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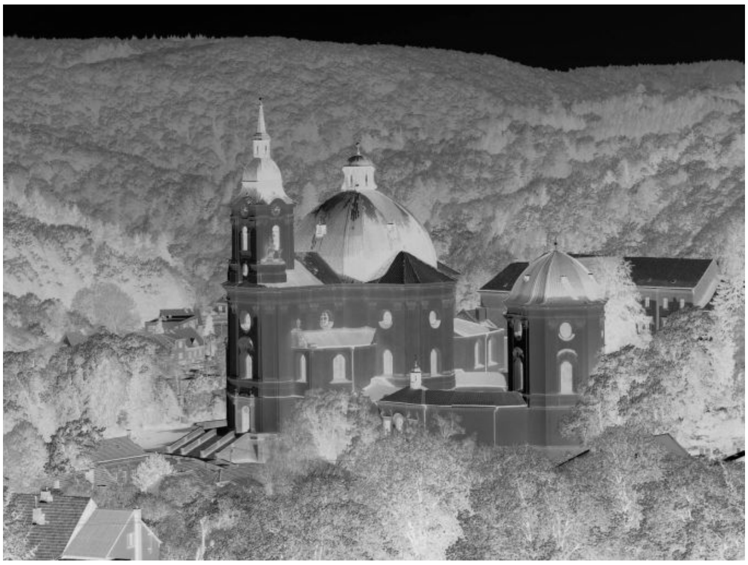

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THE THROUGHPUT OF THE DRAINAGE-RETAINING CHANNEL BOTONEGA IN ISTRIA, CROATIA

Elvis Žic[1], Ivan Marović[2], Nevenka Ožanić[3], Ivana Sušanj[4]

Abstract

The drainage-retaining Botonega Channel represents one of the most significant water-managing facilities of the Istrian peninsula. The Botonega Channel original purpose was the protection against high waters from the Botonega accumulation as well as external waters of streams Zamask, Zigante, Senica, Matisko and St. Cirijak streams. The Channel is closely related to the overall water flow regime and throughput of the lower and central Mirna River basin. The Channel’s main purpose today is the irrigation of the Mirna River downstream areas. The appearances of high waters in the last two decades have caused major hydrological problems in wider catchment area of the Mirna River. The Botonega accumulation and the Botonega evacuation channel played a very important role in reducing large water waves, particularly in the central and lower part of the Mirna River basin. Basic characteristics of the throughput capacity of the drainage-retaining Botonega Channel in winter and summer time are shown in this paper as well as are the significant appearances of its deformability during last ten years. Measures and criteria for the throughput capacity increase of the channel and decrease of its erosive activity are also presented.

Key words

the Botonega Channel, throughput, erosion, vegetation, irrigation, rehabilitation measures

1 INTRODUCTION

The drainage-retaining Botonega Channel is located in the central part of the Istrian peninsula, close to the Botonega accumulation (Figure 1). The Botonega toponym has a two basic versions: Butoniga and Botonega (Bottonega). The Butoniga toponym is older and means „left tributary“ [1]. Toponym Botonega (Bottonega) appears later, in the Venetian Republic period, meaning "rapidly flooding” or torrential watercourses.

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The Botonega accumulation was designed as a multifunctional water-management facility for the purpose of protection against floods (approx. $2*10^6$ m^3) and irrigation of agricultural lands in the Mirna River Valley (approx. 17.500 ha) in the function of drainage-retaining Botonega Channel [2]. With a total capacity of $19,7*10^6$ m^3 Botonega accumulation represents a major hydro-technical facility in terms of water richness in the area of the Mirna River basin [1,2]. The construction of the Botonega accumulation proved very efficient particularly during the big flood periods (November 1991, October and December 1992, September 1993, August 2002) when it protected the drained agricultural lands in the central and down part of the Mirna River basin and all water facilities against disastrous incoming water waves that reached the maximum average hourly flow rate of 301,4 m^3/s [1].

The drainage-retaining Botonega Channel plays a major role in terms of evacuation of large waters from the Botonega accumulation. The Channel is bound to the total water regime and the lower and the central part of the Mirna River basin discharge. The propagation process and forming of the flood waves are highly influenced by solutions of large waters evacuation through the Botonega Channel and by its maintenance over the year. It has been observed that the channel flow can vary a lot depending on the state of vegetation cover. Similarly, years-long maintenance works and cleaning of the channel caused the flow to increase which can be proved primarily by higher water levels and larger quantities of released water from the Botonega accumulation [3,4].

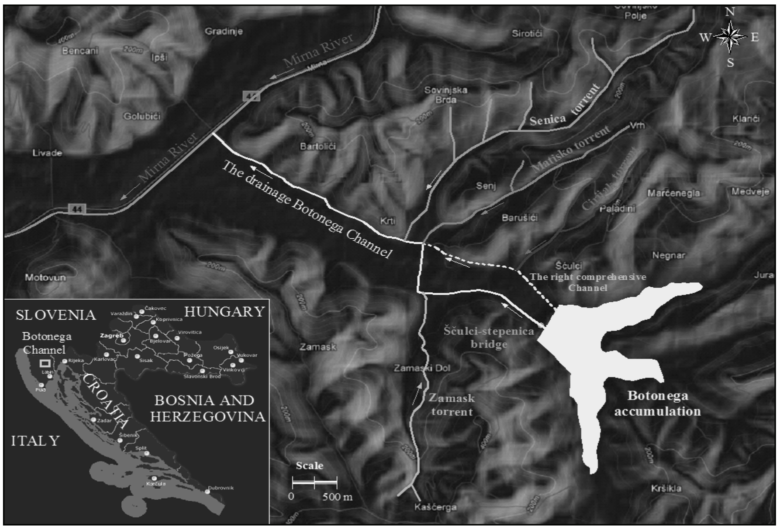

Fig. 1) General layout of the drainage-retaining Botonega Channel with belonging lateral tributaries

2 GEOMORPHOLOGIC CHARACTERISTICS OF THE BOTONEGA CHANNEL

The drainage-retaining Botonega Channel was built in 1971 according to the main project “Protection against outer waters of the Botonega Valley”. The Channel represents the main drainage basin of outer waters (Zamask, Žiganti, Senice, Matisko, St. Cirijak torrents and belonging watershed) and evacuation organs of the Botonega dam (Figure 1). The Project envisaged that the drainage Botonega Channel would evacuate the flow almost 100 m^3/s (if we take into account also outer waters) during a 20-year reflective period.

Overall channel length includes the length from the water level recorder Šćulci-Stepenica (nearby the Botonega dam, chainage 6+012,93 km) to the confluence of the Mirna River (chainage 0+000,0 km) which is shown in Figure 1. From chainage 0+000,00 to 3+769,67 km, the design flow rate of the Botonega Channel is 98,54 m^3/s (beside the roughness coefficient n=0,027 $m^{-1/3}s$), from 3+769,67 to 4+443,15 km it is 76,29 m^3/s, from 4+443,15 to 6+165,90 km it 55,5 m^3/s, while from chainage 6+197,00 km the flow rate is 60,93 m^3/s [2].

The drainage-retaining Botonega Channel is typical and complex trapezoidal earth channel with inundations on both sides. According to the original project, the Botonega Channel has three characteristic sections. Up to the distance of 3+769,67 km, the profile is complex, with 3,0 m wide bottom, 1:2 slopes, 6,0 m sides and 3,0 m wide left defence bank. The Channel bottom slope at this section is I_1=1,3 ‰. There are two 1,03 m high stairs at this section. From chainage 3+769,67 km to 4+443,15 km the Channel bottom slope is I_2=1,0 ‰, the Channel width is 3,0 m and slope is 1:2. The third section of the Botonega Channel (from chainage 4+443,15 km to 6+029,0 km) is characterised by I_3=1,5‰ bottom slope, 3,0 m wide bottom and 1:2 slopes. The left and the right sides of the inundations are 4,0 m wide. The Botonega Channel was built of earth material (clay), the slopes and embankments are covered with grass, while the stairs, a part of the channel under the bridge and the confluence in the Mirna River, as well as confluences of larger torrents, are coated with concrete six-sided prisms. Today's natural channel is characterised by extremely changeable bottom slope along the flow, while its geometry on cross sections significantly changed with respect to the original project profiles (Figure 2). The Botonega Channel has two small stairs with altitude difference of 1,03 m (chainage 2+078,00 km) i.e. 1,04 m (chainage 2+950,00 km). The Channel tortuousness is not that pronounced. However, two extremely sharp turns of the Channel (chainage 3+800,00 km and 4+500,00 km) and nine mild curves are dominant. Rush changes of the flow course in the Botonega Channel are caused by the inflow of the lateral tributary Zamask (chainage 4+500,00 km) and by the right retaining channel (chainage 3+800,00 km).

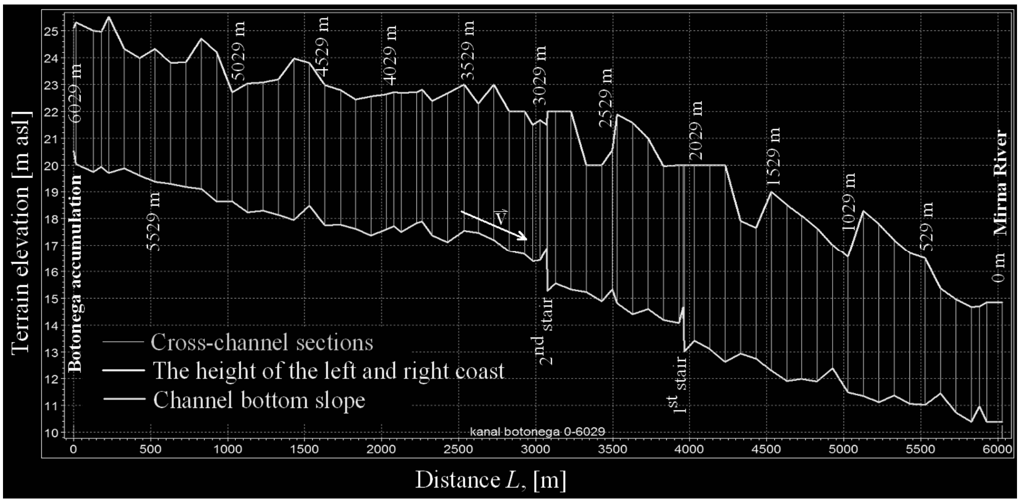

Fig. 2) Longitudinal view of the Botonega Channel bottom slope (current natural riverbed)

Geometric changes of the Botonega Channel depend on large waters periods in winter and autumn and they are manifested by periodic channel expansion and shrinking. Such systematic channel expansion or shrinking is a consequence of a permanent exchange of water regime and deposits which are formed due to changes in confluence (Figure 3).

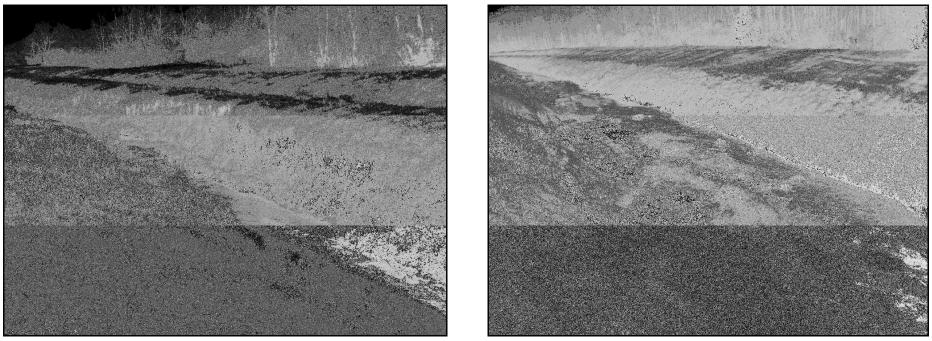

Fig. 3) Water erosion influence on mild curves of the Botonega Channel

Granulometric composition significantly influences the longitudinal slope along the Botonega Channel. Due to reduced grain size along the Channel, the drift moves more and more in form of suspension. Geometric changes of cross profiles of the Botonega Channel depart less from design profiles for the upper channel flow. Large deformability of the Channel in the lower flow, shown in Figure 3, is the consequence of the settlement of its slopes caused by larger throughput water quantities which fill the Channel from lateral inflows [5,6].

3 HYDRAULIC RESEARCH ON THE BOTONEGA CHANNEL

In the area of the Botonega Channel very little systematic scientific researches have been conducted and works published regarding discharge determination. The measurements of the state weather department of the Republic of Croatia (*Meteorological and Hydrological Service*, *DHMZ*) which have been continuously carried out on the Botonega Channel, reveal that 55 m^3/s flow foreseen by the design is not sufficient for the evacuation of large waters from the Botonega accumulation. To that effect, we started to do researches which would re-examine hydraulic characteristics, including primarily the harshness of the Botonega Channel, and their influence on the capacity, that is, the water throughput in the Channel. Further reason for the aforementioned testing were more emphasized influences of the seasonal changes on the Channel plant cover.

The Botonega Channel is not influenced by the sea surge. It is partly controlled by two hydrological water gauges, one of which, the water gauge Motovun, has been in use since 1977 while the water gauge on the Porton bridge, since 1971. The above two water gauges have preformed a lot of water measurements (in different hydrological and hydraulic conditions) for the purpose of defining consumption curve. The most important variable sizes that affect the development of the Channel are the bottom material fleshiness, sediment transfer, longitudinal channel slope and the relationship *B/H* between width and depth of the cross section [5,7]. In terms of throughput reduction of the Botonega Channel, an important role is played by the vegetation and material that formed the Channel (Figure 4).

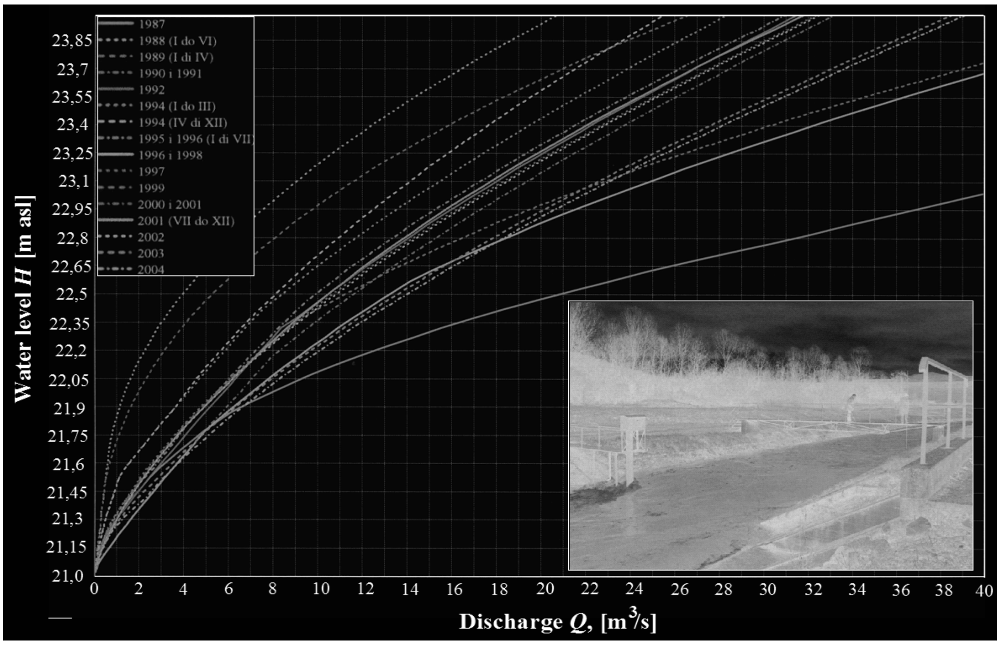

Fig. 4) Consumption curve on the water gauge Ščulci-Stepenica profile

Within the scope of the Botonega Channel throughput determination, five series of flow measurements depending on the amplitude of water level were conducted (Table 1). Hydraulic measurements were performed during 10-hour period from 8 to 18 hours at various sluice gate openings on the occasion of water discharge from the Botonega accumulation that took place on. By means of the computer program MIKE 11 (1D numerical model for unsteady flow), the kinematical analysis of changes in geometric and physical quantities in the Botonega Channel according five measuring series of drainage-retaining Botonega Channel were performed [8]. In continuation of this work, only some of the most significant physical quantities that are important for the present state of the Botonega Channel are analysed.

For the flow rate Q_2=17,202 m^3/s the flow velocity range is about 1,44÷3,04 m/s, at the flow rate Q_3=9,924 m^3/s it ranges between 0,961÷3,01 m/s, at the flow rate Q_4=6,043 m^3/s it ranges between 0,726÷3,0 m/s and for the flow Q_5=2,01 m^3/s it ranges between 0,375÷2,78 m/s. In some places, speed values that were created in order to reduce horizontal surface that was formed as a result of channel slopes slumping are quite high. By numerical simulation model with five different measurements of flow and roughness coefficients (from n=0,015 to n=0,07 m$^{-1/3}$s), the average velocities between 1,3÷2,0 m/s were obtained. Such velocities are too high for earth channels, therefore it is no surprise that many points of the Botonega Channel are subject to erosion. The speed should not be higher than 1,0 m/s thus, it is recommended that the Botonega earth channel be wider with milder slope, allowing a possible installation of additional stairs [6].

Tab. 1) Flow measurement on the measurement bridge Ščulci Stepenica, the Botonega Channel, (Chainage 6+012,93 km), Date of measurement: March 02 2008 (DHMZ Service)

Station name	Stream	Date of measurement	Water-level (cm)	Throughput (m^3/s)	Average velocity (m/s)	Flow area (m^2)	Sluice-gate opening (m)	Water level in the accum. Botonega (m asl)
ŠČULCI STEPENICA	BUTONEGA 1st measurem.	02.03.2008.	188	20,674	1,30	15,90	0,80	39,25
ŠČULCI STEPENICA	BUTONEGA 2nd measurem.	02.03.2008.	168	17,202	1,20	14,30	0,65	39,20
ŠČULCI STEPENICA	BUTONEGA 3th measurem.	02.03.2008.	119	9,924	1,00	9,80	0,35	39,13
ŠČULCI STEPENICA	BUTONEGA 4th measurem.	02.03.2008.	88	6,043	0,85	7,10	0,20	39,11
ŠČULCI STEPENICA	BUTONEGA 5th measurem.	02.03.2008.	37	2,010	0,50	4,10	0,05	39,11

Great variability of flow speed in the Botonega Channel is the result of significant changes in the flow area along the flow which can be characterized as the impact of attrition. The largest changes of flow area on the existing natural bed appear in places of hydraulic jump (two specific water stairs). Flow areas are within the range of 3,32÷14,56 m^2 at flow rate Q_1=20,674 m^3/s, 2,71÷13,33 m^2 at flow rate Q_2=17,202 m^3/s, 1,57÷10,33 m^2 at flow rate Q_3=9,924 m^3/s, that is, between 1,05÷8,32 m^2 for the flow of Q_4=6,043 m^3/s and 0,46÷5,36 m^2 for the flow Q_5=2,01 m^3/s [6].

Hydraulic analysis shows that Manning roughness coefficient varies along the Botonega Channel depending on the water depth and different measured flows. The average value of roughness coefficient n at flow rate Q_1=20,674 m^3/s is n_1=0,0303 $m^{-1/3}s$, at flow rate Q_2=17,202 m^3/s it is n_2=0,0304 $m^{-1/3}s$, at flow rate Q_3=9,924 m^3/s it is n_3=0,0327, while at flow rate Q_4=6,043 m^3/s and Q_5=2,01 m^3/s it equals n_4=0,0344 $m^{-1/3}s$ and n_5=0,0382 $m^{-1/3}s$ respectively [6]. Variability of roughness coefficient along the Botonega Channel may be the consequence of sporadic stumps and trunks and the appearance of erosion activity along the Channel [6].

4 CONCLUSION

Design hydrological parameters on the basis of which the Botonega accumulation was built in 1988 depart significantly from actually perceived parameters [2,4]. This can be supported by the fact that the calculated 100-year maximum inflow into the accumulation is 120 m^3/s, while the observations up to date revealed that even in two cases maximum rates were greater than 300 m^3/s [4]. Therefore, the project assumptions about the flows into the drainage Botonega Channel are questionable. For the purpose of preservation and revitalization of the Channel it is necessary to take into account the hydrological and geological features of the area, both by monitoring on the measurement bridge Ščulci Stepenica and by basic hydrological measurements on the drainage-retaining Botonega Channel. In this way, one could influence the formation of flood waves i.e. a more effective evacuation of high waters through the drainage-retaining Botonega Channel.

In this work the hydraulic analysis of the Botonega Channel based on the development of numerical 1D unsteady flow model has been shown. The Botonega Channel throughput was determined according to five flow measuring series. The analysis revealed that for the measured flows the Botonega earth channel presents relatively high roughness coefficient (between 0,028 and 0,044 $m^{-1/3}s$), and that it does not meet requirements in terms of channel throughput [6]. Obtained water flow velocity values are too high for this type of earth channel, the consequence of which are the observed, strong erosion activities and subsidence effects of unstable channel slopes. Although the channel is not operative throughout the year, it should be constantly maintained (primarily in winter and early spring) because of its evacuation role and it should cover a greater cross-sectional area, as well as have a milder bottom slope. When the flow rate is greater than 22,0 m^3/s, localized water spills over the main riverbed occur, which represents a danger for the areas without lateral embankments and inundations. The future research should be aimed at ensuring appropriate flow measurements in different conditions, including hydrological ones, as well as at linking such measurements (real input hydrograph) with a dynamic research on sediment transfer and deposition.

REFERENCES

[1] RUBINIĆ, J. *The Flood of 1993 in Istria and accumulation function*. Građevinar 47 (6), Zagreb 1995. (in Croatian)

[2] MULLER, B., NARDINI, D. *The Botonega Accumulation – Main Design. Book 3*. Study Elektroprojekt Zagreb, Zagreb, 1971. (in Croatian)

[3] GJETVAJ, G. *Proposal of the method for determining the flow through the reservoir outlet of the Botonega Accumulation*. Professional documentation - Faculty of Civil Engineering Zagreb, Zagreb, 1995. (in Croatian)

[4] RUBINIĆ, J. *Aspects of Hydrological Management of Water Accumulation Locations in Istria.* Hrvatska vodoprivreda 26, Zagreb, 1994. (in Croatian)

[5] JOVANOVIĆ, M. B. *Regulation of Rivers*. Faculty of Civil Engineering Belgrade, Belgrade, 2002. (in Croatian)

[6] ŽIC, E. *Analysis of Roughness Coefficient on the Example of Botonega Channel in Istria*. Master's Thesis. Faculty of Civil Engineering and Architecture Split, Split, 2009. (in Croatian)

[7] JOVANOVIĆ, M. B. *The fundamentals of numerical modelling of linear open flows*. Faculty of Civil Engineering Belgrade, Belgrade, 1998. (in Croatian)

[8] MIKE 11. *A Modelling System for Rivers and Channels*. Reference Manual, DHI Software, 2007.