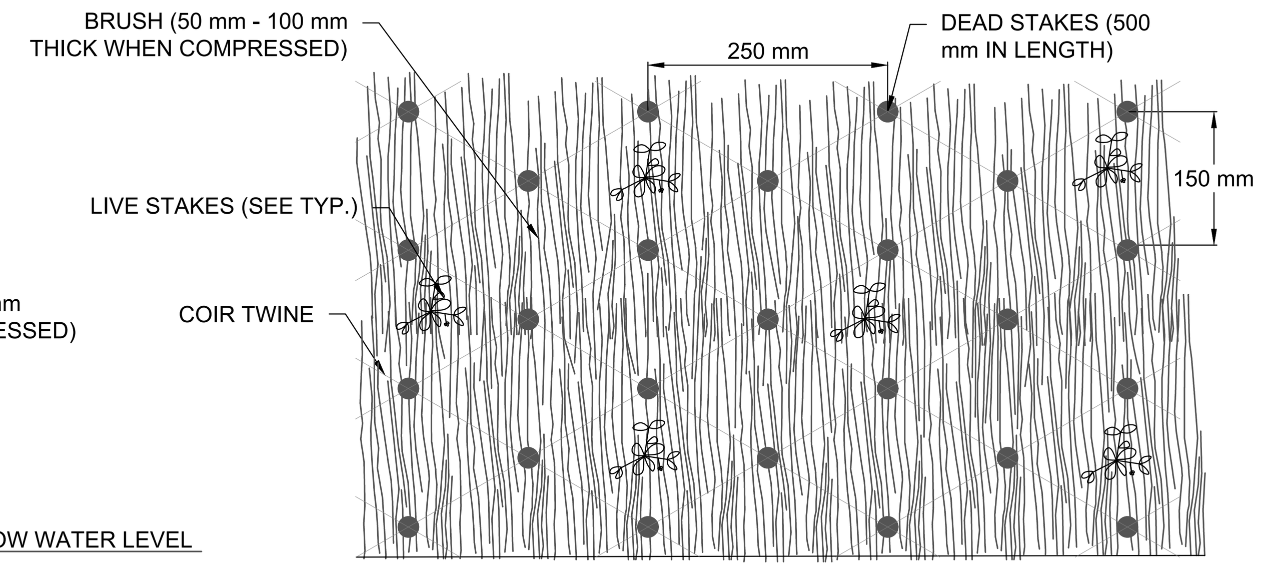
CONCEPTUAL CHANNEL DESIGN
RESTORATION DETAILS

PROJECT No.: 21059 | DRAWING No.: DET-2
SCALE: AS NOTED | SHEET 10 OF 12

DRAFT FOR DISCUSSION

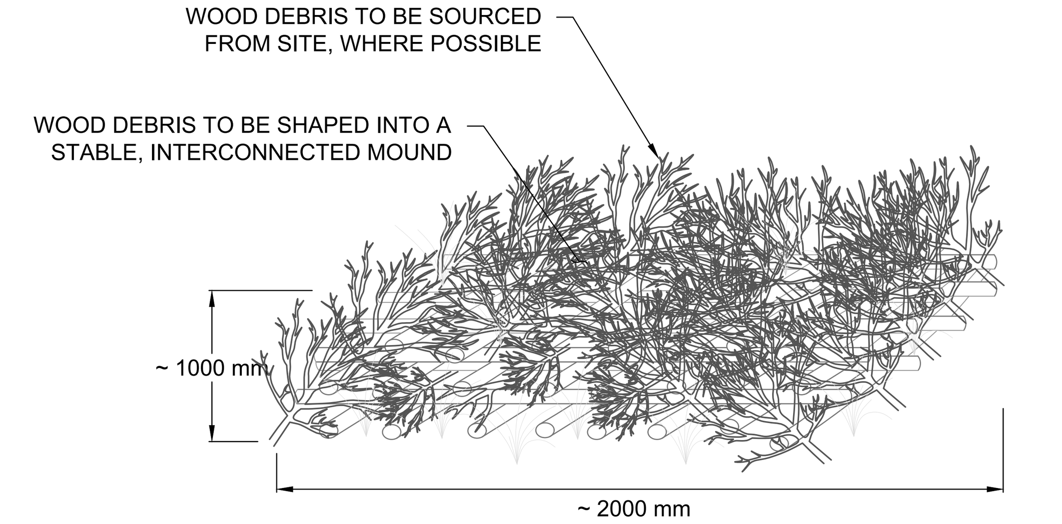
SCALED FOR PLOT ON 'ARCH D'





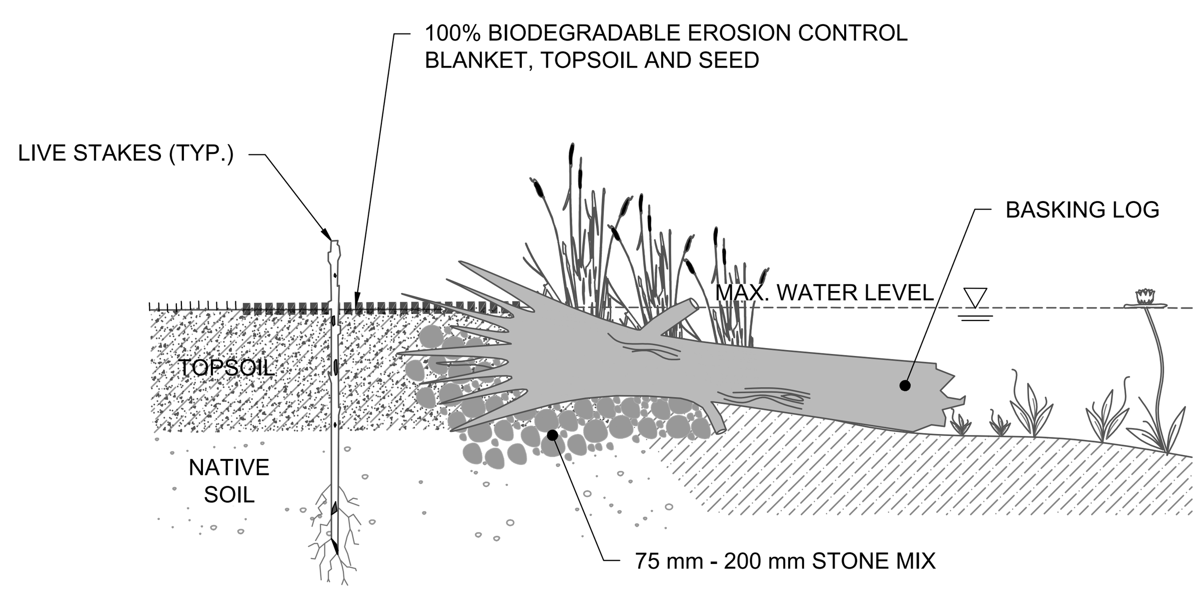
NOTES
1. LIVE BRANCHES TO CONSIST OF WILLOW AND DOGWOOD SPECIES, APPROXIMATELY 1 m IN LENGTH AND 50 mm - 100 mm IN WIDTH.
2. BRANCHES TO BE KEPT IN MOIST AND COLD UNTIL INSTALLATION.
3. BRUSH MATTRESS TO BE INSTALLED WHILE BRANCHES ARE DORMANT.
4. BRANCHES TO BE PLACED ON SLOPE WITH BUTT END TOWARDS VALLEY FLOOR AND PUSHED INTO SOIL.
5. BRANCHES MUST BE FLEXIBLE ENOUGH TO CONFORM TO THE SLOPE SURFACE IRREGULARITIES.
6. 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.
7. TAMP LIVE STAKES BETWEEN DEAD STAKES.
8. FILL VOIDS BETWEEN BRANCHES OF THE BRUSH MATTRESS WITH SOIL TO PROMOTE ROOTING.

BRUSH MATTRESS
N.T.S.



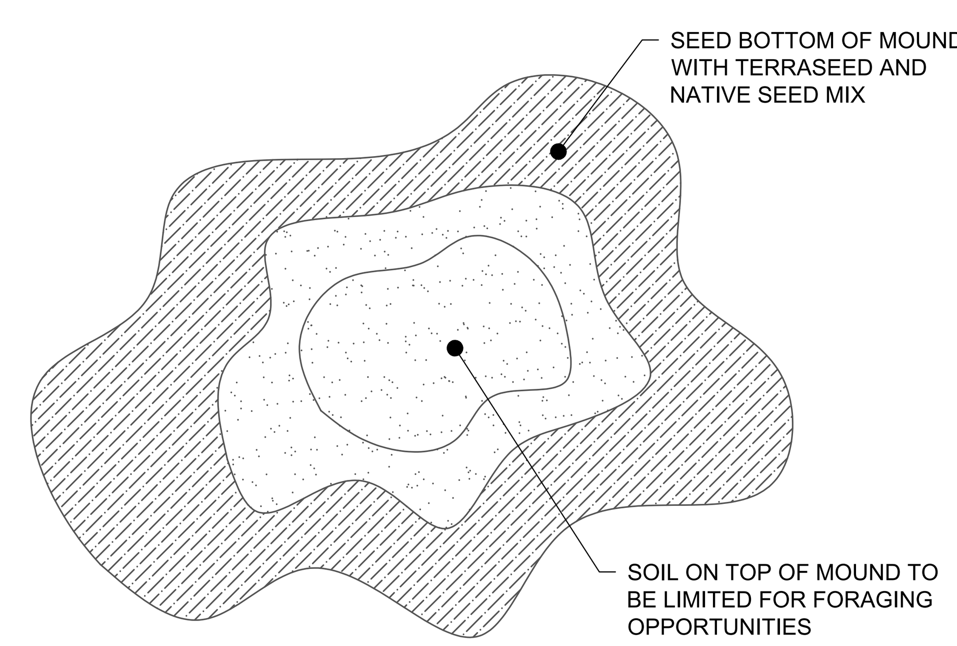
NOTES
1. LARGEST AND HEAVIEST LOG MATERIAL SHOULD BE PLACED ON THE BASE OF THE BRUSH PILE. THE SMALLEST BRUSH MATERIAL SHOULD BE PLACED AT THE TOP.
2. LOGS SHOULD BE FORMED INTO A PALLET SHAPE.
3. HEIGHT OF BRUSH PILE IS NOT TO EXCEED 1.0 M.
4. A MIX OF HARDWOOD AND SOFTWOOD SHOULD BE USED.
5. PLANT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

PALLET TYPE WOOD PILE
N.T.S



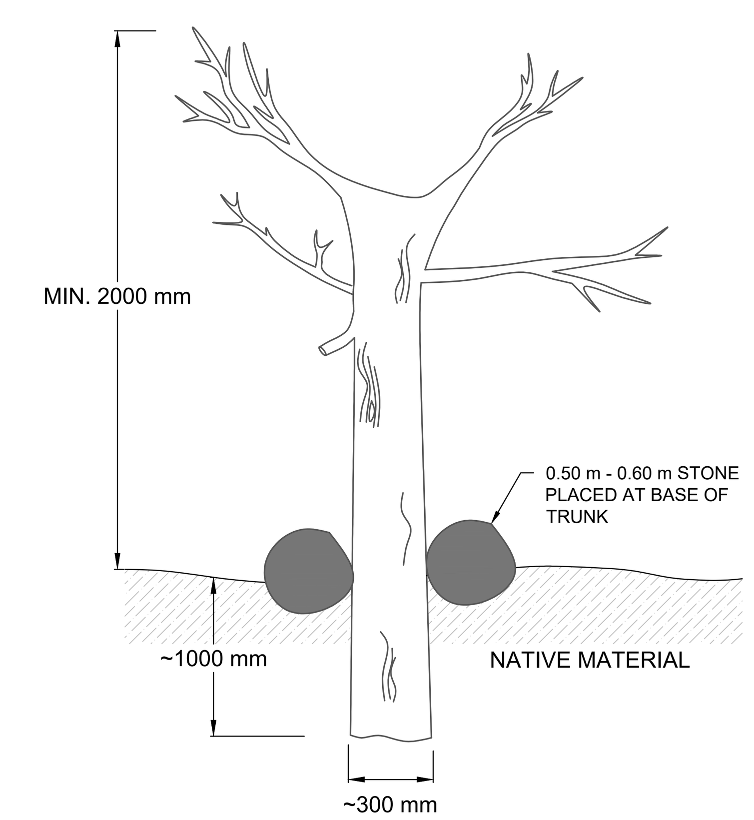
NOTES
1. ANCHOR AND SUPPORT BASKING LOGS WITH 75 mm - 200 mm STONE MIX.
2. FIRMLY COMPACT STONE MIX TO PREVENT THROUGH FLOW.
3. BURY 1/3 OF LOG INTO SOIL.
4. LENGTH OF BASKING LOGS ARE TO BE INSTALLED 1000 - 1500 mm INTO WET AREA.
5. BASKING LOGS TO BE A MINIMUM 500 mm IN DIAMETER AND 2000 - 2500 mm 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.

BASKING LOG
N.T.S.



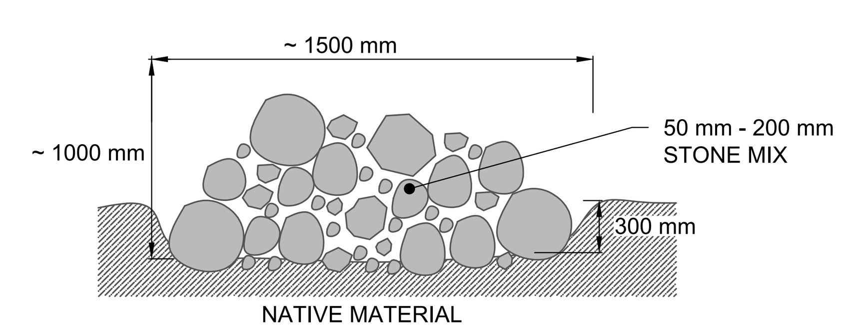
NOTES
1. HEIGHT OF TERRESTRIAL MOUND SHALL BE 1000 mm TO 2000 mm.
2. PLACEMENT OF VEGETATED TERRESTRIAL MOUND TO BE AS PER PLAN, IN DRY AREAS ONLY.
3. CONSTRUCTION OF MOUND TO BE COMPLETED IN CONJUNCTION WITH SITE GRADING ACTIVITIES AS TERRESTRIAL MOUNDS TO BE GRADED TO MATCH EXISTING GROUND AND/OR TIE 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. 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).

RAPTOR POLE
N.T.S.

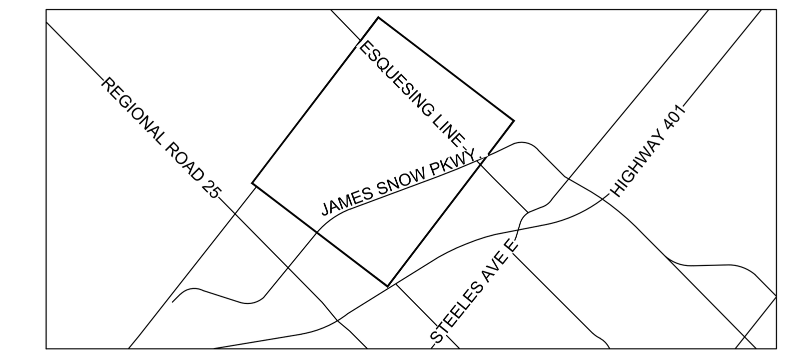


NOTES
1. 50 mm - 200 mm STONE MIX WITH SOME ANGULAR STONES.
2. THE STONE MIX SHOULD PROVIDE A VARIETY OF INTERSTITIAL SPACES.
3. PILES ARE AT LEAST 1500 mm IN DIAMETER AND ~1000 mm HIGH.
4. PARTIALLY BURY PILES 300 - 400 mm TO AVOID ROCKFALL.

ROCK PILE
N.T.S

DRAFT FOR DISCUSSION

SCALED FOR PLOT ON 'ARCH D'



N
N.T.S.

KEY MAP
N.T.S.

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2. ENSURE EQUIPMENT AND MACHINERY ARE IN GOOD OPERATING CONDITION (POWER WASHED), FREE OF LEAKS, EXCESS OIL, AND GREASE.
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2. 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.
3. 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.

2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD | CHECKED BY: PV

DRAWN BY: AS | DATE: APRIL 2022

PROFESSIONAL GEOSCIENTISTS ONTARIO
PAUL V. VILLARD
PRACTISING MEMBER
0957
22.04.14

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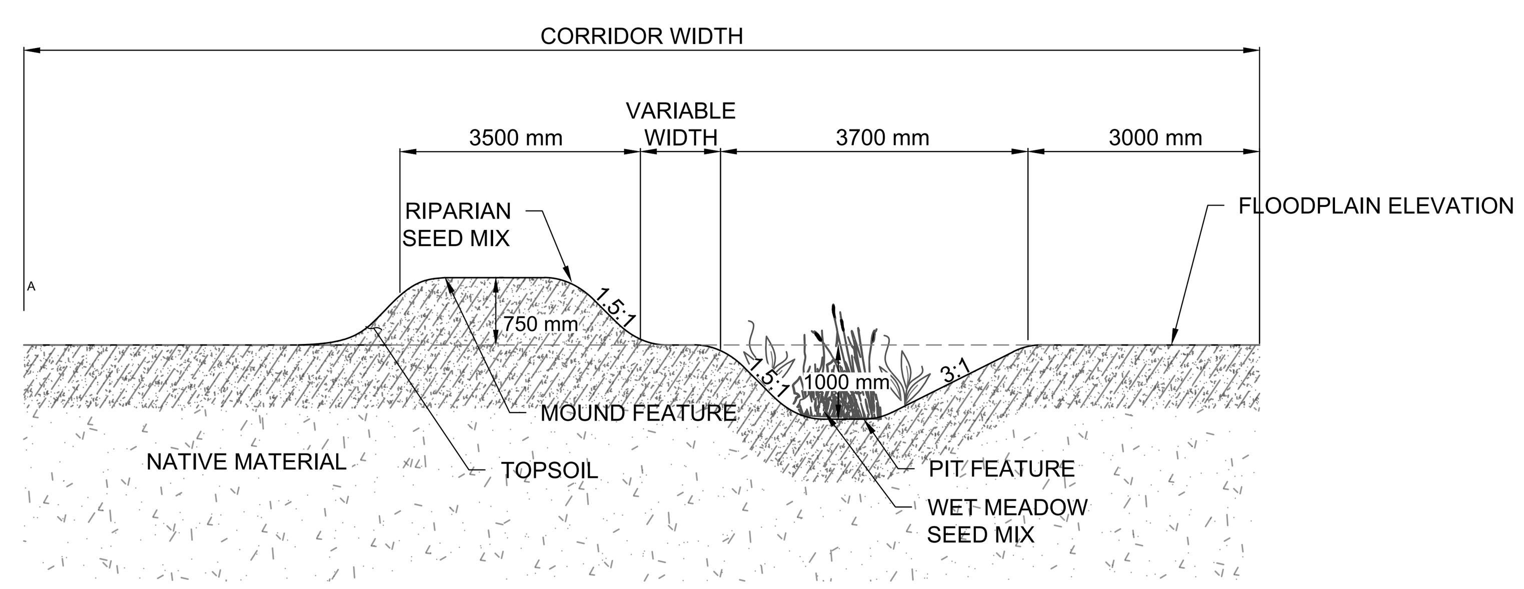
NORTH PORTA LANDS
ORLANDO CORPORATION

CONCEPTUAL CHANNEL DESIGN
RESTORATION DETAILS

PROJECT No.: 21059 | DRAWING No.: DET-3

SCALE: AS NOTED | SHEET 11 OF 12



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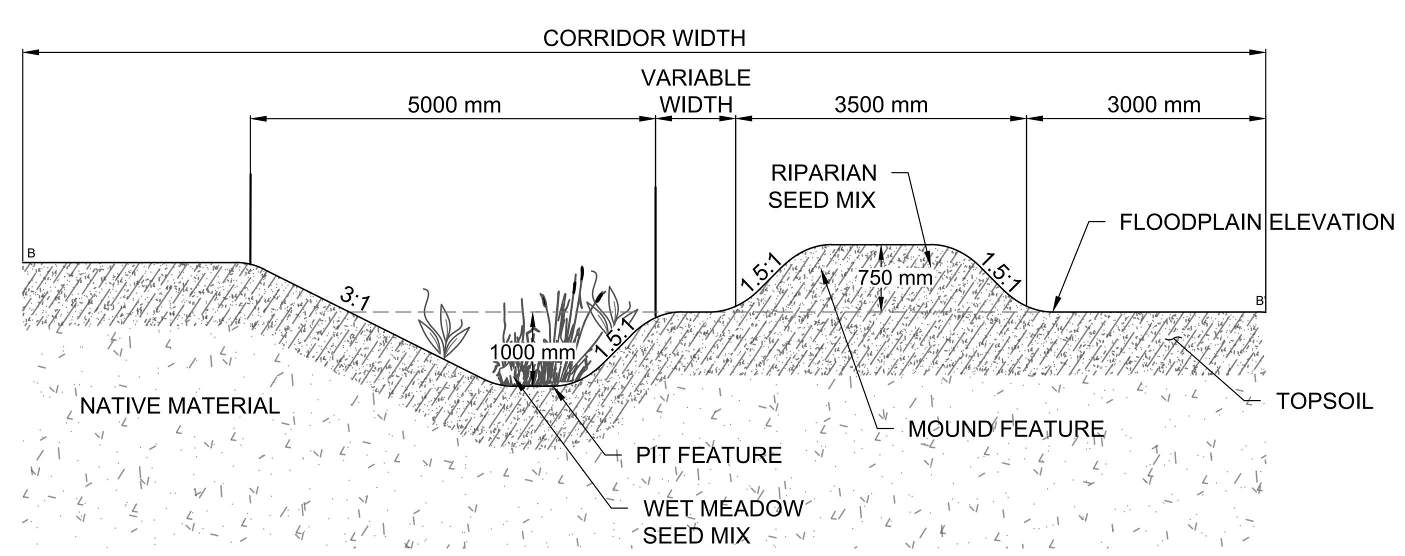

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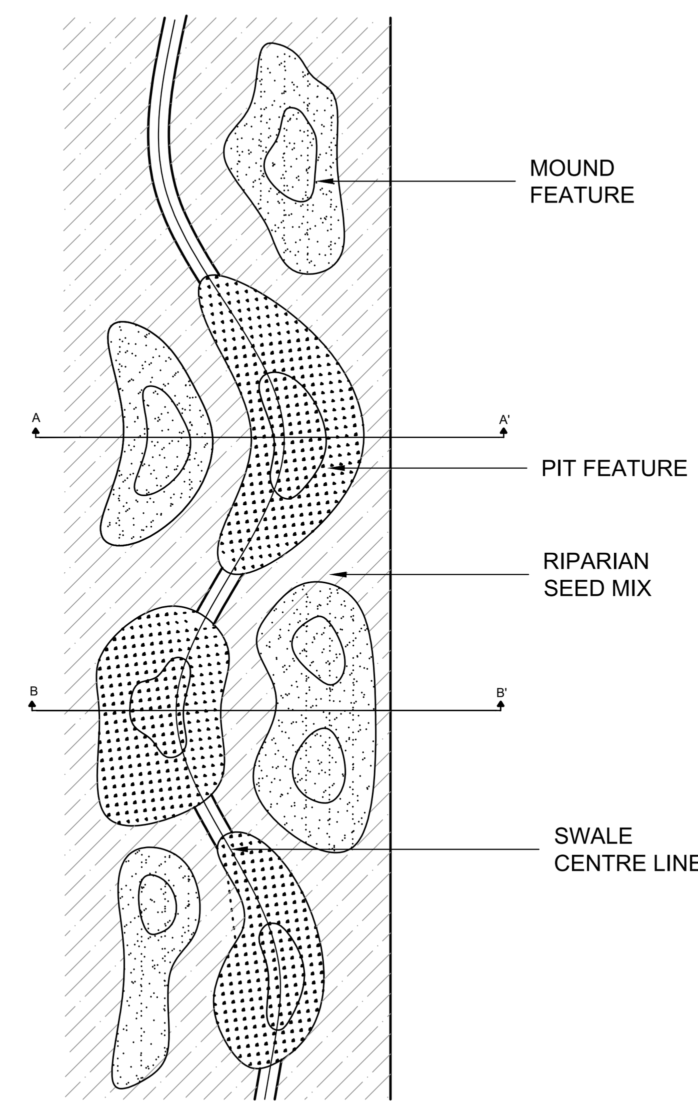

PIT AND MOUND PLAN VIEW

PIT AND MOUND TOPOGRAPHY
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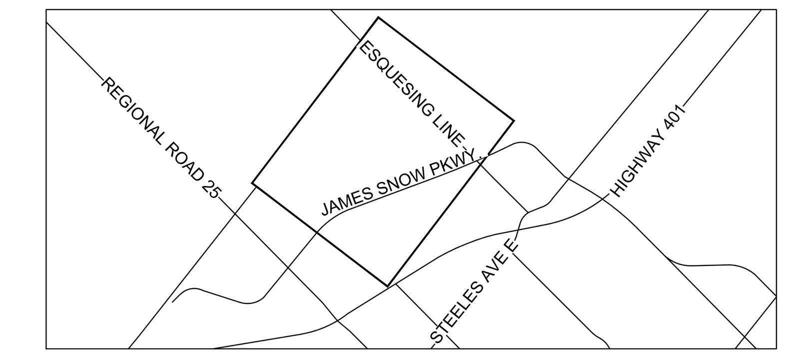

N
N.T.S.

KEY MAP
N.T.S.

GENERAL NOTES

1. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
2. THE CONTRACTOR MUST NOTIFY THE CONTRACT ADMINISTRATOR AND CONSERVATION AUTHORITY OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
3. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
4. LAYOUT MUST BE REVIEWED AND APPROVED BY THE CONTRACT ADMINISTRATOR.

TIMING OF WORKS

1. WORKS SHALL BE COMPLETED BETWEEN JULY 1ST TO MARCH 31ST.
2. TREE CLEARING SHOULD BE COMPLETED OUTSIDE THE BIRD NESTING SEASON 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 STOCKPILED SOILS THAT ARE STORED FOR PROLONGED PERIODS WITH THE APPLICATION OF A NURSE CROP AT A RATE OF 60 kg/ha.
5. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW. ON SOILS THAT WILL BE EXPOSED FOR PROLONG PERIODS, TEMPORARILY INSTALL A BIODEGRADABLE EROSION CONTROL BLANKET ON EXPOSED SOILS, OR APPLY A NURSE CROP AT A RATE OF 60 KG/HA.
6. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE.
7. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
8. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. SEDIMENT CONTROLS MUST BE INSPECTED DAILY TO ENSURE THAT THEY ARE IN GOOD REPAIR AND FUNCTIONING AS INTENDED.
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.

DELETERIOUS SUBSTANCE CONTROL/SPILL MANAGEMENT

1. PREVENT THE RELEASE OF SEDIMENT, SEDIMENT-LADEN WATER, RAW CONCRETE, CONCRETE LEACHATE OR ANY OTHER DELETERIOUS SUBSTANCES INTO ANY WATERBODY, RAVINE OR STORM SEWER SYSTEM.
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.
4. A SPILL CONTAINMENT KIT MUST BE READILY ACCESSIBLE ON SITE IN THE EVENT OF A RELEASE OF A DELETERIOUS SUBSTANCE TO THE ENVIRONMENT. ONSITE STAFF MUST BE TRAINED IN ITS USE.
5. THE CONTRACT ADMINISTRATOR MUST BE NOTIFIED IMMEDIATELY IN THE EVENT OF A SPILL OF DELETERIOUS SUBSTANCE.

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. 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.
3. 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.

2.	22.04.14	AS	SECOND CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
1.	21.08.09	LD	FIRST CONCEPTUAL DESIGN SUBMISSION TO AGENCIES
	DATE	BY	REVISIONS

DESIGNED BY: PV/LD	CHECKED BY: PV
DRAWN BY: AS	DATE: APRIL 2022

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
0957
ONTARIO
22.04.14

GEO MORPHIX
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Earth Science
Observations
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Campbellville, Ontario L9T 1B0
T: 416.920.0926
www.geomorphix.com

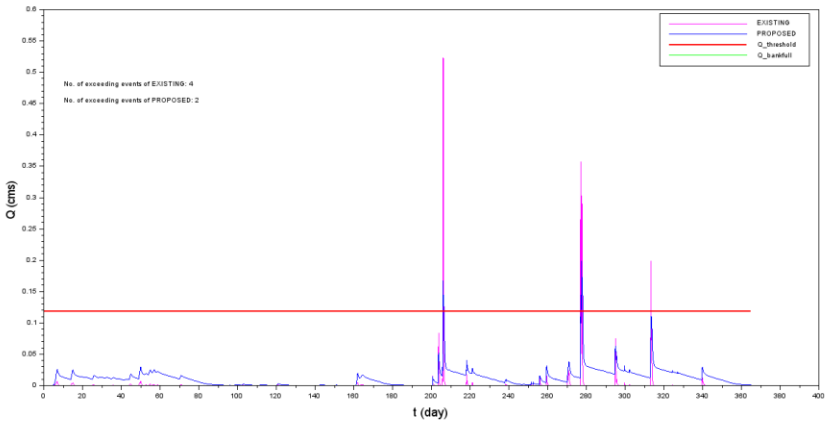
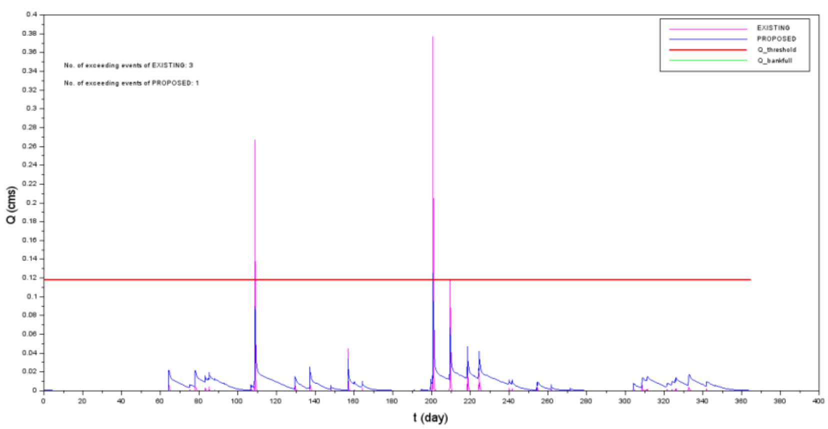
NORTH PORTA LANDS
ORLANDO CORPORATION

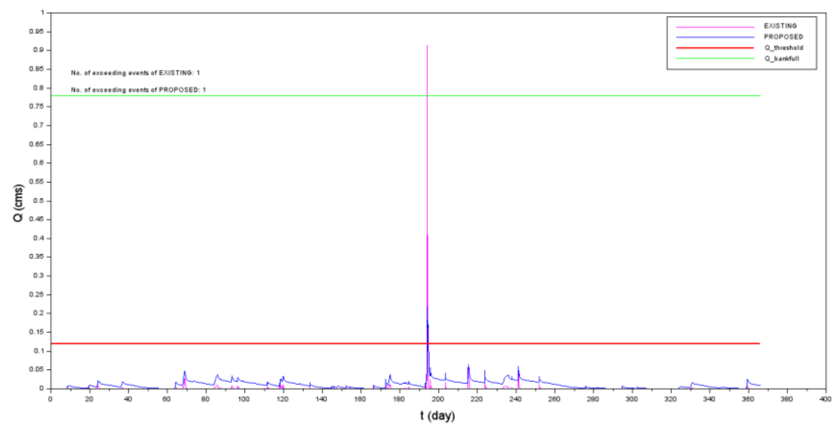
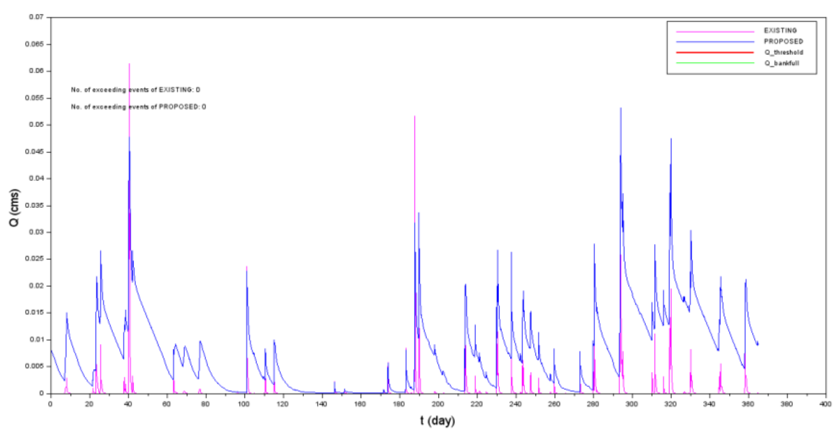
CONCEPTUAL CHANNEL DESIGN
RESTORATION DETAILS

PROJECT No.: 21059	DRAWING No.: DET-4
SCALE: AS NOTED	SHEET 12 OF 12

SCALED FOR PLOT ON 'ARCH D'

Appendix G
Erosion Modelling Hydrographs

Reach **R3S0C** Scenario 1 1962	
Reach **R3S0C** Scenario 1 1963	

Reach **R3S0C** Scenario 1 1964	
Reach **R3S0C** Scenario 1 1965	

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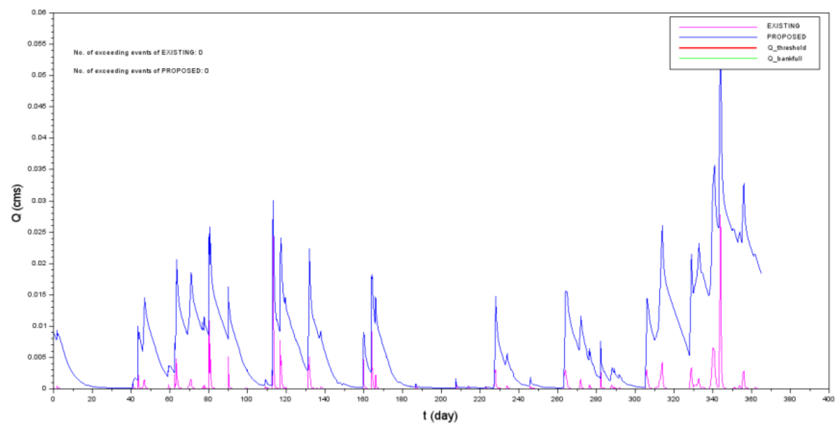
<td>
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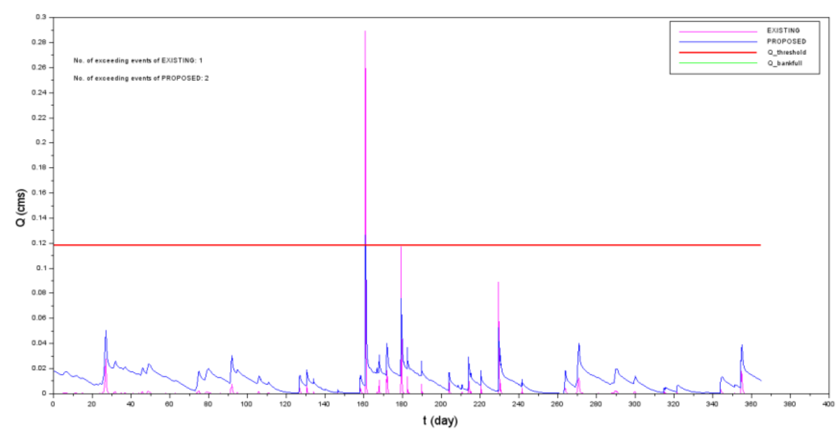
<td>
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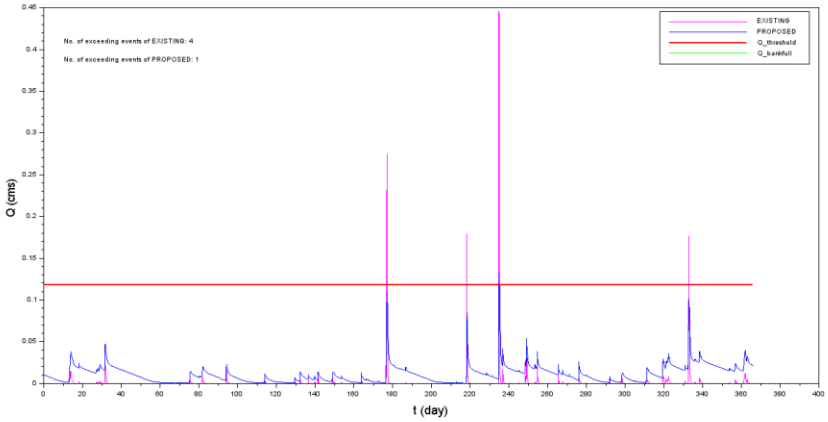
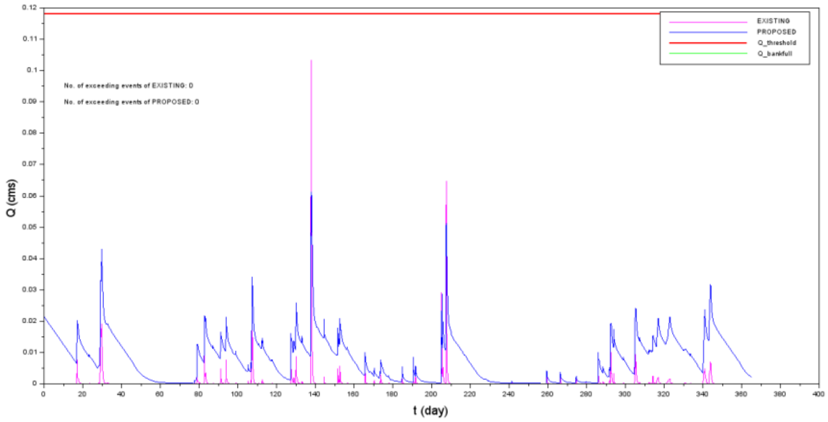
Reach **R3S0C** Scenario 1 1968	
Reach **R3S0C** Scenario 1 1969	

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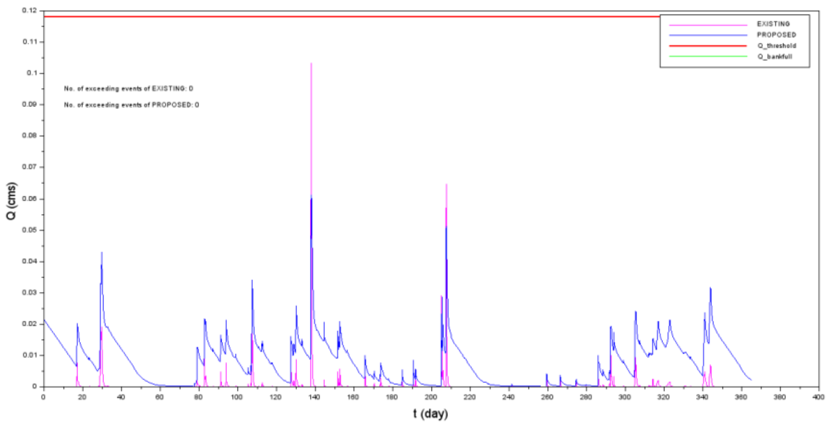
<td>
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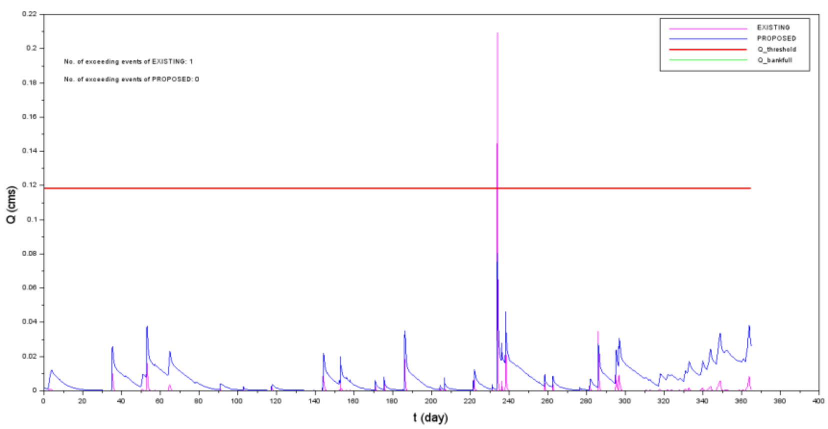
<td>
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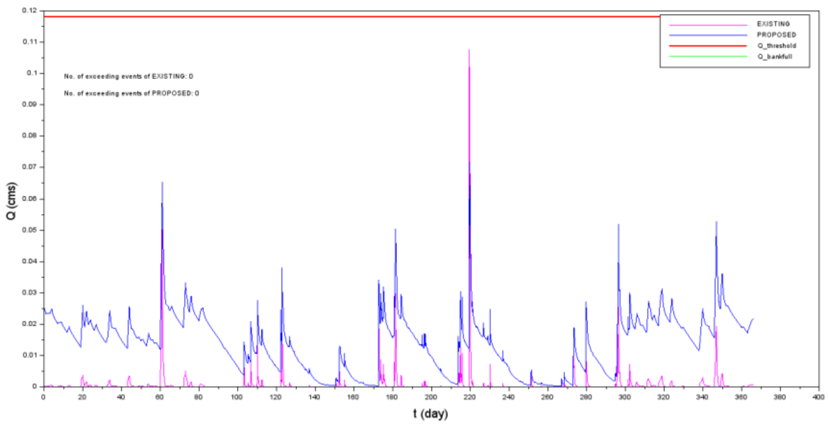
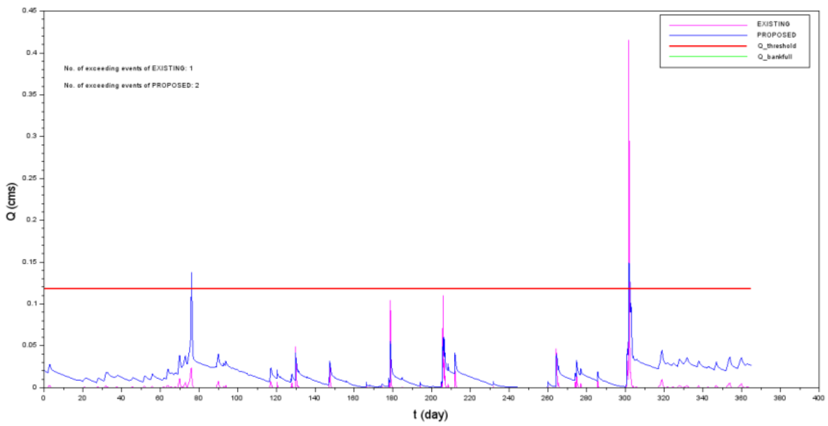
Reach **R3S0C** Scenario 1 1972	
Reach **R3S0C** Scenario 1 1973	

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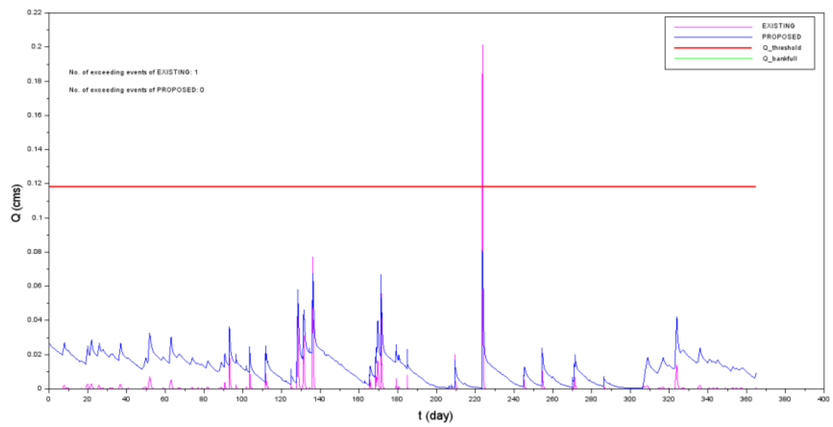
1974</td><td>
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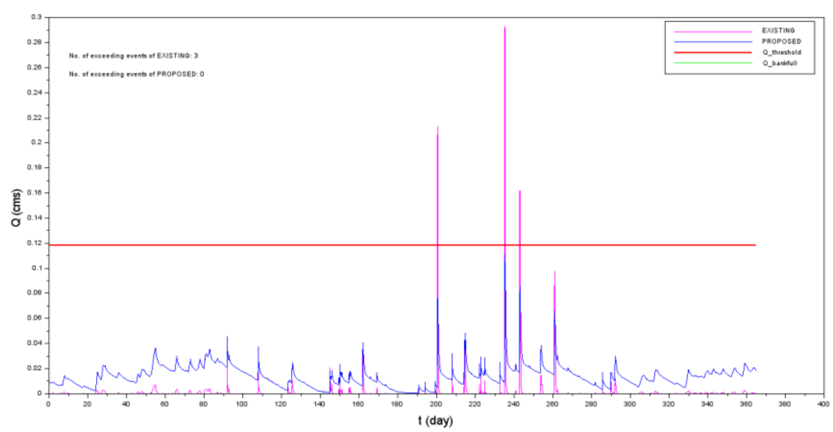
1975</td><td>
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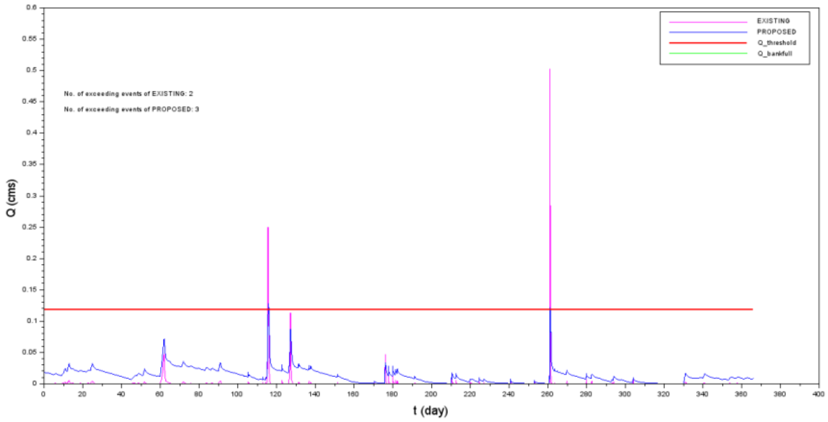
1976</td><td>
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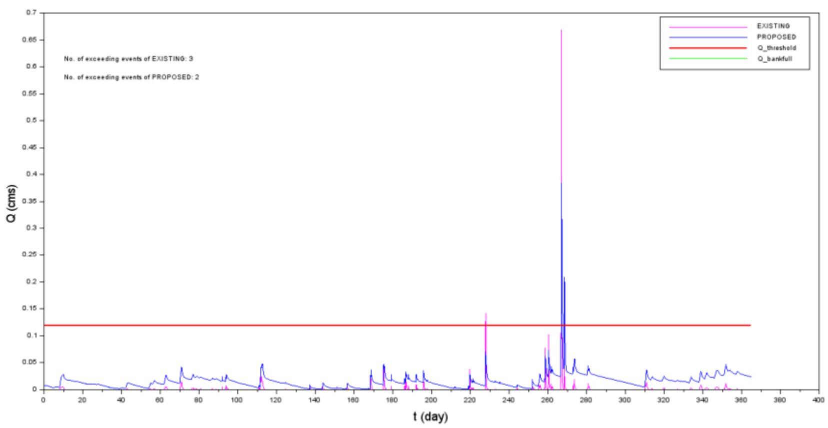
1977</td><td>
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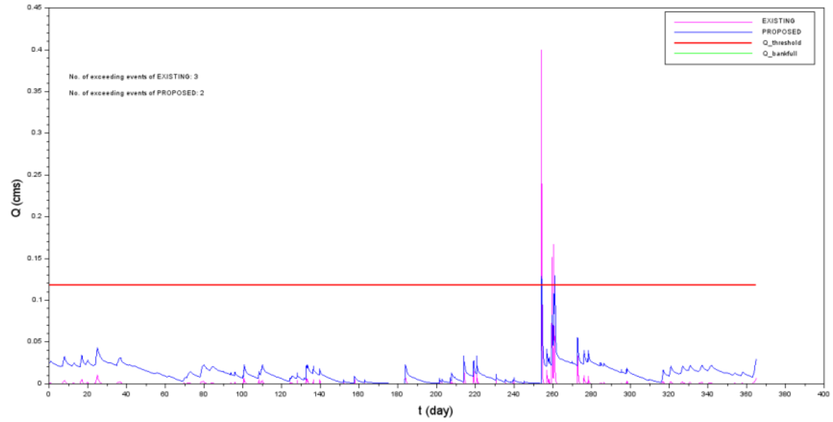
<td>
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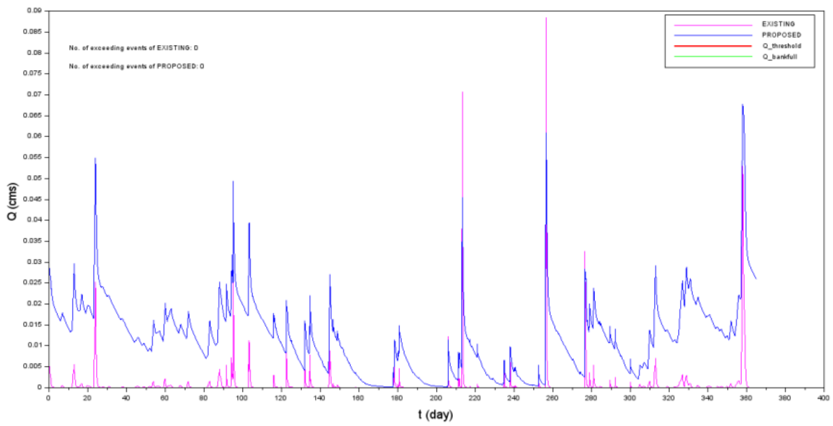
<td>
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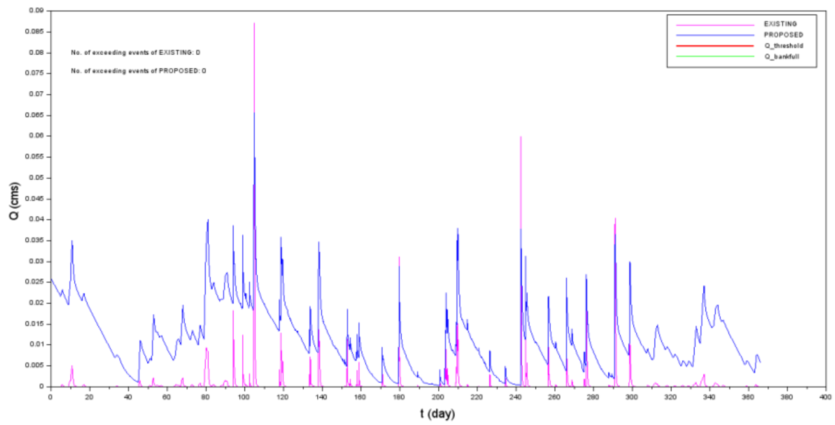
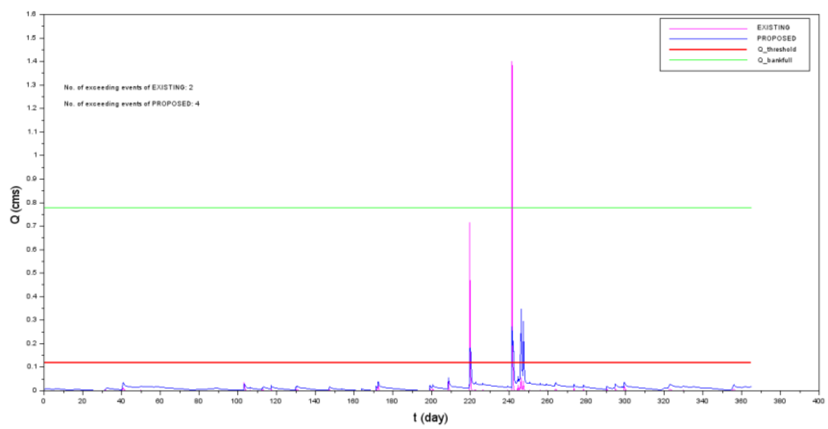
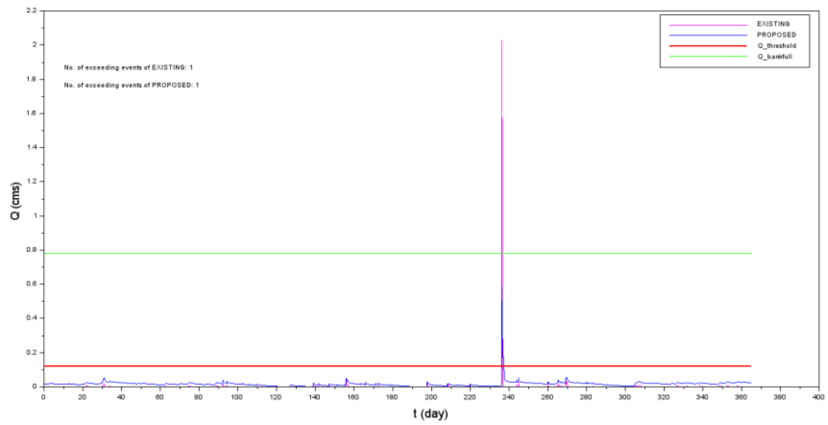
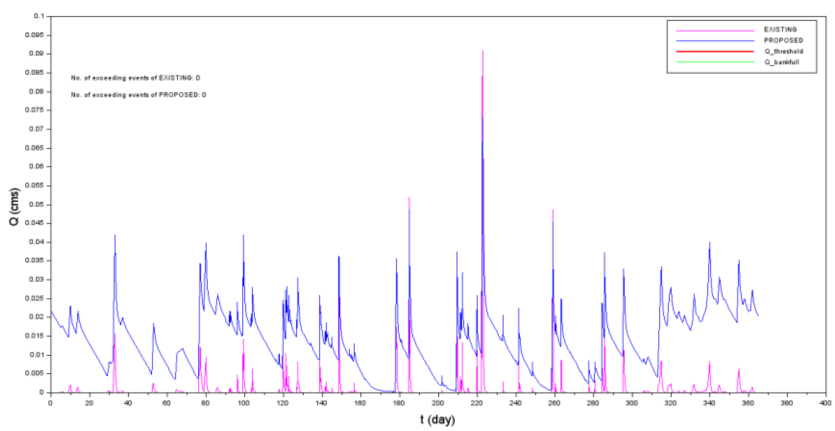
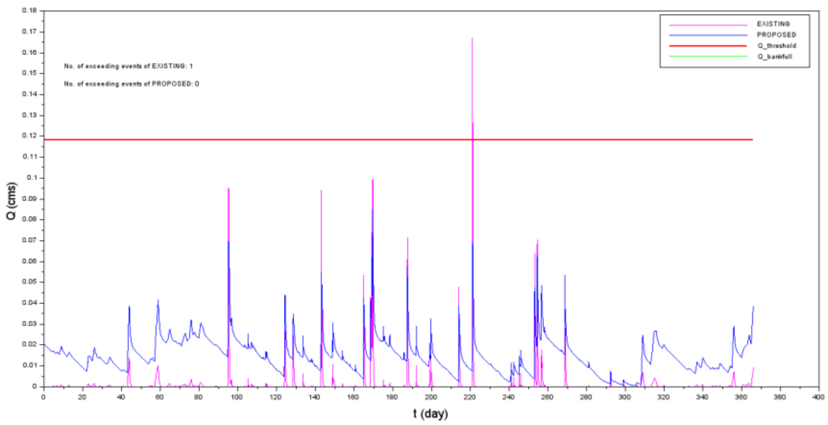
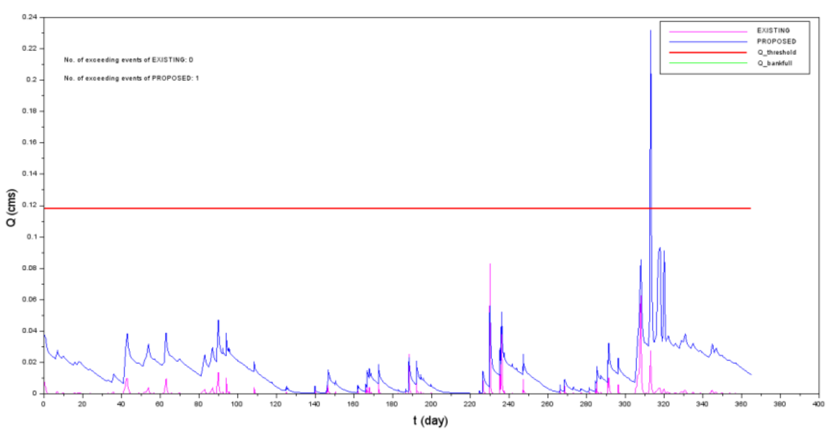
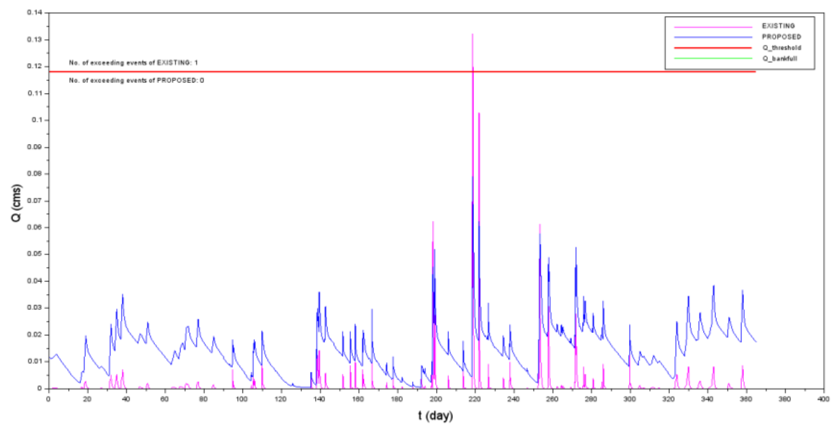
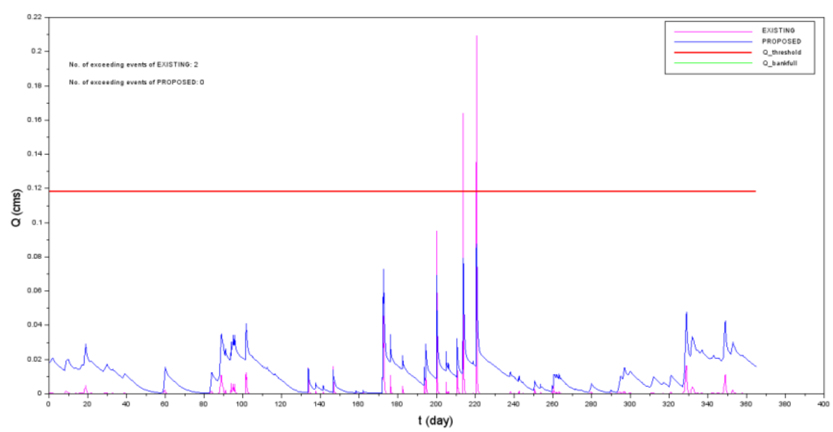
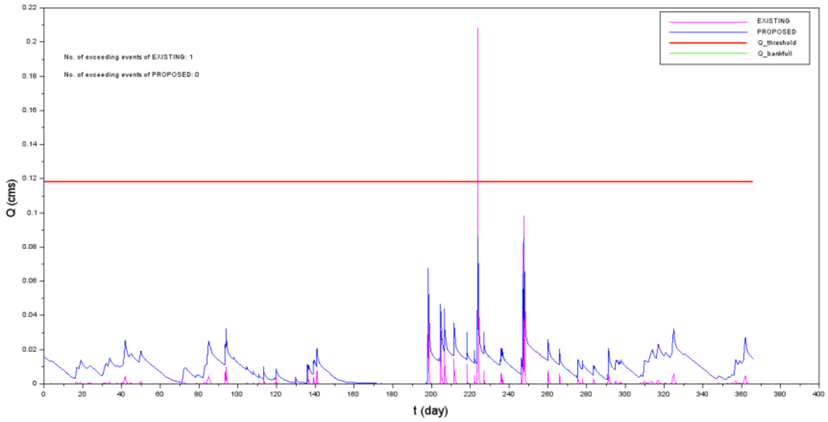
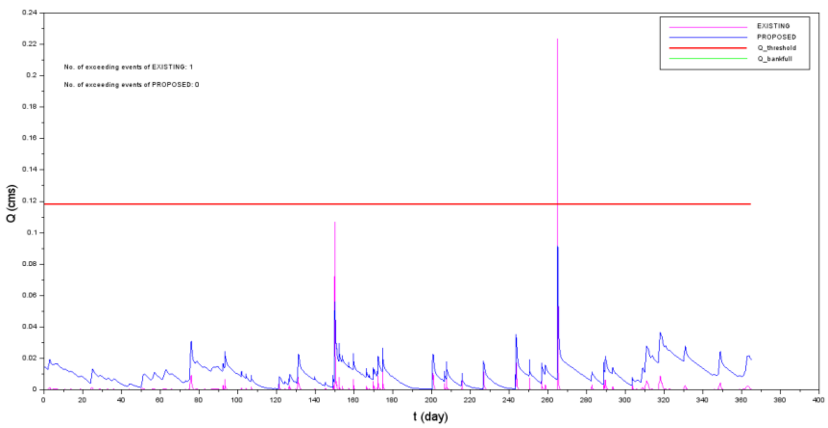
Reach **R3S0C** Scenario 1 1980	
Reach **R3S0C** Scenario 1 1981	

Reach **R3S0C** Scenario 1 1982	
Reach **R3S0C** Scenario 1 1983	

Reach **R3S0C** Scenario 1 1984	
Reach **R3S0C** Scenario 1 1985	

Reach **R3S0C** Scenario 1 1986	
Reach **R3S0C** Scenario 1 1987	

Reach **R3S0C** Scenario 1 1988	
Reach **R3S0C** Scenario 1 1989	

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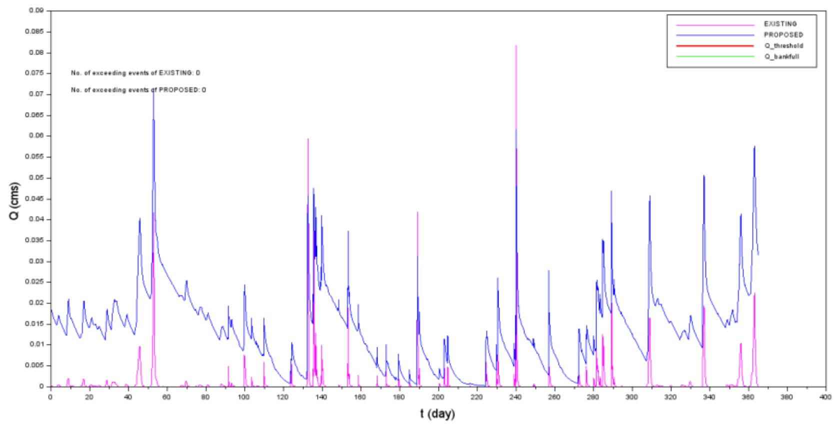
1990</td><td></td></tr>
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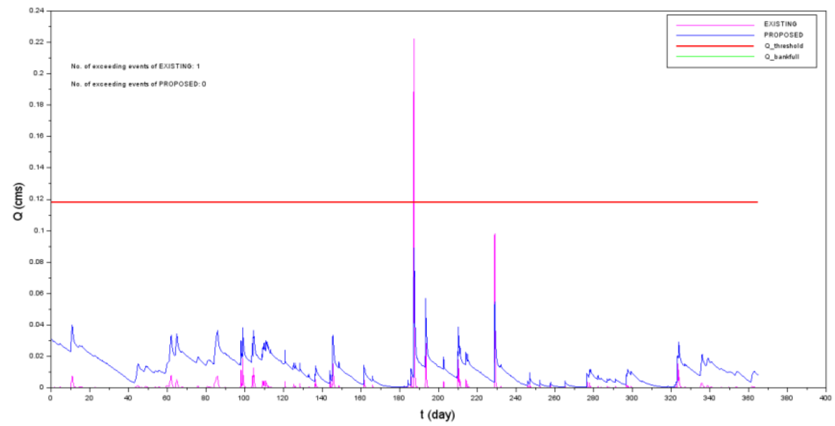
1991</td><td></td></tr>
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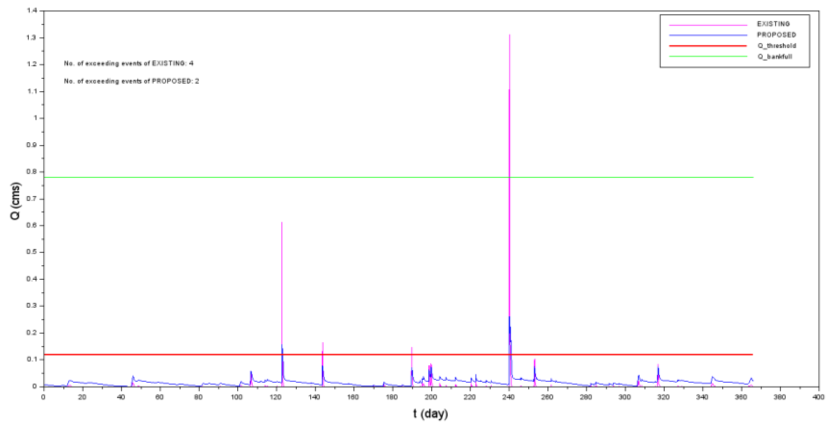
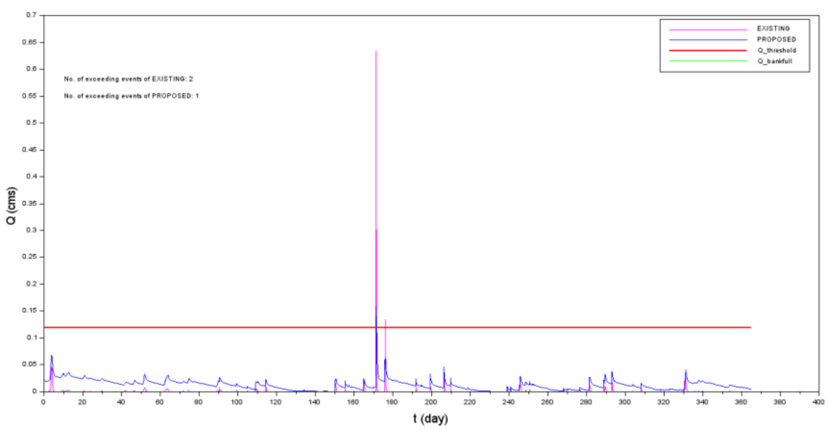
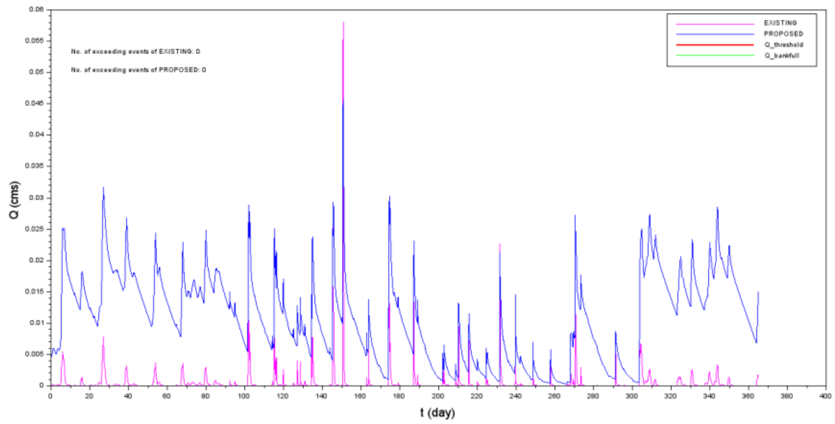
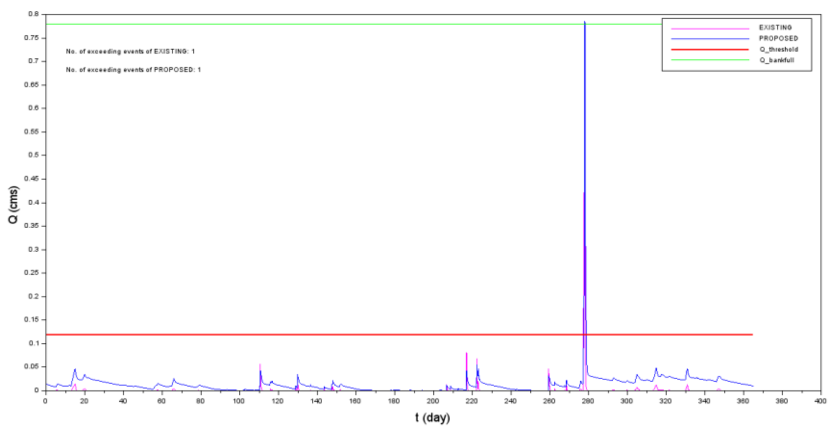
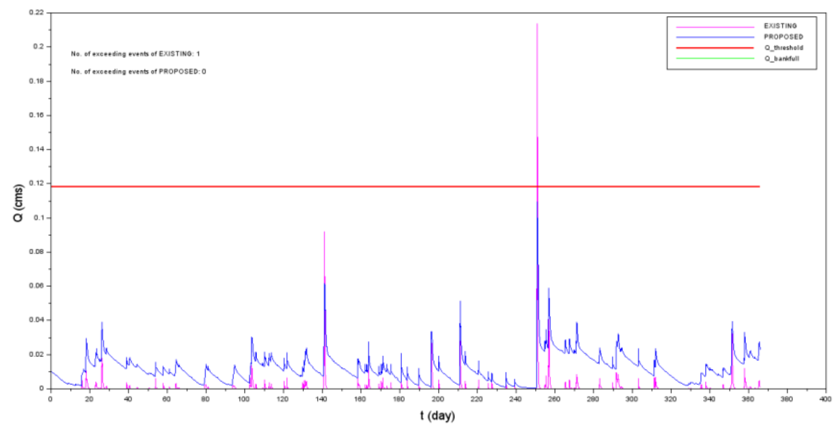
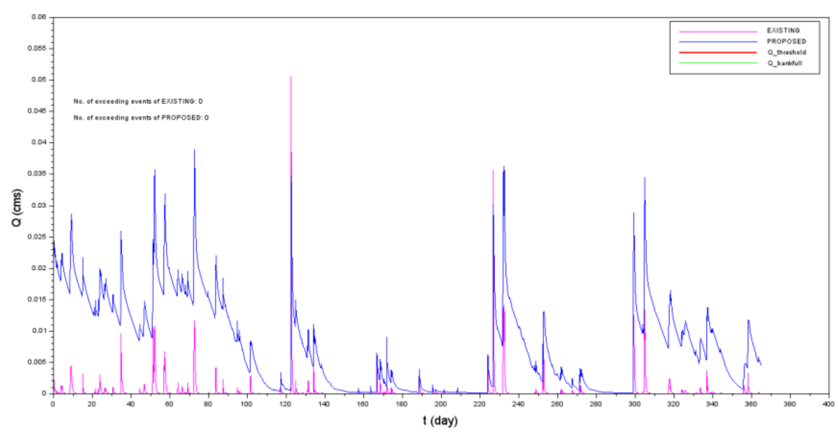
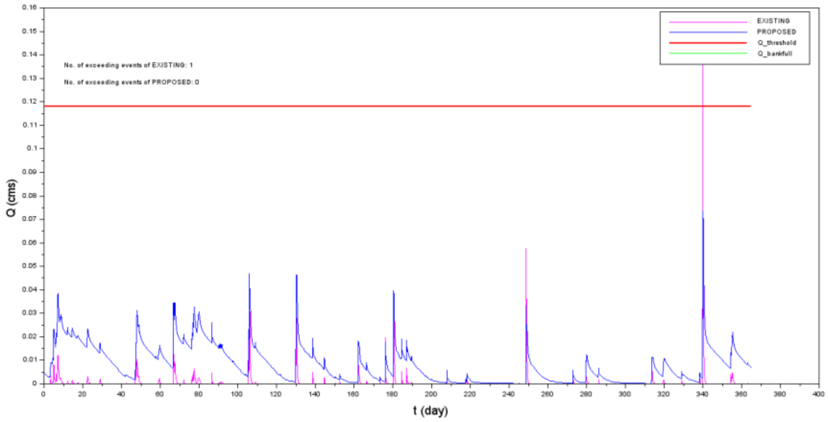
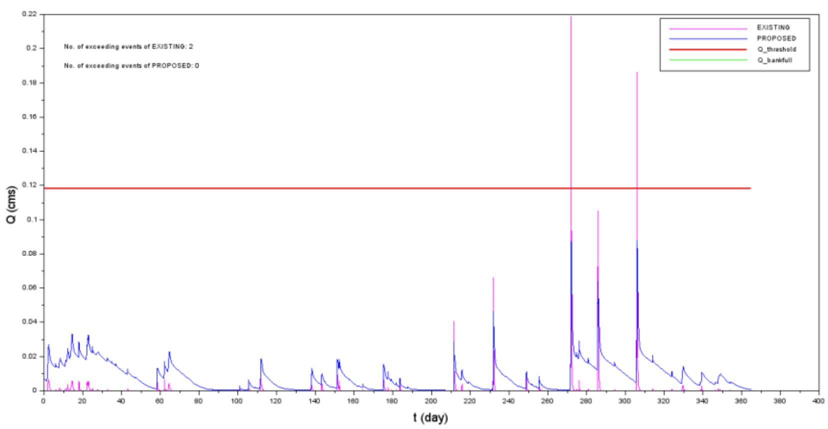
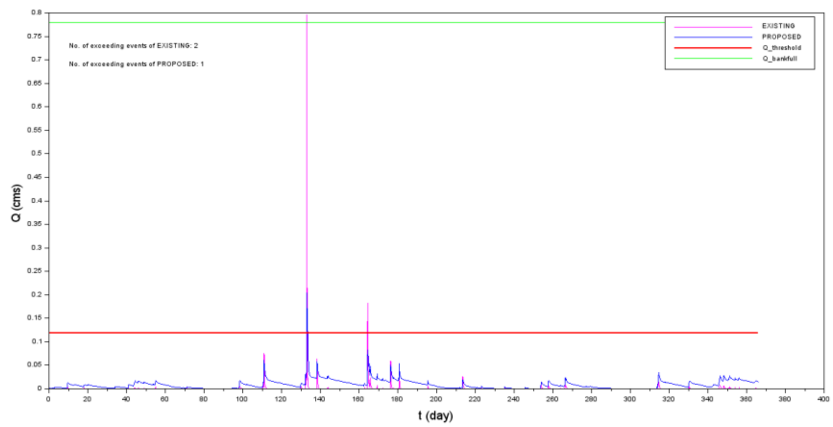
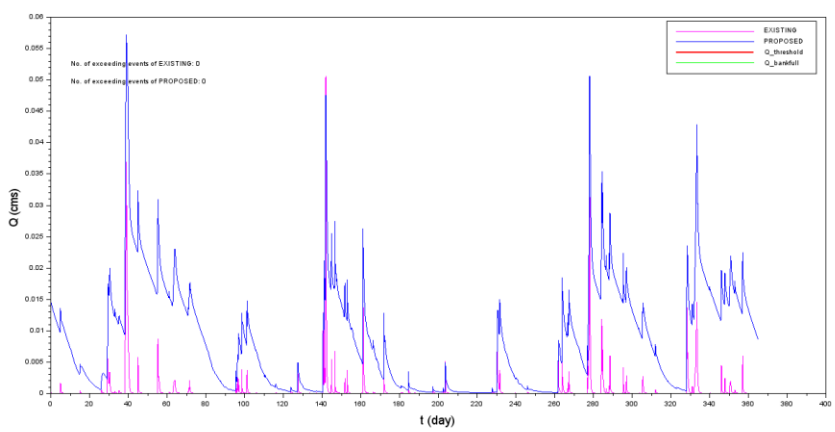
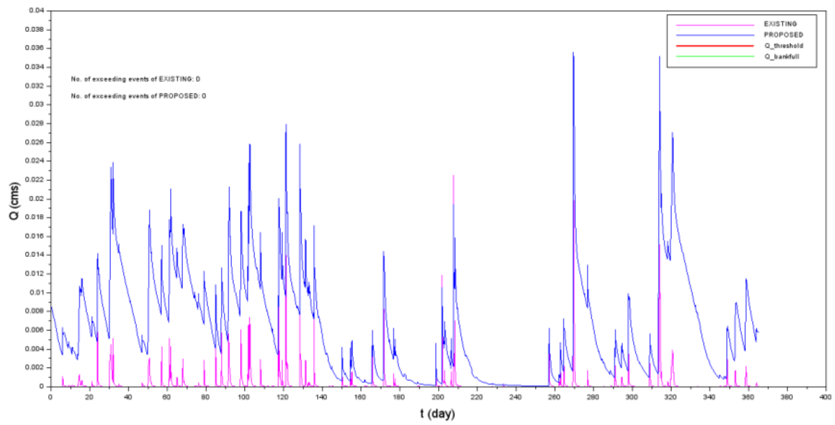
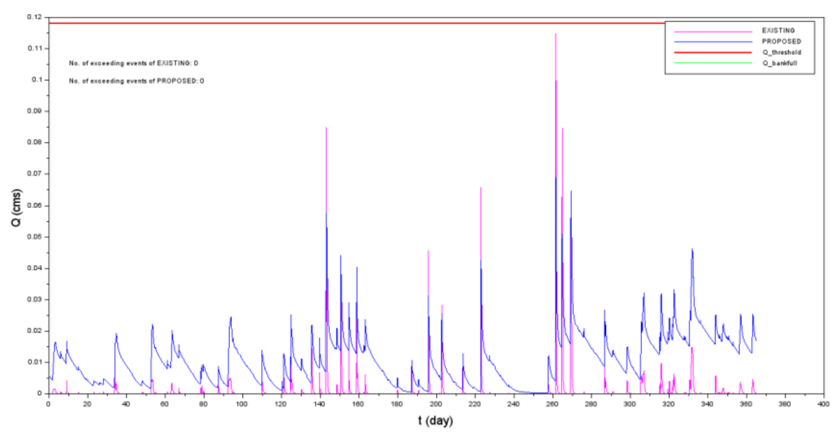
Reach **R3S0C** Scenario 1 1992	
Reach **R3S0C** Scenario 1 1993	

Reach **R3S0C** Scenario 1 1994	
Reach **R3S0C** Scenario 1 1995	

Reach **R3S0C** Scenario 1 1996	
Reach **R3S0C** Scenario 1 1997	

Reach **R3S0C** Scenario 1 1998	
Reach **R3S0C** Scenario 1 1999	

Reach **R3S0C** Scenario 1 2000	
Reach **R3S0C** Scenario 1 2001	

Reach **R3S0C** Scenario 1 2002	
Reach **R3S0C** Scenario 1 2003	

Appendix C2

2021 Water Quantity and Quality Monitoring

Tributaries of Sixteen Mile Creek 2021 Water Quantity and Quality Monitoring Orlando North Porta Lands

Milton, Ontario

Prepared for:
Orlando Corporation
6205 Airport Road
Mississauga, ON
L4V 1E3

March 31, 2022

PN21059

GEO MORPHIX
Geomorphology
Earth Science
Observations

Report Prepared by:	GEO Morphix Ltd. 36 Main St. N. Campbellville, ON L0P 1B0
Report Title:	Tributaries of Sixteen Mile Creek, 2021 Water Quantity and Quality Monitoring, Orlando North Porta Lands, Milton, Ontario
Project Number:	PN21059
Status:	Final
First Submission Date:	March 31, 2022
Prepared by:	Patrick Padovan, M.Sc., Tye Rusnak, B.Sc. Env.
Approved by:	Paul Villard, Ph.D., P.Geo.

Table of Contents

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Appendices

1 Introduction

GEO Morphix Ltd. was retained by Orlando Development Corporation ("Orlando") to undertake pre-development baseline water quantity and quality monitoring for tributaries of Sixteen Mile Creek within the Milton North Porta Lands. The property is generally located west of Esquesing Line, bound by James Snow Parkway and 5th Sideroad in the Town of Milton, Ontario.

Baseline water quantity and quality monitoring was conducted at four (4) locations along the subject watercourses. The monitoring program consisted of continuous water temperature, water level, and discrete water quantity and quality measurements collected between June 3, 2021, and December 6, 2021.

This report provides a detailed summary of the monitoring methodology as well as a thorough record of data collected over the first year of baseline monitoring. The data collected will be used to compare pre- to post-development conditions. Monitoring will continue in 2022.

2 Existing Conditions

The Study Area was part of the larger Sixteen Mile Creek watershed and predominantly drains to a section of the Upper Middle Branch of Sixteen Mile Creek. Monitoring site **MN1** was located within a drainage feature at a culvert crossing at James Snow Parkway approximately 100 m west of Boston Church Road. This feature drains south from 5th Side Road to James Snow Parkway west of Boston Church Road. Site **MN2** was located within a drainage feature at a culvert crossing at James Snow Parkway approximately 550 m west of Esquesing Line. Flows from this tributary originate from an existing woodlot east of Boston Church Road and joins with additional drainage from onsite agricultural fields to flow south and cross James Snow Parkway. Site **MN3** was located along a tributary that bisects the entire site, originating near Boston Church Road and 5th Sideroad and discharging flows at Esquesing Line, approximately 600 m north of James Snow Parkway. Monitoring site **MN4** was located along a section of the Upper Middle Branch which briefly overlaps the northeastern corner of the Study Area along Esquesing Line. Several tributaries of the Upper Middle Branch also cross the site. All monitoring locations within the Study Area are graphically displayed in **Appendix A**.

3 Monitoring Procedures and Sampling Methodology

3.1 Instream Water Quality

Monitoring sites were selected to capture conditions and flows exiting the subject. **Table 1** below summarizes activities conducted at each location in 2021.

Table 1. Water Quantity and Quality Monitoring Sites, Sampling Parameters, and Sampling Duration in 2021

Site	Sampling Parameters	Monitoring Duration	# Visits
MN1	Continuous water level and temperature; Discrete water quantity and quality	June 3 – December 6	12
MN2			
MN3			
MN4			

Activities at each location included the following:

- Continuous water level and temperature monitoring at 15-minute intervals using a HOBO U20 pressure and temperature logger, with an additional control sensor to measure atmospheric pressure and air temperature on site
- Discrete water quality grab sampling including measurements of temperature, TSS, turbidity, dissolved oxygen, and conductivity for 7 water quality events (4 wet events, 3 dry events) where wet events require greater than 10 mm of rain 24 hours prior to sampling, and dry events required more than two consecutive days without rain before sampling
- Install monumented cross sections at each monitoring location for the periodic collection of discharge measurements
- Monumented photographs of all sampling activities to verify location and timing

All sampling activities adhere to the Ontario Stream Assessment Protocol outlined by the Ontario Ministry of Natural Resources (OMNRF, 2017). During the monitoring season data was acquired from a GEO Morphix telemetry-based weather station located approximately 11.2 km southwest from the study site to account for climatic conditions and precipitation.

4 Monitoring Results

4.1 Water Quantity Monitoring

Discrete water level measurements were taken during water quality monitoring visits to gauge stream response during four (4) rainfall and three (3) dry events. During the 2021 monitoring season, there were 17 occurrences of rainfall > 10 mm. Sampled rainfall events ranged from 11.2 – 52.2 mm between June 3 and December 6, with an average rainfall of 28.4 mm per event.

Stilling well water depths measured by staff at each sampling location during water quality monitoring events are summarized in **Table 2**. Continuous water levels as well as discrete measurements are provided in **Appendix B.**

Table 2. Minimum and Maximum Water Depth and Discharge per Sampling Location Over 7 Water Quality Sampling Events

Sampling Location	Water Depth (m)	
	2021	
	Minimum	Maximum
MN1	0.00	0.14
MN2	0.00	0.12
MN3	0.00	0.20
MN4	0.08	0.45

Baseflow is the portion of streamflow derived from natural storage sources and does not include direct runoff from precipitation. The stage hydrograph must not show evidence of any recent storm events to be considered at baseflow levels. Due to the ephemeral nature of the streams, sites **MN1**, **MN2**, and **MN3** where dry for large portions of the monitoring season. During the wetter season during fall, baseflow at these sites was approximately 0.02 - 0.05 m. Baseflow at site **MN4** was approximately 0.08 m and 0.18 m during the summer and fall seasons, respectively.

Water level responses are dependent on the magnitude of the rainfall event and antecedent conditions. The maximum water levels during the monitoring season were observed at all sites following a 26.2 mm rainfall event on October 26. Maximum water levels are likely to be higher during spring freshet conditions compared to those that were observed by staff in 2021. Continuous water level and daily rainfall for the monitoring season as well as discrete water level measurements are presented in **Appendix B**.

In addition to continuous water level and temperature monitoring, discrete measurements of discharge were recorded. A summary of measured discharge at each sampling location is summarized below in **Table 3**.

Table 3. Discharge Monitoring Results per Sampling Location Over 4 Water Quantity Sampling Events

Measurement Date (yyyy-mm-dd)	Event Rainfall (mm)	Sampling Location	Max Water Depth (m)	Discharge (m^3/s)
2021-06-30	52.2	**MN1**	0.04	0.0013
		MN2	0.07	0.0016
		MN3	0.07	0.0004
		MN4	0.11	0.1806
2021-09-15	24.0	**MN1**	0.03	0.0007
		MN2	0.10	0.0035
		MN3	0.12	0.0024
		MN4	0.18	0.2423
2021-10-26	26.2	**MN1**	0.14	0.0100
		MN2	0.12	0.0004
		MN3	0.20	0.0090
		MN4	0.41	0.6910
2021-12-06	29.2	**MN1**	0.17	0.0201
		MN2	0.22	0.0677
		MN3	0.33	0.1064
		MN4	0.48	1.3274

During the 2021 monitoring season, maximum discharges at each site were recorded on December 6 following a 29.2 mm rainfall event. The timing window to achieve water level and discharge values at the peak of a given rainfall event is very small. As such, stage-discharge curves were developed for each individual site to predict discharge at various water levels throughout the season. The stage-discharge curves for all 4 monitoring sites are shown in **Figures 1 and 2** below.

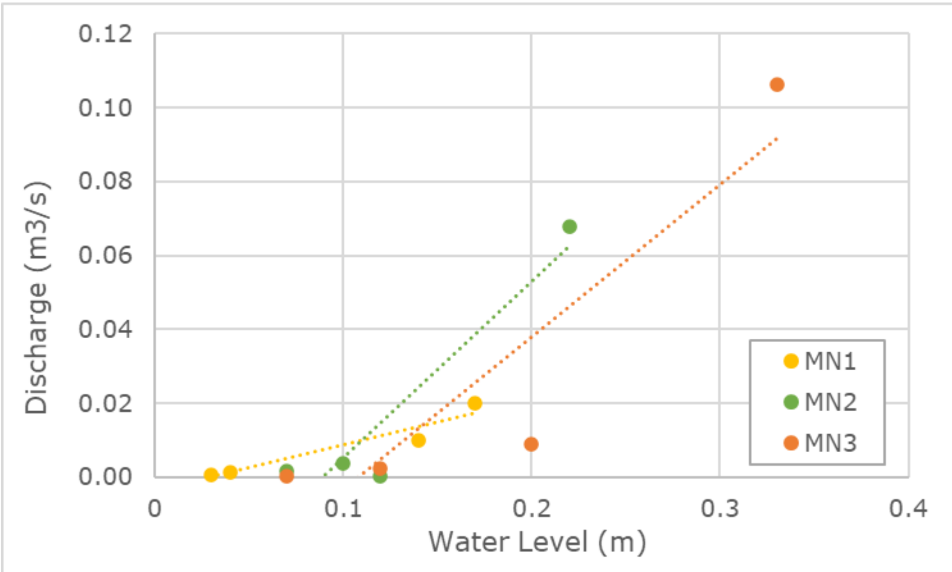


Figure 1. Stage-Discharge Curve for Sites MN1, MN2, and MN3

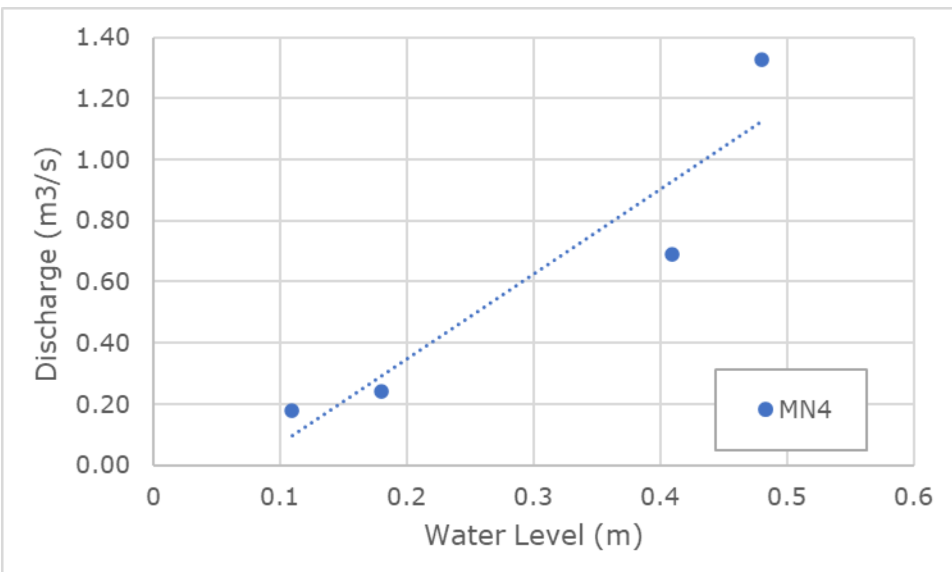


Figure 2. Stage-Discharge Curve for Site MN4

Maximum water levels recorded by continuous pressures sensors occurred on September 23, 2021, following a 57.6 mm rainfall event. When applying these water levels to our stage-discharge curves, theoretical corresponding discharges for sites **MN1**, **MN2**, **MN3**, and **MN4** were 0.0260 m^3/s, 0.3095 m^3/s, 0.2688 m^3/s, and 1.6620 m^3/s, respectively.

Water quantity monitoring will continue in 2022.

4.2 Water Quality Monitoring

In addition to water quantity monitoring, discrete measurements of several water quality parameters including temperature, Total Suspended Solids (TSS), turbidity, dissolved oxygen, and conductivity were collected at each monitoring site during a variety of seasonal conditions. Water quality monitoring parameters are summarized in **Tables 4 - 7**. The data presented below excludes days in which water was not present in channel. Discrete measurement summaries for all site visits are provided in **Appendix B**.

4.2.1 Water Temperature

Temperature plays a major role in influencing aquatic life and chemical interactions within aquatic environments. An aquatic organism's temperature tolerance differs based on a variety of factors including species, age, acclimation temperature, exposure to toxic substances, and season. Changes in temperature also influence the solubility and reaction equilibria of many chemicals including dissolved oxygen. Temperatures measured at each sampling location during water quality monitoring events are summarized in **Table 4**.

Table 4. Minimum and Maximum Temperature Measurements per Sampling Location Over 7 Water Quality Sampling Events

Sampling Location	Water Temperature (°C)	
	2021	
	Minimum	Maximum
MN1	6.9	22.7
MN2	6.8	22.1
MN3	9.4	22.1
MN4	7.8	21.4

There are several elements that can influence baseline water temperatures from year to year. It is normal to observe slight variability in minimum and maximum temperatures. Minimum and maximum temperatures observed during water quality sampling events were comparable to daily and seasonal temperature trends. Further analysis will be completed following subsequent years of monitoring.

In addition to discrete measurements, continuous water temperature was collected. The continuous water temperature, air temperature, and daily rainfall records are presented in **Appendix B**.

4.2.2 Total Suspended Solids (TSS) and Turbidity

TSS and turbidity measure the concentration of organic and inorganic matter in suspension and relate to the lack of clarity or transparency of water. Suspended matter may consist of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, and other microscopic organisms. The higher the concentration of these substances in water, the more turbid the water becomes. Environmental samples vary within the normal range of 1 to 1000 NTUs (CCMOE, 2002). TSS and turbidity will differ from watercourse to watercourse, depending on flow conditions and time of year, thus baselines must be established. TSS and turbidity measurements at each sampling location during water quality monitoring events are summarized in **Table 5.** Accredited laboratory results are included in **Appendix D**, for reference.

Table 5. Minimum and Maximum TSS and Turbidity Measurements per Sampling Location Over 7 Water Quality Sampling Events

Sampling Location	TSS (mg/L)	
	2021	
	Minimum	Maximum
MN1	5.0	96.0
MN2	44.0	50.0
MN3	16.0	48.7
MN4	4.7	61.5
Sampling Location	**Turbidity (NTU)**	
	2021	
	Minimum	**Maximum**
MN1	8.8	166.0
MN2	38.6	149.0
MN3	20.5	79.8
MN4	3.6	92.2

During the 2021 monitoring season, maximum TSS and turbidity readings at all sites demonstrate sediment concentrations in the channel are within a normal range for a watercourse in response to a precipitation event. Further analysis will be completed following subsequent years of monitoring.

4.2.3 Dissolved Oxygen

Dissolved oxygen is one of the most fundamental parameters to aquatic organism life. Oxygen solubility is governed by atmospheric and hydrostatic pressure, turbulence, temperature, salinity, and biological processes. In general, the lowest acceptable dissolved concentration for aquatic life is between 5.5 and 6.0 mg/L depending on life stage of aquatic organism (CCME, 1999). Dissolved oxygen concentration measurements at each sampling location during water quality monitoring events are summarized in **Table 6**.

Table 6. Minimum and Maximum Dissolved Oxygen Concentration Measurements Per Sampling Location Over 7 Water Quality Sampling Events

Sampling Location	Dissolved Oxygen (mg/L)	
	2021	
	Minimum	Maximum
MN1	4.30	19.40
MN2	6.40	10.10
MN3	6.56	19.90
MN4	5.66	14.40
Sampling Location	**Dissolved Oxygen (%)**	
	2021	
	Minimum	**Maximum**
MN1	50.7	160.0
MN2	61.0	88.0
MN3	65.0	175.0
MN4	66.1	121.0

Due the ephemeral nature of the system, it is normal to see low dissolved oxygen levels during drier periods in the summer when there are warm air temperatures and stream flow continuity is limited. When continuous flows are limited and there are only small pools of standing water, low dissolved oxygen is normal especially in headwater drainage features such as sites **MN1** and **MN2**. Maximum dissolved oxygen values for all sites in 2021 were collected on November 3 during a dry event. Although maximum dissolved oxygen levels are typically observed during rain events, it is not uncommon to see higher values during colder periods of weather. The concentration and solubility of oxygen in water has an inverse relationship with temperature where these factors increase as temperature decreases (CCMOE, 1999). Dissolved oxygen concentrations observed at all four sampling locations during the 2021 monitoring period were within an acceptable range when considering local site conditions, water temperatures, and seasonal changes in air temperature.

4.2.4 Conductivity

Conductivity is useful as a general measure of stream water quality. Conductivity measures the ability for electrical current to pass through water and provides an estimate of water salinity. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Mid range conductivity (200 to 1000 μS) is the normal background for most major rivers, conductivity outside this range could indicate that the water is not suitable for certain species of aquatic organisms (ENR, 2017). High levels of conductivity (1000 to 10,000 μS) may be due to increased discharge (rain event), or some other source of pollution has entered a stream (ENR, 2017). In southern Ontario, road salting during the winter results in a significant source of salt that can drain into watercourses and increase conductivity during spring flows. Conductivity measurements at each sampling location during water quality monitoring events are summarized in **Table 7**.

Table 7. Minimum and Maximum Conductivity Measurements per Sampling Location Over 7 Water Quality Sampling Events

Sampling Location	Conductivity (µS)	
	2021	
	Minimum	Maximum
MN1	364	1740
MN2	179	807
MN3	332	931
MN4	373	563

Maximum conductivity values were recorded during the summer months. However, average conductivity levels for all sites throughout the entire monitoring season were below 1000 µS. These values suggest that there is no long-term exposure of high levels of conductivity within the subject streams. Further analysis of conductivity will be completed following subsequent years of monitoring.

5 Summary and Conclusions

The monitoring activities outlined in this report and associated results are representative of baseline conditions observed in a shortened monitoring year (June 3 – December 6, 2021) for the headwater drainage features and tributaries of Sixteen Mile Creek within the Milton North Porta Lands.

Discrete water quantity and quality sampling was conducted throughout 2021 at four (4) monitoring locations established at the downstream extents of the subject property. Data collected thus far are representative of baseline conditions and will be used to compare pre- and post-development conditions.

Baseline monitoring and water quantity and quality sampling will continue in 2022 at four (4) locations established in 2021 to monitor the downstream extents of all drainage features and tributaries located within the subject lands. Continuous water level and temperature monitoring will be initiated in spring 2022 to better understand site conditions.

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

Respectfully submitted,

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

Patrick Padovan, M.Sc, CAN-CISEC
River Scientist

Tye Rusnak, B.Sc., Env.
Junior River Scientist

6 References

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

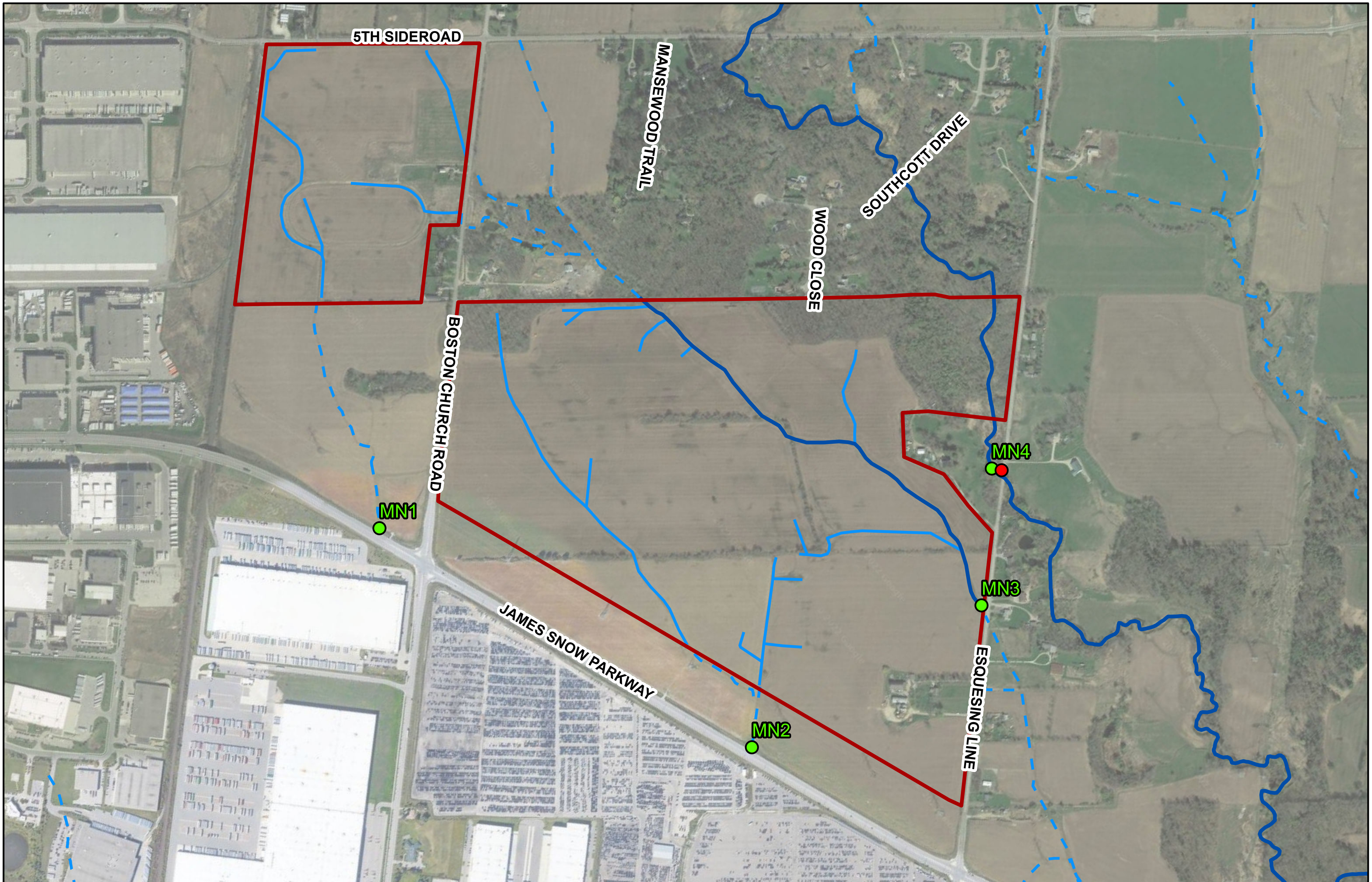
Canadian Council of Ministers of the Environment. 2002. Canadian water quality guidelines for the protection of aquatic life: Total particulate matter. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Chu, C., N. E. Jones, A. R. Piggott, and J. M. Buttle. 2009. Evaluation of a Simple Method to Classify the Thermal Characteristics of Streams using a Nomogram of Daily Maximum Air and Water Temperatures. North American Journal of Fisheries Management 29:1605-1619.

Environment and Natural Resources. 2017. Conductivity.

Stoneman, C. L., and M. L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperature. North American Journal of Fisheries Management 16:728-737.

Appendix A
Monitoring Map



Legend

- Instream Monitoring Site
- Atmospheric Pressure Sensor
- Orlando Lands
- Headwater Drainage Feature
- Assumed Drainage Outside of Accessible Property
- Watercourse

North Milton Business Park

Instream Monitoring Locations

0 125 250

Metres

GEO MORPHIX™

Imagery: Google Earth, 2018.
HDF: Savanta and GEO Morphix Ltd., 2018.
Watercourse: GEO Morphix Ltd., and MNRF, 2019.
Orlando Property and Proposed Development Plan: TMIG, 2018.
Instream Monitoring Site: GEO Morphix Ltd., 2021.
Print Date: April 2022. PN21059. Drawn By: K.W., M.O.

Appendix B
Field Data

Site MN1 Water Temperature

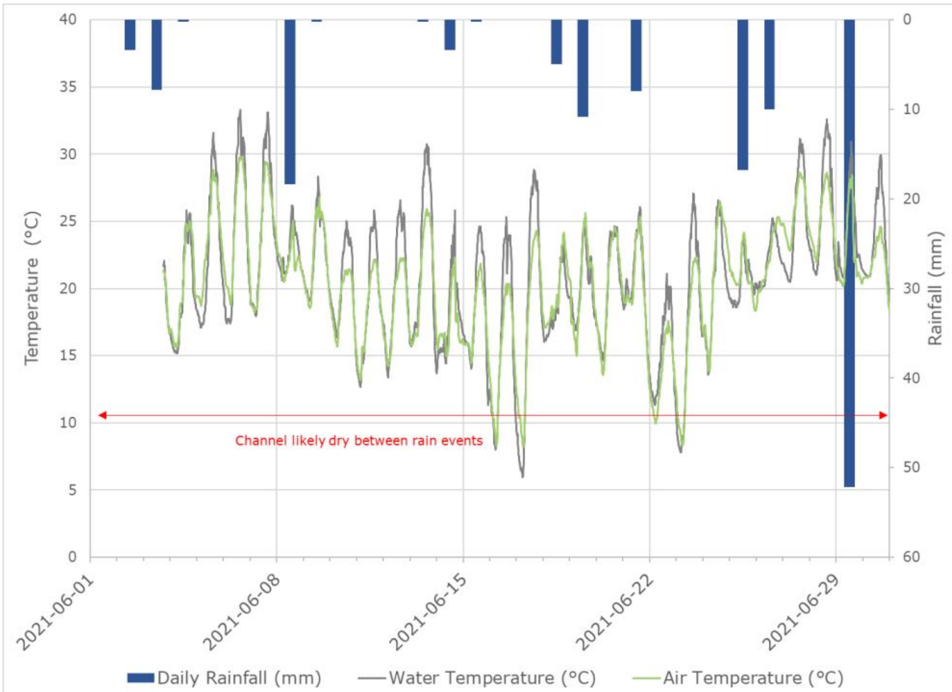
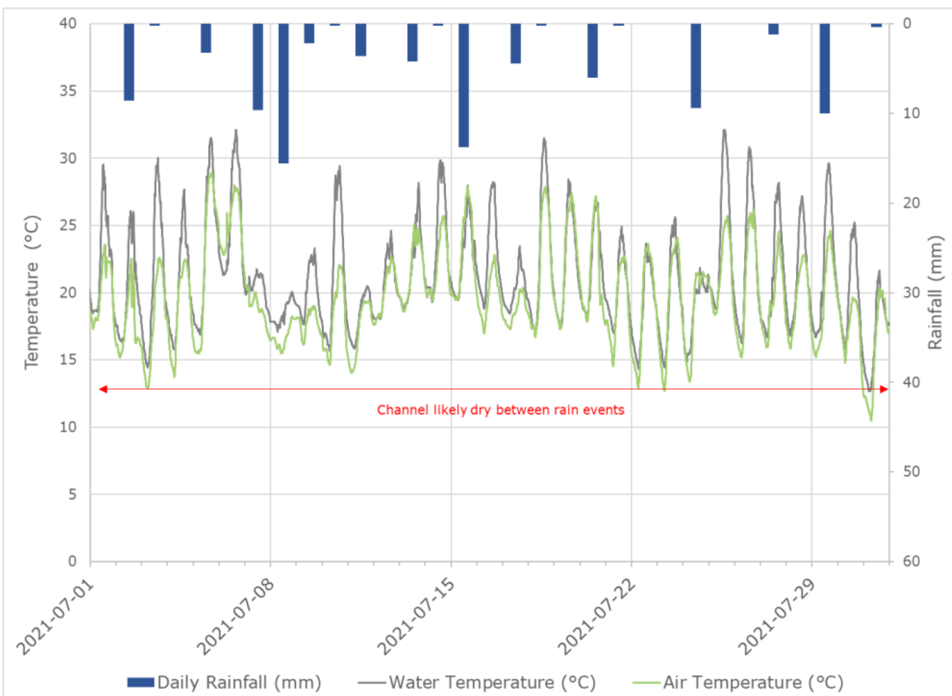
Figure 1	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for June 2021.
Figure 2	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for July 2021.

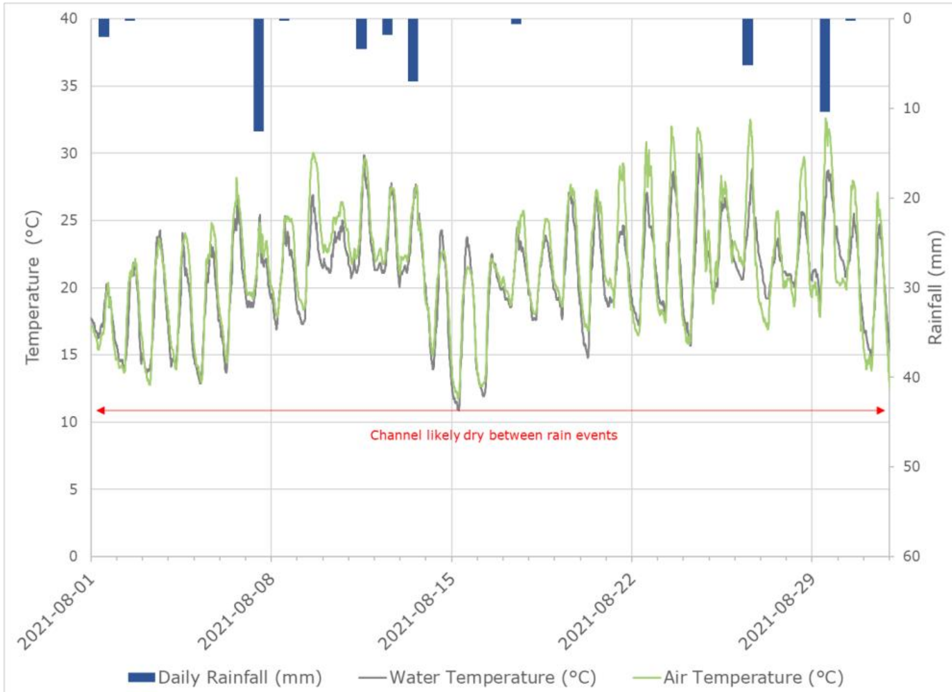
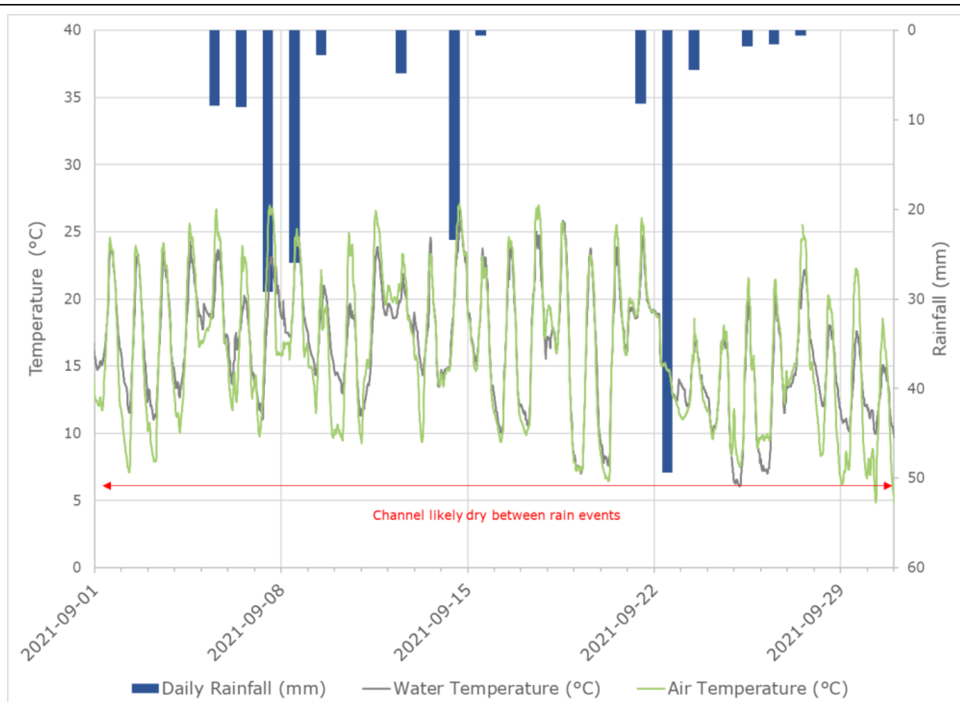
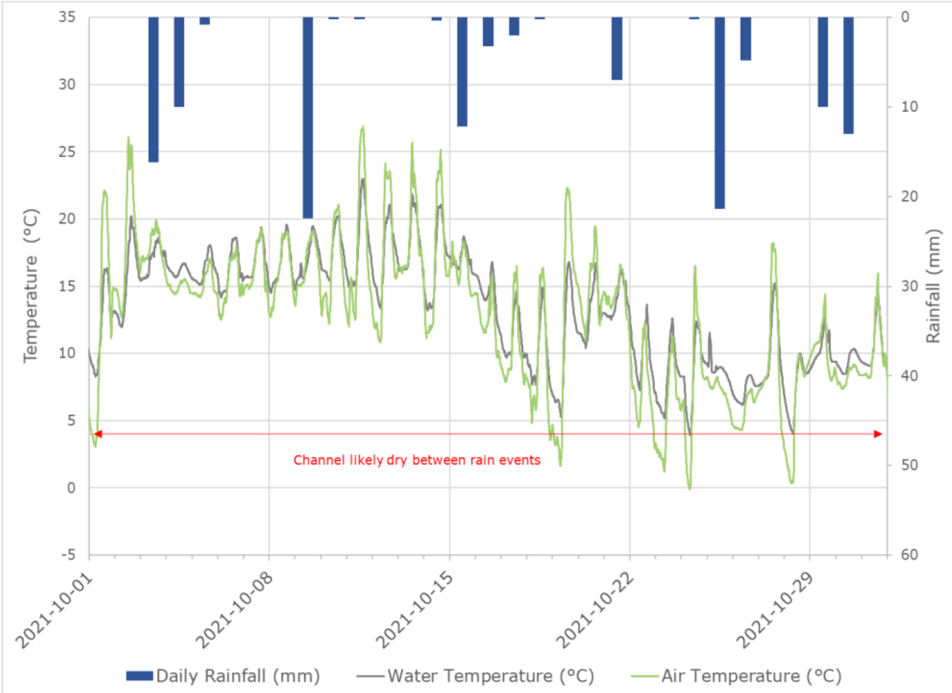
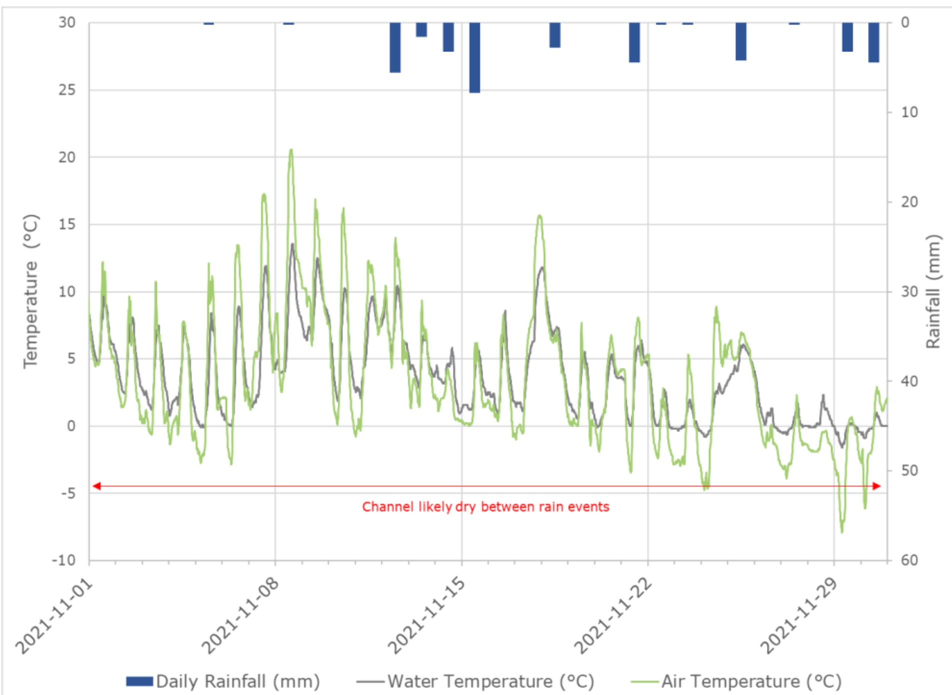
Figure 3	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for August 2021.
Figure 4	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for September 2021.

Figure 5	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for October 2021.
Figure 6	
	Water temperature, air temperature, and daily rainfall at **Site MN1** for November 2021.

Site MN2 Water Temperature

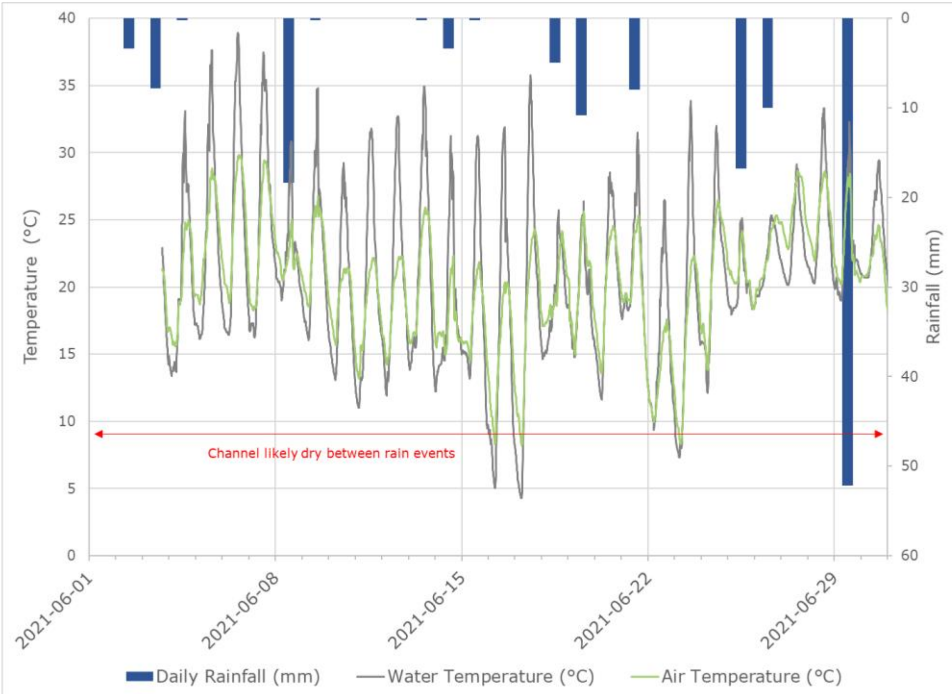
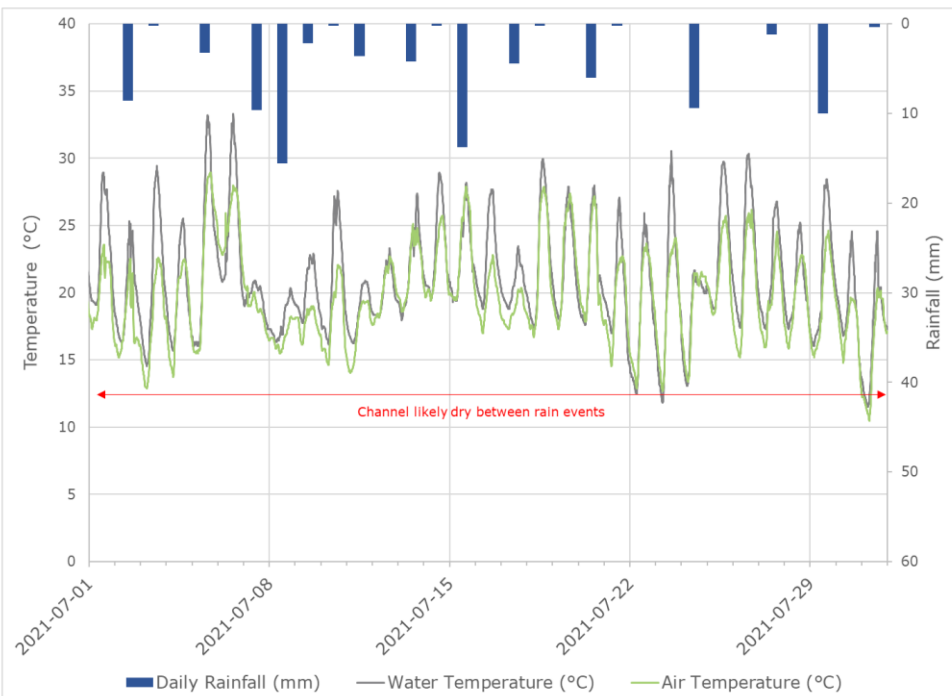
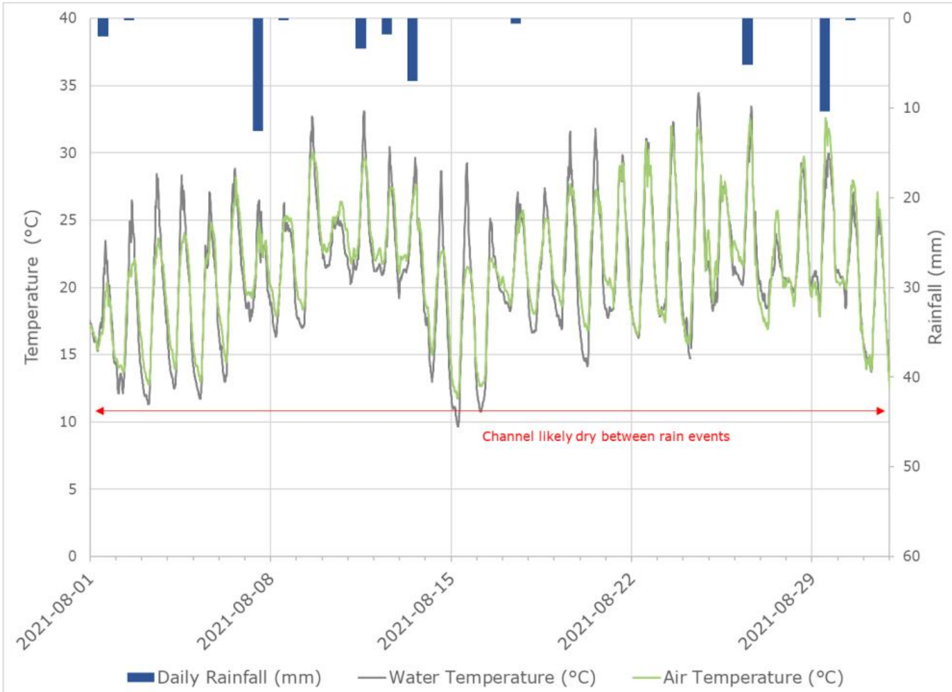
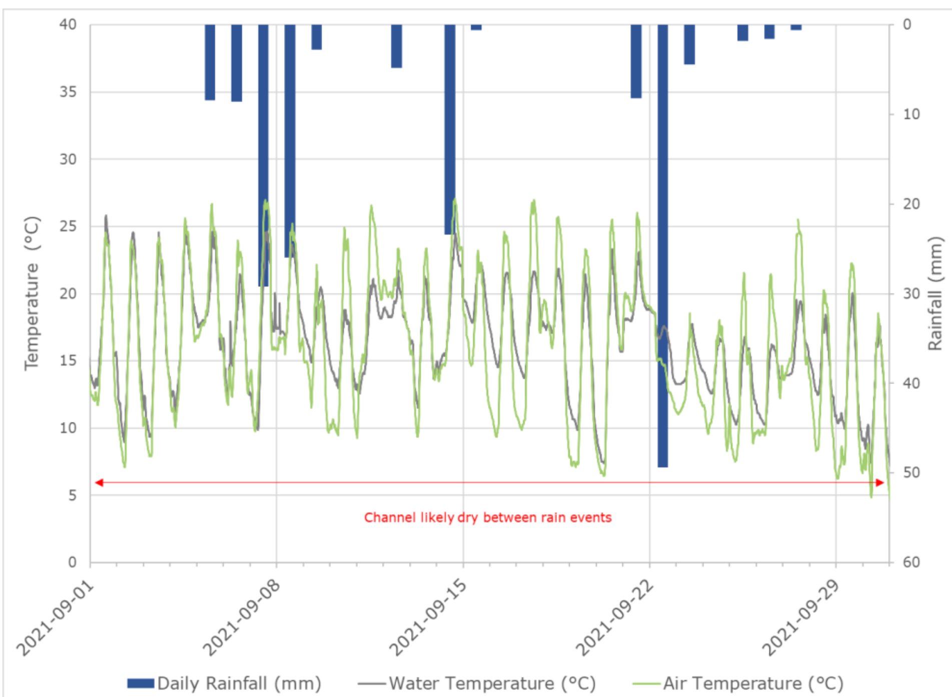
Figure 7	
	Water temperature, air temperature, and daily rainfall at **Site MN2** for June 2021.
Figure 8	
	Water temperature, air temperature, and daily rainfall at **Site MN2** for July 2021.

Figure 9	
	Water temperature, air temperature, and daily rainfall at **Site MN2** for August 2021.
Figure 10	
	Water temperature, air temperature, and daily rainfall at **Site MN2** for September 2021.

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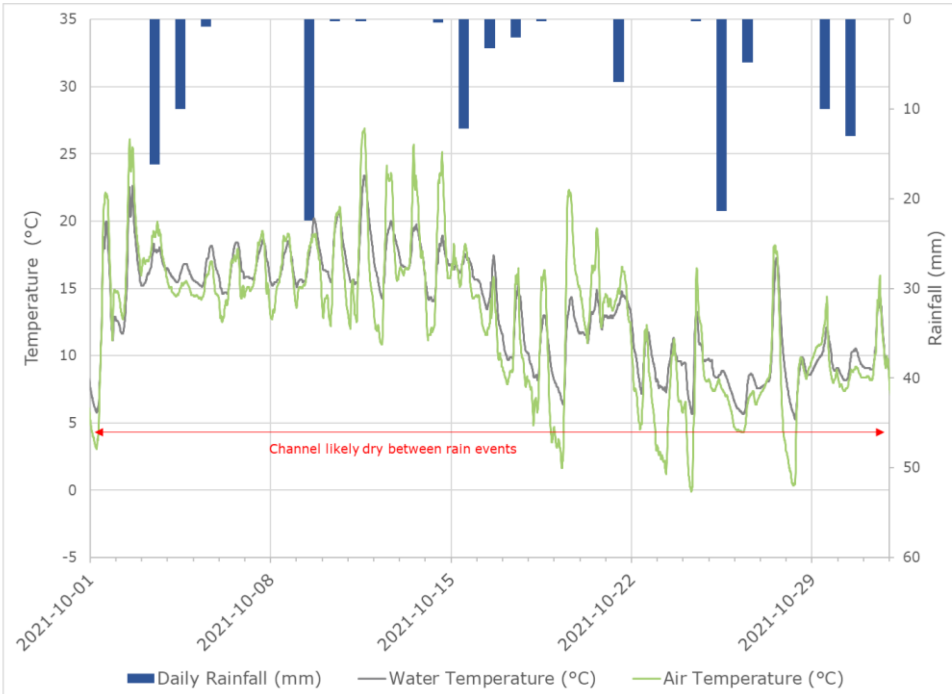
<tr><td rowspan="2">Figure 11</td><td>
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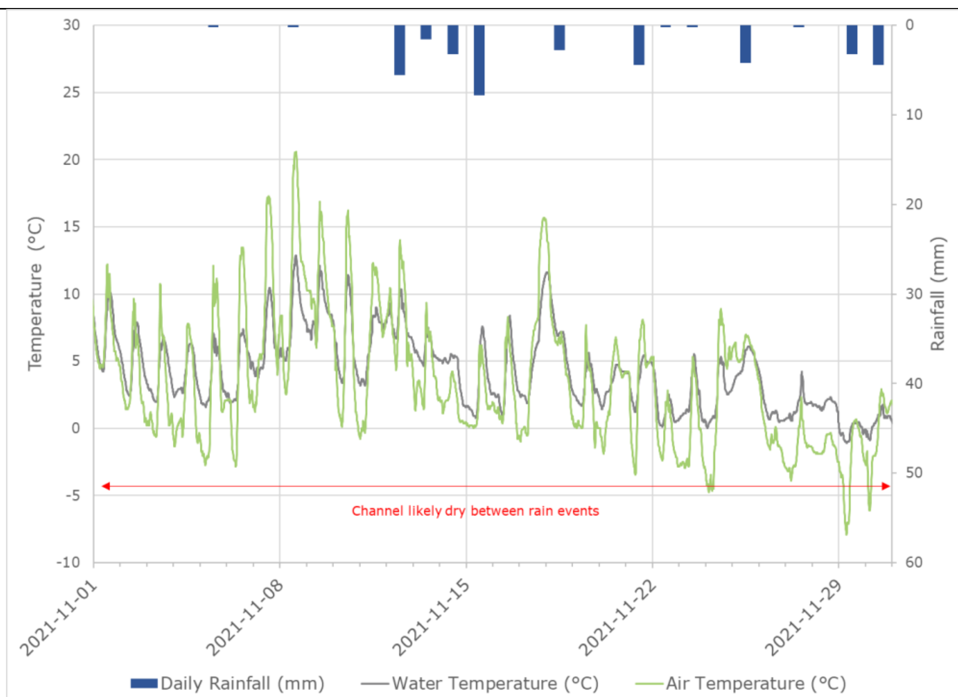
<tr><td>Water temperature, air temperature, and daily rainfall at Site MN2 for October 2021.</td></tr>
<tr><td rowspan="2">Figure 12</td><td>
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Site MN3 Water Temperature

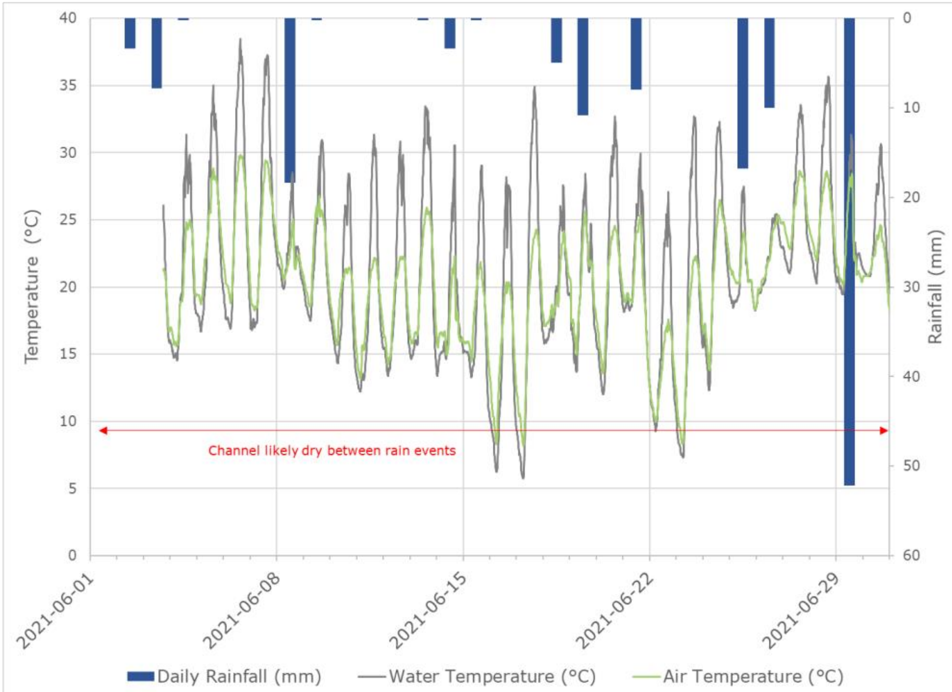
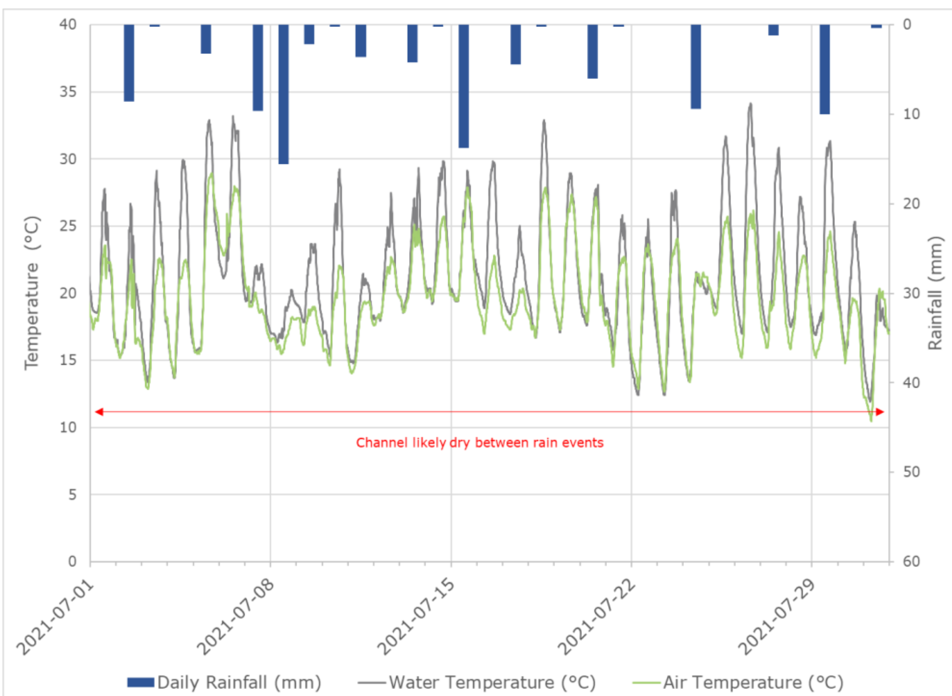
Figure 13	
	Water temperature, air temperature, and daily rainfall at **Site MN3** for June 2021.
Figure 14	
	Water temperature, air temperature, and daily rainfall at **Site MN3** for July 2021.

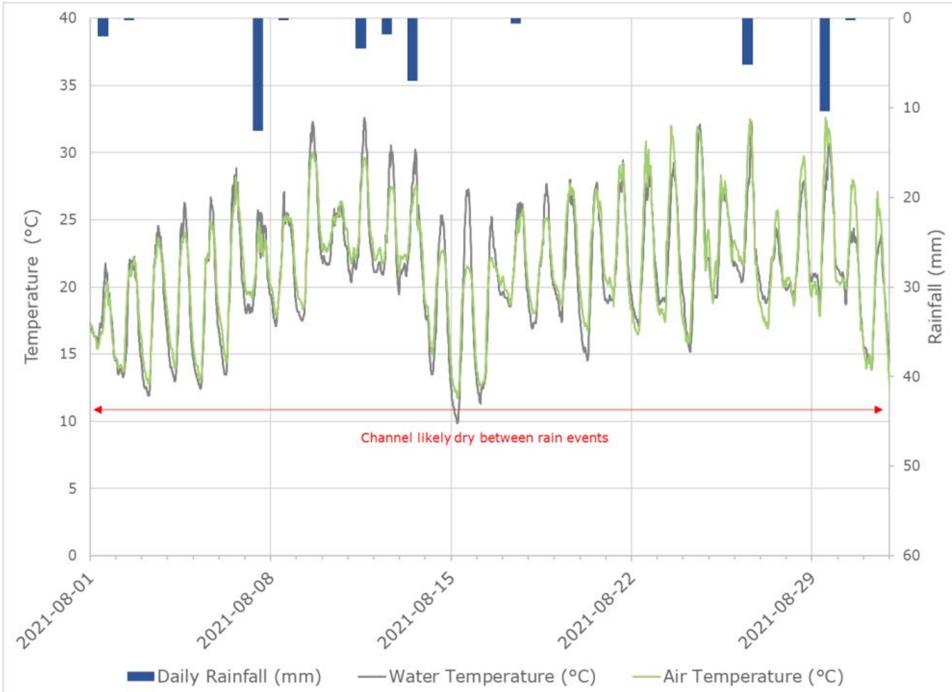
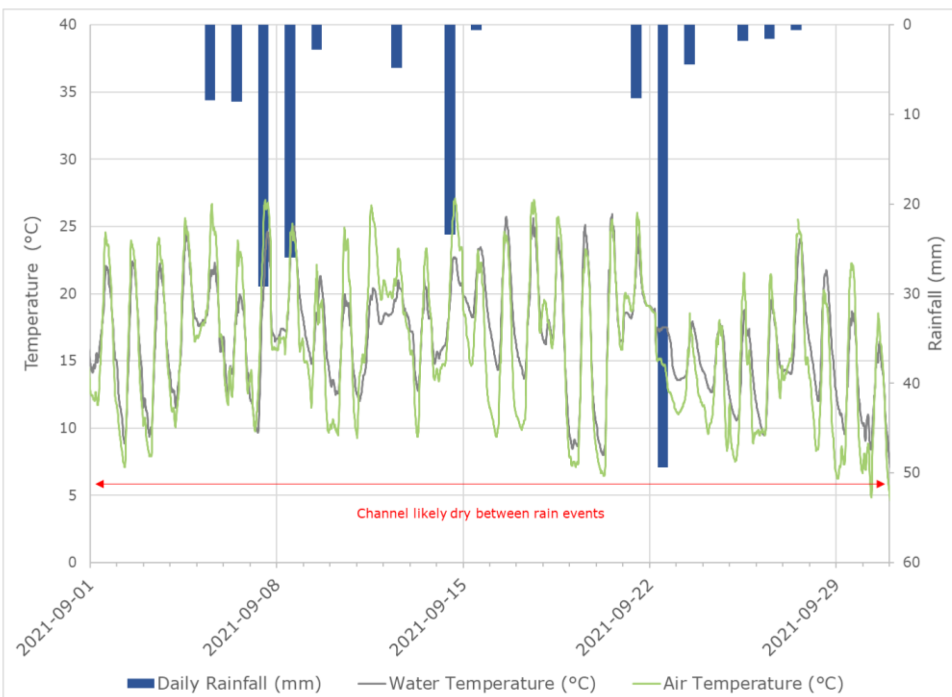
Figure 15	
	Water temperature, air temperature, and daily rainfall at **Site MN3** for August 2021.
Figure 16	
	Water temperature, air temperature, and daily rainfall at **Site MN3** for September 2021.

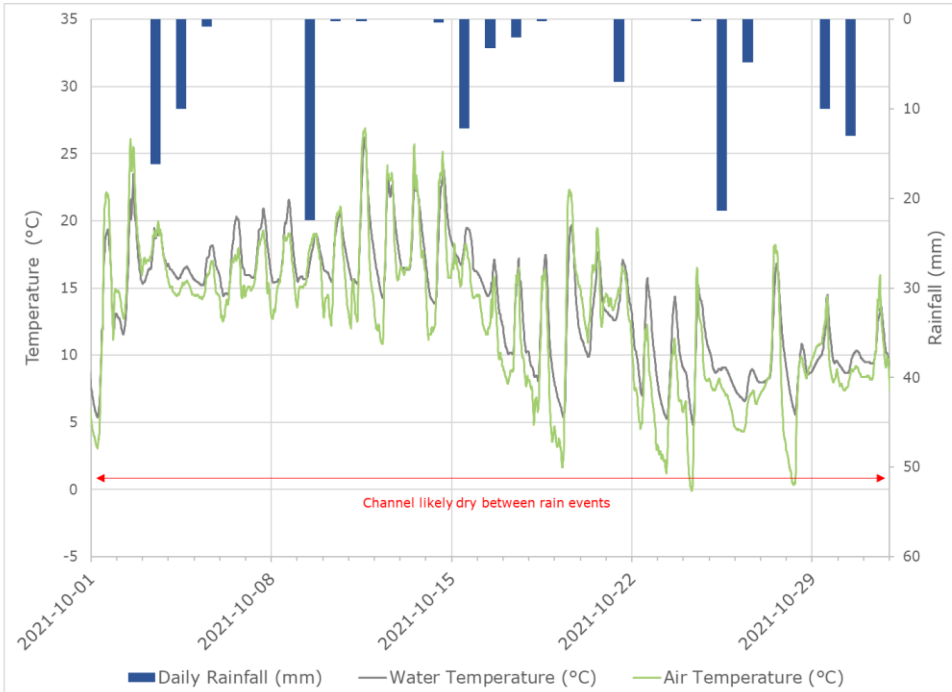
Figure 17	
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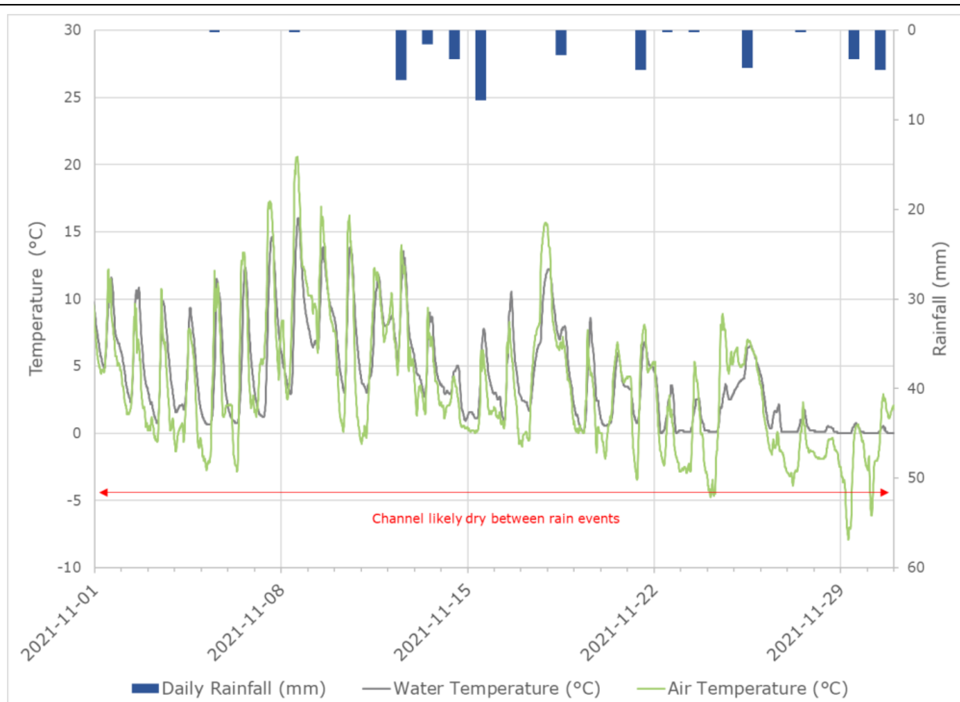
Figure 18	
	Water temperature, air temperature, and daily rainfall at **Site MN3** for November 2021.

Site MN4 Water Temperature

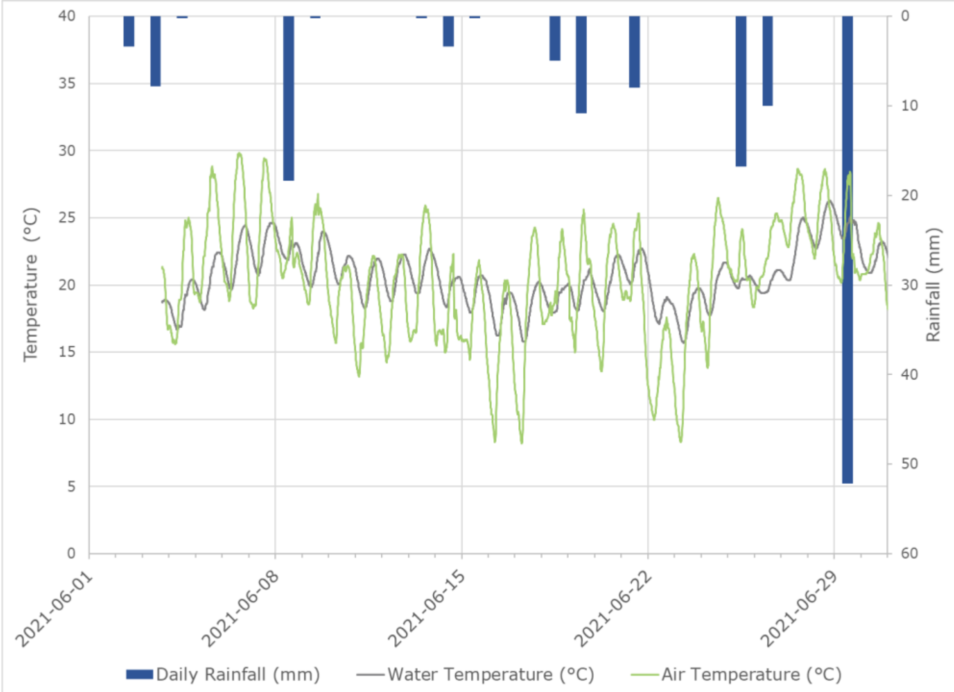
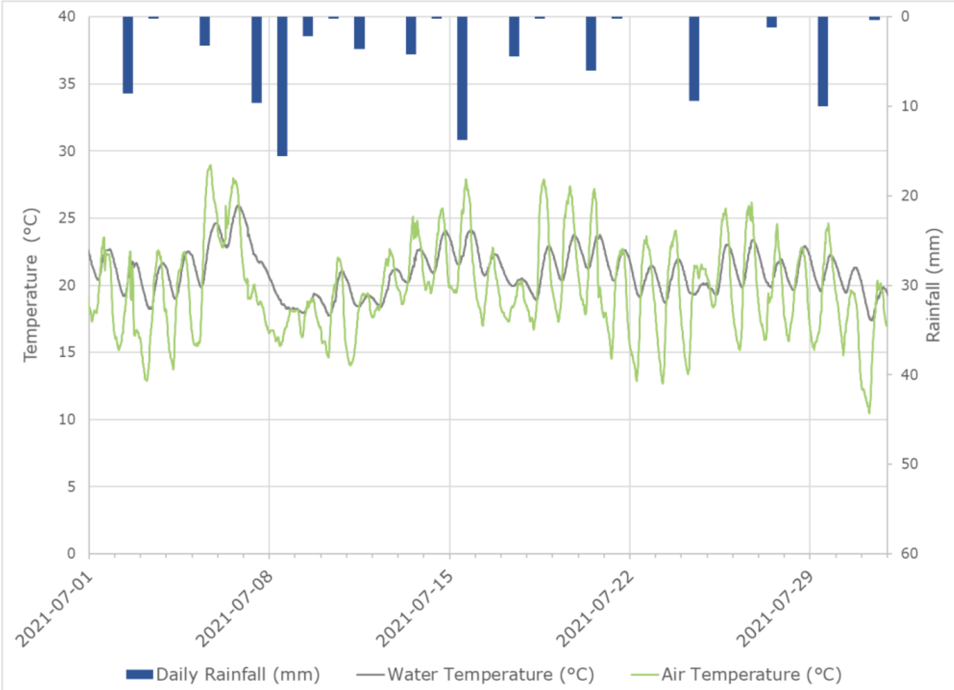
Figure 19	
	Water temperature, air temperature, and daily rainfall at **Site MN4** for June 2021.
Figure 20	
	Water temperature, air temperature, and daily rainfall at **Site MN4** for July 2021.

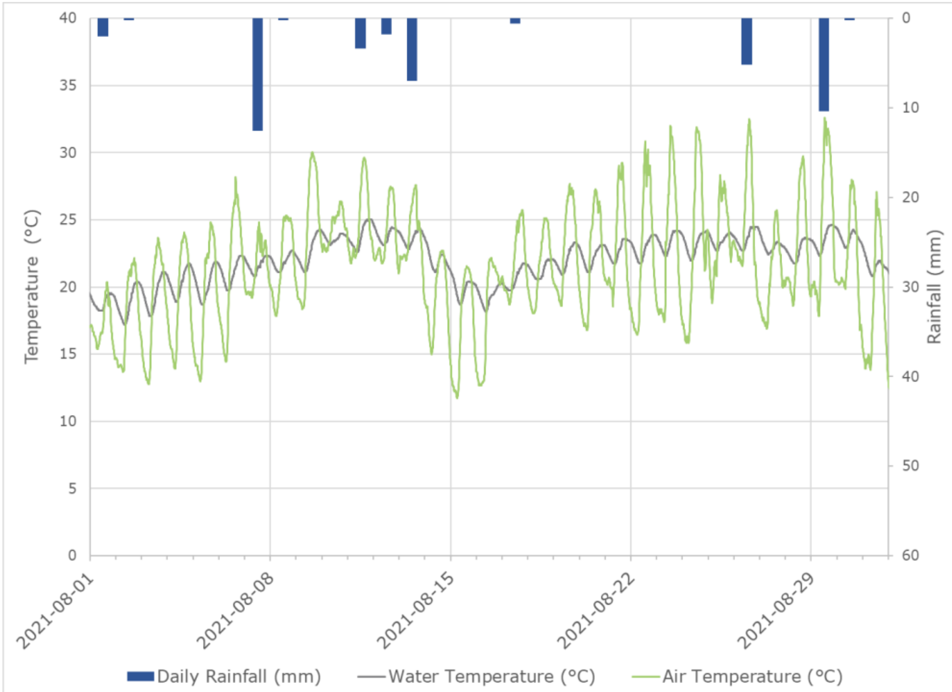
Figure 21	
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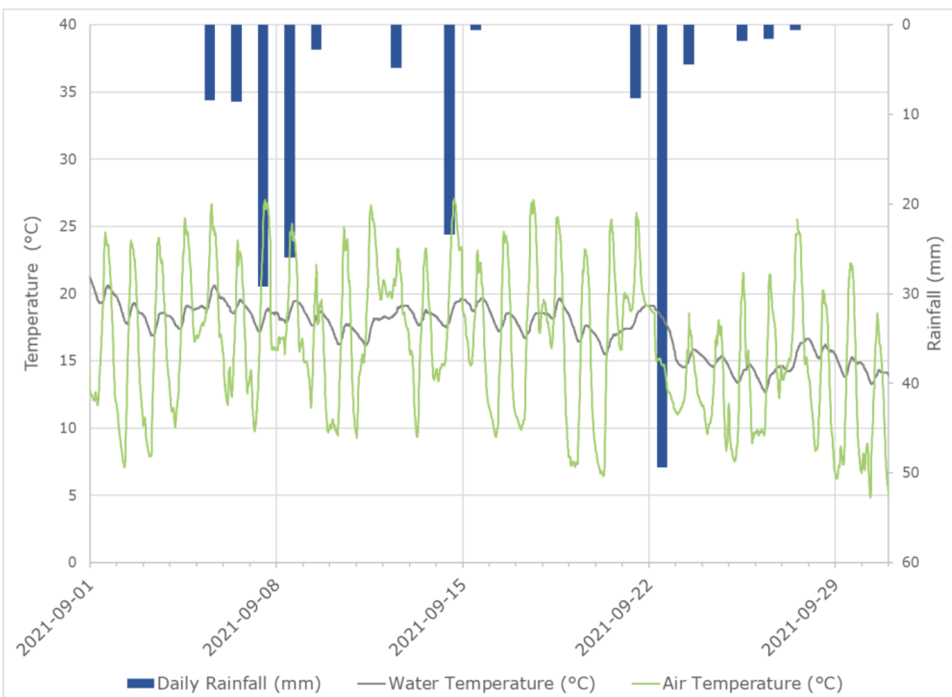
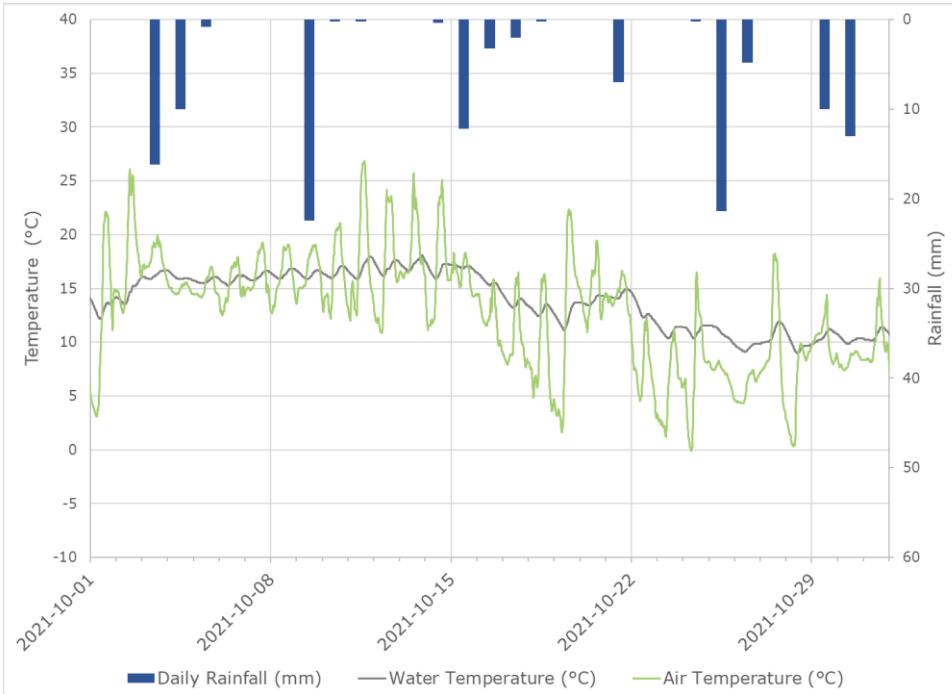
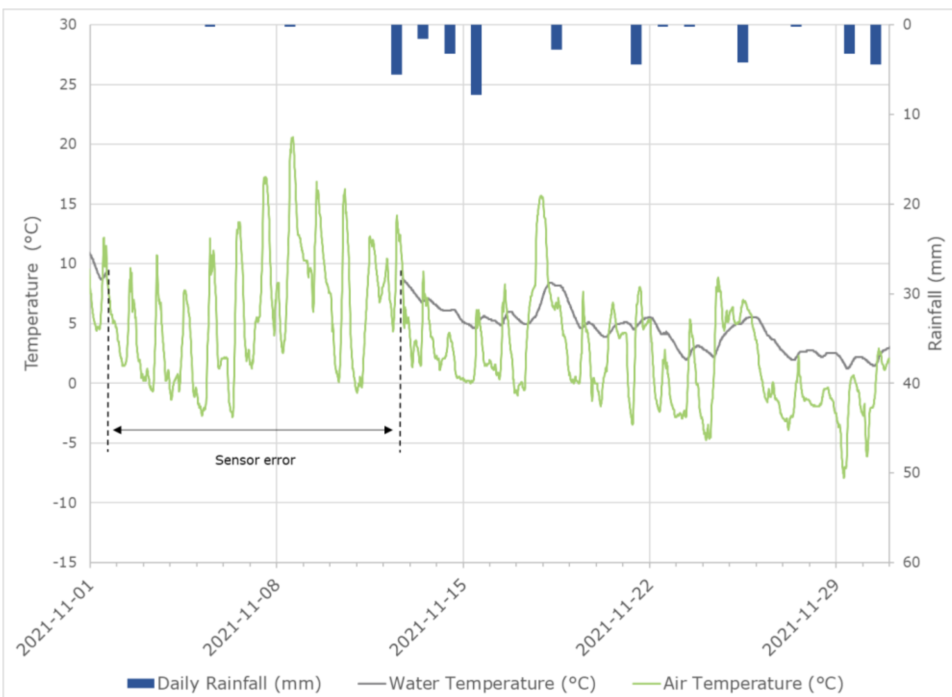
Figure 22	
	Water temperature, air temperature, and daily rainfall at **Site MN4** for September 2021.

Figure 23



Water temperature, air temperature, and daily rainfall at **Site MN4** for October 2021.

Figure 24



Water temperature, air temperature, and daily rainfall at **Site MN4** for November 2021.

Site MN1 Water Level

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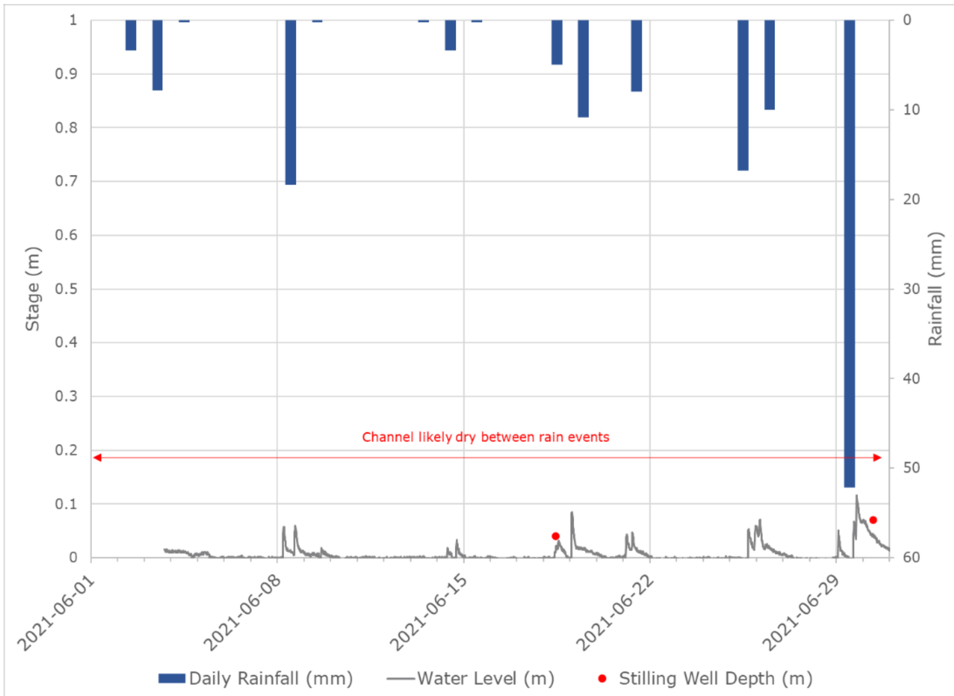
<tr><td rowspan="2">Figure 25</td><td>
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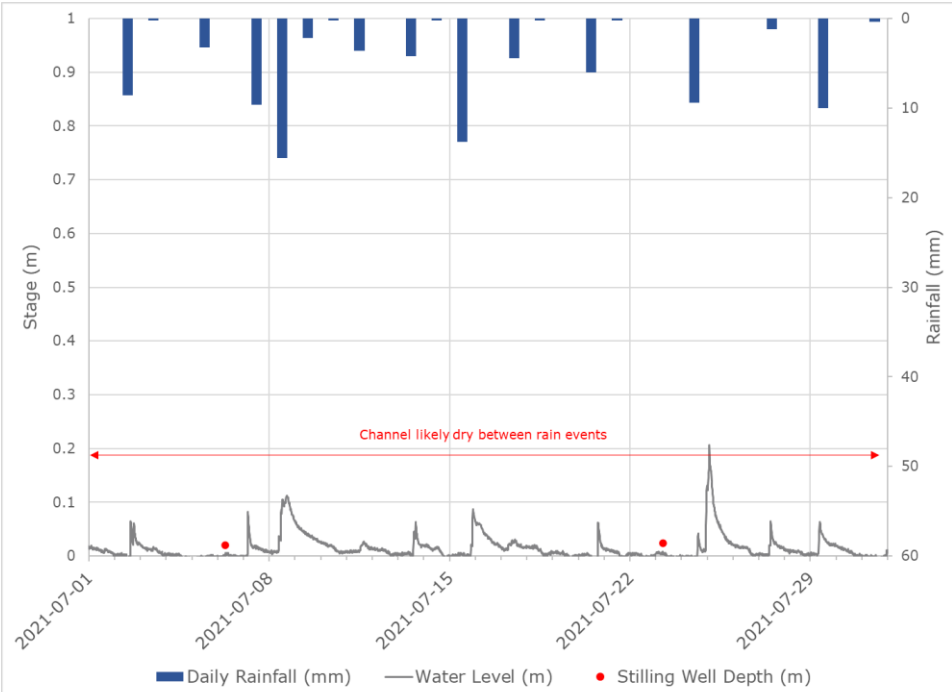
<tr><td>Water level and daily rainfall at Site MN1 for June 2021.</td></tr>
<tr><td rowspan="2">Figure 26</td><td>
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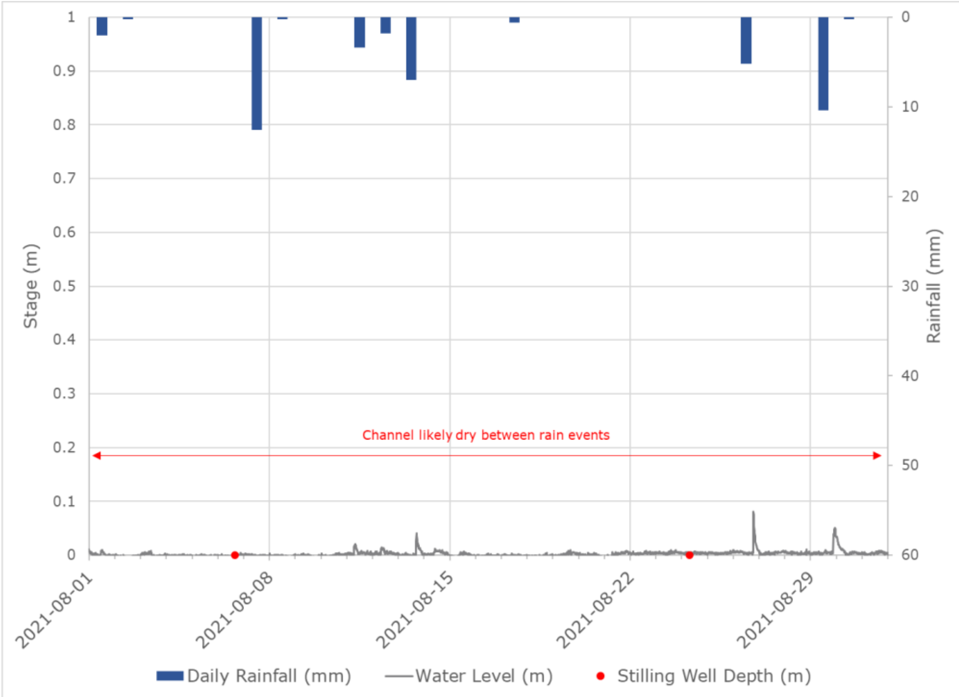
Figure 27	
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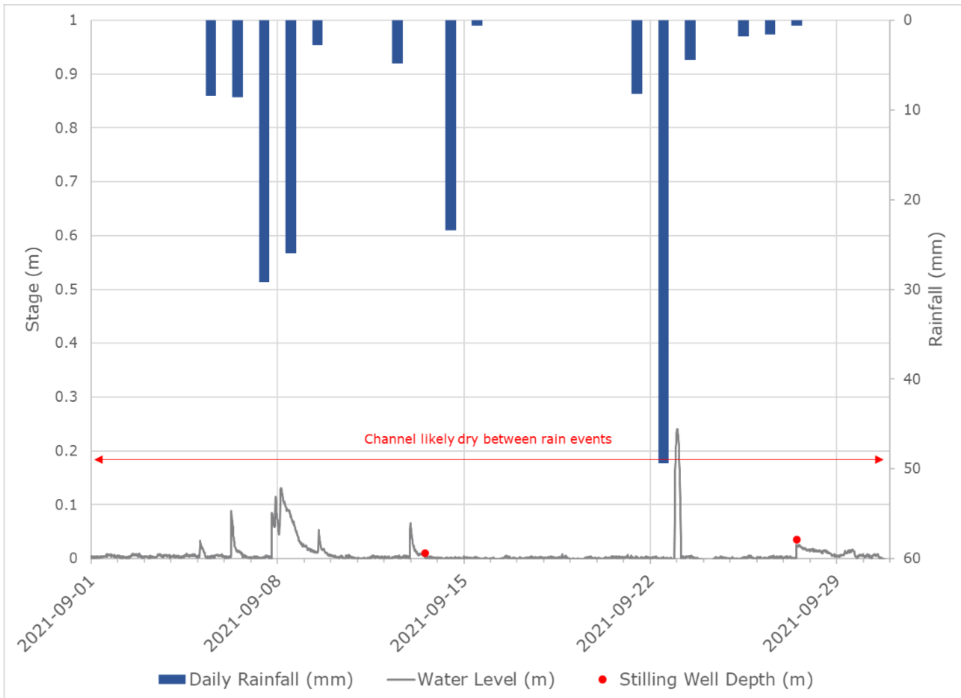
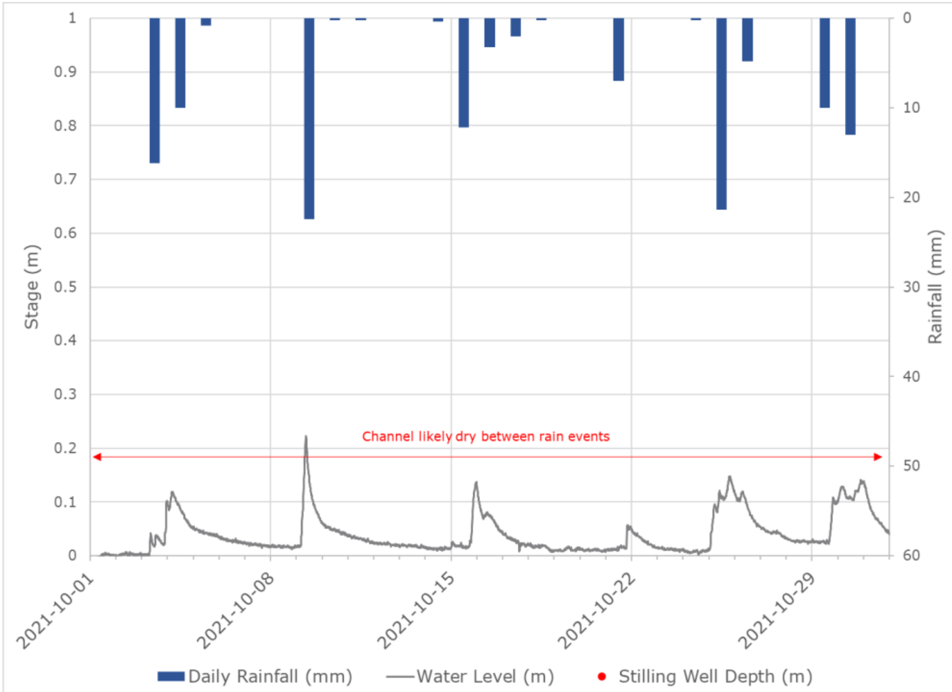
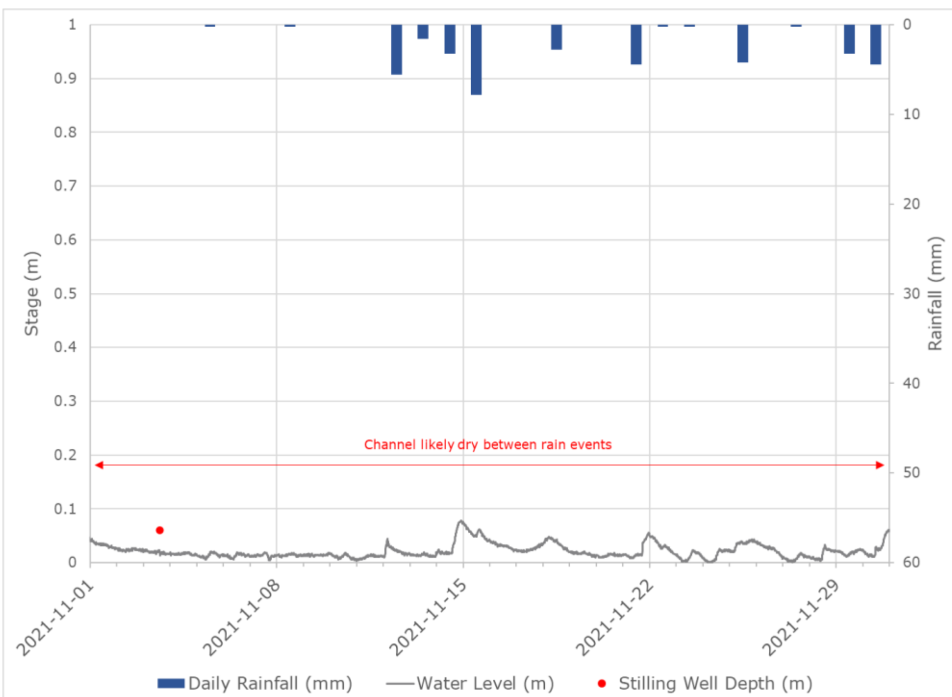
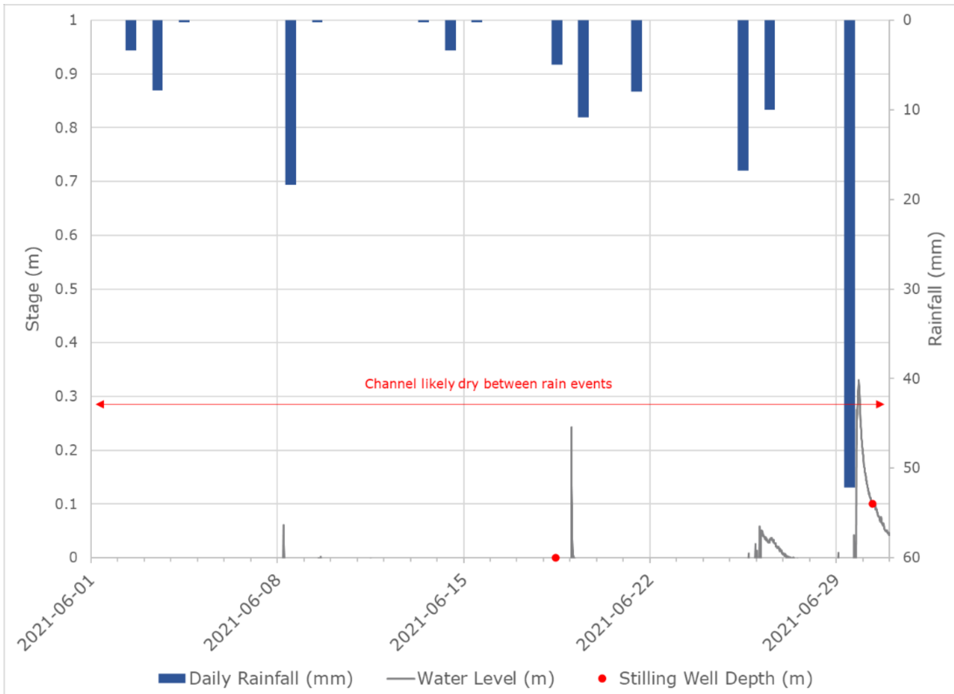
Figure 28	
	Water level and daily rainfall at **Site MN1** for September 2021.

Figure 29	
	Water level and daily rainfall at **Site MN1** for October 2021.
Figure 30	
	Water level and daily rainfall at **Site MN1** for November 2021.

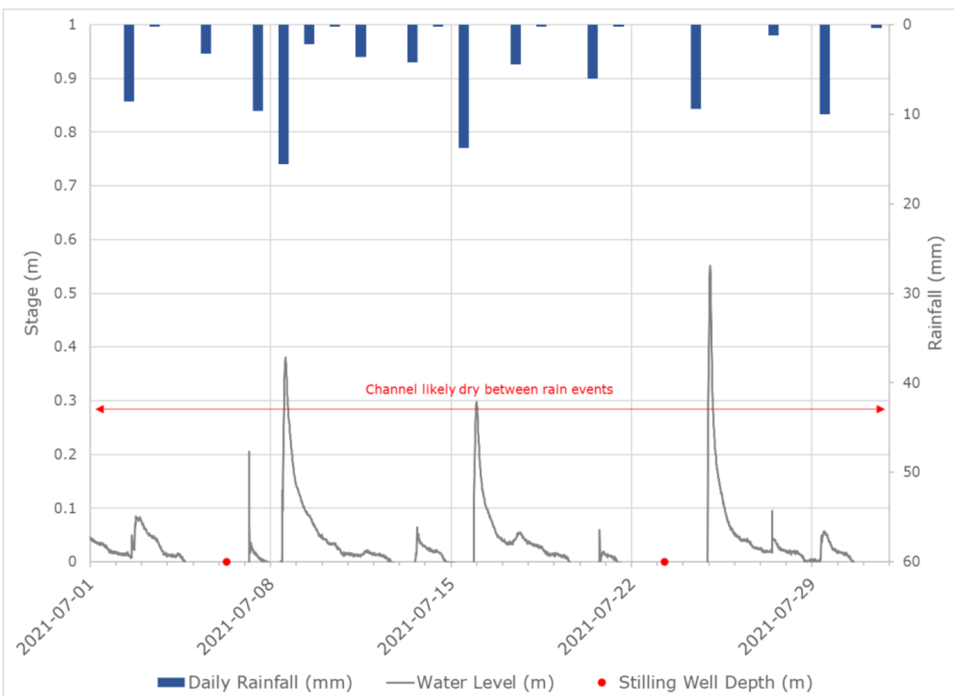
Site MN2 Water Level

Figure 31



Water level and daily rainfall at **Site MN2** for June 2021.

Figure 32



Water level and daily rainfall at **Site MN2** for July 2021.

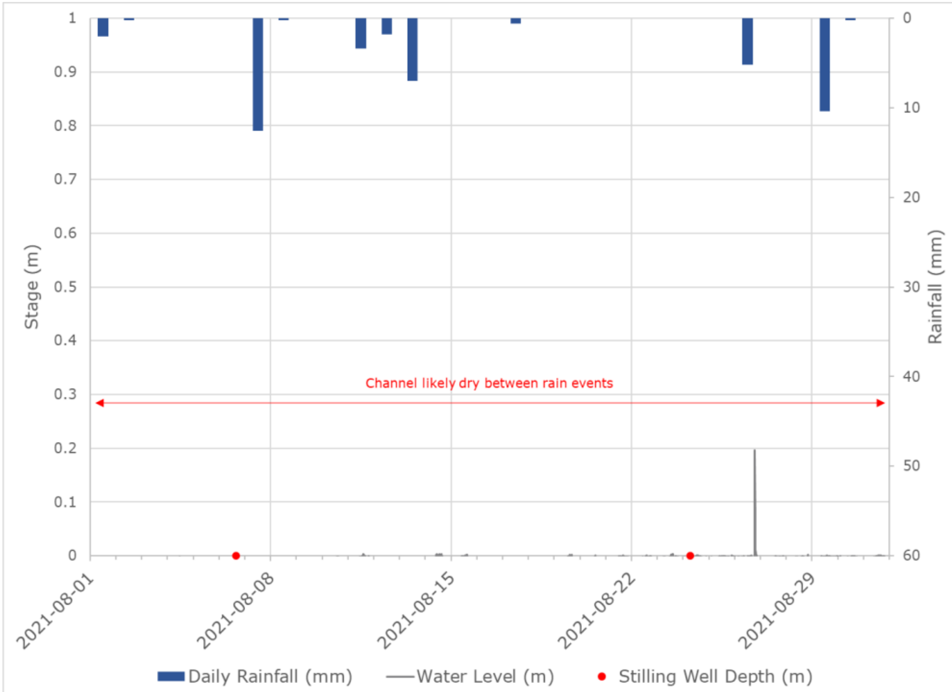
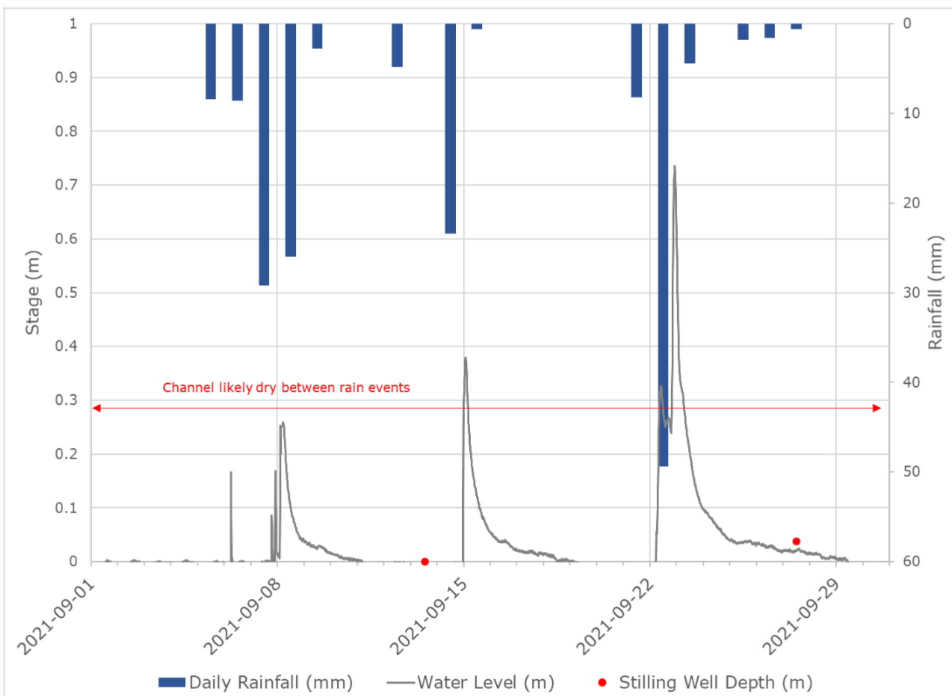
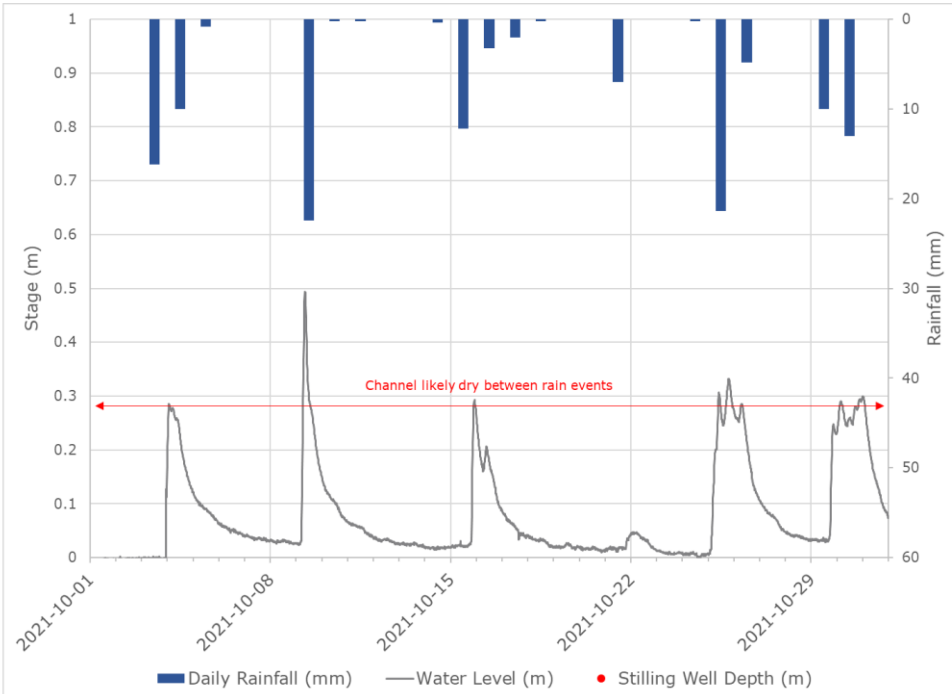
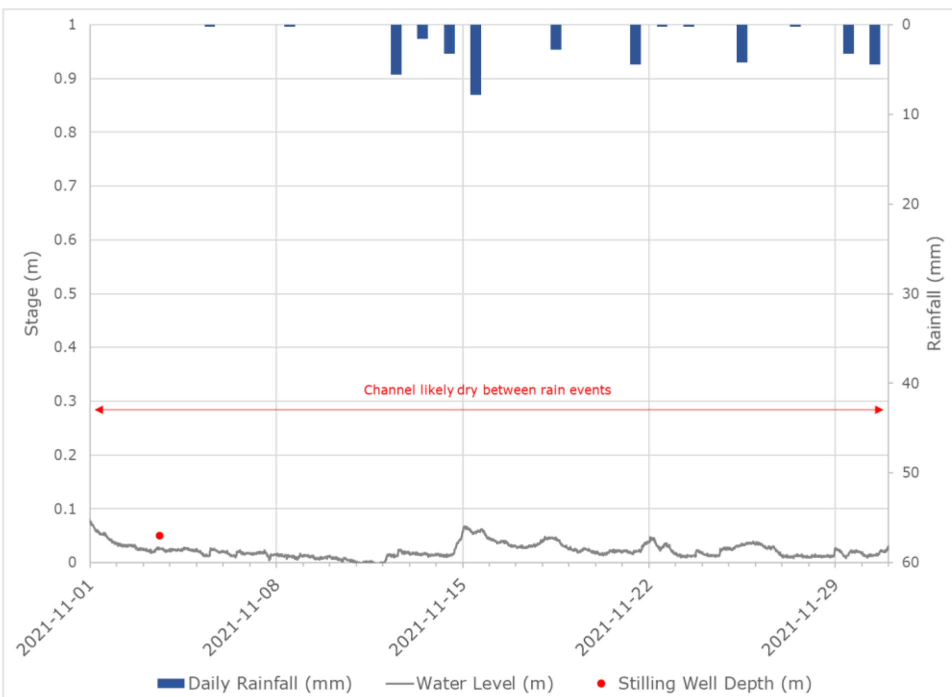
Figure 33	
	Water level and daily rainfall at **Site MN2** for August 2021.
Figure 34	
	Water level and daily rainfall at **Site MN2** for September 2021.

Figure 35	
	Water level and daily rainfall at **Site MN2** for October 2021.
Figure 36	
	Water level and daily rainfall at **Site MN2** for November 2021.

Site MN3 Water Level

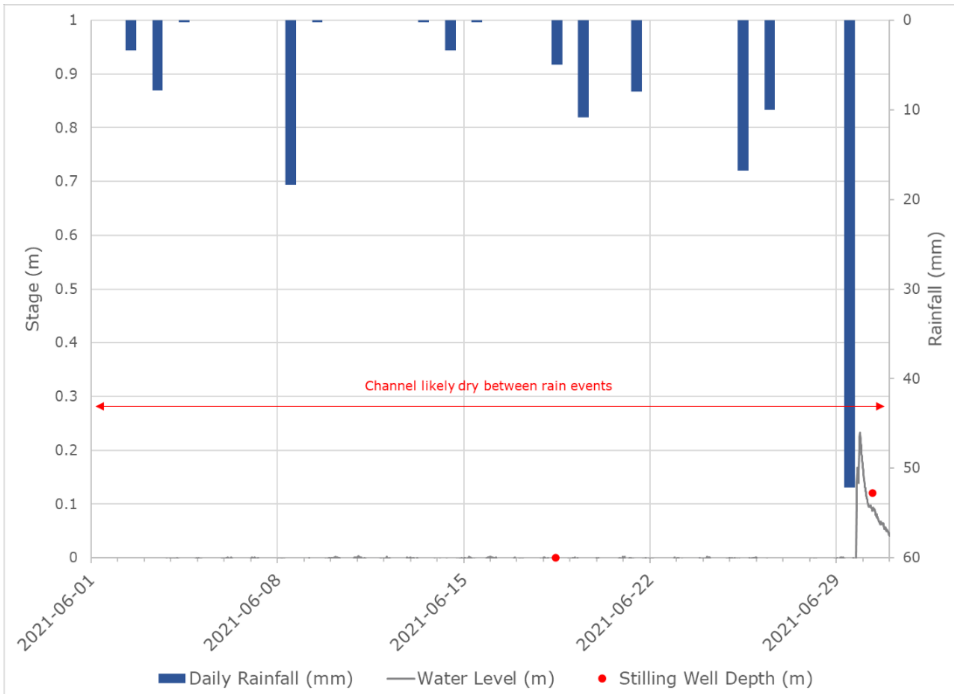
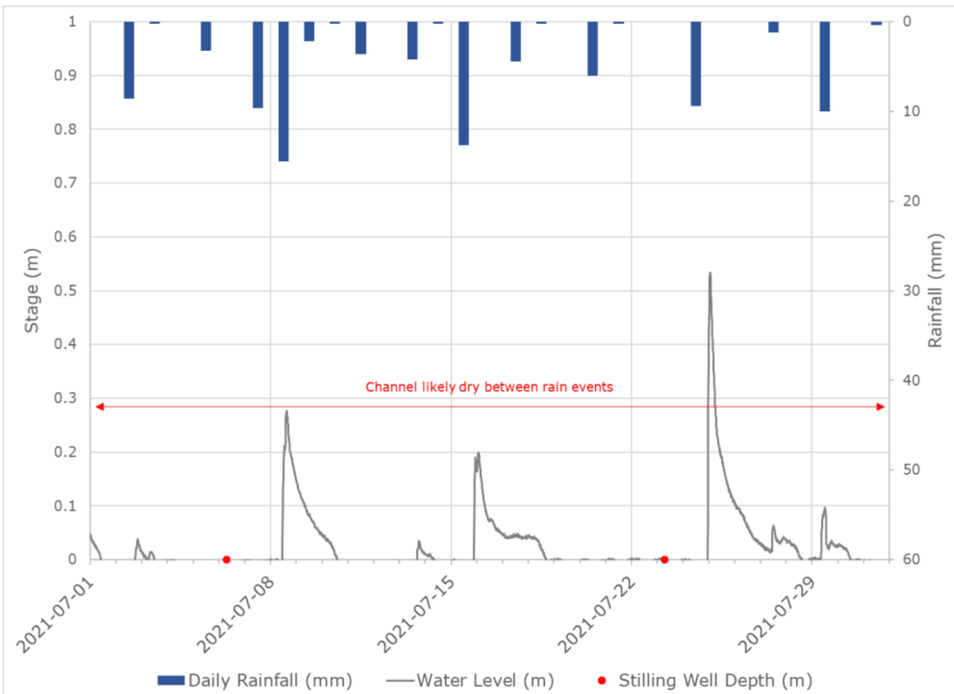
<table>
<tr><td rowspan="2">Figure 37</td><td>
</td></tr>
<tr><td>Water level and daily rainfall at Site MN3 for June 2021.</td></tr>
<tr><td rowspan="2">Figure 38</td><td>
</td></tr>
<tr><td>Water level and daily rainfall at Site MN3 for July 2021.</td></tr>
</table>

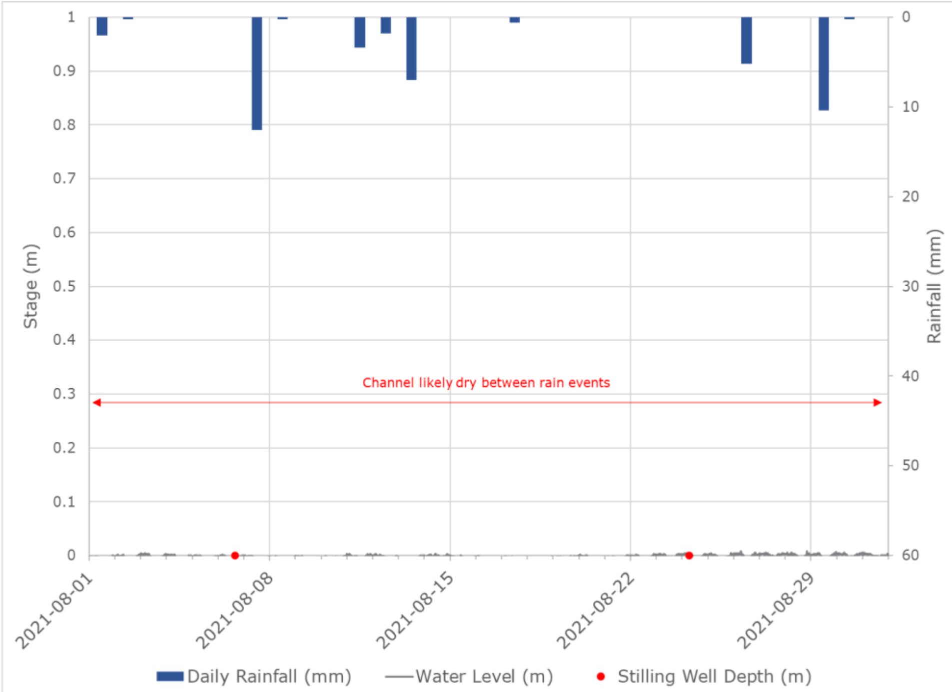
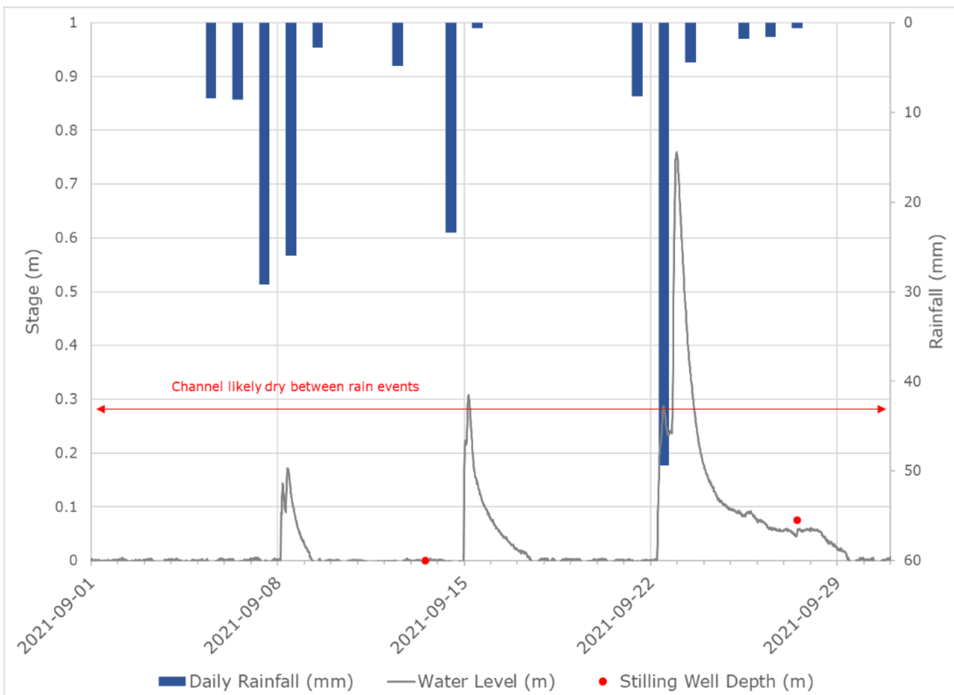
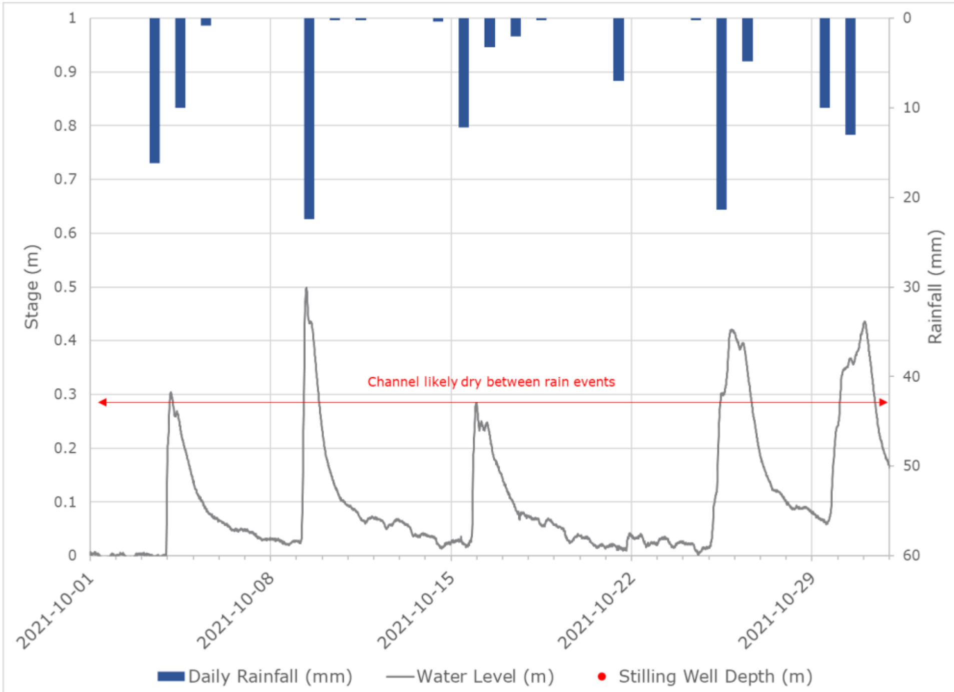
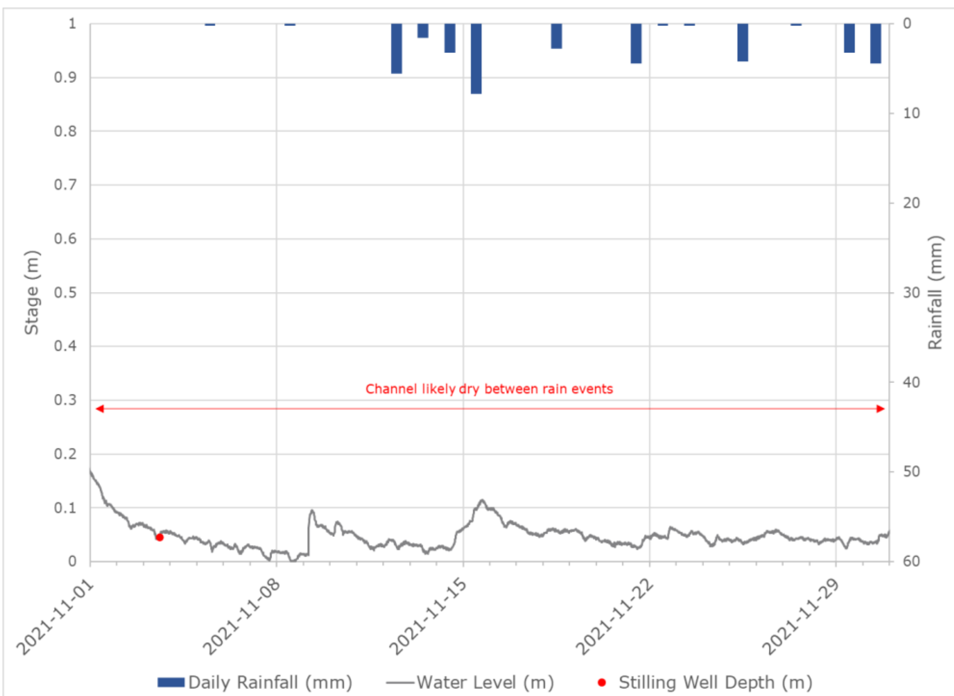
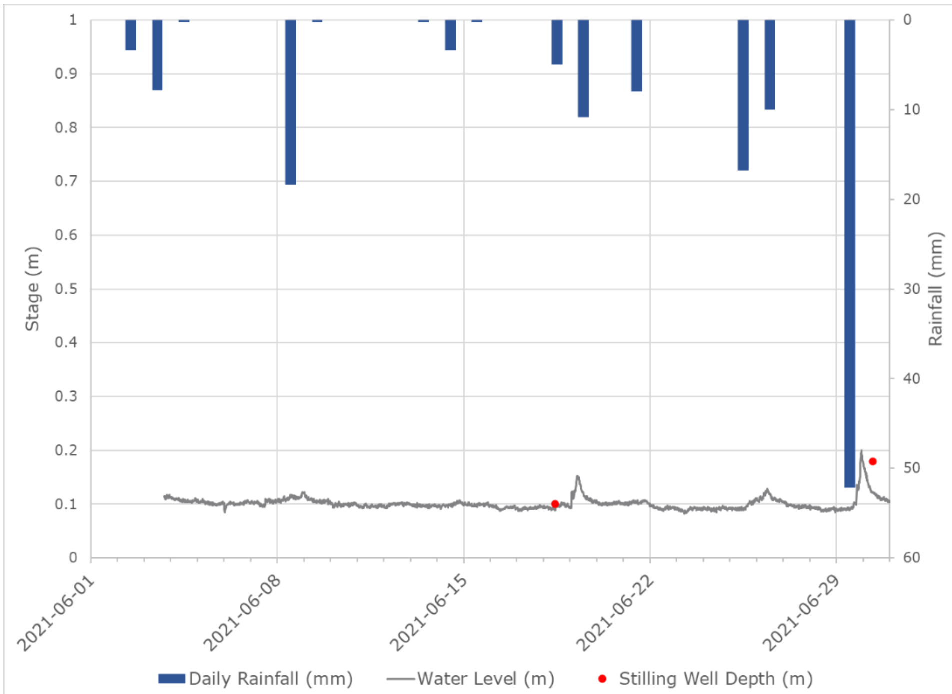
Figure 39	
	Water level and daily rainfall at **Site MN3** for August 2021.
Figure 40	
	Water level and daily rainfall at **Site MN3** for September 2021.

Figure 41	
	Water level and daily rainfall at **Site MN3** for October 2021.
Figure 42	
	Water level and daily rainfall at **Site MN3** for November 2021.

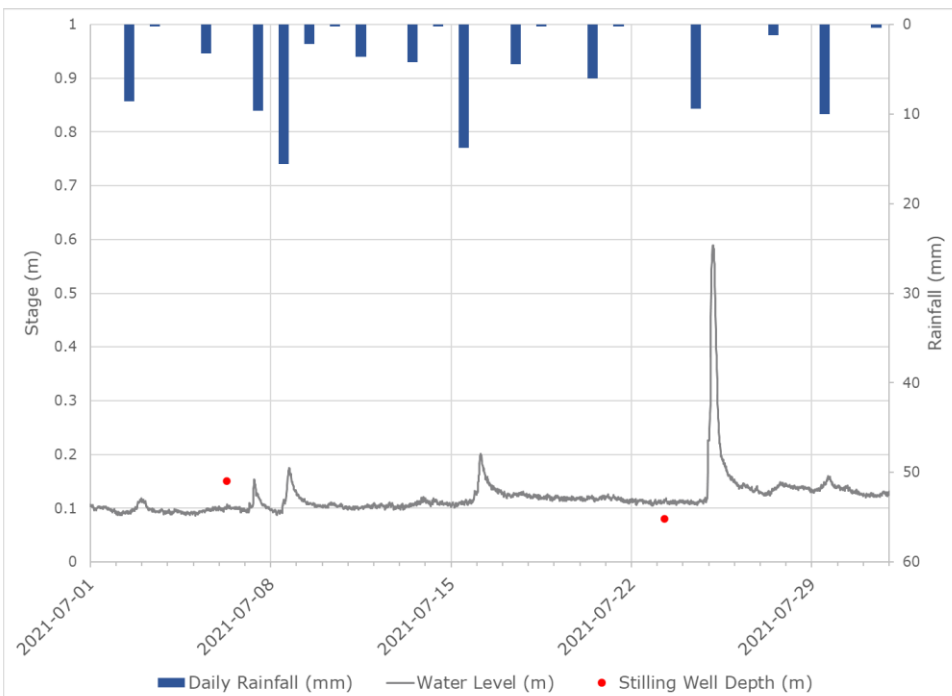
Site MN4 Water Level

Figure 43



Water level and daily rainfall at **Site MN4** for June 2021.

Figure 44



Water level and daily rainfall at **Site MN4** for July 2021.

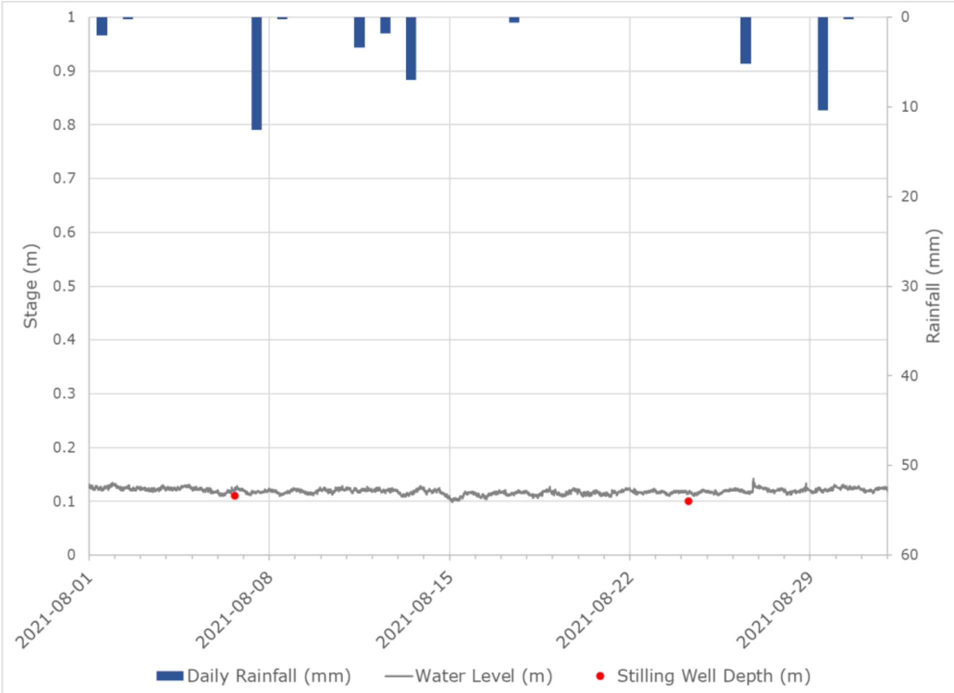
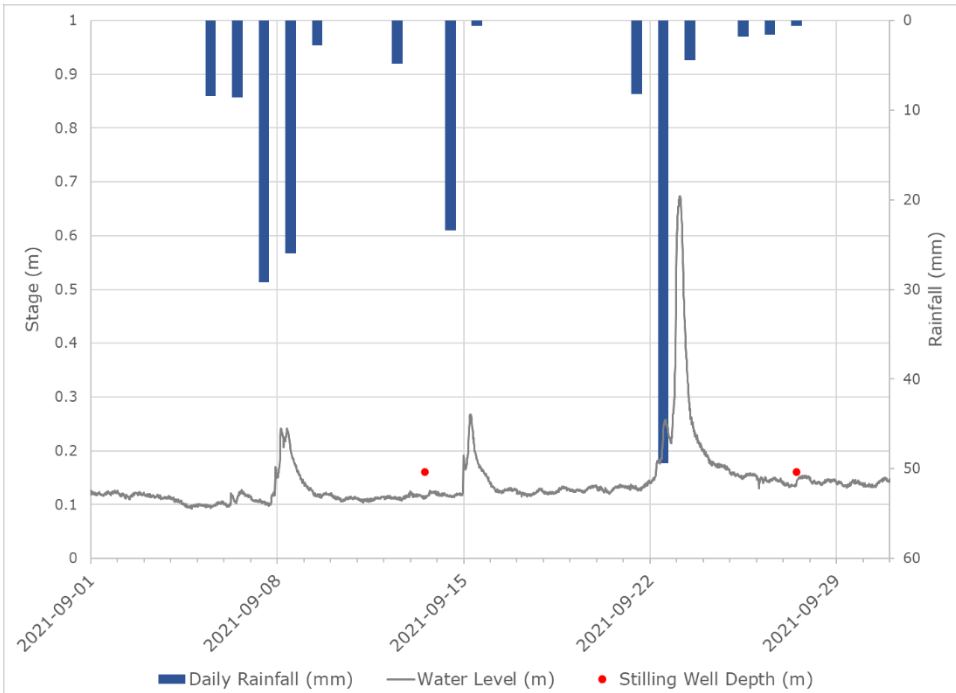
Figure 45	
	Water level and daily rainfall at **Site MN4** for August 2021.
Figure 46	
	Water level and daily rainfall at **Site MN4** for September 2021.

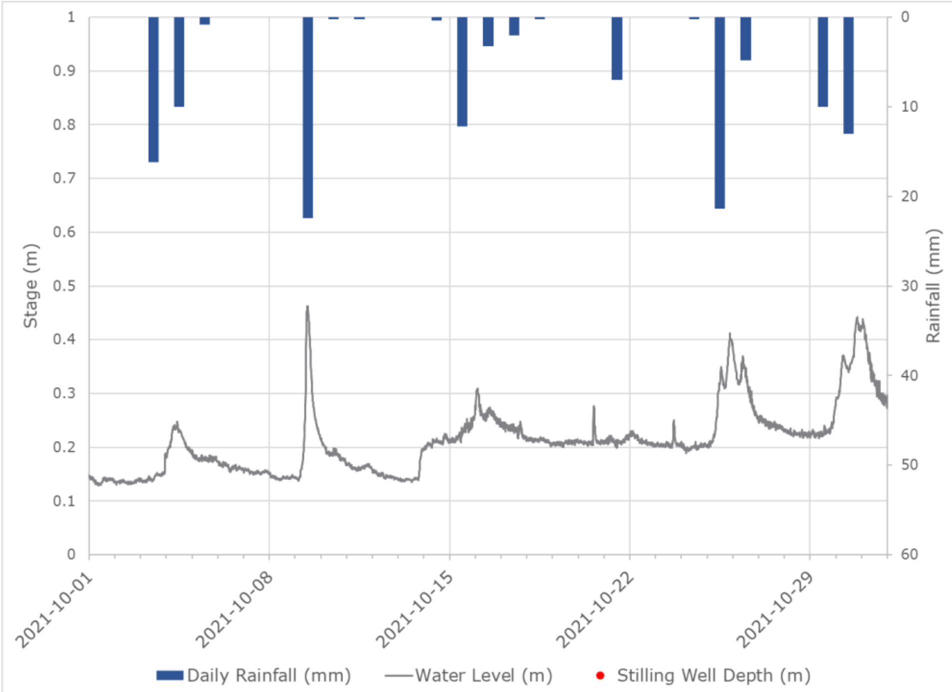
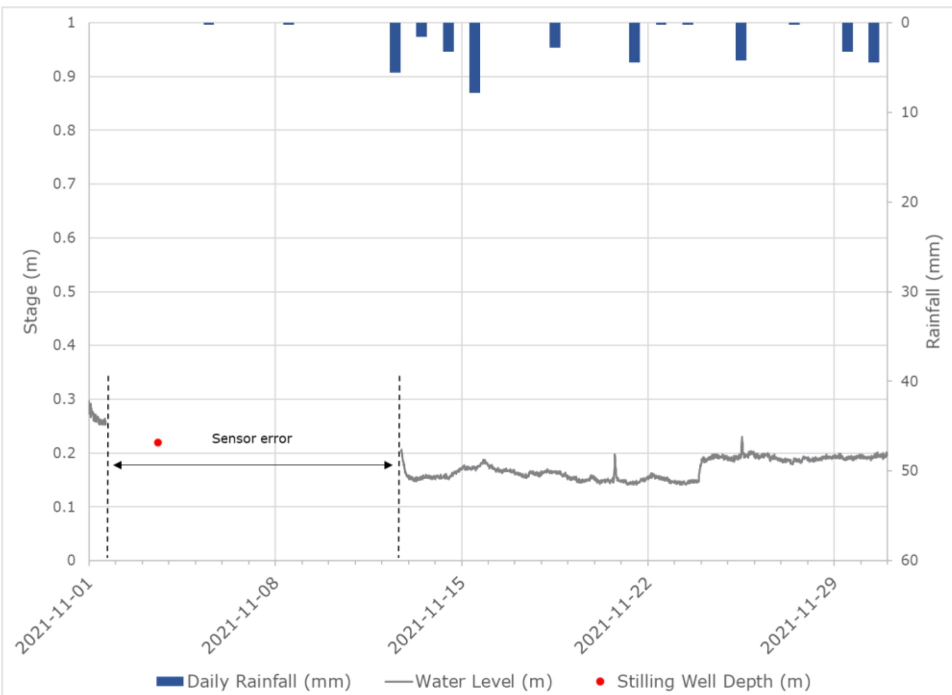
Figure 47	
	Water level and daily rainfall at **Site MN4** for October 2021.
Figure 48	
	Water level and daily rainfall at **Site MN4** for November 2021.

Table 1: Discrete Sampling Data

Date (yyyy-mm-dd)	Sampling Location	TSS (mg/L)	Turbidity (NTU)	Water Temp. (˚C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Conductivity (µS)	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Flow Conditions
2021-06-03	**MN1**	5.0	8.8	21.0	4.34	50.7	1740	3.4	7.8	Rain Event
	MN2	Channel Dry								
	MN3	Channel Dry								
	MN4	9.7	3.6	21.3	5.66	66.1	563			
2021-06-18	**MN1**	N/A	104.8	17.3	5.47	58.4	1822	0.0	5.0	Sensor Downloads; TSS not collected
	MN2		Channel Dry							
	MN3		Channel Dry							
	MN4		3.5	17.8	8.60	92.9	627			
2021-06-30	**MN1**	10.3	26.6	22.7	5.83	69.7	1387	52.2	0.0	Rain Event
	MN2	44.3	80.2	22.1	7.20	83.5	807			
	MN3	16.0	42.9	22.1	6.56	77.6	931			
	MN4	61.5	92.2	20.7	7.98	91.3	563			
2021-07-06	**MN1**	N/A	34.3	21.1	3.40	38.0	N/A	3.2	0.0	Sensor Downloads; TSS not collected
	MN2		Channel Dry							
	MN3		Channel Dry							
	MN4		19.8	22.7	6.00	72.0	551			
2021-07-23	**MN1**	36.3	33.5	16.0	4.30	43.0	626	0.0	0.0	Dry Event
	MN2	Channel Dry								
	MN3	Channel Dry								
	MN4	23.7	18.4	18.8	7.70	84.0	466			

Date (yyyy-mm-dd)	Sampling Location	TSS (mg/L)	Turbidity (NTU)	Water Temp. (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Conductivity (µS)	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Flow Conditions
2021-08-06	MN1	Channel Dry						0.0	0.0	Dry Event
	MN2	Channel Dry								
	MN3	Channel Dry								
	MN4	6.3	9.6	21.4	9.30	107.8	373			
2021-08-24	MN1	N/A	Channel Dry					0.0	0.0	Sensor Downloads; TSS not collected
	MN2		Channel Dry							
	MN3		Channel Dry							
	MN4		6.2	21.9	7.60	88.0	513			
2021-09-13	MN1	N/A	8.6	17.4	2.50	26.0	693	4.8	0.0	Sensor Downloads; TSS not collected
	MN2		Channel Dry							
	MN3		Channel Dry							
	MN4		9.2	18.0	8.70	93.0	469			
2021-09-15	MN1	30.0	36.7	14.3	7.50	75.0	470	23.4	0.6	Rain Event
	MN2	45.3	64.8	13.1	6.40	61.0	254			
	MN3	38.7	35.9	13.0	6.80	65.0	332			
	MN4	17.5	22.2	13.4	7.40	71.0	392			
2021-09-27	MN1	N/A	3.9	15.9	4.80	49.0	15	1.6	0.6	Sensor Downloads; TSS not collected
	MN2		17.9	16.5	4.90	51.0	370			
	MN3		6.7	20.0	10.50	118.0	615			
	MN4		5.7	14.9	9.90	101.0	N/A			

Date (yyyy-mm-dd)	Sampling Location	TSS (mg/L)	Turbidity (NTU)	Water Temp. (°C)	Dissolved Oxygen		Conductivity (µS)	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Flow Conditions
					(mg/L)	(%)				
2021-10-26	**MN1**	96.0	166.0	14.0	9.10	91.0	364	21.4	4.8	Rain Event
	MN2	50.0	149.0	14.0	8.80	88.0	179			
	MN3	32.0	79.8	14.2	8.70	87.0	345			
	MN4	11.7	22.7	14.9	8.70	89.0	477			
2021-11-03	**MN1**	11.7	12.8	6.9	19.40	160.0	853	0.0	0.0	Dry Event
	MN2	44.0	38.6	6.8	10.10	83.0	208			
	MN3	48.7	20.5	9.4	19.90	175.0	497			
	MN4	4.7	9.9	7.8	14.40	121.0	391			

Table 2: Discrete Sampling Data

Date (yyyy-mm-dd)	Sampling Location	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Wetted Width (m)	Wetted Depth (Avg) (m)	Stilling Well Depth (m)	Hydraulic Head (mm)	Flow Conditions
2021-06-03	MN1	3.4	7.8	0.40	0.03	0.03	0.5	Rain Event
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			2.70	0.14	0.18	50.0	
2021-06-18	MN1	0.0	5.0	0.30	0.02	0.04	0.0	Sensor Downloads
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			2.87	0.11	0.11	45.0	
2021-06-30	MN1	52.2	0.0	0.55	0.07	0.07	2.0	Rain Event
	MN2			0.55	0.11	0.10	5.0	
	MN3			1.00	0.07	0.12	0.0	
	MN4			3.60	0.19	0.18	70.0	
2021-07-06	MN1	3.2	0.0	0.40	0.02	0.02	0.0	Sensor Downloads
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			3.00	0.16	0.15	40.0	
2021-07-23	MN1	0.0	0.0	0.21	0.02	0.02	0.0	Dry Event
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			3.43	0.13	0.08	40.0	

Date (yyyy-mm-dd)	Sampling Location	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Wetted Width (m)	Wetted Depth (Avg) (m)	Stilling Well Depth (m)	Hydraulic Head (mm)	Flow Conditions
2021-08-06	**MN1**	0.0	0.0	Channel Dry				Dry Event
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			2.80	0.13	0.11	40.0	
2021-08-24	**MN1**	0.0	0.0	Channel Dry				Sensor Downloads
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			3.10	0.12	0.10	35.0	
2021-09-13	**MN1**	4.8	0.0	0.18	0.02	0.01	0.0	Sensor Downloads
	MN2			Channel Dry				
	MN3			Channel Dry				
	MN4			3.39	0.12	0.16	24.0	
2021-09-15	**MN1**	23.4	0.6	N/A				Rain Event
	MN2							
	MN3							
	MN4							
2021-09-27	**MN1**	1.6	0.6	0.45	0.04	0.04	0.0	Sensor Downloads
	MN2			0.34	0.04	0.04	0.0	
	MN3			0.29	0.06	0.08	0.0	
	MN4			3.69	0.15	0.16	18.0	

Date (yyyy-mm-dd)	Sampling Location	Past 24 hr Rainfall (mm)	Total Rainfall on Day (mm)	Wetted Width (m)	Wetted Depth (Avg) (m)	Stilling Well Depth (m)	Hydraulic Head (mm)	Flow Conditions
2021-10-26	**MN1**	21.4	4.8	0.59	0.10	0.14	1.0	Rain Event
	MN2			0.75	0.12	0.12	1.0	
	MN3			1.50	0.16	0.20	2.0	
	MN4			5.60	0.29	0.45	20.0	
2021-11-03	**MN1**	0.0	0.0	0.07	0.05	0.06	0.0	Dry Event
	MN2			0.33	0.05	0.05	0.0	
	MN3			0.28	0.07	0.05	0.1	
	MN4			4.52	0.31	0.22	130.0	

Appendix C
Photographic Record

Photo 1	
	Photograph facing downstream from site **MN1** during baseflow conditions where the channel was dry.
Photo 2	
	Photograph facing downstream towards site **MN1** following a 52.2 mm rainfall event.

Photo 3	
	Photograph facing upstream towards site **MN2** during baseflow conditions where the channel was dry.
Photo 4	
	Photograph facing upstream towards site **MN2** following a 52.2 mm rainfall event.

Photo 5	
	Photograph facing upstream towards site **MN3** during baseflow conditions where the channel was dry.
Photo 6	
	Photograph facing upstream towards site **MN3** following a 52.2 mm rainfall event.

Photo 7	
	Photograph facing downstream towards site **MN4** during baseflow conditions.
Photo 8	
	Photograph facing downstream at site **MN4** following a 52.2 mm rainfall event.

Appendix D
Laboratory Analysis Results

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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	438861
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205	Regulation:	Information not provided
	Campbellville, ON, L0P 1B0	Project #:	PN21059
Phone:		DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	WM
Date Order Received:	8/9/2021	Analysis Started:	8/16/2021
Arrival Temperature:	9.4 °C	Analysis Completed:	8/16/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN4	1671065	Surface Water	None		8/6/2021	3:46 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

This report has been approved by:

Marc Creighton
Laboratory Director

TESTMARK Laboratories Ltd.
Committed to Quality and Service

CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 438861

WORK ORDER RESULTS

Sample Description	PN21059 - MN4
Sample Date	8/6/2021 3:46 PM
Lab ID	1671065

Solids	Result	MDL	Units
Total Suspended Solids	6.30	0.67	mg/L

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

Quality Control: All associated Quality Control data is available on request.

Field Data: Reports containing Field Parameters represent data that has been collected and provided by the client. Testmark is not responsible for the validity of this data which may be used in subsequent calculations.

Sample Condition Deviations: A noted sample condition deviation may affect the validity of the result. Results apply to the sample(s) as received.

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6820 Kitimat Road Unit 4, Mississauga, ON, L5N 5M3
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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	442715
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205 Campbellville, ON, L0P 1B0	Regulation:	Information not provided
		Project #:	PN21059
Phone:		DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	JT
Date Order Received:	9/16/2021	Analysis Started:	9/22/2021
Arrival Temperature:	10.6 °C	Analysis Completed:	9/22/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN1	1684211	Surface Water	None		9/15/2021	5:45 PM
PN21059 - MN2	1684212	Surface Water	None		9/15/2021	5:22 PM
PN21059 - MN3	1684213	Surface Water	None		9/15/2021	5:00 PM
PN21059 - MN4	1684214	Surface Water	None		9/15/2021	4:26 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 442715

This report has been approved by:

Marc Creighton
Laboratory Director

6820 Kitimat Road Unit 4, Mississauga, ON, L5N 5M3
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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 442715

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN2		PN21059 - MN3		PN21059 - MN4		
Sample Date	9/15/2021 5:45 PM		9/15/2021 5:22 PM		9/15/2021 5:00 PM		9/15/2021 4:26 PM		
Lab ID	1684211		1684212		1684213		1684214		
Solids	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units
Total Suspended Solids	30.0	1.3	45.3	1.3	38.7	1.3	17.5	1	mg/L

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

Quality Control: All associated Quality Control data is available on request.

Field Data: Reports containing Field Parameters represent data that has been collected and provided by the client. Testmark is not responsible for the validity of this data which may be used in subsequent calculations.

Sample Condition Deviations: A noted sample condition deviation may affect the validity of the result. Results apply to the sample(s) as received.

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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	447022
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205 Campbellville, ON, L0P 1B0	Regulation:	Information not provided
		Project #:	PN21059
Phone:	(905) 699-1580	DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	JT DV
Date Order Received:	10/28/2021	Analysis Started:	11/3/2021
Arrival Temperature:	3.6 °C	Analysis Completed:	11/3/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN1	1700826	Surface Water	None		10/26/2021	5:00 PM
PN21059 - MN2	1700827	Surface Water	None		10/26/2021	4:45 PM
PN21059 - MN3	1700828	Surface Water	None		10/26/2021	4:30 PM
PN21059 - MN4	1700829	Surface Water	None		10/26/2021	3:50 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 447022

This report has been approved by:

Marc Creighton
Laboratory Director

6820 Kitimat Road Unit 4, Mississauga, ON, L5N 5M3
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TESTMARK Laboratories Ltd.
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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 447022

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN2		PN21059 - MN3		PN21059 - MN4		
Sample Date	10/26/2021 5:00 PM		10/26/2021 4:45 PM		10/26/2021 4:30 PM		10/26/2021 3:50 PM		
Lab ID	1700826		1700827		1700828		1700829		
Solids	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units
Total Suspended Solids	96 [94]	2	50	2	32.0	1.3	11.70	0.67	mg/L

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

[ ]: Results for laboratory replicates are shown in square brackets immediately below the associated sample result for ease of comparison.

Quality Control: All associated Quality Control data is available on request.

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Sample Condition Deviations: A noted sample condition deviation may affect the validity of the result. Results apply to the sample(s) as received.

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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	447830
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205 Campbellville, ON, L0P 1B0	Regulation:	Information not provided
		Project #:	PN21059
Phone:	(905) 699-1580	DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	DM HH
Date Order Received:	11/5/2021	Analysis Started:	11/12/2021
Arrival Temperature:	4.3 °C	Analysis Completed:	11/12/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN1	1703824	Surface Water	None		11/3/2021	2:43 PM
PN21059 - MN2	1703825	Surface Water	None		11/3/2021	2:35 PM
PN21059 - MN3	1703826	Surface Water	None		11/3/2021	2:31 PM
PN21059 - MN4	1703827	Surface Water	None		11/3/2021	2:29 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 447830

This report has been approved by:

Marc Creighton
Laboratory Director

6820 Kitimat Road Unit 4, Mississauga, ON, L5N 5M3
Phone: (905) 821-1112   Fax: (905) 821-2095   Web: www.testmark.ca

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 447830

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN2		PN21059 - MN3		PN21059 - MN4		
Sample Date	11/3/2021 2:43 PM		11/3/2021 2:35 PM		11/3/2021 2:31 PM		11/3/2021 2:29 PM		
Lab ID	1703824		1703825		1703826		1703827		
Solids	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units
Total Suspended Solids	11.70	0.67	44.0	1.3	48.7 [50.7]	1.3	4.70	0.67	mg/L

LEGEND

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Sample Condition Deviations: A noted sample condition deviation may affect the validity of the result. Results apply to the sample(s) as received.

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CERTIFICATE OF ANALYSIS

Client:	Tye Rusnak	Work Order Number:	432261
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205	Regulation:	Information not provided
	Campbellville, ON, L0P 1B0	Project #:	PN21059
Phone:		DWS #:	
Email:	tyer@geomorphix.com	Sampled By:	TR
Date Order Received:	6/4/2021	Analysis Started:	6/11/2021
Arrival Temperature:	7.9 °C	Analysis Completed:	6/11/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059- MN1	1650529	Surface Water	None		6/3/2021	11:30 AM
PN21059- MN4	1650530	Surface Water	None		6/3/2021	11:00 AM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

This report has been approved by:

Marc Creighton
Laboratory Director

TESTMARK Laboratories Ltd.
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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 432261

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN4		
Sample Date	6/3/2021 11:30 AM		6/3/2021 11:00 AM		
Lab ID	1650529		1650530		
Solids	Result	MDL	Result	MDL	Units
Total Suspended Solids	5.00	0.67	9.67	0.67	mg/L

LEGEND

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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	435502
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205	Regulation:	Information not provided
	Campbellville, ON, L0P 1B0	Project #:	PN21059
Phone:		DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	JV DVC
Date Order Received:	6/30/2021	Analysis Started:	7/7/2021
Arrival Temperature:	26.7 °C	Analysis Completed:	7/7/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN1	1659388	Surface Water	None		6/30/2021	9:14 AM
PN21059 - MN2	1659389	Surface Water	None		6/30/2021	9:04 AM
PN21059 - MN3	1659390	Surface Water	None		6/30/2021	8:53 AM
PN21059 - MN4	1659391	Surface Water	None		6/30/2021	8:38 AM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 435502

This report has been approved by:

Marc Creighton
Laboratory Director

6820 Kitimat Road Unit 4, Mississauga, ON, L5N 5M3
Phone: (905) 821-1112   Fax: (905) 821-2095   Web: www.testmark.ca

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CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 435502

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN2		PN21059 - MN3		PN21059 - MN4		
Sample Date	6/30/2021 9:14 AM		6/30/2021 9:04 AM		6/30/2021 8:53 AM		6/30/2021 8:38 AM		
Lab ID	1659388		1659389		1659390		1659391		
Solids	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units
Total Suspended Solids	10.30	0.67	44.30	0.67	16.00	0.67	61.5	1	mg/L

LEGEND

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CERTIFICATE OF ANALYSIS

Client:	Patrick Padovan	Work Order Number:	438136
Company:	Geo Morphix	PO #:	PN21059
Address:	36 Main St. N. P.O. Box 205 Campbellville, ON, L0P 1B0	Regulation:	Information not provided
		Project #:	PN21059
Phone:		DWS #:	
Email:	patrickp@geomorphix.com	Sampled By:	JV,DM
Date Order Received:	7/29/2021	Analysis Started:	8/6/2021
Arrival Temperature:	10.1 °C	Analysis Completed:	8/6/2021

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
PN21059 - MN1	1668724	Surface Water	None		7/23/2021	6:58 AM
PN21059 - MN4	1668725	Surface Water	None		7/23/2021	6:35 AM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
TSS (A27)	Mississauga	Determination of Total Suspended Solids in water by gravimetry	Modified from SM-2540

This report has been approved by:

Marc Creighton
Laboratory Director

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Committed to Quality and Service

CERTIFICATE OF ANALYSIS

Geo Morphix

Work Order Number: 438136

WORK ORDER RESULTS

Sample Description	PN21059 - MN1		PN21059 - MN4		
Sample Date	7/23/2021 6:58 AM		7/23/2021 6:35 AM		
Lab ID	1668724		1668725		
Solids	Result	MDL	Result	MDL	Units
Total Suspended Solids	36.30	0.67	23.70	0.67	mg/L

LEGEND

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