Andrzej Strużyński, Maciej Wyrębek, Mateusz Strutyński,
Krzysztof Kulesza

The lower part of the mountain river cross-sections change after the pass of the flood in summer 2010 by the means of the CCHE2D program

XXX School of Hydraulics
Wiejce, 16 September 2010

Presentation schedule

- focus to the research project
- Białka River description
- field works
- the goal of the investigation
- presentation of the results
- conclusions

Introduction - research project

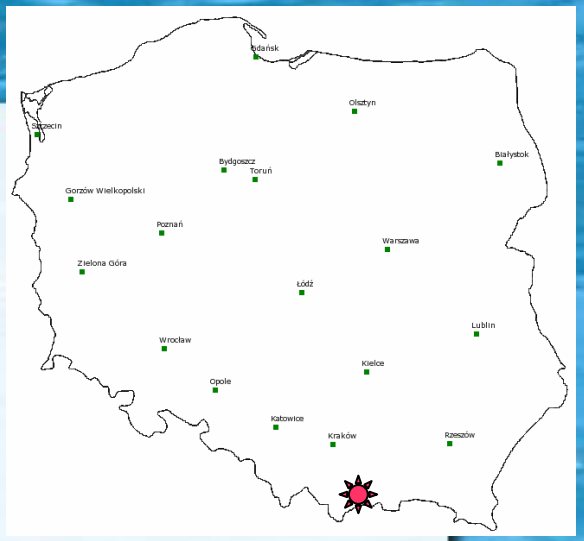
Project name:

“The valuation of balance of the mountain rivers and streams on the basis of their morphological conditions”
Nº: N N305 186537

Investigated objects (2009-2011):
Biały Dunajec, Czarny Dunajec, Białka, Porębianka, Mszanka

The research team:
- Institute of Meteorology and Water Management (IMGW),
- Agriculture University in Kraków (UR),
- Jagiellonian University (UJ).

The Białka River - introduction



Białka – mountain river.
sources – Tatra Mountains, altitude – 1420 m o.s.l.
outlet – Czorstyński lake, altitude – 529 m o.s.l.
basin area 229.9 km2, (in Poland 224.4 km2)
River length – 41 km

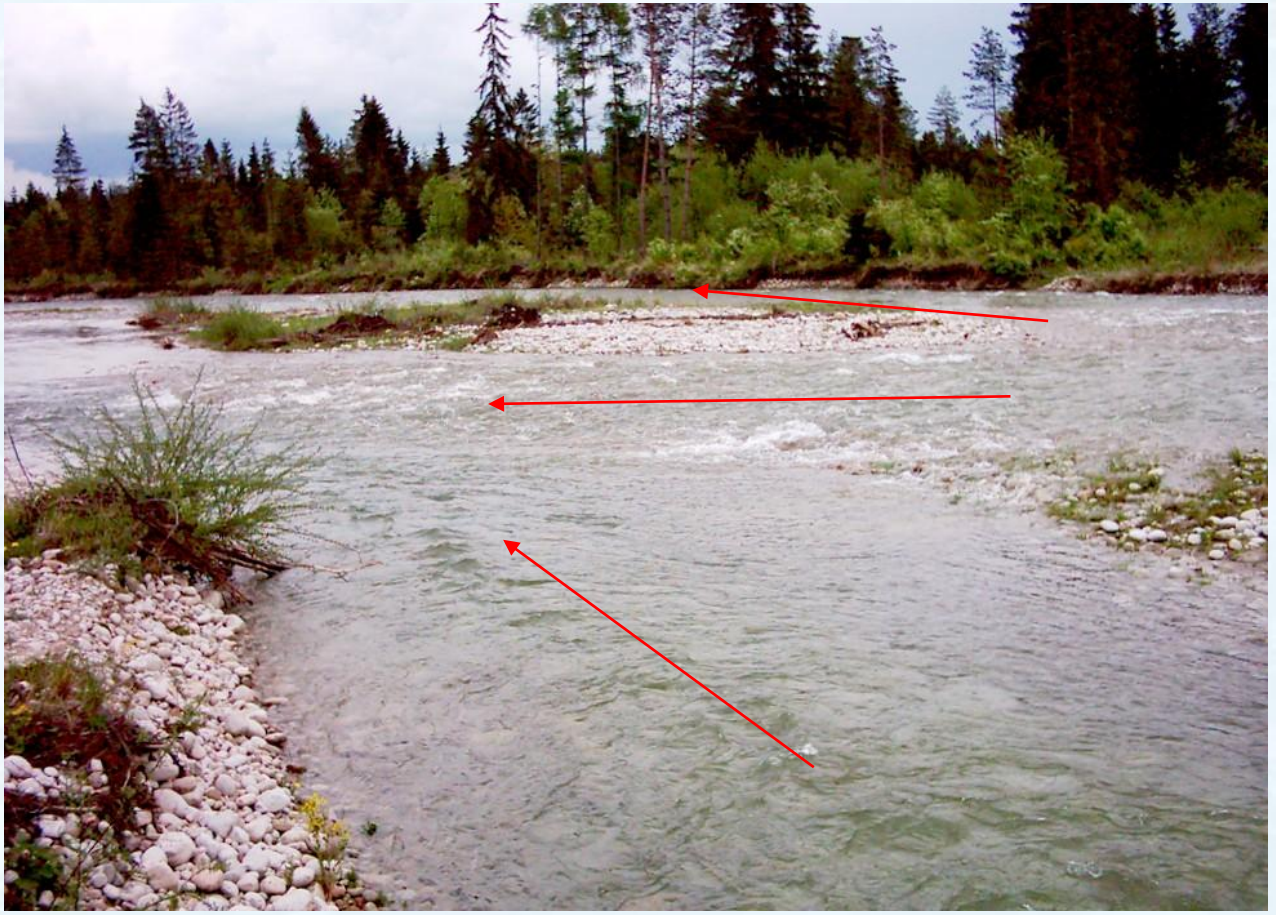
average flow – 5 m3/s, during spring and summer floods below 300 m3/s

The river is named Białka below the connection of the streams: Biela Voda and Rybi Potok.

Investigated river reach starts from the Białka month and runs 2350 meters upstream with the average slope of 1.04%.

Białka River on this reach is a braided river

The Białka River - introduction



The river channel is well developed with 1-3 braids
The main very steep branches are inaccessible since the flow depth reaches about 60-70 centimeters.

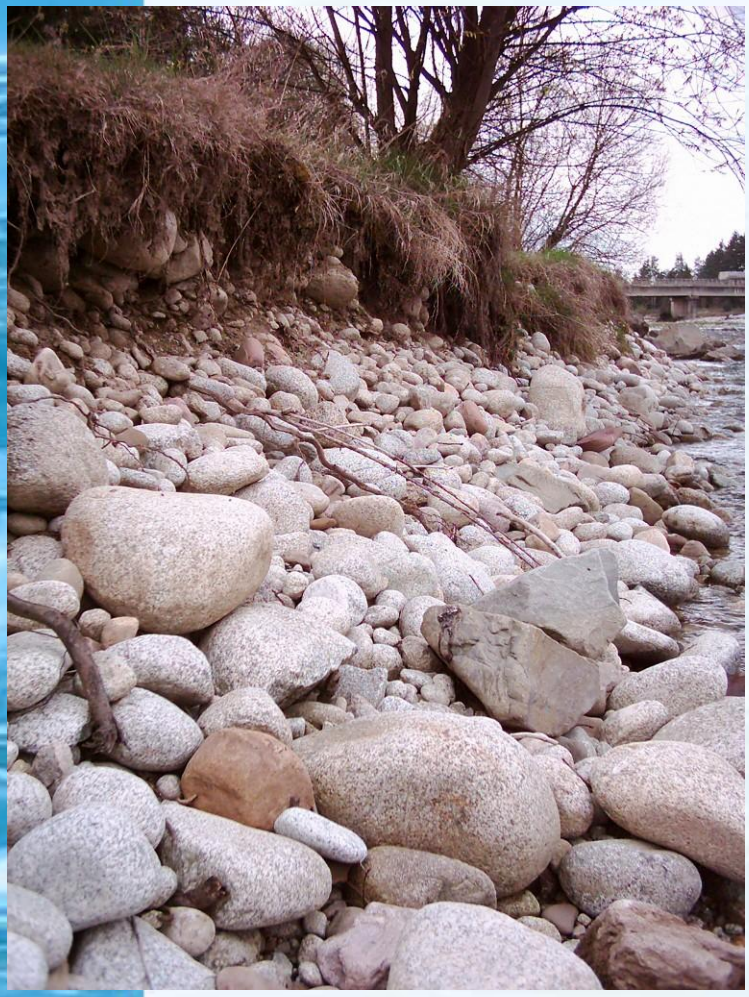
The Białka River - introduction

The water level in branches from the same cross-section can differ in the range of ten-odd centimeters.

The Białka River - introduction

Białka transports mainly sphere shaped granite boulders

The Białka River - introduction

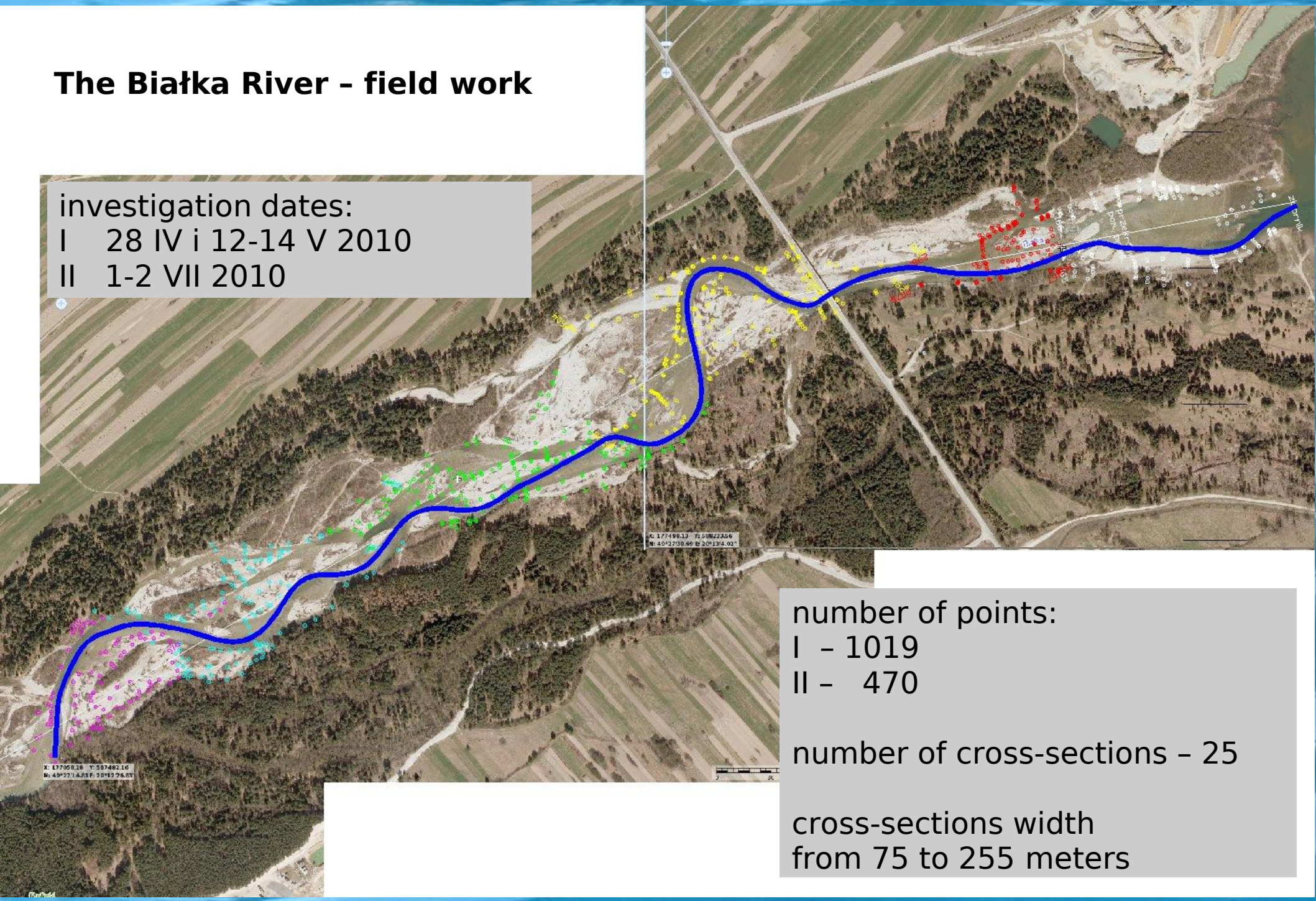


Białka transports mainly sphere shaped granite boulders

The goal of the investigations

- to perform the measurements of the bed change
- to perform the 2D simulation
- to verify the results of measurements and the CCHE2D modeling
- to check validity of the modeled bed change

The Białka River – field work



investigation dates:
I 28 IV i 12-14 V 2010
II 1-2 VII 2010

number of points:
I – 1019
II – 470

number of cross-sections – 25

cross-sections width
from 75 to 255 meters

The Białka River – field work

number of measured grains: 2422
number of localizations: 8

grain classes:
from sands to boulders and stones

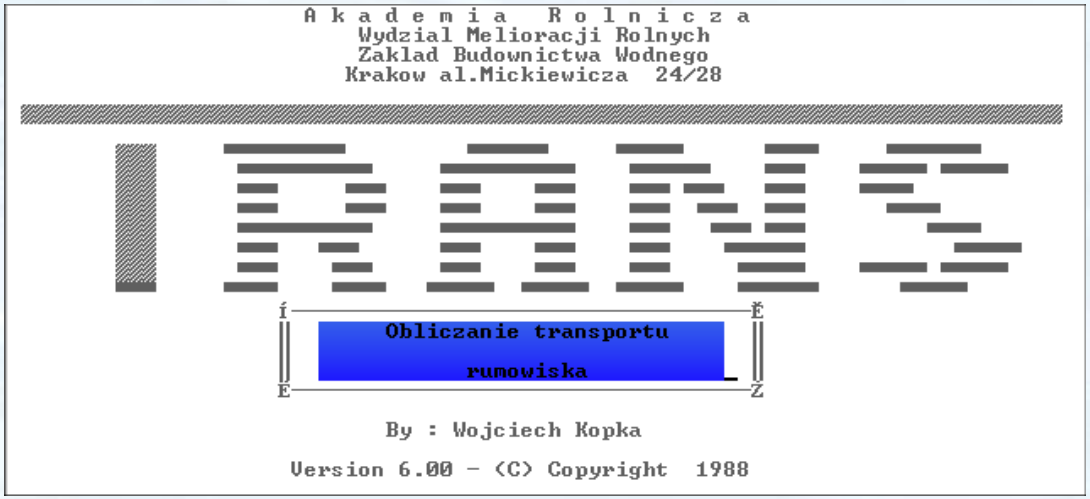
smaller grains – elongated discs, discs, sticks
bigger fractions –
ellipsoids, semi-spheres

Shape factor from 0.4 do 0.7
(average value – 0.6)

Material covering the bottom was measured by using of the photographic method

The Białka River – TRANS program

$$\gamma \frac{Q_m}{Q}\left(\frac{k}{k_m}\right)^{3/2} hI = A'\gamma_s' d + B'\left(\frac{\gamma}{g}\right)^{1/3} q_s'^{2/3}$$



Meyer-Peter, Müller

modified formula

$$q_{si} = \frac{\gamma \cdot h \cdot I - f_i' \gamma_s' d}{\gamma g \beta}$$

The Białka River – TRANS program

$$\tau_c = f_i g \Delta \rho_s d_i$$

$$\varepsilon = f_i / f_m = \left(d_i / d_m \right)^{-r}$$

$$f_i = \frac{f_{m1}}{1.786 \left(\frac{d_i}{d_m} \right)^{0.947}}$$

$$f_i = \frac{f_{m2}}{\left(\frac{d_i}{d_m} \right)^{0.314}}$$

Wang [1977]

[Bartnik, 1992]

$f_{m1} = 0.039\ \delta^{0.26}$ for $d_i/d_m < 0.6$

$f_{m2} = 0.028\ \delta^{0.26}$ for $d_i/d_m > 0.6$

$$f_m = 0.0123\ e^{1.6\ SF}$$

Bartnik [1997]

The Białka River – CCEH2D model

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Continuity Equation:

$$\frac{\partial Z}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0$$

Momentum Equations:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial Z}{\partial x}+\frac{1}{h}[\frac{\partial (h\tau_{xx})}{\partial x}+\frac{\partial (h\tau_{xy})}{\partial y}]-\frac{\tau_{bx}}{\rho h}+f_{Cor}v$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial Z}{\partial y}+\frac{1}{h}[\frac{\partial (h\tau_{yx})}{\partial x}+\frac{\partial (h\tau_{yy})}{\partial y}]-\frac{\tau_{by}}{\rho h}-f_{Cor}u$$

Bedload transport formula
Wu, Wang, Ja (2000)

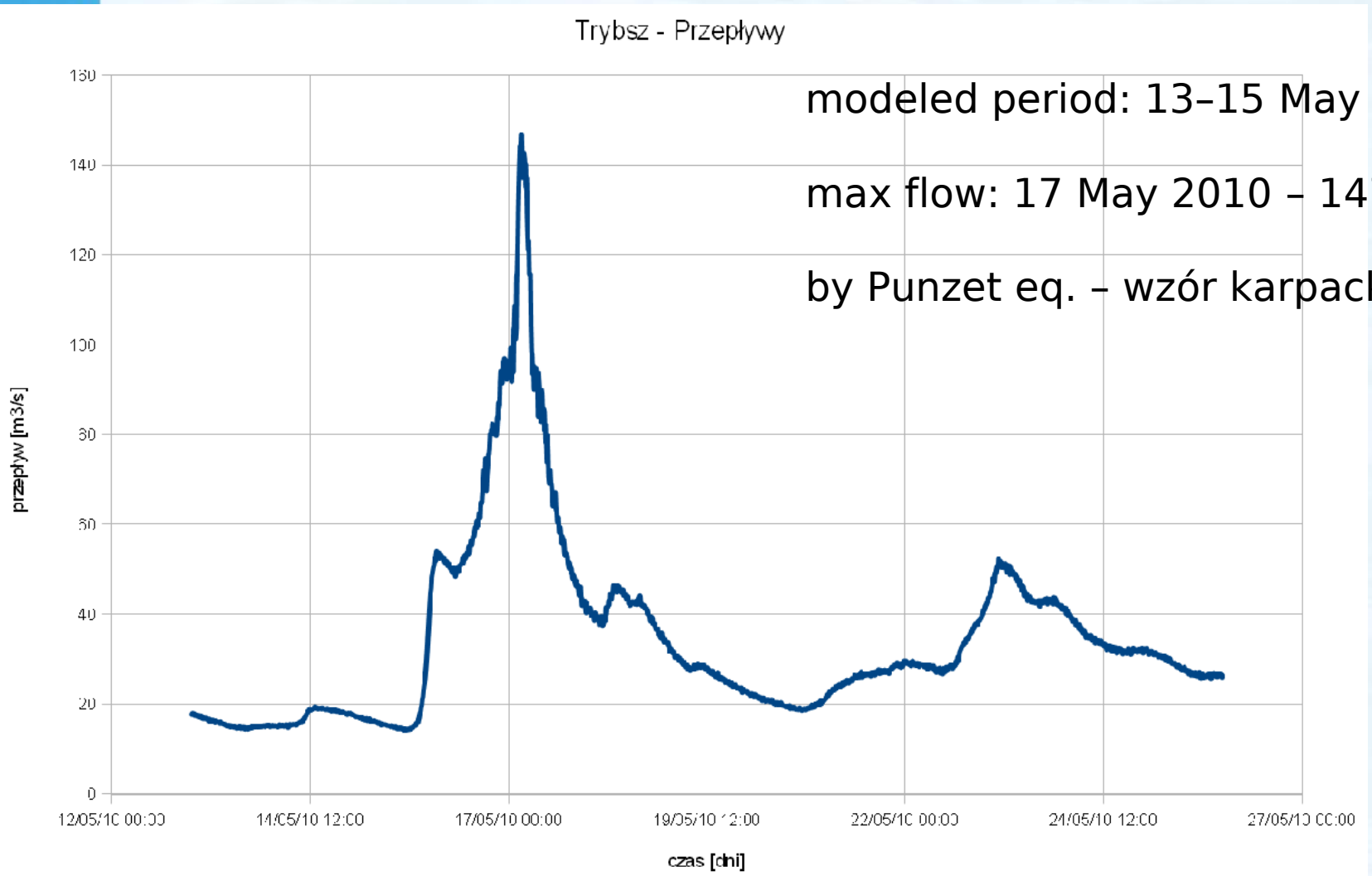
Data Source	Q (m^3/s)	U (m/s)	H (m)	S (10^{-3})	D_I (mm)	q_b ($10^{-3} m^2/s$)
Samaga (1986a)	0.006-0.015	0.49-0.78	0.06-0.11	4.49-6.93	0.073-2.366	0.04-0.22
Kuhnle (1993)	0.01-0.03	0.28-0.81	0.101-0.107	0.47-2.22	0.2-10	1.5e-6-0.064
Wilcock (1993)	0.017-0.057	0.26-1.08	0.088-0.12	0.59-16.2	0.21-64	8.7e-7-0.22
Liu (1986)	0.0035-0.023	0.14-0.67	0.03-0.083	1.5-4	0.31-30	4.9e-5-6.4e-4
Susitna River	799-2800	1.8-2.1	2.4-4.4	1.4-2.4	0.062-128	0.028-0.11
Chulitna River	261-348	1.5-1.8	1.7-1.9	0.64-0.74	0.062-128	0.11-0.23
Black River	20-256	0.44-1.0	0.55-1.9	0.11-0.29	0.062-16	0.0048-0.016
Toutle River	9.3-248	1.3-2.8	0.39-1.5	1.9-5.5	0.062-32	0.11-0.95
Yampa River	26.3-447	0.59-1.3	0.65-3.9	0.40-0.87	0.062-32	0.003-0.054

Weiming Wu (2001)

The Białka River – results and CCHE2D input data

Localization	probe number	d_m [cm]	d_{16} [cm]	d_{84} [cm]	d_{50} [cm]	δ [–]
right riverbank	1	10,99	4,3	16	9,8	1,93
10m upstream the river step	2	12,13	5,3	15,8	12,5	1,73
shallow flow	3	12,85	5,6	20,5	10,3	1,91
flow current downstream	4	30,19	11,6	42,1	28,5	1,92
gravel bar	5	8,21	3,1	12,7	5,9	2,02
flow current upstream	6	15,53	7,1	22,6	14,75	1,78
fine material on the bank	7	6,38	1,7	10,7	5,1	2,51
rough material on the bank	8	17,13	6,5	26,7	14,75	2,03

The Białka River – flow data, CCHE2D input data

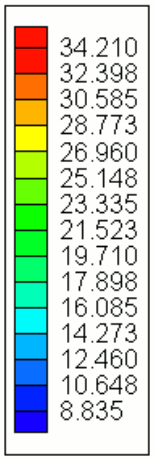


modeled period: 13–15 May 2010 r.

max flow: 17 May 2010 – 147 m3/s

by Punzet eq. – wzór karpacki - Q 30%

Data from Trybsz measuring station



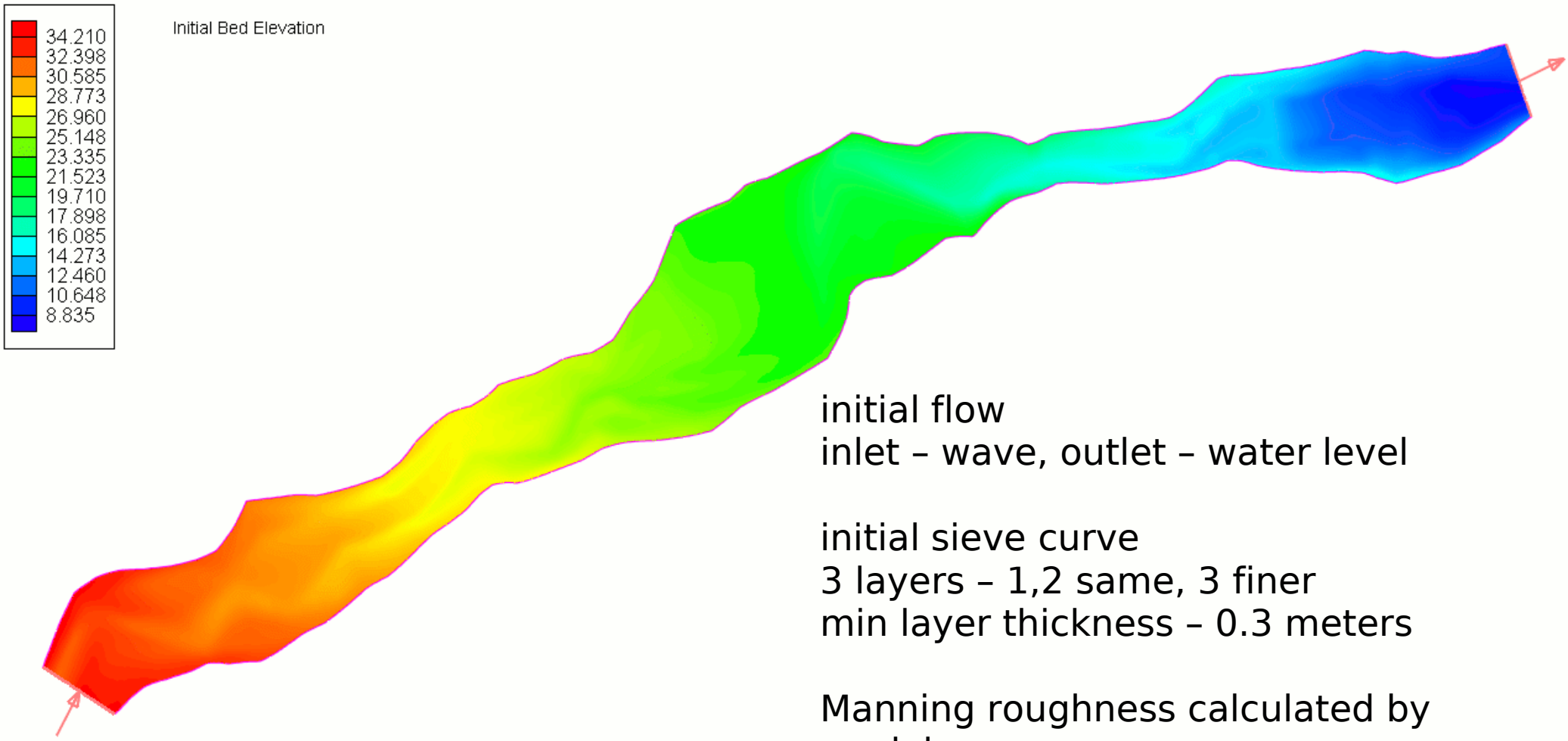
Initial Bed Elevation

The Białka River – CCHE2D input data

i lines - 50
j lines - 801
cells – 40 050

Time = 0(d): 0(h): 0(m): 0(s)

The Białka River – CCHE2D input data



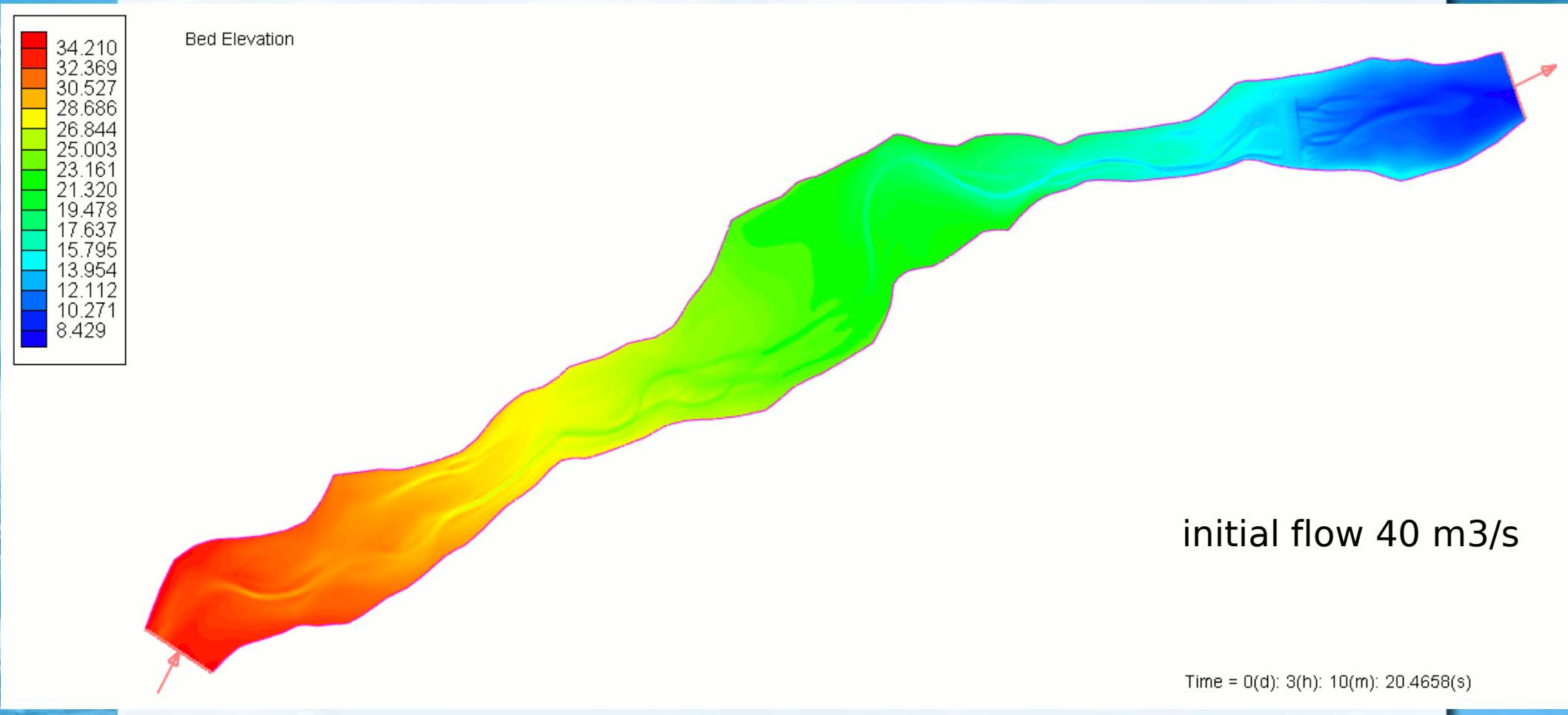
initial flow
inlet – wave, outlet – water level

initial sieve curve
3 layers – 1,2 same, 3 finer
min layer thickness – 0.3 meters

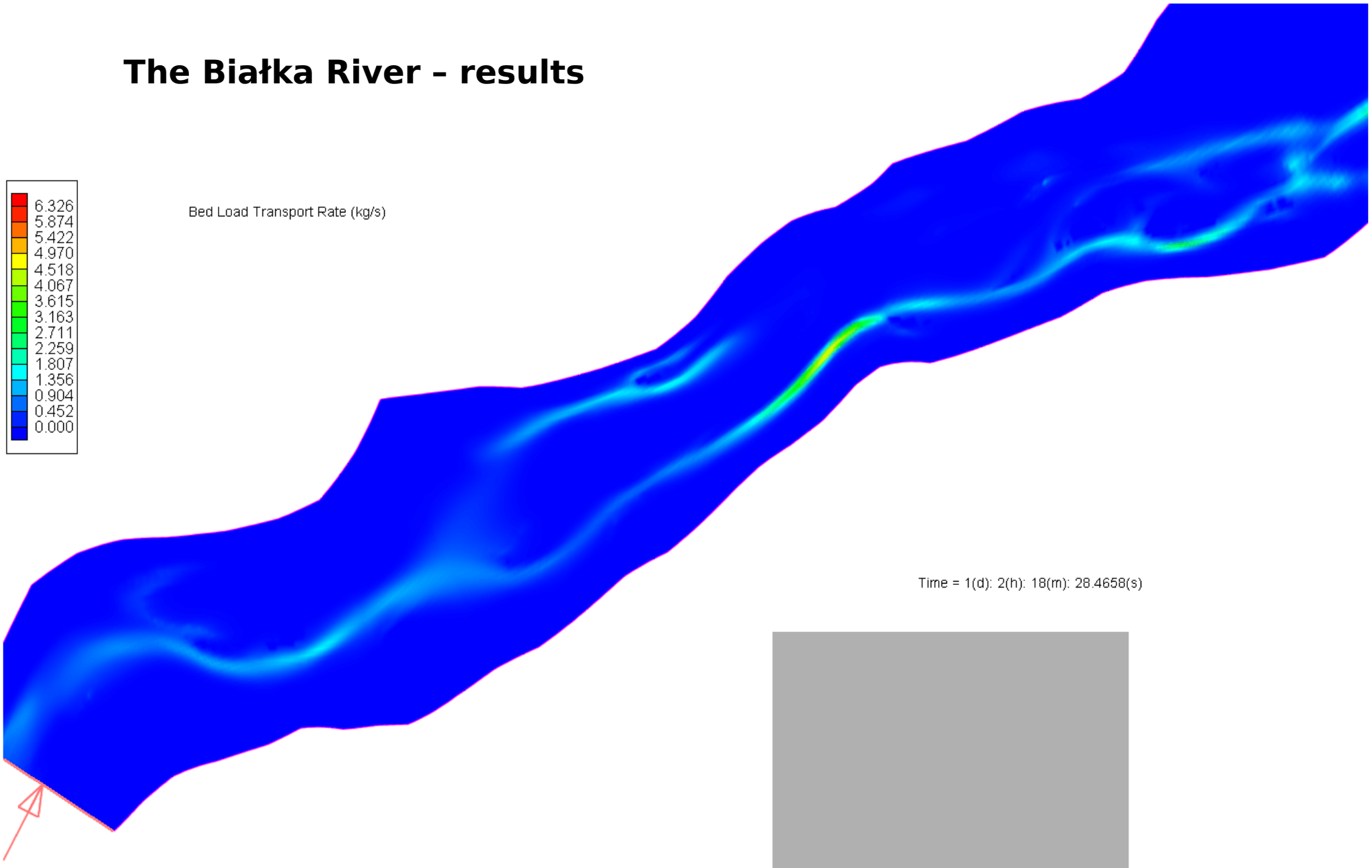
Manning roughness calculated by model

bed is erodible with exception of the step localization

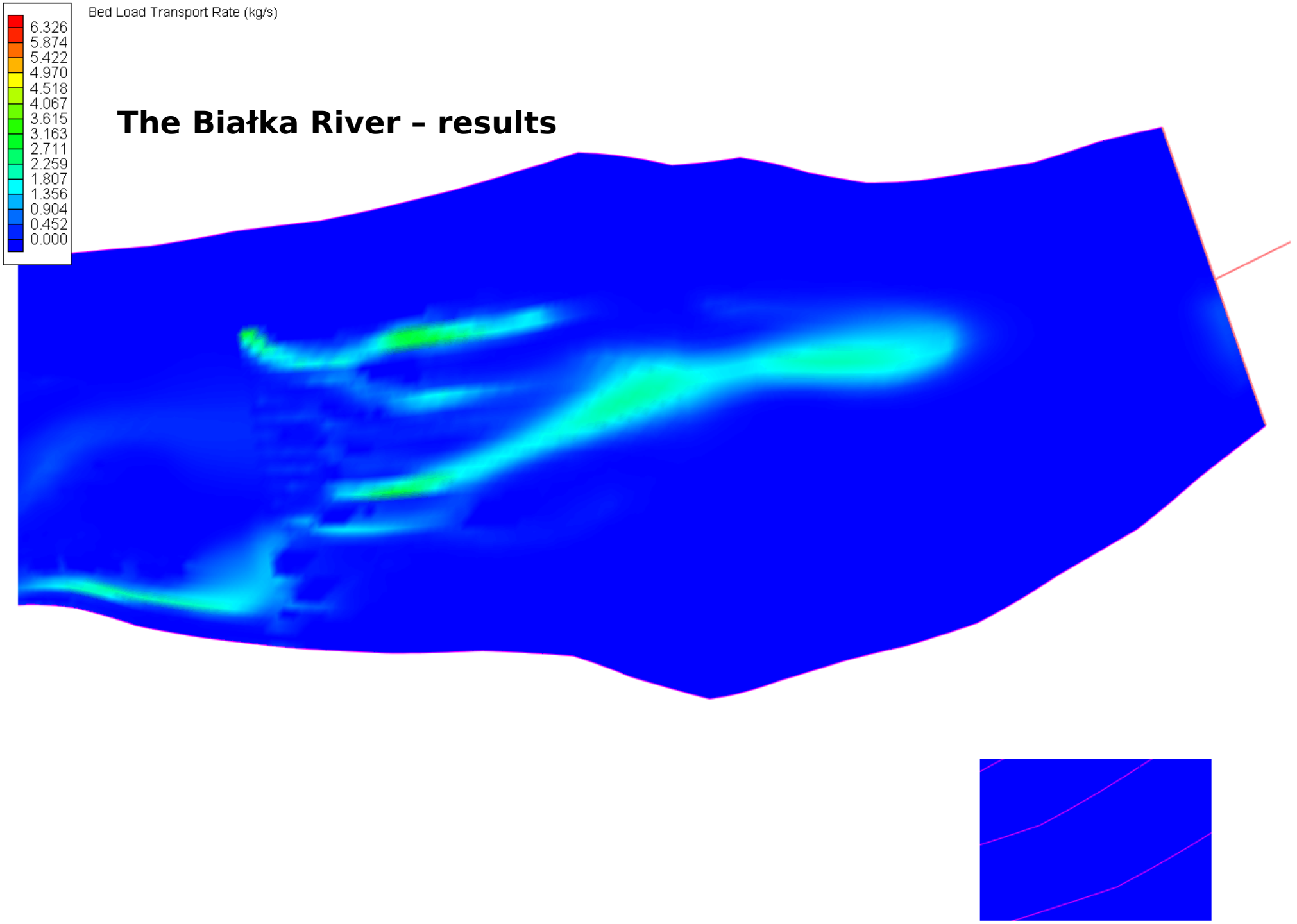
The Białka River – CCHE2D first runs



The Białka River – results

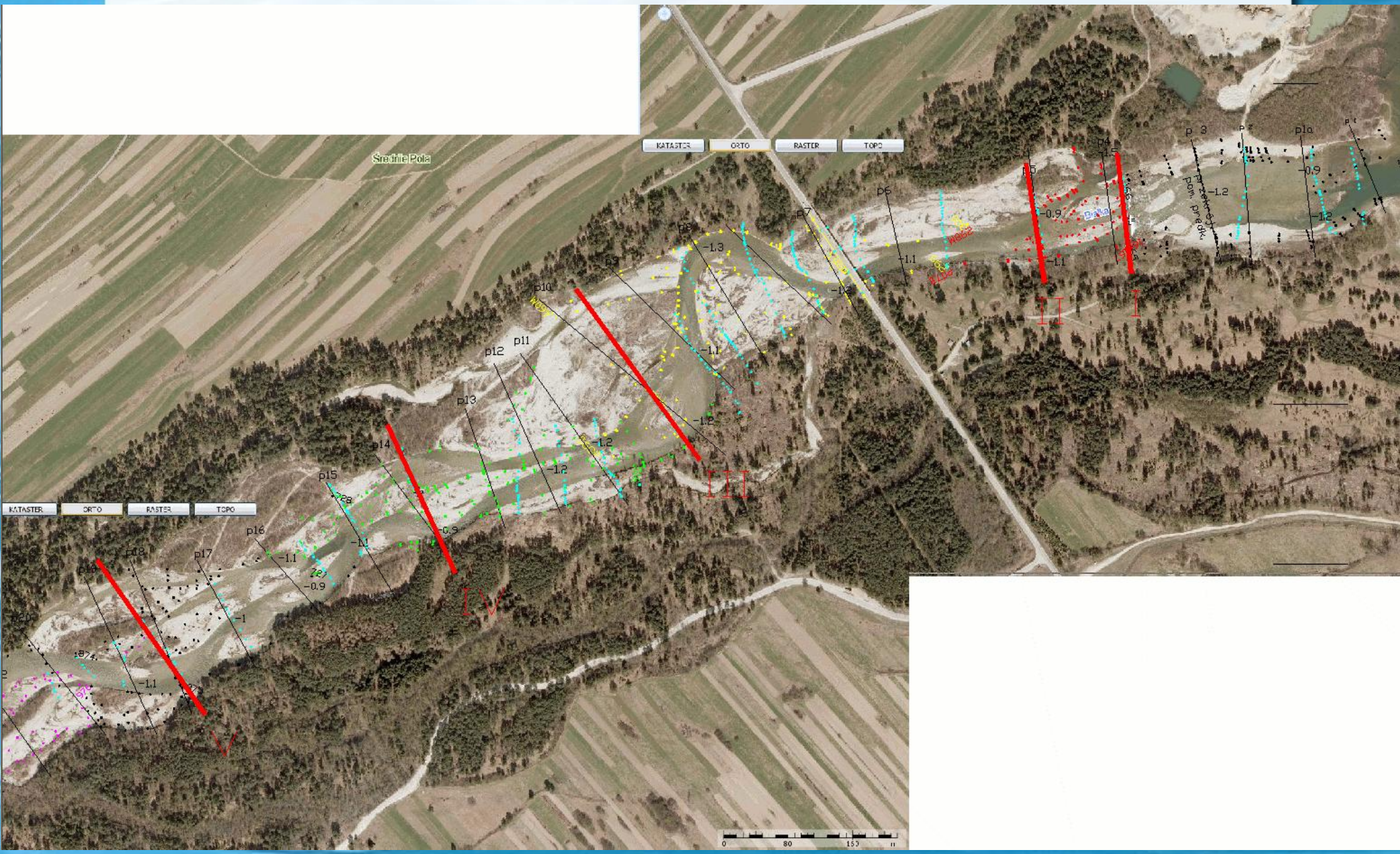


The Białka River – results

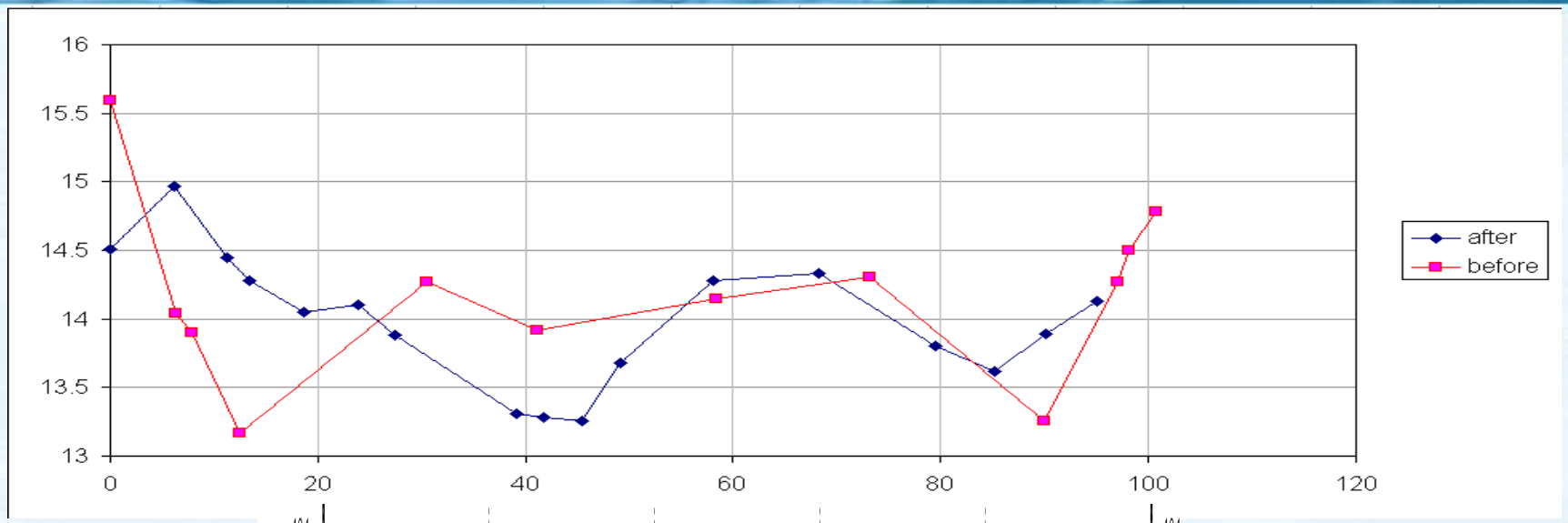


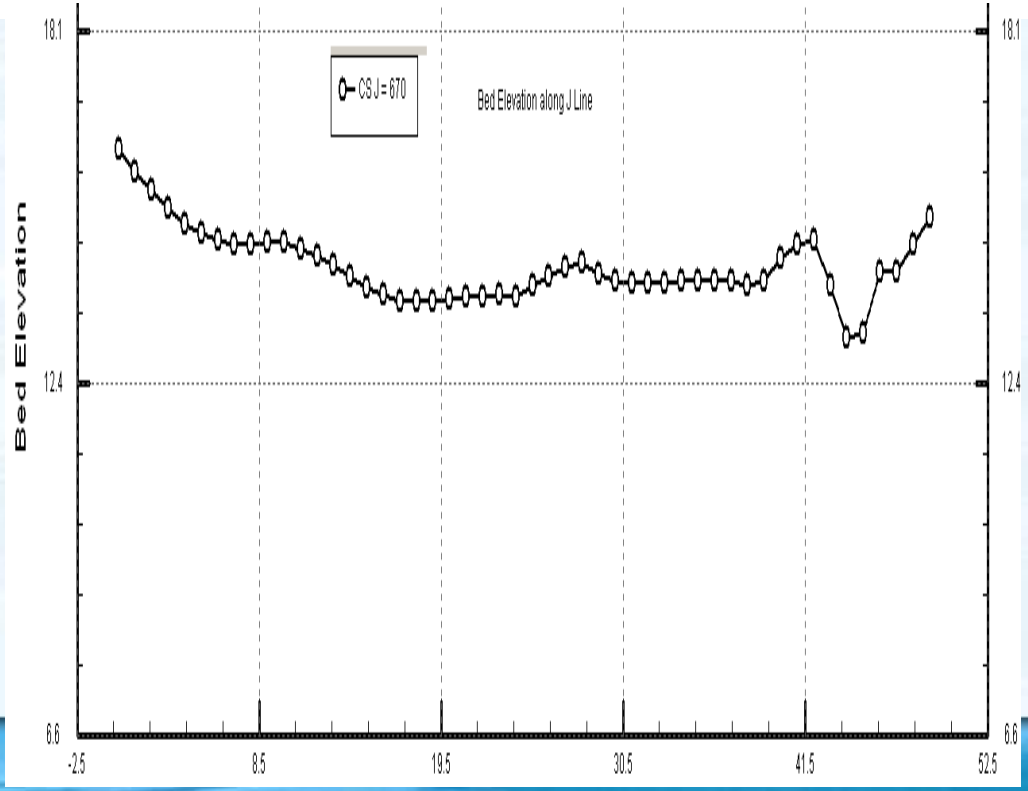
The Białka River – results

The Białka River – comparing results

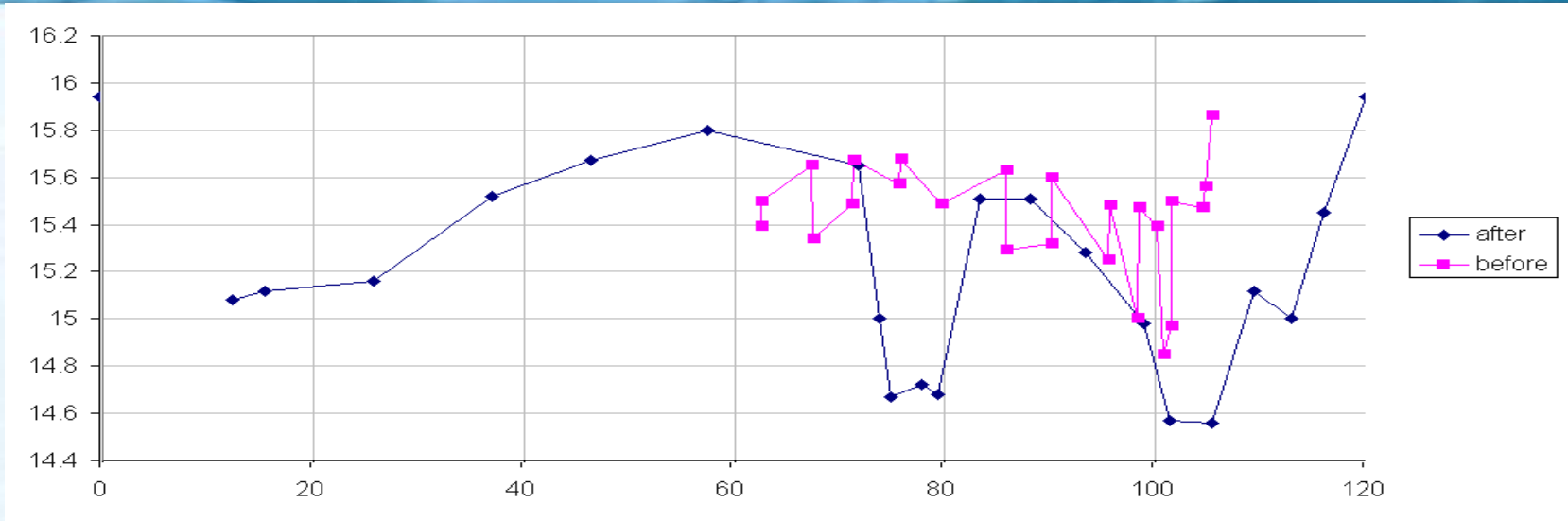


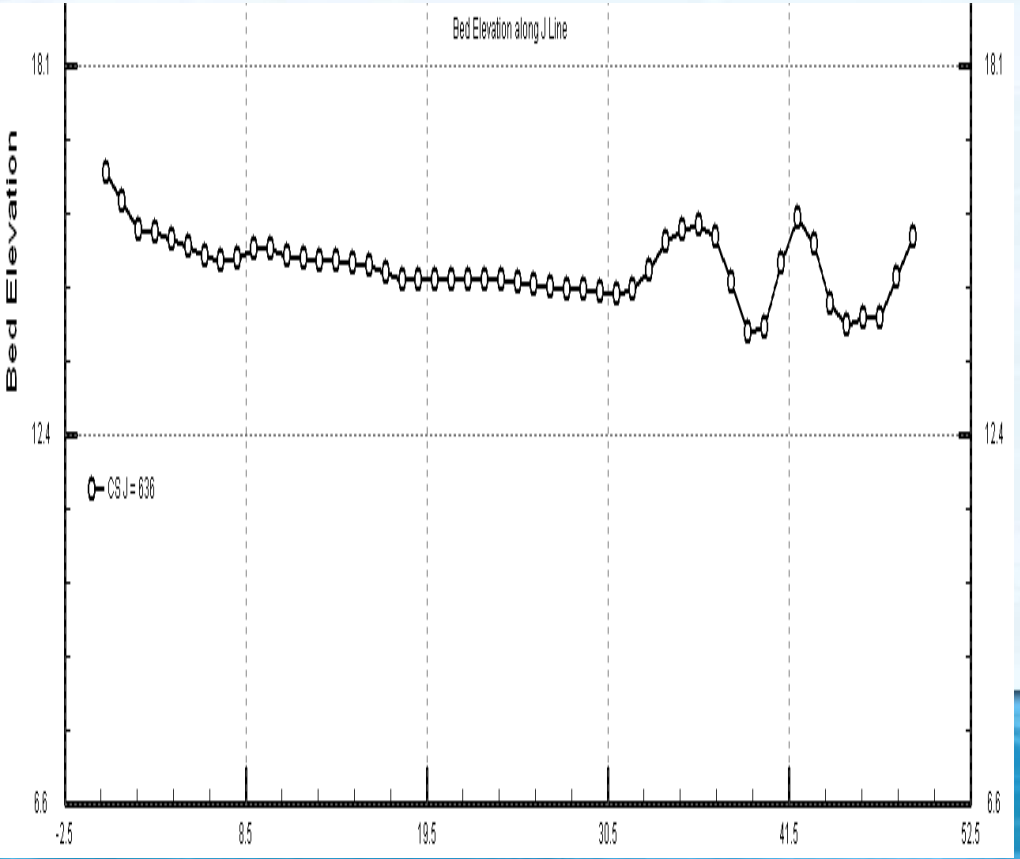
The Białka River – results – cross-section I



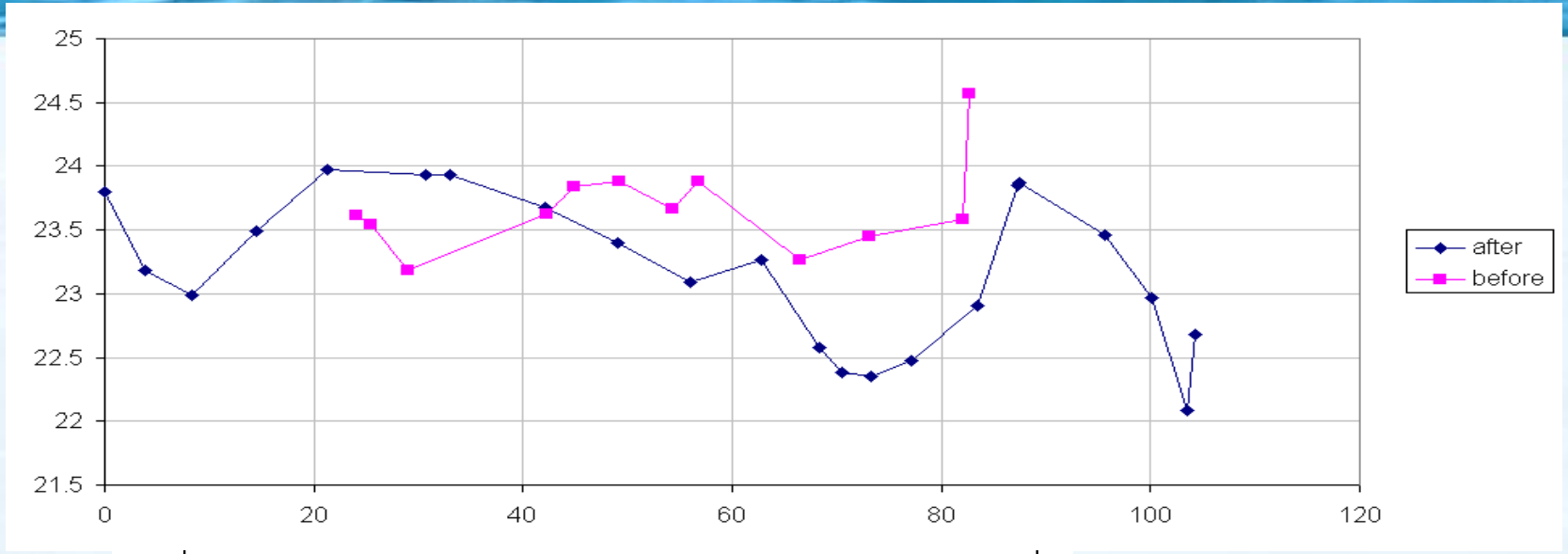


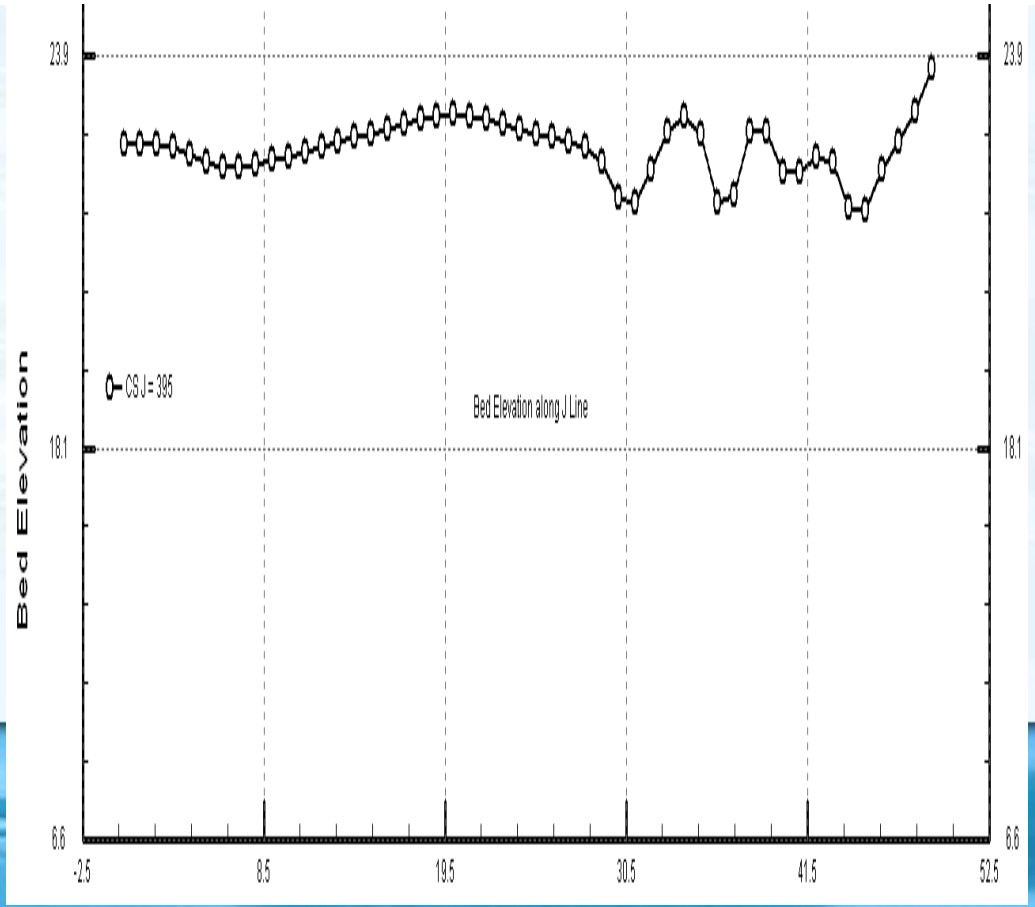
The Białka River – results – cross-section II



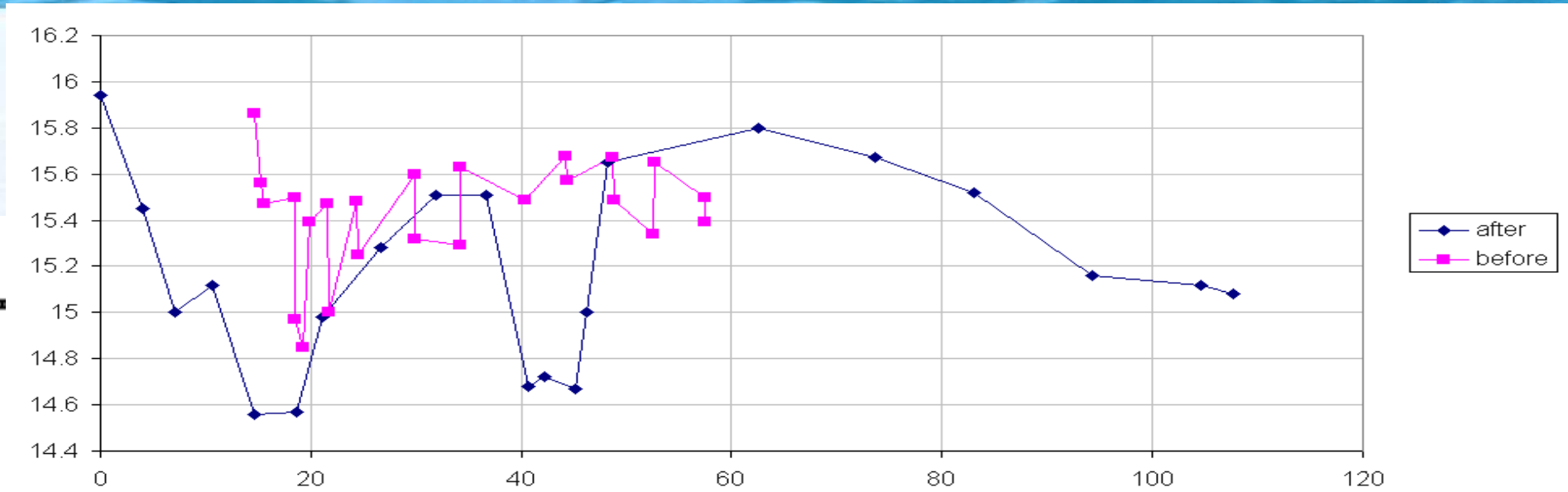


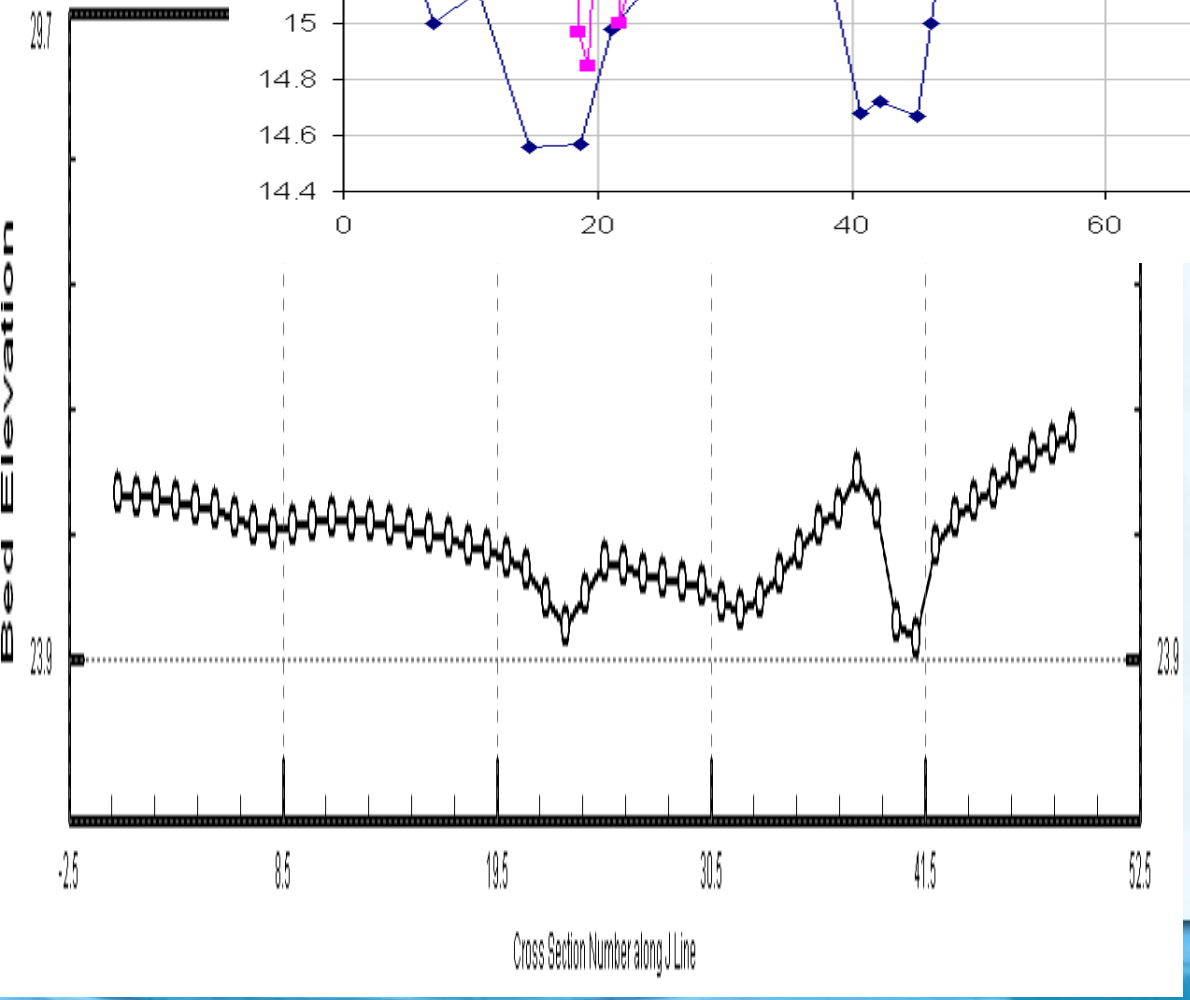
The Białka River – results – cross-section III



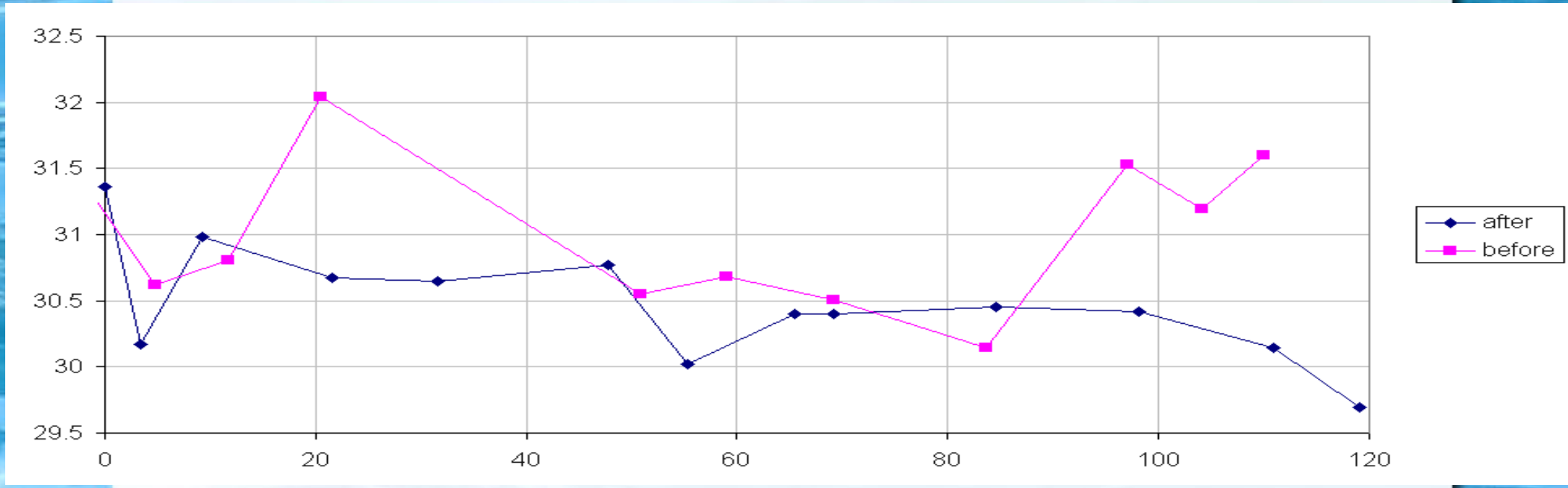


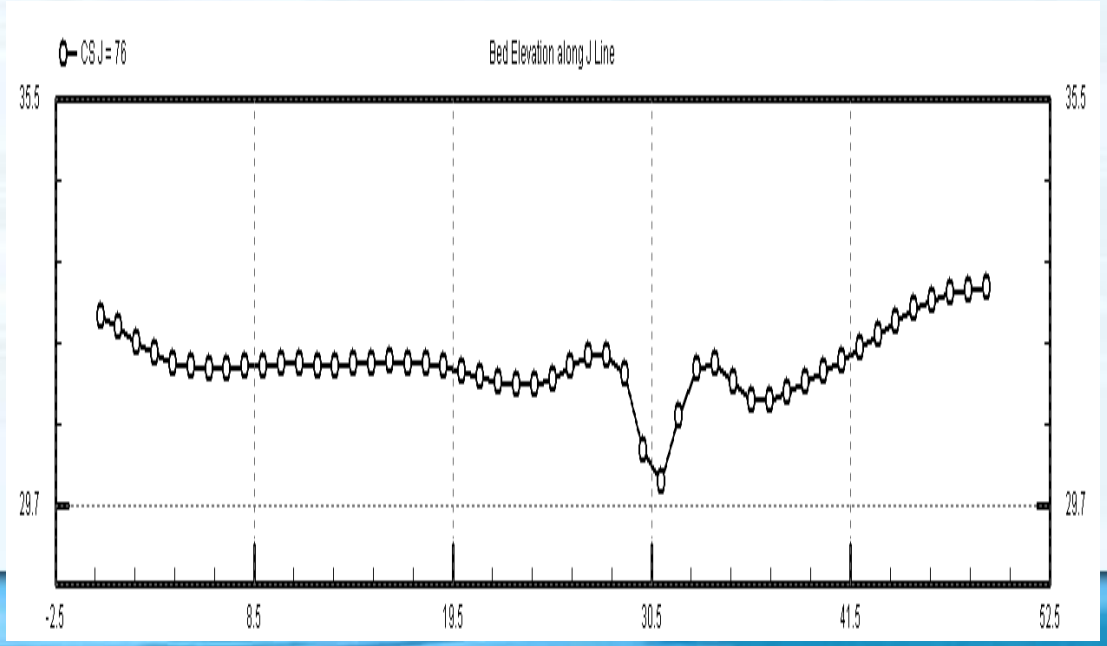
The Białka River – results – cross-section IV



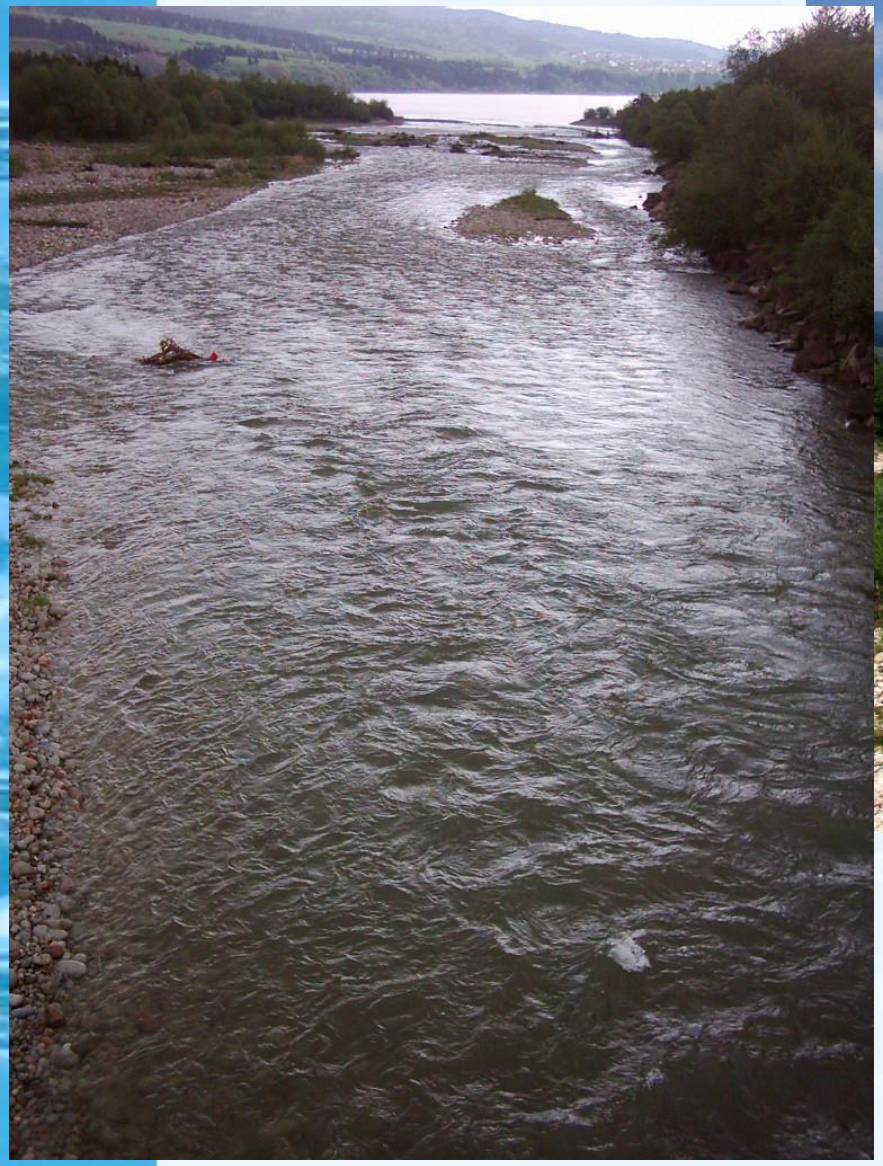


The Białka River – results – cross-section V





The Białka River – bridge neighborhood



bridge upstream

The Białka River – bridge neighborhood

bridge downstream

The Białka River – bridge neighborhood

bridge downstream

Conclusions

- Białka River dynamics is very high even during smaller floods. New branches appeared after the first flood in summer 2010.

- Wu, Jia and Wang formula produced realible output for rough bed and was veryfied succesfully in Białka River in most cross-sections.

- Modeled erosion of bed in few cross-sections differs from the measured one. Transition of the river channels in nature was more dynamic then in the model.

- Modeled channels were often more cut then natural ones. This can be caused by the rocky and non erodible substratum below the movable layers of the transported material. This data could be put into the model as maximum erosion thickness parameter however collecting this data for Białka River is not an easy task.


THANK YOU FOR YOUR
ATTENTION