Technical Design Brief: Tributary of Chedoke Creek Realignment

City of Hamilton, Ontario

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July 24, 2020
PN19110

GEO MORPHIX
Geomorphology
Earth Science
Observations

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Report Title:	Technical Design Brief: Tributary of Chedoke Creek Realignment, City of Hamilton
Project Number:	PN19110
Status:	Final
Version:	1.0
First Submission Date:	July 24, 2020
Revision Date:	--
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Approval Date:	July 24, 2020

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1 Introduction

This design brief provides design recommendations for a realignment and enhancement of a tributary of Chedoke Creek located to the northwest of the Scenic Drive and Sanitorium Road intersection within the City of Hamilton, Ontario. The existing channel will be realigned, which provides an opportunity to replace the existing degraded channel, with a naturalized watercourse that offers significant improvements to channel form and function. The existing morphologically-limited channel will be replaced with a riffle and pool system, with cross sectional dimensions closer to that of a natural watercourse conveying similar flows. The proposed realignment serves to improve channel form and function and enhance aquatic habitat. This technical design brief provides additional insight into the design and is to accompany the detailed design drawings.

Wetland elements will be incorporated in the design to provide a functionally diverse floodplain. The objective of these is to passively store and discharge subsurface flow over longer attenuated periods. These wetland features will also improve water quality through infiltration and retention processes. The channel design serves to improve channel form and function, aquatic habitat, and habitat variability, increase wetted width and low flow habitat, and provide greater substrate and morphological variability.

This report provides:

- Summary of existing channel conditions, including a detailed survey to estimate bankfull geometry
- Description of the natural channel design characteristics and geometry
- Hydraulic sizing of the channel materials
- Recommendations for design implementation including construction timing, and best management practices
- Description of a post-construction monitoring plan

This design brief is provided to facilitate review of the design. The following report outlines the current geomorphological condition of the Tributary of Chedoke Creek, design considerations, and technical details associated with channel sizing and restoration. It also provides recommendations for implementation and monitoring of the proposed design.

2 Existing Conditions

2.1 Field Observations

The upstream extent of the channel assessment began at Scenic Drive where the channel then flows in a north-easterly direction before being piped under Sanatorium Road towards the Niagara Escarpment. The assessed reach consisted of a single thread channel in a partially confined valley with low sinuosity and a moderate gradient. The reach was entrenched at the upstream extent and an old pedestrian crossing was noted at the downstream extent causing minor channel blockage. The riparian zone was mostly comprised of established trees and formed a continuous buffer. A moderate amount of woody debris was found within the channel. The average bankfull width and depth were

2.77 m and 0.32 m. Bank erosion was observed along approximately 75% of the banks with undercuts up to 0.15 m present. Leaning trees and exposed tree roots were also observed. The upstream portion of the reach was dominated by runs and riffle-pool sequences were only noted downstream of the pedestrian crossing. Bed substrate consisted of clay, silt, and sand except at the downstream extent where the bedrock was exposed, and gravel and cobbles were present.

Most of the study area is located within the Iroquois Plains physiographic region with the southern portion bordering the Haldimand Clay Plains region (OGS, 2010). The surficial geology consists of clay to silt-textured till derived from glaciolacustrine deposits or shale and the northern extent of the study site borders paleozoic bedrock (OGS, 2003).

Rapid geomorphological assessments of the Tributary of Chedoke Creek were completed on November 29, 2019. To provide context, a photographic record is provided in **Appendix B** and field notes are included in **Appendix C**. The rapid assessments including the following observations:

- 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)
- Stream classification following a modified Downs (1995) and a modified Brierley and Fryirs (2005) River Styles Classification approach
- Reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow behaviour, geomorphological units, and riparian vegetation on the day
- Instream estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Georeferenced photographs to document the location of all observed erosion and infrastructure

The RGA evaluates systematic adjustments characterized as degradation, aggradation, widening, and planimetric form adjustment at the reach scale. The RGA method relies on the absence or presence of these indicators to evaluate the systematic adjustments in streams associated with natural causes or human activities. Systematic adjustments typically result in changes to the floodplain, channel or valley characteristics. The end result of the RGA is to produce a score, or stability index, which evaluates the degree to which a stream has departed from the equilibrium condition. A stream with a score of less than 0.20 is *in regime*, indicating minimal changes to its shape or processes over time. A score of 0.21 to 0.40 indicates that a stream is *in transition* or *stressed* and is experiencing major change to process and form outside the natural range of variability. A score of greater than 0.41 indicates that a stream is in extreme adjustment, likely exhibiting a new stream type and will continue to adjust to the point of returning to equilibrium, or is moving toward a new equilibrium (MOE, 2003).

The Downs (1995) model of channel evolution is a method used to evaluate the magnitude and potential for channel instability. This model uses physical indicators of systematic adjustment including channel, bank and bar morphology and stability to classify the type of channel evolution. By classifying channels using this model, the nature of fluvial and hillslope processes that are working to change the system can be inferred. Channels are classified as varying degrees of stable, depositional, migrating laterally, enlarging, and experiencing various types of erosion (Downs, 1995; Simon and Downs, 1995).

The assessed tributary had an RGA score of 0.19, indicating that the channel is *in regime*. The dominant modes of adjustment were degradation and widening. These were characterized by exposed pipes, head cutting, exposed tree roots and occurrence of large organic debris. The Down's model classified this channel as 'E' – enlarging, indicating a consistent increase in channel width and depth.

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and consider the ecological functioning of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a *poor* (<13), *fair* (13-24), *good* (25-34) or *excellent* (35-42) degree of stream health. The RSAT was completed and produced a score of 22, indicating the channel is in fair health. Details are provided in **Appendix C**.

2.2 Detailed Assessment

Following the rapid geomorphological assessment, a detailed assessment was completed for the Tributary of Chedoke Creek on November 29, 2019 to determine average bankfull channel characteristics, including cross-sectional geometry and hydraulics, for informing any potential restoration activities. The following activities were completed:

- 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 / substrate sampling

Eight representative cross sections were surveyed, and channel measurements were then used to calculate bankfull flow characteristics such as discharge, average velocity, and erosion or sediment transport sensitivity. Measured and computed values are presented in **Table 1**. As part of the detailed assessment, a longitudinal survey of the bed was completed to determine slope and a composite sample was taken to characterize bed materials. Average bankfull width and depth were 2.79 m and 0.32 m, respectively. The gradient of the bankfull channel was documented to be 0.89%. Bankfull discharge was back-calculated to be 1.11 m^3/s. To be conservative, we also determined a secondary discharge by extending the bankfull channel width to the location where flow would spill into the floodplain. This resulted in a discharge of 2.57 m^3/s. A summary of the detailed survey results are provided in **Table 1** and a summary of the detailed assessment is provided in **Appendix D**.

Table 1: Measured and computed channel parameters

Channel parameter	Bankfull Indicator	Floodplain
Average bankfull channel width (m)	2.79	4.40
Average bankfull channel depth (m)	0.32	0.40
Bankfull channel gradient (%)	0.89	0.89
D_{50} (mm)	< 2.0	< 2.0
Manning's n roughness coefficient	0.040	0.040
Calculated		
Bankfull discharge (m^3/s) *	1.11	2.57
Average bankfull velocity (m/s)	1.26	1.46

* Based on Manning's equation

3 Natural Channel Design

3.1 Design Objectives

Given this section of the Tributary of Chedoke Creek is proposed to be restored and realigned, there is opportunity to replace the existing morphologically-limited channel with a dynamically stable channel containing a naturalized riffle and pool system, with cross sectional dimensions closer to that of a naturalized watercourse conveying similar flows. One goal of the natural channel design is to replace the existing degraded and previously disturbed channel with a watercourse that will offer significant improvements to channel form and function per unit length.

This section of the Tributary of Chedoke Creek was characterized with a perennial flow regime. To maintain and enhance these functions, the design serves to provide good communication with the floodplain, as well as diversity in channel and floodplain morphology. As such, online and offline wetland features will be constructed throughout the floodplain. These features enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form. They also provide functional benefits by storing and discharging water over longer, attenuated periods.

The channel realignment and naturalization provide opportunities for improved riparian conditions and a well-developed bankfull channel with morphological variability. Improvement in morphology and function will provide additional benefits to the sediment balance and substrate variability, floodplain storage, vegetation communities, terrestrial habitat features, edge impacts, fish passage and water quality. From a habitat perspective, the important contributions of the watercourse include the provision of seasonal habitat, organic inputs to the system, provision of a more complex corridor system with elements that have a wide range of hydroperiods, and aquatic and terrestrial habitat elements.

The primary objectives of the design are to:

- Improve the physical form of the channel, including planform and instream characteristics
- Improve the function of the channel and promote interaction with the floodplain

- Improve water quality by extending detention of water through offline wetland features
- Enhance aquatic habitat through the provision of a morphologically diverse channel with spatially varied flows
- Improve riparian habitat by installing woody plantings

3.2 Channel Planform

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

$$Rc = 2.43 \times w \qquad \text{[Eq. 1]}$$

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

Empirical models derived by Hey and Thorne (1986) were followed to determine riffle spacing. Hey and Thorne's (1986) modelled values are often applied in larger watercourses. As such, multiple methods (Eq. 2-4) were considered in order to provide a range of riffle spacing values. These are:

$$Z = 6.31 \times w \qquad \text{[Eq. 2]}$$

$$Z = 9.1186 \times w^{0.8846} \qquad \text{[Eq. 3]}$$

$$Z = 7.36 \times w^{0.896} \times S^{-0.03} \qquad \text{[Eq. 4]}$$

where *Z* represents riffle spacing.

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

$$\Omega = \rho \times g \times d \times S \qquad \text{[Eq. 5]}$$

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

Stream power per unit width (Eq. 6), is given by:

$$\omega = \frac{\Omega}{w} \qquad \text{[Eq. 6]}$$

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

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

3.3 Bankfull Channel

The recommended restoration design focuses on a riffle-pool typology, which will provide significant improvements to not only the channel as it essentially replicates a natural system, but also to aquatic habitat. The proposed detailed design drawings are included in **Appendix E** and design elements are described in further detail below. When it is assessed to be an appropriate channel type, a riffle-pool system offers numerous benefits:

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

Channel design dimensions are determined by bankfull discharge, as this represents what is generally referred to as the "*channel-forming discharge*" or the "*dominant discharge*". Several methods can be applied to select an appropriate bankfull discharge. Back calculation of discharge from a reference reach along with support from hydrological modelling is usually the most appropriate. Based on our detailed assessment and channel survey from November, we determined a bankfull discharge of 1.11 m^3/s based on the bankfull channel indicators observed on site. To be conservative, a secondary discharge was determined by extending the bankfull channel width to the location where flow would spill into the floodplain. This resulted in a discharge of 2.57 m^3/s. As such, to be slightly more conservative while considering the observed bankfull channel indicators, a bankfull discharge of 2.0 m^3/s was defined to be implemented for the channel design.

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed channel. Since pools are designed to contain ineffective space, this model over-predicts the amount of discharge that they convey. As such, the modelled values for the riffles give a better prediction of the channel's capacity. Riffle and pool geometries, as well as anticipated bankfull conditions for the proposed channel, are provided in **Table 2**.

Table 2: Bankfull parameters of the proposed channel

Channel parameter	Riffle	Pool
Bankfull width (m)†	3.15	3.65
Average bankfull depth (m)†	0.32	0.38
Maximum bankfull depth (m)†	0.45	0.65
Bankfull width-to-depth ratio	7.00	5.61
Channel gradient (%)	3.60	0.89
Bankfull gradient (%)	0.89	0.89
Manning's roughness coefficient, *n*	0.04	0.03
Mean bankfull velocity (m/s) *	1.97	--
Bankfull discharge (m^3/s) *	2.01	--
Discharge to accommodate (m^3/s)	2.00	2.00
Tractive force at bankfull (N/m^2)††	158.86	54.82
Stream power (W/m)††	709.66	166.78
Unit stream power (W/m^2)††	270.35	69.28
Maximum grain size entrained (m)†† **	0.16	0.06
Mean grain size entrained (m)†† **	0.12	0.03

† 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. To provide for a stable bed and level of sorting, 60% 200 mm – 250 mm diameter Riverstone and 40% granular 'b' material is proposed for the riffles. Granular 'b' consists of a mix of stone where approximately 20 % - 50 % of the stone is greater than 0.005 m in diameter, but nothing larger than 0.15 m in diameter. These materials will always have a core of sediment that is not entrained under bankfull flow conditions. This material maintains the character of the native material, while providing slightly higher stability and opportunity for sediment sorting.

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 existing length of the Tributary of Chedoke Creek proposed for realignment is approximately 205 m. The realigned corridor will provide a total linear distance of approximately 190 m. To produce a system similar to what would occur in nature, a sinuosity of approximately 1.2 was applied to the realigned channel, resulting in an increased channel length of 234 m. The proposed channel will therefore result in a significant increase in the area of restored and enhanced habitat.

The proposed realignment and naturalization of the Tributary of Chedoke Creek provides 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, water balance, fish passage and water quality.

An online wetland/plunge pool will be installed at the upstream and downstream channel extents and will serve as added protection for the associated outlets. The plunge pool will have a stone core of hydraulically-sized rounded stone, which is the subsurface material used to ensure pool stability. The proposed stone core is expected to be stable under the predicted flow conditions in the wetlands. The substrate within the stone core is proposed to be a mix of 60% 250 mm – 300 mm diameter riverstone and 40% granular 'b'. A layer of topsoil will be installed on top of the stone core to improve vegetation establishment. The stone was hydraulically sized to limit entrainment. A range of techniques were utilized to determine the appropriate stone size, as summarized in the National Engineering Handbook (NRCS, 2007). These techniques are provided in **Table 3**. Based on our detailed assessment and channel survey, the calculated bankfull velocity of 2.28 m/s was used to determine the appropriate stone size for the online wetland/plunge pool. This velocity corresponds to the secondary discharge which was determined by extending the bankfull channel width to the location where flow would spill into the floodplain. The stone size includes a factor of safety to provide additional stability at the maximum outflow, while allowing for volumetric storage and infiltration at lower flows.

Table 3: Substrate sizes for the plunge pool based on a range of techniques

Model	Formula	Velocity (m/s)	Stone Size* (mm)
Plunge Pool Substrate			
Isbash Method (Isbash, 1936)	$D_{50} = (\frac{V_c}{C * \left(2 * g * \frac{\gamma_S - \gamma_W}{\gamma_W}\right)^{0.5}})^2$	2.28	261
USBR Method (Peterka, 1958)	$D_{50} = 0.0122 * V^{2.06}$	2.28	282

*Includes 20% factor of safety

The Isbash method (Isbash, 1936) was developed for the construction of dams by placing rock into moving water. This model predicts the median stone size (D_{50}; ft) under the given flow conditions, given by:

$$D_{50} = (\frac{V_c}{C*(2*g*\frac{\gamma_S-\gamma_W}{\gamma_W})^{0.5}})^2 \quad \text{[Eq.7]}$$

Where:

V_c = critical velocity (ft/s)
C = Isbash constant (dimensionless)
g = gravity (ft/s)
γ_s = stone density (lb/ft^3)
γ_w = water density (lb/ft^3)

The USBR Method (Peterka, 1958) was developed for sizing riprap below a stilling basin. This model predicts the median stone size (D_{50}; ft) under the given flow conditions, given by:

$$D_{50} = 0.0122 * V^{2.06} \quad \text{[Eq.8]}$$

Where:

V = average channel velocity (ft/s)

The values used for each variable in the Isbash method, and USBR method are provided in **Table 4**.

Table 4: Variables and values associated with the plunge pool substrate

Variable	Plunge Pool
Isbash Method	
Critical velocity (V_c) (ft/s)	7.48 (2.28 m/s)
Isbash constant (C) (unitless)	0.86
Gravity (g) (ft/s^2)	32.2 (9.81 m/s^2)
Stone density (γ_s) (lb/ft^3)	165.43 (2650 kg/m^3)
Water density (γ_w) (lb/ft^3)	62.43 (1000 kg/m^3)
USBR Method	
Velocity (V) (ft/s)	7.48 (2.28 m/s)

*note: Values used in modelling are in imperial units. Final values for stone size have been converted to SI units.

A vegetated rock buttress is proposed along the edges of the online wetlands/plunge pools to provide additional stability and reduce erosion. The vegetated rock buttress will consist of a constructed bank of 300 mm diameter stones with container grown plants staggered between the stones and spaced horizontally 1 m apart. The strength of the vegetated rock buttress will be augmented through vegetation establishment. Additionally, the plantings will provide additional thermal mitigation though shade, but will also provide a source of organic matter, to enhance semi-aquatic habitat.

3.4 Channel Corridor

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

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

To stabilize the banks, biodegradable erosion control blanket and live stakes are proposed. Prior to the application of the bank stabilization measures, the banks should be top soiled and graded to match the existing ground. The erosion control blanket is then applied in overlapping rows on top of the seed mix. The use of wooden stakes and live stakes will help keep the bank stabilization measures in place until vegetation has established.

Channel corridor sizing for the Tributary of Chedoke Creek was previously completed and included definition of a meander belt width. Meander belt width delineation is completed in support of defining requirements for a hydrological feature (i.e., the watercourse) within a proposed development. A refined meander belt width of 30 m has since been delineated using the bankfull channel discharges determined through our detailed assessment and outlined in **Table 1**. The accompanying memo provided in **Appendix E** provides additional details into the meander belt width delineation.

3.5 Habitat Restoration

The design incorporates several habitat elements within the channel corridor to improve riparian habitat and promote wildlife biodiversity. To maximize potential for wildlife passage, forage and residency, the habitat design incorporates varying topographies and woody debris. The habitat elements include brush mattresses and root wad bank treatments, which also serve as bank erosion control measures. The accompanying drawings provided in **Appendix F** provide design details and direction for the implementation of the proposed habitat features.

Brush mattress is proposed along the outside meander bend of certain 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.

Root wad bank treatment is also proposed at specific locations within the meander pattern. The treatment is to extend the full length of the outside meander bend between riffles and consists of partially buried root wads on a bedding of riverstone. The rood wad bank treatment provides enhanced bank stability while improving aquatic habitat.

3.6 Natural Erosion Control

Newly constructed features can be vulnerable to erosion. This is particularly true before vegetation has established along the bioswale 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 outlet features, etc.) should be anticipated, and should be reflected in the planting plan. Live staking and shrub stock should be used adjacent to the channel banks 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 because of the potential for higher densities with live staking.

4 Design Implementation

4.1 Construction Timing

Based on resident fish species and their respective life cycles, in-stream work will be restricted to July 1st to March 31st, unless otherwise directed by the Ministry of Natural Resources and Forestry (MNRF).

4.2 Best Management Practices

Site inspection should be performed by an inspector with experience overseeing channel works, as this type of work differs considerably from engineering projects. An experienced inspector will be able to provide quick and appropriate response to issues that may arise and ensure that construction proceeds in accordance with the approved design and contract.

The limits of construction will be delineated to prevent unanticipated impacts to natural surroundings, including trees and the watercourse. Most of the channel can be constructed without interference to the existing watercourse. When the proposed channel does cross the existing channel, cofferdams will be installed upstream and downstream of the work area and the water will be pumped around.

All isolated work areas will be dewatered to perform work under dry conditions. Water will be pumped to a sediment filtration system located at least 30 m from the receiving creek and be allowed to naturally flow over a well-vegetated surface and ultimately return to the channel downstream of the work area. This will allow particles to settle before reaching the watercourse.

All materials and equipment will be stored and operated in such a manner that prevents any deleterious substances from entering the water. Vehicle and equipment re-fuelling and/or maintenance will be conducted away from the watercourse and be free of fluid leaks and externally cleaned/degreased to prevent the release of deleterious substances.

4.3 Post-Construction Monitoring

A post-construction monitoring program is recommended to assess the performance of the implemented design. Monitoring observations can also be used to determine the need for remedial works. Monitoring is recommended for two full calendar years following the year of construction.

The following monitoring and reporting activities are proposed:

- 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 as-built survey of the channel planform, longitudinal profile and cross sections just after construction to obtain reference data for the following two years
- Installation of erosion pins at monumented cross sections after construction
- A general vegetation survey in the spring of each year
- Re-survey of the longitudinal profile and cross sections, as well as monitoring of erosion pins at monumented cross sections for three years following construction
- A yearly report for the first year, with a final report at the end of the two-year period

The monitoring would commence immediately after construction and sites would be reviewed annually to identify natural variability of the system. Reporting would be provided annually, with a summary report at the end of the monitoring period.

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

Respectfully submitted,

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Director, Principal Geomorphologist

Ben Miller, B.Sc., CAN-CISEC
Restoration Technician

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Appendix A
Site Map

Legend

Extent of Reach Assessed

Watercourse

Chedoke Creek Realignment

Extent Assessed

Hamilton, Ontario

N

0 25 50 100

Metres

GEO MORPHIX™

Imagery: Google Earth Pro, June 2018.
Extent of Reach Assessed: GEO Morphix Ltd., 2020.
Watercourse: A.J. Clark and Associates Ltd., 2015
and GEO Morphix Ltd., 2020.
Print Date: July 2020. PN19110. Drawn By: W.B., B.M.

Appendix B
Photographic Record

Photo 1
Tributary of Chedoke Creek, Hamilton, Ontario

Looking upstream at the furthest upstream extent assessed. The single channel flows through predominantly residential lands and exits a culvert downstream of Scenic Drive. Yellow arrow denotes flow direction.

Photo 2
Tributary of Chedoke Creek, Hamilton, Ontario

Downstream view of the channel. Leaning and fallen trees, as well as exposed tree roots, were frequently noted through the extent of the reach and provided evidence of channel widening.

Photo 3 Tributary of Chedoke Creek, Hamilton, Ontario	
	Upstream view of the channel. A rooted knickpoint was observed with apparent head-cutting due to knickpoint migration upstream.
Photo 4 Tributary of Chedoke Creek, Hamilton, Ontario	
	An exposed length of previously buried pipe was observed. Occurrence of large organic debris and substrate fouling was common.

Photo 5 Tributary of Chedoke Creek, Hamilton, Ontario	
	Downstream view of the channel. Bank erosion was present through 60 to 100% of the subject reach and was observed through scouring of the channel banks (circled) and undercutting.
Photo 6 Tributary of Chedoke Creek, Hamilton, Ontario	
	The channel flows through a corrugated steel pipe (CSP) at a pedestrian crossing mid-reach. Upstream was dominated by runs indicating poor physical instream habitat.

Photo 7 Tributary of Chedoke Creek, Hamilton, Ontario	 An additional length of exposed sanitary/storm sewer/pipeline was observed downstream of the pedestrian crossing providing further evidence of degradation.
Photo 8 Tributary of Chedoke Creek, Hamilton, Ontario	 At the downstream extent of the reach, the valley was partially confined and valley wall contact was observed. The channel was worn into bedrock (pictured on right).

Photo 9 Tributary of Chedoke Creek, Hamilton, Ontario	
	At the downstream extent of the reach, the channel entered a culvert at Sanitorium Road. Evidence of widening and degradation were the key geomorphic indicators of channel stability through the reach.
Photo 10 Tributary of Chedoke Creek, Hamilton, Ontario	
	Downstream of Sanitorium Road, a rapid change in gradient was observed. The valley was confined beyond the study limits.

Appendix C
Field Observations

GEO | MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN19110

Date:	Nov 29, 2019	**Stream/Reach:**	CC1
Weather:	CLOUDY 1°C	**Location:**	Sanatorium, Hamilton
Field Staff:	CH + BB	**Watershed/Subwatershed:**	Chedoke Crk

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

Flow Type

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

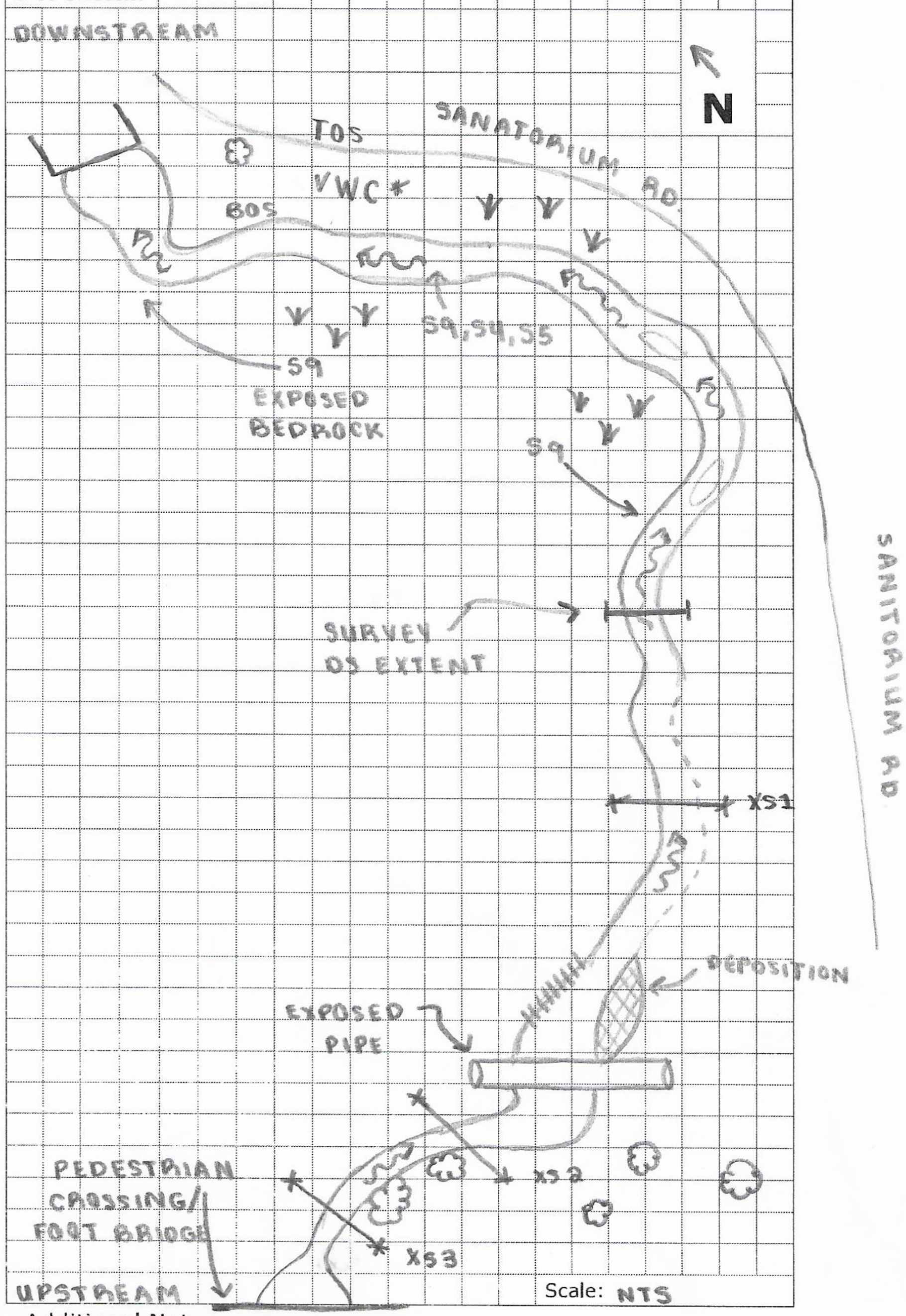
Substrate

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

Other

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

Site Sketch:



Scale: NTS

Additional Notes:

* STEEP SLOPE TO ROAD @ VWC

Completed by: BB Checked by: ________

General Site Characteristics

Project Code: PN19110

Date:	2019-11-29	**Stream/Reach:**	CC1
Weather:	CLOUDY 1°C	**Location:**	SANATORIUM RD, HAMILTON
Field Staff:	CH + BB	**Watershed/Subwatershed:**	CHEDOKE CREEK

Features

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

Flow Type

H1	Standing water
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Substrate

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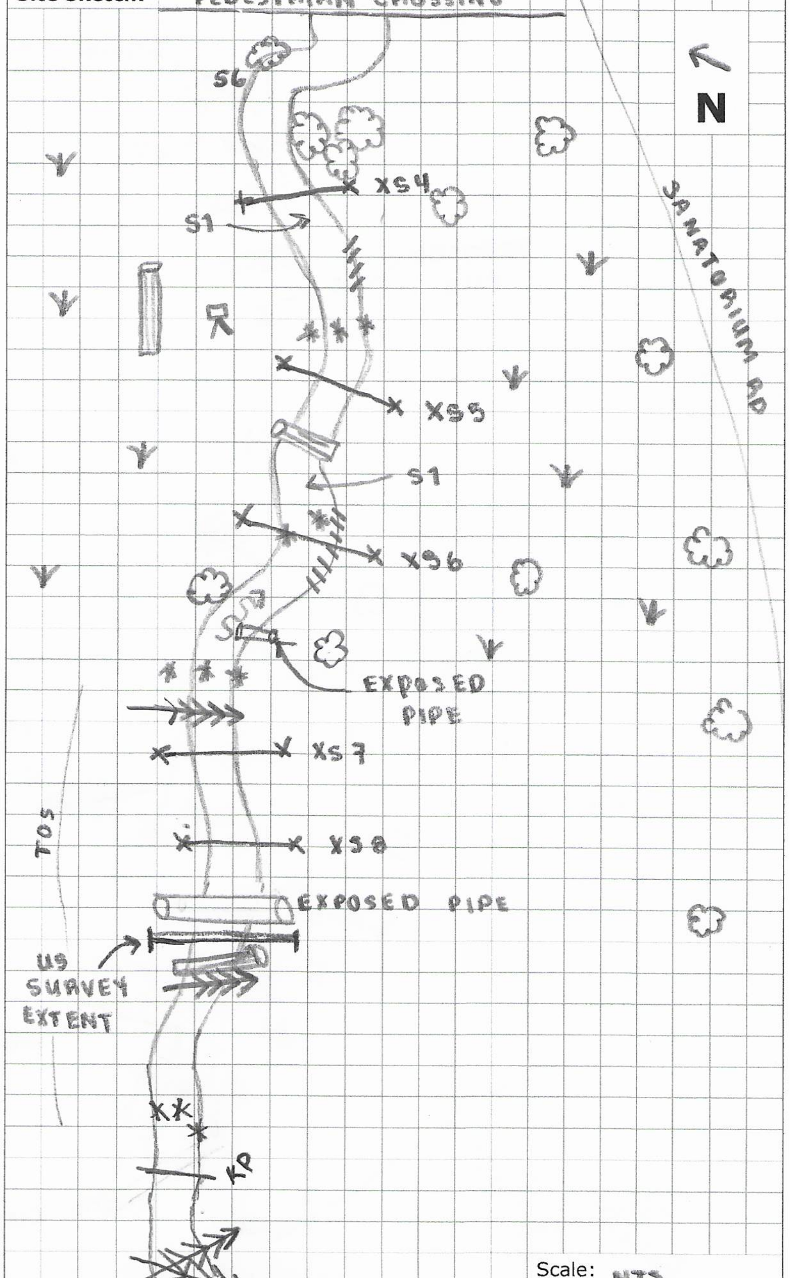
S4	Small cobble	S9	Bedrock/till
S5	Large cobble		

Other

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

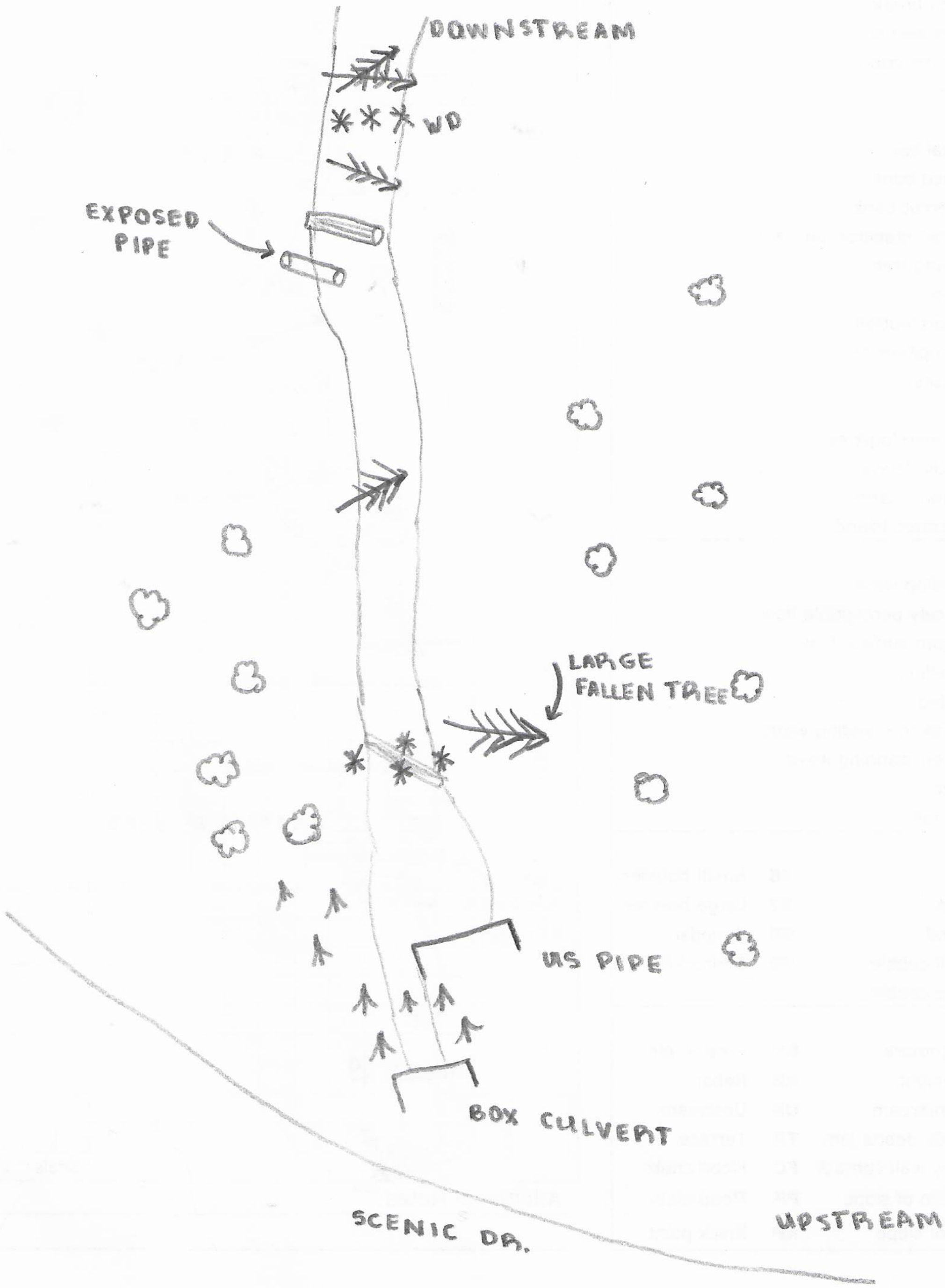
Site Sketch: PEDESTRIAN CROSSING



Scale: NTS

Additional Notes:

Completed by: BB Checked by: ______


DOWNSTREAM
WD
EXPOSED PIPE
LARGE FALLEN TREE
US PIPE
BOX CULVERT
SCENIC DR.
UPSTREAM

BB

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PN19110

Date:	Nov 29, 2019	**Stream/Reach:**	CC1
Weather:	CLOUDY 1°C	**Location:**	Sanatorium + Scenic, Hamilton
Field staff:	CH + BB	**Watershed/Subwatershed:**	Chedoke Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 7 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: ______

Riparian Vegetation

- Dominant Type: (Table 6) 1
- 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) 1

Aquatic/Instream Vegetation

- Type (Table8): 6
- Coverage of Reach (%): 5
- Woody Debris: ☐ Present in Cutbank ☑ Present in Channel ☐ Not Present
- Density of WD: ☐ Low ☑ Moderate ☐ High
- WDJ/50m: 2

Water Quality

- **Odour** (Table 16): 4
- **Turbidity** (Table 17): 4

Channel Characteristics

- Sinuosity (Type) (Table 9): 1
- Sinuosity (Degree) (Table 10): 2
- Gradient (Table 11): 2
- Number of Channels (Table 12): 1
- Entrenchment (Table 13): 2
- Type of Bank Failure (Table 14): 1, 2
- Downs's Classification (Table 15): E

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☐	☐	☐	☑	☐
~~Pool~~ PLAIN Substrate	☑	☐	☐	☐	☐	☐	☐
Bank Material	☑	☐	☐	☐	☐	☐	☑

Bankfull Width (m)	SEE	DETAILED		Wetted Width (m)	\	\	\
Bankfull Depth (m)		ASSESSMENT		Wetted Depth (m)	\	\	\

- Riffle/Pool Spacing (m): N/A
- % Riffles: 5
- % Pools: 0
- Meander Amplitude: N/A
- Pool Depth (m): N/A
- Riffle Length (m): ~3
- Undercuts (m): 0.15
- Comments: ______
- Velocity (m/s): \ | \ | \ — Wiffle ball / ADV / Estimated

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

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

• APPROX. 75%

Notes:
• CROSSING IS BOX CULVERT BUT MAJORITY OF WATER COMING FROM ADJACENT PIPE
• 10 cm SOFT SEDIMENT

• 25 cm KNICK POINT
• EXPOSED BEDROCK @ DS EXTENT
• MOSTLY PLAIN BED HOWEVER RIFFLES @ DS EXTENT

Completed by: ______ Checked by: ______

Rapid Geomorphic Assessment **Project Code:** PN 19110

Date:	Nov 29, 2019	**Stream/Reach:**	CC1
Weather:	CLOUDY 1°C	**Watershed/Subwatershed:**	Chedoke Crk
Field Staff:	CH + BB	**Location:**	Sanatorium, Hamilton

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/6
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	N/A		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	0	6	0.00
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	3/8
	2	Exposed sanitary / storm sewer / pipeline / etc.	✓		
	3	Elevated storm sewer outfall(s)		✓	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knickpoint 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 =	3	5	0.38
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		3/8
	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.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		✓	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	3	5	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/7
	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 with meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0.00

Additional notes:

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

Completed by: CH Checked by: ________

GEO | MORPHIX

Rapid Stream Assessment Technique **Project Code:** PN19110

Date:	Nov 29, 2019	**Stream/Reach:**	CC1
Weather:	CLOUDY 1°C	**Location:**	Sanatorium, Hamilton
Field Staff:	CH + BB	**Watershed/Subwatershed:**	Chedoke 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 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☑ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11

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

Date:	Nov 29, 2019	Reach:	CC1	Project Code:	PN19110

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 N/A BEDROCK
	• 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 N/A
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☑ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☑ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☑ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) = 22	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: CH Checked by: ________

Appendix D
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Chedoke Creek - Bankfull Indicators

Project Number:	PN19110	**Date:**	November 29, 2019
Client:	Valery Homes	**Length Surveyed (m):**	107.0
Location:	Scenic Drive and Sanatorium Road	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Trees
Geology/Soils:	Till (upstream) & bedrock (downstream)	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Residential	**Width of Riparian Cover:**	4-10 Channel widths
Valley Type:	Partially confined	**Age Class of Riparian Vegetation:**	Established (5-30 years)
Dominant Instream Vegetation Type:	Attached algae	**Extent of Encroachment into Channel:**	None
Portion of Reach with Vegetation:	<5%	**Density of Woody Debris:**	Moderate

Hydrology

Measured Discharge (m^3/s):	0.01	**Calculated Bankfull Discharge (m^3/s):**	1.11
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	1.26
Modelled 2-year Velocity (m/s):	Not modelled		

Profile Characteristics

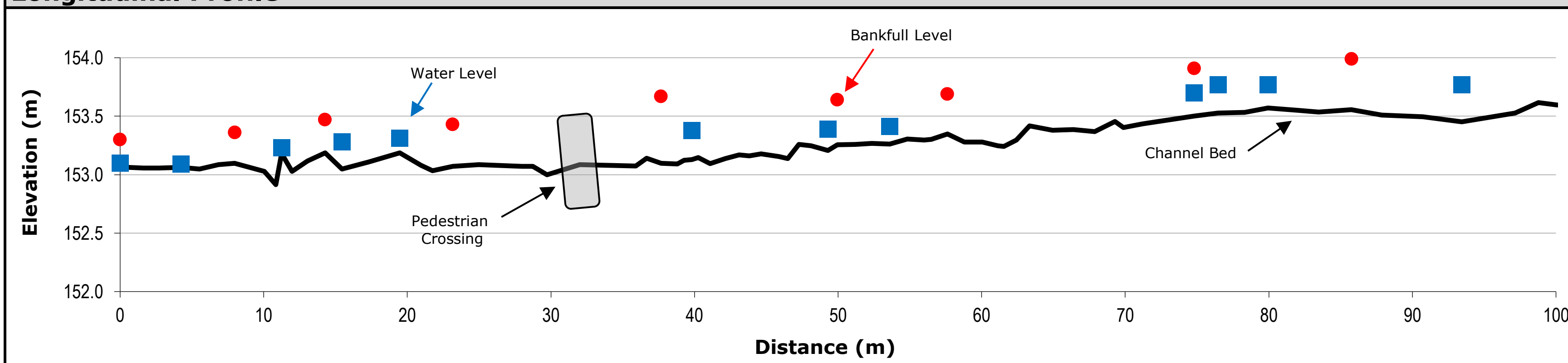
Bankfull Gradient (%):	0.89	
Channel Bed Gradient (%):	0.60	
Riffle Gradient (%):	0.76	*
Riffle Length (m):	5.28	*
Riffle-Pool Spacing (m):	5.19	*

*riffle-pool development only downstream of the pedestrian crossing

Planform Characteristics

Sinuosity:	0.00
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):	0.25	0.80	0.50
Bank Angle (deg):	30	90	50
Root Depth (m):	0.10	0.60	0.35
Root Density (%):	10	70	26
Bank Undercut (m):	0.00	0.29	0.03

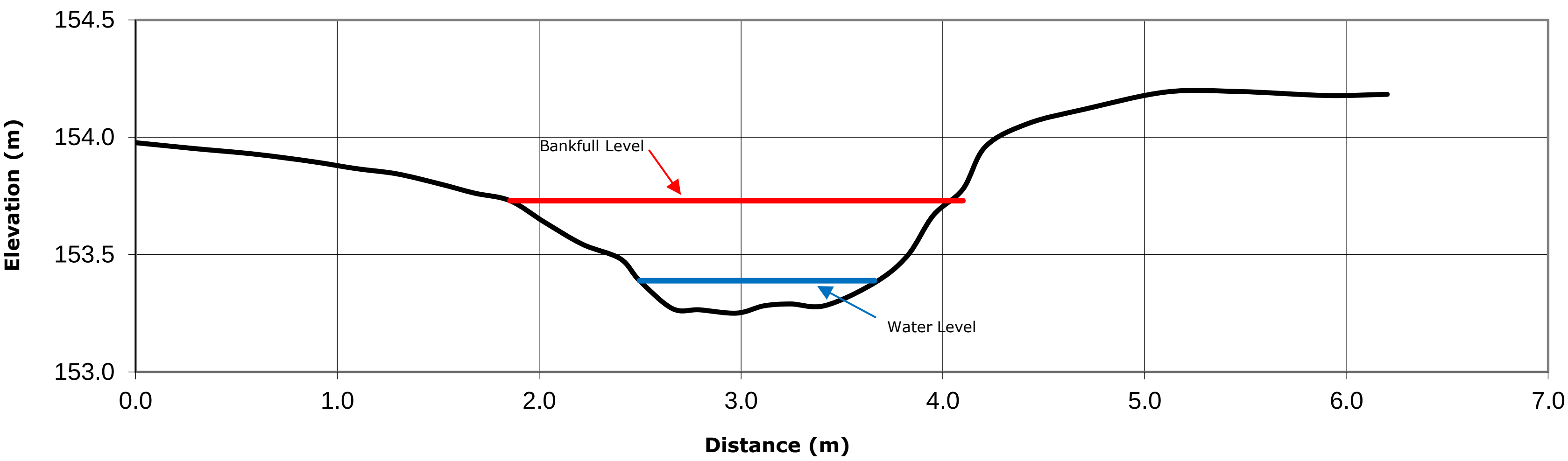
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay and silt	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.05	4.90	2.79
Average Bankfull Depth (m):	0.22	0.42	0.32
Bankfull Width/Depth (m/m):	7	13	9
Wetted Width (m):	0.57	2.04	1.16
Average Water Depth (m):	0.04	0.37	0.19
Wetted Width/Depth (m/m):	2	14	8
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.05	0.35	0.24
Manning's *n*:		0.040	

Photograph at cross section 4 (looking downstream)

Representative Cross-Section 4



Substrate Characteristics

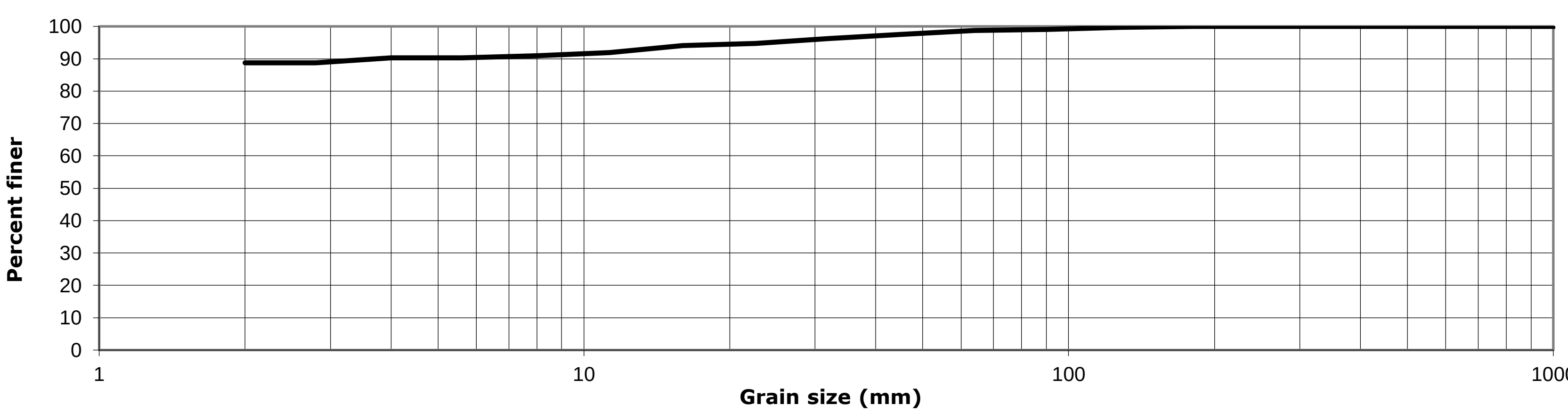
Particle Size (mm)

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

Bed sample taken

Subpavement:	Till upstream and bedrock downstream
Particle shape:	Platy and angular (cross-section 1)
Embeddedness (%):	<5 (cross-section 1)
Particle range (riffle):	Coarse sand to small cobbles
Particle Range (pool):	Clay, silt, and sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	27.80
for D_{50}:	0.00	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.00	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	34.93		

General Field Observations

Channel Description

Reach CC1 consisted of a single thread channel with a low sinuosity and a moderate gradient. The reach was more entrenched at the upstream extent, which is apparent at the upstream cross-sections, 7 and 8. An old pedestrian crossing was noted at the downstream extent of the survey, between cross-sections 3 and 4. The riparian vegetation was mostly comprised of trees and formed a continuous buffer. The average bankfull width and depth were 2.77 m and 0.32 m. Bank erosion was observed along approximately 75% of the banks. Leaning trees and exposed tree roots were also observed. Riffle-pool formation was only noted downstream of the pedestrian crossing. The reach consisted of a plain bed upstream of the pedestrian bridge to Scenic Drive. Substrate consisted of clay, silt, and sand except at cross-section 1, where the bedrock was exposed and gravel and cobbles were measured.

Cross Section 7 - Facing Upstream

Detailed Geomorphological Assessment Summary

Chedoke Creek - Floodplain

Project Number:	PN19110	**Date:**	November 29, 2019
Client:	Valery Homes	**Length Surveyed (m):**	107.0
Location:	Scenic Drive and Sanatorium Road	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Trees
Geology/Soils:	Till (upstream) & bedrock (downstream)	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Residential	**Width of Riparian Cover:**	4-10 Channel widths
Valley Type:	Partially confined	**Age Class of Riparian Vegetation:**	Established (5-30 years)
Dominant Instream Vegetation Type:	Attached algae	**Extent of Encroachment into Channel:**	None
Portion of Reach with Vegetation:	<5%	**Density of Woody Debris:**	Moderate

Hydrology

Measured Discharge (m^3/s):	0.01	**Calculated Bankfull Discharge (m^3/s):**	2.57
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	1.46
Modelled 2-year Velocity (m/s):	Not modelled		

Profile Characteristics

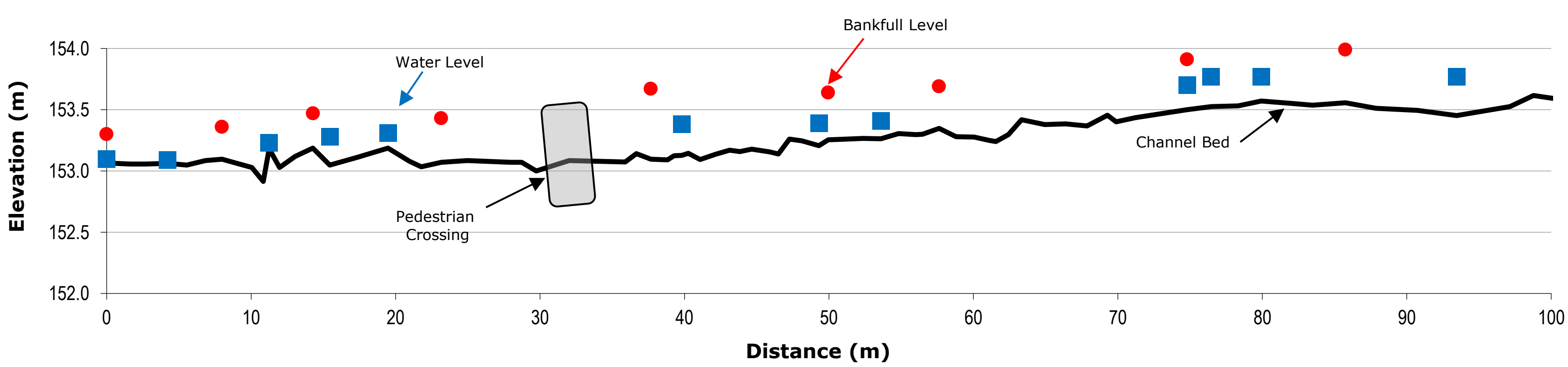
Bankfull Gradient (%):	0.89	
Channel Bed Gradient (%):	0.60	
Riffle Gradient (%):	0.76	*
Riffle Length (m):	5.28	*
Riffle-Pool Spacing (m):	5.19	*

*riffle-pool development only downstream of the pedestrian crossing

Planform Characteristics

Sinuosity:	0.00
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):	0.25	0.80	0.50
Bank Angle (deg):	30	90	50
Root Depth (m):	0.10	0.60	0.35
Root Density (%):	10	70	26
Bank Undercut (m):	0.00	0.29	0.03

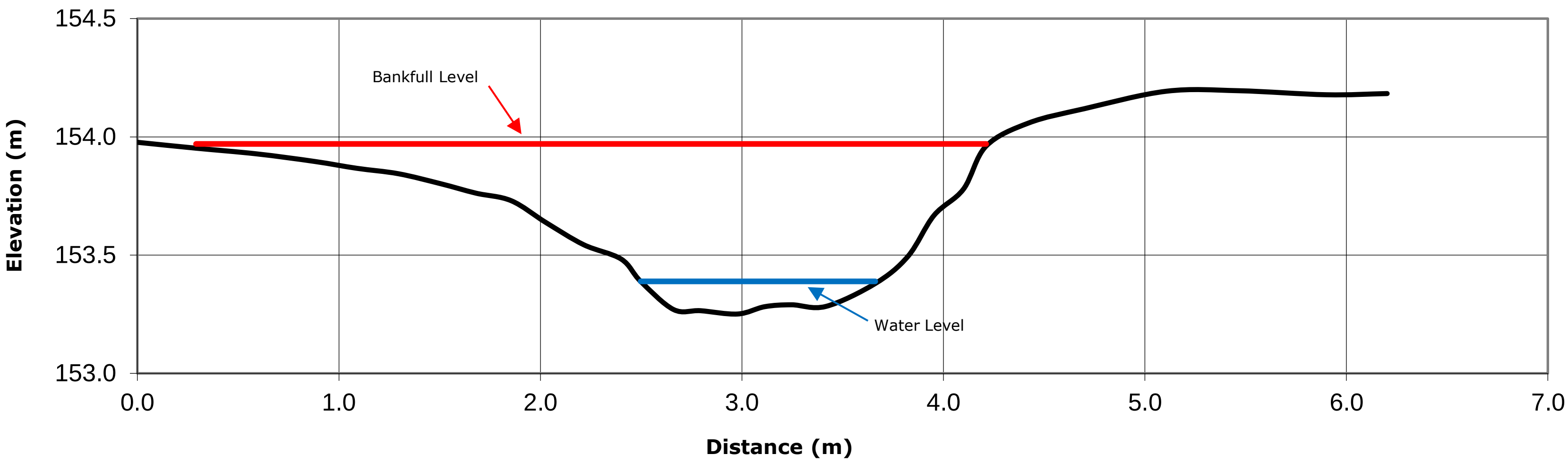
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay and silt	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.03	6.58	4.40
Average Bankfull Depth (m):	0.27	0.58	0.40
Bankfull Width/Depth (m/m):	8	13	11
Wetted Width (m):	0.57	2.04	1.16
Average Water Depth (m):	0.04	0.37	0.19
Wetted Width/Depth (m/m):	1	14	8
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.05	0.35	0.24
Manning's *n*:		0.040	

Photograph at cross section 4 (looking downstream)

Representative Cross-Section 4



Substrate Characteristics

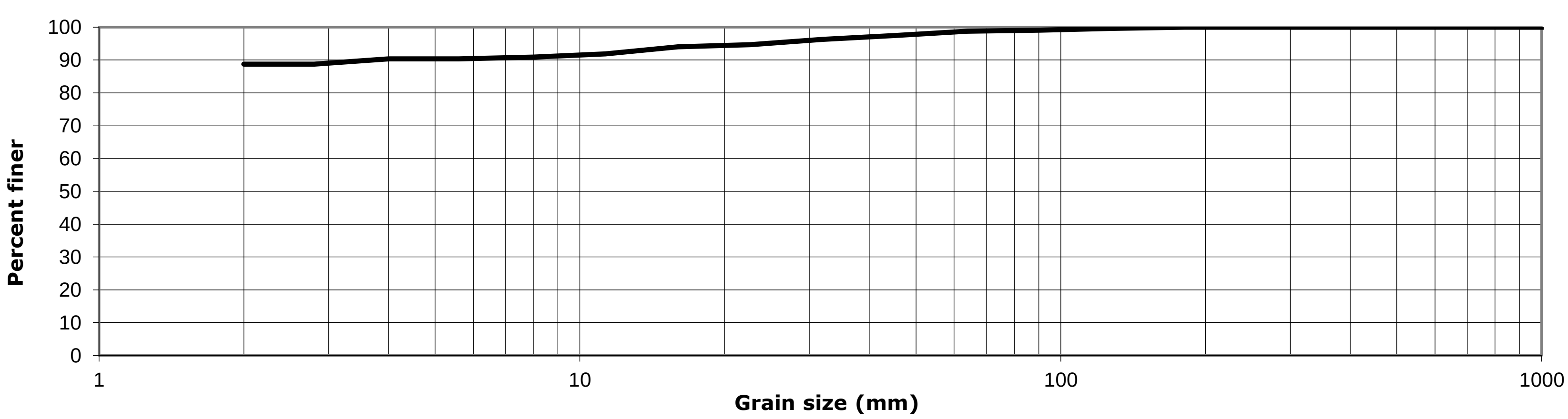
Particle Size (mm)

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

Bed sample taken

Subpavement:	Till upstream and bedrock downstream
Particle shape:	Platy and angular (cross-section 1)
Embeddedness (%):	<5 (cross-section 1)
Particle range (riffle):	Coarse sand to small cobbles
Particle Range (pool):	Clay, silt, and sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	34.89
for D_{50}:	0.00	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.00	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	51.00		

General Field Observations

Channel Description

Reach CC1 consisted of a single thread channel with a low sinuosity and a moderate gradient. The reach was more entrenched at the upstream extent, which is apparent at the upstream cross-sections, 7 and 8. An old pedestrian crossing was noted at the downstream extent of the survey, between cross-sections 3 and 4. The riparian vegetation was mostly comprised of trees and formed a continuous buffer. The average bankfull width and depth were 4.40 m and 0.40 m. Bank erosion was observed along approximately 75% of the banks. Leaning trees and exposed tree roots were also observed. Riffle-pool formation was only noted downstream of the pedestrian crossing. The reach consisted of a plain bed upstream of the pedestrian bridge to Scenic Drive. Substrate consisted of clay, silt, and sand except at cross-section 1, where the bedrock was exposed and gravel and cobbles were measured.

Cross Section 7 - Facing Upstream

Appendix E
Meander Belt Width Delineation Memo

GEO Morphix Ltd.

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July 23, 2020

Valery (Chedoke Browlands) Developments Inc.
2140 King Street East
Hamilton, Ontario
L8K 1W6

Attention: Ted Valeri

Re: Meander Belt Width Delineation Update
Tributary of Chedoke Creek (Scenic Drive and Sanatorium Road)
City of Hamilton, Ontario
GEO Morphix Project No. 19110

This memo summarizes the meander belt width assessment completed for a section of the Chedoke Creek Tributary at Scenic Drive and Sanatorium Road in the City of Hamilton, Ontario. This work, in part, provides support in the definition of environmental constraints associated with future development on site.

To accommodate the development, a section of the Chedoke Creek Tributary is proposed for re-alignment between Scenic Drive and the Niagara Escarpment. Parish Geomorphic (2009) previously completed an assessment of the tributary and suggested a meander belt width of 42.9 m for the feature. GEO Morphix Ltd. was retained to review the Parish (2009) study and provide an update to the meander belt width in the context of available topographic survey, detailed field observations, and proposed future development on site.

In the case of realignment, the meander belt width is a product of the bankfull characteristics of a channel. If a channel is to be realigned, the meander belt width would need to be adjusted to account for the updated or proposed channel configuration. To refine the meander belt width for this section of the Chedoke Creek Tributary, we have reviewed various background data and reporting, completed site reconnaissance to document existing watercourse characteristics, and updated the meander belt width assessment at a reach scale based on existing information and newly collected field observations.

We have determined a range of meander belt widths for the post-restoration condition by defining a potential bankfull channel based on the following assumptions:

- Valley gradient of 0.9% based on the valley gradient determined through our detailed assessment completed November 29, 2019
- Sinuosity of 1.1 and width to depth ratio of 10:1, which is a stable configuration and representative of the system
- 2-year flow of 1.1 m^3/s and 2.6 m^3/s, determined through our detailed assessment completed November 29, 2019

Dillon Consulting summarized previously calculated 2-year flows for the channel in their report titled City of Hamilton Sanatorium Road Realignment Flood and Erosion Impact Assessment (June 2010). A significant range of 2-year flows were determined through various studies (values ranging from 1.7 m^3/s to 8.4 m^3/s). Dillon (2010) also simulated a maximum flow for the channel over a 16-year period, which resulted in a discharge of 10.6 m^3/s. Given that the maximum flow determined by Dillon is similar to the largest reported 2-year flow (8.4 m^3/s) in the Dillon report (2010), we would suggest that the 2-year flow is likely closer to the lower range of 1.7 m^3/s rather than 8.4 m^3/s.

To verify the 2-year flow information outlined by Dillon (2010), we completed a detailed channel survey to document existing bankfull dimensions. Based on our detailed geomorphological field assessment from November 29, 2020, we determined a bankfull discharge of 1.1 m^3/s for the channel. The bankfull channel indicators observed on site suggested a lower bankfull width and depth that resulted in the 1.1 m^3/s discharge. To be conservative, we also determined a secondary discharge by extending the bankfull channel width to the location where flow would spill into the floodplain. This resulted in a discharge of 2.6 m^3/s. Both discharge values still fall within the lower range of values outlined by Dillon (2010). Although the bankfull discharge of a channel is generally lower than the 2-year flow, it is what would normally be implemented for a channel design.

Based on the measured gradient from our detailed survey and the assigned sinuosity, width and depth for the restored channel were back-calculated using the 1.1 m^3/s and 2.6 m^3/s bankfull discharge determined from our detailed survey. The meander belt width was then determined using the modified Williams (1986) model and the back-calculated channel geometry measurements. The empirical relations from Williams (1986) were modified to include channel width and a 20% factor of safety. The empirical relationships are outlined below:

$$B_w = 18A^{0.65} + W_b \times (1.2)$$ [Eq. 1]

$$B_w = 4.3{W_b}^{1.12} + W_b \times (1.2)$$ [Eq. 2]

Where, B_w is meander belt width (m); A is bankfull cross-sectional area (m^2); and W_b is bankfull channel width (m).

The meander belt widths for each discharge scenario are outlined in **Table 1** below. The reported numbers include a 20 percent factor of safety.

Table 1. Meander Belt Widths for Realigned Tributary of Chedoke Creek

Discharge (m^3/s) Scenario	Meander Belt Width (m) Williams – Area Method (1986) [Eq. 1]	Meander Belt Width (m) Williams – Width Method (1986) [Eq. 2]
1.1	23.9	21.4
2.6	35.8	30.5

There are a range of meander belt widths provided as a result of different discharges and empirical models. Generally, most of the determined meander belt widths in **Table 1** fall within or around 30 m. Given that the channel can be designed to accommodate a range of discharges, we are confident that the meander belt width for the realigned channel would not exceed 30 m.

We trust this memo meets your current requirements. Should you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

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

Kat Woodrow, M.Sc.
Environmental Scientist

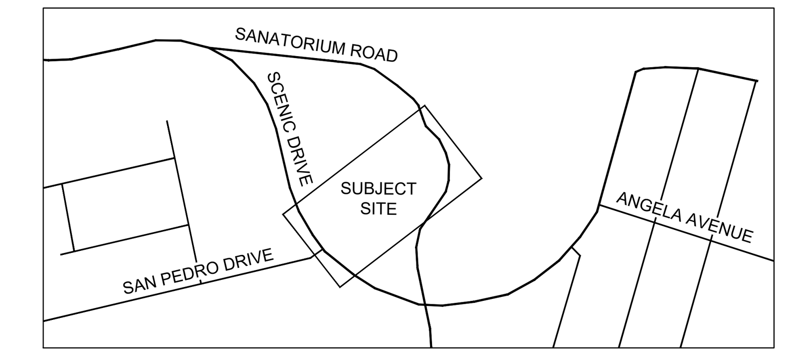
References

Dillon Consulting Limited, June 2010. City of Hamilton Sanatorium Road Realignment Flood and Erosion Impact Assessment. Final Report Submitted to City of Hamilton.

Parish Geomorphic, June 2009. Chedoke Creek Flooding and Erosion Control Impact Assessment, Stage 1: Analysis of Existing Conditions. Final Report Submitted to Dillon Consulting Ltd.

Williams, G.P., 1986. River meanders and channel size. Journal of Hydrology, 88 (1-2): 147-164.

Appendix F
Detailed Design Drawings



N
N.T.S.

KEY MAP

N.T.S.

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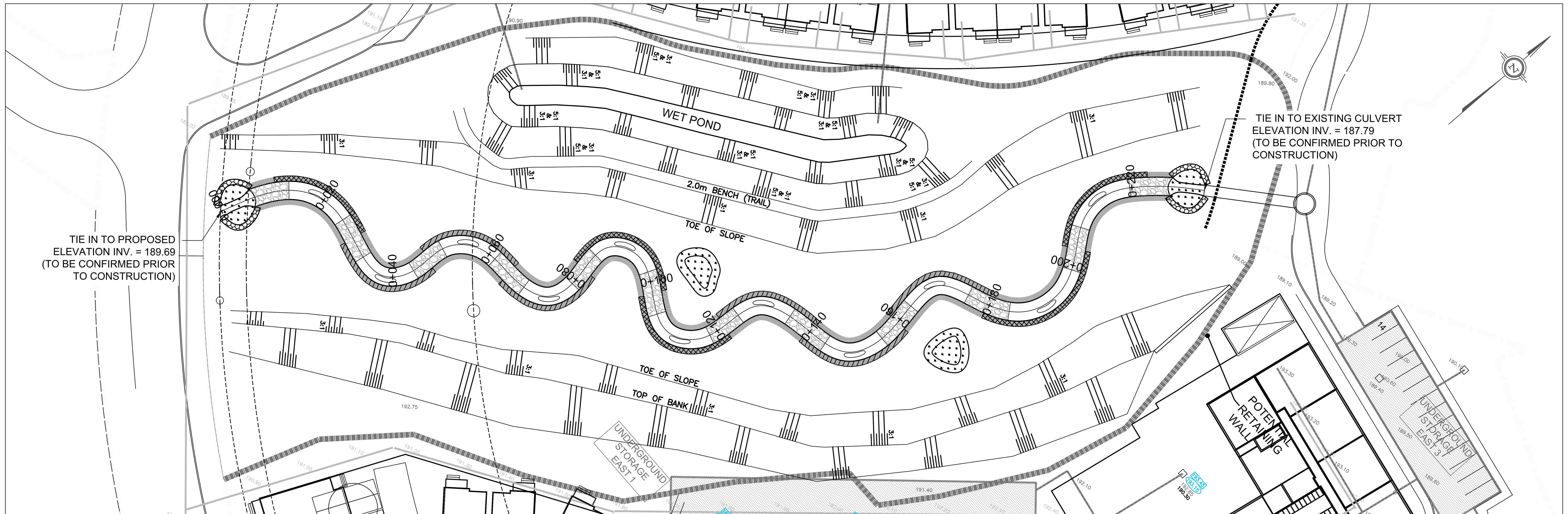
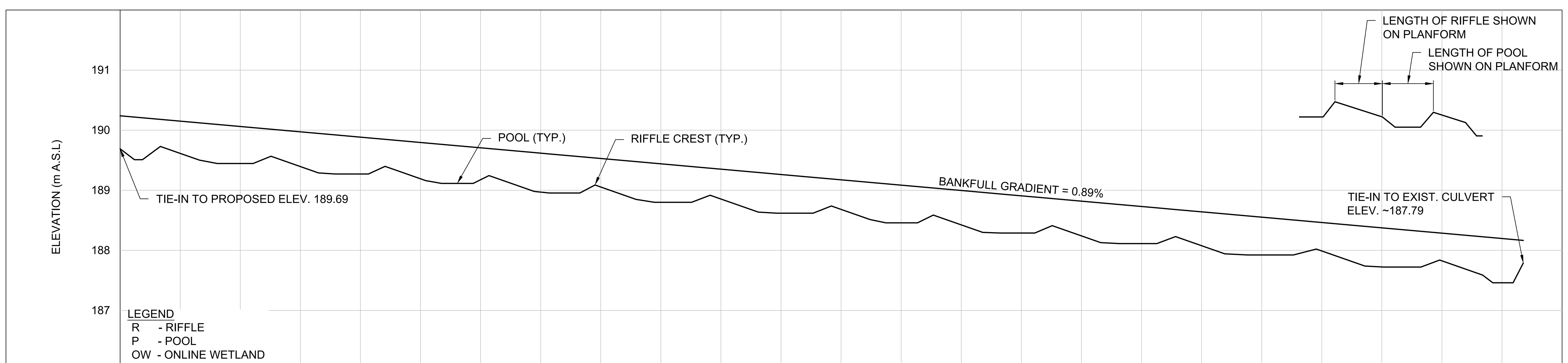


LEGEND

- CHANNEL CENTRELINE
- RIFFLE (SEE DWG DET-1)
- POOL (SEE DWG DET-1)
- ONLINE WETLAND (SEE DWG DET-1)
- OFFLINE WETLAND (SEE DWG DET-1)
- BRUSH MATTRESS (SEE DWG DET-2)
- ROOT WAD BANK ENHANCEMENT (SEE DWG DET-2)
- VEGETATED ROCK BUTTRESS (SEE DWG DET-2)
- 100% BIODEGRADABLE EROSION CONTROL BLANKET (BIONET C125BN OR APPROVED EQUIVALENT) AND LIVESTAKES (SEE DWG DET-2)

PLANFORM
1:500

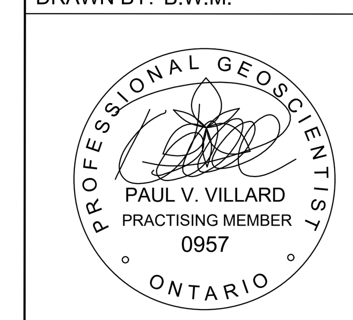


CENTRELINE CHAINAGE	0+000		0+020		0+040		0+060		0+080		0+100		0+120		0+140		0+160		0+180		0+200	0+220	0+240
PROPOSED LOW FLOW ELEVATION	189.69																						
DETAIL TYPICAL	OW	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R P R	OW

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

1.	2020-07-24	BWM	FIRST SUBMISSION
	DATE	BY	REVISIONS

DESIGNED BY: P.V. | CHECKED BY: P.V.
DRAWN BY: B.W.M. | DATE: JULY 2020



2020-07-24

GEO MORPHIX
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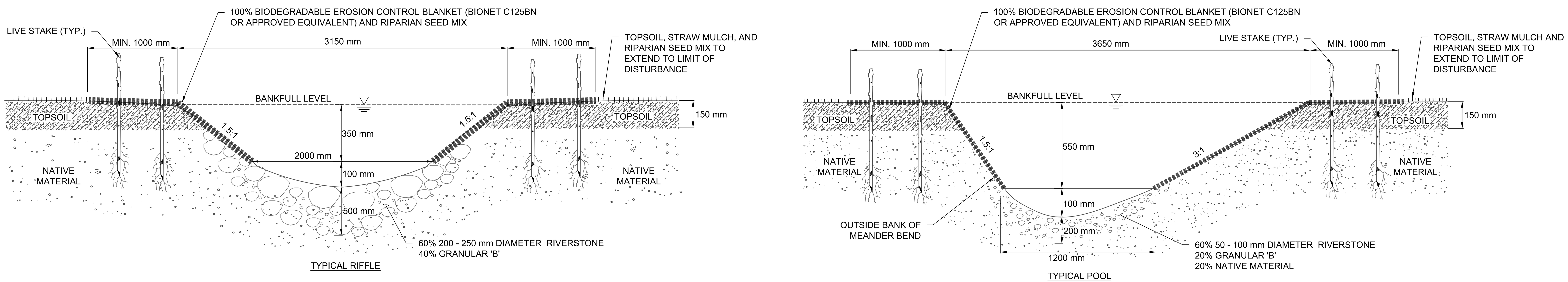
SCENIC DRIVE AND SANATORIUM ROAD
VALERY HOMES

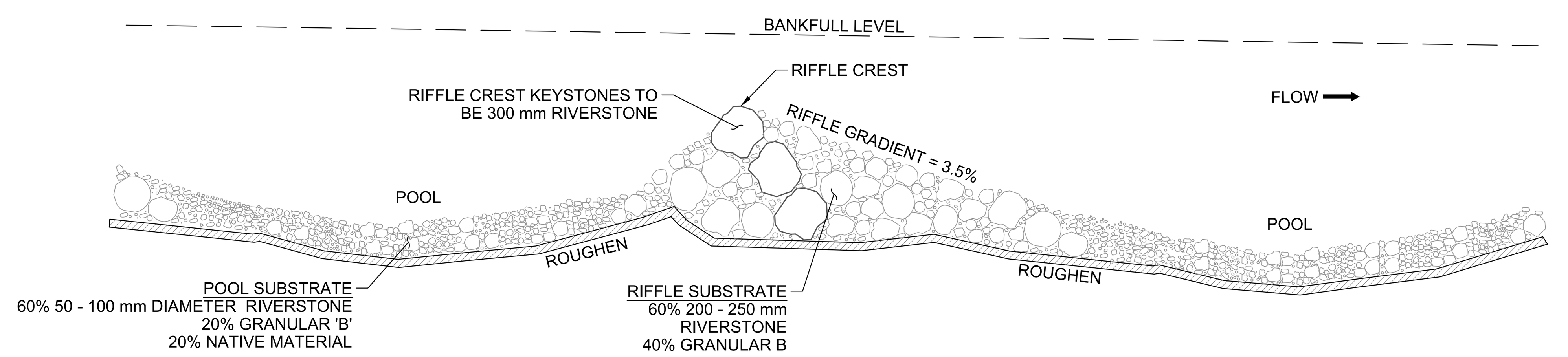
CHEDOKE CREEK
PLANFORM AND PROFILE

PROJECT No.: 19010 | DRAWING No.: GEO-1
SCALE: AS NOTED | SHEET 1 OF 3

SCALED FOR PLOT ON 'ARCH D'



CHANNEL CROSS SECTIONS
N.T.S.



TYPICAL RIFFLE-POOL SEQUENCE
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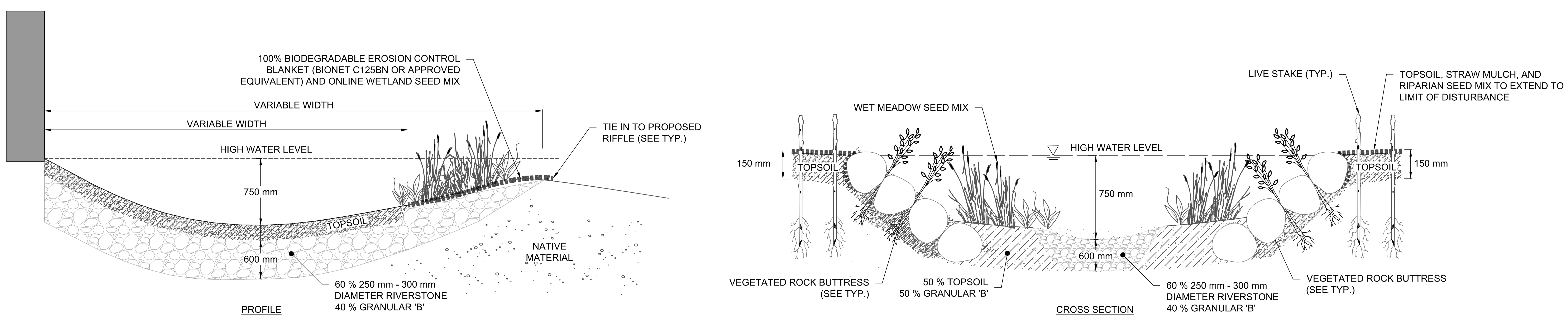

ONLINE WETLAND / PLUNGE POOL
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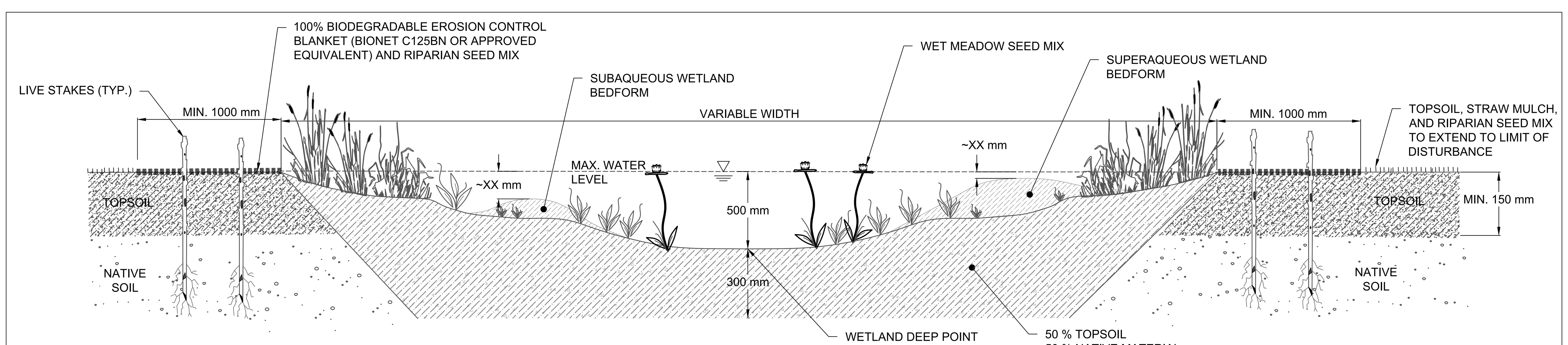
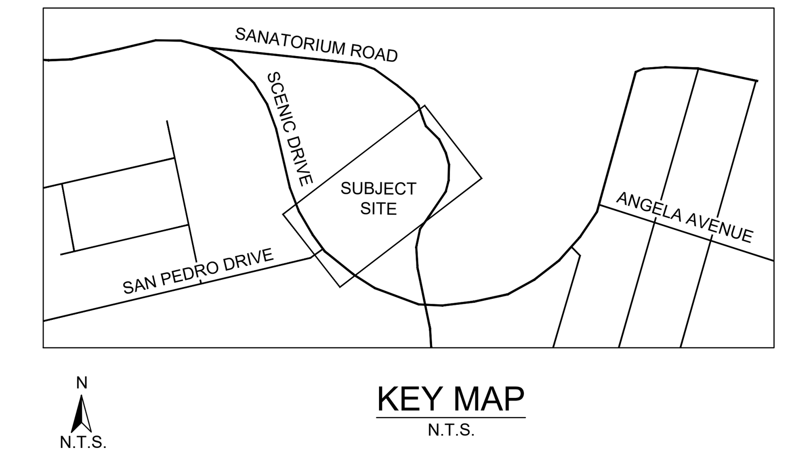


OFFLINE WETLAND
N.T.S.

SCALED FOR PLOT ON 'ARCH D'



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1.	2020-07-24	BWM	FIRST SUBMISSION
	DATE	BY	REVISIONS

DESIGNED BY: P.V.	CHECKED BY: P.V.
DRAWN BY: B.W.M.	DATE: JULY 2020

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
0957
ONTARIO
2020-07-24

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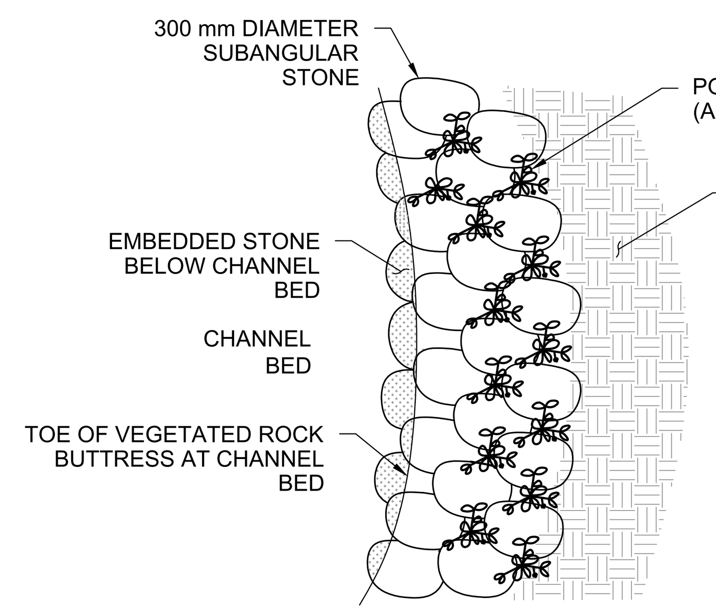
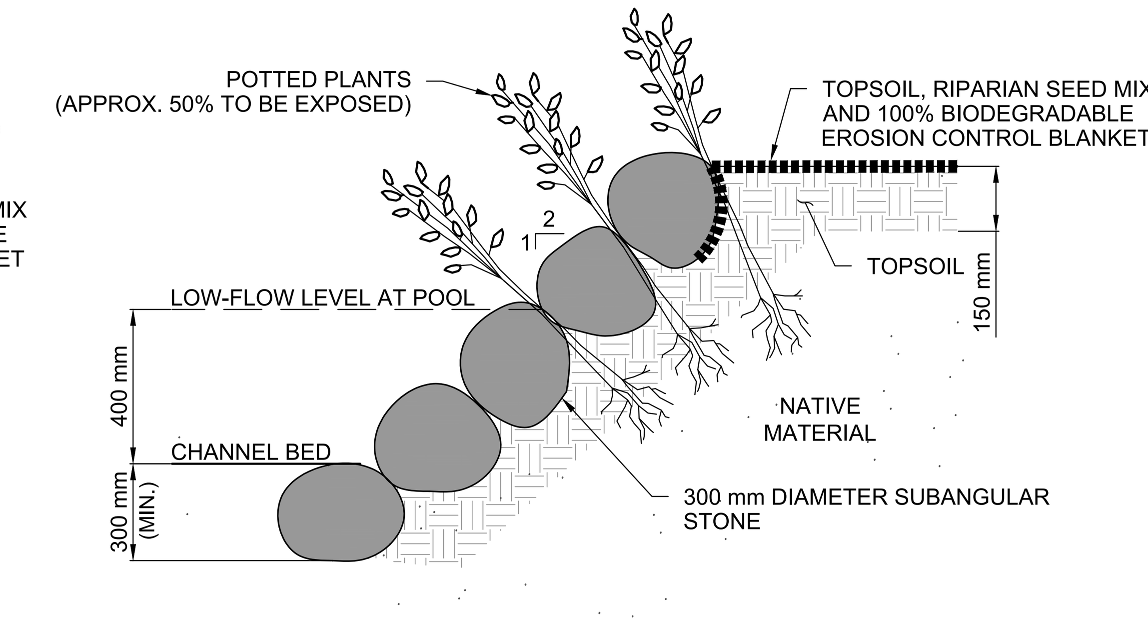
SCENIC DRIVE AND SANATORIUM ROAD
VALERY HOMES

CHEDOKE CREEK
DESIGN DETAILS

PROJECT No.: 19010	DRAWING No.: DET-1
SCALE: AS NOTED	SHEET 2 OF 3



PLAN



CROSS SECTION

CONSTRUCTION NOTES

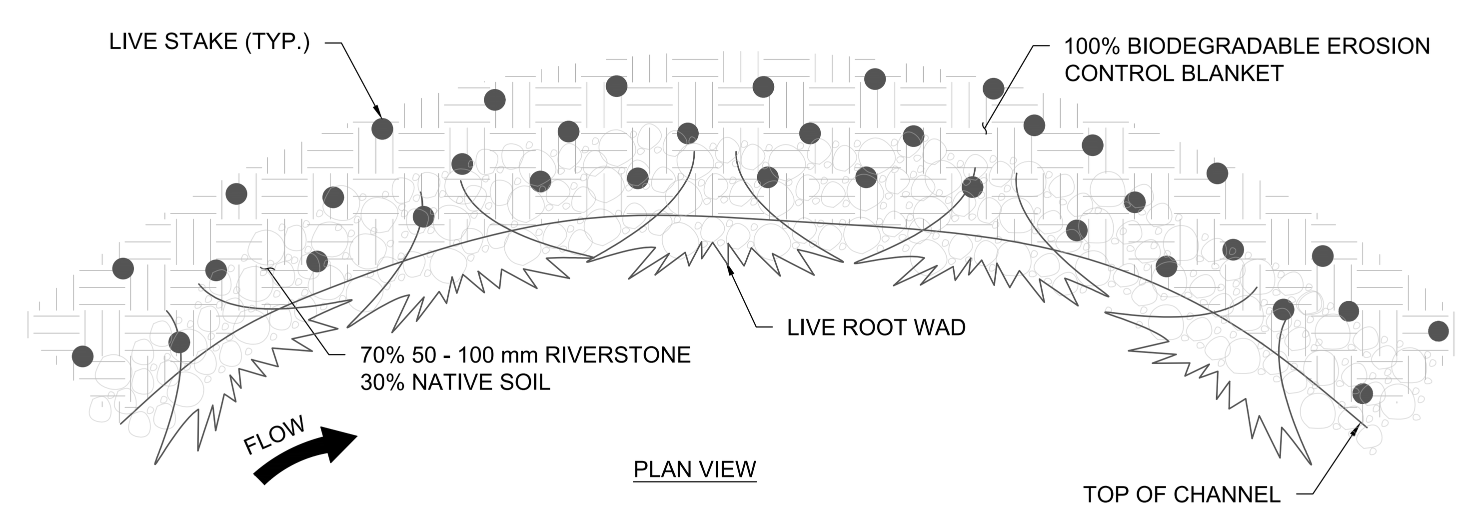
1. VEGETATED ROCK BUTTRESS TO BE INSTALLED IN LIFTS.
2. TOE STONES TO BE EMBEDDED INTO CHANNEL BED A MINIMUM OF 300 mm.
3. INSTALL PLANTS 1 m O/C IN EACH LAYER.
4. LOWEST LAYER OF PLANTS TO BE AT LOW-FLOW LEVEL.
5. LATERALLY STAGGER EACH SUCCESSIVE LAYER OF PLANTS TO AVOID VERTICAL STACKING.
6. WILLOW SPECIES TO BE CONCENTRATED IN LOWER LIFTS.

PLANTINGS SPECIES AND QUANTITIES

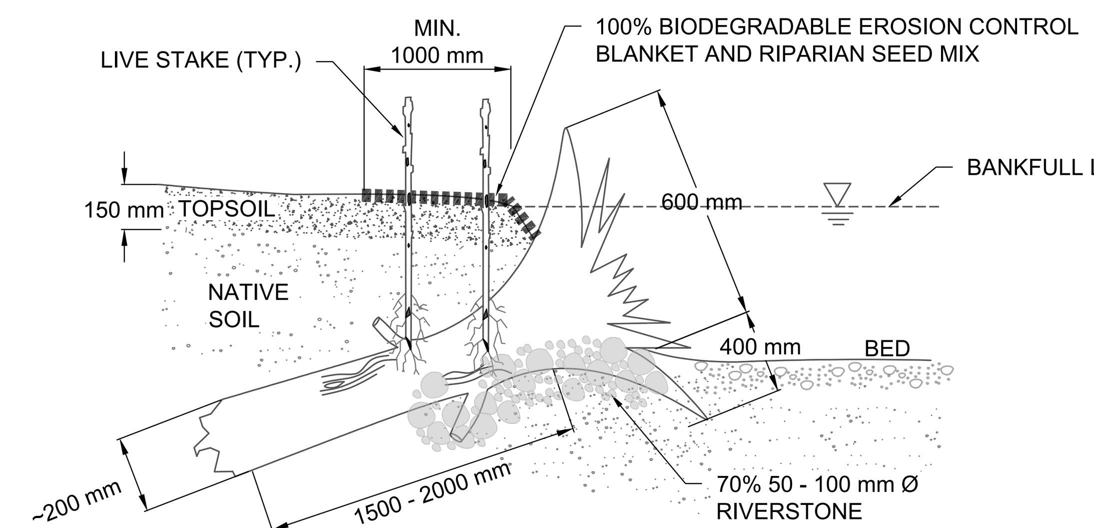
COMMON NAME	SCIENTIFIC NAME	QUANTITY	CONDITION
RED OSIER DOGWOOD	*Salix discolor*	40	1 m ht. POTTED
SANDBAR WILLOW	*Salix exigua*	40	1 m ht. POTTED
SHINING WILLOW	*Salix lucida*	40	1 m ht. POTTED

VEGETATED ROCK BUTTRESS

N.T.S.



PLAN VIEW



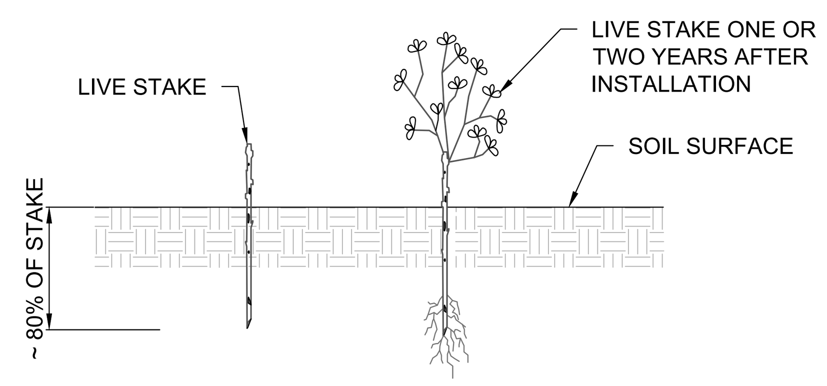
CROSS SECTION

NOTES

1. SALVAGE NATIVE TREES ON SITE, IF POSSIBLE, AND CUT TO DIMENSIONS SHOWN.
2. ROOT WAD TREATMENT TO EXTEND FULL LENGTH OF OUTSIDE BANK OF MEANDER BEND BETWEEN RIFFLES WHERE SHOWN ON PLANFORM.

ROOT WAD BANK ENHANCEMENT WITH STONE BEDDING

N.T.S.



SPECIES AND QUANTITIES

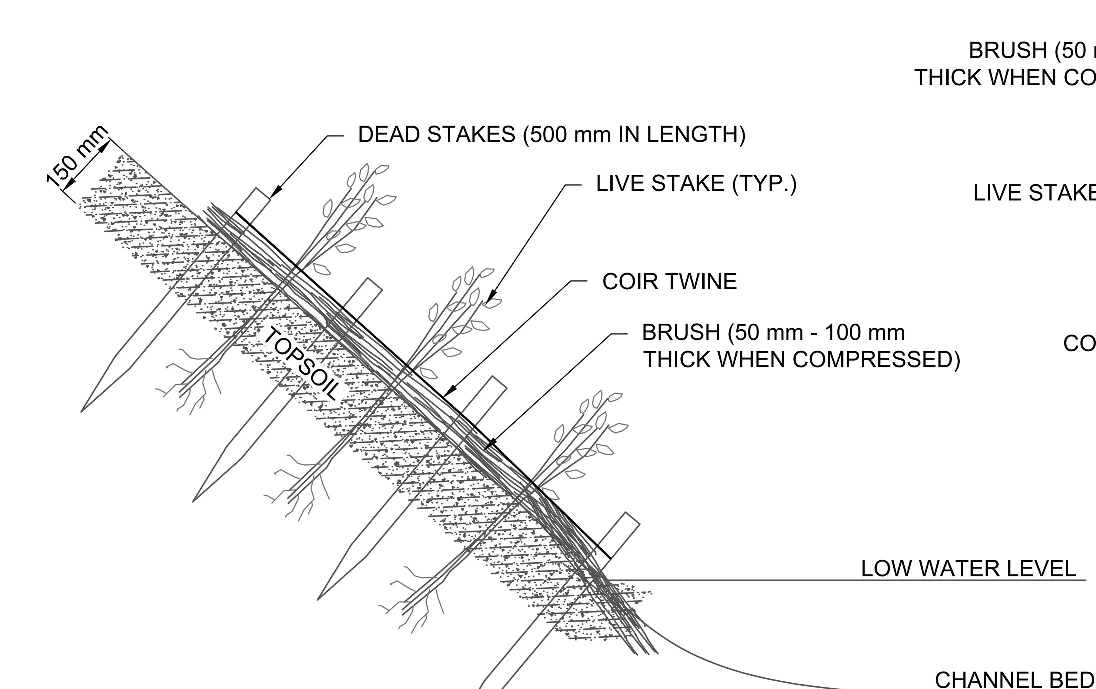
COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
RED OSIER DOGWOOD	*Cornus stolonifera*	725	1 m, BARE ROOT
PUSSY WILLOW	*Salix discolor*	725	1 m, BARE ROOT
SANDBAR WILLOW	*Salix exigua*	725	1 m, BARE ROOT

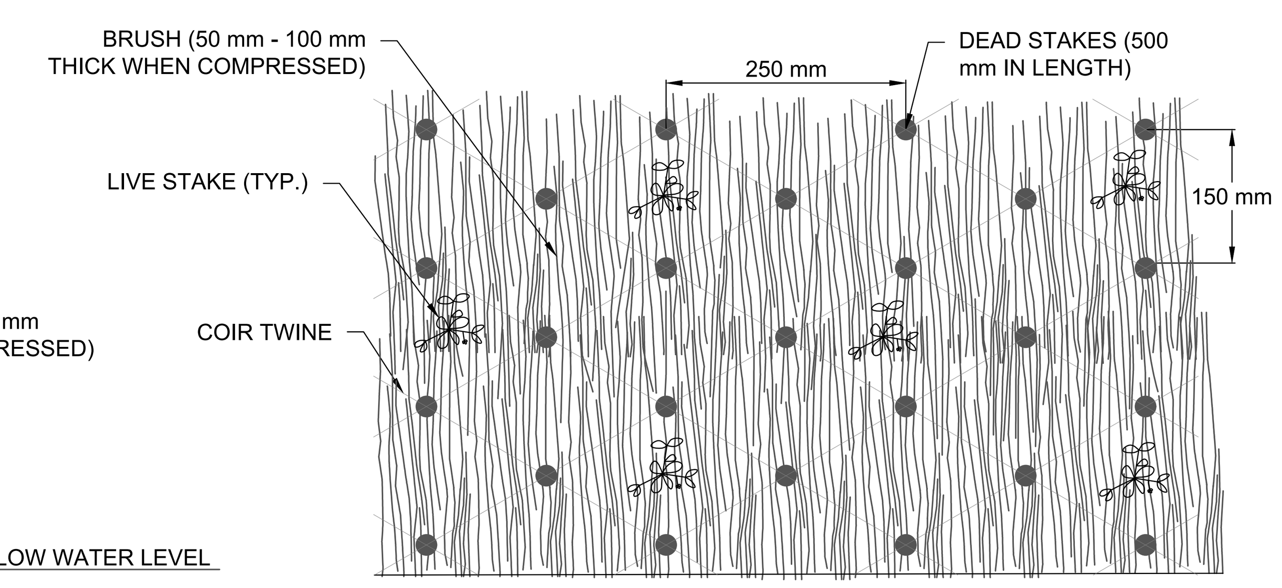
NOTES

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.





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.

RIPARIAN SEED MIX

COMMON NAME	SPECIES	PERCENTAGE
BIG BLUESTEM	*Andropogon gerardii*	25
VIRGINIA WILD RYE	*Elymus virginicus*	5
FOWL BLUEGRASS	*Poa palustris*	25
FOWL MEADOW GRASS	*Glyceria striata*	2
FOX SEDGE	*Carex vulpinoidea*	25
NEW ENGLAND ASTER	*Symphyotrichum novae-angliae*	2
ALLEGHENY MONKEYFLOWER	*Mimulus ringens*	5
AWL FRUITED SEDGE	*Carex stipata*	2
BEBB'S SEDGE	*Carex bebbii*	2
SPOTTED JOE PYE WEED	*Eupatorium maculatum*	1
BONESET	*Eupatorium perfoliatum*	2
BLADDER SEDGE	*Carex intumescens*	1
SWAMP ASTER	*Symphyotrichum puniceum*	2
CANADA ANEMONE	*Anemone canadensis*	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. APPLY A NURSE CROP OF ANNUAL OATS (*Avena Sativa*) AT A RATE OF 60 kg PER HECTARE.
4. WATER SOIL AFTER SEED APPLICATION.

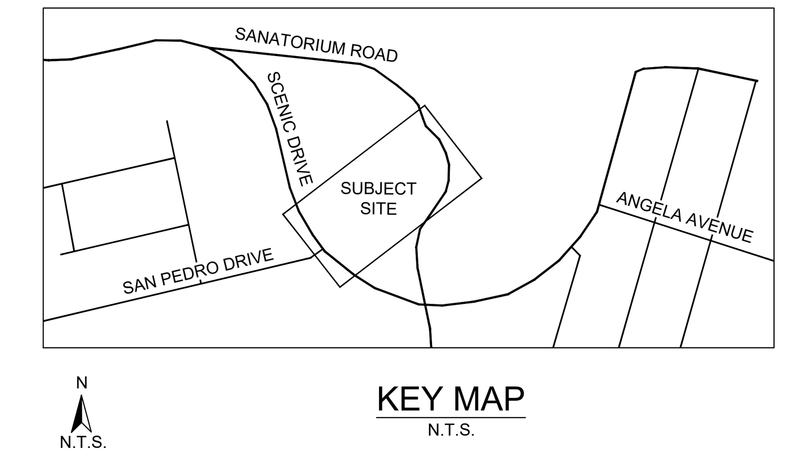
WET MEADOW SEED MIX

COMMON NAME	SPECIES	PERCENTAGE
AWL FRUITED SEDGE	*Carex stipata*	5
BEBB'S SEDGE	*Carex bebbii*	5
FOX SEDGE	*Carex vulpinoidea*	25
BLACK EYED SUSAN	*Rudbeckia hirta*	5
BLADDER SEDGE	*Carex intumescens*	5
BIG BLUESTEM	*Andropogon gerardii*	2
INDIAN GRASS	*Sorghastrum nutans*	6
SPOTTED JOE PYE WEED	*Eupatorium maculatum*	1
FOWL MEADOW GRASS	*Poa palustris*	1
TUSSOCK SEDGE	*Carex stricta*	5
VIRGINIA WILD RYE	*Elymus virginicus*	25
COMMON MILKWEED	*Asclepias syriaca*	12
BLACK EYED SUSAN	*Rudbeckia hirta*	2
NEW ENGLAND ASTER	*Symphyotrichum novae-angliae*	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 ANNUAL OATS (*Avena sativa*) AT A RATE OF 60 kg PER HECTARE.
4. WATER SOIL AFTER SEED APPLICATION.

SCALED FOR PLOT ON 'ARCH D'



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.

1.	2020-07-24	BWM	FIRST SUBMISSION
	DATE	BY	REVISIONS

DESIGNED BY: P.V.	CHECKED BY: P.V.
DRAWN BY: B.W.M.	DATE: JULY 2020

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
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2020-07-24

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SCENIC DRIVE AND SANATORIUM ROAD VALERY HOMES

CHEDOKE CREEK DESIGN DETAILS

PROJECT No.: 19010	DRAWING No.: DET-2
SCALE: AS NOTED	SHEET 3 OF 3