Institute of Hydraulic and Water Resources Engineering, Vienna University of Technology

River Engineering

Tutorial Sheet 2 – Effects of an obstruction in a river

1. Write a short essay, possibly in bullet point form and without mathematics, describing the operations and approximations required to obtain the formula for the water level drop across an obstruction:
$$\frac{\Delta\eta}{A/B} = \frac{\frac{1}{2}\,\Gamma\, C_{\mathrm{D}}\, \mathsf{F}^2}{1-\beta\mathsf{F}^2}\frac{a}{A}, \tag{1}$$
where we have dropped the subscripts 2 (for downstream) used in the lecture notes.

2. Obtain the expression
$$\mathsf{F}^2 = \frac{U^2}{gA/B} = \frac{S}{\Lambda}\frac{B}{P}. \tag{2}$$
from the Chézy-Weisbach resistance formulation, using the lecturer's notation $\Lambda = \lambda/8$.

3. Making the wide-channel approximation $P \approx B$, and for small Froude number $\mathsf{F}^2 \ll 1$, show that if the elevation loss due to resistance in uniform flow in a length of channel L is $\Delta Z = SL$, then the ratio of the two elevation losses is
$$\frac{\Delta\eta}{\Delta Z} \approx \tfrac{1}{2}\,\Gamma\, C_{\mathrm{D}}\frac{a}{A}\frac{A}{B}\frac{1}{\Lambda L}\ ,$$
(note: we have not cancelled the A factors: it is nicer to keep the blockage ratio a/A and the mean depth A/B, for which we can estimate reasonable values) and so if we make the quite reasonable approximations $\Gamma \approx 1$ and $C_{\mathrm{D}} \approx 1$, then the length of channel equivalent to the loss at the bridge is
$$\frac{L}{A/B} = \frac{\text{Equivalent length}}{\text{Mean depth}} = \tfrac{1}{2}\frac{a}{A}\frac{1}{\Lambda}\ .$$

4. Now consider a blockage of say 10% and a minimum value of $\Lambda = 5\times10^{-2}$ on page 31 of the lecture notes, the ratio of length/depth is
$$\frac{\text{Equivalent length}}{\text{Mean depth}} \approx \tfrac{1}{2}\times 0.1 \times \frac{1}{5\times10^{-2}} = 1\ ,$$
which can be neglected in a numerical model.

5. But, a keen student will observe, that on page 59 we found in an example "this would correspond to the surface level change in a length of $400\ \mathrm{m}$, which can hardly be neglected". What is the difference between that and here? The lecturer has been guilty of misrepresentation: in that example he used $\mathsf{F} = 0.5$ and $S = 10^{-4}$, which means $\Lambda \approx S/\mathsf{F}^2 = 10^{-4}/0.25 = 4\times10^{-4}$, far too small for any real river (p31 of the notes). He did, however, then write "In most rivers F is rather smaller than this, and the effect is small. We might have saved ourselves an expensive laboratory program", which was correct as we have seen here.

6. Has the lecturer been wasting our time? No, we have learnt that the effect is probably small and that we do not have to include it, although in some high blockage cases it is necessary. The lecturer hopes that students might appreciate the value of an analytic solution.