Toward nonlinear modeling of meander evolution

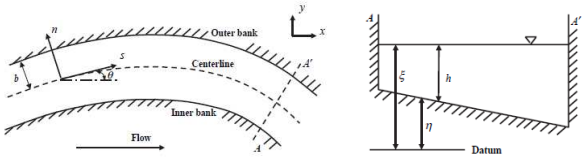
Dong Chen[1], Yun Zhang[2], Willem Ottevanger[3], Koen Blanckaert[3], Leilei Gu[1]

1. Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
2. Environmental Fluid Mechanics Laboratory, Department of Civil and Environmental Engineering, Stanford University, Stanford, USA
3. Department of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

1. Motivation & Purpose

This study aims at modeling the evolution of meanders by coupling the Bank Erosion and Retreat Model (BERM, by Chen and Duan, 2006) with a nonlinear flow model (by Blanckaert and de Vriend, 2010).

1.1 Linear flow method



(a) (b)

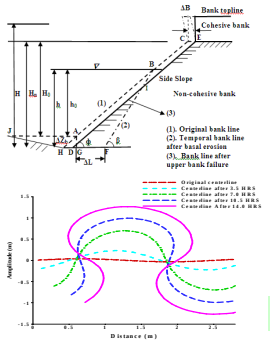
Fig. Definition of variables and coordinate system: (a) plain view;(b) channel cross-section

$$\frac{u-U}{U} = Nbk\theta_0[-\alpha\cos(ks)+\beta\sin(ks)]$$ **By Johannesson & Parker (1989)**

$$\alpha = \frac{kHC_f(A+A_s+F^2+1)}{H^2k^2+4C_f^2}$$ **Assume:** $\theta=\theta_0\cos(ks)$

$$\beta = \frac{2C_f^2(A+A_s+F^2-1)-H^2k^2}{H^2k^2+4C_f^2}$$ **Assume: db/ds=0; r >> b; λ >> b**

1.2 Bank Erosion & Retreat Model (BERM)



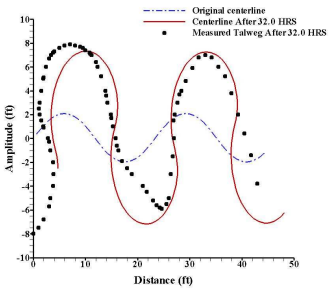


Fig. Comparison of the analytical solution of linear model and experimental result (Friedkin,1945)

1.3 Nonlinear flow method

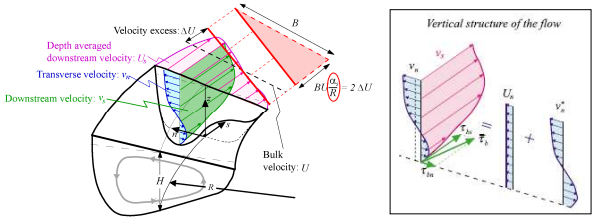


Fig. Schematization of flow structure in a bend; definition of reference system and notations used in the non-linear flow model (adapted from Blanckaert & de Vriend 2010)

2. Theory – physical process which redistribute flow in curved channels

$$\lambda_{\alpha s/R}\frac{\partial}{\partial s}\left(\frac{\alpha_s}{R}\right)+\frac{\alpha_s}{R} = F_{\alpha s/R}$$

$$\lambda_{\alpha s/R} = \frac{1}{2}\frac{H}{\psi C_f}\left\{1-\frac{1}{12}\frac{\alpha_s+1}{R}\frac{B^2}{R}\right\}$$

By Blanckaert & de Vriend (2010)

(Extra terms compared to linear model by Johannesson and Parker (1989))

$$F_{\alpha s/R} = \frac{1}{2}\frac{S_n Fr^2+A-1}{R} - \frac{1}{2}\frac{H}{\psi C_f}\frac{\partial}{\partial s}\left(\frac{1}{R_s}\right)\left(1-\frac{B^2}{6R^2}\right) + \frac{4\chi}{\psi C_f}\frac{H^2}{B^2}\frac{\langle v_s v_n^*\rangle}{HU^2}\left[1+\frac{1}{12}\frac{(S_n Fr^2+A+3)B^2}{R^2}\right] + \frac{1}{24}\frac{H}{\psi C_f}\frac{B^2}{R^2}\frac{\partial}{\partial s}\left(\frac{S_n Fr^2+A}{R}\right)$$

Transverse water surface and bed slope

Changes in curvature

Streamwise momentum redistribution by secondary flow

Cross-flow due to changes in transverse water surface and bed slope

3. Verification of linear & nonlinear flow models

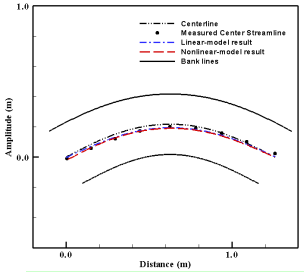


Fig. Compare results of two methods with measurement (Silva, 1995, θ_0 = 30°)

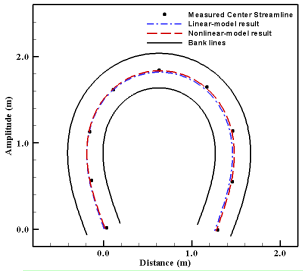


Fig. Compare results of two methods with measurement (Silva, 1995, θ_0 = 110°)

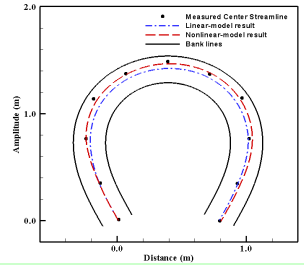


Fig. Compare results of two methods with measurement (Whitening & Dietrich, 1993, θ_0 = 115°)

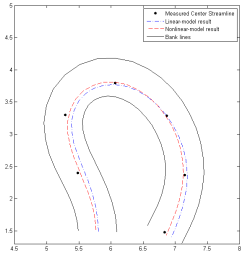


Fig. Compare results of two methods with measurement (Kinoshita flume, Abad and Garcia, 2009) (adapted from Ottevanger et al., 2012)

4. Flowchart for meander evolution model

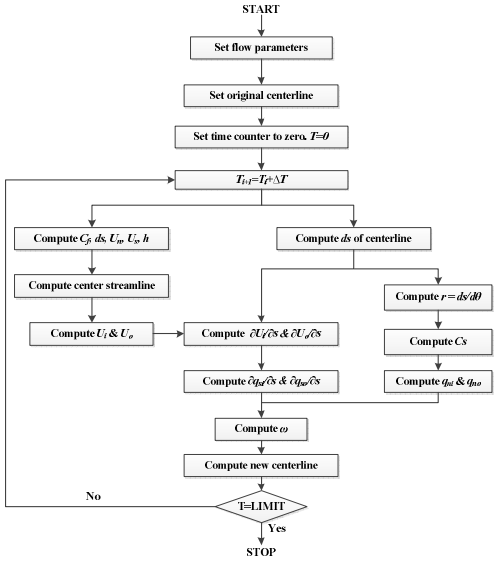


Fig. Flowchart of the calculation process

5. Conclusions

- ✓ **The results of linear & nonlinear flow models are similar in mildly curved channels with a flat bed.**
- ✓ **Linear models overestimate streamwise momentum redistribution by secondary flow in strongly curved channels.**
- ✓ **The nonlinear flow model gives a better result in high-sinuous channels with transverse bed slope.**
- ✓ **A better meander evolution model is expected and being built by coupling the Bank Erosion and Retreat Model (BERM, by Chen and Duan, 2006) with a nonlinear flow model (by Blanckaert and de Vriend, 2010).**

6. References

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