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Modelling of river network with widespread floodplain valleys

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Table of Contents

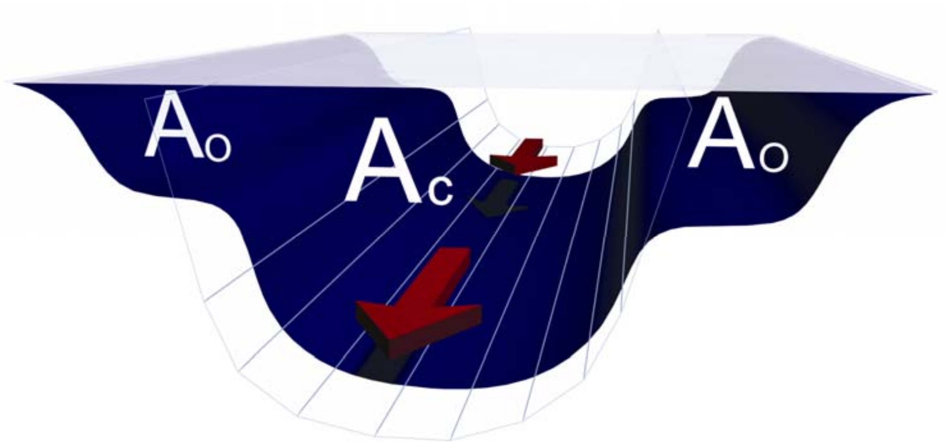
Introduction

- 1D models – most popular tools for modelling of unsteady flow in river networks,
- 1D models provide a good representation of flow transformation as long as the conditions of flow are close to the assumptions of 1D motion,
- Modelling of river network with wide floodplain valleys – 1D models do not provide a good representation of flow transformation.
- Flow movement in floodplains may not be regarded as one-dimensional (particularly in the initial phase of filling the valley with water and in the closing phase, when water returns to the main channel).
- One of the methods used to provide better representation of flow transformation in river network with wide floodplain valleys for 1D flow models is to split the river cross-section into its active and inactive zones.
- The fundamental difficulty is to determine the range of active cross-section.

Basic equations of one-dimensional unsteady flow in open channels (de Saint Venant equations)

The mass conservation equation

$$\frac{\partial Q}{\partial x} + \frac{\partial (A_c + A_o)}{\partial t} = q$$



The momentum equation

$$\frac{\partial Q}{\partial t} + \frac{\partial (\beta Q^2 / A_c)}{\partial x} + gA_c\left(\frac{\partial h}{\partial x} + S_f + S_{ec}\right) + W = 0$$

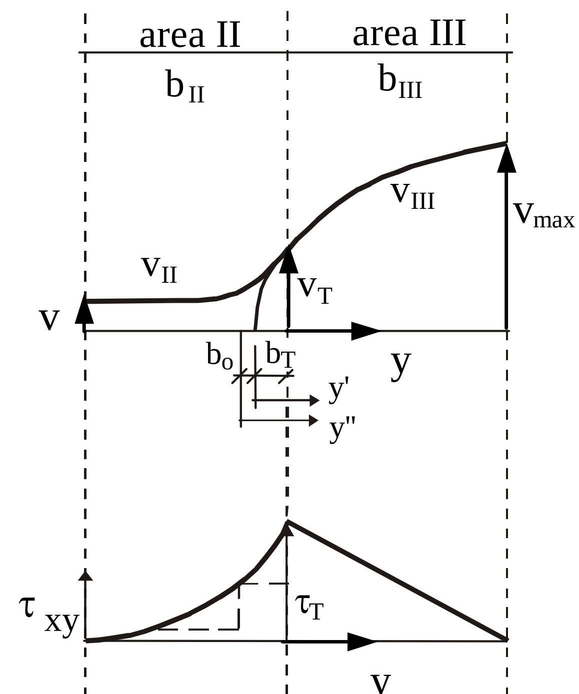
Active flow zone- method of determination

Pasche method is used to determine range of active cross section. It is assumed that the active part of cross-section consists of the area which determines inbank capacity and of the b_{II} zone of interaction between the main channel and floodplains, calculated according to formula :

$$b_{II} = \frac{c\,h_T}{\lambda_z\left(0.068e^{0.56\,C_T} - 0.056\right)}$$

distribution of depth-averaged flow velocities in the cross-section

distribution of turbulent stress in the cross-section

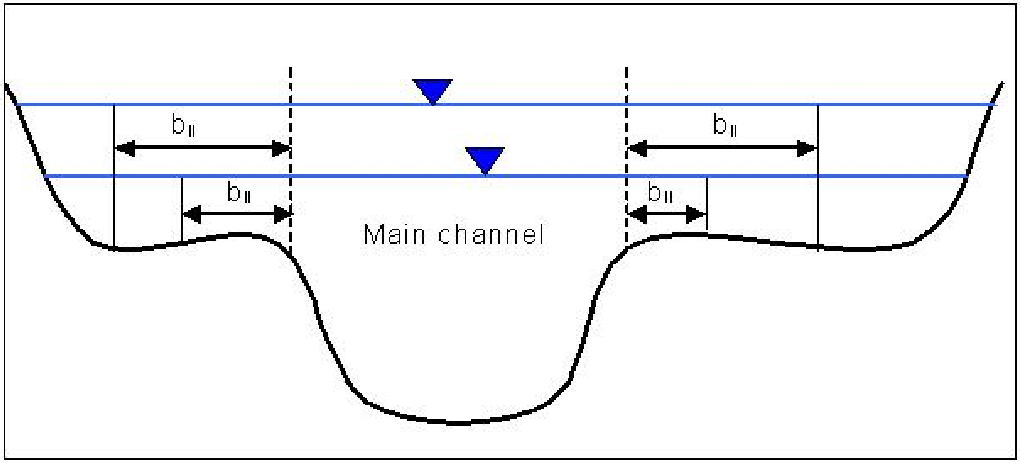


where: λ_z – coefficient of floodplain drag [-], h_T – depth in the dividing plane, c = 1.0 for floodplains,

c = 1.7 for slopes, C_T – slip-velocity .

Active flow zone- method of determination

$$b_{II} = \frac{R_{hz}^{\frac{4}{3}}}{8\, g\, n_z^2 \left(0.068 e^{0.56 C_T} - 0.056\right)}$$



Where: *R_{hz}* – hydraulic radius of floodplain [m], *n_z* – floodplain roughness coefficient[$sm^{-1/3}$], *C_T* – slip-velocity in Pasche's method [-].

Computer implementation

The above assumptions have been implemented in the unsteady flow modelling system SPRUNER developed at the Faculty of Land Reclamation and Environmental Engineering at the University of Life Sciences in Poznan.

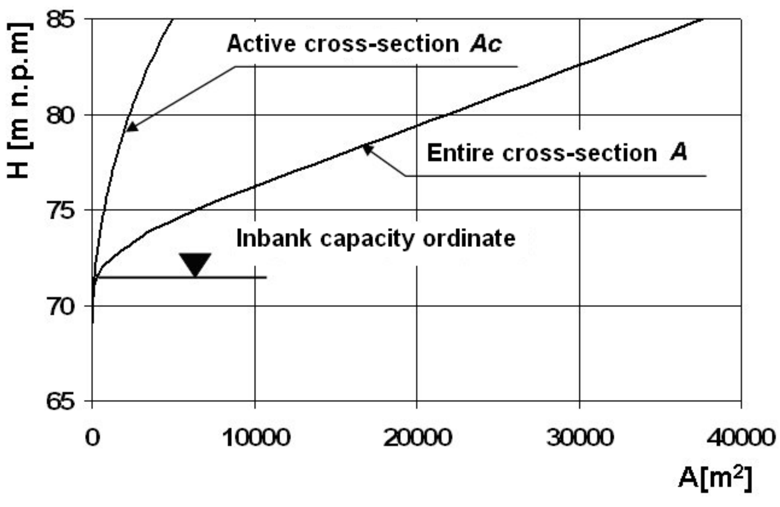
The system determines the active flow zone according to the following scheme:

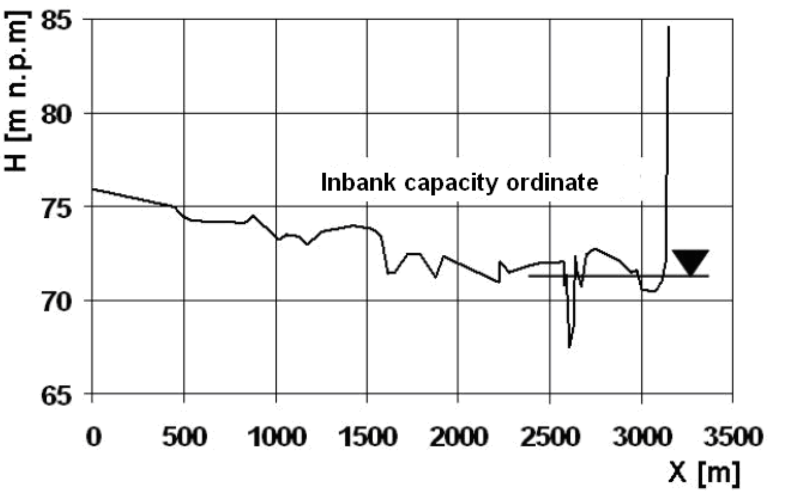
- for water levels below inbank capacity, the active zone and the overall cross-section coincide,
- for water levels exceeding inbank capacity, for each tabulated water level ordinate the range of active zone is calculated according to the above formula for both the left and the right bank,
- given the range of active zone, the surface area *Ac(h)* is calculated, together with all other parameters required for numerical solving of de Saint-Venant equations.

Each cross-section corresponds to two sets of data, separately for the active part and for the entire flow area. The system also stores the values of C_T for each cross-section, separately for the left and the right floodplain. This parameter is considered a model-specific constant, the value of which can be determined in the process of calibration the model to the real situation.

Active flow zone for selected cross-sections of the Warta river (1)

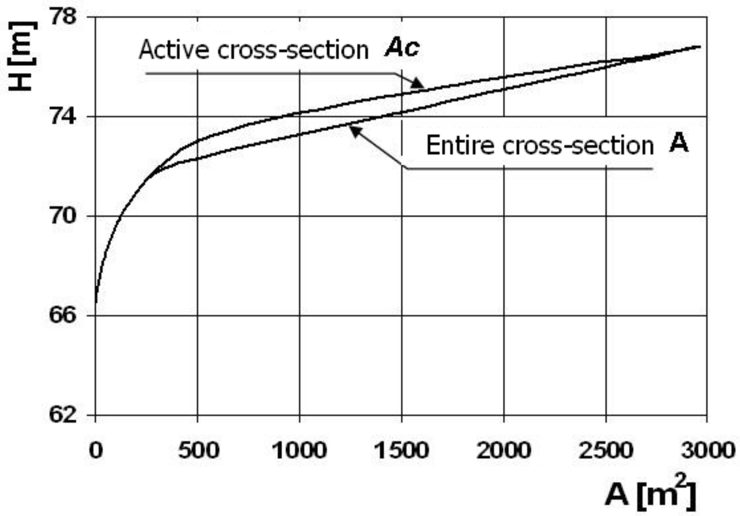
The size of the active part of the cross-section (as a function of water depth) has been analysed for three characteristic river cross-sections of the Warta river

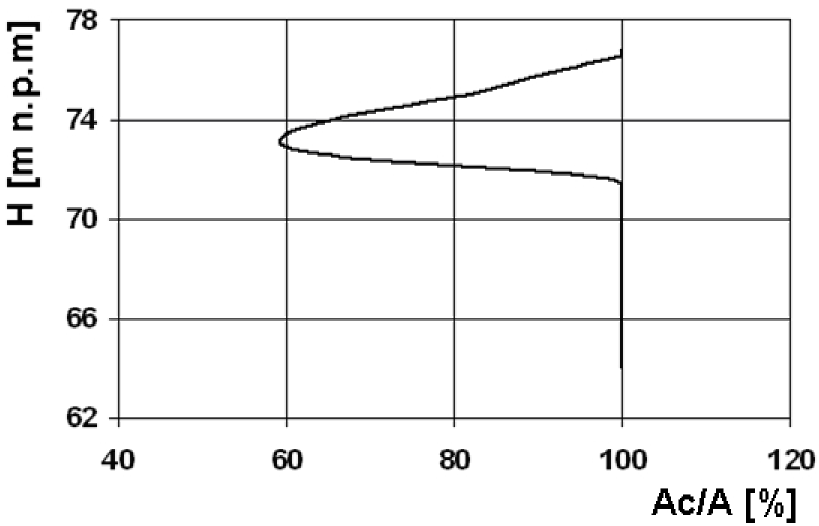




Cross-section of the Warta river at km 350+100.

Active flow zone for selected cross-sections of the Warta river (2)

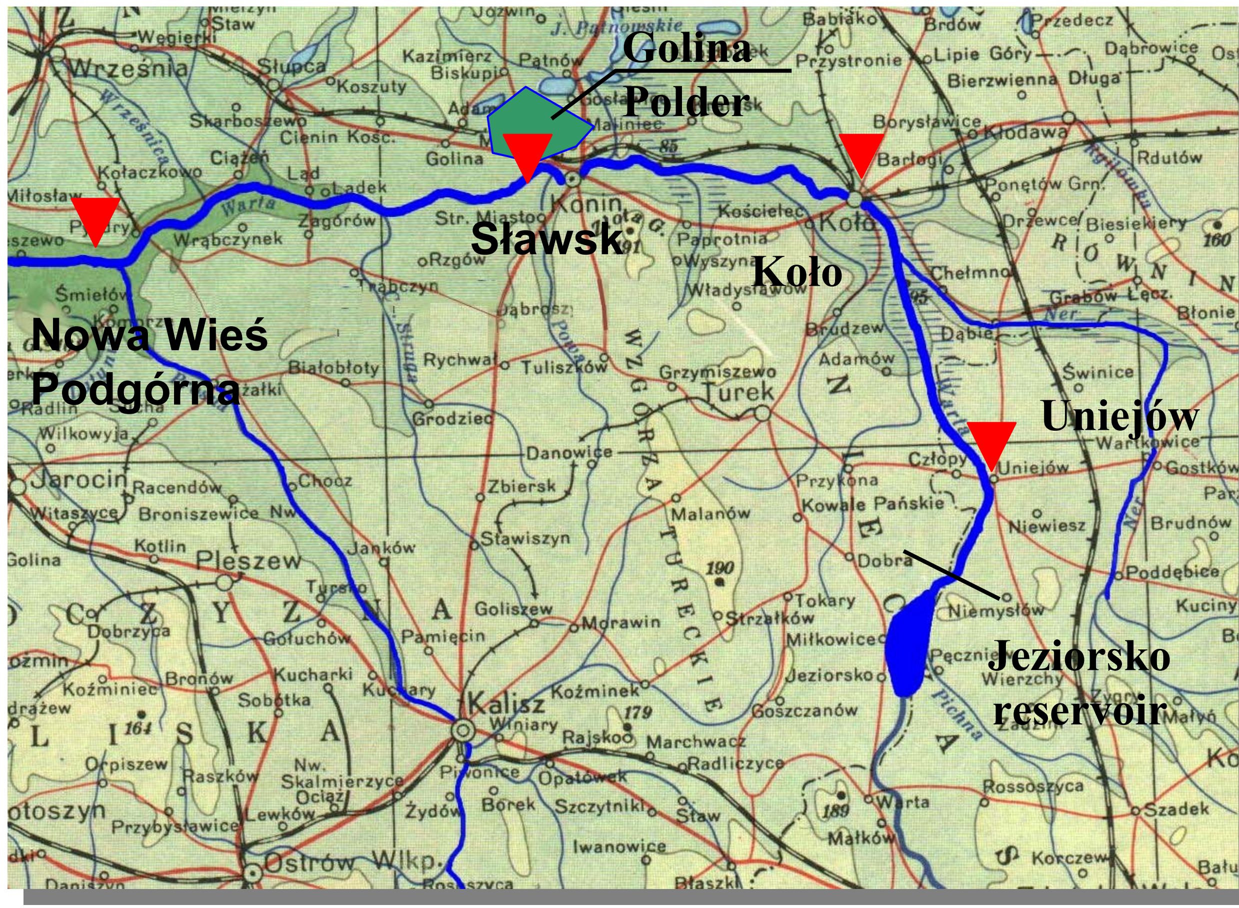




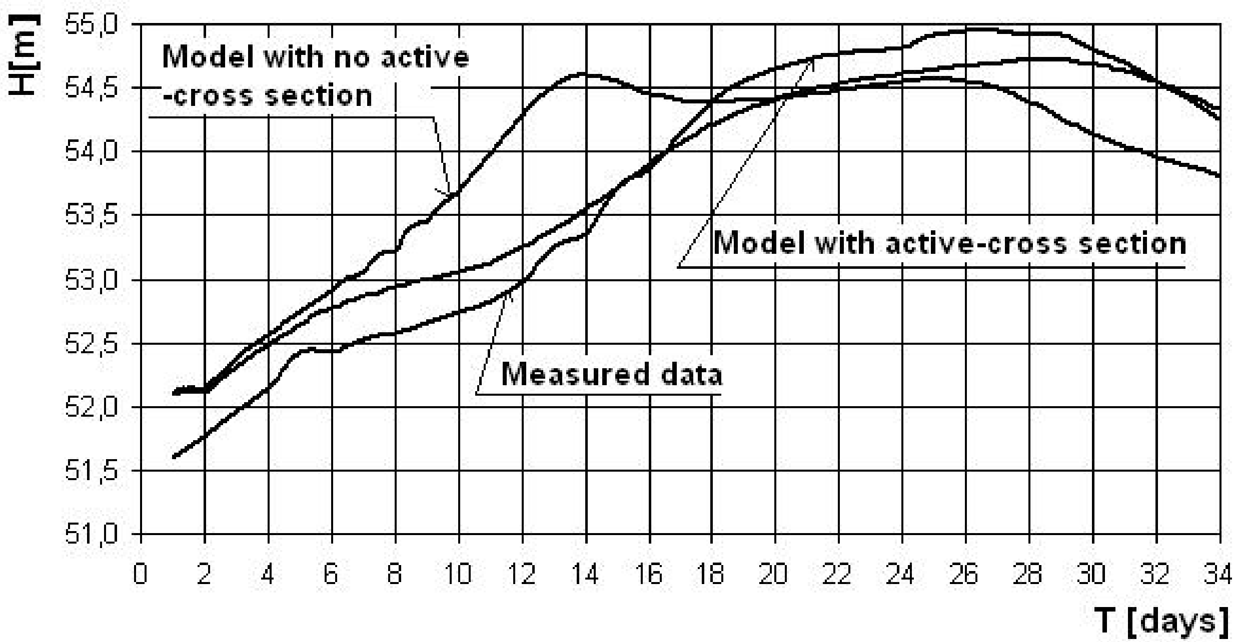
Cross-section of the Warta river at km 348+100

Numerical model of the Warta river section from the Jeziorsko reservoir to Oborniki (180 km)

The model comprised 244 computational sections, 221 cross-sections, 27 bridges, 4 by-pass channels (in Koło, Konin, Śrem and Poznań), 2 embankment weirs and one riverside reservoir (the Golina polder). Two tributaries – Prosna and Ner – were taken into account. Calculations were carried out for two variants: with and without the active zone. The model was also calibrated.



Numerical model of the Warta river section from the Jeziorsko reservoir to Oborniki – results



Conclusions

❑Schemes described in this paper, developed for the representation of wide floodplain valleys, introduce new parameters into one-dimensional unsteady flow models based on de Saint-Venant equations.

❑These parameters require calibrating in the process of calibrating the model to the real situation. In practice, for each simulation, in which a flood wave is analysed, a parameter must be chosen (in the above described scheme C_T) which determines the range of active zone and its water level-dependant behaviour.

❑No out of range roughness coefficient values are introduced into the model, which, in fact, indicates that either the physical background of the model is inadequate or the data describing the watercourse geometrics is uncertain, although geometry is generally considered reliable.