Appendix G
Fluvial Geomorphology

Fluvial Geomorphology and Preliminary Channel Crossing Design
Fifty Creek (WC 12) & Lake Ontario Tributaries WC 5.0, 6.0, 7.0, & 7.1
Phases 3 & 4 Barton Street and Fifty Road Improvements
Municipal Class Environmental Assessment
City of Hamilton

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Fifty Creek and Lake Ontario Tributaries WC 5.0, 6.0, 7.0 and 7.1 have been investigated based on fluvial geomorphic requirements for Fifty Road, Highway 8, and Barton Street crossings in the City of Hamilton. This study includes original reporting for Fifty Creek and WC 7.0 undertaken in 2018 and additional reporting for WC 5.0. 6.0. and 7.1 done in 2021. Scoping level characterization review including rapid assessments, summary of meander belt and erosion limits, recommendations for crossing geometry, and guidance recommendations for scour treatment and channel design have been undertaken. The study area crossing locations are shown on an appended figure.

Watershed and Watercourse Characterization

Fifty Creek

Fifty Creek is a 2nd order watercourse with an upstream topographic drainage area of 2.16km^2 to the study area. The site falls within the Iroquois Plain physiographic region. Upstream catchment land use consists of agricultural, rural and estate residential, urban residential, a large irrigation pond, and Niagara Escarpment forested slope face and plateau.

The watercourse crosses under both Fifty Road and Highway 8 in 3.6m wide open bottom culverts with 20m of intervening channel between structures. Reaches immediately upstream of Fifty Road and downstream of Highway 8 are vegetated by swamp thicket forest with the intervening sub-reach being more marsh type with swamp forest setback from the creek. A marsh pocket also exists below the Highway 8 face. Armourstone bank and wingwall treatments exist upstream, downstream, and offset from the creek between the crossings. The alignment of the channel through each crossing is slightly skewed from perpendicular to the road and the combined angle of both is moderately past perpendicular. The resulting macro planform from upstream to downstream is a large radius meander with easterly trend. The low flow channel is biased against the outside easterly wall under Highway 8. The low flow is highly blocked by deposition in the Fifty Road crossing, resulting in transient pathways and possibly interflow through the bar like formation observed at the time of field work.

Heterogeneous sediments are seen through the area up to cobble size with finer material dominant in the clay to sand range and a high fraction of organic material in the intervening sub-reach and downstream of Highway 8. Upstream of Fifty Road materials appear better sorted with exposed cobble. This cobble appears to be, however, the legacy or relatively recent channel realignment work (as discussed below in historic analysis). The Fifty Road crossing appears to be the start of a depositional zone that continues to the downstream face of Highway 8. Woody debris and other smaller diameter branch and leaf matter are common within the channel although this appears to be generally from external rather than in-situ erosion. The debris adds to flow calming backwater in association with relatively low channel gradient. Emergent wetland vegetation in the form of arrowhead is common except for upstream of Fifty Road. The channel shows characteristic pool and run bedforms below the wetland pocket at Highway 8 with run and riffle form upstream of Fifty Road.

Bankfull channel width is influenced by depositional areas but does not vary highly, being approximately 3.5m outside of deposition and up to 4.5m in deposition. Bankfull depth ranges between approximately 0.4-0.7m. Channel entrenchment is moderate both upstream of Fifty Road and downstream of the wetland pocket below Highway 8. The deposition immediately below Highway 8 results in the shallowest and widest conditions but this pocket wetland quickly narrows back into a well-defined channel within 15m of the crossing. This pool was part of former crossing work, as defined by the geometry of installed armourstone, and has since naturalized into a wetland pocket.

Lake Ontario Tributary WC 5.0

Lake Ontario Tributary WC 5.0 is a 1st order watercourse with an upstream topographic drainage area of approximately 1.67km^2. The site falls within the Iroquois Plain physiographic region. Upstream catchment land use consists of agricultural, urban and rural residential, and Niagara Escarpment forested slope face and plateau.

The watercourse crosses Barton in an elliptical CSP on the upstream side butted to a concrete box culvert on the downstream, which is the presumed original crossing with a cast date of 1934. The upstream channel is partially entrenched and was likely altered and straightened in the past. The upstream right bank is approximately 2.5m high and the upstream left is approximately 1-1.5m high with a gentler bank angle. A commercial banquet hall and a residential property are the respective adjacent land uses. The upstream riparian zone varies up to a few metres wide on each side and is characterized by a wide range of vegetation density from groundcover to shrub to mature forest. The downstream channel is highly entrenched within steep bank to slope transitions up to 3m deep. It appears possible that the height of the adjacent industrial lot on the downstream left is due to past filling. Overall shrub and tree density is lower on the downstream side and transitions quickly to formal lawn on the residential property. The bank up to the industrial lot has a small tree stand close to the road but changes in the upper bank area to just groundcover dominant, going downstream. The channel is at moderate gradient from upstream to downstream with some localized deposition within the crossing itself. The low flow is wide and shallow, in relative terms, but narrows and flows through gravel and cobble inside the crossing. Erosion scars are seen on both sides of the crossing but are most distinct on the higher entrenched banks of the downstream area. Exposed and possibly trimmed off tree roots are observed on the downstream left side close to the crossing.

Heterogeneous sediments are seen through the area up to small boulder size, with more distinct and higher percentage of clay-silt dominant exposed banks on the downstream. The exposed and entrenched downstream banks may be subject to additional weathering from rainfall impact, frost heave, and flow piping, because of a lack of full bank height vegetation cover. Large cobble to small armourstone treatment is seen on the downstream right bank toe with some large cobble also possibly being treatment on the upstream.

Bankfull channel width varies between approximately 2.5 to 3.5m. Bankfull depth averages at approximately 0.5m.

Lake Ontario Tributary 6.0

Lake Ontario Tributary WC 6.0 is a 1st order watercourse with an upstream topographic drainage area of approximately 1.72km^2. Upstream catchment land use consists of agricultural, rural residential, and Niagara Escarpment forested slope face and plateau.

The watercourse crosses Barton St. in a combination of two pipes consisting of concrete box and CSP faces on the upstream side and dual CSP faces on the downstream. The concrete box is therefore butted to a CSP under the road. This configuration is biased to the channel low flow on the upstream side with the second crossing slightly to the west and connected more directly and perpendicular to roadside ditching on the upstream side. Nonetheless, the channel profile and sediment deposition through the downstream side creates low flow backwater through both crossings. The upstream channel is partially entrenched and straightened between residential lots. The downstream channel appears likewise to have been historically straightened but is also moderately angled westerly from the crossing face. The upstream riparian zone is a mix of narrow shrub and tree thicket and formal lawn while the downstream riparian has wider naturalizing swamp forest riparian zones. Relatively recent tree cutting and clearing appears to have occurred in the over bank zone on the downstream left side of the watercourse. Gradient is moderate on the upstream side but appears to be lower on the downstream side with distinct sediment deposition in the form of lobate and point bars. The low flow on the downstream side meanders with modestly more sinuosity than the wider bankfull geometry, but is essentially straight coming into the upstream crossing face.

Heterogeneous sediments are seen through the area up to small boulder size with some sorting and riffle definition on the downstream side. Some of the small boulder material may be legacy bank treatment. Ad hoc rip-rap is also seen on the upstream side. The downstream channel appears to have a high percentage of sandier material possibly due to road treatment input.

Bankfull channel width varies between approximately 2.5 to 3.5m and is moderately entrenched. Bankfull depth averages at approximately 0.5m.

Lake Ontario Tributary WC 7.0

Lake Ontario Tributary WC 7.0 is a 1st order watercourse with an upstream topographic drainage area of approximately 1.59km^2. The site falls within the Iroquois Plain physiographic region. Upstream catchment land use consists of agricultural, rural residential, institutional, irrigation ponds, and Niagara Escarpment forested slope face and plateau.

The watercourse crosses Barton Street in a 2.1m wide elliptical CSP and a smaller structure consisting of a concrete box original crossing (cast dated 1934) butted to a later upstream CSP extension. The structures are skewed relative to road alignment. The upstream channel is relatively straight and has been altered in the past while the downstream reach appeared at the time of initial field review in 2018 to be naturalized with wide radius meanders moving downstream. The reach corridor upstream of Barton St. is vegetated with thicket forest and moderate groundcover density for a short distance before emerging into a dense tall grass meadow. The downstream reach in 2018 was vegetated with moderately dense groundcover and dense tall grass riparian zone, with transition to thicket forest downstream. At the time of initial inspection in early June 2018 the channel was completely dry and moderately to heavily encroached with vegetation. Observed again in May 2021, and standing water pockets were seen but no base flow was occurring. Both of the crossing structures were heavily in-filled with sandy sediment and pieces of woody debris in 2018 but currently appear to have been flushed out. Inspection in May 2021 confirms that natural channel realignment within an engineered cut valley corridor has occurred on the downstream side. Recent air photos appear to show that this channel work was done in 2019. The new alignment of the watercourse meets the existing crossing in a steep riverstone ramp with the crossing face invert cantilevered approximately 0.5m above the low flow. The entire ramp represents an approximate 1.2m drop over 20m, and this then transitions into a mixed riverstone and natural bank channel design at moderate to low gradient. Groundcover dominant revegetation occurs along the new alignment with some shrub and tree planting.

Heterogeneous sediments are seen through the area on the upstream up to cobble size with some sorting and riffle definition. The downstream channel, as noted, is a recently constructed alignment with large riverstone used as grade control and outside meander bank treatment along an alignment cut down into native material.

Bankfull channel width varies between approximately 2.5 to 3m on the upstream and appears to have been constructed at 3m wide in the downstream design. Bankfull depth averages at approximately 0.5m.

Lake Ontario Tributary WC 7.1

Lake Ontario Tributary WC 7.1 is a 1st order watercourse with an upstream topographic drainage area of approximately 1.0km^2. Upstream catchment land use consists of agricultural, rural residential, a large industrial property (E.D. Smith Foods), and Niagara Escarpment forested slope face and plateau.

The watercourse crosses Barton St. in a concrete box culvert (cast dated 1934). Immediately south of the upstream face a short length of CSP exists under a sidewalk. The upstream channel is relatively straight and has been altered in the past while the downstream reach appeared in 2018 to be naturalized with wide radius meanders and erosion scars moving downstream. The reach corridor upstream of Barton St. is vegetated with thicket forest and moderate groundcover density in narrow riparian zones with formal lawn to the west and farm field to the east. The downstream reach in 2018 was vegetated with moderately dense shrub to thicket swamp forest. Subsequent inspection in May 2021 confirmed that natural channel realignment has occurred, which appears to have been done in 2019 at the same time as WC 7.0, based on air photo corroboration. Similar to WC 7.0, a riverstone ramp transition exists from the downstream face to the lower gradient base of the newly constructed corridor. The concrete bed invert of the existing crossing is perched approximately 0.6m above the start of the ramp. The overall ramp grade change and length is also similar to WC 7.0.

Heterogeneous sediments are seen in the upstream channel up to cobble size. The downstream channel, as noted, is a recently constructed alignment with large riverstone used as grade control and outside meander bank treatment along an alignment cut down into native material.

Bankfull channel width varies between approximately 1.5 to 2.5m on the upstream side and appears to have been constructed at 2.5 m wide in the downstream design. Bankfull depth averages at approximately 0.5m.

Rapid Assessment Protocols

Three rapid assessment protocols were undertaken for the upstream and downstream sub-reaches of each crossing and for the intervening sub-reach of Fifty Creek between crossings. Assessments were done over approximately 30m zones coincidental with some sequencing of bedforms and within what typically is the flow expansion and contraction influence area relative to a crossing. Assessments in this study were influenced by past work on Fifty Creek that mixes characteristics of wetland pool and defined bankfull channel. 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 detailed results are appended and included with each are photographs of typical reach conditions. Scoring results are summarized in **Table 1**.

Table1: Rapid Assessment Summary Results

	RGA	RHA	RSAT	Combined
Fifty Creek u/s of Fifty Road	85.4	75.0	80.0	80.1
Fifty Creek d/s of Fifty Road	75.0	54.0	66.0	65.0
Fifty Creek d/s of Highway 8	78.2	73.5	78.0	76.6
WC 5.0 u/s of Barton Street	78.9	60.5	66.0	68.5
WC 5.0 d/s of Barton Street	63.2	44.0	48.0	51.7
WC 6.0 u/s of Barton Street	83.9	70.0	68.0	74.0
WC 6.0 d/s of Barton Street	86.4	66.0	68.0	73.5
WC 7.0 u/s of Barton Street	81.8	55.5	66.0	67.8
WC 7.0 d/s of Barton Street	87.9	61.0	58.0	69.0
WC 7.1 u/s of Barton Street	87.9	60.0	64.0	70.6
WC 7.1 d/s of Barton Street	87.9	62.5	62.0	70.8

The results for Fifty Creek show good to optimal channel stability and habitat conditions above Fifty Road and below Highway 8. The intervening sub-reach is highly aggradational (as are the crossing structures themselves) and this scores lower in terms of channel performance. The reach above Fifty Road is least influenced by aggradation and at the time of field work was observed to have very good habitat performance with large schools of minnows and young of the year fish present.

Tributary WC 5.0 scores on the upstream as just slightly transitional in terms of stability, or in other words very close to dynamically stable. Downstream is however considered as highly transitional and thus close to being continuously unstable. The highly entrenched conditions and lack of bank vegetation contribute to the low stability score on the downstream side. The poor riparian conditions also contribute to low habitat scoring.

Tributary WC 6.0 scores as ‘in regime’, or dynamically stable, on both sides of Barton. Relatively good riparian and in channel physical feature conditions also contribute to good habitat scoring, although no fish were observed at the time of field work.

Tributary WC 7.0 shows high stability based on RGA score but poor to fair habitat conditions based on the observed lack of base flow which precludes resident fish. The recent downstream realignment project has only had two growing seasons of post construction vegetation development. It is assumed that riparian conditions will increasingly improve over time.

Similar to WC 7.0, Tributary WC 7.1 also shows high stability based on RGA score but observed nominal base flow suggests that habitat performance may be slightly better. The recent downstream realignment project has only had two growing seasons of post construction vegetation development. It is assumed that riparian conditions will increasingly improve over time.

Historic Planform Analysis

Past watercourse alterations throughout the study area watersheds are highly apparent from air photo review. Straightening has been the dominant change done for agricultural drainage and more recently to facilitate some residential development. Some enclosure through low density residential has also occurred. Available historic air photos back to the 1950s do not provide clear characterization of pre alteration conditions. In turn, since all alterations predate the available photos there are no interim time steps of comparable pre alteration conditions.

Fifty Creek

Scoping level analysis was undertaken of the Fifty Creek meander amplitude and belt limits. Historic planform comparison figures are appended for reference. Channel realignment occurred in approximately 2006, as seen completed in 2007, on both sides of each road crossing therefore the current alignment has no long-term natural adjustment history. Photos for 2014 and 2019 are included with the 2014 supplying the best leaf free clarity for comparison to as constructed conditions. These is no apparent change between 2007 and 2014.

The new realignment created downstream of Highway 8 has a meander belt of approximately 20m wide, with amplitude as a slightly smaller compound width. The meander belt limits are larger than the existing opening widths, but as noted in rapid assessments and site characterization there is no evidence of significant erosion under current conditions. Aggressive planform adjustment is not occurring in the new alignment.

Lake Ontario Tributary WC 5.0

Historic planform comparison of the alignment of WC 5.0 is appended. The channel planform in 1960 shows past alteration and straightening to facilitate agricultural drainage. By 2002, significant localized land use changes have occurred. The most current alignment as of 2019 shows essentially no change compared to 1960. The planform comparison confirms current observations and rapid assessment results identifying the upstream feature as dynamically stable. There is no meso or macro scale development of a lateral or down corridor meander pattern translating from upstream into the crossing location. The relatively unstable downstream sub-reach is however highly entrenched, as already described. This section may have incised over time without lateral adjustment and this typically indicates that future risk may be a widening phase. Widening occurs because entrenched flows have no flood plain access to attenuate across, and the impact of a low frequency peak event results in bank failures laterally, especially where vegetation cover is lacking. This potential for future meander development may not explicitly move upstream into the crossing location. Given the density and type of abutting urban land uses, any future aggressive lateral adjustment would also likely result in localized erosion control treatment.

Lake Ontario Tributary WC 6.0

Historic planform comparison of the alignment of WC 6.0 is appended. The channel planform in 1960 shows past alteration and straightening to facilitate agricultural drainage. By 2002, significant localized land use changes have occurred. The most current alignment as of 2019 shows essentially no change compared to 1960. At present there is no meso or macro scale development of a lateral or down corridor meander amplitude pattern that would constrain new crossing design.

Lake Ontario Tributaries WC 7.0 and 7.1

Tributaries WC 7.0 and 7.1 planform comparison figures are appended. The 1960 planform on the south side of Barton Street shows alteration and straightening to facilitate agricultural drainage. The northerly downstream sides may have been altered at some point in the past, as well, but were allowed to naturalize until near current times. The 2002 photo shows well developed natural riparian corridors and localized land use changes beyond. The 2019 photo however shows the start of riparian zone clearing as an initial step to corridor regrading and natural channel realignment downstream in each feature. It is assumed that gradient changes have also occurred with the new construction. More current air photos are not available for measurement of planform variables, since 2019, however field work observations in 2021 confirm that each corridor is essentially triangular shaped in cross-section without provision of a relatively flat valley floor. Meander belt and meander amplitude footprints are fully confined as a result.

The planform comparison on the upstream side of Barton Street confirms current observations and rapid assessment results identifying the features as stable. Conditions in the upstream appear to have persisted where erosion thresholds are not significantly exceeded over the long-term flow regime. There is no meso or macro scale development of a lateral or down corridor meander amplitude pattern from the upstream into either crossing location of WC 7.0 and 7.1.

100yr Erosion Limits

Adverse planform adjustment is not seen to be occurring in the study area watercourses based on air photo analysis. The realignment of Fifty Creek does not show any expansive amplitude or down valley meander translation in the constructed pattern. The same applies to the downstream sides of WC 7.0 and 7.1, albeit realignment construction is very recent. Site characterization of each of the other tributaries confirms no evidence of significant erosion moving from upstream into the crossing locations, under current conditions. The results of historic planform comparisons therefore identify a lack of need to consider new crossing opening widths in terms of meso or macro scale planform patterning.

The shift in focus for determining appropriate erosion setbacks turns to 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 and if unavoidable 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 should be 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 future stable channel definition, given the installation of scour treatments. Five field measurements were made of bankfull channel width in proximity to each crossing. Appended is a summary of bankfull measurements for all watercourses, combined with the recommended setbacks based on Provincial Guidelines. The diverse channel bed sediment conditions ranging from fines with organics to cobble and small boulder sized stone would suggest the average criteria from the guideline range for cohesive and non-cohesive sediments. An average setback of 1.5m satisfies integrated consideration of sediment types and bankfull channels less than 5m wide. The recommended opening widths are summarized in **Table 2**.

Table 2: Recommended Crossing Opening Size Widths

	opening width (m)
Fifty Creek (both crossings)	6.5
Tributary WC 5.0	6.0
Tributary WC 6.0	6.1
Tributary WC 7.0	6.0
Tributary WC 7.1	5.5

It is recognized at this point in preliminary design analysis that the two crossings of Fifty Creek are not explicitly proposed for replacement. At some future point when the Fifty Creek crossings become structurally deficient, the recommended opening width should be considered in new design work. The four tributary crossings appear currently to require replacement based on a combination of hydraulic and structural deficiencies. The recommended opening widths should therefore be used as targets during detailed design.

Scour Treatment

Scour treatment finalization at detail design should be undertaken using proposed conditions indicators from HEC-RAS modeling. Recognizing that the Fifty Creek crossings are not currently proposed for replacement, analysis of risk could be done using existing modelling. The available model is however eight years old, and as noted in characterization review, the crossings are in a relatively depositional existing sub-reach, so perceived risk is low. If HEC-RAS is updated during detailed design, for any related grading changes close to the crossings, scour analysis could be done at that time.

Typically, the 100yr event design standard is used for scour analysis, subject to site specific conditions. A lower standard can be 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 typically shows that velocity supersedes shear stress with regard to stability of channel materials. As a result, the maximum 100yr event velocities through each proposed structure should typically be used as input for stone treatment sizing and a FS=1.15 should be applied.

Installation of stone treatment in proposed clear span or open bottom crossings should have overbanks in-filled with cohesive soil to a balance line 10cm 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 fauna along the created overbank terrace. Within the bankfull channel limits, re-used native creek bed substrate material should be added as void fill of the scour treatment. The void fill will thus define the constructed bankfull and low flow wetted perimeter geometry. Physical stream bed conditions for fish habitat and barrier free passage will be mimicked per the intent of MTO WC-12 guidelines (MTO 2008), MTO fish habitat mitigation (MTO 2020), and Conservation Authority requirements.

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 in the daylight area transitions on each end of each crossing.

Preliminary Channel Crossing Design

Design Rationale

The design rationale advocated for the upstream to downstream alignment within each 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 habitat and passage, and provision of terrestrial corridor linkage.

Flow Regime

Flow regime conditions for the proposed channel designs are based on field survey of existing channel forming or bankfull conditions. Field survey cross-sections were done at representative downstream locations of the existing crossings to determine a target bankfull flow. Survey of WC 6.0 was done however on the upstream side due to perceived private property issues on the downstream.

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. Calibrated 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 rates are summarized in **Table 3**.

Table 3: Channel Forming Flows

	Q ($m^3 s^{-1}$)
Fifty Creek	0.95
Tributary WC 5.0	0.77
Tributary WC 6.0	0.83
Tributary WC 7.0	0.69
Tributary WC 7.1	0.64

Erosion threshold indicators from existing cross-section models are not extreme, with velocity ranging approximately 0.7-0.85m s^{-1} and shear stress ranging from 10-20N m^{-2}. These indicators are under typical thresholds of 1.2m s^{-1} and 40N m^{-2} representing protection levels from average vegetation stem density and rooting depth. The indicators agree with observations of stability in most locations, as provided mainly by biotechnical reinforcement. The exception is WC 5.0 on the downstream side where vegetation is lacking. Shading within proposed crossings will preclude vegetative reinforcement therefore the geometry of constructed scour protection will define and reinforce the bankfull channel over the long term.

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 run and riffle features that mimic the existing channel types at bankfull or 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 run section models is preliminary and subject to detailed design adjustment 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 upstream and downstream of each new crossing face, it is recommended that low bank height vegetated stone revetments be used as flow contraction and expansion zone extensions, based on the same standards used for scour treatment. Existing vegetation shading around tie-in areas might impact some new vegetative growth, but using vegetation within stone treatment will protect rooting development from potential flow impact.

Within each 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 and ties in to existing.

Planform and Profile Design

Planform alignment is recommended as simple straight channel plotting given the identified lack of need to account for adjustments occurring external to the crossings. This also allows the crossings to contain the least possible total amount of scour protection.

Profile plotting and construction is recommended as a straight and continuous gradient between tie-in points with riffle installation done subsequently as built up from the bed. The depth of required scour protection is thus installed first with riffles and top void fill installed sequentially after bed and banks are defined. Plotting of detailed design profiles should be done to show how riffle crests will create low flow backwater through the upstream run and into the tailwater toe of the next riffle.

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 preliminary design riffle and run cross-section conditions were used to check the design at each crossing. Detailed results are appended. Water column riffle velocities range from 1.00-1.08m s^{-1} and run velocities range from 0.75-0.82m s^{-1}. Boundary velocities range from 0.70-0.76m s^{-1} for riffles and 0.53-0.57m s^{-1} for runs. The results show that fish as small as approximately 2.0-2.2cm long range can use burst speed to move up the channel boundary of riffles and fish as small as 1.5-1.6cm range can use burst speed to move up the channel boundary of runs. Burst speed distances are theoretically over 100m before velocity shelter is required. Based on the potential final design length of each crossing and the intervening shelter from bedform sequencing, there are no constraints foreseen to the size range of typical fish that will pass the designs 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

Fifty Creek and Lake Ontario Tributaries WC 5.0, 6.0, 7.0 and 7.1 have been investigated based on fluvial geomorphic requirements for Fifty Road, Highway 8, and Barton Street crossings in the City of Hamilton. Scoping level characterization review including rapid assessments, summary of meander belt and erosion limits, recommendations for crossing geometry, and guidance recommendations for design have been undertaken. Flow regime, cross-section, scour treatment, planform, profile, and fish passage characterization for each crossing have been completed. The results of this study are recommended for implementation and finalization during detailed design.

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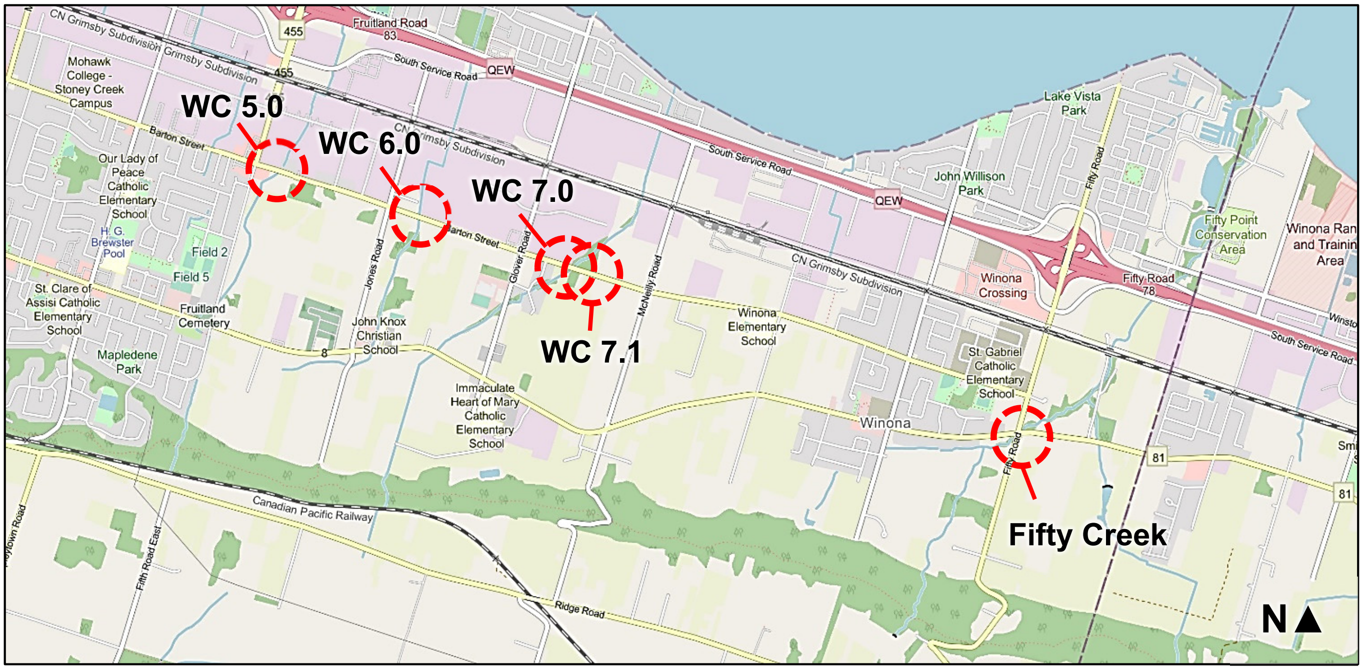
Study Area

Phases 3 & 4 Barton Street and Fifty Road Improvements
Municipal Class Environmental Assessment



GEO-RAP v.1.2 Rapid Assessment Protocol Model

AquaLogic

B. de Geus 03.12

Project: **Barton Street and Fifty Road Class EA**
Fifty Creek @ Fifty Road
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	1
	Accretion on point bars	
	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	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.00

13

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	
	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 =	0.30
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	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	0.15
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	85.4

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	10	20--16	15-11	10-6	5-0
Velocity / Depth Regime	14	20--16	15-11	10-6	5-0
Sediment Deposition	14	20--16	15-11	10-6	5-0
Channel Flow Status	12	20--16	15-11	10-6	5-0
Channel Alteration	12	20--16	15-11	10-6	5-0
Frequency of Riffles	13	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	10	10-8	7-6	5-3	2-0
u/s R	10	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	10	10-8	7-6	5-3	2-0
u/s R	10	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	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	5	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	7	7-6	5-4	3-2	1-0
Biological Indicators	7	8-7	6-5	4-3	2-0
/50	40				
/100	80.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

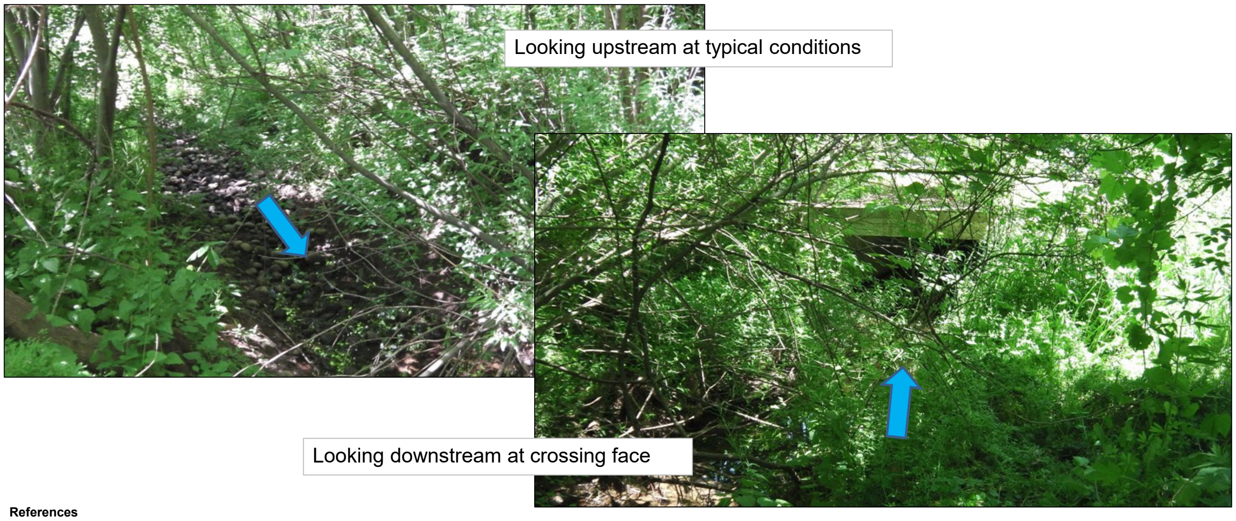
Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	80.1	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 at typical conditions

Looking downstream at crossing face

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

AquaLogic

B. de Geus 03.12

Project: **Barton Street and Fifty Road Class EA**
Fifty Creek @ Fifty Road
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation

Lobate bar	
Coarse material in riffles embedded	
Siltation in pools	1
Medial bars	
Accretion on point bars	1
Poor longitudinal sorting of bed materials	1
Deposition in the overbank zone	1
n/7 =	0.57

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	
Channel worn into undisturbed overburden/bedrock	
n/10 =	0.00

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	1
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 =	0.43

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	0.25
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	75.0

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	12	20--16	15-11	10-6	5-0
Embeddedness	5	20--16	15-11	10-6	5-0
Velocity / Depth Regime	14	20--16	15-11	10-6	5-0
Sediment Deposition	4	20--16	15-11	10-6	5-0
Channel Flow Status	9	20--16	15-11	10-6	5-0
Channel Alteration	17	20--16	15-11	10-6	5-0
Frequency of Riffles	0	20--16	15-11	10-6	5-0
Bank Stability u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	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	8	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	10	10-8	7-6	5-3	2-0
/200	108				
/100	54.0	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	8	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	4	8-7	6-5	4-3	2-0
Water Quality	5	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	33				
/100	66.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	65.0	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 Fifty Road to Hwy. 8

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: **Barton Street and Fifty Road Class EA**
Fifty Creek @ HWY 8
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	1
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.57
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	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.00

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	
	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 =	0.30
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	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.22**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**78.2**

2) Rapid Habitat Assessmemt (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	10	20--16	15-11	10-6	5-0
Velocity / Depth Regime	14	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	12	20--16	15-11	10-6	5-0
Channel Alteration	11	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	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	10	10-8	7-6	5-3	2-0
u/s R	10	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	10	10-8	7-6	5-3	2-0
u/s R	10	10-8	7-6	5-3	2-0
/200	147				
/100	**73.5**	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	8	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	5	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	7	7-6	5-4	3-2	1-0
Biological Indicators	7	8-7	6-5	4-3	2-0
/50	39				
/100	**78.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**76.6**	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 downstream from crossing


Looking upstream at crossing face


Looking downstream below wetland pool

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

AquaLogic

B. de Geus 03.12

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 5.0
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	
Lobate bar	
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	
n/7 =	0.14

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	1
Suspended armour layer visible in bank	
Channel worn into undisturbed overburden/bedrock	1
n/10 =	0.20

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	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 =	0.50

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	
n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	0.21
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	78.9

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	11	20--16	15-11	10-6	5-0
Velocity / Depth Regime	12	20--16	15-11	10-6	5-0
Sediment Deposition	11	20--16	15-11	10-6	5-0
Channel Flow Status	6	20--16	15-11	10-6	5-0
Channel Alteration	12	20--16	15-11	10-6	5-0
Frequency of Riffles	10	20--16	15-11	10-6	5-0
Bank Stability u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	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	121				
/100	60.5	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	8	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	6	7-6	5-4	3-2	1-0
Biological Indicators	3	8-7	6-5	4-3	2-0
/50	33				
/100	66.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	68.5	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 at crossing

Conditions upstream from crossing face

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: **Barton Street and Fifty Road Class EA**
Tributary WC 5.0
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.29
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	1
	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	
	Terrace cut through older bar material	1
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.40

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	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 =	0.50
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	1
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.29

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.37**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**63.2**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	10	20--16	15-11	10-6	5-0
Embeddedness	10	20--16	15-11	10-6	5-0
Velocity / Depth Regime	12	20--16	15-11	10-6	5-0
Sediment Deposition	10	20--16	15-11	10-6	5-0
Channel Flow Status	6	20--16	15-11	10-6	5-0
Channel Alteration	9	20--16	15-11	10-6	5-0
Frequency of Riffles	7	20--16	15-11	10-6	5-0
Bank Stability u/s L	6	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	3	10-8	7-6	5-3	2-0
u/s R	3	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	3	10-8	7-6	5-3	2-0
u/s R	3	10-8	7-6	5-3	2-0
/200	88				
/100	**44.0**	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	4	8-7	6-5	4-3	2-0
Water Quality	4	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	3	7-6	5-4	3-2	1-0
Biological Indicators	3	8-7	6-5	4-3	2-0
/50	24				
/100	**48.0**	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 =	**51.7**	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 at crossing face


Conditions downstream from crossing face

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: **Barton Street and Fifty Road Class EA**
Tributary WC 6.0
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	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)	
	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	1
	Terrace cut through older bar material	1
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.30

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	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	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	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.16**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**83.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	11	20--16	15-11	10-6	5-0
Velocity / Depth Regime	15	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	6	20--16	15-11	10-6	5-0
Channel Alteration	15	20--16	15-11	10-6	5-0
Frequency of Riffles	12	20--16	15-11	10-6	5-0
Bank Stability u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	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	140				
/100	**70.0**	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	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	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	6	7-6	5-4	3-2	1-0
Biological Indicators	4	8-7	6-5	4-3	2-0
/50	34				
/100	**68.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**74.0**	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 across upstream crossing faces

Looking downstream into main crossing

Conditions upstream from 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: **Barton Street and Fifty Road Class EA**
Tributary WC 6.0
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	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)	
	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	1
	Suspended armour layer visible in bank	
	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	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	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	
	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 Assessment (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	15	20--16	15-11	10-6	5-0
Sediment Deposition	11	20--16	15-11	10-6	5-0
Channel Flow Status	6	20--16	15-11	10-6	5-0
Channel Alteration	12	20--16	15-11	10-6	5-0
Frequency of Riffles	10	20--16	15-11	10-6	5-0
Bank Stability u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	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	7	10-8	7-6	5-3	2-0
/200	132				
/100	**66.0**	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	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	8-7	6-5	4-3	2-0
Physical Instream Habitat	5	8-7	6-5	4-3	2-0
Water Quality	5	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	4	8-7	6-5	4-3	2-0
/50	34				
/100	**68.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

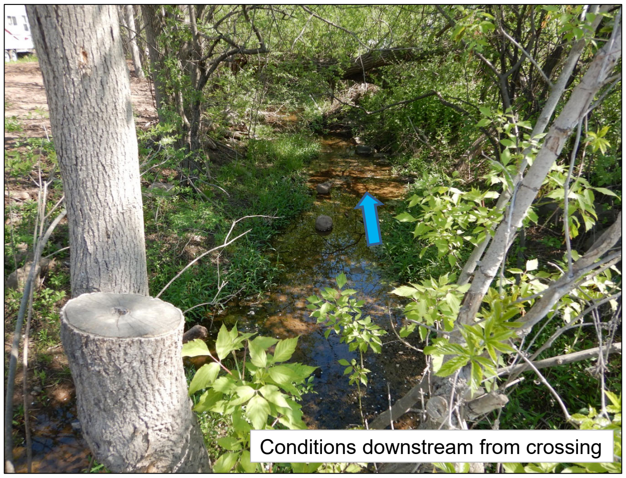
Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**73.5**	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 across downstream faces


Conditions downstream from 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: **Barton Street and Fifty Road Class EA**
Tributary WC 7.0
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation

Lobate bar	
Coarse material in riffles embedded	1
Siltation in pools	1
Medial bars	
Accretion on point bars	
Poor longitudinal sorting of bed materials	1
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	
Channel worn into undisturbed overburden/bedrock	
n/10 =	0.00

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	
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 =	0.30

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	
Bar forms poorly formed/reworked/removed	
n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.18**
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**81.8**

2) Rapid Habitat Assessment (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	0	20--16	15-11	10-6	5-0
Sediment Deposition	9	20--16	15-11	10-6	5-0
Channel Flow Status	0	20--16	15-11	10-6	5-0
Channel Alteration	10	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	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	10	10-8	7-6	5-3	2-0
u/s R	10	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	10	10-8	7-6	5-3	2-0
u/s R	10	10-8	7-6	5-3	2-0
/200	111				
/100	**55.5**	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	7	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	5	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	0	8-7	6-5	4-3	2-0
/50	33				
/100	**66.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

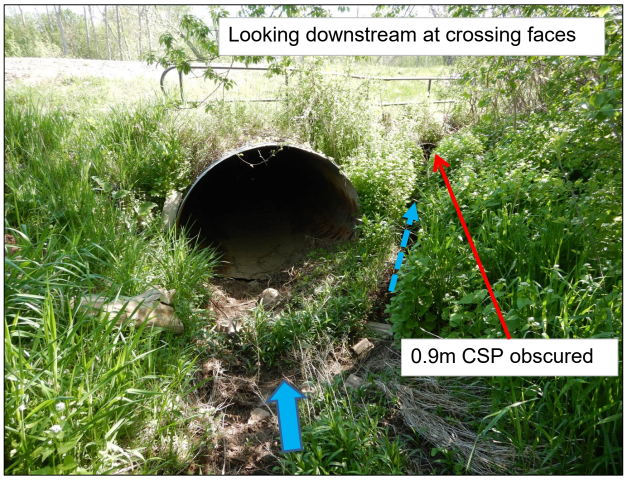
Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**67.8**	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


Looking downstream at crossing faces

0.9m CSP obscured

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: Barton Street and Fifty Road Class EA
Tributary WC 7.0
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.29
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	
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.20

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 =	0.12
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	87.9

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	13	20--16	15-11	10-6	5-0
Velocity / Depth Regime	0	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	0	20--16	15-11	10-6	5-0
Channel Alteration	17	20--16	15-11	10-6	5-0
Frequency of Riffles	15	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	9	10-8	7-6	5-3	2-0
u/s R	9	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	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	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	0	8-7	6-5	4-3	2-0
/50	29				
/100	58.0	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	69.0	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 at crossing faces


Corridor overview looking downstream

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

AquaLogic
B. de Geus 03.12

Project: Barton Street and Fifty Road Class EA
Tributary WC 7.1
Upstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation

Lobate bar	
Coarse material in riffles embedded	
Siltation in pools	1
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)	
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	
Channel worn into undisturbed overburden/bedrock	
n/10 =	0.00

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	
Exposed length of previously buried pipe/cable etc.	
Fracture lines along top of bank	
Exposed building foundation	
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	
n/7 =	0.14

STABILITY INDEX (SI) = (A + D + W + P) / 4 =	0.12
SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	87.9

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	13	20--16	15-11	10-6	5-0
Velocity / Depth Regime	3	20--16	15-11	10-6	5-0
Sediment Deposition	12	20--16	15-11	10-6	5-0
Channel Flow Status	3	20--16	15-11	10-6	5-0
Channel Alteration	11	20--16	15-11	10-6	5-0
Frequency of Riffles	11	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	8	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
/200	120				
/100	60.0	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	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	5	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	6	7-6	5-4	3-2	1-0
Biological Indicators	2	8-7	6-5	4-3	2-0
/50	32				
/100	64.0	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 =	70.6	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

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


Looking downstream at crossing face


Typical conditions looking upstream from 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

AquaLogic

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Project: **Barton Street and Fifty Road Class EA**
Tributary WC 7.1
Downstream of Crossing

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.29
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	
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.20

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 = **0.12**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**87.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	16	20--16	15-11	10-6	5-0
Embeddedness	13	20--16	15-11	10-6	5-0
Velocity / Depth Regime	3	20--16	15-11	10-6	5-0
Sediment Deposition	13	20--16	15-11	10-6	5-0
Channel Flow Status	3	20--16	15-11	10-6	5-0
Channel Alteration	14	20--16	15-11	10-6	5-0
Frequency of Riffles	15	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	9	10-8	7-6	5-3	2-0
u/s R	9	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

		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	5	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	31				
/100	**62.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**70.8**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

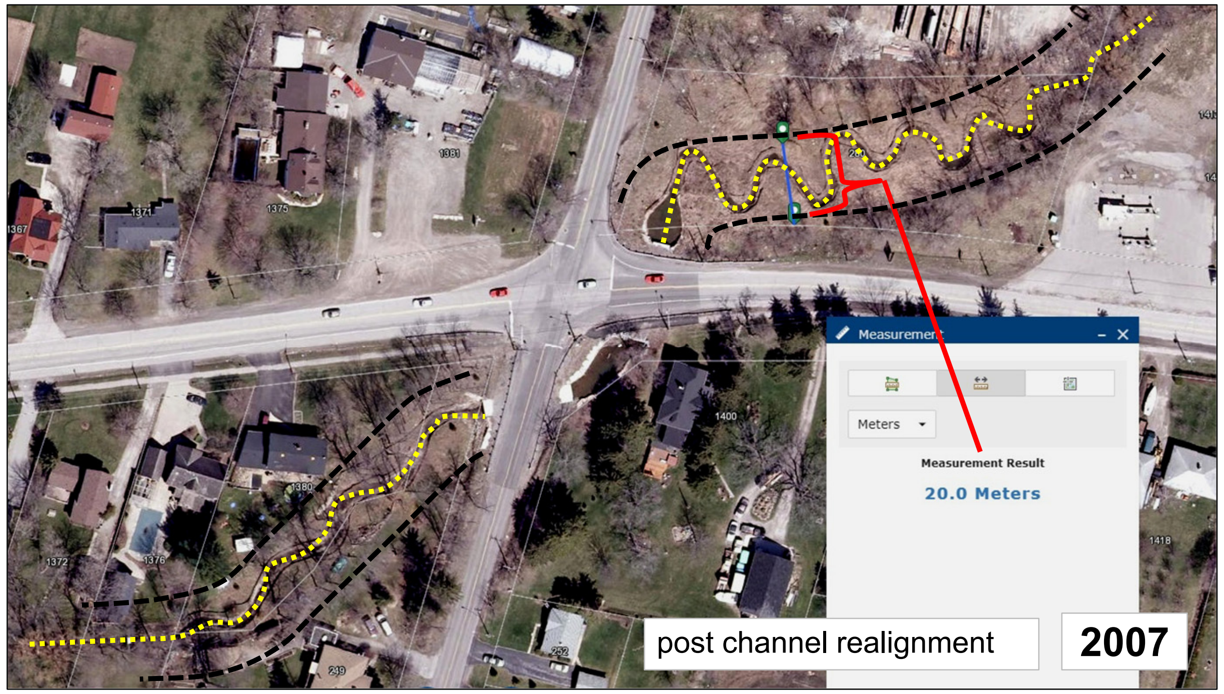
Glide Pool Channel Type

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


Looking upstream at crossing face

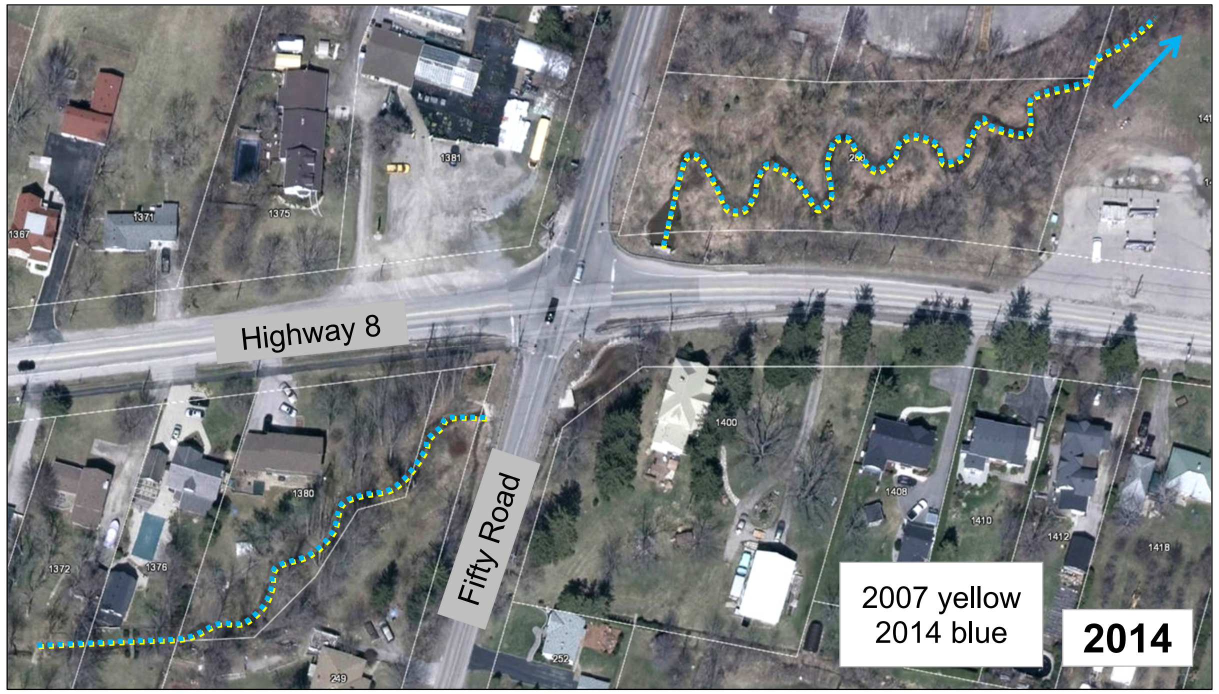

Corridor overview looking downstream

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.



Measurement Result

20.0 Meters



Fifty Creek Historic Planform Comparison

not to scale **N▲**

AquaLogic

air photos: City of Hamilton 2021, McMaster University 2021

WC 5.0
Historic Planform Comparison

not to scale **N▲**


1960

AquaLogic

air photos: City of Hamilton 2021, McMaster University 2021

2002

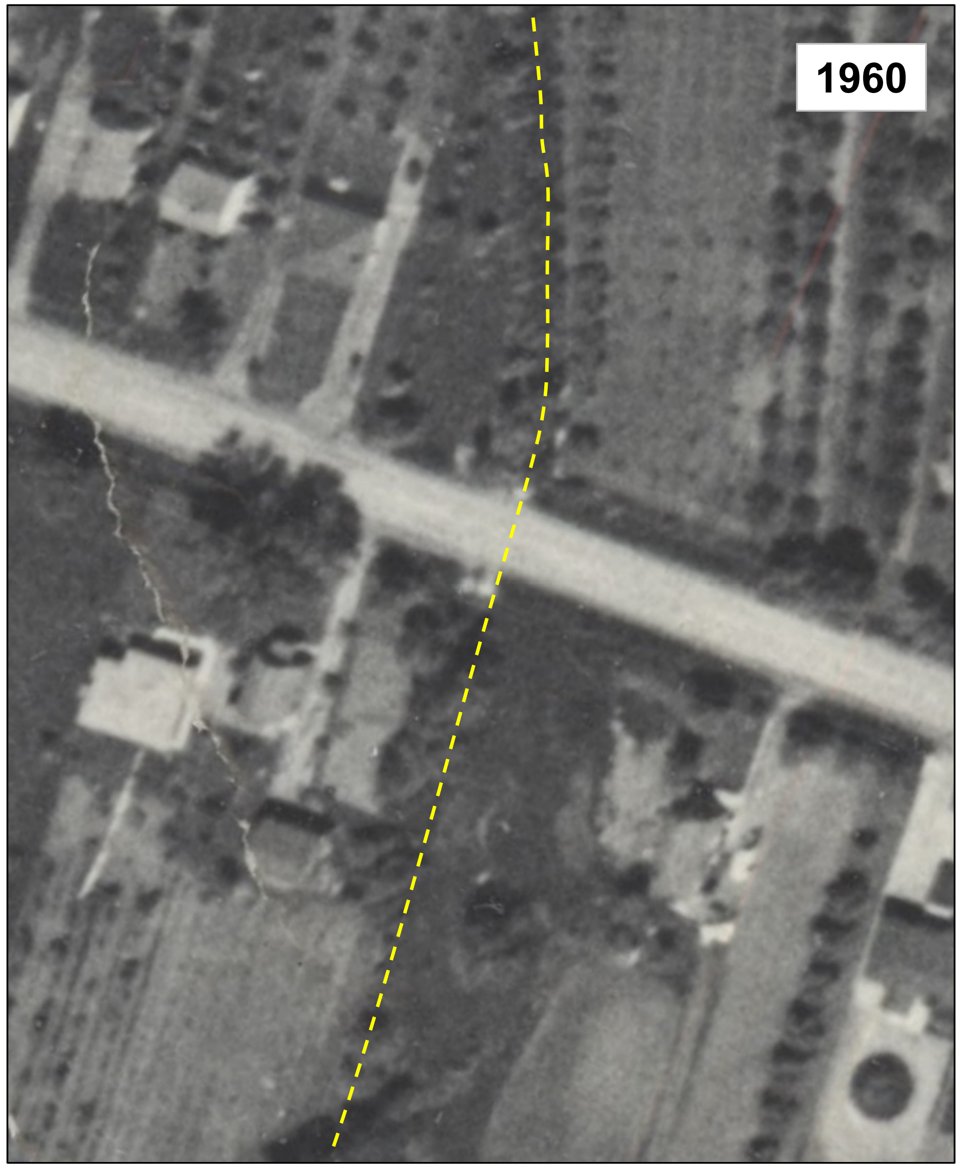
2019

WC 6.0
Historic Planform Comparison

AquaLogic

not to scale **N▲**

air photos: City of Hamilton 2021, McMaster University 2021

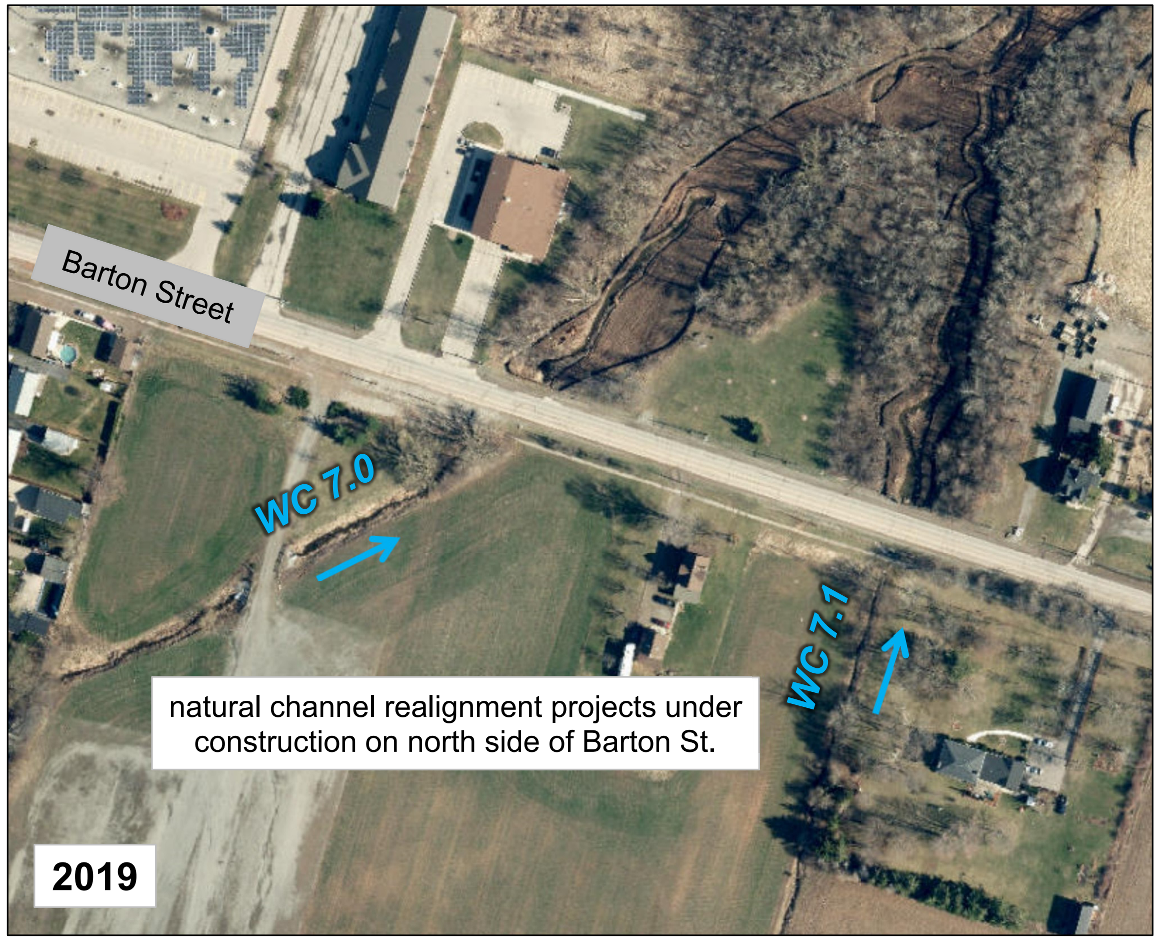


WC 7.0 & 7.1
Historic Planform Comparison

not to scale N▲

AquaLogic

air photos: City of Hamilton 2021, McMaster University 2021



natural channel realignment projects under construction on north side of Barton St.

Fifty Creek & Lake Ontario Tributaries WC 5.0. 6.0. 7.0 & 7.1

Crossing Width Opening Sizing

	bankfull width field measurements (m)
Fifty Creek	(4.0+3.7+3.1+3.2+3.0)/5=3.5
Lake Ontario Tributary WC 5.0	(2.9+2.9+3.1+3.0+2.9)/5=3.0
Lake Ontario Tributary WC 6.0	(3.3+3.2+3.1+2.9+3.2)/5=3.1
Lake Ontario Tributary WC 7.0	(3.1+2.7+2.6+3.0+3.0)/5=2.9, say 3.0 to agree with d/s design
Lake Ontario Tributary WC 7.1	(2.6+2.4+2.5+2.4+2.7)/5=2.5

	bankfull width (m)		erosion allowance (m)		recommended minimum opening width (m)	approx. existing opening width (m)
Fifty Creek	3.50	+	(2 x 1.5m)	=	**6.5**	3.6
Lake Ontario Tributary WC 5.0	3.00	+	(2 x 1.5m)	=	**6.0**	1.8
Lake Ontario Tributary WC 6.0	3.10	+	(2 x 1.5m)	=	**6.1**	1.4 + 1.4
Lake Ontario Tributary WC 7.0	3.00	+	(2 x 1.5m)	=	**6.0**	2.1 + 0.9
Lake Ontario Tributary WC 7.1	2.50	+	(2 x 1.5m)	=	**5.5**	0.9

	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

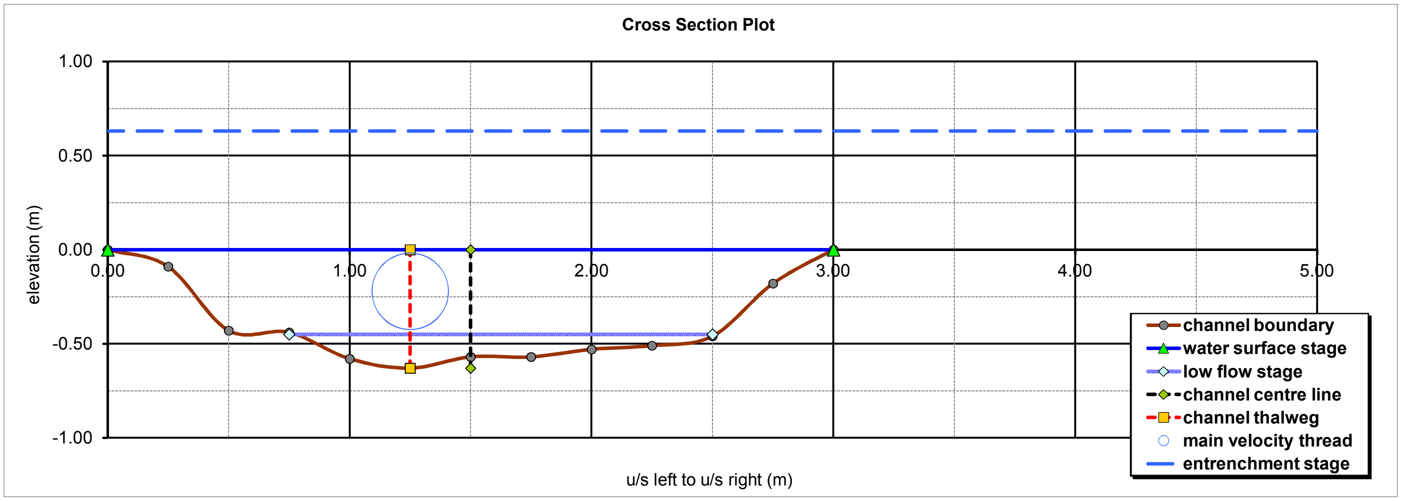
ii) Active Erosion is defined as: bank material is exposed directly to stream flow under normal or flood flow conditions where undercutting, over-steepening, slumping of a bank or down stream sediment loading is occurring. An area may have erosion but there may not be evidence of 'active erosion' either 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

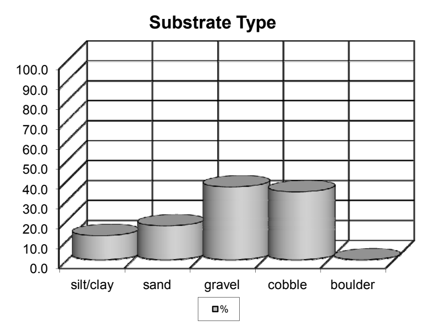
iii) Competent Flow Velocity is the flow velocity that the bed material in the stream can support without resulting in erosion or scour (OMNR 2002)

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

B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Fifty Creek
Bankfull Geometry d/s of Highway 8 - Section 1





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

Hydraulic Geometry	
A (m^2)	1.25
R (m)	0.36
TW (m)	3.00
WP (m)	3.43
max d (m)	0.63
mean d (m)	0.42
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R*/D_{84}	2.91
ff V mean/V*	5.71
ff D_{84}	5.81
ff mean	5.76
ROUGH BED	

Hydraulic Ratios	
ER max d	5.00
r_c / TW	
TW / Lf_w	1.71
TW/max d	4.8
TW/mean d	7.2

Sediment Transport Mode						high	low	
			w_s ($m\ s^{-1}$)	P	wash load	sus. load	sus. load	bedload
k	0.41	D_{30}	0.196	7.56	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.063	D_{50}	0.655	25.26	NO	NO	NO	NO
		D_{84}	1.641	63.25	NO	NO	NO	NO

Section Data					
ER_e (m)	0.63	ER stations L / R	-5.00	10.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.450	Lf stations L / R	0.75	2.50	
W_{fp} (m)	15.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.63	1.25	
E_g ($m\ m^{-1}$)	0.0055				

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_*	10.1	1.0	0.2
B3	0.0019	0.0019	saltation	YES	NO	NO
C3	0.0003	0.0003	rolling	YES	YES	NO
C4	0.0063	0.0067	Ø	NO	NO	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.10	2.00	20.00	125.00	140.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)			19.40	121.25	135.80
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)	0.940	Q (cms)	
V ($m\ s^{-1}$)	0.75	V ($m\ s^{-1}$)	
n	0.050	n	
Fr	0.37	*Fr*	
D_c rectangular (m)	0.22	D_c rectangular (m)	
D_c trapezoidal (m)	0.31	D_c trapezoidal (m)	
D_c triangular (m)	0.46	D_c triangular (m)	
D_c parabolic (m)	0.26	D_c parabolic (m)	
D_c mean (m)	0.31	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω ($watts\ m^{-1}$)	50.66	Ω ($watts\ m^{-1}$)	
ω_a ($watts\ m^{-2}$)	14.77	ω_a ($watts\ m^{-2}$)	
ω_a/TW ($watts\ m^{-1}$)	4.92	ω_a/TW ($watts\ m^{-1}$)	
*Re**	39.7	*Re**	
Re	240433	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds			
τ_{calc} ($kg\ m^{-2}$)	2.00		
τ_{calc} ($N\ m^{-2}$)	19.61	V_c / V_b	
τ D_{crit} (gr-co) (mm)	20.22	Strickler	Limerinos
D_{50} V_c (vcs +) ($m\ s^{-1}$)	0.69	1.31	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.73	3.29	

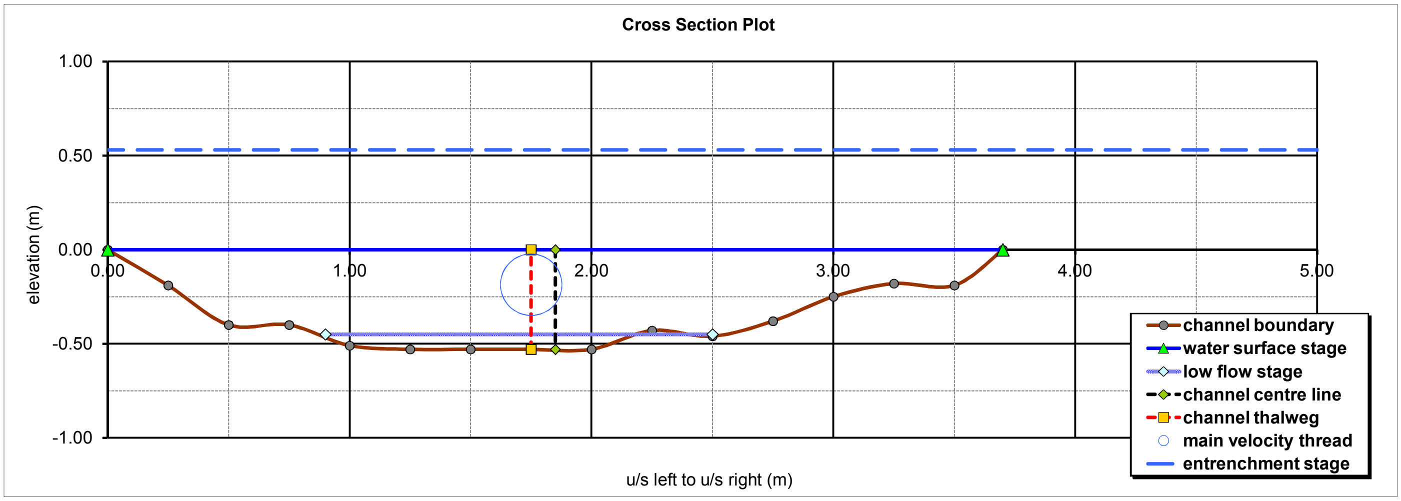
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
12.2	17.1	36.6	34.1	0.0

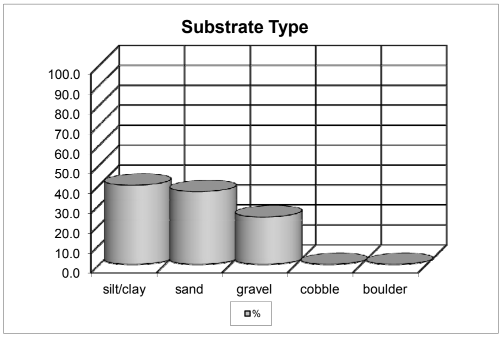
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

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

B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Fifty Creek
Bankfull Geometry d/s of Highway 8 - Section 2





Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	1.37
R (m)	0.34
TW (m)	3.70
WP (m)	4.02
max d (m)	0.53
mean d (m)	0.37
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	56.98
ff V mean/V*	9.20
ff D_{84}	13.04
ff mean	11.12

SMOOTH BED

Hydraulic Ratios

ER max d	4.05
r_c / TW	
TW / Lf_w	2.31
TW/max d	7.0
TW/mean d	10.0

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.003	0.12	YES	YES	YES	YES
V_* ($m\ s^{-1}$)	0.058	D_{50}	0.023	0.97	NO	YES	YES	YES
		D_{84}	0.356	14.83	NO	NO	NO	NO

Section Data

ER_e (m)	0.53	ER stations L / R	-5.00	10.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.70	3.70
Lf_e (m)	-0.450	Lf stations L / R	0.90	2.50	
W_{fp} (m)	15.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		*T* $_e$ (m) *T* $_{o/s}$ (m)	-0.53	1.75	
E_g ($m\ m^{-1}$)	0.0050				

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_*	287.8	86.3	2.9
B3	0.0019	0.0024	saltation	YES	YES	YES
C3	0.0003	0.0016	rolling	YES	YES	YES
C4	0.0063	0.0097	Ø	NO	NO	NO

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.03	0.06	0.20	6.00	30.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)				5.82	29.10
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime Strickler method

Q (cms)	0.946
V ($m\ s^{-1}$)	0.69
n	0.050
Fr	0.36
D_c rectangular (m)	0.19
D_c trapezoidal (m)	0.31
D_c triangular (m)	0.46
D_c parabolic (m)	0.27
D_c mean (m)	0.31
flow type	SUBCRITICAL
Ω (watts m^{-1})	46.34
ω_a (watts m^{-2})	11.54
ω_a/TW (watts m^{-1})	3.12
Re *	0.4
Re	206612
turbulence	LOW

Flow Regime Limerinos method

Q (cms)	
V ($m\ s^{-1}$)	
n	
Fr	
D_c rectangular (m)	
D_c trapezoidal (m)	
D_c triangular (m)	
D_c parabolic (m)	
D_c mean (m)	
flow type	
Ω (watts m^{-1})	
ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	
Re *	
Re	
turbulence	

Erosion Thresholds

		V_c / V_b Strickler	V_c / V_b Limerinos
τ_{calc} ($kg\ m^{-2}$)	1.71		
τ_{calc} ($N\ m^{-2}$)	16.75		
τ D_{crit} (gr-co) (mm)	17.27		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	0.07	0.14	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	0.38	0.79	

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 (%)		

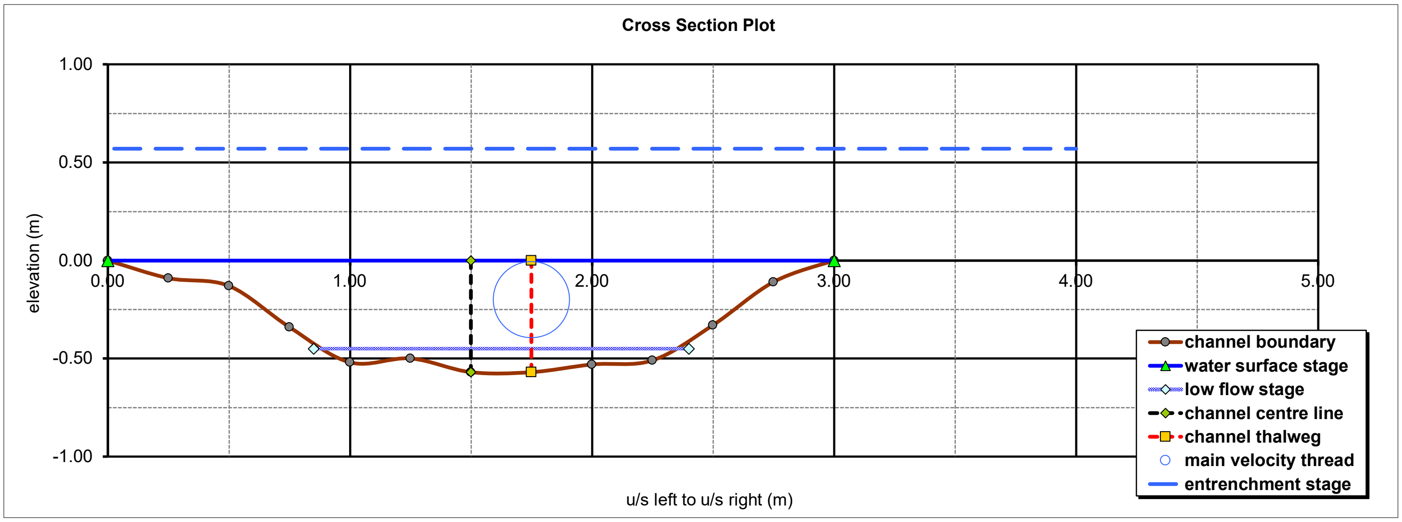
Substrate Type (%)

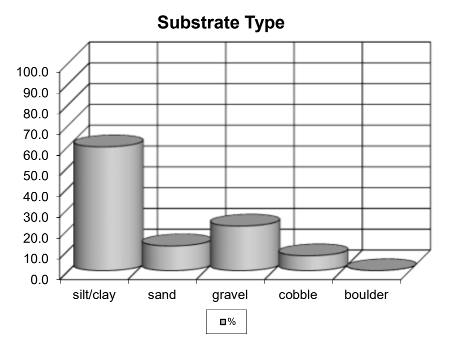
silt/clay	sand	gravel	cobble	boulder
39.7	36.5	23.8	0.0	0.0

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

Project: Barton Street and Fifty Road Class EA
Tributary WC 5.0
Bankfull Geometry

B. de Geus 05.11





Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	1.05
R (m)	0.32
TW (m)	3.00
WP (m)	3.33
max d (m)	0.57
mean d (m)	0.35
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R*/D_{84}	12.60
ff V mean/V*	8.49
ff D_{84}	9.36
ff mean	8.93
SMOOTH BED	

Hydraulic Ratios

ER max d	1.67
r_c / TW	
TW / Lf_w	1.94
TW/max d	5.3
TW/mean d	8.6

Sediment Transport Mode

			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.001	0.08	YES	YES	YES	YES
V_* (m s^{-1})	0.044	D_{50}	0.003	0.16	YES	YES	YES	YES
		D_{84}	0.733	40.44	NO	NO	NO	NO

Section Data

					TW ck
ER_e (m)	0.57	ER stations L / R	-1.00	4.00	
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.450	Lf stations L / R	0.85	2.40	
W_{fp} (m)	5.00	E_s sta. (Limerinos) L / R			
r_c (m)		E_s sta. (Strickler) L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.57	1.75	
E_g (m m^{-1})	0.0031				

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_*	246.7	164.5	0.4
B3	0.0018	0.0019	saltation	YES	YES	NO
C3	0.0002	0.0003	rolling	YES	YES	NO
C4	0.0057	0.0064	Ø	NO	NO	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.03	0.04	0.06	25.00	200.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})				24.25	194.00
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.771	Q (cms)	
V (m s^{-1})	0.73	V (m s^{-1})	
n	0.035	n	
Fr	0.40	*Fr*	
D_c rectangular (m)	0.19	D_c rectangular (m)	
D_c trapezoidal (m)	0.29	D_c trapezoidal (m)	
D_c triangular (m)	0.42	D_c triangular (m)	
D_c parabolic (m)	0.24	D_c parabolic (m)	
D_c mean (m)	0.29	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	23.41	Ω (watts m^{-1})	
ω_a (watts m^{-2})	7.03	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	2.34	ω_a/TW (watts m^{-1})	
*Re**	0.1	*Re**	
Re	202847	*Re*	
turbulence	LOW	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} (kg m^{-2})	0.98		
τ_{calc} (N m^{-2})	9.57		
τ D_{crit} (gr-co) (mm)	9.87		
D_{50} V_c (vcs +) (m s^{-1})	0.04		
D_{84} V_c (vcs +) (m s^{-1})	0.78	1.51	

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 (%)		

Substrate Type (%)

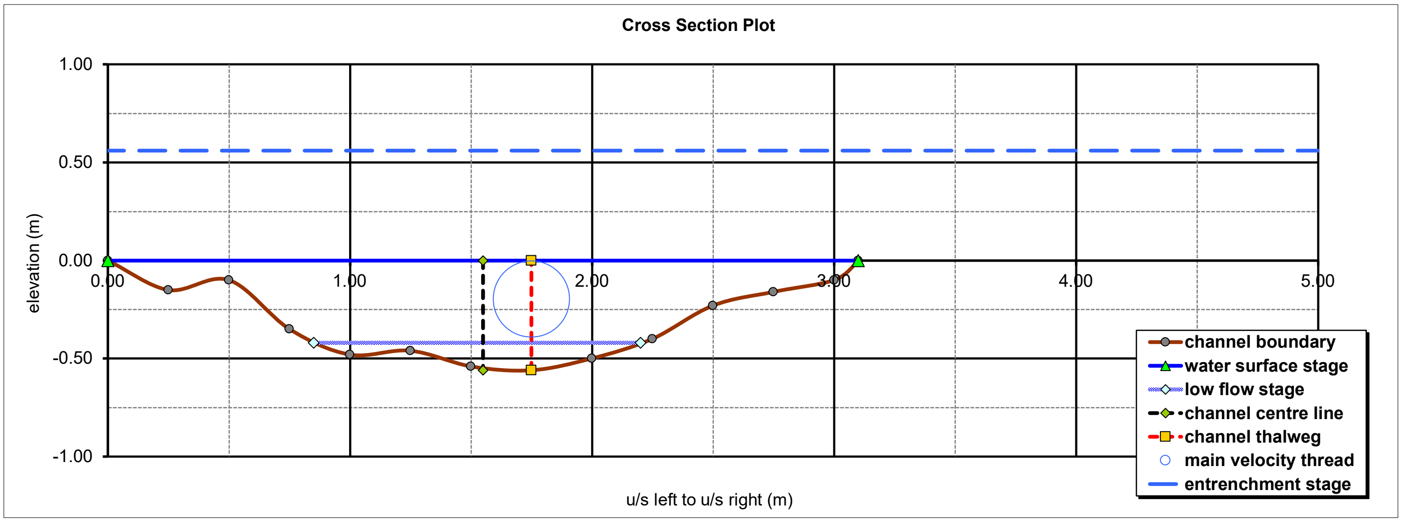
silt/clay	sand	gravel	cobble	boulder
59.5	11.9	21.4	7.1	0.0

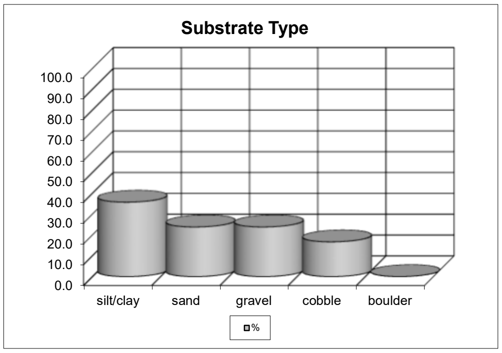
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 6.0
Bankfull Geometry

AquaLogic

B. de Geus 05.11





Morphology Type

cascade	
step	
riffle	●
run	
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	1.00
R (m)	0.29
TW (m)	3.10
WP (m)	3.43
max d (m)	0.56
mean d (m)	0.32
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr R/D_{84}	5.83
ff V mean/V*	7.05
ff D_{84}	7.45
ff mean	7.25
ROUGH BED	

Hydraulic Ratios

ER max d	3.55
r_c / TW	
TW / Lf_w	2.30
TW/max d	5.5
TW/mean d	9.6

Sediment Transport Mode

			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.003	0.12	YES	YES	YES	YES
V_* (m s^{-1})	0.058	D_{50}	0.071	2.98	NO	NO	NO	YES
		D_{84}	1.038	43.52	NO	NO	NO	NO

Section Data

ER_e (m)	0.56	ER stations L / R	-5.00	6.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.10	3.10
Lf_e (m)	-0.420	Lf stations L / R	0.85	2.20	
W_{fp} (m)	11.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.56	1.75	
E_g (m m^{-1})	0.0058				

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_*	284.5	34.1	0.3
B3	0.0018	0.0019	saltation	YES	YES	NO
C3	0.0002	0.0003	rolling	YES	YES	NO
C4	0.0060	0.0064	Ø	NO	NO	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.03	0.06	0.50	50.00	250.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})				48.50	242.50
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.833	Q (cms)	
V (m s^{-1})	0.83	V (m s^{-1})	
n	0.040	n	
Fr	0.47	*Fr*	
D_c rectangular (m)	0.20	D_c rectangular (m)	
D_c trapezoidal (m)	0.30	D_c trapezoidal (m)	
D_c triangular (m)	0.44	D_c triangular (m)	
D_c parabolic (m)	0.26	D_c parabolic (m)	
D_c mean (m)	0.30	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	47.36	Ω (watts m^{-1})	
ω_a (watts m^{-2})	13.80	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	4.45	ω_a/TW (watts m^{-1})	
*Re**	0.8	*Re**	
Re	212927	*Re*	
turbulence	LOW	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} (kg m^{-2})	1.69		
τ_{calc} (N m^{-2})	16.56		
τ D_{crit} (gr-co) (mm)	17.07		
D_{50} V_c (vcs +) (m s^{-1})	0.11		
D_{84} V_c (vcs +) (m s^{-1})	1.10	1.88	

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 (%)		

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
35.7	23.8	23.8	16.7	0.0

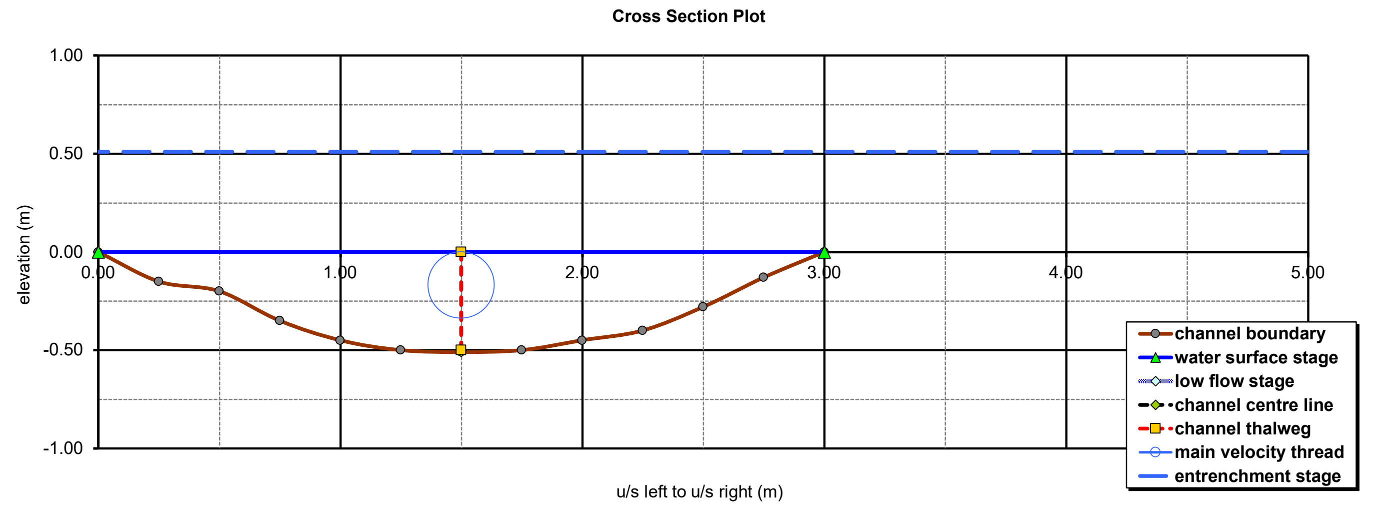
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

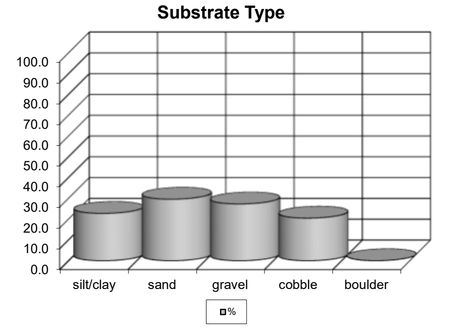
B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 7.0
Bankfull Geometry

Cross Section Plot



Substrate Type



Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.98
R (m)	0.30
TW (m)	3.00
WP (m)	3.22
max d (m)	0.51
mean d (m)	0.33
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R*/D_{84}	4.05
ff V mean/V*	6.26
ff D_{84}	6.47
ff mean	6.37
ROUGH BED	

Hydraulic Ratios

ER max d	3.67
r_c / TW	
TW / Lf_w	
TW/max d	5.9
TW/mean d	9.2

Sediment Transport Mode

			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.023	1.03	NO	YES	YES	YES
V_* (m s^{-1})	0.055	D_{50}	0.196	8.68	NO	NO	NO	NO
		D_{84}	1.271	56.20	NO	NO	NO	NO

Section Data

					TW ck
ER_e (m)	0.51	ER stations L / R	-4.00	7.00	
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.500	Lf stations L / R	1.50	1.50	
W_{fp} (m)	11.00	E_s sta. (Limerinos) L / R			
r_c (m)		E_s sta. (Strickler) L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.50	1.50	
E_g (m m^{-1})	0.0050				

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_*	76.8	7.7	0.2
B3	0.0017	0.0018	saltation	YES	YES	NO
C3	0.0001	0.0002	rolling	YES	YES	NO
C4	0.0055	0.0059	Ø	NO	NO	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.05	0.20	2.00	75.00	200.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})				72.75	194.00
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.694	Q (cms)	
V (m s^{-1})	0.71	V (m s^{-1})	
n	0.045	n	
Fr	0.40	*Fr*	
D_c rectangular (m)	0.18	D_c rectangular (m)	
D_c trapezoidal (m)	0.27	D_c trapezoidal (m)	
D_c triangular (m)	0.40	D_c triangular (m)	
D_c parabolic (m)	0.24	D_c parabolic (m)	
D_c mean (m)	0.27	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	33.98	Ω (watts m^{-1})	
ω_a (watts m^{-2})	10.54	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	3.51	ω_a/TW (watts m^{-1})	
*Re**	3.6	*Re**	
Re	188746	*Re*	
turbulence	LOW	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	V_c / V_b Limerinos
τ_{calc} (kg m^{-2})	1.52		
τ_{calc} (N m^{-2})	14.90		
τ D_{crit} (gr-co) (mm)	15.36		
D_{50} V_c (vcs +) (m s^{-1})	0.22	0.44	
D_{84} V_c (vcs +) (m s^{-1})	1.34	2.71	

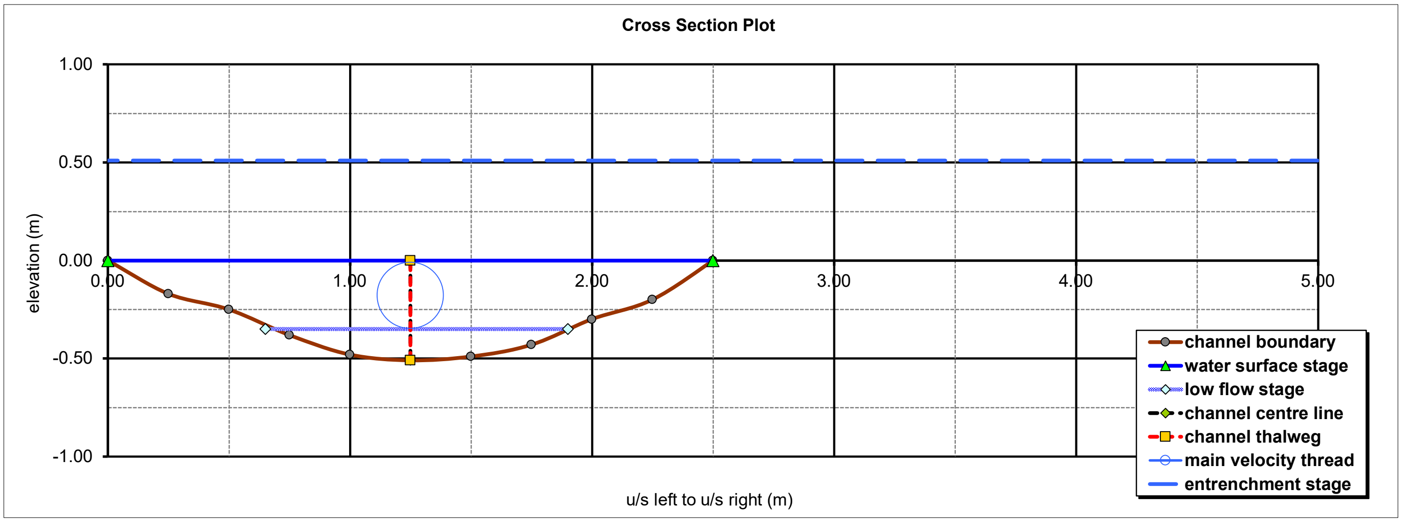
Bank Data

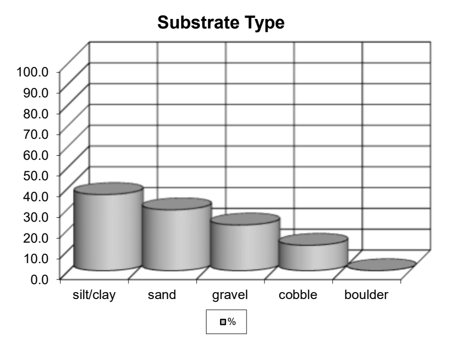
	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
22.7	29.5	27.3	20.5	0.0

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 7.1
Bankfull Geometry





Morphology Type

cascade	
step	
riffle	
run	
glide	
pool	●
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.80
R (m)	0.29
TW (m)	2.50
WP (m)	2.75
max d (m)	0.51
mean d (m)	0.32
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	6.49
ff V mean/V*	6.82
ff D_{84}	7.69
ff mean	7.26
	ROUGH BED

Hydraulic Ratios

ER max d	5.00
r_c / TW	
TW / Lf_w	
TW/max d	4.9
TW/mean d	7.8

Sediment Transport Mode

			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.003	0.12	YES	YES	YES	YES
V_* (m s^{-1})	0.063	D_{50}	0.040	1.57	NO	NO	YES	YES
		D_{84}	0.984	38.36	NO	NO	NO	NO

Section Data

ER_e (m)	0.51	ER stations L / R	-4.00	8.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	2.50	2.50
Lf_e (m)	-0.350	Lf stations L / R	0.65	1.90	
W_{fp} (m)	12.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.51	1.25	
E_g (m m^{-1})	0.0067				

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	0.03	0.06	0.30	45.00	200.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})				43.65	194.00
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Erosion Thresholds

τ_{calc} (kg m^{-2})	1.96		
τ_{calc} (N m^{-2})	19.18	*V* $_c$ / *V* $_b$	
τ D_{crit} (gr-co) (mm)	19.78	Strickler	Limerinos
D_{50} V_c (vcs +) (m s^{-1})	0.08		
D_{84} V_c (vcs +) (m s^{-1})	1.04	1.86	

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
36.6	29.3	22.0	12.2	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 (%)		

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 ∗	329.6	65.9	0.4
B3	0.0017	0.0018	saltation	YES	YES	NO
C3	0.0001	0.0002	rolling	YES	YES	NO
C4	0.0053	0.0061	Ø	NO	NO	YES

Flow Regime Strickler method

Q (cms)	0.640
V (m s^{-1})	0.80
n	0.045
Fr	0.45
D_c rectangular (m)	0.19
D_c trapezoidal (m)	0.27
D_c triangular (m)	0.39
D_c parabolic (m)	0.23
D_c mean (m)	0.27
flow type	SUBCRITICAL
Ω (watts m^{-1})	42.03
ω_a (watts m^{-2})	15.30
ω_a/TW (watts m^{-1})	6.12
Re *	0.5
Re	204418
turbulence	LOW

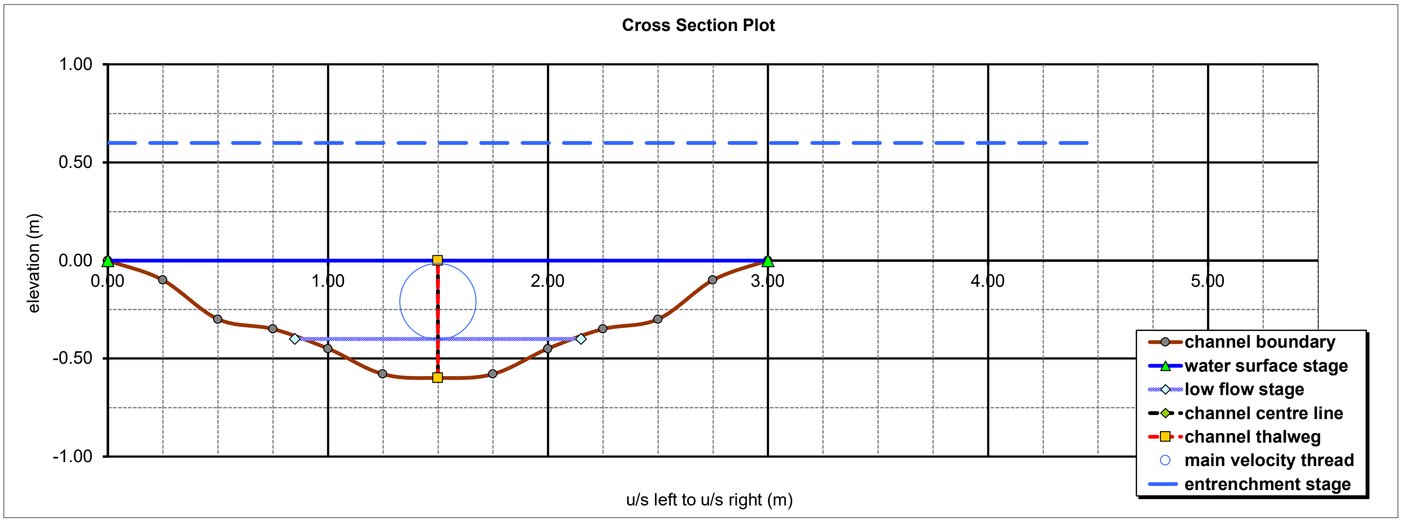
Flow Regime Limerinos method

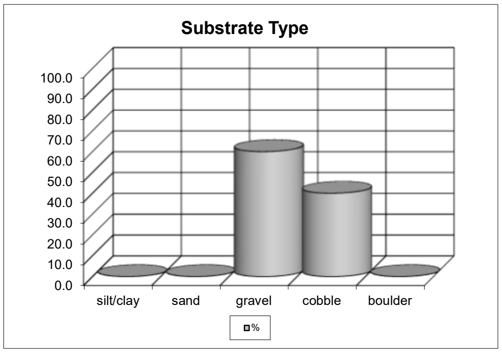
Q (cms)	
V (m s^{-1})	
n	
Fr	
D_c rectangular (m)	
D_c trapezoidal (m)	
D_c triangular (m)	
D_c parabolic (m)	
D_c mean (m)	
flow type	
Ω (watts m^{-1})	
ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	
Re *	
Re	
turbulence	

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

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 6.0
Bankfull Geometry - Proposed Run

B. de Geus 05.11





Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	1.04
R (m)	0.32
TW (m)	3.00
WP (m)	3.29
max d (m)	0.60
mean d (m)	0.35
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	4.21
ff V mean/V*	6.71
ff D_{84}	6.62
ff mean	6.66
	ROUGH BED

Hydraulic Ratios

ER max d	2.00
r_c / TW	
TW / Lf_w	2.31
TW/max d	5.0
TW/mean d	8.7

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	31.80	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.056	D_{50}	1.038	45.01	NO	NO	NO	NO
		D_{84}	1.271	55.14	NO	NO	NO	NO

Section Data

ER_e (m)	0.60	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.400	Lf stations L / R	0.85	2.15	
W_{fp} (m)	6.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
$\underline{z}$		T_e (m) $T_{o/s}$ (m)	-0.60	1.50	
E_g ($m\ m^{-1}$)	0.0050				

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_*	0.6	0.3	0.2
B3	0.0018	0.0018	saltation	NO	NO	NO
C3	0.0002	0.0002	rolling	NO	NO	NO
C4	0.0060	0.0061	Ø	YES	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime Strickler method / Flow Regime Limerinos method

Strickler method		Limerinos method	
Q (cms)	0.849	Q (cms)	
V ($m\ s^{-1}$)	0.82	V ($m\ s^{-1}$)	
n	0.040	n	
Fr	0.44	*Fr*	
D_c rectangular (m)	0.20	D_c rectangular (m)	
D_c trapezoidal (m)	0.30	D_c trapezoidal (m)	
D_c triangular (m)	0.44	D_c triangular (m)	
D_c parabolic (m)	0.26	D_c parabolic (m)	
D_c mean (m)	0.30	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	41.62	Ω (watts m^{-1})	
ω_a (watts m^{-2})	12.64	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	4.21	ω_a/TW (watts m^{-1})	
Re *	79.7	*Re* *	
Re	226318	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} ($kg\ m^{-2}$)	1.58		
τ_{calc} ($N\ m^{-2}$)	15.48		
τ D_{crit} (gr-co) (mm)	15.96		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.92	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	2.35	

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 (%)		

Substrate Type (%)

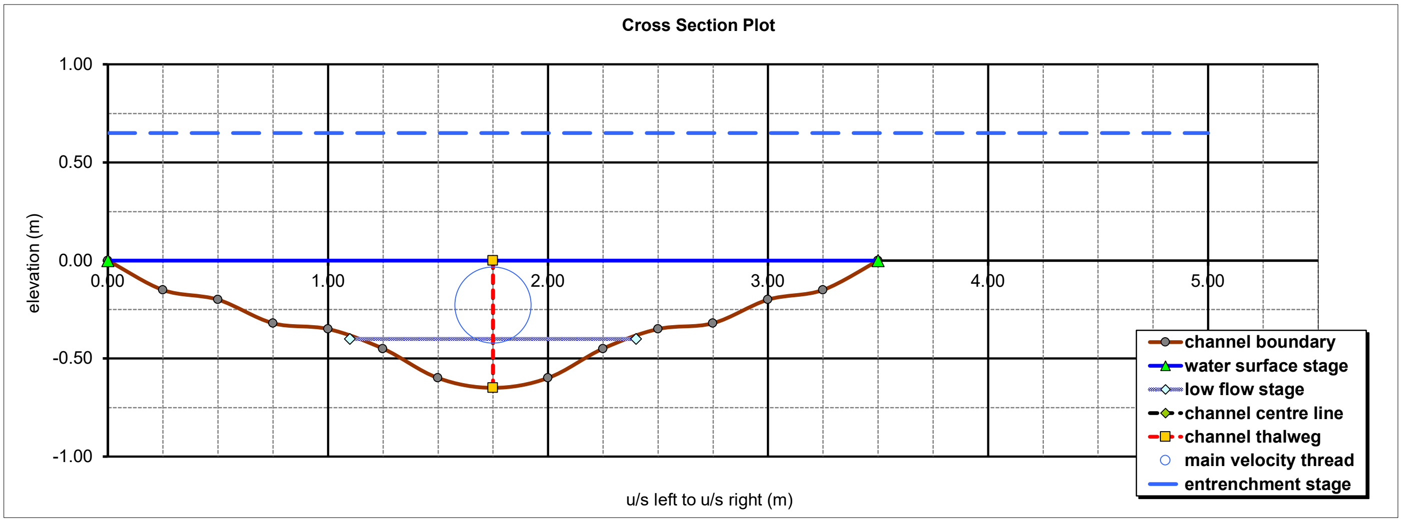
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

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

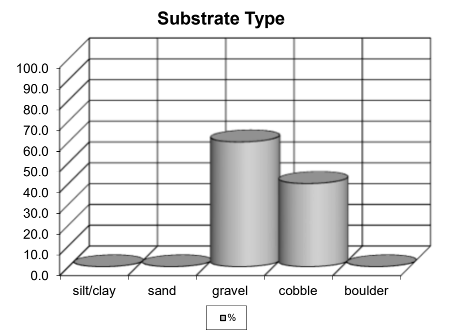
B. de Geus 05.11

Project: Barton Street and Fifty Road Class EA
Fifty Creek
Bankfull Geometry - Proposed Run

Cross Section Plot



Substrate Type



Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	1.20
R (m)	0.32
TW (m)	3.50
WP (m)	3.78
max d (m)	0.65
mean d (m)	0.34
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	4.22
ff V mean/V*	6.70
ff D_{84}	6.59
ff mean	6.64
ROUGH BED	

Hydraulic Ratios

ER max d	1.86
r_c / TW	
TW / Lf_w	2.69
TW/max d	5.4
TW/mean d	10.2

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	31.77	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.056	D_{50}	1.038	44.96	NO	NO	NO	NO
		D_{84}	1.271	55.08	NO	NO	NO	NO

Section Data

ER_e (m)	0.65	ER stations L / R	-1.50	5.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.50	3.50
Lf_e (m)	-0.400	Lf stations L / R	1.10	2.40	
W_{fp} (m)	6.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.65	1.75	
E_g ($m\ m^{-1}$)	0.0050				

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_*	0.6	0.3	0.2
B3	0.0019	0.0019	saltation	NO	NO	NO
C3	0.0003	0.0003	rolling	NO	NO	NO
C4	0.0064	0.0066	Ø	YES	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.980	Q (cms)	
V ($m\ s^{-1}$)	0.82	V ($m\ s^{-1}$)	
n	0.040	n	
Fr	0.45	*Fr*	
D_c rectangular (m)	0.20	D_c rectangular (m)	
D_c trapezoidal (m)	0.31	D_c trapezoidal (m)	
D_c triangular (m)	0.46	D_c triangular (m)	
D_c parabolic (m)	0.28	D_c parabolic (m)	
D_c mean (m)	0.31	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	48.00	Ω (watts m^{-1})	
ω_a (watts m^{-2})	12.69	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	3.63	ω_a/TW (watts m^{-1})	
*Re**	79.1	*Re**	
Re	227148	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} (kg m^{-2})	1.58		
τ_{calc} (N m^{-2})	15.51		
τ D_{crit} (gr-co) (mm)	15.99		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.91	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	2.34	

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 (%)		

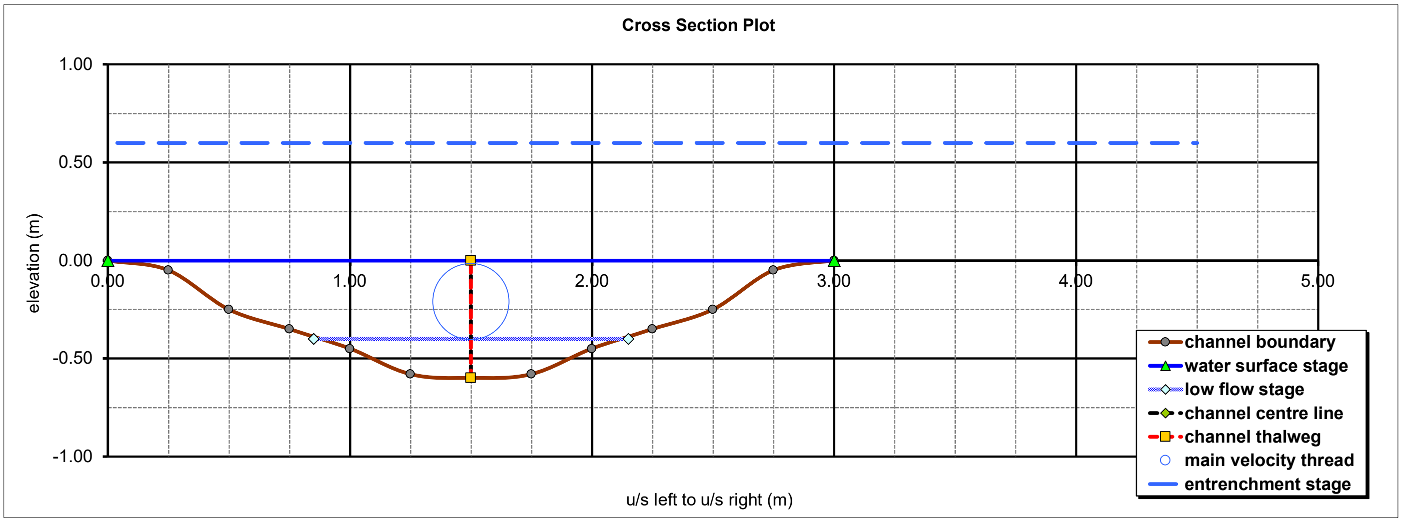
Substrate Type (%)

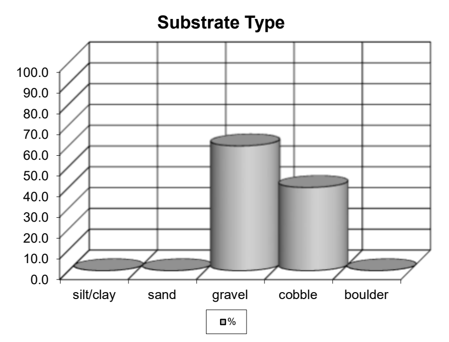
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

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

B. de Geus 05.11

Project: Barton Street and Fifty Road Class EA
Tributary WC 5.0
Bankfull Geometry - Proposed Run





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

Hydraulic Geometry	
A (m^2)	0.99
R (m)	0.30
TW (m)	3.00
WP (m)	3.29
max d (m)	0.60
mean d (m)	0.33
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R*/D_{84}	4.01
ff V mean/V*	6.62
ff D_{84}	6.50
ff mean	6.56
ROUGH BED	

Hydraulic Ratios	
ER max d	2.00
r_c / TW	
TW / Lf_w	2.31
TW/max d	5.0
TW/mean d	9.1

Sediment Transport Mode			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	32.60	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.055	D_{50}	1.038	46.14	NO	NO	NO	NO
		D_{84}	1.271	56.52	NO	NO	NO	NO

Section Data					
ER_e (m)	0.60	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.400	Lf stations L / R	0.85	2.15	
W_{fp} (m)	6.00	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	1.50	
E_g ($m\ m^{-1}$)	0.0050				

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_*	0.6	0.3	0.2
B3	0.0018	0.0018	saltation	NO	NO	NO
C3	0.0002	0.0002	rolling	NO	NO	NO
C4	0.0058	0.0059	Ø	YES	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
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)	0.782	Q (cms)	
V ($m\ s^{-1}$)	0.79	V ($m\ s^{-1}$)	
n	0.040	n	
Fr	0.44	*Fr*	
D_c rectangular (m)	0.19	D_c rectangular (m)	
D_c trapezoidal (m)	0.29	D_c trapezoidal (m)	
D_c triangular (m)	0.42	D_c triangular (m)	
D_c parabolic (m)	0.25	D_c parabolic (m)	
D_c mean (m)	0.29	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω ($watts\ m^{-1}$)	38.34	Ω ($watts\ m^{-1}$)	
ω_a ($watts\ m^{-2}$)	11.64	ω_a ($watts\ m^{-2}$)	
ω_a/TW ($watts\ m^{-1}$)	3.88	ω_a/TW ($watts\ m^{-1}$)	
*Re**	80.4	*Re**	
Re	208441	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds		V_c / V_b Strickler	V_c / V_b Limerinos
τ_{calc} ($kg\ m^{-2}$)	1.50		
τ_{calc} ($N\ m^{-2}$)	14.73		
τ D_{crit} (gr-co) (mm)	15.19		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.98	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	2.43	

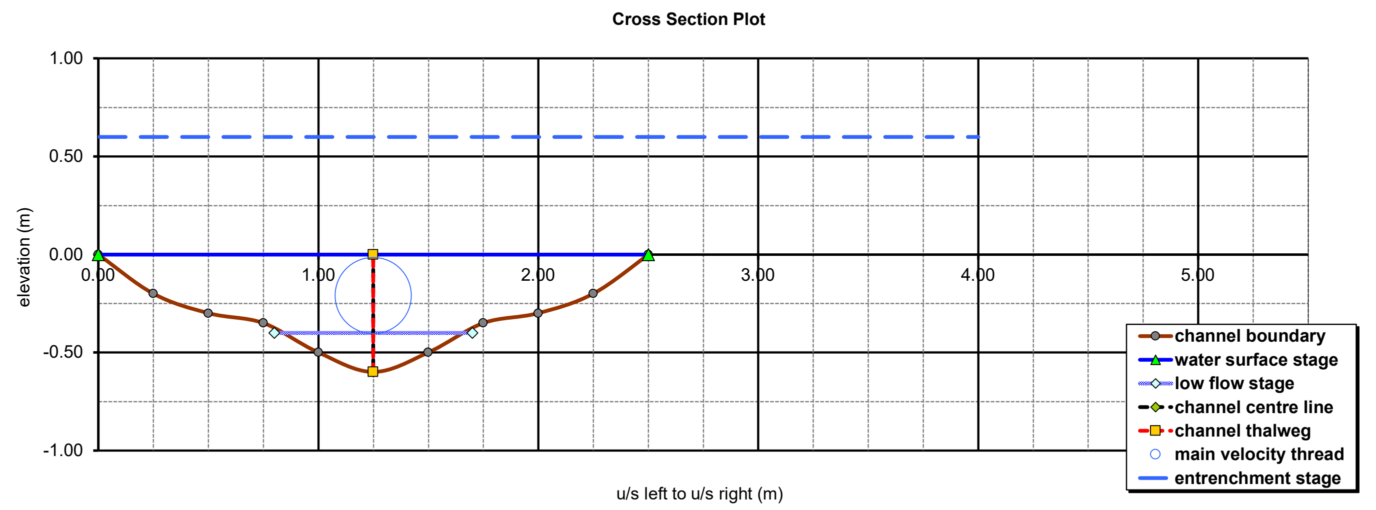
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

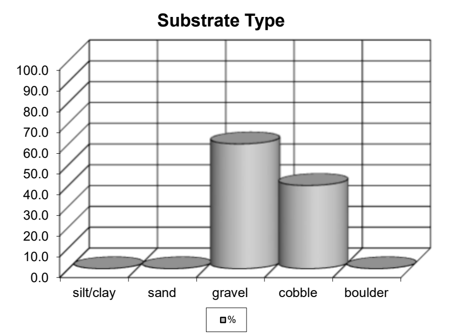
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

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

B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 7.1
Bankfull Geometry - Proposed Run





Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.83
R (m)	0.29
TW (m)	2.50
WP (m)	2.81
max d (m)	0.60
mean d (m)	0.33
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R* /D_{84}	3.91
ff V mean/V*	6.59
ff D_{84}	6.50
ff mean	6.54
ROUGH BED	

Hydraulic Ratios

ER max d	2.20
r_c / TW	
TW / Lf_w	2.78
TW/max d	4.2
TW/mean d	7.6

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	32.99	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.054	D_{50}	1.038	46.69	NO	NO	NO	NO
		D_{84}	1.271	57.20	NO	NO	NO	NO

Section Data

ER_e (m)	0.60	ER stations L / R	-1.50	4.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	2.50	2.50
Lf_e (m)	-0.400	Lf stations L / R	0.80	1.70	
W_{fp} (m)	5.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.60	1.25	
E_g ($m\ m^{-1}$)	0.0050				

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_*	0.6	0.3	0.2
B3	0.0017	0.0017	saltation	NO	NO	NO
C3	0.0001	0.0001	rolling	NO	NO	NO
C4	0.0053	0.0054	Ø	YES	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.642	Q (cms)	
V ($m\ s^{-1}$)	0.78	V ($m\ s^{-1}$)	
n	0.040	n	
Fr	0.43	*Fr*	
D_c rectangular (m)	0.19	D_c rectangular (m)	
D_c trapezoidal (m)	0.27	D_c trapezoidal (m)	
D_c triangular (m)	0.39	D_c triangular (m)	
D_c parabolic (m)	0.23	D_c parabolic (m)	
D_c mean (m)	0.27	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	31.44	Ω (watts m^{-1})	
ω_a (watts m^{-2})	11.19	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	4.47	ω_a/TW (watts m^{-1})	
*Re**	81.7	*Re**	
Re	200249	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	V_c / V_b Limerinos
τ_{calc} ($kg\ m^{-2}$)	1.47		
τ_{calc} ($N\ m^{-2}$)	14.38		
τ D_{crit} (gr-co) (mm)	14.83		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	2.01	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	2.47	

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

Bank Data

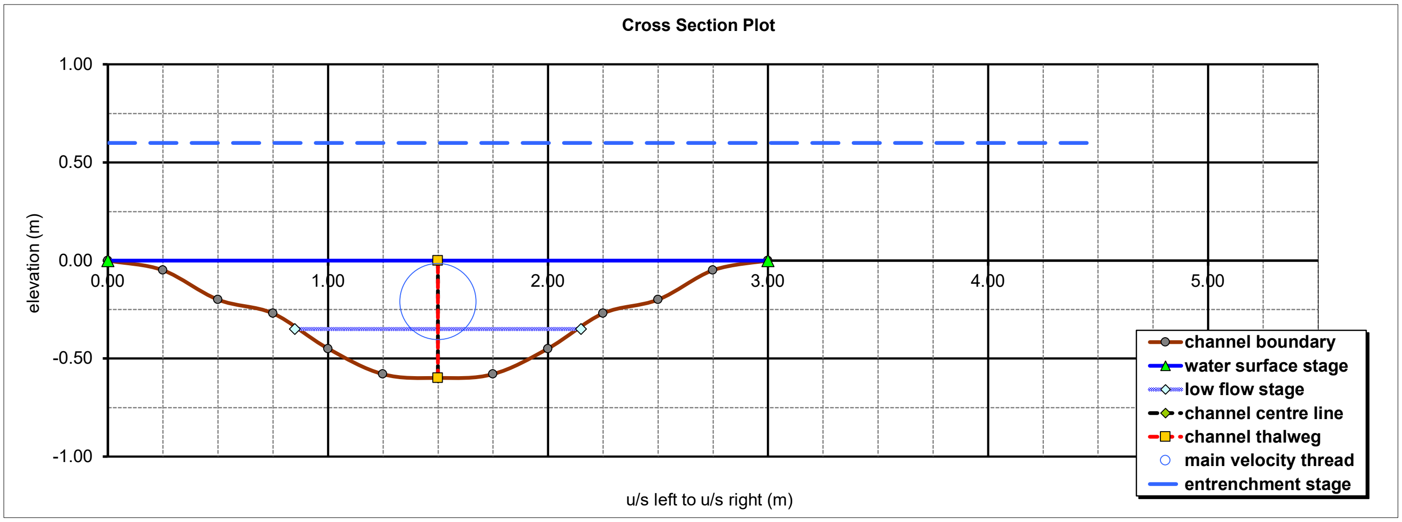
	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

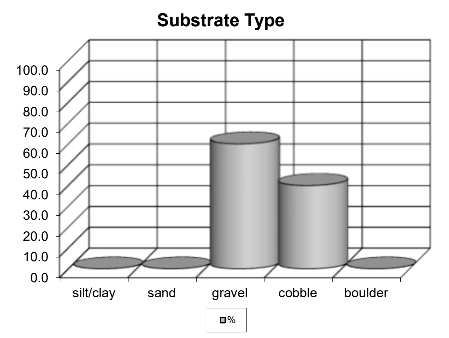
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

Project: Barton Street and Fifty Road Class EA
Tributary WC 7.0
Bankfull Geometry - Proposed Run

B. de Geus 05.11





Morphology Type

cascade	
step	
riffle	
run	●
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.93
R (m)	0.28
TW (m)	3.00
WP (m)	3.29
max d (m)	0.60
mean d (m)	0.31
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr R/D_{84}	3.74
ff V mean/V*	6.50
ff D_{84}	6.33
ff mean	6.41
ROUGH BED	

Hydraulic Ratios

ER max d	2.00
r_c / TW	
TW / Lf_w	2.31
TW/max d	5.0
TW/mean d	9.7

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	33.73	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.053	D_{50}	1.038	47.74	NO	NO	NO	NO
		D_{84}	1.271	58.48	NO	NO	NO	NO

Section Data

ER_e (m)	0.60	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.350	Lf stations L / R	0.85	2.15	
W_{fp} (m)	6.00	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	1.50	
E_g ($m\ m^{-1}$)	0.0050				

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_*	0.6	0.3	0.2
B3	0.0017	0.0017	saltation	NO	NO	NO
C3	0.0001	0.0002	rolling	NO	NO	NO
C4	0.0055	0.0055	Ø	YES	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.698	Q (cms)	
V ($m\ s^{-1}$)	0.75	V ($m\ s^{-1}$)	
n	0.040	n	
Fr	0.43	*Fr*	
D_c rectangular (m)	0.18	D_c rectangular (m)	
D_c trapezoidal (m)	0.28	D_c trapezoidal (m)	
D_c triangular (m)	0.41	D_c triangular (m)	
D_c parabolic (m)	0.24	D_c parabolic (m)	
D_c mean (m)	0.28	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	34.22	Ω (watts m^{-1})	
ω_a (watts m^{-2})	10.39	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	3.46	ω_a/TW (watts m^{-1})	
*Re**	81.4	*Re**	
Re	185989	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} ($kg\ m^{-2}$)	1.40		
τ_{calc} ($N\ m^{-2}$)	13.76		
$\tau\ D_{crit}$ (gr-co) (mm)	14.19		
$D_{50}\ V_c$ (vcs +) ($m\ s^{-1}$)	1.10	2.07	
$D_{84}\ V_c$ (vcs +) ($m\ s^{-1}$)	1.34	2.54	

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 (%)		

Substrate Type (%)

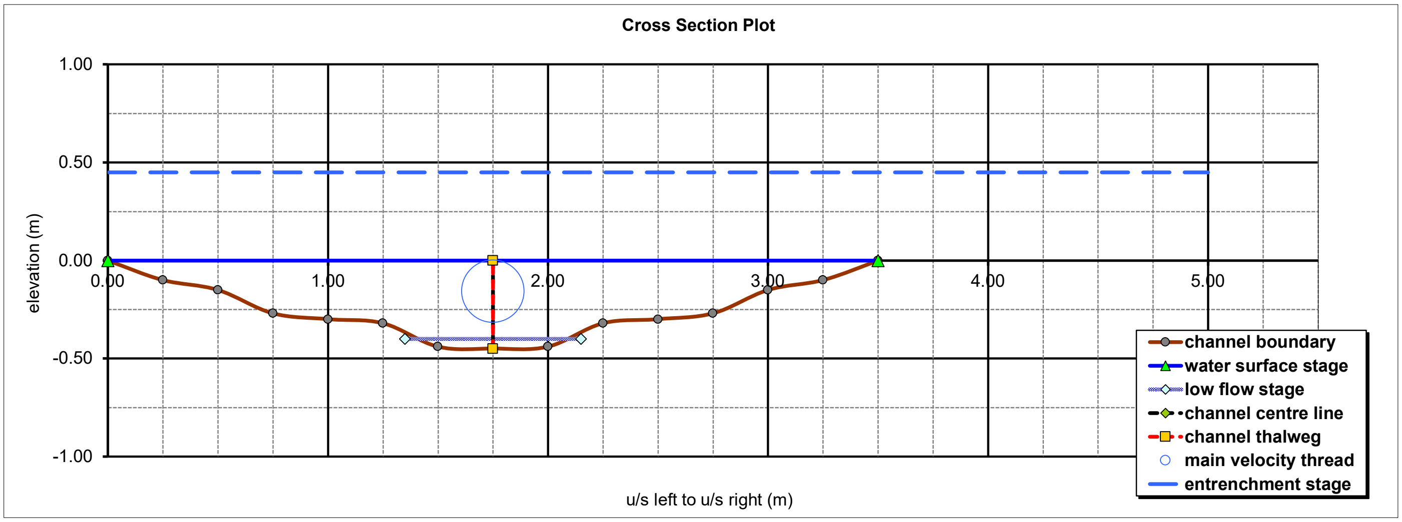
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

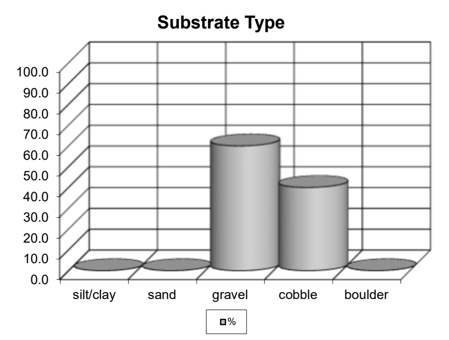
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Fifty Creek
Bankfull Geometry - Proposed Riffle





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

Hydraulic Geometry	
A (m^2)	0.90
R (m)	0.25
TW (m)	3.50
WP (m)	3.66
max d (m)	0.45
mean d (m)	0.26
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R* / D_{84}	3.28
ff V mean/V*	5.88
ff D_{84}	5.89
ff mean	5.89
ROUGH BED	

Hydraulic Ratios	
ER max d	1.86
r_c / TW	
TW / Lf_w	4.38
TW/max d	7.8
TW/mean d	13.6

Sediment Transport Mode			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	20.79	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.086	D_{50}	1.038	29.43	NO	NO	NO	NO
		D_{84}	1.271	36.05	NO	NO	NO	NO

Section Data					
ER_e (m)	0.45	ER stations L / R	-1.50	5.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.50	3.50
Lf_e (m)	-0.400	Lf stations L / R	1.35	2.15	
W_{fp} (m)	6.50	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
$\underline{z}$		T_e (m) $T_{o/s}$ (m)	-0.45	1.75	
E_g ($m\ m^{-1}$)	0.0150				

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	0.7	0.5
B3	0.0019	0.0019	saltation	NO	NO	NO
C3	0.0003	0.0003	rolling	YES	NO	NO
C4	0.0064	0.0067	Ø	NO	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
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)	0.961	Q (cms)	
V ($m\ s^{-1}$)	1.06	V ($m\ s^{-1}$)	
n	0.045	n	
Fr	0.67	*Fr*	
D_c rectangular (m)	0.20	D_c rectangular (m)	
D_c trapezoidal (m)	0.32	D_c trapezoidal (m)	
D_c triangular (m)	0.46	D_c triangular (m)	
D_c parabolic (m)	0.29	D_c parabolic (m)	
D_c mean (m)	0.32	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	141.24	Ω (watts m^{-1})	
ω_a (watts m^{-2})	38.56	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	11.02	ω_a/TW (watts m^{-1})	
*Re**	91.4	*Re**	
Re	230076	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds			
τ_{calc} ($kg\ m^{-2}$)	3.70		
τ_{calc} ($N\ m^{-2}$)	36.22	V_c / V_b	
τ D_{crit} (gr-co) (mm)	37.34	Strickler	Limerinos
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.47	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	1.80	

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 (%)		

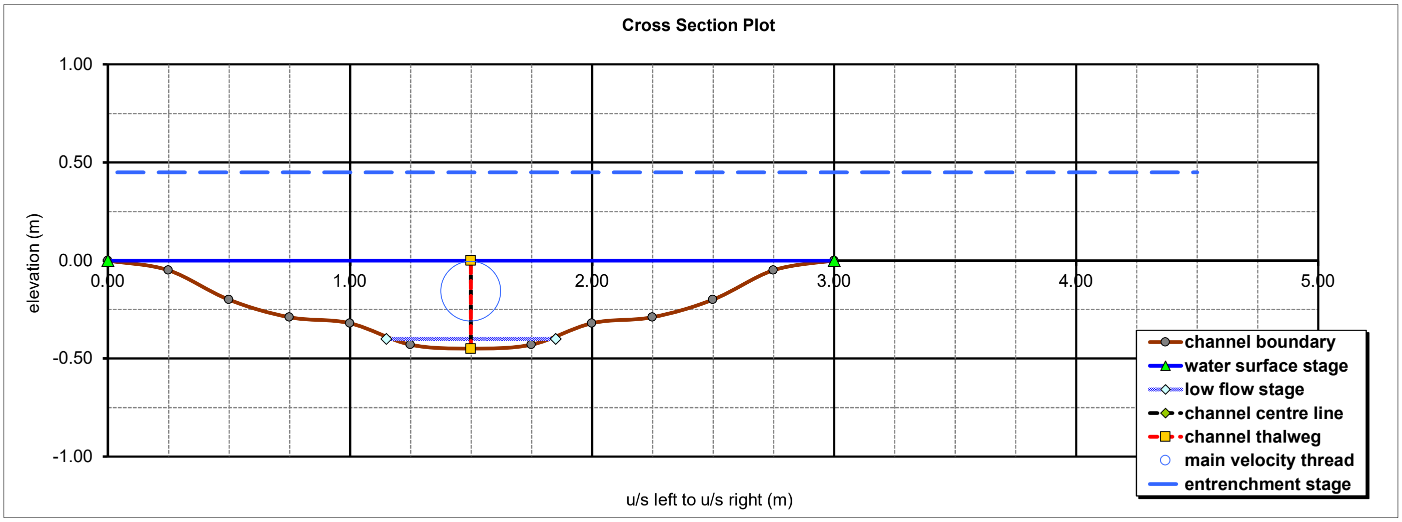
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

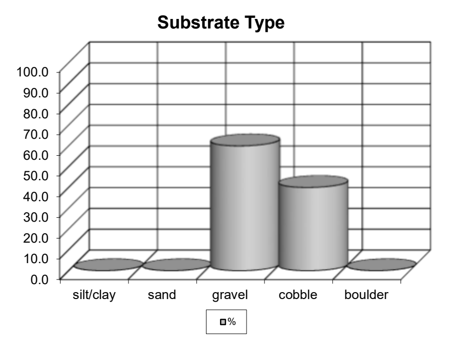
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

B. de Geus 05.11

Project: Barton Street and Fifty Road Class EA
Tributary WC 5.0
Bankfull Geometry - Proposed Riffle


Cross Section Plot


Substrate Type

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

Hydraulic Geometry	
A (m^2)	0.76
R (m)	0.24
TW (m)	3.00
WP (m)	3.18
max d (m)	0.45
mean d (m)	0.25
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R*/D_{84}	3.18
ff V mean/V*	5.84
ff D_{84}	5.84
ff mean	5.84
ROUGH BED	

Hydraulic Ratios	
ER max d	2.00
r_c / TW	
TW / Lf_w	4.29
TW/max d	6.7
TW/mean d	11.9

Sediment Transport Mode			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	21.13	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.085	D_{50}	1.038	29.91	NO	NO	NO	NO
		D_{84}	1.271	36.64	NO	NO	NO	NO

Section Data					
ER_e (m)	0.45	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.400	Lf stations L / R	1.15	1.85	
W_{fp} (m)	6.00	E_s sta. (Limerinos) L / R			
r_c (m)		E_s sta. (Strickler) L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.45	1.50	
E_g ($m\ m^{-1}$)	0.0150				

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_*	1.4	0.7	0.5
B3	0.0018	0.0018	saltation	NO	NO	NO
C3	0.0002	0.0002	rolling	YES	NO	NO
C4	0.0058	0.0061	Ø	NO	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
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)	0.789	Q (cms)	
V ($m\ s^{-1}$)	1.04	V ($m\ s^{-1}$)	
n	0.045	n	
Fr	0.66	*Fr*	
D_c rectangular (m)	0.19	D_c rectangular (m)	
D_c trapezoidal (m)	0.30	D_c trapezoidal (m)	
D_c triangular (m)	0.43	D_c triangular (m)	
D_c parabolic (m)	0.27	D_c parabolic (m)	
D_c mean (m)	0.30	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	116.00	Ω (watts m^{-1})	
ω_a (watts m^{-2})	36.53	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	12.18	ω_a/TW (watts m^{-1})	
*Re**	92.4	*Re**	
Re	217967	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds			
τ_{calc} ($kg\ m^{-2}$)	3.58		
τ_{calc} ($N\ m^{-2}$)	35.06	V_c / V_b	
τ D_{crit} (gr-co) (mm)	36.15	Strickler	Limerinos
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.50	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	1.84	

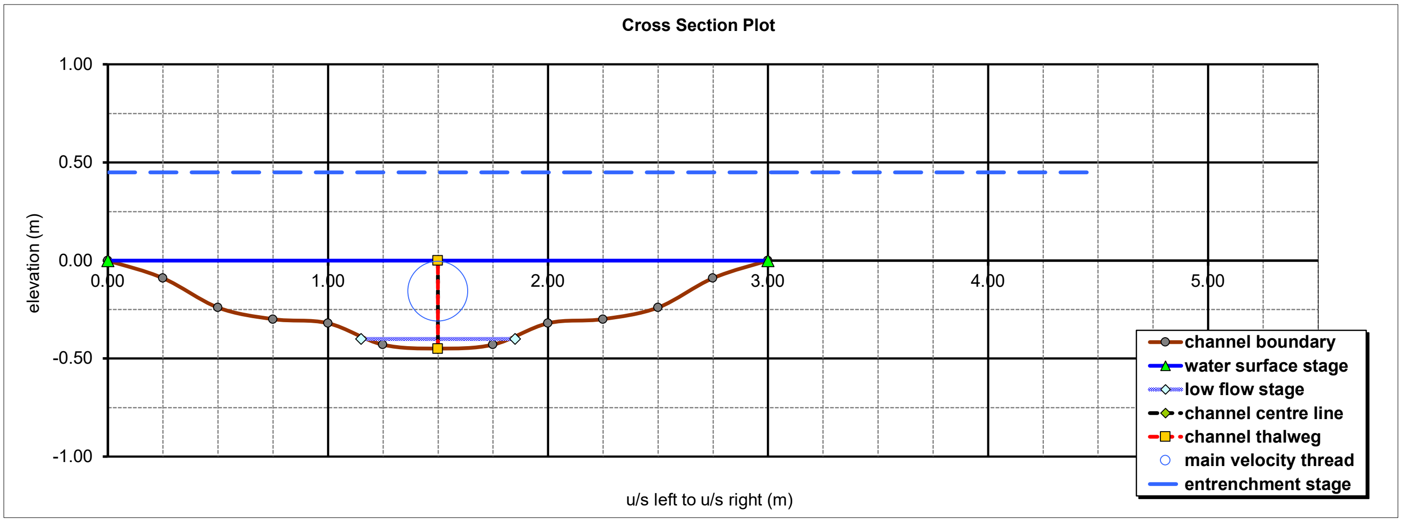
Bank Data	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

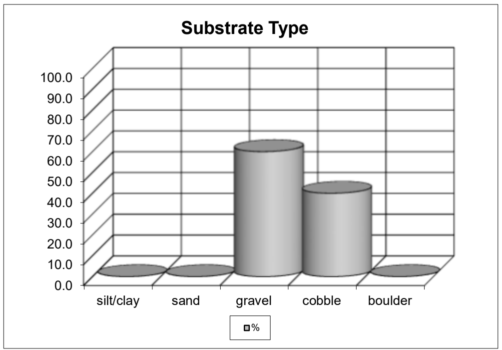
Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

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

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 6.0
Bankfull Geometry - Proposed Riffle

B. de Geus 05.11





Morphology Type

cascade	
step	
riffle	●
run	
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.80
R (m)	0.25
TW (m)	3.00
WP (m)	3.18
max d (m)	0.45
mean d (m)	0.27
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr R/D_{84}	3.37
ff V mean/V*	5.93
ff D_{84}	5.98
ff mean	5.96
ROUGH BED	

Hydraulic Ratios

ER max d	2.00
r_c / TW	
TW / Lf_w	4.29
TW/max d	6.7
TW/mean d	11.2

Sediment Transport Mode

			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	20.54	NO	NO	NO	NO
V_* (m s^{-1})	0.087	D_{50}	1.038	29.07	NO	NO	NO	NO
		D_{84}	1.271	35.61	NO	NO	NO	NO

Section Data

ER_e (m)	0.45	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.400	Lf stations L / R	1.15	1.85	
W_{fp} (m)	6.00	E_s sta. $_{(Limerinos)}$ L / R			
r_c (m)		E_s sta. $_{(Strickler)}$ L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.45	1.50	
E_g (m m^{-1})	0.0150				

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_*	1.5	0.8	0.5
B3	0.0018	0.0019	saltation	NO	NO	NO
C3	0.0002	0.0003	rolling	YES	NO	NO
C4	0.0061	0.0064	Ø	NO	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method		Limerinos method	
Q (cms)	0.869	Q (cms)	
V (m s^{-1})	1.08	V (m s^{-1})	
n	0.045	n	
Fr	0.67	*Fr*	
D_c rectangular (m)	0.21	D_c rectangular (m)	
D_c trapezoidal (m)	0.31	D_c trapezoidal (m)	
D_c triangular (m)	0.44	D_c triangular (m)	
D_c parabolic (m)	0.28	D_c parabolic (m)	
D_c mean (m)	0.31	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	127.68	Ω (watts m^{-1})	
ω_a (watts m^{-2})	40.17	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	13.39	ω_a/TW (watts m^{-1})	
*Re**	91.6	*Re**	
Re	239727	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds

		V_c / V_b	
τ_{calc} (kg m^{-2})	3.79		
τ_{calc} (N m^{-2})	37.12		
τ D_{crit} (gr-co) (mm)	38.27	Strickler	Limerinos
D_{50} V_c (vcs +) (m s^{-1})	1.10	1.45	
D_{84} V_c (vcs +) (m s^{-1})	1.34	1.77	

Bank Data u/s L u/s R

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

Substrate Type (%)

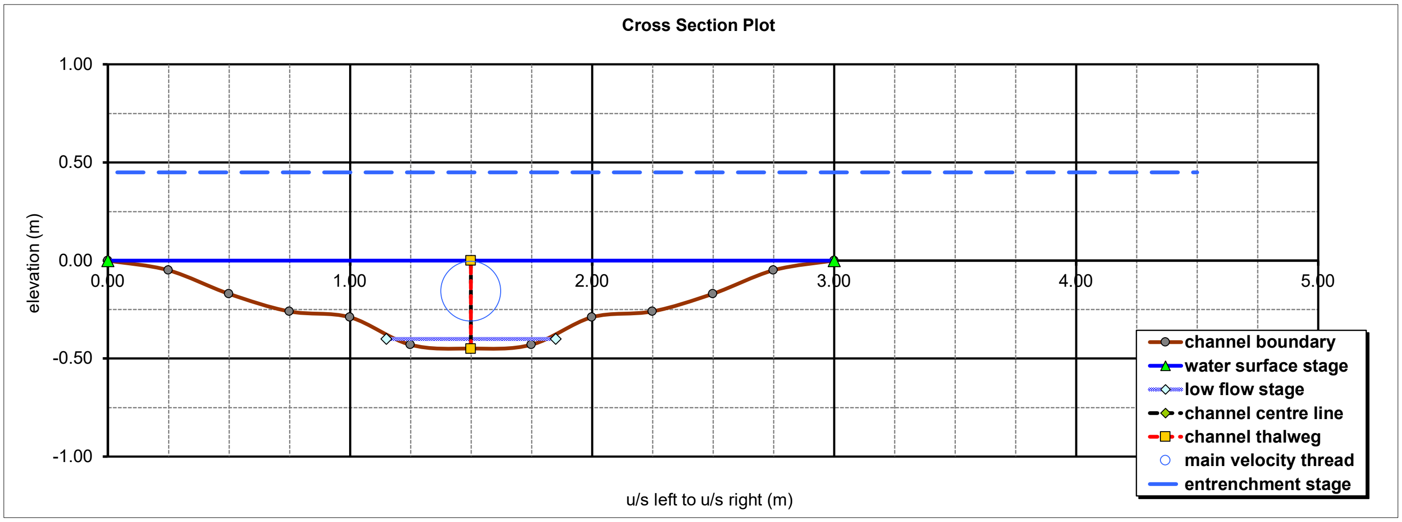
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

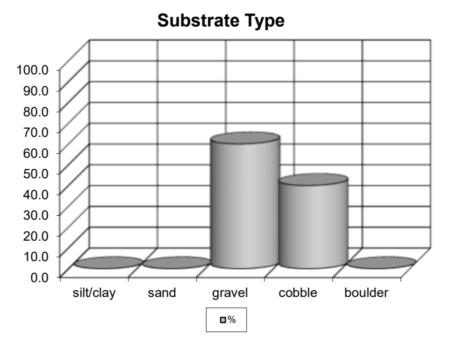
GEO-X v.5.1 Geomorphic Cross-section Analysis Model

AquaLogic

B. de Geus 05.11

Project: Barton Street and Fifty Road Class EA
Tributary WC 7.0
Bankfull Geometry - Proposed Riffle





Morphology Type

cascade	
step	
riffle	●
run	
glide	
pool	
thalweg out of phase	

Hydraulic Geometry

A (m^2)	0.71
R (m)	0.22
TW (m)	3.00
WP (m)	3.17
max d (m)	0.45
mean d (m)	0.24
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness

rr *R*/D_{84}	2.99
ff V mean/V*	5.73
ff D_{84}	5.68
ff mean	5.71
ROUGH BED	

Hydraulic Ratios

ER max d	2.00
r_c / TW	
TW / Lf_w	4.29
TW/max d	6.7
TW/mean d	12.6

Sediment Transport Mode

			w_s ($m\ s^{-1}$)	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	21.78	NO	NO	NO	NO
V_* ($m\ s^{-1}$)	0.082	D_{50}	1.038	30.83	NO	NO	NO	NO
		D_{84}	1.271	37.77	NO	NO	NO	NO

Section Data

ER_e (m)	0.45	ER stations L / R	-1.50	4.50	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	3.00	3.00
Lf_e (m)	-0.400	Lf stations L / R	1.15	1.85	
W_{fp} (m)	6.00	E_s sta. (Limerinos) L / R			
r_c (m)		E_s sta. (Strickler) L / R			
z		*T* e (m) *T* o/s (m)	-0.45	1.50	
E_g ($m\ m^{-1}$)	0.0150				

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_*	1.4	0.7	0.5
B3	0.0017	0.0018	saltation	NO	NO	NO
C3	0.0002	0.0002	rolling	YES	NO	NO
C4	0.0055	0.0058	Ø	NO	YES	YES

Substrate Gradation

	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} ($N\ m^{-2}$)	9.70	24.25	48.50	72.75	121.25
high turbulence - angular (mm)					
high turbulence - rounded (mm)					
low turbulence - angular (mm)					
low turbulence - rounded (mm)					

Flow Regime

Strickler method

Q (cms)	0.713
V ($m\ s^{-1}$)	1.00
n	0.045
Fr	0.66
D_c rectangular (m)	0.18
D_c trapezoidal (m)	0.28
D_c triangular (m)	0.41
D_c parabolic (m)	0.26
D_c mean (m)	0.28
flow type	SUBCRITICAL
Ω (watts m^{-1})	104.76
ω_a (watts m^{-2})	33.00
ω_a/TW (watts m^{-1})	11.00
*Re**	93.4
Re	196949
turbulence	HIGH

Flow Regime

Limerinos method

Q (cms)	
V ($m\ s^{-1}$)	
n	
Fr	
D_c rectangular (m)	
D_c trapezoidal (m)	
D_c triangular (m)	
D_c parabolic (m)	
D_c mean (m)	
flow type	
Ω (watts m^{-1})	
ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	
*Re**	
Re	
turbulence	

Erosion Thresholds

		V_c / V_b Strickler	Limerinos
τ_{calc} (kg m^{-2})	3.37		
τ_{calc} ($N\ m^{-2}$)	33.00		
τ D_{crit} (gr-co) (mm)	34.02		
D_{50} V_c (vcs +) ($m\ s^{-1}$)	1.10	1.57	
D_{84} V_c (vcs +) ($m\ s^{-1}$)	1.34	1.92	

Substrate Type (%)

silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

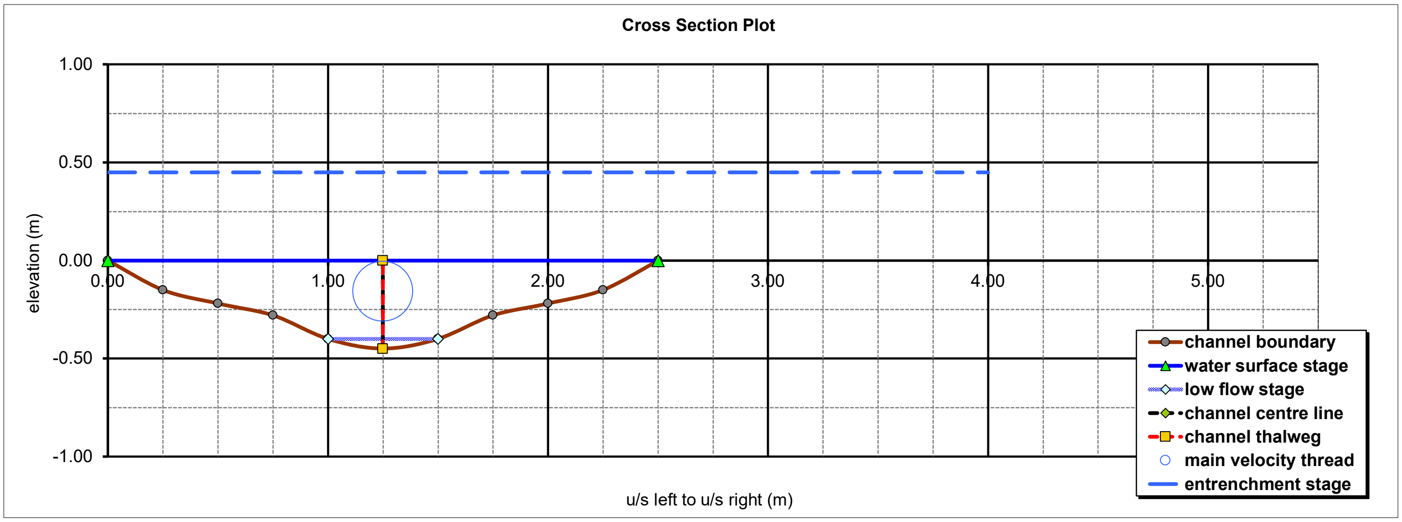
Bank Data

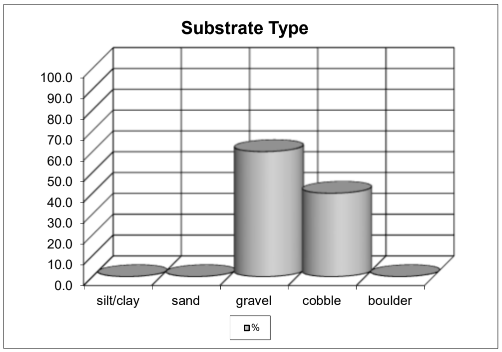
	u/s L	u/s R
H_b (m)		
Bf_d (m)		
RDp (m)		
H_b/Bf_d		
RDp/H_b		
RDn (%)		
BA (°)		
BFP (%)		

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

B. de Geus 05.11

Project: **Barton Street and Fifty Road Class EA**
Tributary WC 7.1
Bankfull Geometry - Proposed Riffle





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

Hydraulic Geometry	
A (m^2)	0.64
R (m)	0.24
TW (m)	2.50
WP (m)	2.68
max d (m)	0.45
mean d (m)	0.26
$E_{s\ (Limerinos)}$ (m) [+]	
$E_{s\ (Strickler)}$ (m) [+]	

Hydraulic Roughness	
rr *R* /D_{84}	3.17
ff V mean/V*	5.84
ff D_{84}	5.86
ff mean	5.85
ROUGH BED	

Hydraulic Ratios	
ER max d	2.20
r_c / TW	
TW / Lf_w	5.00
TW/max d	5.6
TW/mean d	9.8

Sediment Transport Mode			w_s (m s^{-1})	P	wash load	high sus. load	low sus. load	bedload
k	0.41	D_{30}	0.733	21.16	NO	NO	NO	NO
V_* (m s^{-1})	0.085	D_{50}	1.038	29.95	NO	NO	NO	NO
		D_{84}	1.271	36.69	NO	NO	NO	NO

Section Data					
ER_e (m)	0.45	ER stations L / R	-1.50	4.00	TW ck
WS_e (m)	0.000	WS stations L / R	0.00	2.50	2.50
Lf_e (m)	-0.400	Lf stations L / R	1.00	1.50	
W_{fp} (m)	5.50	E_s sta. (Limerinos) L / R			
r_c (m)		E_s sta. (Strickler) L / R			
z		T_e (m) $T_{o/s}$ (m)	-0.45	1.25	
E_g (m m^{-1})	0.0150				

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_*	1.4	0.7	0.5
B3	0.0017	0.0017	saltation	NO	NO	NO
C3	0.0001	0.0002	rolling	YES	NO	NO
C4	0.0054	0.0056	Ø	NO	YES	YES

Substrate Gradation	D_{15}	D_{30}	D_{50}	D_{84}	D_{100}
Existing Conditions (mm)	10.00	25.00	50.00	75.00	125.00
Stability Design Targets (mm)					
τ_{cr} (N m^{-2})	9.70	24.25	48.50	72.75	121.25
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)	0.663	Q (cms)	
V (m s^{-1})	1.04	V (m s^{-1})	
n	0.045	n	
Fr	0.66	*Fr*	
D_c rectangular (m)	0.20	D_c rectangular (m)	
D_c trapezoidal (m)	0.28	D_c trapezoidal (m)	
D_c triangular (m)	0.40	D_c triangular (m)	
D_c parabolic (m)	0.24	D_c parabolic (m)	
D_c mean (m)	0.28	D_c mean (m)	
flow type	SUBCRITICAL	flow type	
Ω (watts m^{-1})	97.42	Ω (watts m^{-1})	
ω_a (watts m^{-2})	36.34	ω_a (watts m^{-2})	
ω_a/TW (watts m^{-1})	14.54	ω_a/TW (watts m^{-1})	
*Re**	93.1	*Re**	
Re	216842	*Re*	
turbulence	HIGH	turbulence	

Erosion Thresholds		V_c / V_b	
τ_{calc} (kg m^{-2})	3.57		
τ_{calc} (N m^{-2})	34.95		
τ D_{crit} (gr-co) (mm)	36.03	Strickler	Limerinos
D_{50} V_c (vcs +) (m s^{-1})	1.10	1.51	
D_{84} V_c (vcs +) (m s^{-1})	1.34	1.84	

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 (%)		

Substrate Type (%)				
silt/clay	sand	gravel	cobble	boulder
0.0	0.0	60.0	40.0	0.0

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

B. de Geus 07.12

Project: **Barton Street and Fifty Road Class EA**
Crossing Analysis
Proposed Bankfull Conditions - Fifty Creek

Velocity 1 riffle
Velocity 2 run

Velocity Data

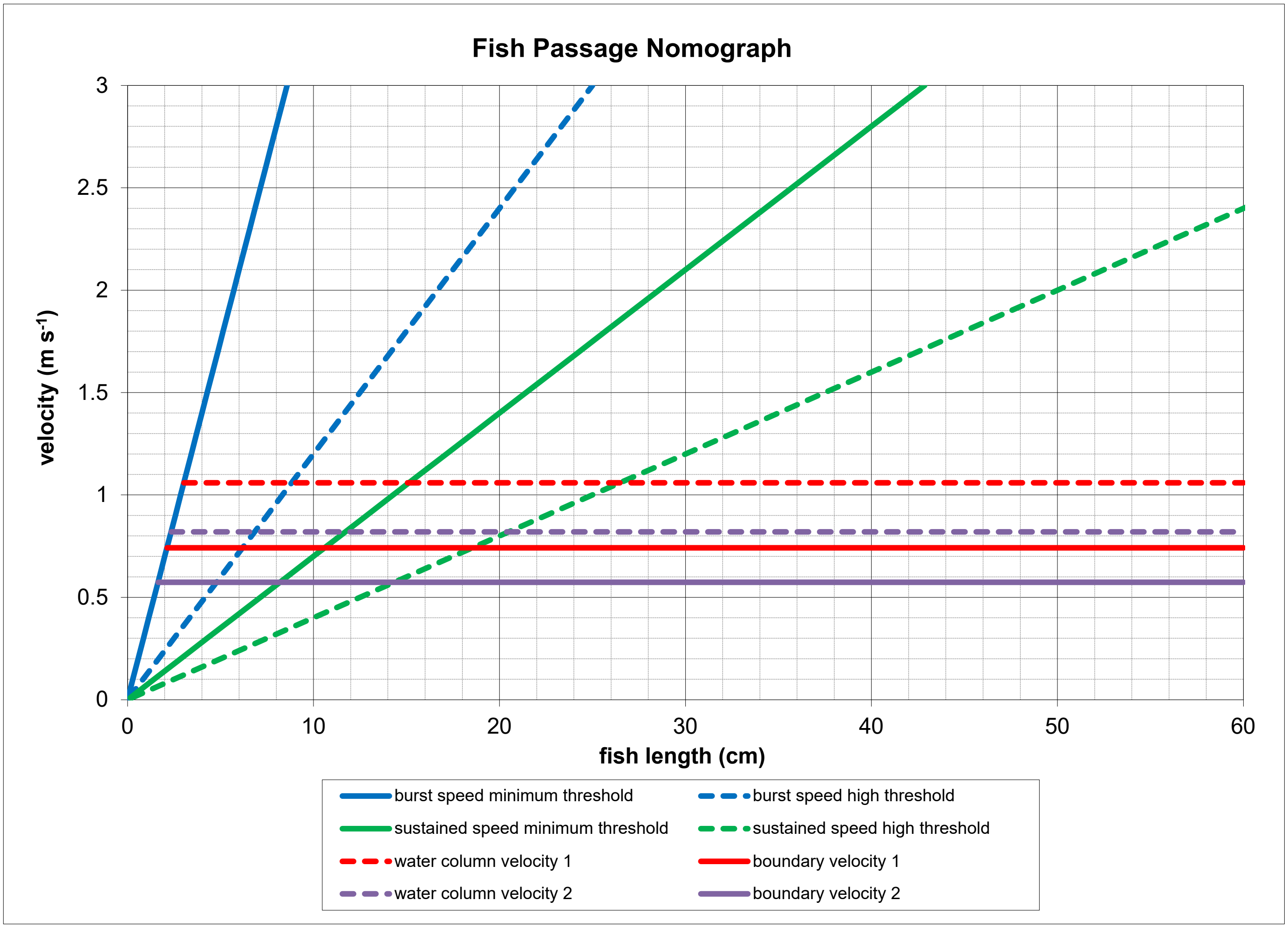
	1	2
water column velocity V (m s^{-1})	1.06	0.82
boundary velocity V_b (m s^{-1})	0.74	0.57

S_b D_s burst speed swimming distance (m)

	1	2
water column	106.7	119.9
boundary	124.2	133.4

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	26.5	15.1	8.8	3.0
	fish length L_f (cm) at V_b	18.6	10.6	6.2	2.1
2	fish length L_f (cm) at V	20.5	11.7	6.8	2.3
	fish length L_f (cm) at V_b	14.4	8.2	4.8	1.6



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

B. de Geus 07.12

Project: **Barton Street and Fifty Road Class EA**
Crossing Analysis
Proposed Bankfull Conditions - Tributary WC 5.0

Velocity 1 riffle
Velocity 2 run

Velocity Data

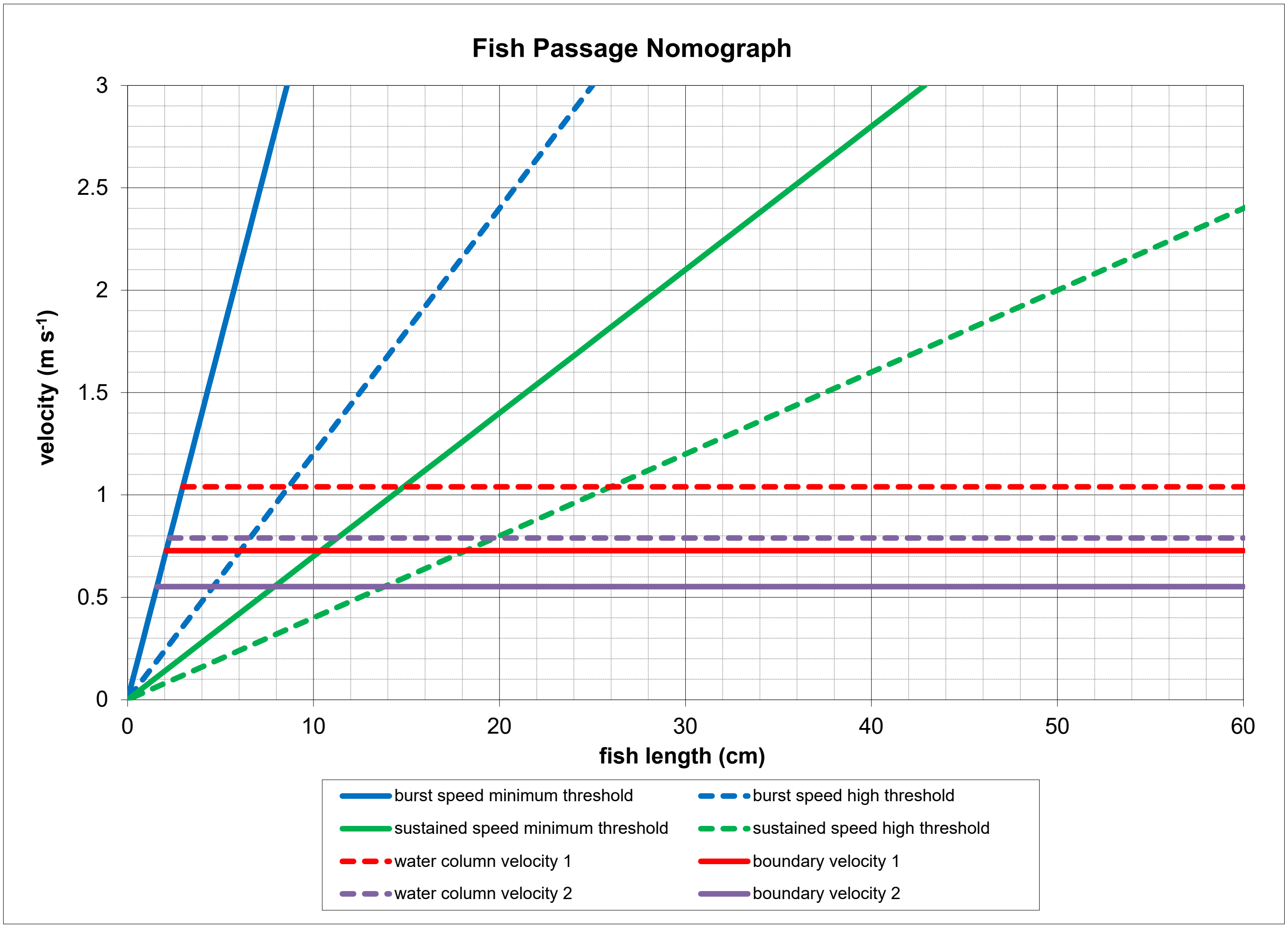
	1	**2**
water column velocity V (m s^{-1})	1.04	0.79
boundary velocity V_b (m s^{-1})	0.73	0.55

S_b D_s burst speed swimming distance (m)

	1	**2**
water column	107.8	121.6
boundary	125.0	134.6

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	26.0	14.9	8.7	3.0
	fish length L_f (cm) at V_b	18.2	10.4	6.1	2.1
2	fish length L_f (cm) at V	19.8	11.3	6.6	2.3
	fish length L_f (cm) at V_b	13.8	7.9	4.6	1.6



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

B. de Geus 07.12

Project: **Barton Street and Fifty Road Class EA**
Crossing Analysis
Proposed Bankfull Conditions - Tributary WC 6.0

Velocity 1 riffle
Velocity 2 run

Velocity Data

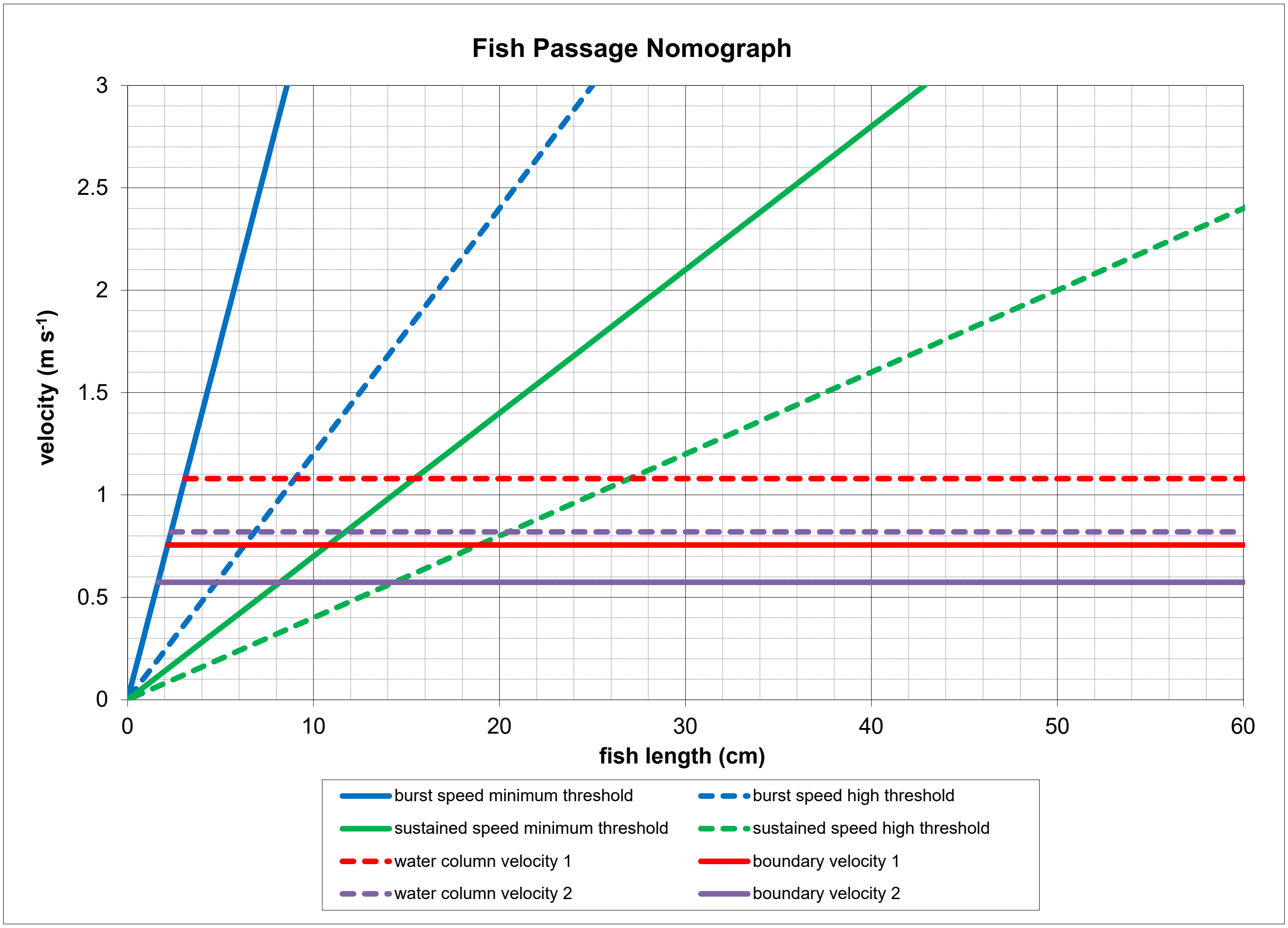
	1	2
water column velocity V (m s^{-1})	1.08	0.82
boundary velocity V_b (m s^{-1})	0.76	0.57

S_b D_s burst speed swimming distance (m)

	1	2
water column	105.6	119.9
boundary	123.4	133.4

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	27.0	15.4	9.0	3.1
	fish length L_f (cm) at V_b	18.9	10.8	6.3	2.2
2	fish length L_f (cm) at V	20.5	11.7	6.8	2.3
	fish length L_f (cm) at V_b	14.4	8.2	4.8	1.6



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

B. de Geus 07.12

Project: Barton Street and Fifty Road Class EA
Crossing Analysis
Proposed Bankfull Conditions - Tributary WC 7.0

Velocity 1 riffle
Velocity 2 run

Velocity Data

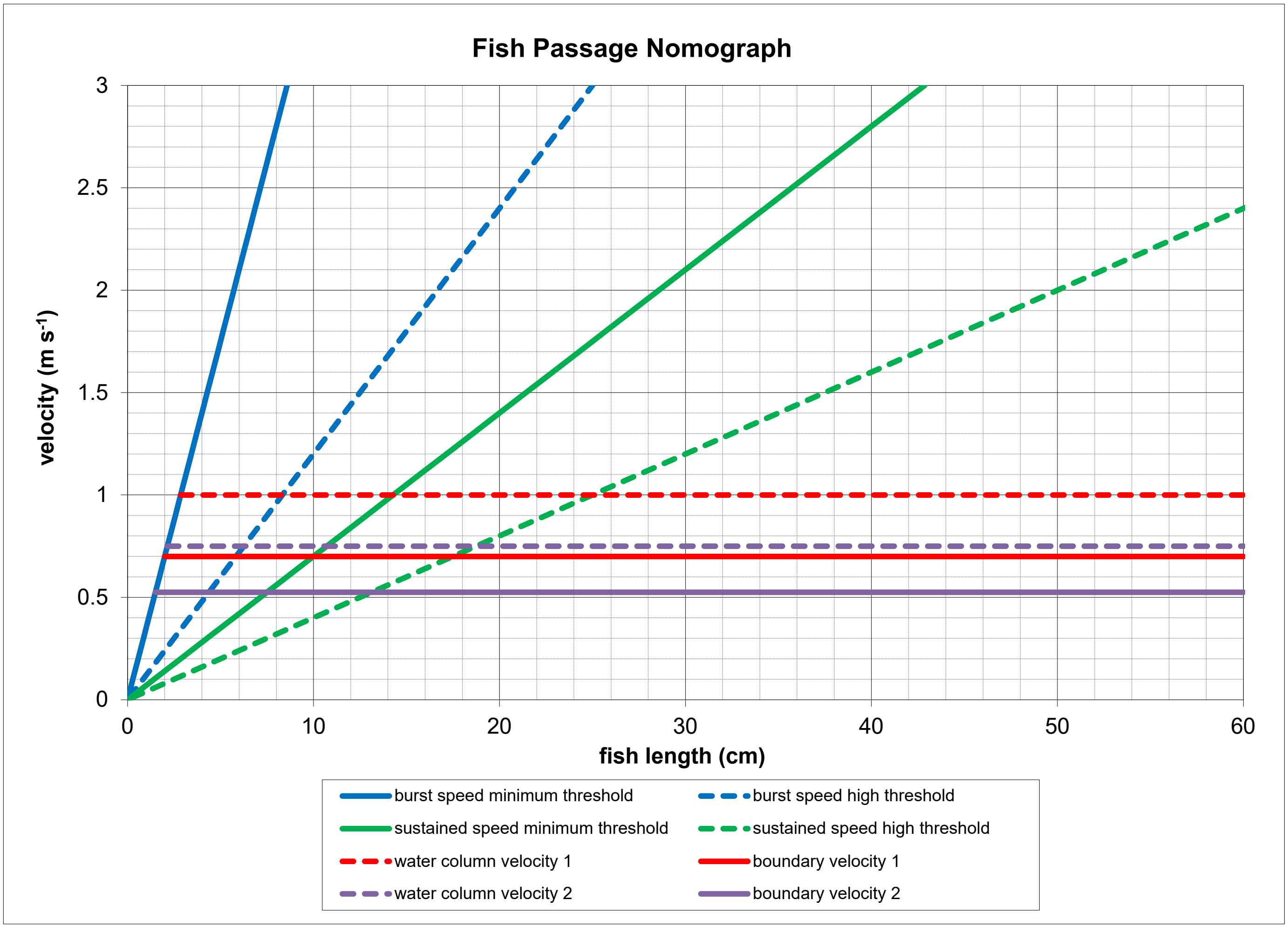
	1	2
water column velocity V (m s^{-1})	1.00	0.75
boundary velocity V_b (m s^{-1})	0.70	0.53

S_b D_s burst speed swimming distance (m)

	1	2
water column	110.0	123.8
boundary	126.5	136.1

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	25.0	14.3	8.3	2.9
	fish length L_f (cm) at V_b	17.5	10.0	5.8	2.0
2	fish length L_f (cm) at V	18.8	10.7	6.3	2.1
	fish length L_f (cm) at V_b	13.1	7.5	4.4	1.5



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

B. de Geus 07.12

Project: Barton Street and Fifty Road Class EA
Crossing Analysis
Proposed Bankfull Conditions - Tributary WC 7.1

Velocity 1 riffle
Velocity 2 run

Velocity Data

	1	2
water column velocity V (m s^{-1})	1.04	0.78
boundary velocity V_b (m s^{-1})	0.73	0.55

S_b D_s burst speed swimming distance (m)

	1	2
water column	107.8	122.1
boundary	125.0	135.0

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	26.0	14.9	8.7	3.0
	fish length L_f (cm) at V_b	18.2	10.4	6.1	2.1
2	fish length L_f (cm) at V	19.5	11.1	6.5	2.2
	fish length L_f (cm) at V_b	13.7	7.8	4.6	1.6