

Letter to Editor

Model Assessing Changes of the Raba River Runoff Caused by the Dobczyce Reservoir (Poland)

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Abstract

The Dobczyce Reservoir is one of the new man-made lakes located at the Raba River in the Carpathian Mountains. The drainage basin is underlain by flysch with a high proportion of sandstone. The river is characterized by great variability of runoff. The mean annual discharge is about $12 \text{ m}^3 \cdot \text{s}^{-1}$. The dam began to function in 1986 and about $2.1 \text{ m}^3 \cdot \text{s}^{-1}$ of fresh water has been withdrawn from the reservoir to Cracow. The model was calculated for estimating Raba River discharge down the reservoir. Analysis of the river discharge before and after the dam construction has shown that one of the most important effects of the Dobczyce Reservoir is a change of the Raba River runoff: mean minimum and maximum monthly discharges increased and mean monthly discharge decreased.

Keywords: man-made lakes, hydrological model, anthropogenic river regime, Carpathian Mts.

Introduction

Dams and water reservoirs were built as early as at the turn of the 17th century, and particularly in the 19th century in Poland. In the 20th century numerous man-made lakes came into operation, first as protection against floods and later for water power engineering. At present, reservoirs are built to accomplish many different tasks. Most of them supply urban consumers [2]. Many reservoirs are located in the Carpathian Mountains in the southern part of Poland. The water resources of the Carpathian river basins are considerable and the quality of river water is good. There is a lack of fresh water in other regions of Poland, and there is a necessity to withdraw water from there to other localities.

Some Carpathian rivers with reservoirs were receiving the most attention [1, 8]. The Raba River has been investigated the most on geomorphological activity in the river channel [10, 11]. There is lack of research on the Dob-

czyce Reservoir – the main source of drinking water for Cracow – the biggest city in the southern part of Poland (850,000 of population).

The aim of presented research is to assess the influence of the Dobczyce Reservoir and changes in the Raba River discharges.

Area of Investigation

The study was focused on the Dobczyce Reservoir – one of the new artificial lakes located on the Raba River, the Carpathian tributary of the Vistula River (Fig. 1). The Raba River drains the Beskidy Mts., which range up to 1310 m a.s.l. in elevation. The drainage basin is underlain by flysch with a high proportion of sandstone. Floods occur usually in March and April during the meltwater period and in July due to summer rains [9]. The river is characterized by great variability of runoff. The mean annual discharge of the Raba River amounts to about $12 \text{ m}^3 \cdot \text{s}^{-1}$ (1951-1980); the highest measured discharge was $1300 \text{ m}^3 \cdot \text{s}^{-1}$ (1958) and the lowest was $0.65 \text{ m}^3 \cdot \text{s}^{-1}$ (1971).

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Table 1. Errors of estimation (%) of Raba River discharge (1961-1983).

Discharge	Nov.	Dec.	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Minimum	1.4	10.0	20.9	24.4	43.1	7.9	4.7	4.7	11.3	1.3	11.1	11.1
Mean	0.5	2.2	4.6	4.9	0.5	7.1	0.8	1.7	2.3	2.3	4.5	0.5
Maximum	11.7	42.4	3.8	6.4	9.9	1.7	30	13	34.6	8.9	15.3	32.4

In 1986 the dam began to function. It is located at 60.1 km of the river course; the drainage basin - 768 km². The area of the reservoir is about 10.65 km², with total storage of 127·10⁶ km³, and dead storage of 14.5·10⁶ km³. Mean depth amounts to 11m and maximum depth is 28m [6]. The reservoir was built to supply Cracow and other cities with freshwater and for flood control. At present an average of about 2.1 m³·s⁻¹ of fresh water has been withdrawn from the reservoir to Cracow and has been returned to the Vistula River as wastewater. There is also located a power station by the dam (2.4 MW).

Methods

Two water level gauging stations were investigated: the Stróža station – 80.6 km at the Raba course, and the Gdów station – 50.2 km at the Raba course (Fig. 1). There was a relationship between the Stróža gauge and the the Gdów gauge stations: the Stróža station influenced the discharge at the Gdów station before dam construction.

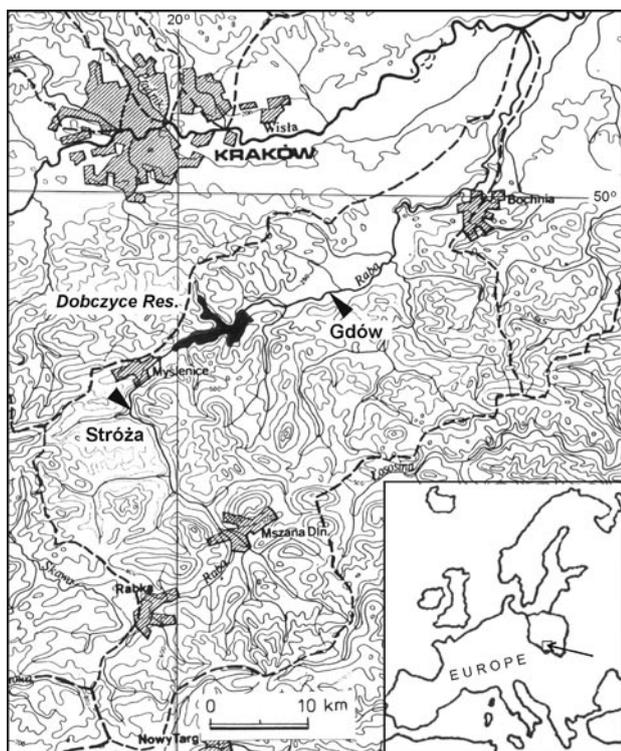


Fig. 1. Location of the investigated area and gauging stations.

River discharge data 1961-1986 was considered. Because of a nonhomogeneity of this time series [7], data 1961-1983 was taken to calculate a model for estimating Raba River discharge at the Gdów gauge station:

$$Q_G = 1.2264 Q_S^{1.0175} \quad (1)$$

where:

Q_G – daily discharge at Gdów (m³·s⁻¹),
 Q_S – daily discharge at Stróža (m³·s⁻¹).

There were calculated daily river discharges at Gdów in 1961-1983, and compared with observed values. According to the analysis of errors of estimation minimum, mean and maximum discharges in 1961-1983, it may be stated that the model calculates the best minimum and mean discharges of the Raba River. The enormous errors of estimation refer to maximum values, in particular in December, May, July and October (Table 1).

Results

On the base of the model, the daily river discharges at Gdów were calculated and compared with observed data in 1987-1995, i.e. after the dam construction, in the following years:

- 1987 – in the first half of the year the reservoir slightly decreased daily discharge (the reservoir was filling up), and in the second half of the year the floods were smoothed significantly,
- 1988 – decrease of river discharge except January and February,
- 1989 – decrease of river discharge, beginning of reservoir management,
- 1990 – no data,
- 1991 – slightly smoothed daily discharge,
- 1992 – the reservoir influence was significant in the second half of the year – reduction of maximum discharge,
- 1993 – decrease of daily river discharge and reduction of floods, except winter,
- 1994 – decrease of daily river discharge and reduction of floods except April and June (Fig. 2),
- 1995 – decrease of daily river discharge.

Analysis of the river discharge before and after the dam construction has shown that the dam caused an increase of the mean minimum (from 0.86 to 1.11 m³·s⁻¹) and maximum (from 233 to 336 m³·s⁻¹) monthly discharges, and

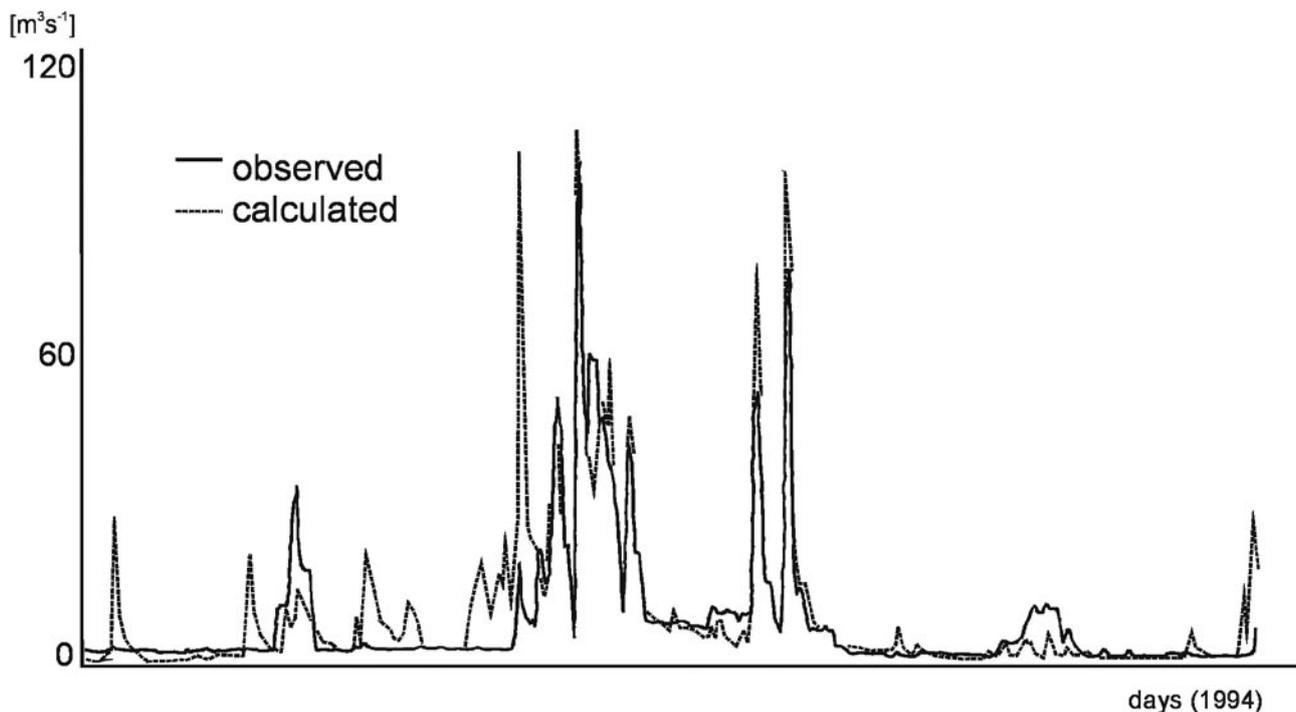


Fig. 2. Observed and calculated hydrographs of the Raba River at Gdów gauging station in 1994.

Table 2. Comparison of the observed and calculated mean monthly discharges ($\text{m}^3 \cdot \text{s}^{-1}$) of the Raba River at Gdów.

Discharge	1961-1983	1987-1995	
	Q_G (observed)	Q_G (observed)	Q_G (calculated)
Minimum	0.65	1.11	0.86
Mean	12.9	8.86	11.2
Maximum	995	336	233

caused a decrease (from 11.2 to $8.86 \text{ m}^3 \cdot \text{s}^{-1}$) of the mean monthly discharge 1987-1995 (Table 2).

Discussion

To assess the influence of the Raba River by the Dobczyce Reservoir, the computed model can be used to estimate daily discharge. However, due to enormous error of estimation, another model calculating maximum discharges should be considered.

One of the most important influences of the Dobczyce reservoir is a change of the Raba River runoff, i.e. mean minimum and maximum monthly discharge increase and mean monthly discharge decrease. Thus, the reservoir changed a seasonal variability of runoff.

Hydrological changes of river regime and withdrawal of water are favourable to changes in water balance of the river basin [3]. Moreover, changes of the runoff of the Raba River can cause change of the Vistula River runoff

because its upper part is influenced by the Carpathian rivers. Their contribution in the Vistula River runoff is significant and dominant (about 80%).

Final Remarks

There are other results of the artificial lake at the Raba River. The dominant useful effect has been the storage of water which has been used to supply urban consumers. Water from the reservoir meets 52% of Cracow needs of freshwater. It is purified and pumped to Cracow (about 40 km). Another useful effect has been the energy production.

Changes of the runoff caused differences in sediment transport. After the dam construction the bed load and almost the whole (96%) suspended sediment load carried from upstream is deposited within the reservoir [4, 5]. Changes to channel morphology must also be changed and it would be interesting to compare result of previous geomorphological research (before the dam construction) with contemporary river channel activity. It would be interesting also to study downstream impacts on river ecosystems and the local people.

References

1. DYNOWSKA I. Zmiana reżimu odpływu w wyniku oddziaływania zbiorników retencyjnych. *Czasopismo Geograficzne*, **3**, 301-316, **1984**.
2. JAGUS A., RZĘTAŁA M. Zbiornik Poraj. Charakterystyka fizycznogeograficzna. Wydział Nauk o Ziemi US, Sosnowiec, **81**, **2000**.
3. LINSLEY R.K., FRANZINI J.B., FREYBERG D.L.,

- TCHOBANGOLOUS G. Water-resources Engineering. McGraw-Hill Inc. 843, **1992**.
4. ŁAJCZAK A. Retencja rumowiska w zbiornikach zaporowych karpackiego dorzecza Wisły. *Czasopismo Geograficzne*, **57**, 47, **1986**.
 5. ŁAJCZAK A. The impact of river regulation, 1850-1990, on the channel and floodplain of the upper Vistula River, southern Poland. In: Hickin, E.J. (Ed.), *River Geomorphology*. Wiley, Chichester, pp. 209-233, **1995**.
 6. MATEREK E. Hydrologia dopływów i zbiornika [In: Starmach J., Mazurkiewicz-Boroń G. (Ed.), *Zbiornik Dobczycki. Ekologia - eutrofizacja - ochrona*. PAN, Kraków, pp. 15-31, **2000**.
 7. PUNZET J. Badanie jednorodności długoletnich materiałów hydrologicznych na przykładzie danych z górnej Wisły i jej karpackich dopływów. *Gospodarka Wodna*, **12**, 271, **1991**.
 8. PUNZET J. Kilka uwag o zmianie reżimu przepływów Sanu poniżej zbiorników Solina-Myczkowce. *Gospodarka Wodna*, **7**, 146, **1991**.
 9. PUNZET J. 1969, Hydrological characteristics of the River Raba, *Acta Hydrobiol.* **11**, 423, **1969**.
 10. WYŻGA B. Present-day downcutting of the Raba River channel (Western Carpathians, Poland) and its environmental effects. *Catena*, **18**, 551, **1991**.
 11. WYŻGA B. River response to channel regulations: case study of the Raba River, Carpathians, Poland. *Earth Surface Processes and landforms*, **18**, 541, **1993**.