

## APPENDIX C2 – MEANDER BELT ANALYSIS

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TO: Harold Sich, IBI Group

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SUBJECT: Highland Creek Meander Belt Width Assessment – Morningside Avenue

Introduction

A Light Transit crossing is proposed for Highland Creek at Morningside Avenue (Figure 1). There are two possibilities for the crossing location: either the current bridge can be expanded to accommodate the crossing, or a second bridge can be constructed for the new system. PARISH Geomorphic has been retained to complete a meander belt width assessment at this location and to provide recommendations for the crossing location. This memorandum will outline the methodology and results of the assessment of the meander belt width and erosion potential associated with the proposed Light Transit crossing of Highland Creek at Morningside Avenue. Specifically, the following tasks were undertaken:

- A review of the background information was completed including a review of historical aerial photography.
- A field assessment to confirm existing conditions and document evidence of erosion in vicinity of the proposed crossing location;
- Delineation of the meander belt width using topographic mapping, historic and current aerial photographs.

Based on this information, an appropriate crossing width based on geomorphic principles is proposed for the Light Transit crossing.



Figure 1. Valley Segment GH-9 showing general study limits on Highland Creek at Morningside Avenue.

Background Review

As part of the background review, drawings for the original design of the Morningside Avenue stream road crossing, in addition to the rehabilitation of the bridge in the 1980's, were reviewed. The current bridge crossing was determined to have a bottom-width span of approximately 120 meters between the riprap retaining walls associated with the bridge abutments. In addition to the abutments, the bridge design included five piers spaced 30.48 meters apart.

Previous Studies

As part of the natural science investigations along the watercourses within the Toronto and Region Conservation Authority, PARISH Geomorphic Ltd. was retained to investigate the geomorphology of streams within the TRCA jurisdiction. In 2002, this work involved the collection of baseline geomorphic information from representative stream sections within the Don River, Rouge River and Highland Creek watersheds. This work like earlier efforts on the Humber River, Etobicoke and Mimico Creeks utilized map interpretation to stratify the rivers into relatively homogenous geomorphic units or "valley segments". Sampling within these strata will enable extrapolation of conditions to unsampled segments within the sample area. As illustrated in Figure 2, the portion of Highland Creek in vicinity of Morningside Avenue was deemed one valley segment (GH-9).

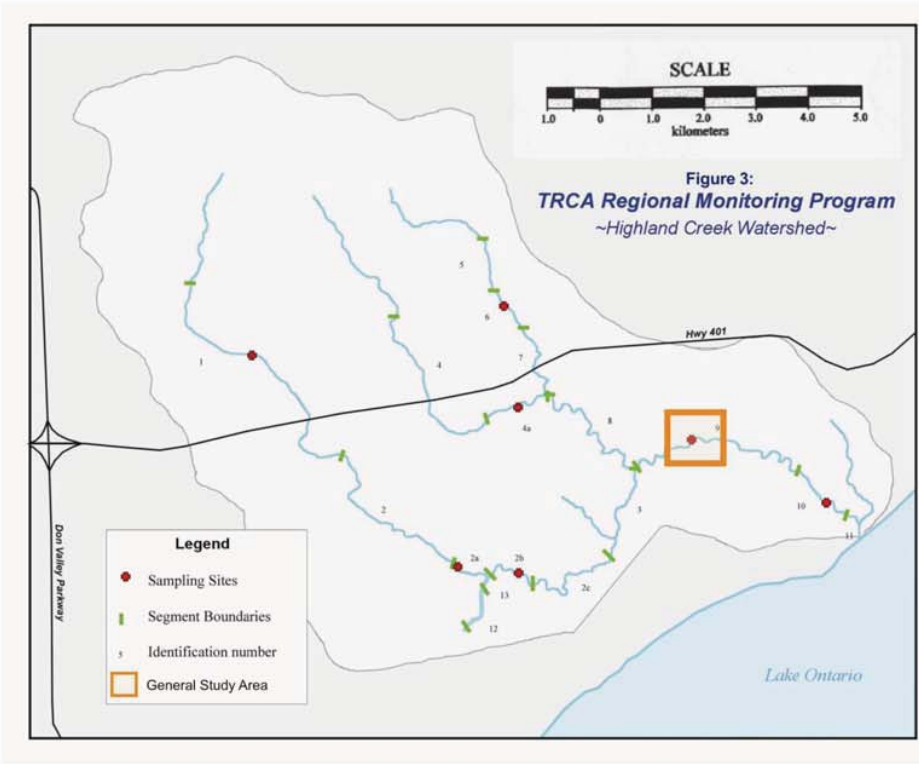
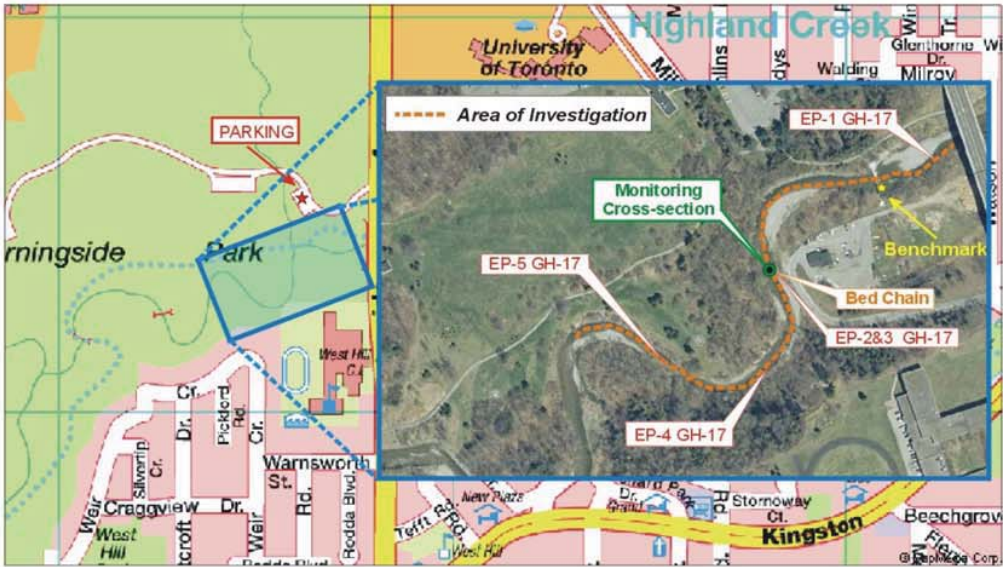


Figure 2. Valley segment delineation for Highland Creek watershed.



As part of a Regional Monitoring Program undertaken by PARISH Geomorphic Ltd. on behalf of Toronto and Region Conservation Authority (TRCA) a long-term monitoring station was established on Highland Creek upstream of Morningside Avenue in 2003 (**Figure 3**). Monitoring efforts at the site included a control cross-section, erosion pins, and bed chain. At the time of establishment, a full detailed field investigation was also completed, including a long profile survey.



**Figure 3.** Extent of detailed field site established through TRCA Regional Monitoring Program.

Subsequent to the establishment of this monitoring site, High flows associated with the August 19<sup>th</sup> storm event of 2005 resulted in significant erosion and adjustments in channel planform along several sections of Highland Creek, including the portion of channel in vicinity of Morningside Avenue. This adjustment resulted in the exposure of a bridge pier footing, watermain and Bell Canada conduit at the site (**Photos 1-3**). In response to these issues, the City of Toronto retained PARISH Geomorphic Ltd. to develop a design to mitigate these issues as part of an Emergency Works project. In 2007, a design was completed for these emergency works on Highland Creek. As part of the field work in support of this design, the creek was re-surveyed in 2007. **Figure 4** illustrates the location of the channel thalweg location in 2003 and 2007, illustrating the dynamic nature of Highland Creek at this site. **Figure 5**, meanwhile, illustrates the recommended design solution in which the active channel was enlarged to increase channel capacity, and a series of riffles were constructed to act as grade control and train flows to ensure a central thalweg and protect existing infrastructure. While initial design alternatives did consider a complete channel realignment within this section of Highland Creek to increase meander amplitude and stream length, this option was considered inappropriate due to factors such as cost and constructability. Construction of the preferred design alternative is currently on-going.



**Photo 1.** Looking downstream at Morningside Avenue (post August 19<sup>th</sup>).



**Photo 2.** Exposed bridge pier and eroded bank.





Photo 3. Exposed and undermined watermain and conduit.



Figure 4. 2003 and 2007 survey showing the change in thalweg location near Morningside Avenue.

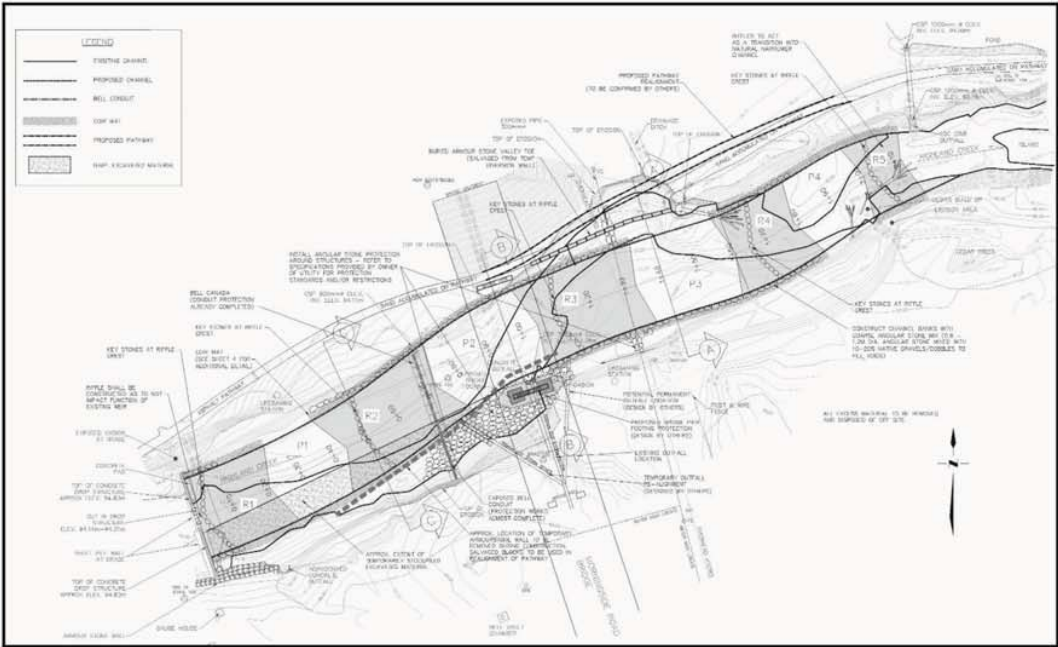


Figure 5. Recommended design solution currently being implemented at Morningside Ave.

### Historic Assessment

As part of this study, an historic assessment was completed which consisted of examining historic aerial photographs from 1939, 1954, 1965, 1978 and 2005 to determine changes in land use and any changes to the planform over time.

The 1939 aerial photographs show a very sinuous channel that appeared to be transporting large quantities of sediment and eroding laterally. Surrounding land use appears to be scrub land and agricultural lands with some forested lands to the north of the creek. The 1954 aerial photographs show that a large meander bend has been cut off in the vicinity of where Morningside Avenue now crosses. It was not evident in the aerial photographs if the avulsion had been natural or anthropogenic. There was also some residential development to the south of the creek. By 1965 the Morningside Avenue crossing of Highland Creek had been constructed. Additionally, a small pedestrian bridge and weir had been constructed immediately upstream of Morningside Avenue. The meander scar visible in the 1954 photographs was no longer visible in the 1965 photographs due to construction south west of the creek and Morningside Avenue. Channel work also appeared to have been completed on the meander immediately upstream of Morningside Avenue as the meander geometry appeared to be smoother than in the previous photograph. There was increased residential development south of the creek and increased development north of the creek. The 1978 photographs didn't show any significant changes to land use from 1965 although there were some small changes in planform. The 2005 photographs showed only minor changes in planform in addition to an increase in tree-cover surrounding development, particularly immediately south of the creek. Clearly,



the 2005 aerial photography did not capture the planform adjustments associated with the August 19<sup>th</sup> storm event.

Following the historical assessment, the aerial photographs from 1965, 1978, and 2005 were used to determine migration rates for the calculation of the 100-year erosion rate. Migration rates quantify the rate at which a meander bend of a stream moves across its valley, and are used to help predict future channel shifts. The 100-year erosion rate is therefore the distance the bank will erode over a 100 year period. Measurements are generally taken from a benchmark that is consistent within each aerial photograph, to the outer extent of a meander bend. Migration rates were calculated for several meanders and averaged to yield an average rate of 0.16 m/year for points upstream of Morningside Avenue (**Figure 6**).



Figure 6. Locations of migration rate calculations on Highland Creek.

Field Assessment

A key component of any fluvial geomorphological assessment is a synoptic level survey of the system. The purpose of the rapid stream assessment is to document areas of active erosion, collect basic channel dimensions and gain an understanding of the active channel processes along a stream. The field walk also enables confirmation of observations made based on aerial photograph interpretation and is used to guide decisions regarding the number and location of detailed field sites. In other words, a rapid assessment is a synoptic survey meant to quickly and qualitatively assess streams in order to identify any specific problems, assess overall channel stability and sensitivity, and validate mapping and aerial photography work (i.e. the desktop analysis). Field reconnaissance was conducted in November 2008.

During the field reconnaissance, about 1 km of channel was walked up and downstream of Morningside Avenue on Highland Creek. Areas of substantial erosion were noted and rapid assessments were completed (i.e. Rapid Geomorphic Assessment and Rapid Stream Assessment Technique). A Rapid Geomorphic Assessment (RGA) documents observed indicators of channel instability (MOE, 1999).

Observations are quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. For each category of channel sensitivity (ie aggradation, degradation etc), the indicators present are summed and divided by the total number of indicators for that category. The values for the four categories are then averaged to produce the final value. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40) or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) provides a broader view of the system by also considering the ecological functioning of the stream (Galli, 1996). Observations include instream habitat, water quality, riparian conditions, and biological indicators. Additionally, the RSAT approach includes semi-quantitative measures of bankfull channel dimensions, type of substrate, vegetative cover, and channel disturbance. Bankfull channel dimensions are created by the channel-forming discharge. This typically corresponds to discharges with a recurrence interval of 1 to 2 years. It is often defined as flow that determines channel parameters and is frequently smaller than top of bank dimensions. RSAT scores rank the channel as maintaining a low (<20), moderate (20-35) or high (>35) degree of stream health. Photographs taken during the rapid stream assessment work are provided in **Appendix A** along with a map indicating where the photographs were taken.

The rapid assessments resulted in an RGA score of 0.39 indicating that the channel was in a stressed or transitional state. This means the channel is undergoing adjustments as a result of channel disturbances. The dominant process observed in the study area was channel widening followed closely by channel aggradation. Channel widening was evidenced through falling and leaning trees, large organic debris, exposed tree roots, basal scour on the inside of meander bends and exposed utilities. The RSAT score was 25; indicating moderate stream stability. The RGA and RSAT scores were consistent with what had been observed in 2003 when an RGA of 0.36 and an RSAT of 21.5 were recorded. Bankfull widths varied between 10.5 and 18.5 m with corresponding depths of 1.3-2.2 meters. Wetted widths at the time of reconnaissance (late November) ranged from 9-16 meters with depths of 0.3 to 1.2 meters. The gradient was moderate to low with moderate entrenchment. Sediment size in the riffles was coarse ranging from gravel up to boulders while in the pools the substrate consisted of gravel and pebbles. Vegetation consisted of grasses, shrubs and some trees. Significant disturbances to Highland Creek in this area included the Morningside Avenue crossing, a weir upstream of Morningside Ave, a pedestrian bridge, and several locations with gabion baskets.

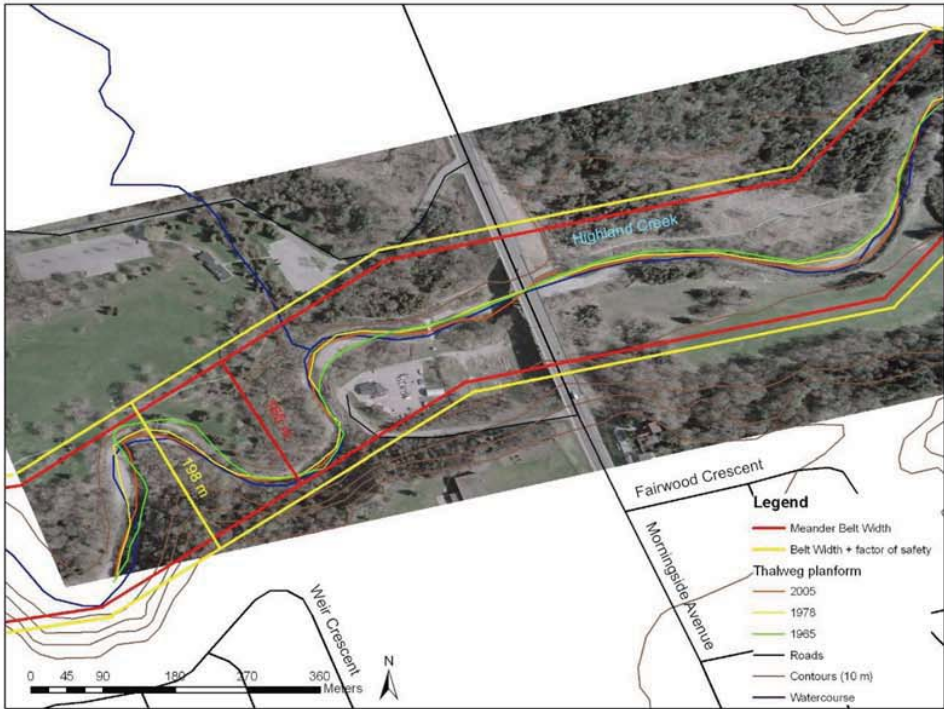
Meander Belt Width

As a channel naturally erodes and meanders across its floodplain, the extent of this movement can be defined by the meander belt width. A meander belt width defines a potential hazard area; or a zone within which the stream can potentially occupy, or has occupied in the past, and which usually coincides with the flood plain. For the purposes of this study, a meander belt width was delineated in vicinity of the Morningside Avenue crossing.

The meander belt width was delineated follow protocols outlined in the *Belt Width Delineation Procedures* (PARISH Geomorphic Ltd., 2004). The meander axis was first determined by following the general down-valley orientation of the meander pattern. Following the identification of the meander axis, the preliminary belt width was determined by drawing parallel lines tangential to the outside defining meanders of the planform. Given the dynamic nature of the creek, historic planform information was also taking into consideration in determining the belt width. Based on this approach, the preliminary belt width for Highland Creek at Morningside Avenue was determined to be 165 meters.



To account for any future migration, a factor of safety was applied to the meander belt width. Where possible, the 100 year migration rate is used when it can be calculated from the meanders defining the belt width. In this case, the 100 year migration rate of 16 m was primarily driven by measurements taken from meanders which did not define the belt width. Therefore, the 100-year migration rate was compared against a generic 20% factor of safety (10% to be applied on either side of the belt width) that can also be applied in lieu of migration rate analysis (PARISH Geomorphic Ltd., 2004). This resulted in a setback of 16.5 m which was equivalent to the quantified migration rates, and a final belt width of 198 m. **Figure 7** shows the meander belt width plus factor of safety in addition to the planform overlay determined from the 2005, 1978 and 1965 aerial photographs.



**Figure 7.** Meander belt width delineation for Highland Creek at the crossing of Morningside Ave.

**Recommendations**

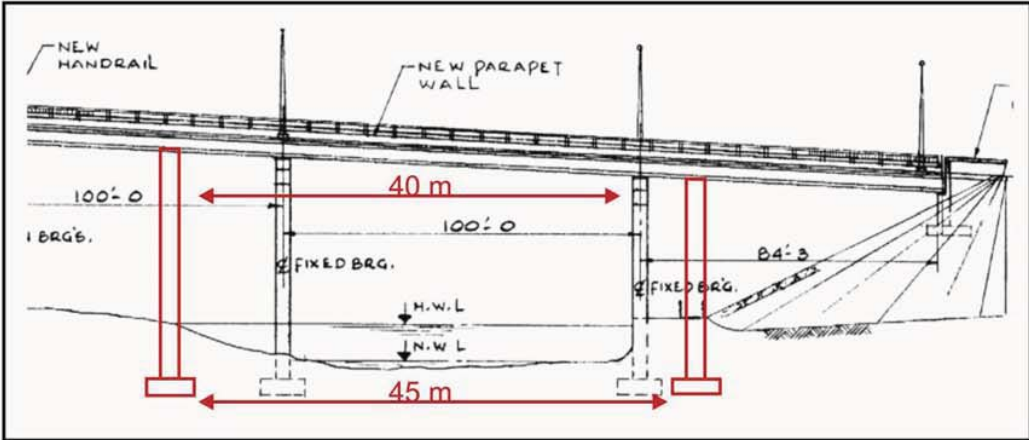
The two most likely alternatives for the proposed Light Rail system along Morningside Avenue involve widening of the existing bridge, or construction of a new crossing parallel to the existing bridge. Based on the geomorphic analyses undertaken for this study, a number of points can be made which form the basis of our ultimate recommendations. From a geomorphic perspective, the following criteria can be used to identify the optimum location for a stream road crossing:

- At a straight, stable section of the watercourse (i.e., riffle area with minimal lateral migration).
- At the narrowest point of a valley (if applicable).

- In an area that has been previously disturbed, or already has an existing crossing (retrofit).

Based on these criteria, the Morningside Avenue crossing of Highland Creek is in an optimum location. Having said that, recent peak flow events (August 2005) have initiated major planform adjustments within the system which indicate that Highland Creek has yet to adjust to its urbanized flow regime and could be expected to migrate or widen in the future in order to achieve a new state of dynamic equilibrium. While emergency works design alternatives did consider a channel realignment within this section of Highland Creek to address this issue, the option was considered inappropriate due to cost and constructability. As a result, steps were taken to increase channel capacity while protecting infrastructure and training flow under the bridge. With this in mind, it is reasonable to assume that measures will be taken to ensure that Highland Creek maintains its current meander geometry within the foreseeable future.

While, in a defined valley system, the meander belt width is generally considered the optimum span for a stream road crossing, it is also recognized that this type of structure is often cost prohibitive. Upon reviewing the existing structural drawings and in consideration of the optimal location of the crossing relative to channel planform, the current span of 120 m can be considered an appropriate dimension. Of greater interest is the location and span between bridge piers. As illustrated in **Figure 8**, the first and second piers along the north abutment were not placed outside of the high water level of Highland Creek.



**Figure 8.** Existing and proposed Morningside Avenue bridge pier locations.

Therefore, it is recommended that the current crossing location and span could be maintained, however the distance between the piers should be increased to allow for some natural adjustment of the channel while minimizing the risk to infrastructure. Currently, the bridge piers are 30.48 m apart, however a span of approximately 40-45 meters would allow the piers to span the high water level and most active section of channel within the valley floor. Conversely, if a new crossing were proposed, the 120 m span would likely be sufficient, but would be centered on the channel with pier spans of 40-45 m. Both options maintain the existing 90 degree road alignment to the creek at a fairly straight riffle section. As has been demonstrated, Highland Creek is a highly dynamic system.

**References**

Galli, J., 1996. *Rapid stream assessment technique, field methods*. Metropolitan Washington Council of Governments. 36pp.

Ontario Ministry of Environment 1999. *Ontario Ministry of Environment. Revised Stormwater Management Guidelines*. Draft Report.

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PARISH Geomorphic Ltd. 2003. *Regional Monitoring Program – Geomorphological Component (Don River, Rouge River and Highland Creek Watersheds)*. Submitted to: TRCA.

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**APPENDIX A**





**Photo 1.** Elevated storm sewer outlet and erosion downstream of the pedestrian bridge.



**Photo 2.** Armour stone wall downstream of Morningside Avenue.



**Photo 3.** Bank erosion and exposed concrete pipe downstream of Morningside Avenue.



**Photo 4.** The weir upstream of Morningside Avenue.





**Photo 5.** Toe erosion on the inside meander bend upstream of the weir.



**Photo 6.** Failed gabion baskets upstream of Morningside Avenue.



**Photo 7.** Looking downstream at a riffle towards erosion on the south bank.