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Numerical modeling of flow dynamics on a gravel bar during high discharge in a mountain river

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Presentation schedule

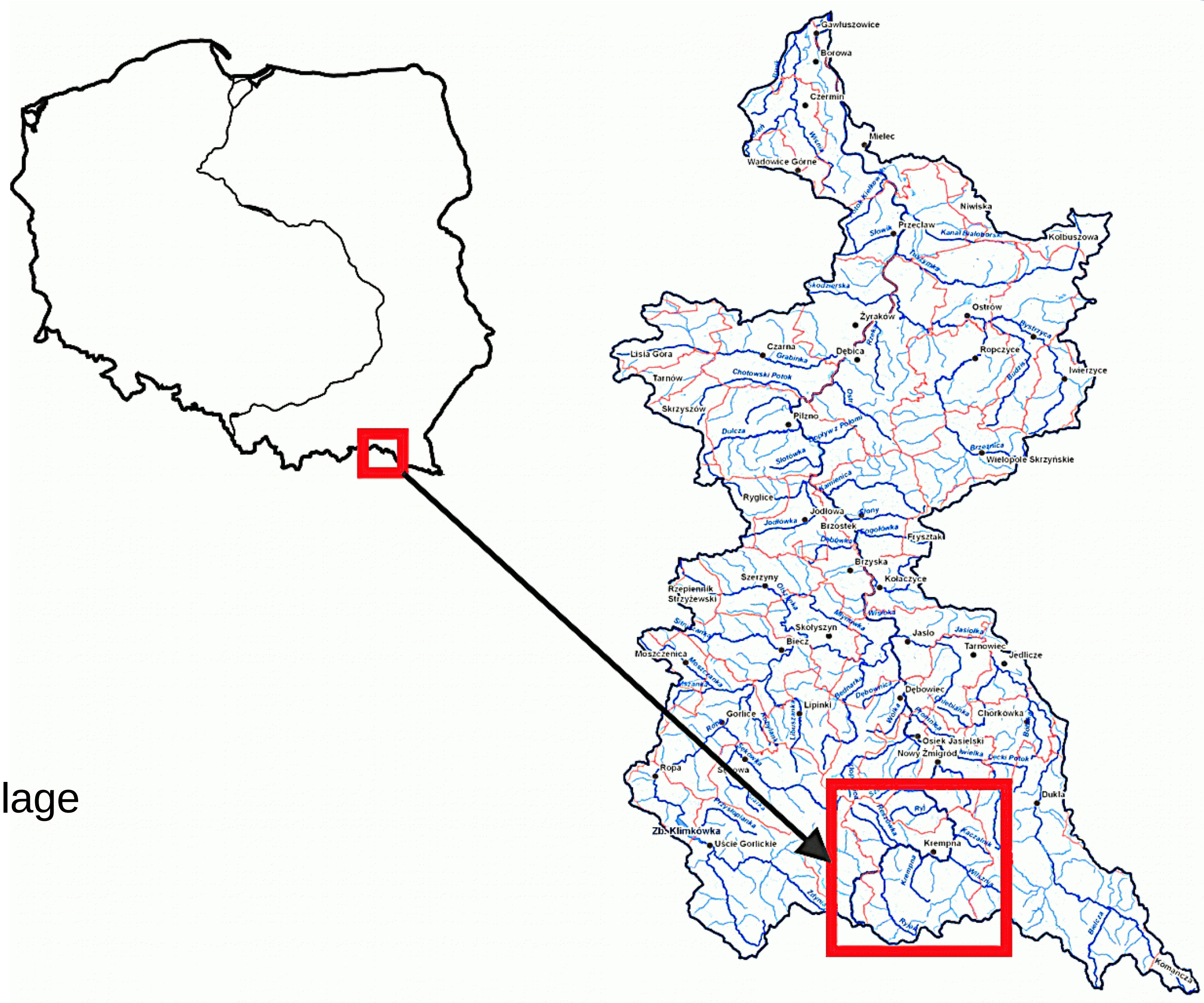
1. Object description
2. The goal of the study
3. Methodology
4. Results
5. Conclusions

Wisłoka River

basin area: 4110 km^2
river length: 173 km

sources: Beskid Niski Mountains 575 m a.s.l.

outlet: Wisła Ostrówek village 154 m a.s.l.



Wisłoka River reach

location:
Magurski National Park

subbasin area: 138.6 km^2
length from sources: 16 km

sources: 575 m a.s.l.
study site: 391 m a.s.l.
village: Świątkowa Mała

annual precipitation: 750 mm

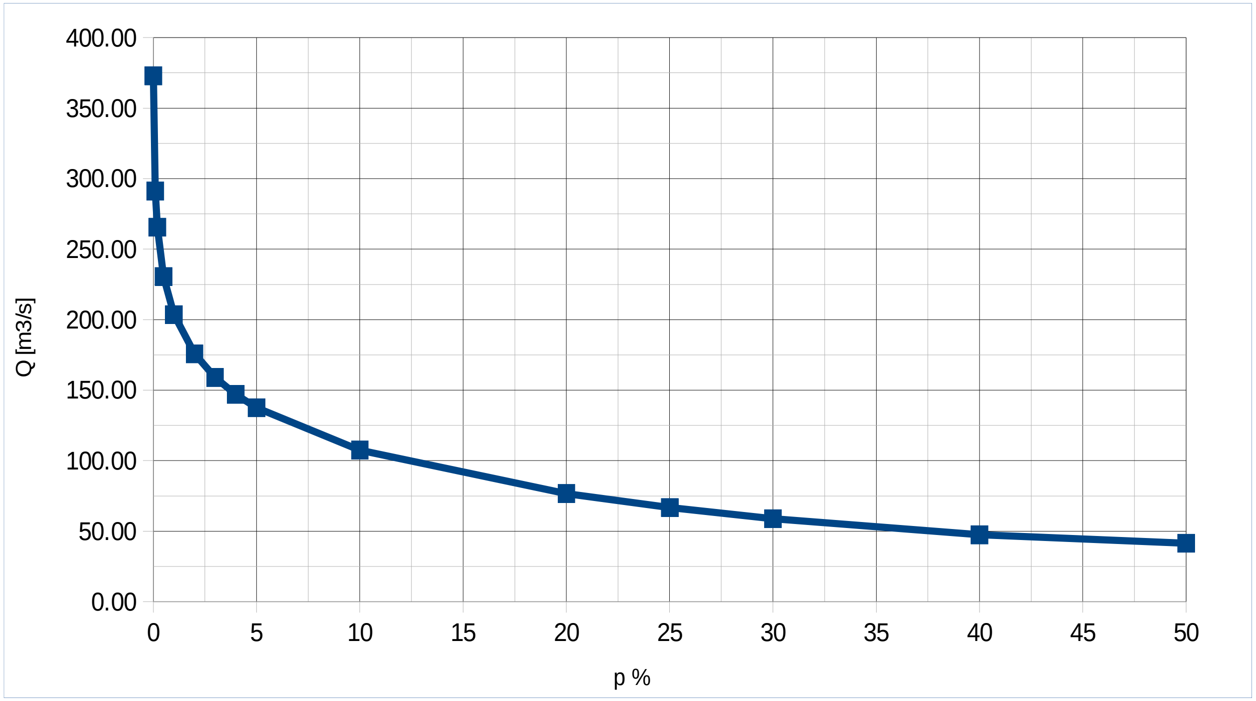
investigated reach

width of alluvial terrace:
350 – 400 m

reach length: 400 m
river slope: 0.37 %

type of the bar: side bar
bar length: 170 m
bar width: 50 m

village: Świątkowa Mała



p [%]	Q [m3/s]
0.01	372.89
0.1	291.18
0.2	265.54
0.5	230.66
1	203.61
2	175.79
3	158.98
4	146.95
5	137.56
10	107.53
20	76.69
25	66.74
30	58.85
40	47.38
50	41.51

measured in Krempna-Kotań station
May 2014 – 149 m^3/s

calculated from long term measurements:
WWQ: 221 m^3/s
SWQ: 78.5 m^3/s
SSQ:3.4 m^3/s
SNQ: 0.26 m^3/s
NNQ: 0.15 m^3/s

Qischarges

river channel

bar

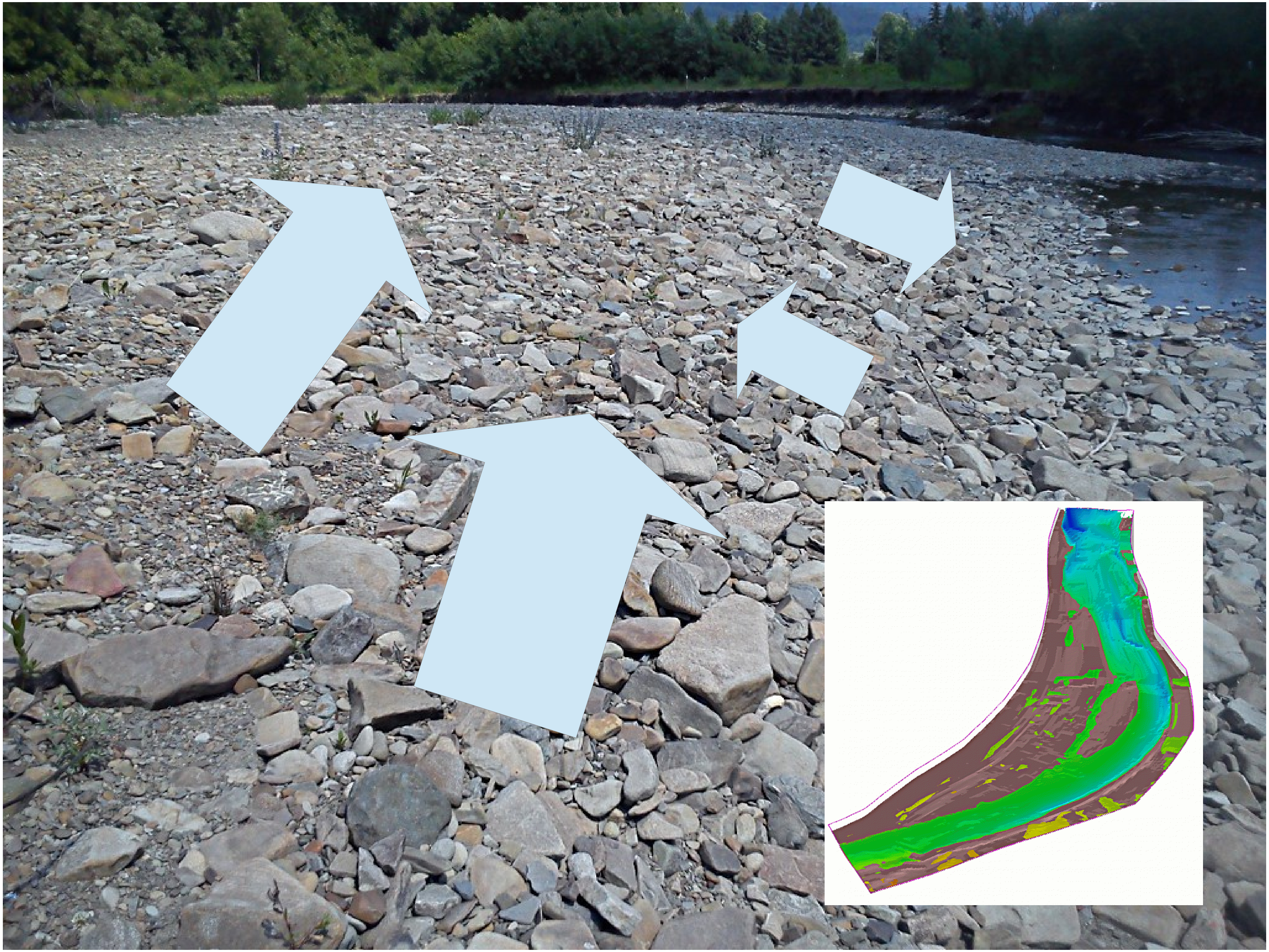
bed material

Sample N°	d_{50} (m)
1	0.086
2	0.071
3	0.083
4	0.019
5	0.092
6	0.041
8	0.003
9	0.036
12	0.005
14	0.041
15	0.099
16	0.108
17	0.085
18	0.070

head of the bar

bar tail

body of the bar



define fluvial processes acting on the bar

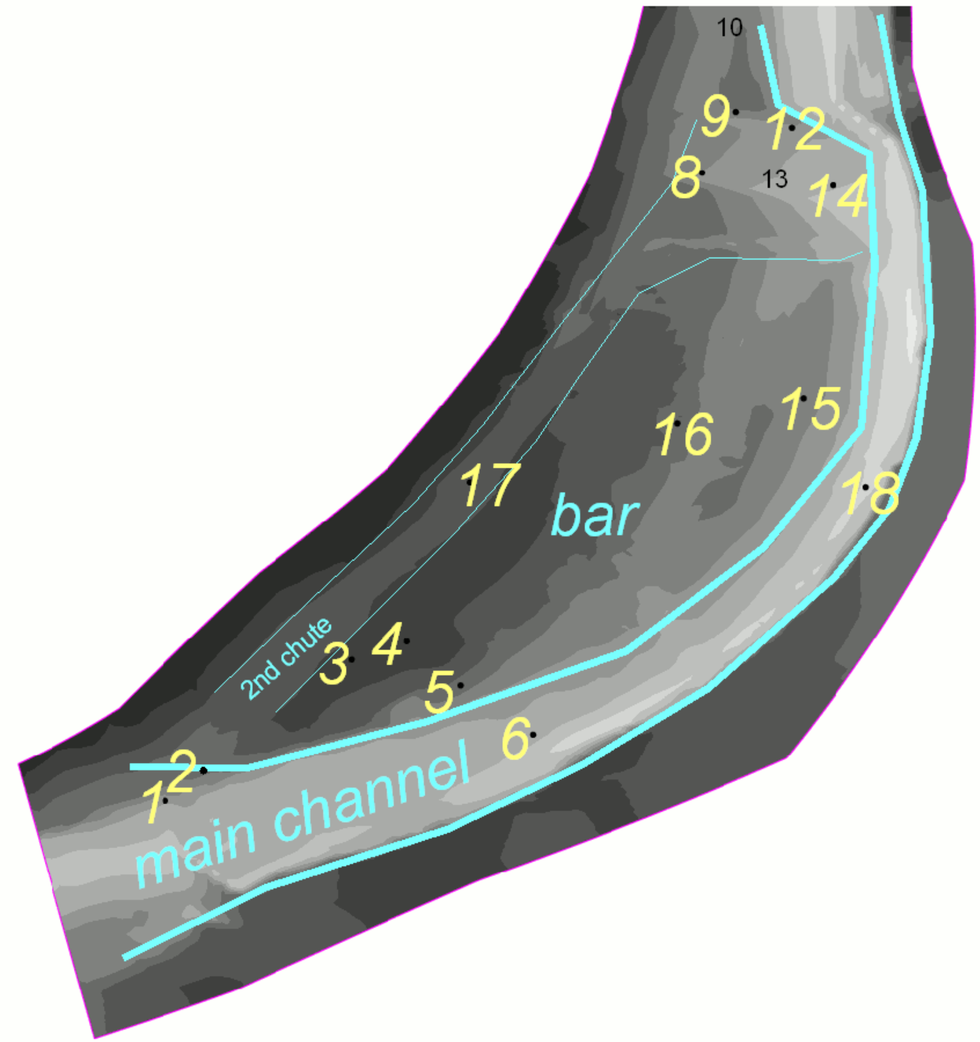
hiding,	describe the process in details
sorting,	
inclination,	???
size,	
direction	many questions

Field studies performed in 2011, 2012
and 2014 resulted with questions
of bar forming and moderating processes.

Geodetic measurements carried out
in multiple bars could not answer the details
of the processes.

The goal of the study was to use
2D computer model for detailed prognosis
of fluvial processes found in mountain rivers
with bars.

The model itself was based on data collected
during field research in 2015.



Geodetic measurements

- period
  spring 2017

- measured distance
  400 meters

- No. of cross-sections
  56

- measurement raster
  40 meters in average

- 2000 measured points

DTM

- date
  2012

- resolution 0.5 meters

CCHE2D model

I and J line numbers were 70 and 200

cell size of average dimensions 0.7 x 0.85 m.

Bank roughness was determined by reading
the Manning table (Chow 1959)

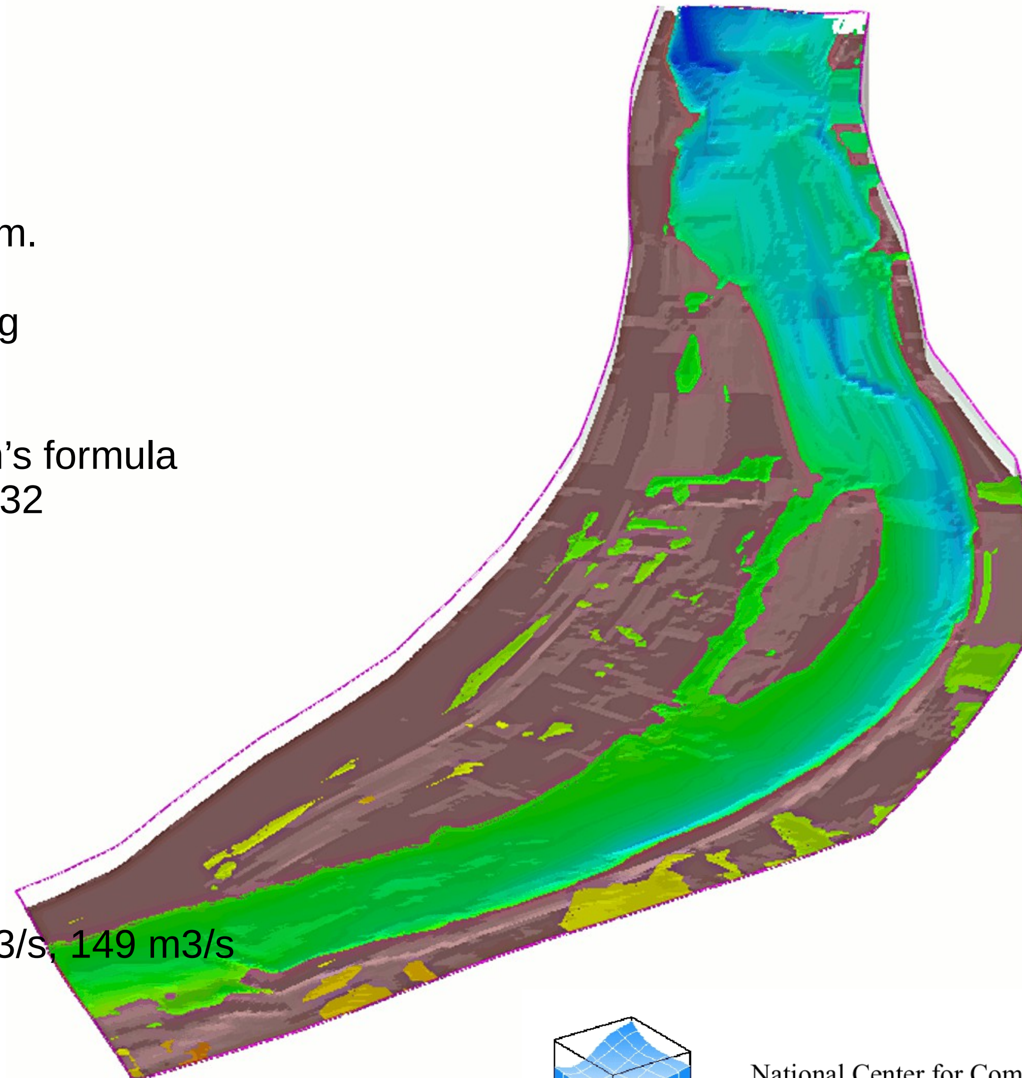
bed roughness was calculated from Cowan's formula
Manning's values used were 0.045 and 0.032

outlet boundary (water level)
was calculated for all discharges
with "Konsum" software

Simulations were run
for **six** different discharges
(semi-steady flow conditions):
3 m3/s, 30 m3/s, 45 m3/s, 79 m3/s, 110 m3/s, 149 m3/s

simulation time - 1 hour

time step - 0.2 s.



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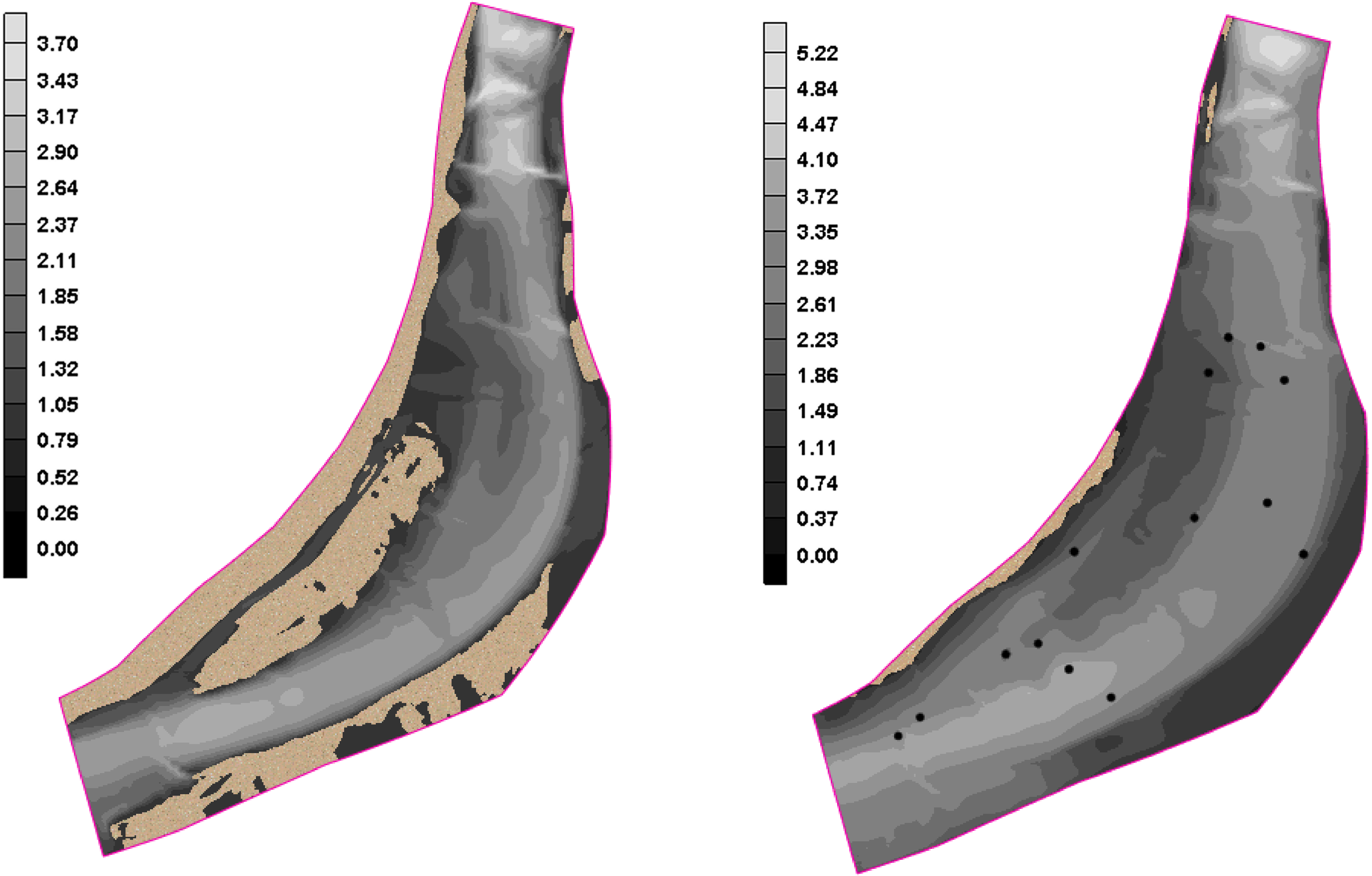
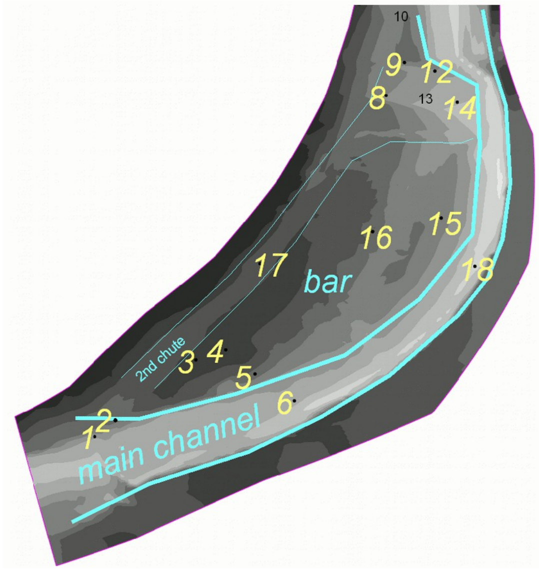
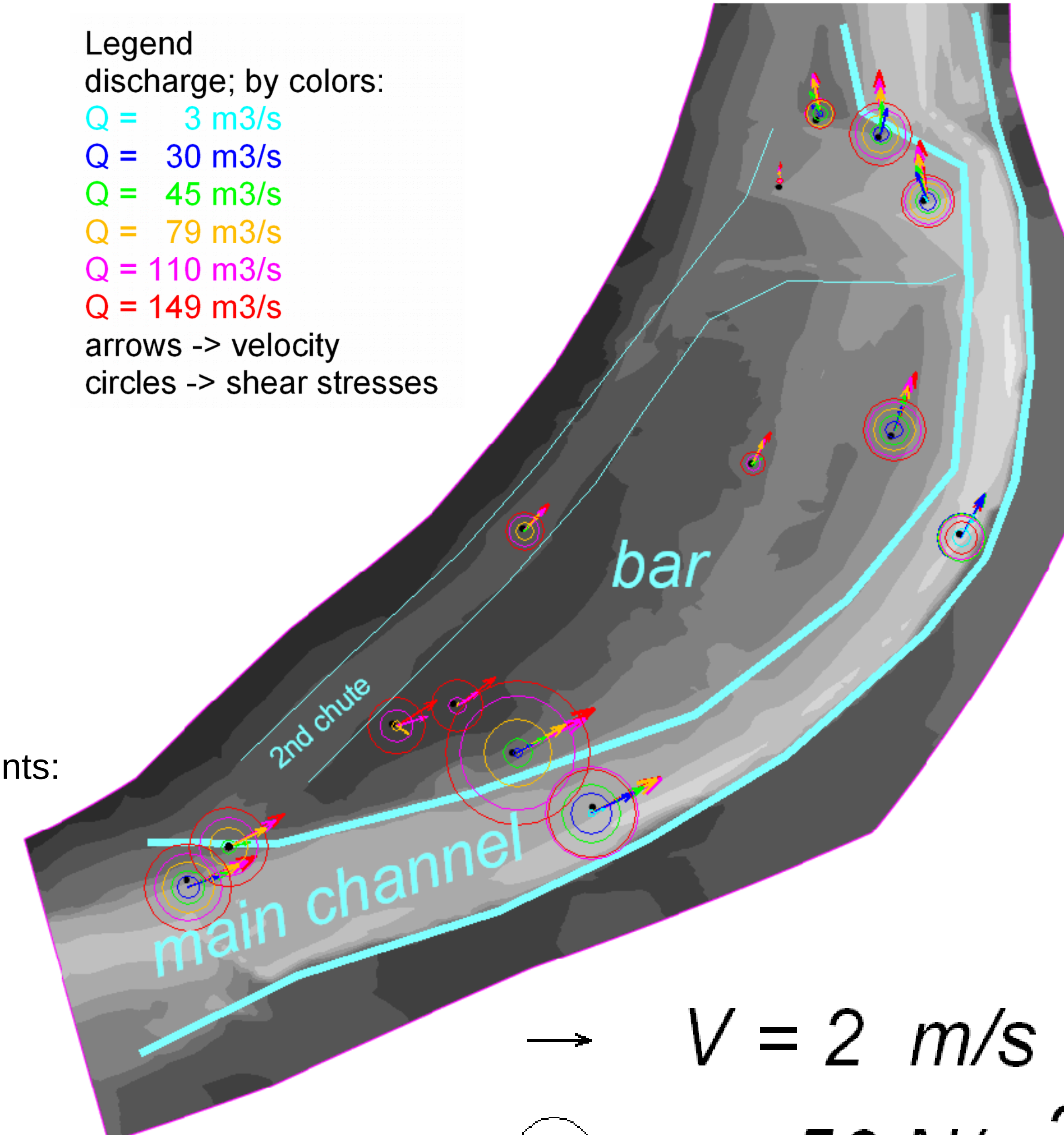


45 m^3/s (left) and 145 m^3/s (right)

from all of: 3 m^3/s, 30 m^3/s, 45 m^3/s, 79 m^3/s, 110 m^3/s, 149 m^3/s



Legend
discharge; by colors:
Q = 3 m3/s
Q = 30 m3/s
Q = 45 m3/s
Q = 79 m3/s
Q = 110 m3/s
Q = 149 m3/s
arrows -> velocity
circles -> shear stresses



measured in Krempna-Kotań station
May 2014 – 149 m3/s

calculated from long term measurements:
WWQ: 221 m3/s
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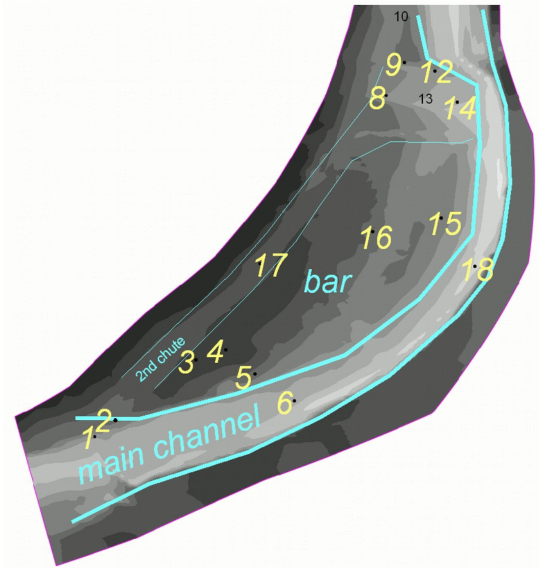
SNQ: 0.26 m3/s
NNQ: 0.15 m3/s

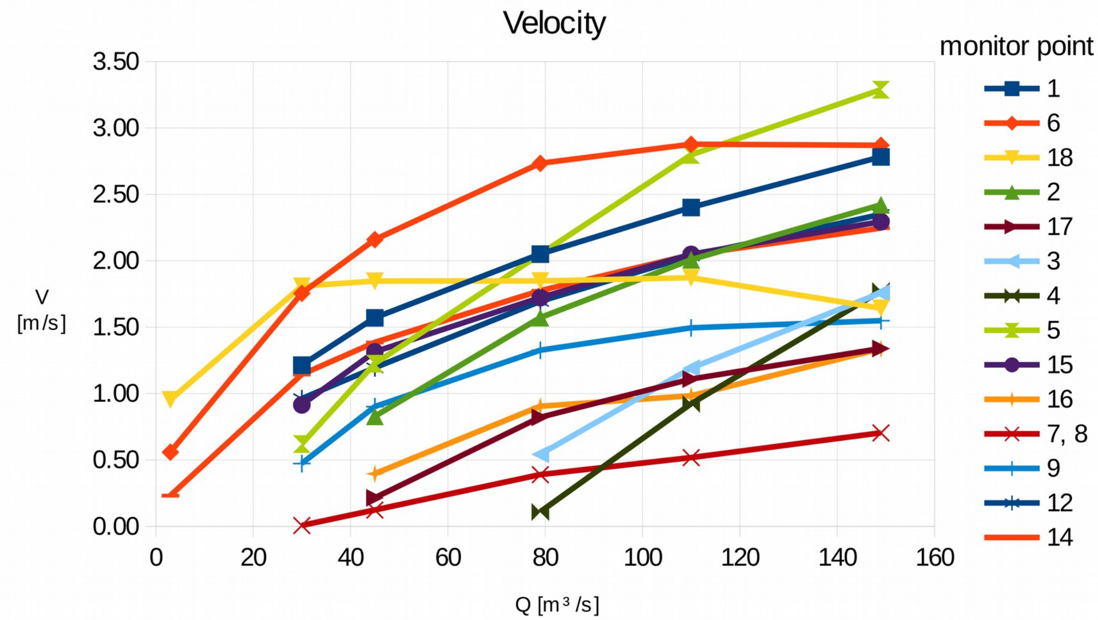
→ $V = 2\ m/s$

○ $\tau_0 = 50\ N/m^2$

45 m³/s (left) and 145 m³/s (right)

from all of: 3 m³/s, 30 m³/s, 45 m³/s, 79 m³/s, 110 m³/s, 149 m³/s





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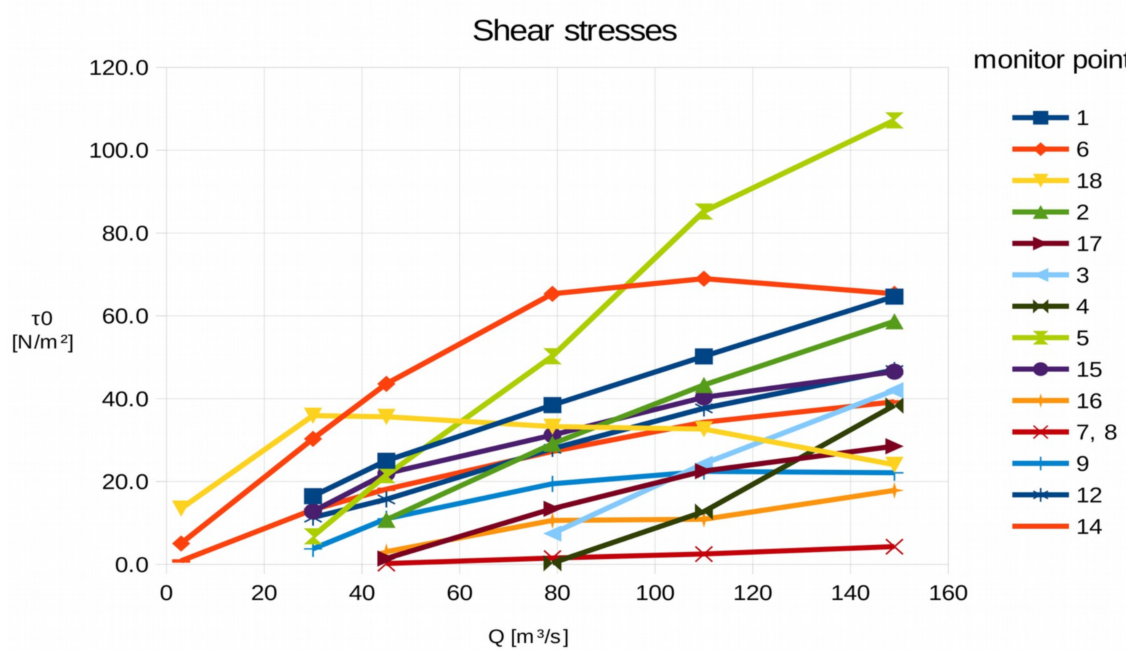
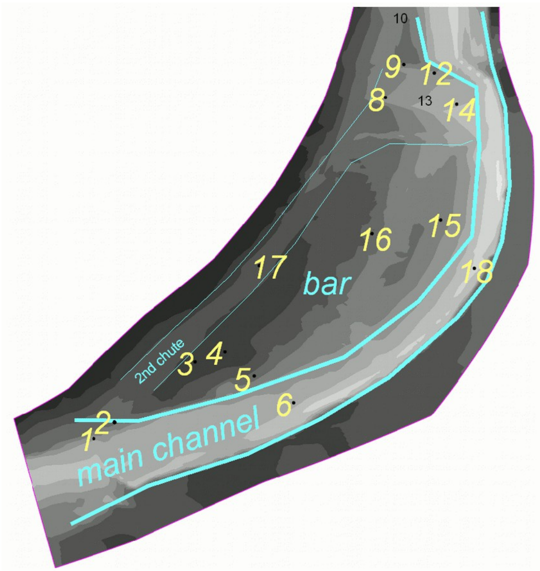
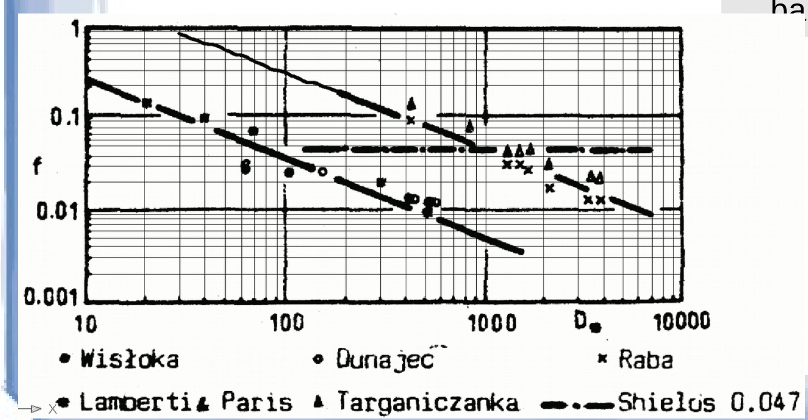
A rise in the discharge was accompanied by growing velocity at all monitoring points and the same was observed for bed shear with the exception of points **6**, 9 and 18.





Location	point No	d_{50} [m]	bed material	Bonnefille parameter	Shields parameter	τ_{cr} [N/m^2]
bar tail	8	0.003	fine gravel	69	0.400	19.4
bar tail	12	0.005	fine gravel	115	0.250	20.2
bar head	4	0.019	coarse gravel	436	0.085	26.1
bar_tail	9	0.036	coarse gravel	816	0.060	34.5
channel	6	0.041	coarse gravel	942	0.045	29.9
bar tail	14	0.041	coarse gravel	942	0.045	29.9
channel	18	0.07	cobbles	1630	0.029	32.9
2nd chute	2	0.071	cobbles	1631	0.029	33.3
bar head	3	0.083	cobbles	1907	0.025	33.6
2nd chute	17	0.085	cobbles	1956	0.025	34.5
channel	1	0.086	cobbles	1976	0.024	33.4
bar head	5	0.092	cobbles	2119	0.023	34.3
bar top	15	0.099	cobbles	2282	0.022	35.4
bar top	16	0.108	cobbles	2478	0.021	36.7



Bartnik 1992

The modeling results were consistent with field observations.
The proximal part of the bar underwent the most intensive transformations.
The largest simulated flow velocity achieved in this bar section was
3.29 m/s and the shear stresses reached 107.2 N/m^2.
In the main channel,
during the discharge of 79 m^3/s, the sediment transport was fixed
(shear stresses value below 70 N/m^2). In the central part of the gravel bar,
shear stresses and velocity values were lower, however, in the distal part of the bar,
the values of the analyzed hydraulic parameters slightly increased.

Erosion of the right concave bank decreased during bank-full flows due to rapidly increasing
width of the river channel.
During floods, the main current shifts towards the bar.
The flowing water sculpts the shape of the downstream section of the bar
and improves the capacity of its profile.

The discussed modeling confirmed a tendency to frequent and significant morphodynamic changes
in this section of the upper Wisłoka.
The use of CCHE2D software provided new possibilities for the spatial data analysis,
and enabled recognition of the relationships between the morphology of the gravel bar,
its grain size characteristics, and water flow conditions.


Thank you for your attention