Appendix C: Fluvial Geomorphology Review and Preliminary Channel Design (2018)

Fluvial Geomorphology Review and Preliminary Channel Design
Fourteen Mile Creek & McCraney Creek
Lakeshore Road West Improvements
Class Environmental Assessment
Town of Oakville

Submitted to:

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Fluvial Geomorphology Review and Preliminary Channel Design
Fourteen Mile Creek & McCraney Creek
Lakeshore Road West Improvements Class Environmental Assessment
Town of Oakville

Fourteen Mile Creek and McCraney Creek have been investigated based on fluvial geomorphic requirements for Lakeshore Road improvements in the Town of Oakville. Scoping level characterization review including rapid assessments, summary of meander belt and erosion limits leading to recommendations for crossing geometry, and guidance recommendations for scour treatment and erosion control, have been undertaken.

Proposed preliminary channel design analysis and plotting has been undertaken specifically for McCraney Creek. Existing conditions include a valley wall contact erosion site coincident with the Lakeshore Road embankment on the upstream west side of the crossing. Emergency protection treatment has been installed but a long term solution is required for integration with proposed road widening and other improvements.

Watershed and Watercourse Characterization

Fourteen Mile Creek

Fourteen Mile Creek is a 3rd order watercourse with an upstream drainage area of approximately 25.8km^2 to the study area. The site falls within the Iroquois Plain physiographic region. Upstream catchment land use consists of low and some mixed density residential, industrial and commercial, protected valley, golf course, rural, and highway corridor. Several stormwater management ponds are seen in the residential catchment areas of the watershed.

The local watercourse from upstream to downstream of the Lakeshore Road crossing (~18m long open bottom span) consists of three distinct sub-reach types. Upstream of the crossing, two block high embedded armourstone bank treatment and armourstone grade control steps (three) have been installed with additional riverstone fill and shaping, over a length of 50m. Tree and shrub planting has been done along the top of bank behind armourstone with shrubs also colonizing the intervening riverstone treatment. A local storm sewer outlet is accommodated through the face of armourstone on the upstream left side just above the crossing wall. The armoured banks transition flush to the existing crossing width of approximately 15m. The alignment of the channel into the crossing biases flow against the westerly wall with depositional material biased easterly and extending slightly downstream. The downstream east side also shows distinct sedimentary bedrock layers exposed at and slightly above the elevation of the low flow. Downstream of the crossing, natural wooded flood plain conditions occur along the riparian zone with a single low head armourstone grade control, and additional riverstone bank treatment, installed in and along the channel.

Bankfull channel width in proximity to Lakeshore Road varies from approximately 8-11m on the downstream side of the crossing where natural indicators can be identified. Bankfull depth ranges broadly between approximately 0.5m to 1.5m downstream of the crossing, but is highly variable under the crossing to the upstream side due to deep scour pools, as noted below. Armourstone channelization on the upstream side precludes good definition of the bankfull channel. Bedform development is influenced by the presence of the armourstone step structures both upstream and downstream of the crossing. Below the sequence of three steps upstream of the crossing, a distinct scour pool has formed with a maximum low flow depth of 1.7m. This pool has incised through a clay till layer and sedimentary shale and limestone under the till. A subsequent deep pool exists under the crossing biased to the westerly downstream side. Similar till and bedrock geology is seen in this pool, which has a low flow depth of 1.4m. Below the end of the pool outside of the crossing the next armourstone step weir is drowned out by backwater from the crest of deposits further downstream.

Native channel bed geology consists of a wide gradation of shale dominant sand to cobble and boulder sized material mixed with imported gravel to cobble sized riverstone used within channelization geometry. Block shaped limestone cobble to boulder material also mixes with the shale. Much of the large cobble and small boulder sized material appears relatively stable under frequent flow conditions with algae and mineralization stains on water contact faces. Degradation and incision nonetheless indicates that weathering breakdown and scour occurs under peak events. Some erosion of banks above both sides of the step weir downstream of the crossing is evident. The pool under the crossing biased to the west side has scoured its deepest thalweg point against the crossing wall and some bank erosion naturally extends down the west side bank immediately from the crossing face.

McCraney Creek

McCraney Creek is a 2nd order watercourse with an upstream drainage area of approximately 10km^2 to the study area. The site falls within the Iroquois Plain physiographic region. The upstream catchment area is dominated by mixed density residential, with protected valley, institutional, commercial and industrial, vacant rural, and highway corridor land uses. There is a lack of stormwater management ponds in the catchment.

The watercourse upstream of Lakeshore Road turns sharply west and is fully confined against the roadside embankment before turning northerly up the valley corridor. The corridor is a relatively mature forest feature that results in high levels of shading and reduced groundcover density. Rooting density is thus lower than optimum for channel protection. The roadside embankment confinement is a distinct vertical eroding slope at a maximum height of 4.5m which tapers down to approximately 1m high over 40m of meander arc (see report cover picture of pre emergency works installation conditions). Recent emergency treatment stone works have been installed (by early 2018) to partially address the pre-existing erosion scar. The former vertical erosion scar transitioned to be an undercut channel edge scar which can still be seen moving upstream past the limits of recent work. A local storm sewer outlet set back from the eroding bank also results in an entrenched gully that cuts through the channel bank. This erosion reach is identified as the top ranking *Priority Localized Area of Concern* in the Town of Oakville's "Creek Inventory and Assessment Study" (Aquafor Beech 2016).

The channel enters the crossing in a sharp turn that is characterized by a distinct outcrop mound of sedimentary limestone bedrock at the crossing face that splits the low flow and that appears to extend under the crossing footings. The bedrock transitions to a cast concrete channel bed apron that is in a failed condition with dislodged elements downstream. The lip of the failed concrete results in a drop to a scour pool and widened flow from wall to wall that is approximately 0.9m deep. A distinct clay till layer also emerges at the face of the drop under which are further layers of shale and limestone. The pool extends several metres to approximately two thirds of the length of the crossing. The crossing structure itself is actually two structures of different age and geometry, butted together. The north half is a cast concrete open bottom arch with vertical lower walls and the south half is an open bottom precast box. The opening width is approximately 5.4m.

Through the downstream face of the crossing and southerly towards Lake Ontario the channel is relatively straight, over widened, and lined with dual armourstone rows on the west from the crossing. The channel passes under an approximate 10m span of a pedestrian bridge on the Appleby College property, 20m downstream. Similar forested conditions as upstream exist downstream and similar lack of rooting density is evident.

Bankfull channel width varies from approximately 5-8m where natural indicators can be identified. Bankfull depth varies from approximately 0.5-1m. Bedform development is influenced by the presence of sedimentary shale and limestone layers in various states of weathering and breakdown. Deposits of gravel to boulder sized bedrock fragments are distinct upstream and downstream of the crossing and weathered layers are seen in toe erosion above low flow. The embankment slope erosion site upstream of the crossing has a deep sand face layer above bedrock up to the height of topsoil cover.

The downstream easterly bank below the crossing also shows moderate erosion down through the piles supporting the pedestrian bridge. A small amount of ad hoc stone and concrete debris protection appears to be placed along this bank. Bed material beyond the crossing limits appears to be a mix of stable and mobile sizes, above and below medium cobble range respectively. Channel evolution conditions appear to be a legacy of past incision evolving into more current widening dominant processes. The level of bedrock exposure and stone pavement bed cover is generally more resistant than channel bank soils and this has resulted in the noted erosion scars resulting from channel widening.

Rapid Assessment Protocols

Three rapid assessment protocols were undertaken for the upstream and downstream sub-reaches and for a sub-reach directly under each crossing. Field observations were used to score relative geomorphic and environmental attributes. Rapid Geomorphic Assessment (RGA) was used to rate channel stability and infrastructure impact. Rapid Habitat Assessment (RHA) was used to define in-stream and riparian habitat. Rapid Stream Assessment Technique (RSAT) was used to test broad indicators of channel stability, aquatic habitat, and water quality. A weighted score out of 100 was transposed from the results of each protocol and a combined average score was determined from the three tests. Four qualifying ranges of poor, fair, good, and optimal are maintained in the RHA and RSAT protocols, between the original scoring and the weighted scoring out of 100, while the three original ranges in RGA scoring are reflected as fair, good, and optimal (urban vs. natural conditions considered). The combined average score is qualified by poor to optimal ranges designed as a best fit of the individual protocol ranges. The upstream sub-reach for McCraney Creek was specifically assessed based on pre-existing conditions before recent emergency works were installed. The detailed results are appended and included with each are photographs of typical reach conditions. Scoring results are summarized in **Table 1**.

Table1: Rapid Assessment Protocol Summary Scoring Results

	RGA	RHA	RSAT	Combined
Fourteen Mile u/s of Lakeshore Road	86.4	68.5	72.0	75.6
Fourteen Mile crossing	72.1	62.5	60.0	64.0
Fourteen Mile d/s of Lakeshore Road	64.3	75.0	70.0	69.8
McCraney u/s of Lakeshore Road	58.2	61.0	52.0	57.1
McCraney Crossing	69.3	57.5	56.0	60.9
McCraney d/s of Lakeshore Road	73.2	65.5	56.0	64.9

The results of rapid assessment confirm generally fair to good channel conditions given the urban context. Stability is highest in the armoured reach of Fourteen Mile Creek and lowest through the significant erosion site on McCraney Creek upstream of the crossing. Habitat assessment generally scores in the fair to lower range of good, based on reasonable riparian and bed conditions, with lowest scores reflecting the short sub-reaches within each crossing structure. Each structure nonetheless provides large pool habitat, as described in the characterization discussion. The rapid assessments do not necessarily reflect positive habitat benefits from manmade structures, or specific functions of specific individual features.

Meander Belt Analysis

Fourteen Mile Creek

The Fourteen Mile Creek crossing creates a fixed horizontal control to the watercourse due to the existing structure walls and the upstream erosion control transition into the structure. Constraints between historical abutting land uses and legal property boundaries also contribute to limited opportunity to consider crossing relocation or very large span increases. As a result, detailed pre-development historic channel planform conditions are not deemed necessary for meander belt or amplitude screening, and a review of relatively recent conditions was deemed appropriate.

Comparisons of digital air photos (Town of Oakville, 2015) spanning 1995 to 2015 (1995, 1999, 2002, 2006, 2008, 2010, 2012, 2015) was done. Using the 1999 (better clarity than 1995) and 2015 photos a side by side comparison and digital centre line trace was made of natural channel patterns downstream of the crossing. The detailed results are appended.

The comparison shows essentially identical planform patterns at both intervals. As a result, there is no evidence of expansive amplitude or expansive meander belt development. Likewise there is no evidence of reach or meander based up or down valley translation of aggressive erosion patterns. Based on this summary there is a lack of opportunity, and no explicit need, to make recommendations for meander pattern related requirements for crossing sizing.

The existing planform based point of crossing is not explicitly perpendicular to a straight section of the watercourse. The upstream channelization creates the equivalent of a large radius westerly meander arc which results in the existing low flow bias against the westerly wall within the crossing. This also results in the bar formation within and downstream of the crossing, as biased to the east side. The best fit cross-section within the crossing under future conditions would thus be an asymmetrical pool with the thalweg biased westerly.

Requirements of OMNRF permitting regarding Redside Dace habitat dictate meander belt identification, plus additional setback, to define permit limits.

Cross-reference to topographic and GIS mapping contour patterns shows evidence of past meander development downstream of the crossing. This planform pattern may have existed well before the original construction of Lakeshore Road. Appended schematics show the pattern and a hypothetical meander belt width of approximately 75m. For comparison, meander belt limits were also defined by an empirical data approach. The appended regional regression analysis shows Southern Ontario meander belt measurement as a function of drainage area. The calculated meander belt width was determined to be 64.2m using this approach. The measured limits of 75m are seen to fall within the data scatter in the regime relationship but are more conservative than the best fit, and are thus recommended for implementation.

The bias in downstream valley bottom definition and the resultant bias in the measured belt limits are to the east of the crossing. For implementation ease it is suggested that a one third westerly to two thirds easterly split in the belt limits be applied in the work zone for road improvements. This results in 25m west of centre and 50m east of centre of the crossing defining the belt limit habitat zone, measured on the centre line of Lakeshore Road. An appended air photo schematic shows the proposed alignment of the belt limits and the additional 30m Redside Dace habitat zone setbacks required by Ontario Regulation 242/08 of the Endangered Species Act (OMNRF 2016).

McCraney Creek

The McCraney Creek crossing creates a 5.4m wide fixed horizontal control to the watercourse due to the existing structure walls. Constraints between historical abutting land uses and legal property boundaries also contribute to limited opportunity to consider crossing relocation or very large span increases. As a result, detailed pre-development historic channel planform conditions are not deemed necessary for meander belt or amplitude screening, and a review of relatively recent conditions was deemed appropriate.

Comparisons of digital air photos (Town of Oakville, 2015) spanning 1995 to 2015 (1995, 1999, 2002, 2006, 2008, 2010, 2012, 2015) was done. Using the 1999 (better clarity than 1995) and 2015 photos a side by side comparison and digital centre line trace was made of natural channel patterns downstream of the crossing. The detailed results are appended.

The comparison shows essentially identical planform patterns at both intervals with possible reflection of some down valley movement in the eroding bend leading directly into the crossing. There is no evidence of widespread expansive amplitude or expansive meander belt development. Based on this summary there is a lack of opportunity, and no explicit need, to make recommendations for meander pattern related requirements for crossing sizing. Addressing the erosion site upstream of the crossing will involve in-situ adjustment of the channel that will likely result in some adjustment of the planform leading to the crossing.

100yr Erosion Limits

The results of meander belt analysis identify a lack of need to consider opening widths in terms of planform patterning. The shift in focus therefore turns to localized channel stability using standard criteria from existing guidelines. From a geomorphic perspective, opening width and protection requirements are based on a combination of bankfull channel width plus appropriate 100yr erosion contingency integrated with scour treatment requirements. A lower standard can be used when constraints are identified. Scour treatments are shaped to define bankfull channel geometry and are enhanced with appropriate substrate for fish habitat and barrier free fish passage (details discussed further below).

The crossing locations are targeted for channel stability based on the 100yr scour protection requirements of MTO Guidelines WC-1/WC-3 for collector roads (MTO 2008). A Provincial Guideline criterion for 100yr erosion limits (MNR 2002) in turn applies for stable channel definition given the installation of scour treatments. Five field measurements were made of bankfull channel width in proximity to each crossing and the appropriate channel setback is deemed to be the equivalent of stable conditions. Appended is a summary of bankfull measurements combined with the recommended setbacks based on Provincial Guidelines. The diverse channel bed sediment conditions ranging from weathered shale and limestone to clay till would suggest the median criteria from the guideline range. An average setback of 3.5m satisfies integrated consideration of bedrock with evidence of erosion and stable heterogeneous soils, for channels over 5m wide. Using average bankfull widths of 9.5m and 6.5m for Fourteen Mile and McCraney respectively, the recommended opening widths of 16.5m and 13.5m would apply, subject to implementation of scour protection treatment. The existing crossing opening of Fourteen Mile Creek is moderately smaller (15m) than recommended (16.5m) and the existing crossing of McCraney Creek is significantly smaller (5.4m) than recommended (13.5m). The existing opening width for Fourteen Mile Creek is deemed acceptable because the relative difference to recommended is minor from a geomorphic perspective, and because related hydraulic and structural analysis confirms the structure to be acceptable. Consideration for widening and related channel and corridor integration can be done when the structure requires replacement due to life cycle structural deficiencies.

McCraney Creek Preliminary Channel Design Analysis

Design Rationale

The existing slope toe contact erosion site on the upstream west side of the crossing dictates that either a protect in place strategy or a channel realignment strategy be used to address the hazard and risk, in association with road widening and other road improvements. The recently installed emergency works only partially resolve the problem. The widening proposal for Lakeshore Road necessitates crossing width enlargement and crossing length increases to the upstream side. These geometry changes need to adjust the creek alignment regardless of existing conditions and clearly it would be unreasonable to only move the creek insofar to realign it along the new slope/abutment toe when a better solution exists.

Existing conditions are also impacted by the full confinement of the two existing old crossing structures, the presence of a low flow bedrock encroachment on the upstream side of the existing crossing, and the lack of bedform sequencing that matches upstream and downstream. The full confinement impacts terrestrial corridors for small mammal movement, with the westerly slope toe confinement completely closing off corridor continuity on this side. The existing crossing width confinement also results in a lack of conveyance capacity from an engineering perspective.

Channel realignment achieves a better integrated corridor solution by providing channel integrity and symmetrical terrestrial function on both sides instead of just one. Realignment eliminates the slope contact hazard and replaces it specifically with a new slope at better angle with reinforcing vegetation. Based on this summary the realignment channel design solution was pursued for detailed analysis as the preferred option.

The design rationale advocated for the upstream to downstream realignment and the McCraney Creek crossing is rehabilitation of reference conditions that result in improved channel performance and corridor function. Accommodation of bankfull channel width with overbank setbacks is intended to achieve stable geomorphic form with fish passage and habitat improvement, and terrestrial linkage.

Flow Regime

Flow regime conditions for the proposed channel design are based on field survey of existing active flow or bankfull conditions. Field survey was done at two representative locations, upstream and downstream of the existing crossing, to determine a target bankfull flow.

Channel bed and bank geometry and bankfull flow geomorphic indicators were measured at each cross-section for use in geomorphic modeling. Channel bed substrates were measured through random-step Wolman pebble counts and recorded using the Wentworth sediment distribution scale. Cross-section locations were selected on evidence of active channel processes and defined bankfull shape and stage. Points of significant organic debris blockage that create localized backwater conditions were avoided. Observable tailwater flow indicators such as matted or flattened vegetation edges and root structures were located along banks and within encroaching vegetation for demarcation of cross-section limits.

Geomorphic open channel flow models were created for each cross-section location. Each model required input of channel bed substrate data, cross-section dimensions, gradient, and bank geometry. Modeling tests were done for each cross-section to determine hydraulic geometry, erosion thresholds, and bankfull flow. The detailed modeling results for existing bankfull conditions are appended. The proposed design bankfull flow rate was determined to be $3.65 m^3 s^{-1}$. Based on the urbanized watershed context and lack of known upstream stormwater management facilities it is expected that bankfull or channel forming flows occur potentially several times a year and that peak events have flashy timing. Erosion threshold indicators from proposed design sections are not extreme, with velocity ranging from $1.1\text{-}1.4 m s^{-1}$ and shear stress ranging from $30\text{-}80 N m^{-2}$/. Indicators are moderately high enough however that sympathetic design treatments are warranted, given the specific consideration that shading will impact vegetative reinforcement.

Cross-Section Design

Based on the results of opening width recommendations and the surveys of existing bankfull conditions, proposed design cross-section models were produced for riffle and pool features that mimic the existing channel type at channel forming flow. The sections were designed at the average bankfull width noted in erosion limits discussion. Detailed results are appended showing the proposed bankfull channel forming geometry. Channel forming slope used in section models was adjusted to match the combination of proposed planform requirements and hydraulic analysis. Riffle slope was modeled at feature face slope to be conservative for stability design and to not constrain fish passage.

In daylight areas it is recommended that low bank height vegetated stone revetments be used along outside pool banks that transition to intervening riffles. This will fix the new realignment in place while vegetation establishes over time. As noted, the corridor shading will impact some vegetative growth but using vegetation within stone protects rooting development from the potential impact of frequent bankfull flow events. It is further recommended to construct pools as symmetrical instead of asymmetrical cross-sections. This will initially shift the thalweg or deepest point away from the bank apex and allow the thalweg to adjust over time. In weathered shale bedrock and forested conditions this is preferred as it initially shifts the highest shear and to a degree the highest velocity away from newly installed vegetation, seeding, and topsoil placement. The intent is to maximize the opportunity for vegetation to establish as much as possible in the constrained geologic and canopy shade environment.

Within the crossing the proposed bankfull cross-section and overbanks will be shaped within the recommended scour treatment minus cover cap depth for overbank terraces and bed cover depth for fish habitat, as described further below. The overbanks from the bankfull limits should be essentially flat to the crossing wall limits. The upstream and downstream crossing tie-ins will need to have overbank grading that blends from existing. These areas are recommended for integrated erosion protection treatment as needed in the contraction and expansion zones.

An additional consideration in detailed cross-section design and implementation is the identified deep pool that currently exists specifically within the existing crossing. This pool has incised into bedrock and provides a unique feature that is uncommon otherwise within the general reach from further downstream to further upstream. Based on the distinct form and function of this pool it is recommended that it be preserved as best as possible with new channel construction. Demolition of the existing structure may impact the lateral limits of this pool therefore it is imperative to specifically include adequate restoration with stable treatment that restores the feature morphology. It is assumed that it will be necessary to inspect the feature in post demolition conditions to adjust any detailed design plans. Regardless of selection of scour treatment typology a more specific treatment may be needed for the pool.

Scour Treatment

Scour treatment design was undertaken using proposed conditions indicators from HEC-RAS modeling. Typically the 100yr event design standard is used for analysis, subject to site specific conditions. A lower standard is used when constraints are identified and understood. Using 'collector road' criteria, a 1.15 factor of safety is applied to scour treatment analysis to meet the intent of MTO Highway Drainage Design Standards (MTO 2008). HEC-RAS review shows that velocity supersedes shear stress with regard to stability of channel materials therefore velocity was used for analysis. The maximum 100yr event velocity of 3.34m s^{-1} through the proposed structure was used as input for a treatment sizing model and the FS=1.15 was applied. Detailed results of modeling are appended. Given the high relative velocity and high factor of safety, the recommended stone size treatment is excessive with the D_{100} equal to 1.1m and a D_{50} of 0.8m diameter for rounded stone. Layer thickness would be onerous and potentially deeper than proposed footing depth. As a result, an alternate best fit solution was iteratively checked for the maximum realistic solution.

Review of upstream and downstream conditions shows that velocities are generally lower in the wider flood plain conditions than within the crossing, as expected. Specifically, as flows drop to and below the 25yr event, velocities drop to be within a realistic range for vegetative reinforcement and typical levels of stability for cobble to boulder gradation of bed materials. There is still risk to exposed and unprotected banks where vegetation is lacking due to shading of groundcover growth but the 25yr event appears practical as a continuum target for the crossing. An additional stone size treatment test was done at the 25yr event velocity, in the crossing, of 3.09m s^{-1} with FS=1. Detailed results are appended. This velocity is moderately lower than the 100yr and with lower FS results in a more realistic stone treatment gradation. Representative D_{100} and D_{50} sizes are 70cm and 55cm respectively for riverstone. Given that weathered sedimentary shale bedrock is expected within excavations, and potentially more resistant limestone layers, it is recommended that angular stone is better suited to both the geologic environment and from a stability perspective in both engineering and geomorphic terms. This will provide a better level of surface contact and thus resistance to movement. A summary sheet is appended, after stone size modeling sheets, showing the recommended treatment details.

Installation of stone treatment in the clear span crossing will have overbanks in-filled with cohesive soil to a balance line 20cm above the installed stone depth to match upstream and downstream daylight grades and to mimic bare native soil that would exist under shaded crossing conditions. The fill cap should be compacted in place to a level natural surface that allows movement of small mammals along the created overbank terrace. Within the bankfull channel limits, re-used native creek bed substrate material will be used as void fill of the scour treatment. The void fill will define the constructed bankfull and low flow geometry to mimic physical stream bed conditions for fish habitat and barrier free passage per the intent of MTO WC-12 guidelines (MTO 2008), MTO fish habitat mitigation (MTO 2009), and CH requirements.

The lack of groundcover and forest shading under future conditions is expected to persist therefore an extension zone of treatment that helps create defined channel entry and exit, and a buffer around the ends of the crossing walls, is recommended. Vegetated stone revetment treatments of the bankfull channel can be sized similarly to scour protection stone and a fully integrated solution can be achieved.

The preferred scour treatment approach is influenced by alternate options that follow current practice and requirements of Conservation Halton and the Ontario Ministry of Natural Resources and Forestry. Appended schematics show the MTO Guideline approach followed by CH and OMNRF approaches. Summary annotations are provided regarding the treatments and summary discussion is provided of the risk levels and functional values of each option. The MTO Guideline approach is the preferred approach recommended for municipal design. Potential channel reconstruction and restoration is deemed to be a risk at less than the highest standard possible. Maintenance costs and practical feasibility of restoring channels in constrained access crossings are current issues that characterize historic lack of due diligence with original design and construction. The best long term scour protection design therefore helps ensure the anticipated long term life cycle concurrently provided by structure design. Further discussion of the alternate approaches may be required at detailed design.

Planform Design

Planform plotting of the proposed preliminary channel design was done to show the bankfull channel limits through the crossing and upstream in the realigned footprint. A schematic plan view of the proposed realignment with new crossing is appended.

Starting on the downstream side, the new widened opening of the crossing will require grade blending and adjustment adjacent to the channel. Existing armourstone on the west side will require resetting to new westerly definition along the valley toe. This stone will transition to existing stone that protects the westerly piles of an existing pedestrian bridge on the Appleby College property. The grading on the east side will facilitate channel protection installation in the form of vegetated stone that should be extended to protect the easterly piles supporting the pedestrian bridge. The proposed planform will tie-in with the existing channel just below the crossing. A riffle transition is appropriate using the existing bed as a foundation with augmented stone placement to define low flow backwater upstream. The low flow backwater will help define and maintain the alignment through the existing deep pool. Removal of the bedrock barrier just upstream of the deep pool will be replaced with a riffle bedform that transitions to the upstream face of the new structure. The alignment will then deviate from the existing channel footprint in a mirrored reflection of the current channel against the slope toe. The existing point bar to terrace transition that exists opposite the erosion site meander is proposed to be excavated for the new alignment. This will take advantage of a slight bank face that currently exists on the east side of this terrace, which will define part of the upstream right bank of the new channel. A pool to riffle pattern is proposed using standard geomorphic sequencing design through the upstream realignment. This pattern will tie-in at the upstream end with tailwater conditions in the existing channel. Augmented riffle stone placement is possible at the tie-in zone to help define this transition.

The overall realignment footprint is also intended to allow the full restoration of the westerly slope erosion, with removal or burial of emergency works. The new slope and road embankment will be graded with a stable slope angle and be treated with integrated seeding, planting, and bioengineering. The slope toe to channel transition area will be characterized by the backfilled old channel and a new riparian edge that transitions into the overbank through the new crossing, which in combination will establish the new westerly terrestrial corridor.

Profile Design

Preliminary design of the proposed realignment channel profile was done using the planform plotting of relative distance between key bedform points and using field surveyed upstream and downstream existing channel tie-in elevations. The proposed low flow depth variation between riffles and pools was iteratively adjusted and the deep pool invert under the crossing was set based on field measurement of existing conditions. The profile plot is appended showing bedform sequencing and the bankfull flow profile under proposed conditions.

Fish Passage Analysis

Fish passage confirmation was undertaken using a velocity nomograph to assess the size of fish capable of moving upstream against specific nose velocities. Bankfull event velocities under proposed design riffle and pool cross-section conditions were used to check the preliminary design. Detailed results are appended. The results show that fish as small as approximately 2-3cm long range can use burst speed to move up the channel boundary and fish as small as 3-4cm range can use burst speed to move suspended through the water column. Burst speed distances are theoretically 90m or more before velocity shelter is required. Based on the proposed length of the crossing and the intervening shelter from bedform sequencing in the realignment, there are no constraints foreseen to the size range of typical fish that will pass the design during high flows. These results are conservative because they represent the peak of freshet or infrequent storm events when fish are more likely to only be active during the rise or upon the recession of flows to levels less than bankfull

Conclusions

Fourteen Mile Creek and McCraney Creek have been investigated based on fluvial geomorphic requirements for Lakeshore Road improvements in the Town of Oakville. Characterization rapid assessments, summary of meander belt and erosion limits, crossing geometry sizing, and guidance recommendations for scour treatment and erosion control, have been undertaken.

The recommended meander belt limits for delineation of Fourteen Mile Creek related Redside Dace habitat are 75m, with 25m measured westerly and 50m measured easterly from the creek centreline along Lakeshore Road. The existing crossing opening width for Fourteen Mile Creek is considered acceptable and the minimum crossing opening width recommended for McCraney Creek is 13.5m which encompass bankfull width of 6.5m with 3.5m overbanks on both sides. Larger crossing opening width would also be suitable, with overbank width adjusted accordingly. Opening sizing is conditional on implementation of scour protection to feasible levels.

Analysis of preliminary realignment channel design for McCraney Creek has been done to address new crossing geometry and to address a valley wall contact erosion site coincident with the Lakeshore Road embankment on the upstream west side. Flow regime, cross-section, scour treatment, planform, profile, and fish passage characterization for the realignment have been done and the results are recommended for implementation and finalization during detailed design.

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GEO-RAP v.1.2 Rapid Assessment Protocol Model

B. de Geus 03.12

Project: **Fourteen Mile Creek**
Lakeshore Road West Improvements Class Environmental Assessment
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	1
	Siltation in pools	
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	1
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.40

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.14**
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**86.4**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	12	20--16	15-11	10-6	5-0
Velocity / Depth Regime	17	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	18	20--16	15-11	10-6	5-0
Channel Alteration	5	20--16	15-11	10-6	5-0
Frequency of Riffles	14	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
/200	137				
/100	**68.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	7	8-7	6-5	4-3	2-0
/50	36				
/100	**72.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**75.6**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Looking upstream from the existing crossing

References
1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.
2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

GEO-RAP v.1.2 Rapid Assessment Protocol Model

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Project: Fourteen Mile Creek
Lakeshore Road West Improvements Class Environmental Assessment
Inside Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	1
	n/7 =	0.43
Degradation	Exposed bridge footing(s)	1
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.40

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.29

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.28**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment

100 - (100*SI) = **72.1**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

	Score	Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	12	20--16	15-11	10-6	5-0
Velocity / Depth Regime	17	20--16	15-11	10-6	5-0
Sediment Deposition	8	20--16	15-11	10-6	5-0
Channel Flow Status	18	20--16	15-11	10-6	5-0
Channel Alteration	4	20--16	15-11	10-6	5-0
Frequency of Riffles	8	20--16	15-11	10-6	5-0
Bank Stability u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	125				
/100	62.5	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

	Score	Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

	Score	Optimal	Good	Fair	Poor
Channel Stability	7	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	0	7-6	5-4	3-2	1-0
Biological Indicators	7	8-7	6-5	4-3	2-0
/50	30				
/100	60.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

	Score				
(RGA + RHA + RSAT) / 3 =	64.9	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

	Score				
(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Looking upstream within the crossing

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

GEO-RAP v.1.2 Rapid Assessment Protocol Model

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Project: **Fourteen Mile Creek**
Lakeshore Road West Improvements Class Environmental Assessment
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	1
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.29
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	1
	Suspended armour layer visible in bank	1
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.50

Widening	Fallen/leaning trees/fence posts etc.	1
	Occurrence of Large Organic Debris	1
	Exposed tree roots	1
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	1
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.50
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.14

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.36**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment

100 - (100*SI) = **64.3**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	12	20--16	15-11	10-6	5-0
Velocity / Depth Regime	17	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	18	20--16	15-11	10-6	5-0
Channel Alteration	15	20--16	15-11	10-6	5-0
Frequency of Riffles	14	20--16	15-11	10-6	5-0
Bank Stability u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
/200	150				
/100	**75.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	7	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	5	7-6	5-4	3-2	1-0
Biological Indicators	7	8-7	6-5	4-3	2-0
/50	35				
/100	**70.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**69.8**	100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		100-80	80-56	55-30	29-0

Looking downstream from the existing crossing

References
1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.
2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

GEO-RAP v.1.2 Rapid Assessment Protocol Model

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Project: **McCraney Creek**
Lakeshore Road West Improvements Class Environmental Assessment
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	1
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.43
Degradation	Exposed bridge footing(s)	1
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	1
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	1
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.50

Widening	Fallen/leaning trees/fence posts etc.	1
	Occurrence of Large Organic Debris	1
	Exposed tree roots	1
	Basal scour on inside meander bends	1
	Basal scour on both sides of channel through riffle	1
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.60
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.14

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.42**
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**58.2**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	12	20--16	15-11	10-6	5-0
Velocity / Depth Regime	11	20--16	15-11	10-6	5-0
Sediment Deposition	11	20--16	15-11	10-6	5-0
Channel Flow Status	13	20--16	15-11	10-6	5-0
Channel Alteration	10	20--16	15-11	10-6	5-0
Frequency of Riffles	14	20--16	15-11	10-6	5-0
Bank Stability u/s L	5	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	4	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	122				
/100	**61.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	6	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	2	8-7	6-5	4-3	2-0
/50	26				
/100	**52.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**57.1**	100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		100-80	80-56	55-30	29-0


Looking upstream over typical conditions above erosion site


Looking downstream over erosion site leading to the crossing

References
1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.
2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

GEO-RAP v.1.2 Rapid Assessment Protocol Model

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Project: **McCraney Creek**
Lakeshore Road West Improvements Class Environmental Assessment
Inside Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	1
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	1
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	1
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.60

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	1
	n/10 =	0.20
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.29

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.31**
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**69.3**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	13	20--16	15-11	10-6	5-0
Embeddedness	6	20--16	15-11	10-6	5-0
Velocity / Depth Regime	18	20--16	15-11	10-6	5-0
Sediment Deposition	11	20--16	15-11	10-6	5-0
Channel Flow Status	13	20--16	15-11	10-6	5-0
Channel Alteration	4	20--16	15-11	10-6	5-0
Frequency of Riffles	8	20--16	15-11	10-6	5-0
Bank Stability u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	115				
/100	**57.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	7	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	2	8-7	6-5	4-3	2-0
/50	28				
/100	**56.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**60.9**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0


Looking downstream within the crossing

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.
2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

GEO-RAP v.1.2 Rapid Assessment Protocol Model

B. de Geus 03.12

Project: **McCraney Creek**
Lakeshore Road West Improvements Class Environmental Assessment
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	1
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.43
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	1
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	1
	Exposed tree roots	1
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.30
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	0.27
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	73.2

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	12	20--16	15-11	10-6	5-0
Velocity / Depth Regime	13	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	13	20--16	15-11	10-6	5-0
Channel Alteration	10	20--16	15-11	10-6	5-0
Frequency of Riffles	14	20--16	15-11	10-6	5-0
Bank Stability u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
/200	131				
/100	65.5	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	7	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	5	7-6	5-4	3-2	1-0
Biological Indicators	2	8-7	6-5	4-3	2-0
/50	28				
/100	56.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	64.9	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

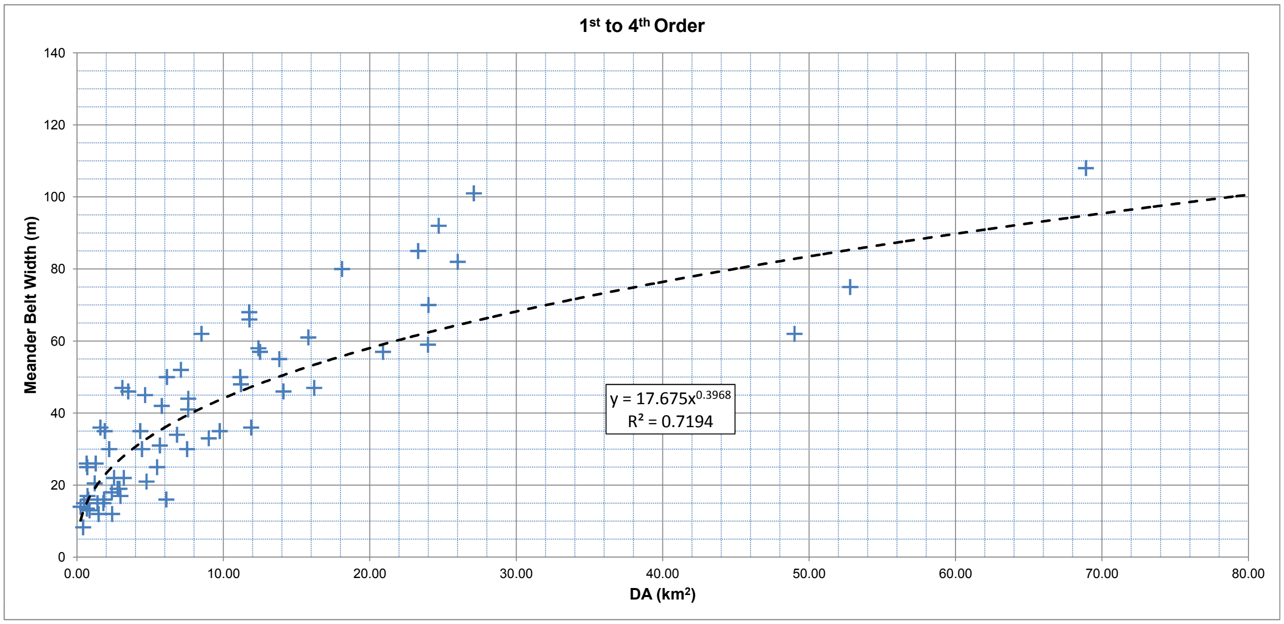
(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

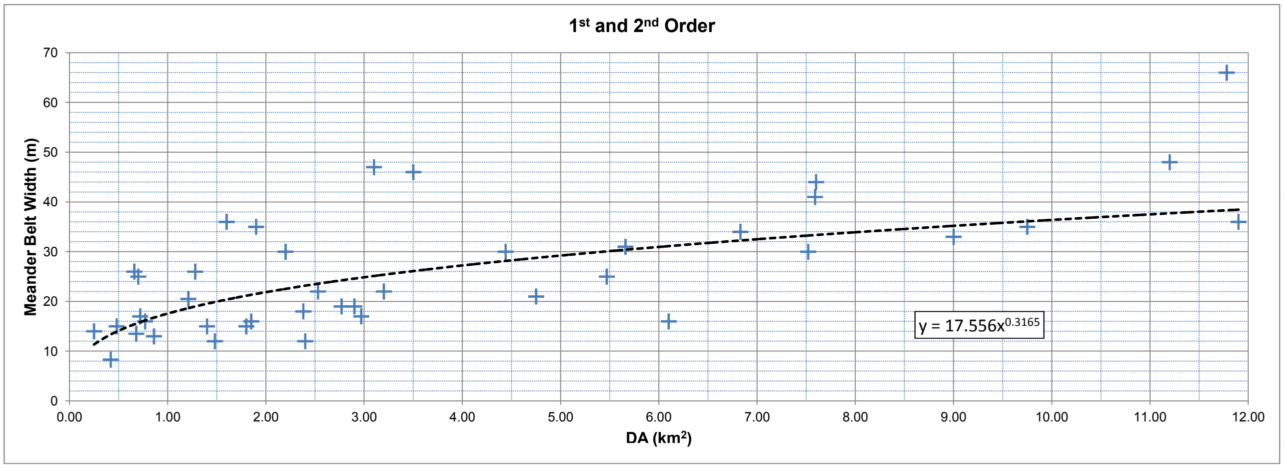

Looking downstream from the existing crossing

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.
2) USEPA. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

Regional Regression Curves for Meander Belt Width - Southern Ontario Data





Using 1st to 4th Order Equation, Solve for:

	DA (km^2)	meander belt width (m)
Fourteen Mile Creek @ Lakeshore Road	**25.8**	**64.2**

Fourteen Mile Creek - Planform Comparison
Lakeshore Road West Improvements Class Environmental Assessment

AquaLogic

Fourteen Mile Creek - Meander Belt Width
Lakeshore Road West Improvements Class Environmental Assessment

AquaLogic

Find area, length, or location

Meters

Measurement Result

74.8 Meters

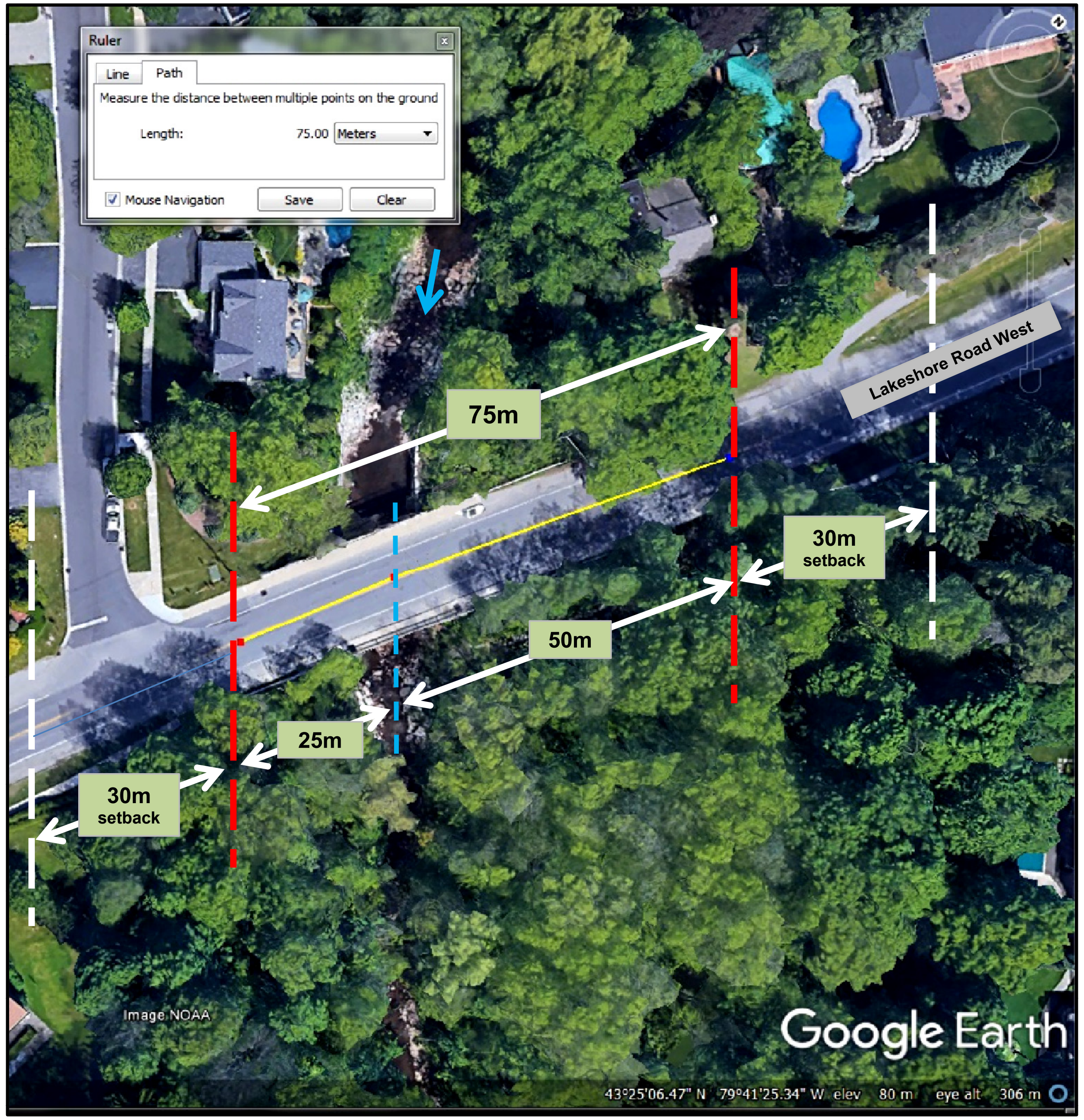
meander belt width = 75m

existing alignment

historic alignment based on contours

City of Hamilton, Town of Oakville, Ontario Base Map, Ontario MNR, Province of Ontario, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, EPA, USDA, AAFC, NRCan

POWERED BY esri



Ruler

Line | Path

Measure the distance between multiple points on the ground

Length: 75.00 Meters

☑ Mouse Navigation

Save

Clear

75m

50m

25m

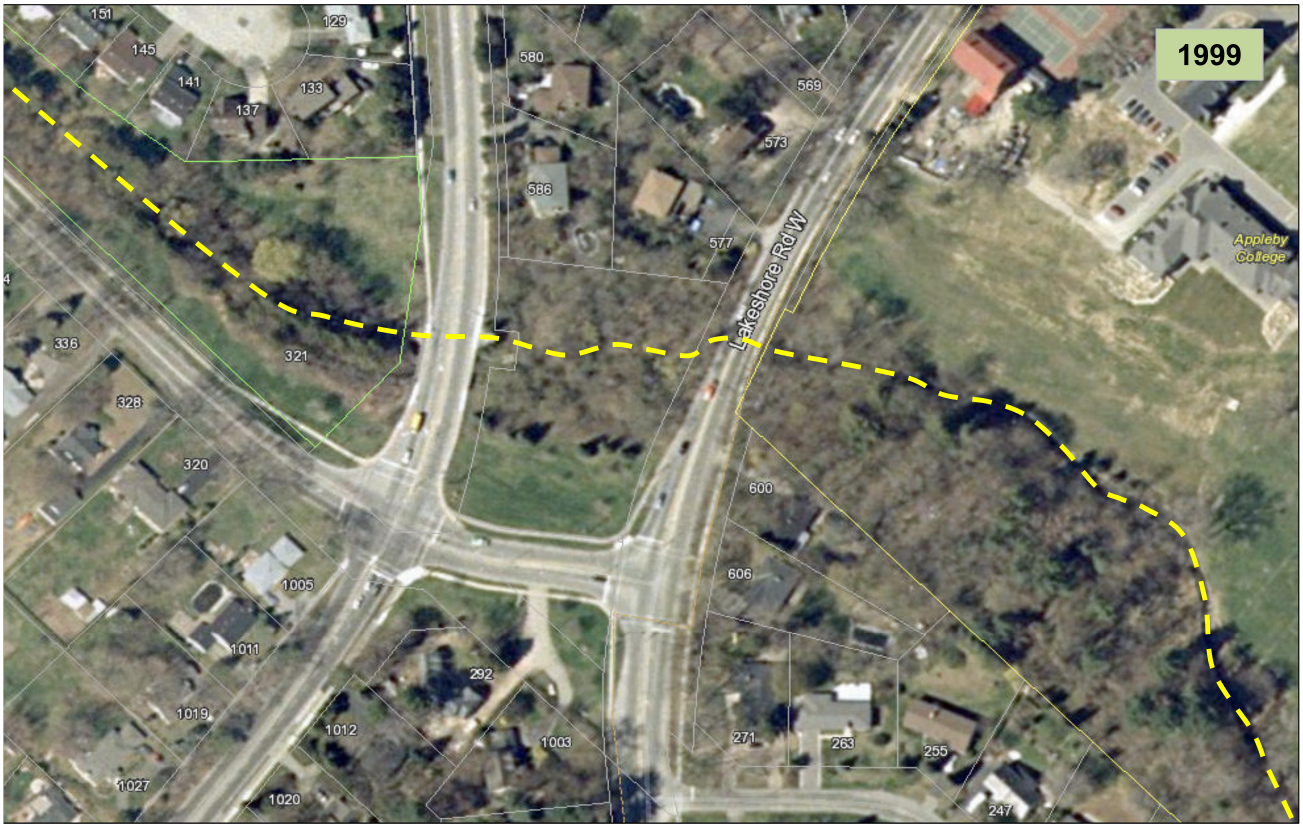
30m setback

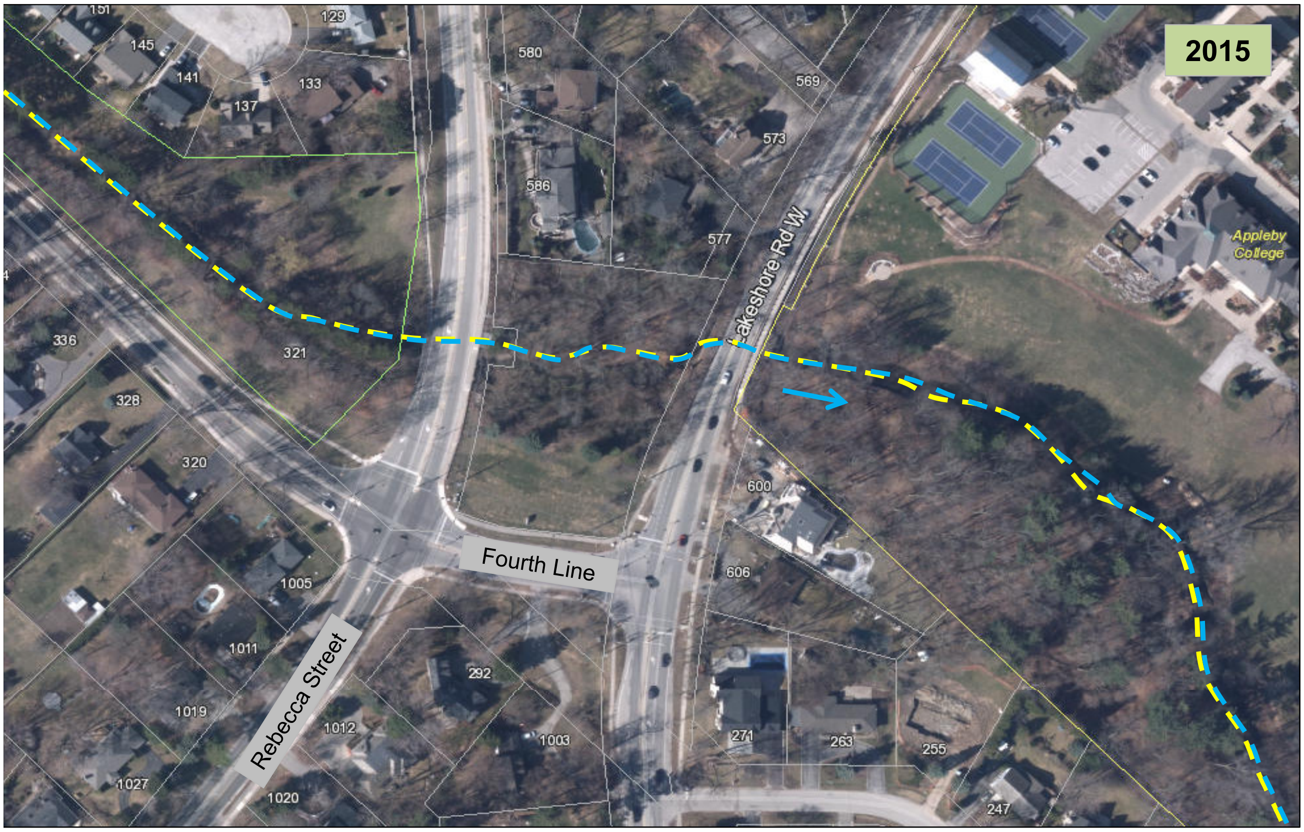
30m setback

43°25'06.47" N 79°41'25.34" W elev 80 m eye alt 306 m

McCraney Creek - Planform Comparison
Lakeshore Road West Improvements Class Environmental Assessment

AquaLogic





Fourteen Mile Creek
McCraney Creek
Lakeshore Road West Improvements Class Environmental Assessment
Crossing Width Opening Sizing

	bankfull width field measurements (m)
Fourteen Mile Creek	(10.8+10.7+9.1+8.2+8.6)/5=9.5
McCraney Creek	(5.4+7.3+6.5+6.0+7.5)/5=6.5

	bankfull width (m)		erosion allowance (m)		recommended minimum opening width (m)	existing opening width (m)
Fourteen Mile Creek	9.5	+	(2 x 3.5m)	=	**16.5**	15.0
McCraney Creek	6.5	+	(2 x 3.5m)	=	**13.5**	5.4

	Range of Suggested Toe Erosion Allowances			
	Evidence of Active Erosion or Bankfull Flow Velocity > Competent Flow Velocity	No Evidence of Active Erosion or Bankfull Flow Velocity < Competent Flow Velocity		
		Bankfull Width		
Native Soil Structure		<5m	5-30m	>30m
Hard Rock (granite)	0-2m	0m	0m	1m
Soft Rock (shale, limestone), Cobbles, Boulders	2-5m	0m	1m	2m
Stiff/Hard Cohesive Soil (clays, clay silt), Coarse Granular (gravels), Till	5-8m	1m	2m	4m
Soft/Firm Cohesive Soil, Loose Granular (sand, silt), Fill	8-15m	1-2m	5m	7m

i) Where a combination of different native soil structures occurs, the greater or largest range of applicable to erosion allowances for the materials found at the site should be applied

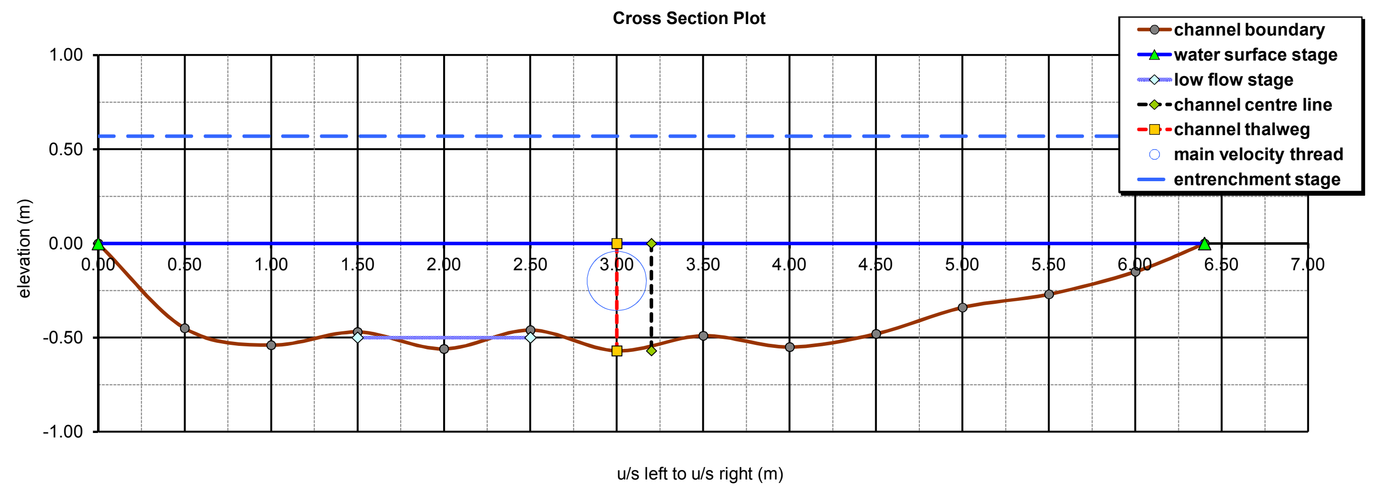
ii) Active Erosion is defined as: bank material is exposed directly to stream flow under normal or flood flow conditions where undercutting, over-steepening, slumping of a bank or down stream sediment loading is occurring. An area may have erosion but there may not be evidence of 'active erosion' either as a result of well rooted vegetation or as a result of a condition of net sediment deposition. The area may still suffer erosion at some point in the future as a result of shifting of the channel

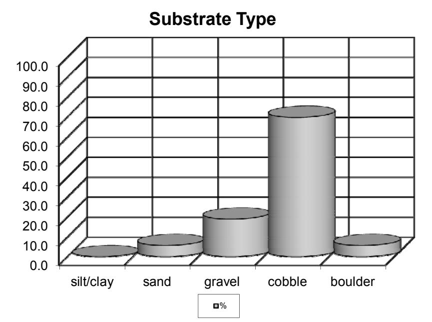
iii) Competent Flow Velocity is the flow velocity that the bed material in the stream can support without resulting in erosion or scour (OMNR 2002)

GEO-X v.5.1 Geomorphic Cross-section Analysis Model

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
Existing Conditions Active Channel - Section 1 upstream

B. de Geus 05.11





Morphology Type	
cascade	
step	
riffle	●
run	
glide	
pool	
thalweg out of phase	

Hydraulic Geometry	
A (m^2)	2.66
R (m)	0.40
TW (m)	6.40
WP (m)	6.70
max d (m)	0.57
mean d (m)	0.42
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R*/D_{84}	2.15
ff V mean/V*	5.32
ff D_{84}	4.83
ff mean	5.07
ROUGH BED	

Hydraulic Ratios	
ER max d	1.48
r_c / TW	
TW / Lf_w	6.40
TW/max d	11.2
TW/mean d	15.4

Sediment Transport Mode			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	1.353	29.28	NO	NO	NO	NO
V_* (m s^{-1})	0.113	D_{50}	1.574	34.06	NO	NO	NO	NO
		D_{84}	1.997	43.20	NO	NO	NO	NO

Section Data					
ER_e (m)	0.57	ER stations L / R	-0.50	9.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	6.40	6.40
Lf_e (m)	-0.500	Lf stations L / R	1.50	2.50	
W_{fp} (m)	9.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
$\underline{z}$		T_e (m) $T_{o/s}$ (m)	-0.57	3.00	
E_g (m m^{-1})	0.0160				

Bedload Transport Data	Strickler Q	Limerinos Q				
Rosgen	Q_{sb}	Q_{sb}		D_{30}	D_{50}	D_{84}
type	(kg sec^{-1})	(kg sec^{-1})	T_*	0.8	0.6	0.3
B3	0.0028	0.0027	saltation	NO	NO	NO
C3	0.0037	0.0033	rolling	NO	NO	NO
C4	0.0119	0.0116	Ø	YES	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	30.00	85.00	115.00	185.00	330.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})	29.10	82.45	111.55	179.45	320.10
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime Strickler method		Flow Regime Limerinos method	
Q (cms)	3.620	Q (cms)	
V (m s^{-1})	1.36	V (m s^{-1})	
n	0.050	n	
Fr	0.68	*Fr*	
D_c rectangular (m)	0.32	D_c rectangular (m)	
D_c trapezoidal (m)	0.54	D_c trapezoidal (m)	
D_c triangular (m)	0.78	D_c triangular (m)	
D_c parabolic (m)	0.51	D_c parabolic (m)	
D_c mean (m)	0.54	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	567.57	Ω (watts m^{-1})	
ω_a (watts m^{-2})	84.76	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	13.24	ω_a/TW (watts m^{-1})	
*Re**	215.3	*Re**	
Re	474202	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds		V_c / V_b Strickler	Limerinos
τ_{calc} (kg m^{-2})	6.35		
τ_{calc} (N m^{-2})	62.23		
τ D_{crit} (gr-co) (mm)	64.16		
D_{50} V_c (vcs +) (m s^{-1})	1.66	1.74	
D_{84} V_c (vcs +) (m s^{-1})	2.11	2.21	

Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	5.7	18.9	69.8	5.7

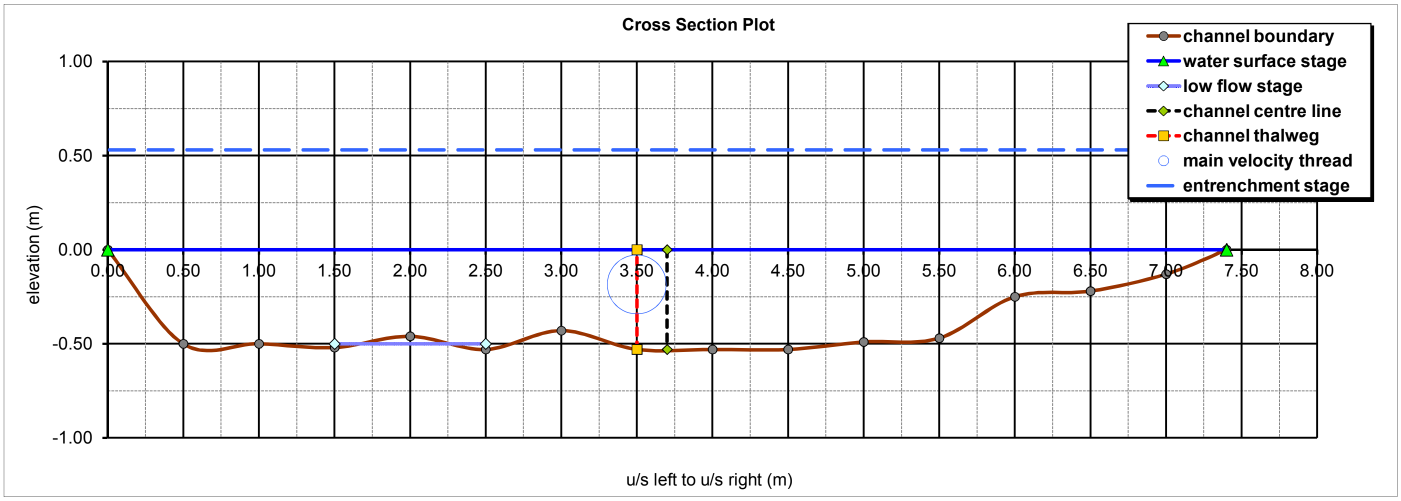
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

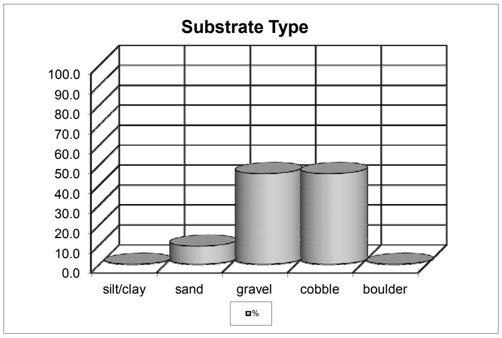
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

B. de Geus 05.11

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
Existing Conditions Active Channel - Section 2 downstream





Morphology Type	
cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry	
A (m^2)	3.04
R (m)	0.39
TW (m)	7.40
WP (m)	7.71
max d (m)	0.53
mean d (m)	0.41
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R*/D_{84}	2.63
ff V mean/V*	5.55
ff D_{84}	5.32
ff mean	5.44
	ROUGH BED

Hydraulic Ratios	
ER max d	1.55
r_c / TW	
TW / Lf_w	7.40
TW/max d	14.0
TW/mean d	18.0

Sediment Transport Mode			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.567	13.66	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.101	D_{50}	0.928	22.36	NO	NO	NO	NO
		D_{84}	1.798	43.32	NO	NO	NO	NO

Section Data					
ER_e (m)	0.53	ER stations L / R	-0.50	11.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	7.40	7.40
Lf_e (m)	-0.500	Lf stations L / R	1.50	2.50	
W_{fp} (m)	11.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.53	3.50	
E_g ($m\ m^{-1}$)	0.0130				

Bedload Transport Data	Strickler Q	Limerinos Q				
Rosgen type	Q_{sb} (kg sec^{-1})	Q_{sb} (kg sec^{-1})		D_{30}	D_{50}	D_{84}
			T_*	3.4	1.3	0.3
B3	0.0028	0.0028	saltation	YES	NO	NO
C3	0.0039	0.0041	rolling	YES	YES	NO
C4	0.0121	0.0123	Ø	NO	NO	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	4.00	15.00	40.00	150.00	220.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	3.88	14.55	38.80	145.50	213.40
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime Strickler method		**Flow Regime Limerinos method**	
Q (cms)	3.712	Q (cms)	
V ($m\ s^{-1}$)	1.22	V ($m\ s^{-1}$)	
n	0.050	n	
Fr	0.61	*Fr*	
D_c rectangular (m)	0.30	D_c rectangular (m)	
D_c trapezoidal (m)	0.53	D_c trapezoidal (m)	
D_c triangular (m)	0.79	D_c triangular (m)	
D_c parabolic (m)	0.51	D_c parabolic (m)	
D_c mean (m)	0.53	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	472.88	Ω (watts m^{-1})	
ω_a (watts m^{-2})	61.31	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	8.28	ω_a/TW (watts m^{-1})	
*Re**	74.9	*Re**	
Re	422107	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds		V_c / V_b Strickler	V_c / V_b Limerinos
τ_{calc} ($kg\ m^{-2}$)	5.12		
τ_{calc} ($N\ m^{-2}$)	50.18		
τ D_{crit} (gr-co) (mm)	51.74		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	0.98	1.15	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.90	2.22	

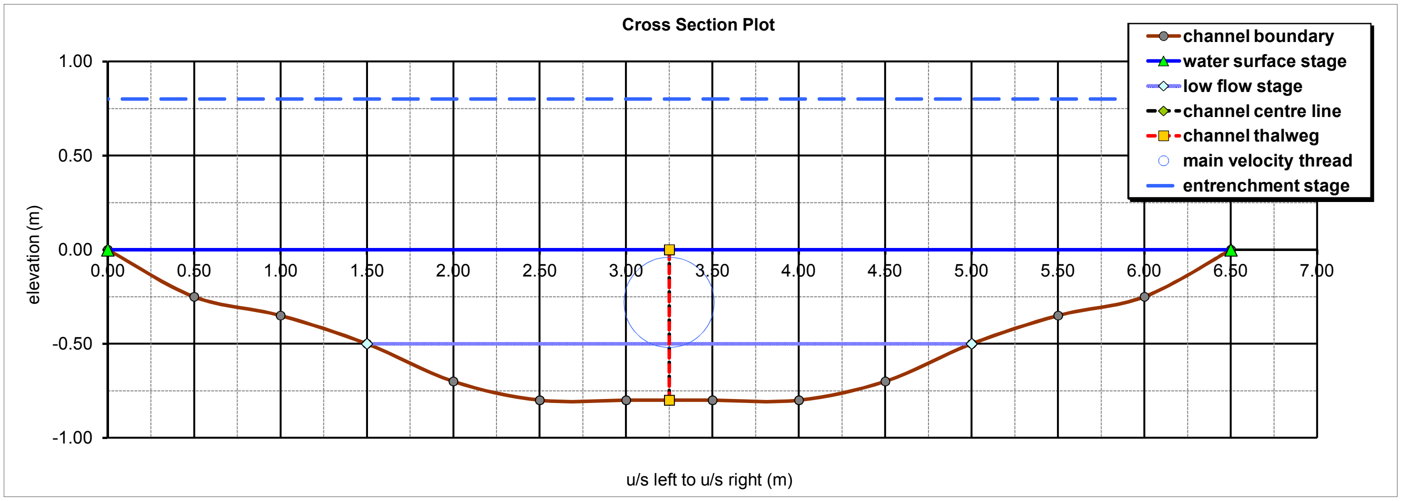
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	9.1	45.5	45.5	0.0

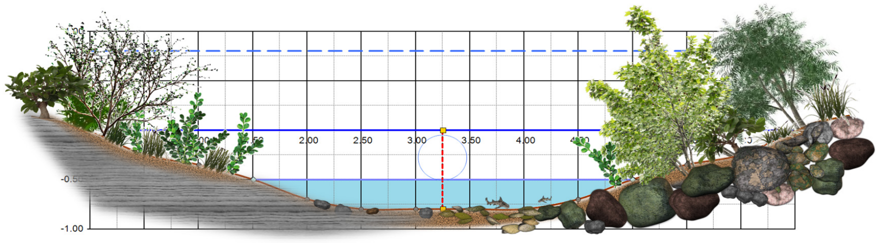
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

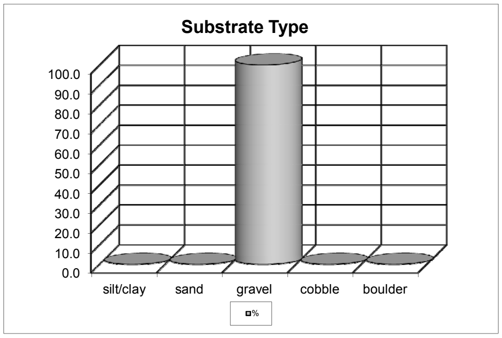
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

B. de Geus 05.11

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
Proposed Pool Section







Morphology Type	
cascade	
step	
riffle	
run	
glide	
pool	●
thalweg out of phase	

Hydraulic Geometry	
A (m^2)	3.40
R (m)	0.50
TW (m)	6.50
WP (m)	6.78
max d (m)	0.80
mean d (m)	0.52
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr R/D_{84}	11.15
ff V mean/V*	7.74
ff D_{84}	8.90
ff mean	8.32
	SMOOTH BED

Hydraulic Ratios	
ER max d	3.85
r_c / TW	
TW / Lf_w	1.86
TW/max d	8.1
TW/mean d	12.4

Sediment Transport Mode						high	low	
			w_s ($m\ s^{-1}$)	P	wash load	sus. load	sus. load	bedload
k	0.41	D_{30}	0.655	20.60	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.078	D_{50}	0.868	27.27	NO	NO	NO	NO
		D_{84}	0.984	30.93	NO	NO	NO	NO

Section Data

ER_e (m)	0.80	ER stations L / R	-10.00	15.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	6.50	6.50
Lf_e (m)	-0.500	Lf stations L / R	1.50	5.00	
W_{fp} (m)	25.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.80	3.25	
E_g ($m\ m^{-1}$)	0.0060				

Bedload Transport Data

	Strickler Q	Limerinos Q				
Rosgen	Q_{sb}	Q_{sb}		D_{30}	D_{50}	D_{84}
type	($kg\ sec^{-1}$)	($kg\ sec^{-1}$)	T_*	1.5	0.9	0.7
B3	0.0028	0.0031	saltation	NO	NO	NO
C3	0.0038	0.0079	rolling	YES	NO	NO
C4	0.0120	0.0144	Ø	NO	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	15	20	35	45	50
Stability Design Targets (mm)	15	20	35	45	50
τ_{cr} ($N\ m^{-2}$)	14.55	19.40	33.95	43.65	48.50
high turbulence - angular (mm)	10.5	14.7	31.5	37.8	42.0
high turbulence - rounded (mm)	11.7	16.3	35.0	42.0	46.7
low turbulence - angular (mm)	6.3	12.6	21.0	27.3	31.5
low turbulence - rounded (mm)	7.0	14.0	23.3	30.3	35.0

Flow Regime Strickler method		**Flow Regime Limerinos method**	
Q (cms)	3.686	Q (cms)	
V ($m\ s^{-1}$)	1.08	V ($m\ s^{-1}$)	
n	0.045	n	
Fr	0.48	*Fr*	
D_c rectangular (m)	0.32	D_c rectangular (m)	
D_c trapezoidal (m)	0.53	D_c trapezoidal (m)	
D_c triangular (m)	0.79	D_c triangular (m)	
D_c parabolic (m)	0.48	D_c parabolic (m)	
D_c mean (m)	0.53	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω ($watts\ m^{-1}$)	216.74	Ω ($watts\ m^{-1}$)	
ω_a ($watts\ m^{-2}$)	31.97	ω_a ($watts\ m^{-2}$)	
ω_a/TW ($watts\ m^{-1}$)	4.92	ω_a/TW ($watts\ m^{-1}$)	
*Re**	56.6	*Re**	
Re	476994	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds			
τ_{calc} ($kg\ m^{-2}$)	3.01		
τ_{calc} ($N\ m^{-2}$)	29.49	V_c / V_b	
$\tau\ D_{crit}$ (gr-co) (mm)	30.40	Strickler	Limerinos
$D_{50}\ V_c$ (vcs +) ($m\ s^{-1}$)	0.92	1.21	
$D_{84}\ V_c$ (vcs +) ($m\ s^{-1}$)	1.04	1.37	

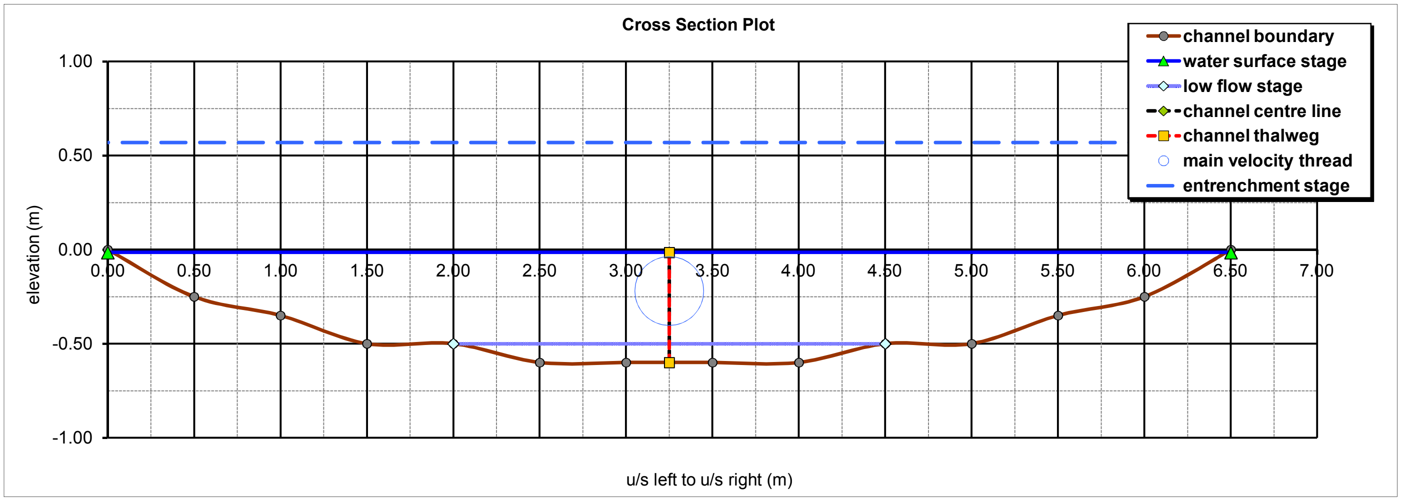
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	100.0	0.0	0.0

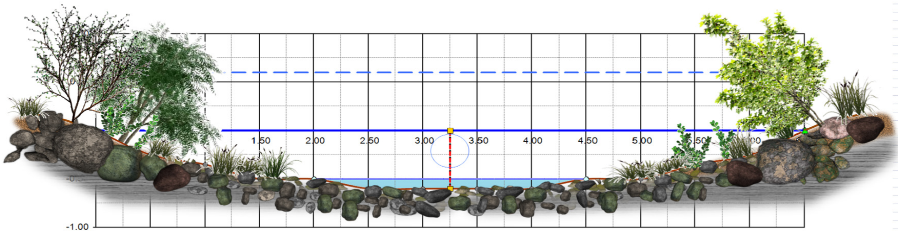
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

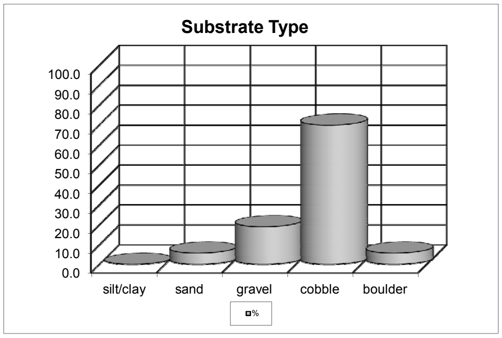
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

B. de Geus 05.11

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
Proposed Riffle Section







Morphology Type

cascade	
step	
riffle	●
run	
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	2.70
R (m)	0.41
TW (m)	6.44
WP (m)	6.63
max d (m)	0.59
mean d (m)	0.42
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	6.27
ff V mean/V*	6.28
ff D_{84}	7.45
ff mean	6.86
ROUGH BED	

Hydraulic Ratios

ER max d	3.88
r_c / TW	
TW / Lf_w	2.58
TW/max d	11.0
TW/mean d	15.3

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.803	15.34	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.128	D_{50}	1.038	19.82	NO	NO	NO	NO
		D_{84}	1.183	22.60	NO	NO	NO	NO

Section Data

ER_e (m)	0.57	ER stations L / R	-10.00	15.00	TW ck
WS_e (m)	-0.015	WS stations L / R	0.00	6.50	6.50
Lf_e (m)	-0.500	Lf stations L / R	2.00	4.50	
W_{fp} (m)	25.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.60	3.25	
E_g ($m\ m^{-1}$)	0.0200				

Bedload Transport Data

Rosgen type	Strickler Q Q_{sb} ($kg\ sec^{-1}$)	Limerinos Q Q_{sb} ($kg\ sec^{-1}$)		D_{30}	D_{50}	D_{84}
			T_*	2.7	1.6	1.3
B3	0.0028	0.0032	saltation	YES	NO	NO
C3	0.0038	0.0096	rolling	YES	YES	YES
C4	0.0120	0.0151	Ø	NO	NO	NO

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	25	30	50	65	75
Stability Design Targets (mm)	25	30	50	65	75
τ_{cr} ($N\ m^{-2}$)	24.25	29.10	48.50	63.05	72.75
high turbulence - angular (mm)	15.0	21.0	45.0	54.0	60.0
high turbulence - rounded (mm)	16.7	23.3	50.0	60.0	66.7
low turbulence - angular (mm)	9.0	18.0	30.0	39.0	45.0
low turbulence - rounded (mm)	10.0	20.0	33.3	43.3	50.0

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} ($kg\ m^{-2}$)	8.15		
τ_{calc} ($N\ m^{-2}$)	79.85		
$\tau\ D_{crit}$ (gr-co) (mm)	82.32		
$D_{50}\ V_c$ (vcs +) ($m\ s^{-1}$)	1.10	1.15	
$D_{84}\ V_c$ (vcs +) ($m\ s^{-1}$)	1.25	1.31	

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
0.0	5.7	18.9	69.8	5.7

Bank Data

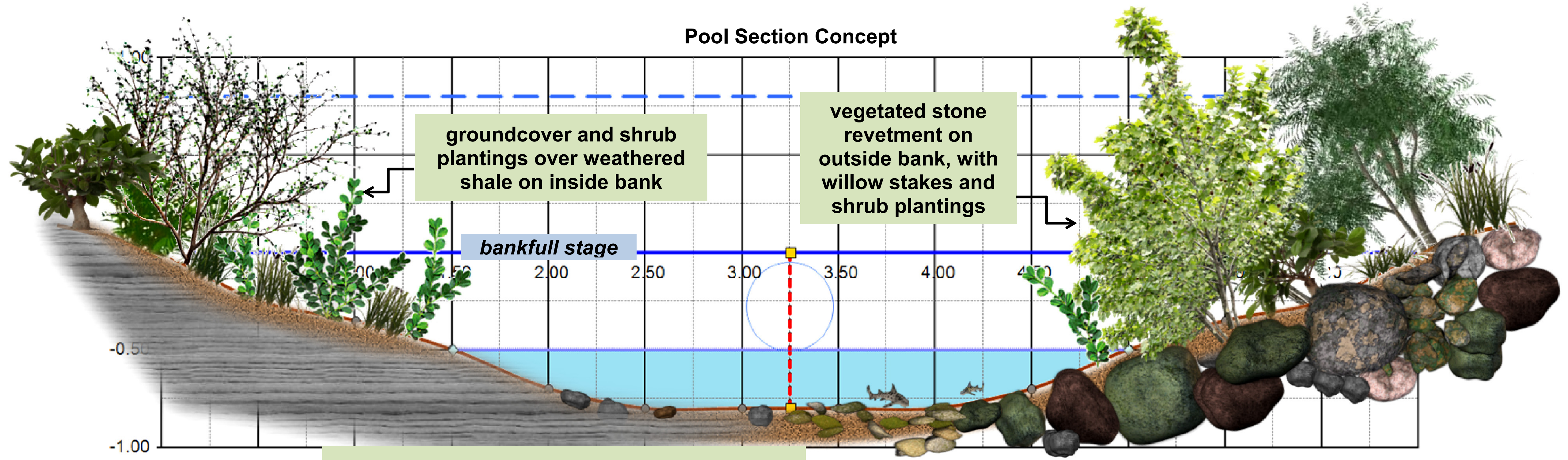
	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

Flow Regime

Strickler method		Limerinos method	
Q (cms)	3.674	Q (cms)	
V ($m\ s^{-1}$)	1.36	V ($m\ s^{-1}$)	
n	0.057	n	
Fr	0.67	*Fr*	
D_c rectangular (m)	0.32	D_c rectangular (m)	
D_c trapezoidal (m)	0.54	D_c trapezoidal (m)	
D_c triangular (m)	0.79	D_c triangular (m)	
D_c parabolic (m)	0.51	D_c parabolic (m)	
D_c mean (m)	0.54	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω ($watts\ m^{-1}$)	720.20	Ω ($watts\ m^{-1}$)	
ω_a ($watts\ m^{-2}$)	108.55	ω_a ($watts\ m^{-2}$)	
ω_a/TW ($watts\ m^{-1}$)	16.86	ω_a/TW ($watts\ m^{-1}$)	
*Re**	105.4	*Re**	
Re	485820	*Re*	
turbulence	HIGH	turbulence	

McCraney Creek
Preliminary Channel Design
Lakeshore Road Crossing

AquaLogic

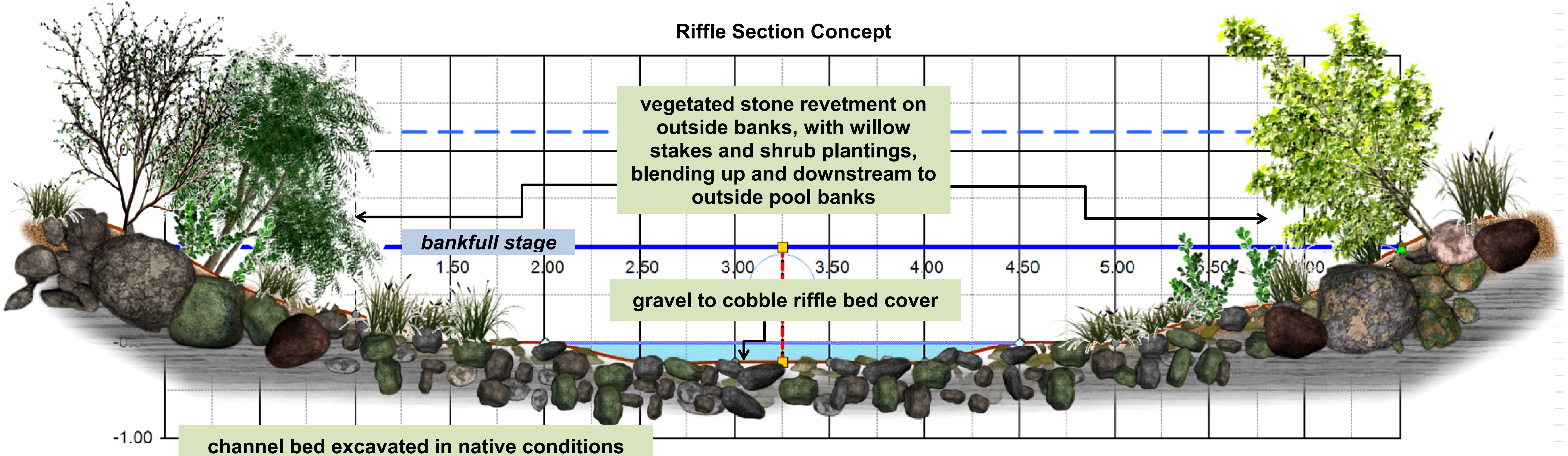


Pool Section Concept

groundcover and shrub plantings over weathered shale on inside bank

vegetated stone revetment on outside bank, with willow stakes and shrub plantings

channel bed excavated in native conditions



Riffle Section Concept

vegetated stone revetment on outside banks, with willow stakes and shrub plantings, blending up and downstream to outside pool banks

gravel to cobble riffle bed cover

channel bed excavated in native conditions

McCraney Creek Preliminary Channel Design
HEC-RAS Summary

River Sta	Profile	Q Tot (m3/s)	Top W (m)	E.G. Sl (m/m)	V Left (m/s)	V Chnl (m/s)	V Rght (m/s)	Shear L (N/m2)	Shear Ch (N/m2)	Shear R (N/m2)	Froude # Chl	Powr Chn (N/m s)
631.663		Bridge	Rebecca									
612.3046	2Years	18.58	11.63	0.01017		2.65			69.95		1	185.61
612.3046	5Years	28.32	12.83	0.00949		3.02			83.48		1	252.13
612.3046	10Years	34.73	13.58	0.00912		3.2			90.19		1	288.71
612.3046	25Years	42.77	14.44	0.00879		3.4			97.69		1	331.85
612.3046	50Years	48.86	15.06	0.00858		3.53			102.63		1	361.79
612.3046	100Years	54.24	15.56	0.00844		3.63			106.89		1	388.17
595.3819	2Years	18.58	22.04	0.00222	0.23	1.51	0.14	7.61	20.58	3.44	0.49	31.14
595.3819	5Years	28.32	28.72	0.0018	0.26	1.66	0.19	8.42	22.49	5.38	0.47	37.37
595.3819	10Years	34.73	30.41	0.00179	0.3	1.79	0.22	10.25	25.05	6.54	0.47	44.75
595.3819	25Years	42.77	32.13	0.00187	0.34	1.95	0.25	12.55	28.86	8.05	0.49	56.3
595.3819	50Years	48.86	33.27	0.00194	0.36	2.07	0.27	14.28	31.9	9.16	0.51	66.12
595.3819	100Years	54.24	34.54	0.00196	0.38	2.16	0.29	15.43	34.06	9.98	0.51	73.61
570.5971	2Years	18.58	36.86	0.00044	0.22	0.73	0.02	4.72	4.59	0.09	0.22	3.34
570.5971	5Years	28.32	39.91	0.00041	0.25	0.85	0.07	5.46	5.7	0.77	0.23	4.85
570.5971	10Years	34.73	41.32	0.00044	0.27	0.94	0.09	6.24	6.69	1.16	0.24	6.27
570.5971	25Years	42.77	42.55	0.00047	0.29	1.05	0.11	7.31	8.03	1.73	0.25	8.4
570.5971	50Years	48.86	43.4	0.0005	0.31	1.12	0.13	8.14	9.09	2.13	0.26	10.2
570.5971	100Years	54.24	44.33	0.00052	0.33	1.18	0.14	8.76	9.9	2.39	0.27	11.71
544.1928	2Years	18.12	9.98	0.01056		2.61			69.02		1	180.41
544.1928	5Years	28.72	13.62	0.01026		2.75			73.79		1	202.62
544.1928	10Years	35.45	15.99	0.01016		2.79			75.46		1	210.65
544.1928	25Years	43.77	18.54	0.01		2.85			77.49		1	220.77
544.1928	50Years	49.99	19.85	0.00986		2.91			79.73		1	232.08
544.1928	100Years	55.87	20.4	0.00968		2.99			82.79		1	247.85
538.303*	2Years	18.12	17.47	0.00414		1.6			26.05		0.62	41.55
538.303*	5Years	28.72	19.17	0.00337		1.79			29.3		0.59	52.34
538.303*	10Years	35.45	20.15	0.00308		1.88			31.01		0.58	58.39
538.303*	25Years	43.77	21.29	0.00282		1.99			32.85		0.57	65.22
538.303*	50Years	49.99	22.08	0.0027		2.06			34.28		0.56	70.53
538.303*	100Years	55.87	22.73	0.00258		2.11			35.28		0.56	74.56
531.5748		Bridge	Lakeshore									
531.5748BR U	2Years	18.12	14.65	0.01186		2.3			58.71		0.79	135.13
531.5748BR U	5Years	28.72	14.65	0.01104		2.68			72.55		0.83	194.59
531.5748BR U	10Years	35.45	14.65	0.01071		2.88			79.94		0.85	229.87
531.5748BR U	25Years	43.77	14.65	0.01047		3.09			88.49		0.87	273.31
531.5748BR U	50Years	49.99	14.64	0.01024		3.22			93.73		0.87	301.92
531.5748BR U	100Years	55.87	14.64	0.01011		3.34			98.67		0.88	329.67
531.5748BR D	2Years	18.12	14.65	0.00205		1.33			16.7		0.39	22.28
531.5748BR D	5Years	28.72	14.64	0.00224		1.63			23.01		0.43	37.44
531.5748BR D	10Years	35.45	14.64	0.00242		1.8			27.23		0.45	48.96
531.5748BR D	25Years	43.77	14.64	0.00267		2			32.75		0.48	65.51
531.5748BR D	50Years	49.99	14.64	0.00289		2.15			37.31		0.5	80.32
531.5748BR D	100Years	55.87	14.64	0.00309		2.29			41.56		0.52	95.05

River Sta	Profile	Q Tot (m3/s)	Top W (m)	E.G. Sl (m/m)	V Left (m/s)	V Chnl (m/s)	V Rght (m/s)	Shear L (N/m2)	Shear Ch (N/m2)	Shear R (N/m2)	Froude # Chl	Powr Chn (N/m s)
510.818*	2Years	18.12	16.25	0.00192		1.28			15.48		0.44	19.85
510.818*	5Years	28.72	16.92	0.00199		1.53			20.28		0.46	30.95
510.818*	10Years	35.45	17.26	0.00207		1.67			23.36		0.48	38.9
510.818*	25Years	43.77	18.02	0.00216		1.83			27.2		0.5	49.77
510.818*	50Years	49.99	18.61	0.00228		1.95			30.41		0.51	59.45
510.818*	100Years	55.87	19.59	0.00237		2.06			33.32		0.53	68.77
501.0021	2Years	18.12	11.78	0.0107		2.47			63.8		1	157.89
501.0021	5Years	28.72	14.9	0.01012	0.08	2.69		2.09	71.2		1	191.34
501.0021	10Years	35.45	16.59	0.00972	0.19	2.82		8	75.86		1	214.11
501.0021	25Years	43.77	20.81	0.00928	0.19	2.95		8.02	80.26		0.99	237.02
501.0021	50Years	49.99	24.92	0.00864	0.24	3.03	0.1	10.88	81.96	3.09	0.97	248.38
501.0021	100Years	55.87	29.76	0.00822	0.25	3.12	0.16	11.72	84.42	6.21	0.96	263.15
500.008*	2Years	18.12	14.34	0.00157		1.27			14.53		0.41	18.47
500.008*	5Years	28.72	15.37	0.00212		1.62			22.65		0.48	36.81
500.008*	10Years	35.45	16.23	0.00248	0.06	1.83		0.92	28.25		0.53	51.81
500.008*	25Years	43.77	17.5	0.00255	0.12	2		2.94	32.41		0.54	64.84
500.008*	50Years	49.99	24.02	0.00249	0.16	2.06	0.03	4.53	33.54	0.38	0.54	68.95
500.008*	100Years	55.87	32.37	0.00224	0.23	2.08	0.1	7.3	33.26	2.17	0.52	69.21
500		Bridge	pedestrian									
500 BR U	2Years	18.12	14.18	0.00158		1.28			14.66		0.41	18.72
500 BR U	5Years	28.72	14.71	0.00215		1.64			23.15		0.48	38.08
500 BR U	10Years	35.45	15.53	0.00262	0.05	1.87		0.8	29.43		0.53	55
500 BR U	25Years	43.77		0.00775	0.1	2.16		2.79	48.09		0.54	103.99
500 BR U	50Years	49.99	0.76	0.01011	0.11	2.47		3.5	62.72		0.6	154.9
500 BR U	100Years	55.87	3.62	0.01262	0.14	2.76		5.43	78.29		0.66	216.03
500 BR D	2Years	18.12	14.09	0.00137		1.22			13.23		0.38	16.16
500 BR D	5Years	28.72	15.23	0.00196	0.03	1.58		0.38	21.38		0.46	33.88
500 BR D	10Years	35.45	16.12	0.00235	0.08	1.81		1.65	27.21		0.5	49.12
500 BR D	25Years	43.77	1.55	0.00698	0.12	2.1		3.04	44.69		0.52	93.65
500 BR D	50Years	49.99	4.68	0.0091	0.13	2.39		4.65	58.23		0.58	139.29
500 BR D	100Years	55.87	6.61	0.01133	0.19	2.67		7.98	72.54		0.64	193.7
494.045*	2Years	18.12	14.34	0.00138		1.22			13.29		0.38	16.26
494.045*	5Years	28.72	15.8	0.00195	0.03	1.58		0.34	21.19		0.46	33.42
494.045*	10Years	35.45	16.69	0.00228	0.08	1.79		1.56	26.7		0.51	47.85
494.045*	25Years	43.77	18.81	0.00263	0.1	2.03		2.24	33.31		0.55	67.54
494.045*	50Years	49.99	22.2	0.00287	0.12	2.19		2.88	38.13		0.58	83.38
494.045*	100Years	55.87	24.87	0.00312	0.15	2.32		4.21	42.63		0.61	99.03
448.3297	2Years	18.12	27.78	0.00168	0.12	1.35		2.64	16.2		0.43	21.89
448.3297	5Years	28.72	36.48	0.00237	0.2	1.75		6.06	26.08		0.52	45.71
448.3297	10Years	35.45	39.08	0.00299	0.24	2.02		8.75	34.27		0.59	69.31
448.3297	25Years	43.77	42.05	0.0037	0.3	2.32		12.37	44.35		0.66	102.81
448.3297	50Years	49.99	44.21	0.00412	0.33	2.5		15.16	51.05		0.7	127.64
448.3297	100Years	55.87	45.87	0.0045	0.37	2.66		17.96	57.36		0.73	152.74
396.6188	2Years	18.12	35.47	0.00668	0.45	2.24		12.61	48.81		0.81	109.29
396.6188	5Years	28.72	46.48	0.00664	0.61	2.5		19.38	57.38		0.83	143.28
396.6188	10Years	35.45	50.9	0.006	0.67	2.52		22.19	56.61		0.8	142.44
396.6188	25Years	43.77	51.66	0.00641	0.79	2.7		28.37	63.88		0.84	172.35
396.6188	50Years	49.99	52.14	0.00678	0.86	2.84		33.1	69.86		0.87	198.17
396.6188	100Years	55.87	52.59	0.00704	0.93	2.95		37.33	74.77		0.89	220.54

GEO-ROX v.1.6 Rock Size Treatment Model

B. de Geus 01.11

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
100yr Event with FS=1.15 Scour Protection Treatment

Threshold Velocity

USDA Isbash Method

Notation:

V_i = Isbash velocity
W = average rock weight

	g (kg m^{-3})
dolomite	2900
granite	2800
limestone	2650
pure shale	2400
calcareous shale	2600
sandstone	2500

Input:

design storm frequency	100yr	
mean channel velocity (V_{mean})	3.34	m s^{-1}
Isbash adjustment factor (F_v)	1.15	
density of rock (g)	2650	kg m^{-3}

V_i
3.84 m s^{-1}

W required
214.6 kg

Equivalent average diameters:

D_{50} cube	43.3 cm	17.0 inches
D_{50} river stone	53.7 cm	21.1 inches
D_{50} angular	48.5 cm	19.1 inches

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	80.5	107.4
D_{85}	69.8	96.6
D_{50}	53.7	80.5
D_{30}	32.2	37.6
D_{15}	16.1	26.8
sub-pavement depth	107.4	161.0

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	72.7	96.9
D_{85}	63.0	87.3
D_{50}	48.5	72.7
D_{30}	29.1	33.9
D_{15}	14.5	24.2
sub-pavement depth	96.9	145.4

Threshold Shear Stress

Newbury-Fischenich Method

Input:

τ_{calc} (N m^{-2})	99.0
Shear pulse adjustment factor (F_s)	2.0
τ D_{crit} (gr-co) (cm)	19.404

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	19.4	38.8
D_{85}	16.8	34.9
D_{50}	12.9	19.4
D_{30}	7.8	13.6
D_{15}	3.9	9.7
sub-pavement depth	25.9	38.8

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	17.5	34.9
D_{85}	15.1	31.4
D_{50}	11.6	17.5
D_{30}	7.0	12.2
D_{15}	3.5	8.7
sub-pavement depth	23.3	34.9

Dimensionless Shear

Shields-Rosgen Method (C3-C4 channel type)

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	52.1	69.4
D_{85}	45.1	62.5
D_{50}	34.7	52.1
D_{30}	20.8	24.3
D_{15}	10.4	17.4
sub-pavement depth	69.4	104.2

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	47.0	62.7
D_{85}	40.8	56.4
D_{50}	31.4	47.0
D_{30}	18.8	21.9
D_{15}	9.4	15.7
sub-pavement depth	62.7	94.1

GEO-ROX v.1.6 Rock Size Treatment Model

AquaLogic

B. de Geus 01.11

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
25yr Event with FS=1.0 Scour Protection Treatment

Threshold Velocity
USDA Isbash Method

Notation:

V_i = Isbash velocity
W = average rock weight

	g (kg m^{-3})
dolomite	2900
granite	2800
limestone	2650
pure shale	2400
calcareous shale	2600
sandstone	2500

Input:

design storm frequency	25yr	
mean channel velocity (V_{mean})	3.09	m s^{-1}
Isbash adjustment factor (F_v)	1.0	
density of rock (g)	2650	kg m^{-3}

V_i	W required
3.09 m s^{-1}	58.2 kg

Equivalent average diameters:

D_{50} cube	28.0 cm	11.0 inches
D_{50} river stone	34.7 cm	13.7 inches
D_{50} angular	31.4 cm	12.4 inches

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	52.1	69.5
D_{85}	45.2	62.5
D_{50}	34.7	52.1
D_{30}	20.8	24.3
D_{15}	10.4	17.4
sub-pavement depth	69.5	104.2

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	47.1	62.7
D_{85}	40.8	56.5
D_{50}	31.4	47.1
D_{30}	18.8	22.0
D_{15}	9.4	15.7
sub-pavement depth	62.7	94.1

Threshold Shear Stress
Newbury-Fischenich Method

Input:

τ_{calc} (N m^{-2})	90.0
Shear pulse adjustment factor (F_s)	2.0
τ D_{crit} (gr-co) (cm)	17.64

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	17.6	35.3
D_{85}	15.3	31.8
D_{50}	11.8	17.6
D_{30}	7.1	12.3
D_{15}	3.5	8.8
sub-pavement depth	23.5	35.3

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	15.9	31.8
D_{85}	13.8	28.6
D_{50}	10.6	15.9
D_{30}	6.4	11.1
D_{15}	3.2	7.9
sub-pavement depth	21.2	31.8

Dimensionless Shear
Shields-Rosgen Method (C3-C4 channel type)

River stone gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	33.7	44.9
D_{85}	29.2	40.4
D_{50}	22.5	33.7
D_{30}	13.5	15.7
D_{15}	6.7	11.2
sub-pavement depth	44.9	67.4

Angular gradation and sub-pavement depth:

	low turbulence Q lower limit (cm)	high turbulence Q upper limit (cm)
D_{100}	30.4	40.6
D_{85}	26.4	36.5
D_{50}	20.3	30.4
D_{30}	12.2	14.2
D_{15}	6.1	10.1
sub-pavement depth	40.6	60.9

McCraney Creek Preliminary Channel Design
Lakeshore Road Crossing

Scour Treatment Summary

Standard Approach

Velocity from HECRAS

($m\ s^{-1}$)

3.34 (100yr)

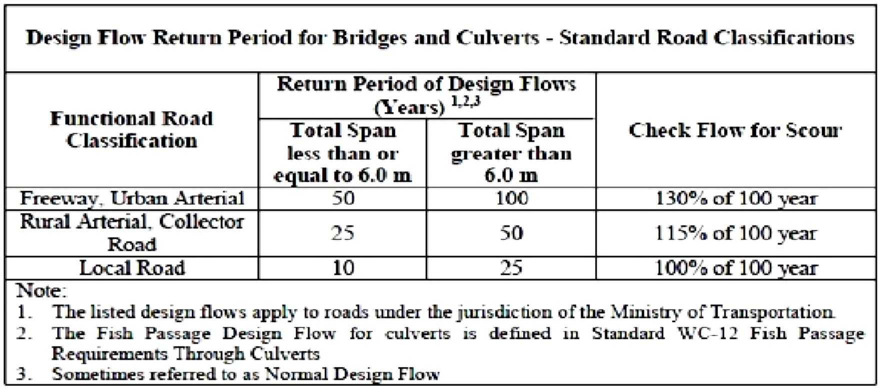
MTO multiplier = 1.15

(FS to satisy intent)

Final Design Velocity

($m\ s^{-1}$)

3.84 (100yr)



Design Flow Return Period for Bridges and Culverts - Standard Road Classifications

Functional Road Classification	Return Period of Design Flows (Years) [1,2,3]		Check Flow for Scour
	Total Span less than or equal to 6.0 m	Total Span greater than 6.0 m	
Freeway, Urban Arterial	50	100	130% of 100 year
Rural Arterial, Collector Road	25	50	115% of 100 year
Local Road	10	25	100% of 100 year

Note:

1. The listed design flows apply to roads under the jurisdiction of the Ministry of Transportation
2. The Fish Passage Design Flow for culverts is defined in Standard WC-12 Fish Passage Requirements Through Culverts
3. Sometimes referred to as Normal Design Flow

Alternate Approach

Velocity from HECRAS

($m\ s^{-1}$)

3.09 (25yr)

design multiplier = 1.0

(recommended)

Final Design Velocity

($m\ s^{-1}$)

3.09 (25yr)

	D_{15} (cm)	D_{30} (cm)	D_{50} (cm)	D_{84} (cm)	D_{100} (cm)	
Angular Stone	15.0	25.0	50.0	55.0	65.0	(i)
River Stone	20.0	30.0	55.0	65.0	70.0	

(i) - satisfied by OPSS 1004 R-50 rip-rap up to D_{30}

stone treatment layer thickness (cm)	overbank treatment layer thickness (ii) (cm)	bed treatment layer thickness (iii) (cm)
100	20	10

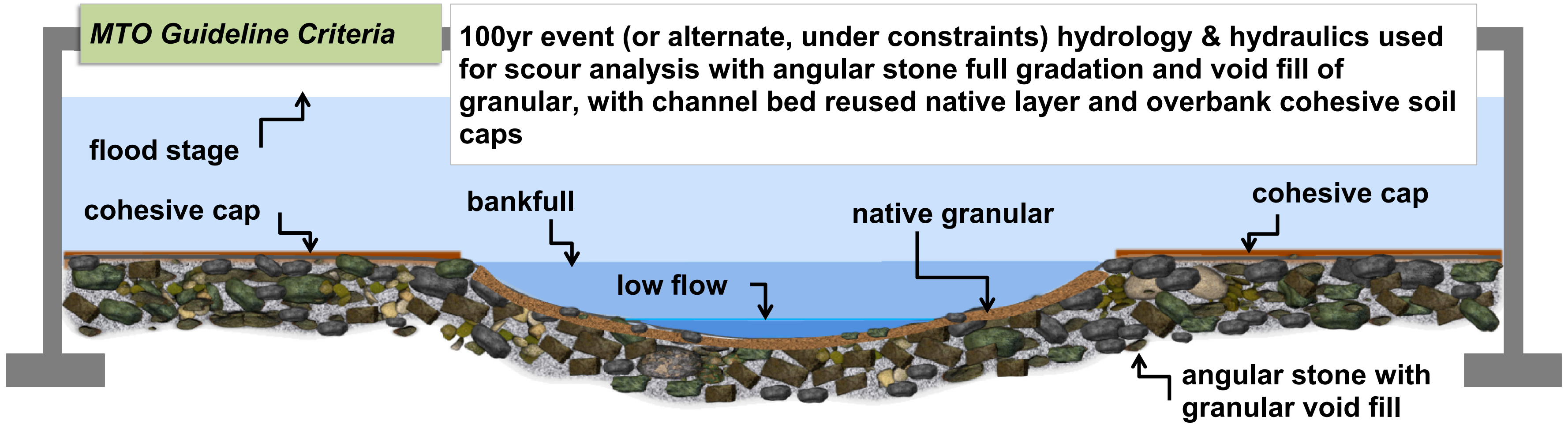
(ii) - satisfied by native excavation clay-silt with some granular material

(iii) - satisfied by native granular with some fines and some gravel-cobble

McCraney Creek Preliminary Channel Design
Lakeshore Road Crossing

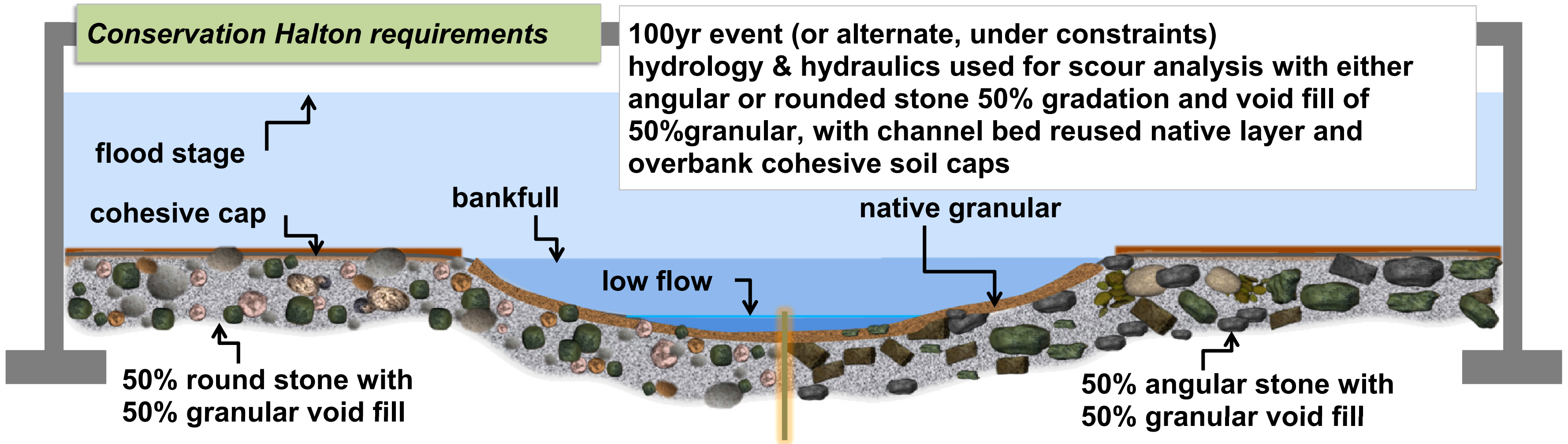
AquaLogic

Scour Treatment Options



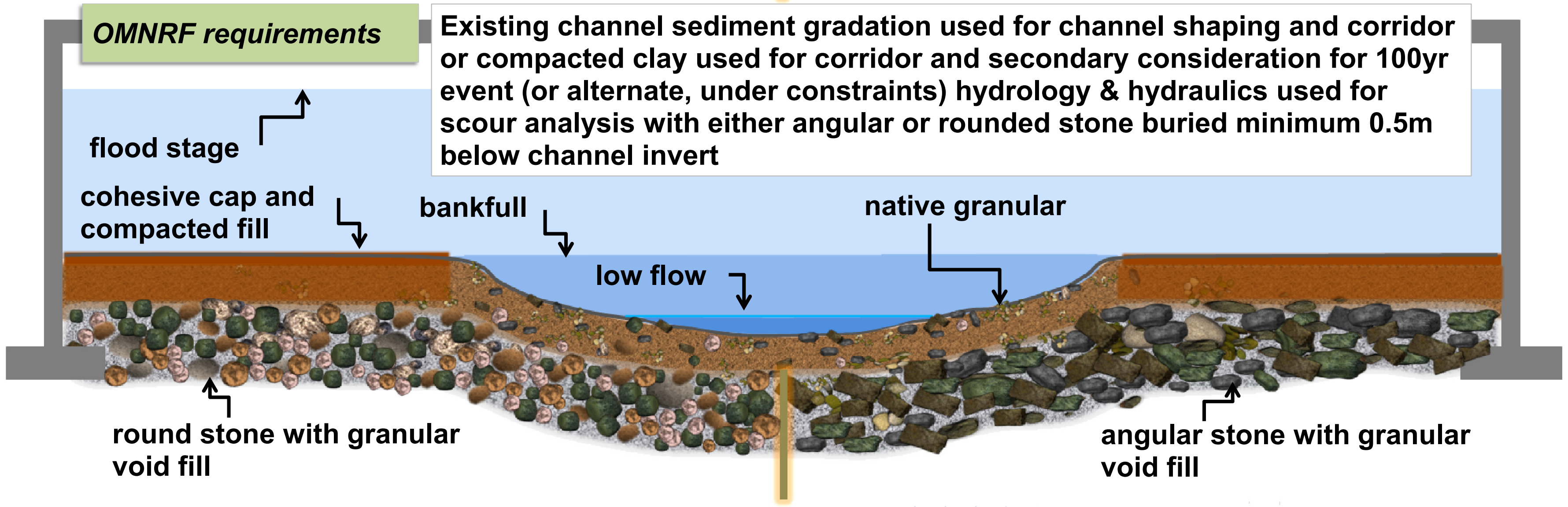
MTO Guideline Criteria

100yr event (or alternate, under constraints) hydrology & hydraulics used for scour analysis with angular stone full gradation and void fill of granular, with channel bed reused native layer and overbank cohesive soil caps



Conservation Halton requirements

100yr event (or alternate, under constraints) hydrology & hydraulics used for scour analysis with either angular or rounded stone 50% gradation and void fill of 50%granular, with channel bed reused native layer and overbank cohesive soil caps



OMNRF requirements

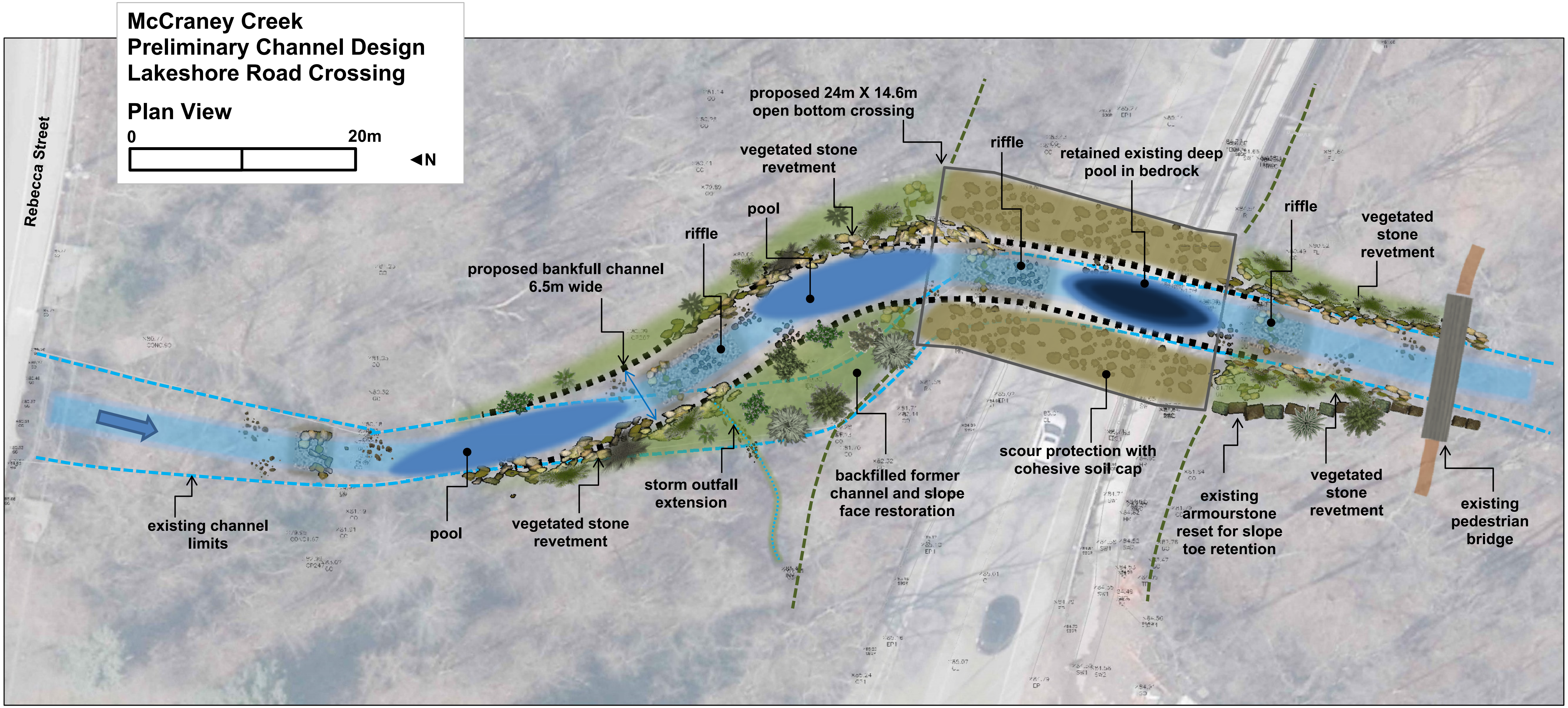
Existing channel sediment gradation used for channel shaping and corridor or compacted clay used for corridor and secondary consideration for 100yr event (or alternate, under constraints) hydrology & hydraulics used for scour analysis with either angular or rounded stone buried minimum 0.5m below channel invert

Risk and Value Summary

Scour Protection	*Channel Morphology*	*Fish Habitat*	*Terrestrial Corridor*
Low Risk High Value - designed specifically for long term structural integrity	Low Risk High Value - designed specifically for long term channel maintenance - stone effectively replaces biotechnical reinforcement with structural reinforcement	Medium Risk Medium Value - designed specifically for long term channel maintenance - not as heterogeneous as native conditions	Medium Risk Medium Value - designed specifically for long term corridor integrity - not as heterogeneous as native conditions, some stone will likely be exposed
Medium Risk Medium Value - compromise on long term structural integrity for sake of more heterogeneous conditions	Medium Risk Medium Value - compromise on long term channel maintenance for sake of more heterogeneous conditions - compromise on reinforcement	Medium Risk Medium Value - compromise on long term channel maintenance for sake of more heterogeneous conditions	Medium Risk Medium Value - compromise on long term corridor integrity for sake of more heterogeneous conditions
High Risk Low-Med Value - compromise on long term structural integrity for sake of more heterogeneous conditions - channel will erode deeply at infrequent events but footings likely protected	Medium Risk Medium Value - compromise on long term channel maintenance for sake of more heterogeneous conditions - lack of long term channel reinforcement means channel will erode deeply with unpredictable replacement by aggradation	Medium Risk Med-High Value - compromise on long term channel maintenance for sake of more heterogeneous conditions - short term conditions ultimately replaced by erosion with unpredictable replacement by aggradation but likely evolution to a large pool feature	High Risk Low-Med Value - compromise on long term corridor integrity for sake of more heterogeneous conditions - short term conditions ultimately replaced by erosion with potential corridor cut off by wall to wall low flow

McCraney Creek
Preliminary Channel Design
Lakeshore Road Crossing

Plan View



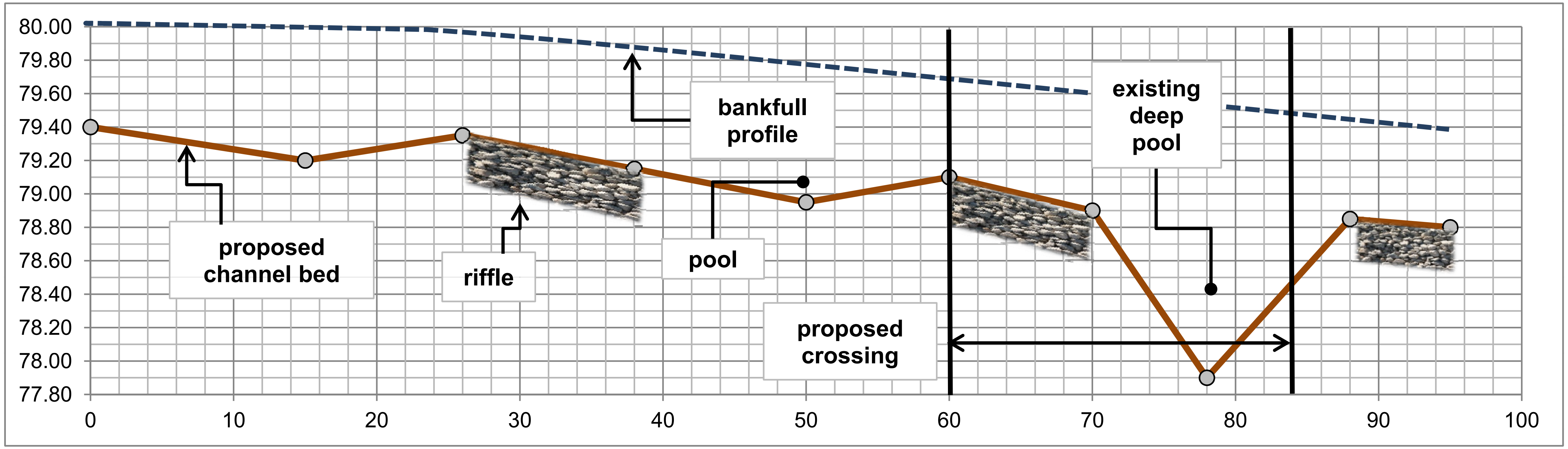
AquaLogic

McCraney Creek
Preliminary Channel Design
Lakeshore Road Crossing

AquaLogic

Channel Profile

elev. m	distance m	ID
79.40	0	bottom of riffle / upstream tie-in
79.20	15	max depth pool
79.35	26	top of riffle
79.15	38	bottom of riffle
78.95	50	max depth pool
79.10	60	top of riffle
78.90	70	bottom of riffle
77.90	78	max depth existing deep pool
78.85	88	top of riffle
78.80	95	bottom of riffle / downstream tie-in



FSH-PASS v.2.2 Fish Passage Channel Velocity Analysis Model

AquaLogic

B. de Geus 07.12

Project: **McCraney Creek Preliminary Channel Design**
Lakeshore Road Crossing
Proposed Bankfull

Velocity 1 proposed riffle
Velocity 2 proposed pool

Velocity Data

	1	2
water column velocity V (m s^{-1})	1.36	1.08
boundary velocity V_b (m s^{-1})	0.95	0.76

S_b D_s burst speed swimming distance (m)

	1	2
water column	90.2	105.6
boundary	112.6	123.4

Fish Length Data

		sustained speed high threshold	sustained speed minimum threshold	burst speed high threshold	burst speed minimum threshold
1	fish length L_f (cm) at V	34.0	19.4	11.3	3.9
	fish length L_f (cm) at V_b	23.8	13.6	7.9	2.7
2	fish length L_f (cm) at V	27.0	15.4	9.0	3.1
	fish length L_f (cm) at V_b	18.9	10.8	6.3	2.2