Scientific Bulletin of Politehnica University of Timişoara

Transactions on HYDROTECHNICS

Volume 62(76), Issue 2, 2017

The history of hydraulic structures realized in Banat hydrographical area (Romania)

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Abstract: Banat hydrographical area is situated in the western and south-western part of Romania and includes the hydrographical basins of the rivers: Aranca, Bega Veche, Bega, Timiș, Bârzava, Moravița, Caraș, Nera, Cerna and other smaller Danube river's tributaries. The relief of this region is very diverse, with altitudes that decrease from east to west and fluctuate between 70 m and 2291 m. The characteristics of the hydrographical network and of the surface, which have a very low drainage slope in the plain area, sometimes nonexistent as well as the limited possibilities of surface water infiltration, due to the low soil permeability, have in the past led to the occurrence of unstable watercourses, with many channels that were often lost in the lowlands where they formed large flood plain meadow and marshes. For the economic development and the profitability of Banat region, an intensive water management activity has been carried out, which targeted the design and execution of several hydraulic structures through all known hydrotechnical techniques, some of them unique in the Romanian space.
Keywords: Banat hydrographical area, water resources management, hydraulic structures, non-permanent storages, permanent storages

1. INTRODUCTION

Water resources management from Banat hydrographical area has been a long-term activity, which resulted from the need to expand the agriculture in order to ensure decent living conditions of the population, which has imposed from the begenning, the execution of some large-scale hydraulic structures for preventing and eliminating the danger of floods and the excess humidity in the low areas.

In order to ensure the economic development and the profitability of the region, the drainage of the marshes, but also the transport of wood and agricultural products, in the year 1716, there was a request for the realization of a water resource management activity in this hydrographical area, with the help of a sustained hydrotehnic control plan, which has respected the principle of mastering and multilateral use of water, of some hydraulic structures and of a more and more hydrotehnic control scheme (Dunca, 2017).

In Timişoara, the largest and the most important city of this region there is a rather old tradition in the field of hydrotechnical works, for the reason that the city initially situated on a low and marshy terrain, had to conduct a steady and constant struggle in order to combat excess water (Dunca, 2017).

The Banat hydrographical area which overlaps a part of the Banat historical region, is situated in the western and south-western part o Romania, bounded north of the Mureș river, south of the Danube and east of the Romania's border with Serbia. From an administrative point of view this area spreads in our country on the territory of five countries: Timiș, Caraș-Severin, Arad, Mehedinți and Hunedoara.

This region covers a surface of 18.320 km^2 (7,7 % from the surface of Romania) and includes the hydrographical basins of the rivers: Aranca, Bega Veche, Bega, Timiș, Bârzava, Moravița, Caraș, Nera, Cerna and other smaller tributaries of the Danube river (Dunca, Bădăluță-Minda, 2017).

The relief of this region is very diverse, from east to west the forms of the relief are successively descending in altitude. Altimetric Banat runs between the minimum value of 70 m altitude, recorded in the southern extremity, on the Danube, in Orșova and in the western extremity, at the boundary of the area, where the Tisa river is situated, and the maximum value of 2291 m altitude, recorded in the eastern part, in the Gugu Mountains of the Godeanu Mountains (Arba, 2015) (fig. 1).

From a climatic point of view, the Banat hydrographical area falls in the transition temperate continental climate, a climate present in all the country, but with mediterranean influences, with the result of overlapping atlantic air circulation and invasions of mediterranean air. This climate generates a moderate character of the thermal regime, with periods of heating in winter and also of the pluviometric regime, the annual average of precipitations amount ranging from 600-1400 mm/year (Dunca, Bădăluță-Minda, 2017).

Because of to the suddenly decrease in altitude in this area from the high relief, mountainous and hilly highlands, located in the eastern, to lower relief, such as plains which are situated on the western side, also

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the abundant rainfall at certain times of the year and at high altitudes, and the influence of the Mediterranean climate experienced by the early melting of snow in the high area, the watercourses generally have a pronounced torrential character, recording a rather large variation in discharges during one year.

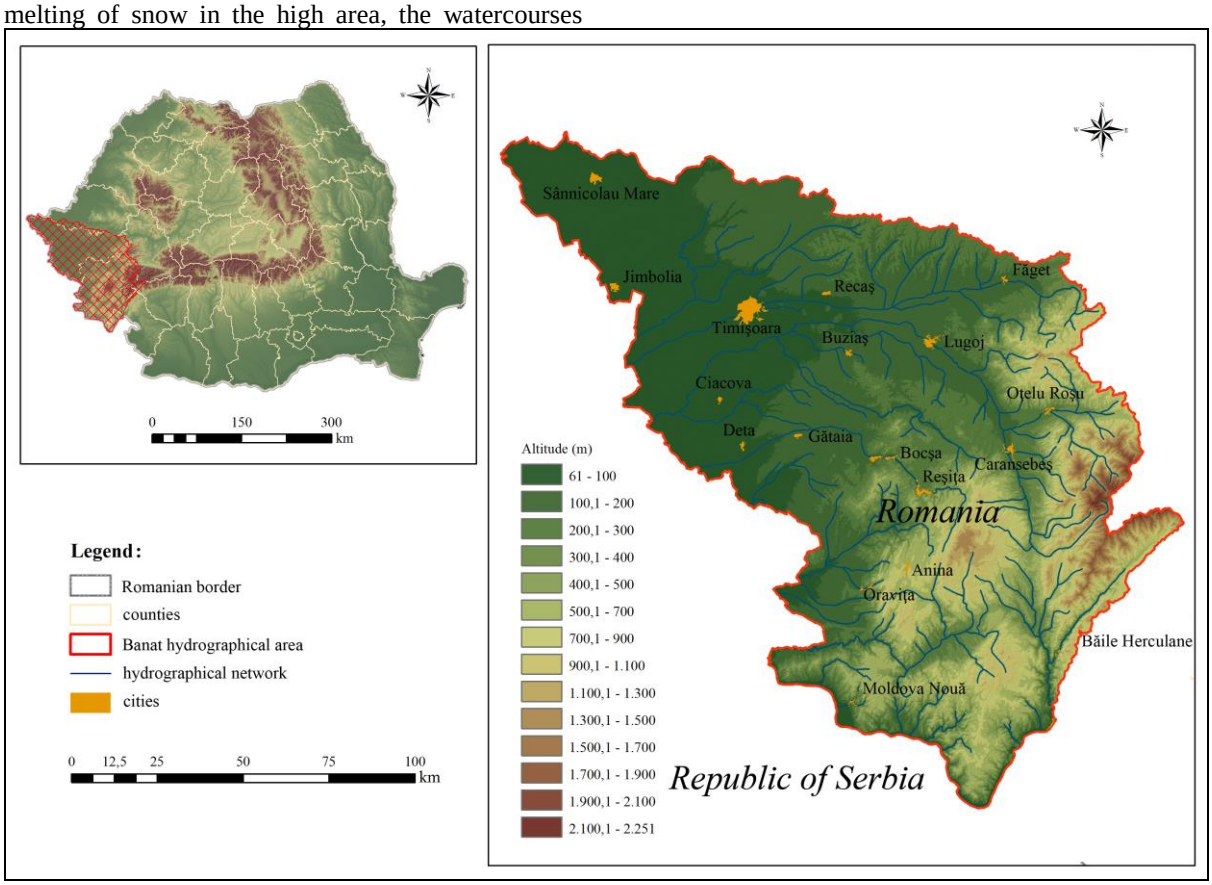

Figure 1. Hypsometric map of Banat hydrographical area

The rivers that collect the waters of this region have physical-geographic characteristics specific to the southwestern part of the country, but at the same time they are individualized as river systems with characteristics specific to each river basin (Dunca, Bădăluță-Minda, 2017).

The characteristics of the hydrographical network and of the surface, which have a very low drainage slope in the plain area, sometimes nonexistent and the limited possibilities of surface water infiltration, due to the low soil permeability, had determined the occurrence of unstable watercourses, with many channels that were often lost in the lowlands where they formed large flood plain meadow and marshes.

The surfaces from Banat plain were in the past unsuitable for practicing intensive agriculture because they were marshy, being subject to periodic floods and deprived of drainage. These inconveniences led to the emergence and implementation of a hydrotehnic control plan, one of the largest and most modern land improvement systems in Romania, with the aim of protecting land from flooding and sanitation of the entire area.

Floods are extreme hydrological phenomena that occur with a fairly high frequency in Banat. An analysis of these phenomena over the past three centuries reveals that the periodicity of the major floods is around thirty years, with some cases when they occurred at intervals of only a few years (1906 și 1912, 1966 și 1970, 2000 și 2005) (Arba, 2010, Arba, 2013).

Thanks to a long-term water resource management activity of about 300 years, Banat hydrographic area benefits from a very complex hydrotechnic control scheme that includes all hydrotechnical techniques, some of them unique in Romania and several types of works hydrotechnics, with a very important role in the formation and influence of leakage water processes (Dunca, 2017, Munteanu, Harabagiu, 2001-2002).

The water management activity of this region began in the 18th century, when the first arrangements were made for the transport of wood and when the first dams, landing lakes (länd-uri) and rakes were built (installations removing the logs from the water).

2. TYPES OF HYDRAULIC STRUCTURES

The exploitation of the hydrotechnical potential of Banat mountains watercourses has undergone several main stages, as follows: the use of river bed for wood transportation by floating, the production of the mechanical energy needed to train various household installations (mills, joagăre), the production of electricity needed for the steel and metallurgical industry, as well as household consumption, regularization of course flows, storage of water resources and flood protection and complementary activities (fishery funds, nautical sports, tourism etc.) (*Sistemul Hidroenergetic*

Complex Nera–Timiş Superior Bârzava Superioară. Elemente de Patrimoniu Industrial, 2006).

The hydraulic structures carried out in Banat have focused on the largest rivers (Timiș and Bega) and on their main tributaries. The most important types of works performed are: hydraulic structures for the regulation of peak discharge and mitigation of floods waves (damming works, permanent storages and non-permanent storages) for the purpose of defending against floods and reducing the negative effects that these extreme hydrological phenomena might have, and the regulation hydraulic structures of some river beds and embankment of the largest banks flowing waters in the perimeter of the most important cities and rural areas (Arba, 2016).

The regulation hydraulic structures

Despite the huge economic potential of the Banat's historical region, when Ottoman administration and army left the region, this was a devastated and depopulated area of wars between the two empires, with a strictly local subsistence economy based on villages and nearby environments.

Thus, during the imperial administration (1716-1778) for the economic development and the profitability of Banat historical province, the channeling of the Bega river (Timişul Mic) and the regulation of the Timiş river, which was channeled around the Timişoara fortress and rectified by works. These works had to take over water surplus in high water and floods, to mitigate the adverse effects that floods might cause and to regulate very unpredictable discharges (Dunca, 2017).

The Bega Channel is the first navigable canal in Romania, built between Timisoara and Titel situated in Serbia, with a total length of 114 km, of which 44 km in our country and 70 km in Serbian territory (Arba, 2016).

Between 1728 and 1738, Claudius Florimund Mercy, realizing that effective provincial control required primarily the development of infrastructure and the recommendation of Prince Eugene de Savoya, implements the dewatering plan of Banat muds, river training and channeling the Bega river, which connected directly on the water way, the capital of the province (Timişoara) to the imperial capital (Viena).

In November 1732, after the completion of these hydraulic structures, the first ship to Pancevo (Serbia) navigated on this variant of the canal, but because of the difficulties encountered in navigation, especially due to the presence of numerous sandy trails, the route was abandoned (Arba, 2016).

Later on, due to the fact that floods continued to affect this area, new regulatory measures to reduce the flood risk were imposed by the Dutch engineer Maximilian Emmanuel de Fremaut beginning with the year 1739 as a continuation of the works initiated by Claudius Florimund de Mercy (Arba, 2016).

In order to have the water needed for the city of Timişoara, the discharge water useful for navigation on the Bega Channel and for the prevention of floods, Maximilian Fremaut drained the marshes from the Timişoara-Belinţ-Ficătar area and made the Timiş-Bega interconnection (1758-1760) link between the two rivers (fig. 2) (Dunca, Bădăluță-Minda, 2017, Olaru, 2006).

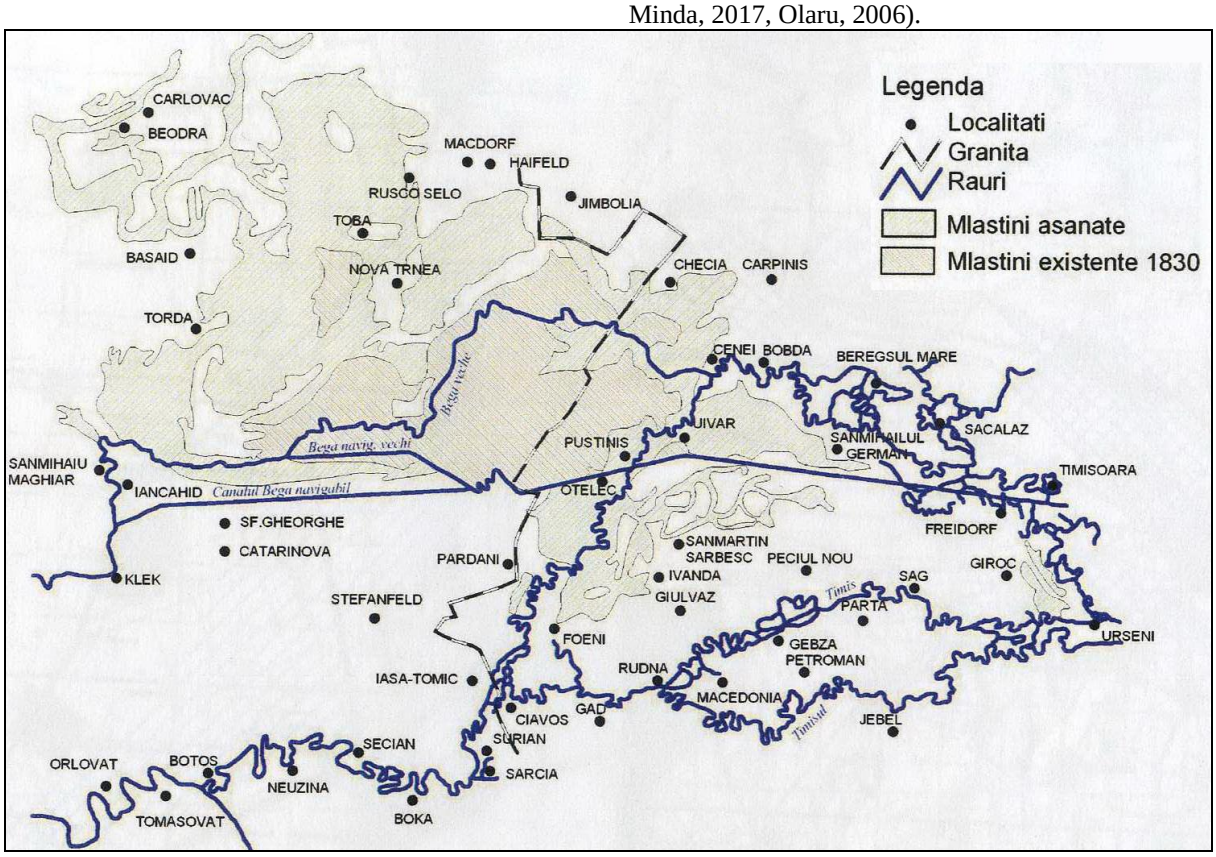

Figure 2. The sketch of the great swamps located west of Timisoara, drained until 1830
(*Source: Report on the flash flood from April 2005 in the Banat hydrographical space, p. 4)*

Maximilian Fremaut, master of channels and swamps, which he had turned them into civilization penetrations, is considered to be the father of modernization works on everything related to water tidying in order to make them navigable in Banat. At 250 years since the realization system river training of the Timiș-Bega discharges has been set up, the works he designed are still the central elements for water management in this hydrographical area.

In 1778, Maximilian Fremaut designed in Timisoara a system consisting of a hydro-mechanical installation, which set in motion two pumps, lifting the water from a well on the Bega river, so that although it came from the river, the water was subject to a natural filtering process. The water was then raised in a waterbed where it was chemically treated before it was distributed to the city through a pipeline system.

Morover, beginning with the year 1783, in Banat, the visionary engineer designed and led works for the regulation of the Bârzava river for most of its course. The arrangement of the Bârzava course was carried out for timber rafting, specifically for the transport of logs cut from the forests of the Semenic Mountains, which were intensely used back then for the production of charcoal (Chira, 1996).

The Bega Channel, was the only link to Central Europe and Western Europe for the city of Timişoara until the construction of the railway (1957), so that heavy goods could be transported to Rotterdam. In this way, Timişoara became the first Romanian city with a navigable canal and a harbor (Crețan, 1999).

In 1872, all regulation watercourses societies from Timiș and Torontal counties met in the "The regulation Society of the Timiș-Bega Valley", with the main purpose of uniformly regulate all surface waters in this river hydrographical basin to prevent floods and their negative effects.

The Bega Channel planning continued until the beginning of the 20th century, with a considerable development through the provision of a lock system (1900-1916), their modernization, the reconstruction of the dikes, the consolidation of the banks and the commissioning of Timisoara's first hydropower plant from our country (1910) (foto 1).

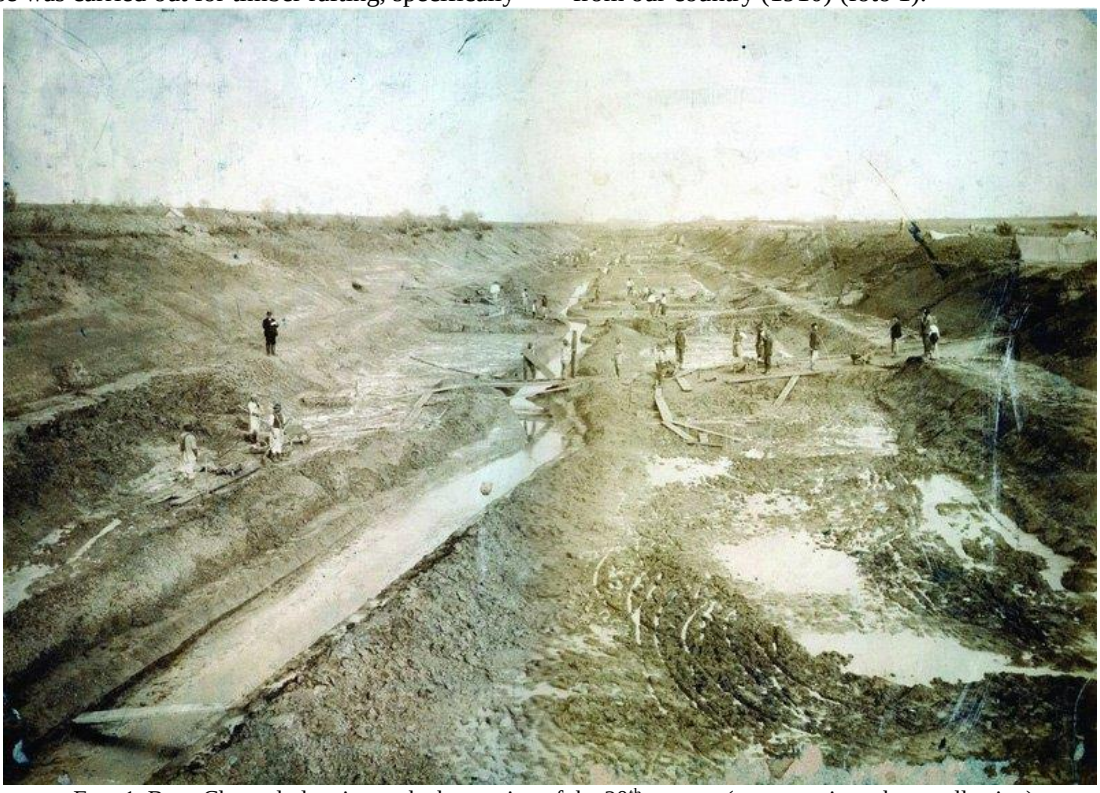

Foto 1. Bega Channel planning at the begenning of the 20th century (source: privat photo collection)

The Bega Channel lock system comprises a total of 6 locks, downstream of Timişoara, 2 on the territory of Romania (Sânmihaiu Român and Uivar) and 4 on the territory of Serbia (Srpski Itebej, Klek, Ecka și Stajicevo) (Arba, 2016).

Passengers transport peaked in 1944, after which due to the Second World War, freight traffic and transport of people on the Bega Channel ceased (Olaru, 1999).

The reopening of the navigation channel has been under discussion beginning with 1990, but then the authorities did not have the necessary funds to dredge the channel, but in a few years (2002), with the support of the Dutch government, the first feasibility study was developed on the rehabilitation of the Bega Channel, which also aimed at reopening navigation on the Romanian side, up to the border with Serbia. A similar study, finalized in 2004 was also carried out in Serbia for the Serbian side of the channel.

In 2008 began the backwashing and greening works of the Bega Channel from the Hydroelectric Plant (U.H.E.) in Timisoara, to the Romanian border with Serbia, and regarding the dredged sludge, it was deposited in ecological deposits (Arba, 2016).

The Bega Channel's navigable function is currently not being exploited, because the project works that provided this utility for Bega were blocked at a time for lack of funds.

However, in the town of Timişoara, the Bega Channel is used for leisure and recreation purposes and it has been also meant to be used for navigation purposes by reopening the transport of passengers. For this purpose, in 2016 the Timisoara City Hall purchased 7 ships, which are in the RATT administration bearing emblematic names such as: Burebista, Decebal, Traian, Glad, Huniade, Savoya şi Ferdinand.

Moreover, in 2017, the financing contract for the project "Strengthening and redevelopment the Bega Channel Infrastructure", signed under the INTERREG IPA Cross-border Cooperation Program Romania-Serbia, a partnership through which the Romanian and Serbian parties proposed to develop the navigation infrastructure on the Bega Channel, which will become navigable again.

This project foresees: reconstruction of the installations in the hydro-technical complexes of Srpski Itebej and Klek (Serbia), arrangement of bicycle tracks along the channel, 30 km long, construction of a floating dock in the town of Zrenjanin (Serbia), and rehabilitation of the node hydrotechnic from Sânmihaiu Român (România).

Approximately 260 years ago, the system of double connection between the most important rivers in Banat (Timis and Bega) was developped, which represents even today the basic axis of the Timiş-Bega hydrotechnical system (Wehry, Panţu, 2008).

By means of the double connection, the water of Timiş could be routed in the Bega Canal if necessary, so that it could always be navigable and if too much water was added for navigation and to reduce the danger of flooding Timisoara, the surplus water on the Bega river, can be conducted in the Timiş river (Lazić et al., 1995).

The purpose of such hydraulic structure is multiple because it contributes to: the increasing the natural discharges on the Bega river in order to satisfy the initial use of the floating, the navigational and water supply of the Timişoara fortress and the multiple uses in industry and agriculture that occurred with the development of the city and the protection of localities from the area against the risk of floods and achievement of dilution discharges for improving the water quality, while the water waste treatment processes through the water waste treatment plants are inadequate (Banat River Basin Administration, Timişoara).

Coştei-Chizătău Feeding Channel is part of the double connection, made in the 18th century (1757-1758), as part of a complex of hydraulic structures, regularization and sanitation works in Banat marshlands, for urban and industrial development, to ensure navigation on the Bega Channel and to practice agriculture in the Timiş Plain (Arba, 2016).

Coştei Hydrotechnical Node is located on the river Timiş, 9 km downstream of Lugoj, in the immediate vicinity of Coştei, being the main hydro-technical development in Timiş-Bega river basin, which has a historical interest in the development of hydro-technical constructions in the our country.

Topolovăţ-Hitiaş Discharge Channel, also known as the Ferdinand Channel, was built in the 19th century (1759-1760) in order to protect Timişoara from the possible floods that Bega river could cause them (Arba, 2016).

Topolovăţ Hydrotechnical Node is located along Bega river downstream of Chizătău and is equipped with several constructions and installations designed to provide the water needs for Bega Channel downstream and to maintain a water level in U.H.E. Timişoara, allowing the gravitational discharge of the right tributaries of the Bega Channel under conditions of non-invasiveness.

As a result of the regulation structures in the region, the values of the sinuosity coefficient and of branching coefficient values have been significantly reduced. Regarding the Timiş watercourse, the value of the sinuous index was in 1720 between 1.05 (Topolovăţ-Ictar sector) and 2.82 (Dragşina-Buziaş sector), and in 1975 these values oscillated between 1.03 (Ictar-Jabar sector) and 1.40 (Şag-Timişul Mort sector). In 1720, the value of the branch index in the Coştei-Şag sector was 0.46, and by 1975 it was reduced considerably to 0.04 (Andrieş, 1998, quoted by Munteanu, Rodica, 1998).

The flood control works

The low surface of Timiş-Bega hydrographical system has been affected for many years by large floods that have led to the flooding of some lands, the recording of numerous damages and in the most unfortunate cases even loss of human life, factors which led to the emergence of flood protection, imposed in the mid 18th century (Arba, 2010).

Simultaneously with the large works carried out for the river training of Tisa from the middle of the 19th century, in the valley of Timiş and Bega started as well the floods defense activity through the embankment of the main rivers.

The damming

In 1841, The Technical Service of Bega Channel established the first damming project in Banat hydrographical area, whose aim was to improve the hydrological situation around Timişoara, and stipulating the embankment of the right bank of Timiş, between Topolovăţ and Şag (Cozma et. al., 1974).

With the largest flood ever occurred until then (July 1859), which led to the flooding of a total area of 500,000 ha, up to the rivers: Tisa and Danube, the issue of flood defense was brought back into discussion (Arba, 2016).

The Technical Service of Bega Channel has drafted a new project, which stipulates that Bega floods will be led to the Timiş river through the Topolovăţ-Hitiaş Discharge Channel, and from Topolovăţ to Modoş, the right bank of Timiş will be damped, leaving an opening at the mouth of the Timişaţ Channel through which the waters on the left bank of the Bega river are discharged in Timiş (Cozma et al., 1974).

The floods occurred in May 1887 proved once again that Bega in its form was not able to carry its own floods at that time, and that Timiş river had not had the proper capacity and nor did all the other rivers and channels that were within the „Timiş–Bega Association" area which still needed significant works to reduce the risk of flooding (Dunca, 2017).

Thus, between 1887-1889, six projects were drafted as follows: the management and direction of the Bega, Bârzavei, Timiş and Alibunar floods, the separate floods on Bega, the combined floods of Timiş and Bega rivers (Cozma et al., 1974).

Following the examination of these projects, it was decided to start new hydrotechnical projects to solve the flood defense for Timis-Bega hydrographical system, by applying the principle of flood storage (Arba, 2016).

Later on, in the period 1896-1914, „Timiş–Bega Association" carried out several works, namely: reconstruction of the Coştei dam, transformation of the Topolovăţ hydraulic installations, enlargement of Topolovăţ discharge channel, regulation of the Bega channel between Topolovăţ and Timişoara, the infiltration channels, the completion of the dams of Timiş and its tributaries as a result of Bega river's water management, to correspond to a maximum level, calculated on the assumption of meeting the flood peaks on both water courses, drainages and navigation facilities on the Bega Channel, to: Sînmartinul Maghiar and Sînmartinul Român (Cozma et al., 1974).

Between 1944 and 1960, several works were realized, completed and redeveloped in the drainage systems: Checea-Jimbolia (1958-1962), Timişaţ-Ţeba (1958-1962), Rudna, Banloc-Tolvadia (1954-1958), Pustiniş-Uivar (1958-1960), Răuţi (1955-1956), Sînmihai-Timişoara (1955-1956), Caraci (1954-1955) and Partoş (Cozma, et. al., 1974).

Since 1950, many hydraulic structures have been carried out within Banat hydrographical area, which have the aim to consolidate the dams and their annexes to increase their safety and riverside territory against large waters (Dunca, 2017).

The most important of these are: the elevation and completion of the Bega Veche dike (1948, 1957-1959), the upgrading of the Bega channel, upstream of Timişoara (1954) and numerous consolidation works performed at the points where the erosion caused by the water threatened the existence of the dykes on Timiş and its affluent Bârzava (Cozma, et al., 1974).

The most important works were: cantoning and completing the embankment of the Bega Veche river (1948, 1957-1959), the rise of the Bega Channels dikes upstream of Timişoara (1954) and the consolidation of the banks at the points where the erosion caused by the waters in danger of the dykes (Arba, 2016).

Thus, in Banat hydrographical area several embankment works were carried out on the most important rivers (Timiş and Bega), but also on their main tributaries (Sebeş, Bistra, Şurgani, Pogăniş, Bârzava, Nera, Miniş, Chizdia, Glaviţa etc.).

The Timiş river was embanked for the flood protection of interest objectives, both on the right bank and on the left bank, in the upper course (Sacu-Slatina Timiş), with the help of the investment „Timiş–Bega Association", in the middle course (Caransebeş and Lugoj) and downstream (downstream of Jabăr to the border of Romania with Serbia) (Arba, 2016).

Bega river has been damped and channeled, starting with Bodo untill the country`s exit, in order to increase safety against large water in the most important localities that this river crosses, such as: Bodo, Balinţ, Ictar- Budinţi, Ghiroda, Timişoara, Utvin, Sînmihaiu Român, Uivar, Otelec etc. (Arba, 2016).

Most of the embankment works listed above were completed by 1962, but embankment works were made later this year, due to the fact that the dykes existing at that time were not enough to protect the flood areas.

In order to complete the flood control system in Banat hydrographical area, it was necessary to make permanent and non-permanent storages with an important role in the hydrotechnical control scheme of this region.

Permanent storages are made on the watercourses in the upper waters of hydrographical basins, with the primary role of retaining a portion of the flood wave's volume discharging through rivers, attenuating the runoff from downstream.

The permanent storages are made on the watercourses in the upper waters of hydrographical basins, with the primary role of retaining a portion of the flood wave's volume discharging through rivers, attenuating the runoff from downstream.

In Banat, the main purposes for which the permanent storages were put into operation are: the mitigation of flood waves during the high waters periods, the exploitation of the hydro-energetic potential of the waters from the mountain area, the provision of water supplies for downstream localities and the supplementation of discharges during the low waters periods.

The most important permanent storages from Banat are: Trei Ape (Timiş), Rusca (Râul Rece), Poiana Mărului (Bistra Mărului), Zerveşti (Sebeş), Surduc (Gladna), Valea lui Iovan (Cerna), Herculane (Cerna), Gozna (Bârzava), Secu (Bârzava), Văliug (Bârzava), Buhui (Buhui) etc.

Among the first permanent storages built in ~~the~~ Banat hydrographical area are: Buhui built on the valley with the same name (1904) and Văliug on the Bârzava river (1909) and Mărghitaş put into service on the Buhui river (1940).

After 1950, a series of permanent storages were realized, among which we can mention: Gozna, put into operation on the Bârzava river (1954), Secu, made on the Bârzava river (1963), Trei Ape, located on the Timiş river (1970), Surduc, located on the Gladna river (1976), Poiana Mărului, made on the river Bistra Mărului (1992), Zerveşti, put into operation on the river Sebeş (1988), Poiana Ruscă (Rusca) on the Râul Rece (2006), Gura Golumbului

on the Miniș valley, Poneasca in the valley with the same name etc. (Banat Water Basin Administration).

Banat hydrographical area comprises all hydrotechnical control techniques and two complex hydrotechnical planning facilities, namely: Timiș-Bega Interconnection and Complex Upper Bârzava.

The complex development of the Bega Channel has been designed to combat excess moisture and floods, to navigate and to ensure the need for water, which includes the following types of works: hydro-meliorative works, sewage and regulation works, derivation works from the Timiș river in the Bega river and vice versa, embankment works, hydrotechnical knots of derivation, hydrotechnical knotting nodes and hydrotechnical nodes of reaching and navigation (Dunca, Bădăluță-Minda, 2017).

The complex planning of the Upper Bârzava was designed to provide the drinking and industrial water supply of Reșița and to produce electricity, among the types of works it comprises are: storages, derivations, adductions, coastal channels, facilities for production the electricity.

The non-permanent storages are damming surfaces in a major river bed, designed to attenuate the flood waves. The surface within a non-permanent accumulation is used for agricultural purposes, being flooded only during the high waters, when the free surface level has to be limited to a maximum admitted downstream (Munteanu, Harabagiu, 2001-2002).

Due to the fact that there are large areas in Banat, which have a high risk of floods, during the 20th century, several non-permanent storages were made, among–which the most important are: Hitiaș (Timiș and Bega), Cadar-Duboz (Pogăniș), Pădureni (Timiș), Gad (Lanca Birda), Pișchia (Bega Veche), Mănăștur (Apa Mare), Gherteniș (Bârzava), Moravița (Moravița) etc.

The best example is the Hitaș non-permanent storage, which was carried out in the plain triangle between Timiș and the Topolovăț-Hitiaș Channel and which serves as a safety valve of the dyed downstream sector due to the mitigation effect of the floods that would represent a danger to the safety of the two rivers dikes, Timiș and Bega (Wehry, Panțu, 2008).

3. CONCLUSIONS

Nowadays, Banat hydrographical area benefits from a very complex hydrotechnic control, it also benefits from all hydrotechnical techniques provided in a control plan and carried out in more than 300 years of activity in the water management field, mainly in order to prevent and eliminate the danger of floods and excess moisture in the plain areas.

The most important types of hydraulic structures performed in Banat are: hydraulic structures for the regulation of peak discharge and mitigation of floods waves (damming works, permanent storages and non-permanent storages) for the purpose of defending against floods and reducing the negative effects these extreme hydrological phenomena might have, and the regulation hydraulic structures of some river beds and embankment of the largest banks flowing waters in the perimeter of the most important cities and rural areas.

Approximately 260 years ago, a harmonious and very close hydrotechnical link was realized between two of the most important rivers (Timiș and Bega) through two channels (The Coștei-Chizătău Feeding Channel and The Topolovăț-Hitiaș Discharge Channel), which transfers the water from one river to the other, and vice versa and which is still the main axis of this hydrotechnical system.

The natural discharges on the Bega river are supplemented through this extensive hydraulic structure, the localities in the area are protected against the risk of flooding and the dilution discharges for the improvement of the water quality.

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