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EXTENDED ABSTRACT

Simulation of Flow Hydraulics and Sediment Load in River Bends (Case Study: Karoun river)

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Introduction

Simulation of lateral distributions of velocity and suspended sediment concentration in river bends is of great significance, and has many applications for river engineering projects. Due to secondary flow development, flow structure in river bends has 3-dimensional nature. As shown in Fig. 1, the secondary flow, coupled with the longitudinal primary movement, causes a helical flow that forms in the river bend (Perkins, 1970). In this case, 1-dimensional mathematical models (e.g. HEC-RAS, MIKE-11 and ISIS) are generally not satisfactory and 2 or 3-dimensional mathematical models should be used instead. However, the large amount of computational time needed to simulate flow field in rivers by 3D or 2D mathematical models, justifies the use of quasi 2D modes. Among the numerous quasi 2D models, the Shiono and Knight model has attracted great attention of river engineers. This mathematical model is based on the depth averaged integration of Navier-Stocks equations. Due to suitable form of in this study, at first with field measurement of lateral distributions of velocity and suspended sediment concentration in three bends located at the Karoun river (namely Maliheh, Jangieh and Khabineh), the Shiono and Knight quasi-two dimensional model (1991) has been calibrated. Using the lateral velocity profiles obtained by this mathematical model, sediment transport capacities were computed. The results showed that in all three river bends, among the empirical sediment equations selected for this study, the sediment transport equation of Yang has very well agreement with the measured lateral suspended sediment concentration, in comparison to the Ackers-White and Engelund-Hansen equations.

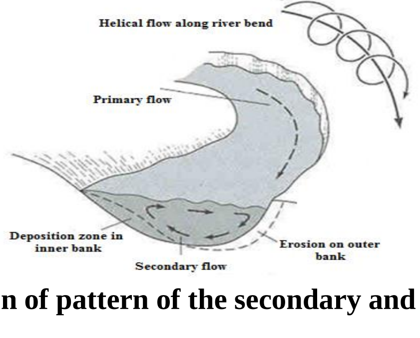

Fig. 1– Representation of pattern of the secondary and helical flows in a river bend

Methodology

Lateral velocity distribution

For straight simple and compound channels under uniform flow, Shiono and Knight (1991) developed a well-known mathematical model named SKM for prediction of depth-averaged velocity based on the combination of continuity and momentum equations as follows:

$$\rho g H S_0 - \rho \frac{f}{8} u_d^{\,2} \sqrt{1+\frac{1}{s^2}} + \frac{\partial}{\partial y}\left\{ \rho \lambda H^2 \left(\frac{f}{8}\right)^{1/2} u_d \frac{\partial u_d}{\partial y} \right\} = \underbrace{\frac{\partial \rho H (\overline{U}\overline{V})_d}{\partial y}}_{\Gamma} \qquad (1)$$

where (g) is the gravitational acceleration, (H) is the water depth, (S_0) is the bed slope, (f) is the Darcy– Weisbach friction factor, (u_d) is the depth-averaged stream-wise velocity, s is the main channel lateral side slope, and (λ) is the dimensionless eddy viscosity. $(\overline{\mathrm{U}})$ and $(\overline{\mathrm{V}})$ are the longitudinal and transverse time-averaged velocity components in the x and y directions, respectively. The (x) axis is parallel to the main channel flow and the (y) axis is normal to the x axis in the horizontal plane. Equation (1) has four distinct components or terms. On the left hand side of the equation, the three terms are the flow weight component (or hydrostatic pressure term, $(\rho g H S_0)$, bed shear stress component (the second term), and turbulence component arising from Reynolds shear stress (the third term), respectively. The right hand side term (Γ) defines the secondary flow effect that is more significant in the meandering channels.

Lateral distribution of sediment concentration

The detailed equations by the three methods are given in Table (1).

Table 1– Empirical equations of sediment transport selected for this study

Researchers	Equation
Ackers and White (1973)	$Q_t = QC\frac{d_{50}}{R}\left(\frac{V}{u_*}\right)^n\left(\frac{F_g}{A}-1\right)^m$ $F_g = \frac{u_*^n}{\sqrt{gd_{50}(G_s-1)}}\left(\frac{V}{\sqrt{32\log(10R/d_{50})}}\right)^{1-n}$
Engelund and Hansen (1967)	$Q_t = 0.05Q\,\frac{G_s}{G_s-1}\frac{VS_0}{\sqrt{(G_s-1)gd_{50}}}\frac{RS_0}{(G_s-1)d_{50}}$
Yang (1979)	$\log C_t = I + J\,\log\left(\frac{VS_0}{w}\right)$ $I = 5.165 - 0.153\log\frac{wd_{50}}{\nu} - 0.297\log\frac{u_*}{w}$ $J = 1.780 - 0.360\log\frac{wd_{50}}{\nu} - 0.480\log\frac{u_*}{w}$

Notes: Q_t is the total sediment discharge, C_t is the total sediment concentration, Q is the flow discharge, u_* is the shear velocity, V is the flow velocity, R is hydraulic radius, S_0 is the bed slope, d_{50} is the mean sand diameter, G_s is the sediment specific gravity, w is the sand settling velocity, g is acceleration due to gravity, ν is the fluid kinematic viscosity, and n, A, m and C are constant parameters in Ackers-White equation.

Results and Discussion

Lateral velocity distribution prediction

As can be seen in Fig. 2, this procedure has led to a good fit for calculated and measured flow velocities for the three river bends.

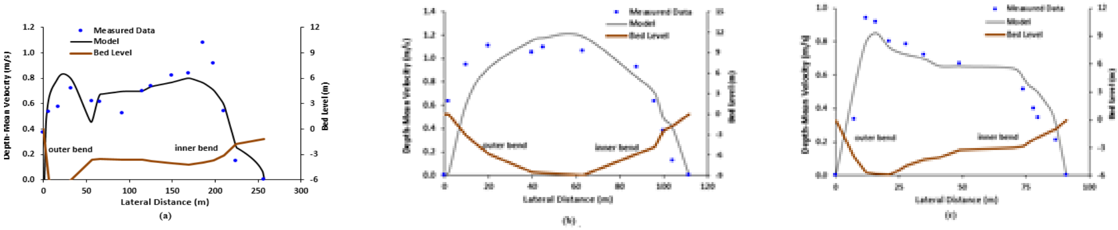

Figure 2– Comparison of computed and measured lateral distribution of flow velocity in three selected bends, a) Jangieh, b) Khabineh and c) Maliheh

Prediction of lateral sediment transport distribution

Following the computation of lateral velocity distribution in river bends, the obtained depth averaged velocities were utilized in sediment transport formulas to compute the lateral distribution of total sediment concentration. The results showed that in all three river bends, among the empirical sediment equations selected for this study, the sediment transport equation of Yang has very well agreement with the measured lateral suspended sediment concentration, in comparison to the Ackers-White and Engelund-Hanssen equations Fig (3).

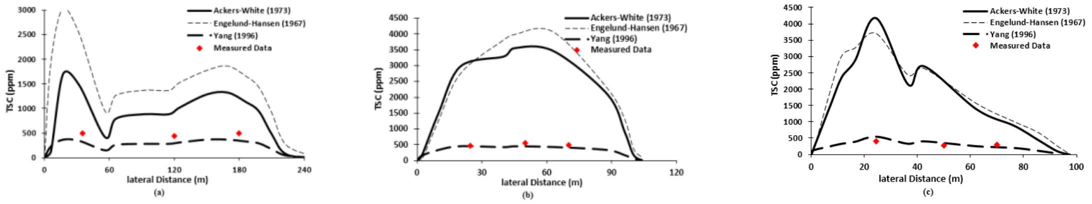

Figure 3– Comparison of lateral distribution of total sediment concentration (TSC) obtained by three empirical sediment transport equations with measured values in the three selected bends, a) Jangieh, b) Khabineh and c) Maliheh

Conclusions

Results of this study showed that the predicted lateral velocity distributions has a good agreementwith the measurements, and that the maximum relative error for the flowrate prediction is about 5%. For sediment transport prediction, it is found that the Ackers-White and Engelund-Hansen equations over-predicted the sediment concentration with large errors up to 450%; however, Yang equation has shown a much more reliable prediction of sediment concentration compared with the Ackers-White and Engelund-Hansen methods. Because the unit stream power is the basis of Yang equation derivation and in this theory, the transport of each sediment particle mainly depends to its flow velocity; hence ,the Yang sediment transport equation has shown higher accuracy for given reliable velocity.

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