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Late Pleistocene and Holocene Climatic Variability in the Carpathian-Balkan Region

ABSTRACTS VOLUME

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Changes of the hydrodynamic conditions in the braided river

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Introduction

The paper focuses on the understanding of the basic hydrodynamic conditions along the braided gravel-bed river. The measuring cross-section was located in the Ochotnica River, where its braided channel development was observed. Investigations take place from 2003 up to 2014. Measurements were performed for selected characteristic points. The study focused mostly on the measurements of water velocities under different flow conditions, and next on finding basic hydraulic parameters of flow: shear velocity, shear stresses, Reynolds number, Froude number. In addition, the gravel material from the river bed was examined, in order to find sedimentological characteristics of it.

Study area

The Ochotnica River (Fig. 1) is 22.7 km long. It is located in the southern part of Poland in the Gorce Mountains. It is the left-bank tributary of the Dunajec River. It begins at the Kiczora peak (1200 m a.s.l.). The area of catchment is 108 km^2. The decrease of the river ranges from 5.68% in the upper parts to 1.55% in the lower parts, so the average decrease is 3.61%.

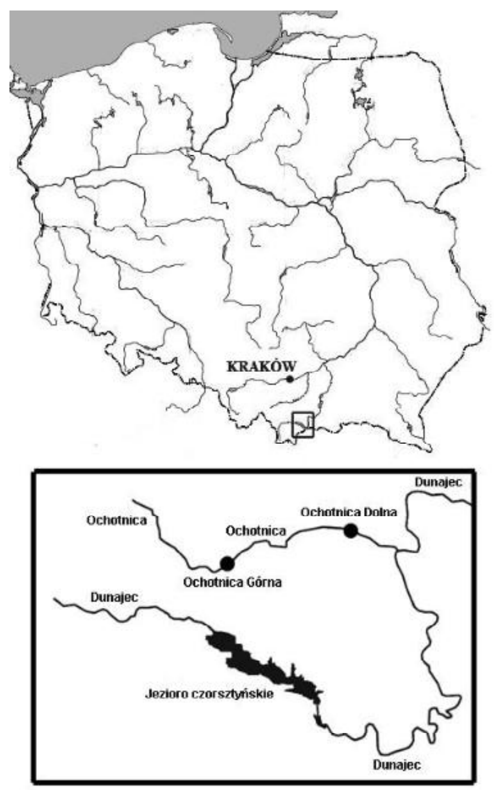

Fig. 1 Localization of research region

The Ochotnica River is classified typologically into the rivers of the Carpathians. The river discharge is changeable and variable according to precipitation and snowmelt. The river regime is characterized by frequent changes of water levels, considerable potential for flood and significant erosion of river banks and river bed.

The research section of the river was located in Ochotnica Górna village. The mean diameter of the gravel which form the river bars in the Ochotnica channel is:

d_m = 0.102 m and the other characteristic diameter are respectively: d_{20} = 0.022 m, d_{50} = 0.085 m, d_{80} = 0.170 m.

Granulometric parameters are as follow:
- The Trask sorting coefficient S_0 = 2.31
- Hazen's storting coefficient u = 32.5
- Knoroz's grain-size diversity indication ε = 185.71
- Kollis' uniformity indication C_d = 0.16

Methods

Velocity measurements were performed on the Ochotnica River in the cross section, where the watercourse is braided. The number of measurement points along the cross section was from 4 up to 13 according to conditions of the flow regime. The measurements were repeated 5 times under different discharge conditions.

Measurements of velocities were done using the hydrometric current meter OTT Nautilus 2000. This device can measure velocities of water in range from 0.001 $m \cdot s^{-1}$ to up 10 $m \cdot s^{-1}$. Measurements were done directly above the river bed. The values of obtained velocities were used to draw the velocity curves over the particular measurement points. Those measurements were used to determinate such parameters us:
- mean velocities,
- shear velocities, using Gordon formula: $V_* = \frac{a}{5{,}75}\ [m \cdot s^{-1}]$
- shear stresses, using formula: $\tau = \rho \cdot (V_*)^2\ [N \cdot m^{-2}]$
- Reynolds numbers: $Re = \frac{v \cdot d}{\upsilon}\ [-]$
- Froude numbers: $Fr = \frac{v}{\sqrt{gh}}\ [-]$

where:
a - slope coefficient V = f(h) form the equation y = ax + b
ρ = 1000 $kg \cdot m^{-3}$ - water density
V - water velocity
h - depth in the watercourse or size of grain of the bed channel
υ- kinetic coefficient of viscosity
g – gravity

Results

Along the first period of measurements (25.04.2003) under the low flooding conditions, water full-filled two channels of the braided reach: 1A-1C and 2A-2B (Fig. 2, Tab. 1).

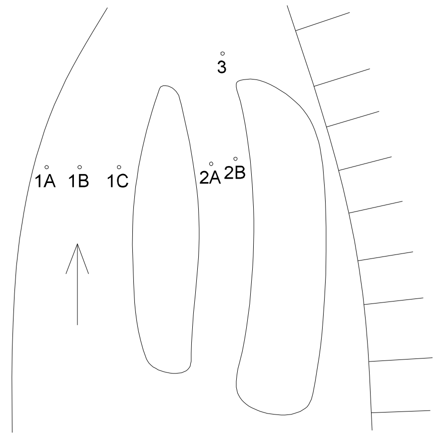

Fig. 2 Channel system during the 1st series measurement

Table 1 Hydrodynamic parameters during the 1st series measurement

25.04.03 Points	V_{av} [m · s^{-1}]	h_{max} [m]	V_{max} [m · s^{-1}]	V_* [m · s^{-1}]	τ [N · m^{-2}]	Fr_{max} [-]	Re_{max} [-]	Re_{d50} [-]	Re_{ks} [-]
1A	0,165	0,32	0,165	0,0068	0,0467	0,093	40364	10596	75052
1B	0,791	0,20	0,791	0,0163	0,2650	0,565	120939	50794	359793
1C	0,591	0,27	0,591	0,0232	0,5374	0,363	121986	37951	268821
2A	0,660	0,18	0,660	0,0181	0,3265	0,497	90819	42382	300206
2B	0,989	0,20	0,989	0,0665	4,4182	0,706	151212	63509	449855
3	0,127	0,60	0,127	0,0183	0,3354	0,052	58252	8155	57767

The next measurements were performed in 29.07.2003 during the low flood (Fig. 3, Tab. 2). We observed many changes in the watercourse of the river. Water filled only the left channel and covered a left gravel bar, eroding it. River channel width was extended in 12 m in comparison with the last period of measurements. Additionaly, we established a new measurement point no 4 in the left gravel bar.

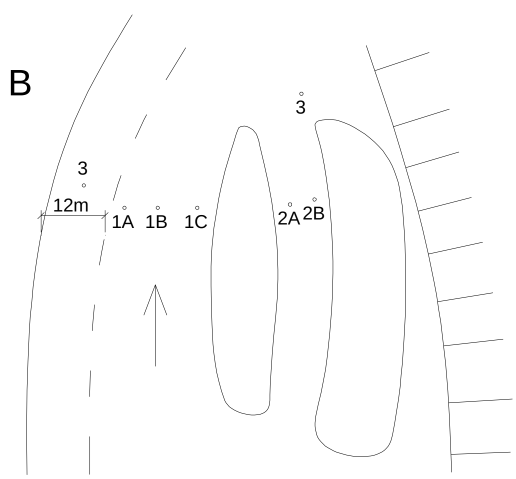

Fig. 3 Channel system during the 2nd series measurement

Table 2 Hydrodynamic parameters during the 2nd series measurement

29.07.03 Points	V_{av} [m · s^{-1}]	h_{max} [m]	V_{max} [m · s^{-1}]	V_* [m · s^{-1}]	τ [N · m^{-2}]	Fr_{max} [-]	Re_{max} [-]	Re_{d50} [-]	Re_{ks} [-]
1A	0,501	0,24	0,520	0,0448	2,0102	0,327	91920	33392	227884
1B	1,139	0,32	1,160	0,0524	2,7439	0,643	278633	74490	518083
1C	0,269	0,10	0,302	0,0138	0,1897	0,272	20564	19393	122357
2A	0,535	0,12	0,565	0,0302	0,9105	0,493	49079	36282	243349
2B	0,570	0,12	0,590	0,0347	1,2074	0,525	52290	37887	259269
3	0,105	0,70	0,131	0,0091	0,0821	0,040	56188	8412	47760
4	0,515	0,08	0,530	0,0113	0,1286	0,581	31496	34034	234252

The next measurements were done in 05.04.2004 after the spring flood (Fig. 4, Tab. 3). The river channel geometry has changed a lot. The water was flooding within the whole cross section between the left and right river banks. The water also was covering the middle gravel bar, where plants living there were broken.

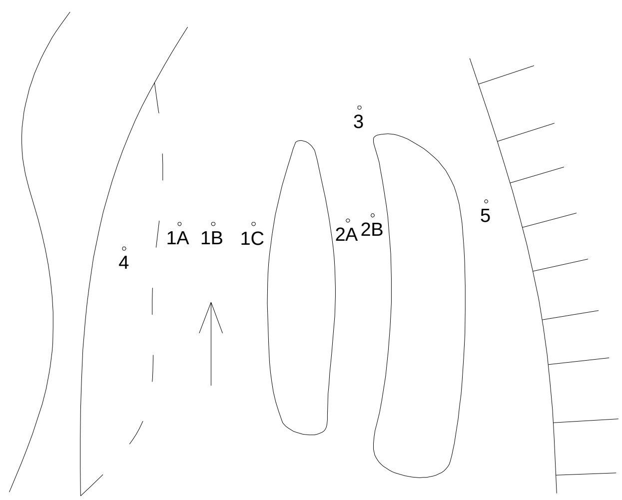

Fig. 4 Channel system during the 3rd series measurement

Table 3 Hydrodynamic parameters during the 3rd series measurement

05.04.04 Points	V_{av} [m · s^{-1}]	h_{max} [m]	V_{max} [m · s^{-1}]	V_* [m · s^{-1}]	τ [N · m^{-2}]	Fr_{max} [-]	Re_{max} [-]	Re_{d50} [-]	Re_{ks} [-]
1A	0,723	0,26	0,808	0,0093	0,0866	0,453	143705	51886	328862
1B	1,420	0,36	1,472	0,0051	0,0260	0,756	390796	94525	645899
1C	0,623	0,15	0,638	0,0101	0,1024	0,514	71439	40969	283377
2A	0,808	0,22	0,812	0,0214	0,4591	0,550	135892	52143	367525
2B	0,487	0,12	0,534	0,0102	0,1031	0,449	44675	34291	221516
3	0,177	0,58	0,184	0,0123	0,1503	0,074	78480	11816	80510
4	0,331	0,12	0,336	0,0066	0,0439	0,305	30365	21576	150558
5	0,137	0,08	0,140	0,0151	0,2268	0,155	8379	8990	62316

The next measurements performed in 29.10.2004 (Fig. 5, Tab. 4). The watercourse of the river was interrupted by river engineering works in the research cross-section. The natural fluvial braided processes were stopped. The water course was concentrated only in the middle channel of the river.

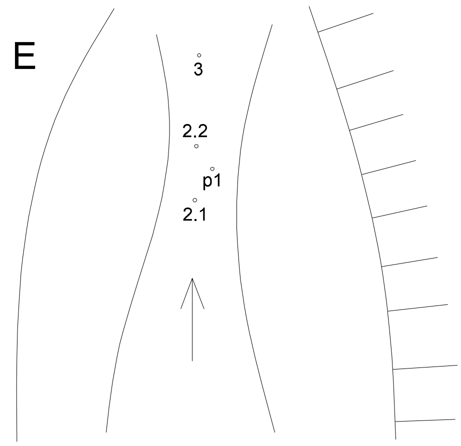

Fig. 5 Channel system during the 4th series measurement

Table 4 Hydrodynamic parameters during the 4th series measurement

29.10.04 Points	V_{av} [$m \cdot s^{-1}$]	h_{max} [m]	V_{max} [$m \cdot s^{-1}$]	V_* [$m \cdot s^{-1}$]	τ [$N \cdot m^{-2}$]	Fr_{max} [-]	Re_{max} [-]	Re_{d50} [-]	Re_{ks} [-]
2.1	1,039	0,30	1,107	0,0447	2,0008	0,606	238285	71086	472598
2.2	0,382	0,27	0,397	0,0213	0,4517	0,235	78847	25493	173756
p1	0,020	0,12	0,022	0,0016	0,0026	0,019	1862	1413	9234
3	0,732	0,40	0,750	0,0566	3,2065	0,370	223836	48161	332956

In 25.08.2014, we performed cross-section and longitude profile measurement on the Ochotnica River (Fig. 6). Additionally, we made hydrodynamics parameters measurement during the flow Q = 1.5 $m^3 \cdot s^{-1}$ (Tab. 5). The river was reconstructing its bars by depositing gravel. We observed two gravel bars and three water channels (one main and two side). The water flowed one out (main channel) of three channels. The river cuts the right bank.

In the central channel, the water flows during the medium water level. In the comparison with measurement day (25.08.2014), the water level must be grow up about 0.37 m. Then the water may be flow into the central channel through the local road. At measurement day, the water get to the central channel across the alluvial material of bar A, which was located below the road. In the left channel was dry. The water was only during in the high water level.

The values of velocity in the main channel were noticed $V_{av} > 0.63$ $m \cdot s^{-1}$. The highest value (V_{av} = 1.70 $m \cdot s^{-1}$, V_{max} = 2.14 $m \cdot s^{-1}$) was obtained at the point 6. In this place were observed a few over-sized grains, what caused the appearance a very turbulence (Re = 490 788). At the point 9, we also measured the high value of velocity (V_{av} = 1.16 $m \cdot s^{-1}$) and the low value of water depth (h_{max} = 0.13 m). At this place, we observed a riffles in the bed river.

In the central channel, the water either stagnate or flowed with the low speed. At the point 13, the velocity value was noticed (V_{av} = 0.22 $m \cdot s^{-1}$). The other hydrodynamic parameters were also lower than observed in the main stream. The value of shear stress was equaled τ = 0.096 $N \cdot m^{-2}$. The values of Reynolds number and Froude number was noticed Re_{max} = 14 984 and Fr_{max} = 0.338 respectively.

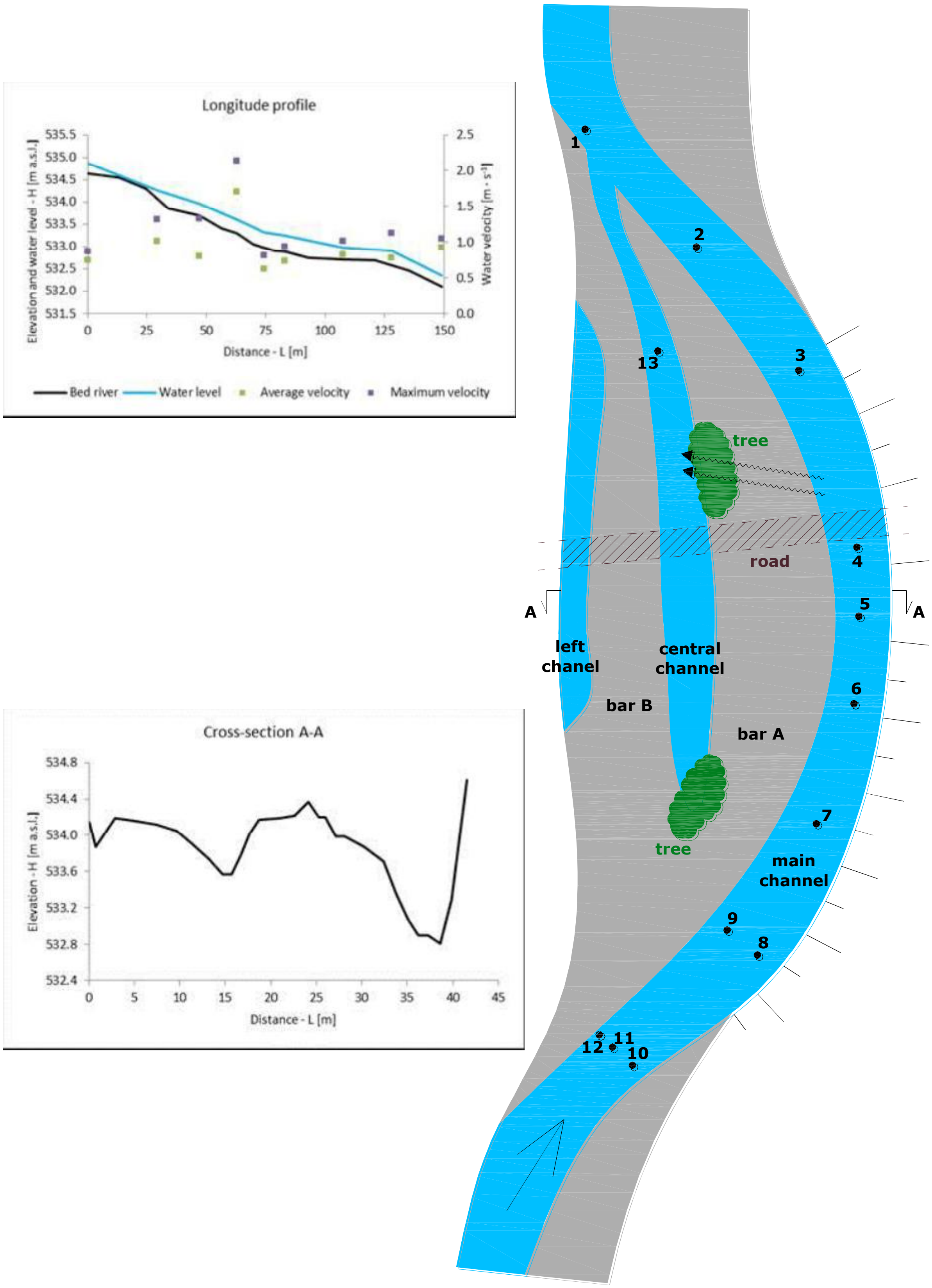

Fig. 6 Channel system during the 5th series measurement

Table 5 Hydrodynamic parameters during the 5th series measurement

25.08.14 Points	V_{av} [m · s^{-1}]	h_{max} [m]	V_{max} [m · s^{-1}]	V_* [m · s^{-1}]	τ [N · m^{-2}]	Fr_{max} [-]	Re_{max} [-]	Re_{d50} [-]	Re_{ks} [-]
1	0.920	0.25	1.050	0.0247	0.610	0.670	200 673	1 926	11 235
2	0.780	0.33	1.130	0.0387	1.498	0.628	285 070	3 018	17 603
3	0.820	0.26	1.010	0.0204	0.416	0.632	200 749	1 591	9 279
4	0.740	0.36	0.940	0.0190	0.361	0.500	258 696	1 482	8 642
5	0.630	0.34	0.810	0.0339	1.149	0.444	210 534	2 643	15 420
6	1.700	0.30	2.140	0.0413	1.706	1.247	490 788	3 220	18 786
7	0.800	0.27	1.330	0.0215	0.462	0.817	274 520	1 676	9 779
8	0.860	0.24	1.340	0.0094	0.088	0.873	245 853	733	4 276
9	1.160	0.13	1.300	0.0097	0.094	1.151	129 195	756	4 412
10	0.790	0.23	0.930	0.0125	0.156	0.619	163 520	975	5 686
11	0.700	0.31	0.800	0.0180	0.324	0.459	189 588	1 404	8 187
12	0.630	0.15	0.720	0.0199	0.396	0.594	82 562	1 552	9 052
13	0.220	0.07	0.280	0.0098	0.096	0.338	14 984	764	4 458

Conclusions

The conclusions are following:

1. Under high water level conditions, center and right channel of the Ochotnica River was functioning, which resulted in the formation of the active gravel bars. Within the periods of low water level those two channels were inactive and did not occur any changes in their morphology.
2. During low water level conditions, a pool behind the right gravel bar was filled up with the water and the water was present all the time within the pool no matter if all river channels were active. It might suggest that a large part of running water is moving primarily through alluvial gravel bed of the river.
3. In all measurement points the Reynolds number calculated using roughness value of the river bed was several times higher than in the case when the Reynolds number was calculated using maximum water depth and mean diameter of the river bed. This demonstrates the roughness effects on flow conditions in the river channel.
4. The values of shear stresses and the Shields parameter in the analyzed channel depend mostly on the flow velocity. These parameters were the highest in the points where the water velocity was the highest, while water depth was less significant factor.
5. The river study showed that despite the devastation of the river channel during illegal gravel mining river bars and channel braids are sill being formed which means that the river go back to the natural process of braiding.

6. The impact of human pressure on the river bed is negative phenomena. The local road caused the lowering the grade line of bars and destroying their natural structures. However, it also caused the increasing the grade line of side channel, what in results the blocking and stopped of flowing the water in these structures.