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Wapiti River Geomorphology Assessment

Introduction

Geomorphology is one of the five basic components of an Instream Flow Needs assessment. Because there are no hydraulic structures, such as a dam or weir, in the Wapiti River mainstem, the geomorphology of the Wapiti River is not expected to be significantly impacted by current water management or any proposed development. The analysis contained in this report will therefore focus on using simplified, though well-established, techniques for estimating at what point water use in the Wapiti River will require a more thorough analysis of geomorphology.

Regime Theory Approach

Regime Theory is the concept that a river channel's geometry can be predicted based on the flow of the river and the sediment which it carries. It is an empirical approach where generalized equations are developed based on observed channel conditions in a wide variety of rivers. The concept was originally developed in India to calculate stable geometries of irrigation canals. This approach has been used around the world to predict stable channel geometries since the early 20th century. Over the decades, many studies have continued to develop new empirical and theoretical equations. The method also has a long history of use in Alberta since one of its foremost developers, Tom Blench, was the first professor of Hydraulic Engineering at the University of Alberta where he taught from 1948 to 1971. An overview of the Regime theory approach can be found in Singh (2003).

The equations generally take the form of power-law relationships that may be derived from theoretical relationships, observed stable channel geometries, or a combination of these methods. Using such equations it is possible to estimate how much a channel's geometry will change in response to a change in either flow or sediment. In the Wapiti River, the primary concern is how channel geometry will change in response to changes in flow. In this study, the equations derived by Millar (2005) will be used to estimate how channel width, and depth may change under various levels of net water withdrawal from the Wapiti River.

Results

The Millar (2005) equations for channel width and depth are:

$$W^* = 16.5Q^{*0.70}S^{0.60}\mu'^{-1.10} \quad (1)$$

$$D^* = 0.125Q^{*0.16}S^{-0.62}\mu'^{0.64} \quad (2)$$

Where, W^* is the non-dimensional channel width, D^* is the non-dimensional channel depth, Q^* is the non-dimensional bankfull discharge, S is the channel slope, and μ' is a unitless measure of the erodibility of the channel bank relative to the channel bed. The parameters were non-dimensionalized by the following relationships:

$$W^* = W/d_{50} \quad (3)$$

$$D^* = D/d_{50} \quad (4)$$

$$Q^* = \frac{Q}{{d_{50}}^2\sqrt{g d_{50}(s-1)}} \quad (5)$$

Where, *W* is the channel width, *D* is the channel depth, *Q* is the bankfull discharge, d_{50} is the median particle size, *g* is the acceleration due to gravity, and *s* is the specific gravity of sediment. From Kellerhals *et al* (1972), for the Wapiti River near Grande Prairie, at a flow rate of 835 m^3/s the channel width is 168 metres and the channel depth is 2.65 metres. At this location, this flow represents a 2-year peak flow rate that is still confined to the banks of the Wapiti River. This flow rate will therefore represent the bankfull discharge for this analysis. Since bankfull discharges typically fall in the range of 2 to 5 year peak flows, this represents a conservative estimate.

Kellerhals *et al* (1972) also identifies the d_{50} at this location as 48 mm. The specific gravity of the sediment is assumed to be approximately 1.7, which is typical for gravel sediment. The slope of the Wapiti River near Grande Prairie was found to be 1.7 m/km from the Government of Alberta's digital elevation model.

From Millar (2005), a value for μ' can be calibrated from:

$$W/D = 155 {Q^*}^{0.53} S^{1.23} \mu'^{-1.74} \quad (6)$$

From Equation 6, and the observed ratio W/D = 168 m/2.65 m = 63.4, μ' can be found to be 1.08. Equations 1 and 2 can now be used to estimate the geomorphically stable channel characteristics of the Wapiti River for any given bankfull discharge, channel slope, and sediment material. The resulting channel width and depths are W = 183 m and D = 2.78 m, which compares favourably with the observed values of 168 m and 2.65 m. The Millar (2005) equations can therefore be used to estimate potential changes in geomorphology of the Wapiti River for different volumes of water use by analysing the changes in the 2-year discharge.

Conclusions

Channel width is more sensitive than channel depth to changes in channel forming discharge (Table 1). To produce a 1% reduction in channel width, the channel forming flow needs to decline by 11.9 m^3/s while a 1% reduction in channel depth would require a 50.9 m^3/s reduction in flow. 11.9 m^3/s is equivalent to a net annual withdrawal 377 million m^3. Assuming that changes of less than 1% represent negligible changes in channel properties, a more detailed analysis of geomorphology for the Wapiti River is not necessary until net allocations in the Wapiti River exceed 300 million m^3/year or a significant hydraulic structure, such as a dam, is proposed.

It should be emphasized that this analysis is limited to estimating changes to the large scale geomorphology of the Wapiti River due to changes in river flows. Localized changes near intake and outfall structures are still to be expected and so this analysis does not mean that these localized effects are necessarily negligible.

References

Kellerhals, R., C. R. Neill, D. I. Bray, 1972, Hydraulic and Geomorphic Characteristics of Rivers in Alberta, Alberta Cooperative Research Program in Highway and River Engineering, 52 pages.

Millar, R.G., 2005, Theoretical regime equations for mobile gravel-bed rivers with stable banks, Geomorphology, 64, 207-220.

Singh, V. P., 2003, On the Theories of Hydraulic Geometry, International Journal of Sediment Research, 18, 196-218.

Table 1 – Changes in channel width and depth in response to changes in channel forming flow based on Millar (2005).

Q (m^3/s)	W		D	
	(m)	% change	(m)	% change
835.0	182.7	0.00%	2.779	0.00%
823.1	180.9	-1.00%	2.772	-0.23%
784.1	174.9	-4.31%	2.751	-1.00%