Outlets capacity analysis of the Złotniki storage reservoir on the Kwisa River

Jerzy Machajski, Wojciech Rędowicz

Nach der großen Flutkatastrophe von 1897 haben die deutschen Behörden beschlossen eine Reihe von Speicherbecken in Niederschlesien zu bauen, welche dem Hochwasserschutz dienen sollten. Die ersten Talsperren sind im Einzugsgebiet des Flusses Bóbr erbaut worden. In dem vorliegenden Beitrag wird die Staustufe in Złotniki auf dem Fluß Kwisa unterhalb der Stadt Gryfów Śląski vorgestellt. In dem Beitrag findet man sowohl eine allgemeine Charakteristik als auch Betriebsbedingungen der Einrichtung während des Hochwassers. Eine eingehende Analyse der Flutwelle, die über dieses Speicherbecken gegangen ist, hat gezeigt, daß die bestehenden Betriebseinrichtungen nicht mehr in der Lage sind, die hypothetische Flutwelle laut der geltenden Bestimmungen zu reduzieren. Anhand von hydraulischen Vor-Berechnungen hat man eine Reihe von technischen Lösungen des Problems vorgeschlagen, welche einen sicheren Betrieb des Objektes unter der extremalen Betriebsbedingungen während der erhoften Flutwelle sicherstellen sollten.

1 Introduction

Technical Regulations concerning the technical conditions which should be satisfied with regard to engineering and technical installations in the sphere of water economics hydraulic constructions”, which had been in force since 1973, were changed in December 1996. The changes have been influenced on the existing classification of the main hydraulic constructions. For instance the first class in the existing hierarchy of the importance, included earth and concrete hydraulic structures, constructed on the bed rock, of the water damming level of over 30 m, and the same structures but constructed on non-rock bed of the water damming level exceeding 20 m.

In this situation, the classification of many hydraulic structures was changed in Poland. It also involved the change of many calculation requirements for these structures including, first of all, the change of the calculation discharges, the change of the safety factors, and the change of the required the dam crest excedance with regard to the water calculation levels – designed and control ones. It turned out that many structures are not prepared for the passing by significantly higher calculation discharges.

The paper deals with the consequences of the classification change on the example of the storage reservoir „Złotniki" on the Kwisa River, which can be seen, in particular, in the conditions of the passage of the control calculation flow. At the same time the paper shows possible, in the existing situation, departures from the requirements with regard to, among others, new excedance of the dam crest determined by the regulations of 1996.

2 Characteristics of the storage reservoir „Złotniki"

The stone dam forms the storage reservoir „Złotniki". The dam is localized in 103+150 km of the Kwisa river course, left tributary of the Bóbr River. It was built in 1919 ÷ 1924 as a stone construction, placed on the rock bed built of granite-gneiss.

The average dam base width is 27 m. The dam body was built without dilatation and it was shaped on the level of the dam crest as an arc of the radius of 158 m. The maximum height of the dam is 36 m. The 0.60 m stone wall secures the upstream face of the dam body; below the wall the dam body is sealed with a 0.05 m waterproof cement mortar. The stone wall with a cement mortar covers the downstream face of dam body. The dam crest is 5 m wide. The total length of the dam crest is 169 m (Fig. 1).

Inside the dam body there is a vertical drainage system with outlets in two control galleries - the bottom and the top ones, connected with a vertical shaft of diameter 0,80 m. The drainage water from those two galleries is supplied to the bottom outlet channel and drained to the tail-water.

The excess water from the reservoir is passing through control sections, which consist of four bottom outlets, including three pipelines of 1400 mm, and one pipeline of 1000 mm diameter, and the side weir. Two bottom outlet pipelines, are situated in the dam body on the left side of the dam. The remaining two pipeline, are situated in the diversion channel of 150 m long, hammered in the right slope of the valley. The section of the channel is similar to the 4.40 m high and 5.60 m wide eclipse. Two flap gates, each 22.50 m long, were mounted on the side weir crest. Water comes from the weir to the tail water by a stepped spillway, irregularly shaped in the left side of the rock. The maximum control sections discharge is approximately 480 m^3/s, where 380 m^3/s flows through the side weir and stepped spillway.

In the water power plant situated below the dam, three turbine sets were equipped with Francis turbines. The total installed power is 4.90 MW. The total capacity of water turbines at the ordinate of the normal water damming level on the reservoir is 20.30 m^3/s.

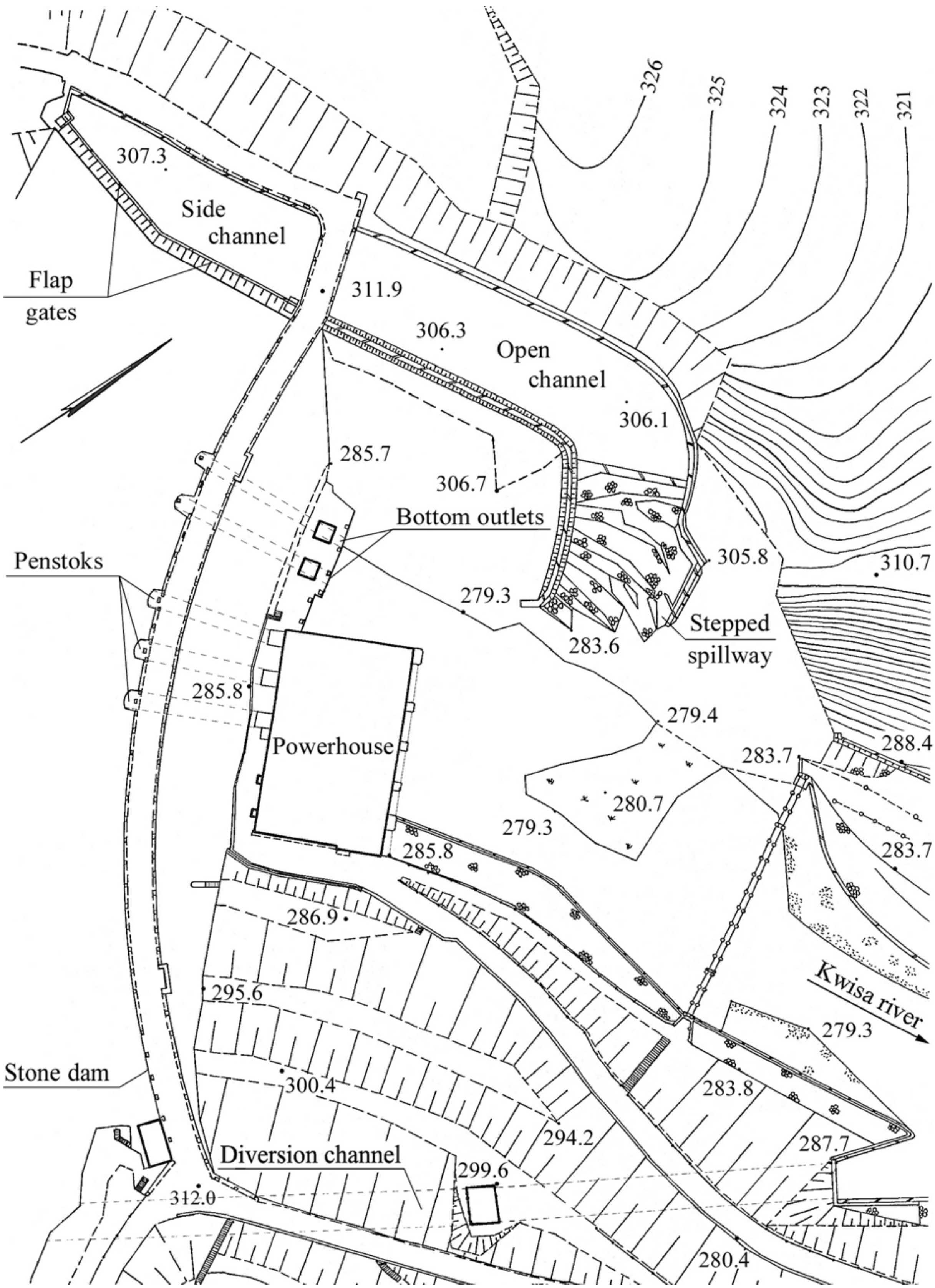

Figure 1 The location plan of the dam in Złotniki

3 Water management on the Złotniki storage reservoir

3.1 Historic flood events

Intense floods in the Kwisa river catchment were recorded, among others, in 1351, 1432, 1570, 1590, 1591 and 1667. However, the flood that took place in 1897 is considered to be the biggest one, which can be confirmed by historic records. The flood wave, which occurred on July 31st, 1897 and passed through the unbuilt at that time location of Złotniki storage reservoir dam, was then estimated as approximately 780 m^3/s (Bachmann, 1906).

In the period 1950÷2002 the flood wave of 1977, 1981, 1997 and 2002 are considered to be significant ones. The flood of 1981 is regarded to be the greatest in the postwar history of the structure. The water-level gauging station on the Kwisa River in Mirsk – km 105+700, is usually adopted to be comparative measure of the flood. In order to compare the flood waves in the past, the data from the Mirsk gauging station were calculated into the Złotniki and Leśna gauging stations on the basis of the catchment area growth. Table 1 shows the approximate results. They include maximum single flood waves. It should be stressed that two or three flood events, often occurred in a short period 2 ÷ 5 days. It should also be mentioned that in the XX$^{\underline{th}}$ century, the maximum flows were twice smaller if compared to the one of 1897. The wave of 1981 was of the biggest volume and due to the fact that the storage reservoir in Leśna was empty because of the repair works, it was possible to reduce considerably the disastrous flood.

Table 1 Parameters of historic flood waves on the Kwisa River.

Year	Gauging station Mirsk km 105,7 A=186 km^2		Złotniki dam km 91,7 A=289,4 km^2		Leśna dam km 87 A=304,5 km^2	
	Q_{max} [m^3/s]	V [hm^3]	Q_{max} [m^3/s]	V [hm^3]	Q_{max} [m^3/s]	V [hm^3]
1897	-	-	-	-	780	43,1
1977	158	35,8	203	46,1	209	47,4
1981	186	40,3	239	40,3	246	53,4
1997	142	19,0	183	24,4	188	25,2
2002	190	15,2	244	15,2	252	20,1

3.2 Hydrological data

The catchment area of „Złotniki" storage reservoir is controlled in the gauging station Leśna, which is situated approximately 400 m below the Leśna storage reservoir dam. Characteristic and probable flows for „Złotniki" storage reservoir are presented in table 2.

Table 2 Characteristic and probable discharges for gauging station Złotniki

Name	NNQ	SNQ	SSQ	$Q_{0,5\%}$	$Q^{\alpha}_{0,5\%}$	$Q_{0,1\%}$	$Q^{\alpha}_{0,1\%}$
Q [m^3/s]	0,050	0,200	1,120	397	470	478	600

3.3 Water management

Storage reservoirs „Złotniki", and Leśna, which is situated directly below, create jointly determined flood retention, which is required to protect the lands lying below. Attenuation of the flood events by 13 do 60 %, in the condition of the inflow to the reservoirs above 100 m^3/s is the consequence of the operation of these two reservoirs.

„Złotniki" storage reservoir performs the energy–flood function. Its total capacity to the crest of the flap gate is 10.5 hm^3. It is also energy capacity and it can be maintained on the reservoir in the period from October 16 to May 15. In spring-summer period, from May 16 to October 15, a normal water level damming should be maintained on the reservoir, which corresponds to the energy capacity of 9.70 hm^3.

For the purposes of flood protection, water in the reservoir may be accumulated to the ordinate of the maximum water level damming, which corresponds to the value of the reservoir capacity of 12,10 hm^3. At the accumulation to the dam crest ordinate, the total capacity of the reservoir is 13,20 hm^3, and the flooded area is 1,25 km^2.

4 Analysis of flood routing through the reservoir

4.1 Hypothetic waves

As the starting hydrological material, for the calculation of hypothetic wave transformation, were the data supplied by IMGW in Wrocław for the purpose of the study „Study of flood protection on the Kwisa river catchment area. Hydrology of flood water " (Radczuk i in., 2005). This work deals with hypothetic waves of different exceeded probability in the Złotniki storage reservoir location. The wave of $Q_{0,5\%}$ = 397 m^3/s was chosen for the calculations as a designed wave , whereas the wave of $Q^{\propto}_{0,1\%}$ = 600 m^3/s was selected as a control one.

4.2 Methods and calculation assumptions

The direct aim of the calculations was to determine maximum ordinates of water level damming in the reservoir and reduced outflows of water. The routing flood through the reservoir can be described by the equation of continuity (1):

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \tag{1}$$

where: Q – water flow, m^3/s, x – coordinate consistent with the direction of water flow, m, A – flow area, m^2, t – time, s.

After integration from x_1 to x_2, and appropriate transformation, the equation (1) takes the form of a differential equation (2):

$$Q(x_1) = Q(x_2) + \frac{\Delta V}{\Delta t} \tag{2}$$

where: $Q(x_1)$ is the inflow rate whereas $Q(x_2)$ is the outflow rate. The value ΔV shows the storage volume of water in the reservoir in time Δt.

Knowing the hydrogram of the flooding wave, the curve of reservoir capacity and characteristics of the dam outlets, it is possible to calculate the transformation of the flooding wave by the reservoir using the equation. The analysis of the wave passage through the reservoir was made making use of the assumptions of the analytic-graphic L. Puls method (Gosh, 1999). The calculations were made numerically with the additional conditions given below:

- It was assumed that the dam crest exceed was secured for designed and control flows by 1.0 m and 0.10 m, respectively,
- It was assumed that during the passage of the control wave through the reservoir all the outlets are opened and in operation,
- It was assumed that during the passage of a reliable wave the bottom outlets number 3 and 4 will be excluded from exploitation/regular use,
- The calculations were made for two starting levels of water surface: 309.30 m W.S.El. i 303.00 m W.S.El.

4.3 Analysis of the calculation results

The analysis results of hypothetical wave transformation through the reservoir are presented in the graph in figures 2 and 3. The analysis makes it possible to state that the hypothetical waves cannot be safely transformed through the reservoir. When the designed wave passes, the dam crest elevation, required by the regulations, over the maximum water level in the reservoir is not maintained.

When initial water level in the reservoir is 309.30 m over W.S.El., after the wave transformation it will be 311.66 m W.S.El., that is 0.44 m below the dam crest ordinate. When the minimum water level of 303.00 m over W.S.El., kept, the final filling will be 311.58 m over the sea level, that is. 0.52 m below the dam crest ordinate. The maximum, designed and control flow of water 397 m^3/s would be 360 m^3/s.

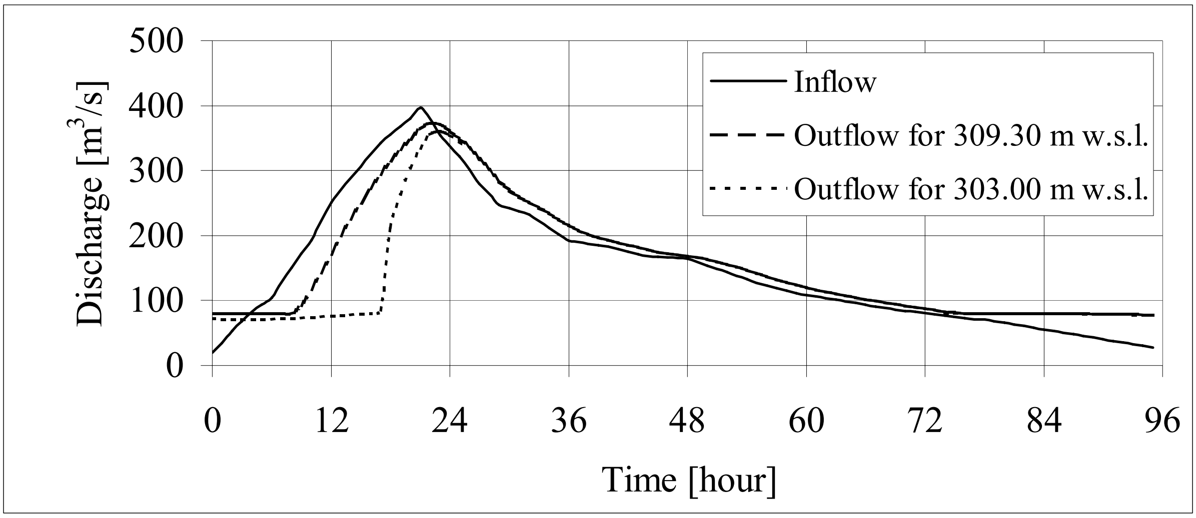

Figure 2 Routing of flood through Złotniki reservoir for designed wave

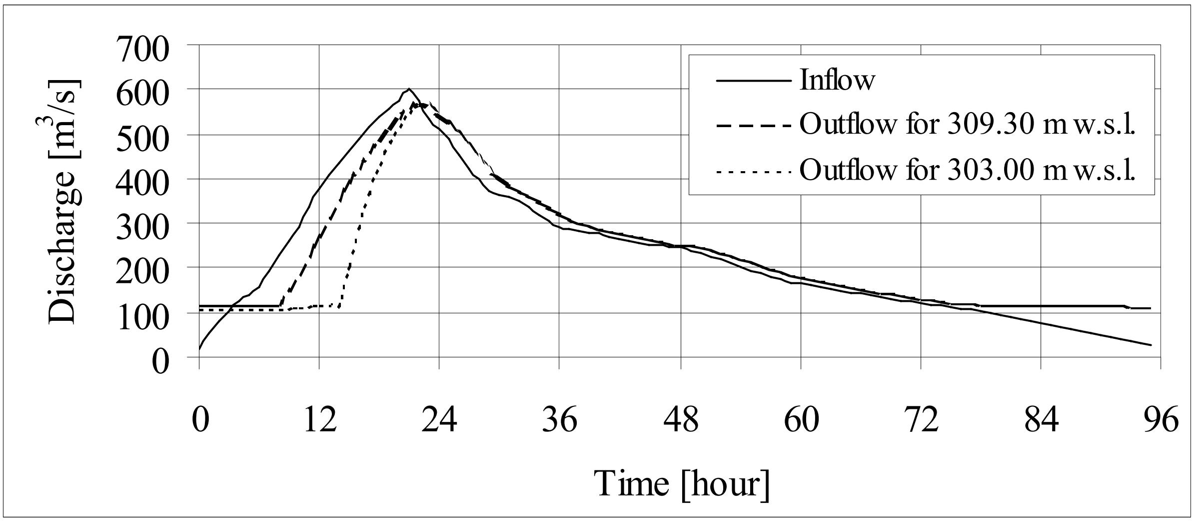

Figure 3 Routing of flood through Złotniki reservoir for control wave

During the passage of the control wave the water level in the reservoir would considerably exceed the dam crest ordinate. According to the calculations the elevation was 0.75 m at the initial state 309.30 m over W.S.El. and 0.70 m for the initial filling of the reservoir to the ordinate 303.00 m over W.S.El. These values are slightly overestimated since in the calculations the amount of water overflowing the valley slopes was not taken into account. The maximum probable control flow of water 600 m^3/s would be reduced to 547 m^3/s.

5 Conclusion

The calculations showed that it is not possible to pass hypothetical flood waves through the reservoir in Złotniki according to the regulations binding in Poland and current operational manual as well as the instruction of water management in the reservoir even in the situation when there is a maximum permissible lowering of water level. In the present situation having in mind the safety of the structure and lands situated below and assuming that the hydrological data are reliable the only solution is to modernize considerably the control sections of the dam. Taking into consideration available technical possibilities and the requirement of maintaining the damming up water in reservoir, relatively the simplest and probably the cheapest modernization would be to restructure bottom outlets situated in the in the derivation channel in order to increase their capacity. At the same time the possibility of constructing at least three storage reservoirs is being analyzed. The reservoirs would be constructed above the Złotniki reservoir, and their size and localization would make it possible to reduce culmination on the river Kwisa in the section on the entrance into the Złotniki reservoir.

6 References

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Authors:

Dr.-Ing. Jerzy Machajski,
Institute of Geotechnics
and Hydrotechnics
Wrocław University of Technology
Wybrzeże Wyspiańskiego 27
50-370 Wrocław
Tel.: ++48 – 071 – 3203940
Fax: ++48 – 071 – 3284814
jerzy.machajskil@pwr.wroc.pl

Dr.-Ing. Wojciech Rędowicz,
Institute of Geotechnics
and Hydrotechnics
Wrocław University of Technology
Wybrzeże Wyspiańskiego 27
50-370 Wrocław
Tel.: ++48 – 071 – 3203368
Fax: ++48 – 071 – 3284814
wojciech.redowicz@pwr.wroc.pl