Water resources and wetlands, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

THE DANUBE RIVER IN THE PONTIC SECTOR - HIDROLOGYCAL REGIME*

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Abstract

The lower sector of the Danube, with the exception of the Iron Gates gorge, is characterized through an asymmetric development under morpho-hydrographical aspect, with a floodplain, developed on the left (between Drobeta-Turnu Severin and Calaraşi) in Romania, with unequal extensions of 5 km at Greaca, 12 km at Calaraşi and fragmented by narrowing at Islaz, Zimnicea, Giurgiu, Olteniţa. From Calaraşi to Brăila, the floodplain has the largest expansion, being between the arms of the Danube, which form, in natural conditions, two wetlands of *Mesopotamian type*, known as *Romanian hydronyms Balta Ialomiţei (Borcea) and Balta Brăilei*. The total area of the Danube floodplain including the delta is 9230 km^2, respective 4% from the Romanian territory. In natural conditions, before the embankment and drainage works (1960), the Danube floodplain and delta was an *amphibious territory* consisting of *lakes, streams, backwater, eutrophic marshes, willow and poplar forests on fluvial banks* being flooded at spring-summer high water 93% (hydrograde 8). It is estimated that at 1.5 m thick layer of accumulated water for 1-2 months a year, the volume of water stored was about 4.3 km^3, contributing to attenuation of floods and at the same time to water renewal of lakes, alluvial and cleaning of *ecotonal area*. Also, the Danube floodplain and delta is an important area of *genetic capital* for reproduction of many fish species. The famous hydrobiologist Grigore Antipa studied the floodplain and the delta, scientifically arguing through its work from 1910 (*The flooding region of the Danube*) the role of this flooded area in biological functionality and productivity. The anthropogenic interventions in various aspects, on the main artery - *"free space"*, on the tributaries and throughout drainage basin, in correlation with climate changes have caused changes of discharge regime, especially in high water phase causing major material damages due to flooding (in 1970 and more recently in 2006, 2009), but also during low water phases (1921,1947,1954).

Keywords: Danube, lower sector, floodplain, hydrological regime

1. GENERAL HYDROGRAPHIC FEATURES OF THE DANUBE

The Danube is the second largest water course in Europe (after the Volga) in terms of length (2860 km) and area (817,000 km^2) The river springs from the central-western part of Europe (Schwarzwald), runs through the central part of the continent, crosses the Pannonian Depression to the confluence with the Drava, then pierces the Carpathian Mountains through the Iron Gate Gorge. Farther down it separates the southern part of the Romanian Plain from the Prebalkan Tableland, and the eastern part of the Plain from the Dobrogea Plateau and Mountains. The last sector of the river, up to the Black Sea, encompasses the Delta area. The Danube basin occupies 8% of Europe and has different lengths on the territory of several states – Germany, Austria, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Serbia, Montenegro, Bulgaria, Romania, the Republic of Moldova and Ukraine.

In Romania the Danube is 1075 km long and drains 97% of the country's territory. It flows through regions of distinct morphology, e.g. the old Hercynian Mountains, the young Alpine-Dinaric-Carpathian-Balkan chain, tablelands and plains, regions affected by Oceanic, Baltic, Mediterranean and temperate-continental climatic influences that stamp their mark on the morpho-hydrographic and hydrologic characteristics of the river.

The upper Danube course (1060 km) extends from the sources to the Devin Gate in the vicinity of Bratislava, wherefrom the river enters the Pannonian Depression. *The middleDanube course* (725 km) stretches from the Pannonian Depression to Baziaş.

The lower Danube course (1075 km) represents Romania's natural border with Serbia, Bulgaria, Ukraine and the Republic of Moldova.

Here *in the lower course,* the river forms the longest and most beautiful gorge area – the *Iron Gate* (144 km), between Baziaş and Gura Văii, a sector with an asymmetric valley (Drobeta Turnu Severin – Călăraşi, 566 km), a large floodplain sector (Rom. "baltă") between Călăraşi and Brăila (195 km), and a sector of maritime navigation, Brăila – Sulina, 170 km, also including the Danube Delta. The Iron Gate Gorge, a name already used in the international specialist literature, unfolds between Baziaş and Gura Văii.

It is a difficult sector and a very trying experience for naviagators. In order to remedy the situation, management works (1890 – 1898) targeted a former canal route dating from Roman times. Vessels would be dragged by an engine through a canal 75 m wide, 2m deep and 2 km long.

Navigation difficuties were resolved in 1970 by the construction of the Gura Văii dam and storage-lake, raising the water level and the backwater at the dam, which under certain conditions, reached beyond Belgrade, up to the junction of the Danube with the Tisa (cca. 230 km long). The hydro power station-the Iron Gate, started operating at full capacity (2100 MW) in 1971 and it is shared by Romania and Serbia.

In the so-called *Pontic sector* (Drobeta-Turnu Severin – Călăraşi) the stream gradient falls from 0.045 to 0.06‰, forming some islets (Rom. "ostrov") (Ostrovul Mare, Păpădia, Calnovăț, Băloiu and Ostrovul Păsărilor) and a 4 – 13 km-wide floodplain on the lefthandside, which before dyking and draining had encompassed numerous lakes. In this sector, the lefthandside tributaries of the Danube in Romania – the Jiu, Olt and the Argeş, are bigger than in Serbia and Bulgaria, but they are more numerous (Timok, Ogosta, Iskar, Vit, Osam, Iantra and Lom). A second hydro power station was built at Ostrovul Mare in cooperation with Serbia. A road-and-rail bridge (commissioned in 1954) spans the river between Giurgiu (Romania) and Ruse (Bulgaria). In the future, a new bridge for vehicle traffic will be built between Calafat (Romania) and Vidin (Bulgaria).

The *floodplain lake sector* (Rom."bălți") between Călăraşi and Brăila features the Danube branching out into several arms and encompassing the floodplain proper. Because of the numerous lakes, backwaters and frequent flooding, the area was suggestively named *Balta Ialomiței* (*Borcea).* It extends between the Dunărea Veche and Borcea branches; *Balta Brăilei* between Dunărea Nouă (with several ramifications – Vâlciu, Mănuşoaia, Cremenea, Pasca, Calia and Arapu), forming smaller islets in the west, and the Măcin Arm (Dunărea Veche) in the east. These two areas (except for the Balta Mică a Brăilei) were dammed and the terrain used for agriculture. A famous rail bridge between Feteşti and Cernavodă was built by Anghel Saligny in the years 1890 – 1895. It was then the longest bridge in Europe. A second road-and-rail bridge, parallel to it, was commissioned in 1987. The waterway between Constanța port and the middle and the upper courses of the Danube was significantly shortened when the Danube – Black Sea Canal was opened to navigation (1984). Downstream, where the river forms one single stream-channel, stands a road bridge that spans the distance between Giurgeni and Vadu Oii (1450 m long of which 750 m are suspended over the river). It was the longest bridge across the Danube, and the eighth in the world at that time (1970).

The final *maritime sector* derives its name from the management works performed towards the end of the 19th century to allow big tonnage sea vessels to sail through the Sulina arm and farther on to the Danube up to the town of Brăila (170 km). The major tributaries in this sector are the Siret and the Prut rivers, both on the lefthandside of the River Danube.

The *sub-sector of the Danube Delta* extends between the arms of Chilia in the north (117 km), Tulcea (19 km) and Sfântu Gheorghe (109 km; what has remained after corrections to its meandering course is 70 km) in the south. All in all, the Delta covers 2540 km^2 of Romanian territory. With a view to facilitating maritime navigation, a series of correction works were made to the Sulina–Sfântu Gheorghe arms which that run through mid-delta, the route remaining 63 km long. The territory of the Danube Delta is steadily evolving, due on the one hand, to the action of the river and its flow of 6510 m^3/sec (multiannual mean) and the sediments transported by it, and on the other hand, to the battering of sea waves on the coast. In 1990 this geographical unit, with its unique fauna and flora in Europe, was declared a biosphere reserve (fig.1).

2. HYDROGEOGRAPHICAL FEATURES OF THE LOWER DANUBE SECTOR

As mentioned, the lower Danube sector, between Baziaş to its mouth at the Black Sea, has a length of 1075 km, including the Danube Delta. Whether in the first sector, the Iron Gate gorge, due to morphological conditions, the **floodplain** has a reduced, insignificant development covered, presently, by the Iron Gate reservoir, from Drobeta-Turnu Severin to Calafat, it is more fragmentarily developed, but from Calafat to the Danube Delta, the floodplain has a continuous development, especially, on the left Romanian bank, including on the Ukrainian bank downstream Galați, excepting 900 m belonging to the Republic of Moldova.

The Danube River Floodplain, an important morpho-hydrographic component, has variable width, a surface up to the delta - Ceatalul Chiliei of 5550 km^2, being dammed for the most part, in 56 modules, on about 4380 km^2 and thus removed from its natural system with its very important functions: *hydrological, biochemical, ecological, climatic and socio-economical.*

The hydrological function of the Danube floodplain consists on retention of approximately 6 km³ water during floods and so floods attenuation, deposition of alluvium beneficial in soil formation, supplying and maintaining groundwater with avoiding their salinization. As a result of reducing the area, respective the free space, an increasing of the level and flow, of the pressure on dykes has occurred with associated risks, flooding downstream, in this case, accentuated in the Danube Delta, as happened in 2006.

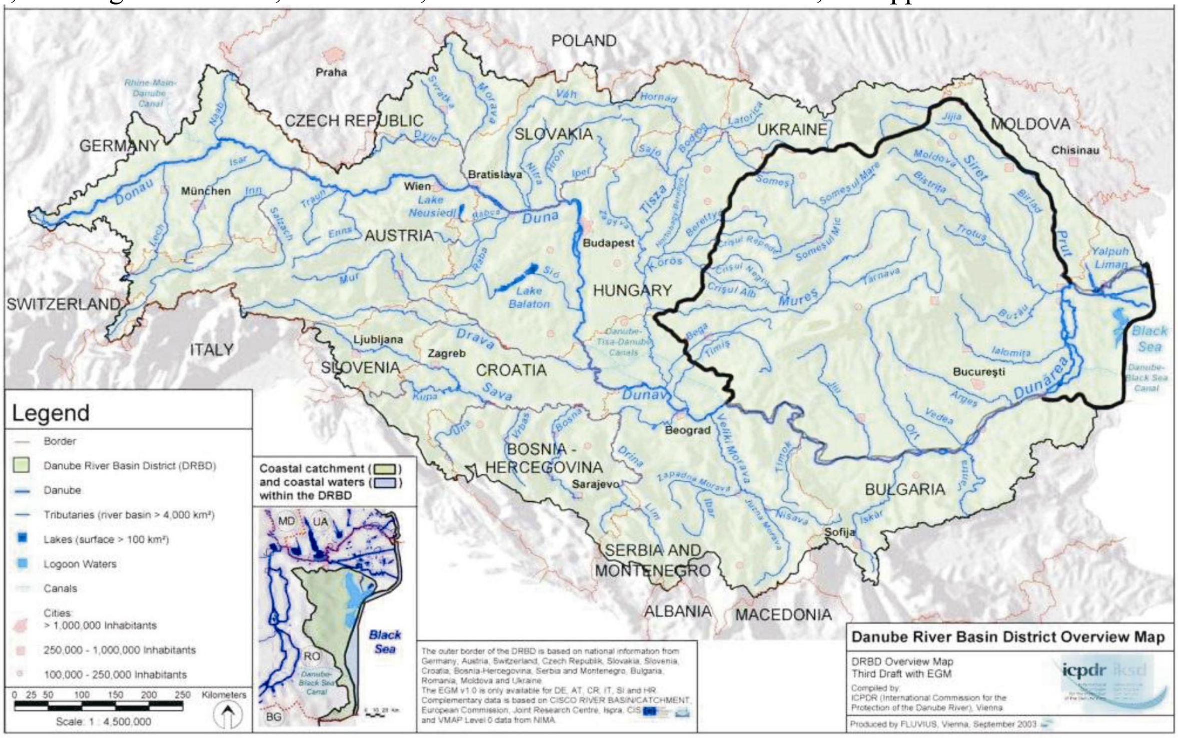


Fig.1. The Danube River Basin

The biochemical (ecotonal) function results from hydrological function through maintaining the balance in the carbon-nitrogen-phosphorus cycle, nutrients recycling, retention of toxic substances (pesticides, heavy metals due to the bio-filter role of alluvium), and transformation of organic pollutants in inorganic compounds. The decreasing of ecotonal space along the Danube River is leading to pollutants concentration increasing in the Danube Delta and in the coastal and marine waters. The consequences are numerous in terms of *ecological* aspects through modification of habitats, biodiversity and genetic assets, *topoclimatic* and *socio-economic* by reducing the fish reproductive potential, hunting animals and obvious of renewable resources valorisation. But besides the floodplain, the Danube River has supported morphohydrological alterations of the river bed, through hydropower works, urban and harbour activities, water abstractions for irrigations, which due to climatic changes has influenced and influences the liquid and solid discharge regime and the water quality. Since the begging of the XXth century, the Danube floodplain embankment had the attention of two major Romanian personalities Anghel Saligny, civil engineer, and Grigore Antipa, hydrobiologist, with different views. Thus, Saligny claimed the total embankment of 180,000 ha by a law promoted in 1910, but Antipa, through a statement from 1912, claimed the embankment of 130,000 ha with maintaining of flooded areas for fish breeding.

From the first agricultural management works - Chirnogi, 1904-1906, followed by those from Mânăstirea, Luciu Giurgeni, of several thousand hectares, the embankment action ended in 1990, when almost the entire floodplain, from Calafat to Tulcea, was removd from the benefic effect of the floods with elimination / mitigation of the above mentioned functions (H. Ioanițoaia et al., 2007) (Tab. 1, Fig. 2).

Tab.1. The dammed areas in the Danube floodplain*

Sector	Location (km)	Flooded area (ha)	Area remained in natural regime (ha)	Dammed area (ha)
Gruia – Calafat	851-795	5500	950	4550
Calafat - Bechet	795-679	47315	7345	39970
Bechet - Corabia	679-630	21960	2820	19140

Sector	Location (km)	Flooded area (ha)	Area remained in natural regime (ha)	Dammed area (ha)
Corabia -Tr.Măgurele	630-590	4640	2680	1960
Tr.Măgurele - Zimnicea	590-554	22565	3265	19300
Zimnicea - Giurgiu	554-493	23705	4075	19630
Giurgiu - Olteniţa	493-430	42885	3465	39420
Olteniţa - Călăraşi	430-365	45005	5455	39550
Călăraşi - Hârşova	365-252	113368	30698	82670
Hârşova - Brăila	252-170	153418	41761	111637
Brăila - Tulcea	170-72	69252	9282	59970

*South East Europe, Danube Floodrisk, 2010

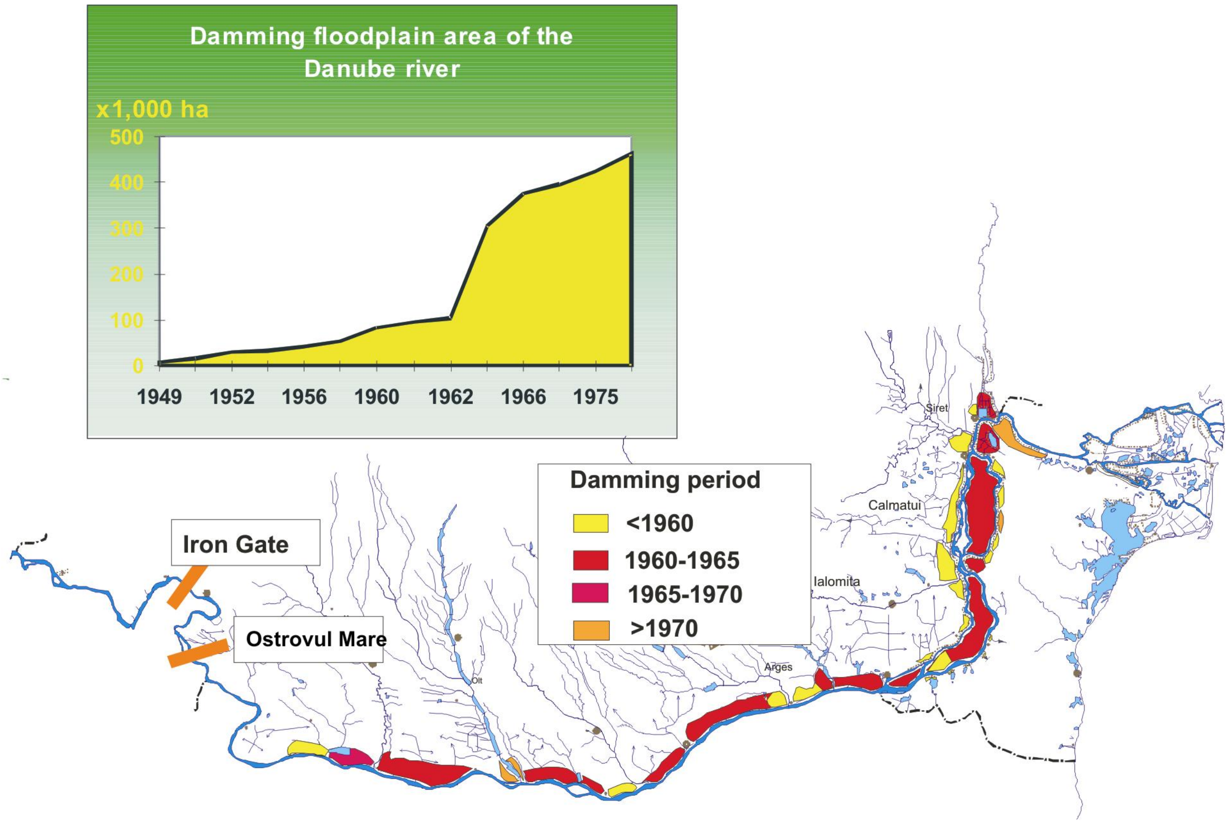


Fig.2 The evolution of the Danube floodplain damming process

3. HYDROLOGICAL FEATURES

In analyzing the hydrological regime of the lower Danube course, it shall be taken into consideration the discharge formation/determination in the upper and middle. In the upper course, the tributaries of the northern slopes of the alpine area (Riss, Iller, Gunz, Mindel, Lech, Isar, Inn, Traun, Enns), out of which Inn has at Passau, 810 m^3/s at the confluence of the Danube (660 m^3/s) have high discharges in the summer time (June-July) due to the snow melting. In the middle course, more importantly, are the tributaries of the southern Pannonian Plain, where the Danube receives three major tributaries - Drava with 578 m^3/s, Tisa with 814 m^3/s, Sava 1613 m^3/s, to which, Morava from the Serbian territory and Timis, from the Romanian territory are associated, largely determining the liquid discharge regime configuration in the lower Danube course, with high waters in spring (April-May, sometimes June) and low waters in late summer and early autumn (August-September, sometimes in the winter from January to February).

As a consequence of this situation, the Danube multiannual average discharge increases gradually from upstream to downstream, as follows: 1470 m^3/s at Passau, after the Inn confluence, 1920 m^3/s at

Vienna, 2350 m^3/s at Budapest, 5590 m^3/s at Baziaş, at the entry into the Iron Gate gorge and increases, only by 920 m^3/s with the contribution of the lower Danube tributaries (Timok, Isker and Intra on the right side, and Cerna, Jiu, Olt, Vedea, Argeş, Ialomiţa, Siret and Prut on the left side), up to 6510 m^3/s at Ceatal Chilia, entry into the Danube Delta.

The hydrological regime monitoring activity of the Romanian Lower Danube has a history of over 150 years. The first gauging station was set up at Orşova in 1836, followed by Drencova in 1854 and Baziaş in 1874, both located in Iron Gates gorge and also Brăila, Galaţi, Tulcea in 1874. Tulcea gauging station was set up in 1857 by the European Commission of the Danube River for ensuring the discharge regime knowledge for selection the maritime navigation way. During the years, the number of gauging stations located on the lower Danube has increased reaching in present, a number of 21 stations with observations on level variation and 20 stations with liquid discharge measurements (South East Europe, Danube Floodrisk, 2010).

Studies on the discharge regime have been done and is regularly elaborated, in the first stage determined by the river navigation activities, the construction of railway and road bridges, and then for hydraulic works construction – embankments, dams and hydropower plants, but also for the ensuring the knowledge of the monthly, seasonal and annual variation regime of the transited water volume, important from eco-hydrological point of view. Of the complex hydrological studies, in which the data of the gauging stations from the period 1921 - 1962 are critically and professionally analyzed, we mention the study - **The Danube River between Baziaş and Ceatal Izmail - hydrological monograph, 1967**, published under the auspices of the **Institute of Hydrotechnical Studies and Research, Bucharest.** Thereafter, the National Institute of Hydrology and Water Management, for different reasons, had no longer considered the decade 1921-1930, validating the data obtained during 1931-2010, which are used in this analysis for the entire respective hydrological spectrum, average, maximum and minimum discharges. It should be mentioned that in this study, we use the name of Ceatal Chilia instead of Ceatal Izmail, due to the fact that the Izmail locality is situated at 20 km on Chilia arm, downstream to Ceatal Chilia where the measurements are done.

In some articles and studies through different methods, there were made correlations and extensions on the levels obtained at Orşova gauging station, especially for the maximum discharges, starting with 1840. It was considered useful to note the average, maximum and minimum discharges for the period 1921-1930 for highlighting the low discharges, especially, in 1921, but in 1928, 1929 and 1930, as well. In 1921, the lowest value of the minimum discharge during the entire period with validated measurements at Ceatal Chilia, respective the value of **1350 m^3/s** was registered (tab.2).

Tab.2. The maximum, average and minimum discharges for the period 1921-1930

year	Orşova max. average min.	Zimnicea max. average min.	Olteniţa max. average min.	Ceatal Chilia max. average min. **average**
1921	7440 3680 **1550**	8220 4090 **1540**	7750 4090 **1580**	7210 3930 **1350** **3947**
3192 1922	10300 6000 2210	11100 6600 2520	11500 6650 2360	10490 6530 1850 **6445**
1923	10500 5560 2090	11780 6300 2210	11900 6300 2290	10800 6430 2210 **6147**
1924	**14200** 6130 2240	12150 6500 2690	**13800** 6950 2870	11500 6700 3170 **6570**
1925	9180 5030 1810	8870 5400 1960	8480 5350 2120	7870 5240 1870 **5255**
1926 1927	13100 7250 2940 8290 5320 2780	**12540** 7840 3530 8720 5810 3260	13700 7960 3760 8780 5990 3480	**12050** 8100 4210 **7782** 8370 5990 3330 **5777**
1928	8940 4650 2270	9410 5150 2410	9380 5220 2510	8600 5000 2510 **5005**
1929	8600 4580 1660	9560 5100 1770	9680 5240 1990	9390 5330 2380 **5062**
1930 **average**	8380 4920 2740 **5312**	8400 5260 2860 **5805**	8140 5400 2930 **5915**	8260 5210 3020 **5197** **5845** **5719**

It should be mentioned, that the lowest discharge on the lower Danube course (**990 m^3/s)** has been registered at Gruia gauging station in 1985. This minimum discharge was measured at Gruia, downstream to the two hydropower plants works and it is not representing a discharge resulted from the natural hydraulic regime but due to the retention of a water volume in the two reservoirs – Iron Gates and Ostrovul Mare (tab.3).

Tab.3. The multiannual average, maximum and minimum discharges (period 1931-2010)

Station	Baziaş	Gruia	Guirgiu	Olteniţa	Chiciu Călăraşi	Vadu Oii	Brăila	Ceatal Chilia
Average values - m³/s	5590	5570	6056	6115	6133	6245	6170	6510
Maximum values - m³/s (year)	15800 (2006)	15800 (2006)	16300 (2006)	16200 (2006)	16200 (2006)	16200 (2006)	15800 (2006)	15900 (2006)
Minimum values - m³/s (year)	1040 (1949)	**990 (1985)**	1485 (1954)	1490 (1954)	1530 (1947)	1400 (1992)	1460 (1954)	1790 (1947)

From the **discharge** values analysis during 1075 km of the lower Danube, it is noted an increasing of the **multiannual average discharges** from upstream – Baziaş (5590 m^3/s) to downstream – Ceatal Chilia (6510 m^3/s) and of **minimum discharges** (1040 m^3/s at Baziaş to 1790 at Ceatal Chilia), as a result, especially, of the tributaries contribution on the Romanian territory (tab. 2, fig. 3.).

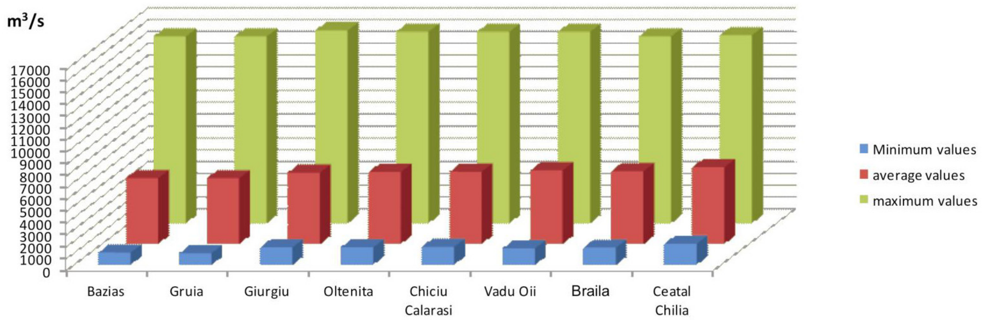


Fig. 3. Multiannual, annual maximum and minimum discharges at the main stations

Regarding the **maximum discharges**, they are influenced by the configuration of the minor river bed and by the non-embanked flooded surfaces (1120 km²) as they are attenuated, for discharges of over 13,000 m³/s. A situation which reflects the role of the flooded area, it is that of the year 2006, when there were recorded /produced the highest maximum discharges at all gauging stations in the analyzed period (1931-2010), but the maximum values were registered at intermediate stations -Giurgiu, Olteniţa and Vadu Oii and less at Brăila and Ceatal Chilia, the cause being floods produced in the sector between Hârşova and Danube Delta (Tab.3, fig.3). Concerning the maximum discharges at Ceatal Chilia, there are mentioned, in different sources, non-homologated values which differs greatly, as folows: 35,000 m³/s in 1897 (Ch. Hartley in the documents of the European commission of the Danube River); 28,300 m³/s in 1891 (Albrecht Penck,1891);19,233 m³/s in July 1897 (Gh. Mirică, 1957); 19,347 m³/s in July 1897 (M. Constantineanu,1958); 17,700 m³/s in July 1897, (C. Mociorniţă, 1961). By correlating the levels with the discharges for the period 1921-1990 and levels based extrapolation at Orşova (Tulcea?) starting with the year 1840, C. Bondar determined the monthly maximum discharges at Ceatal Chilia with values > 11 000 m^3/s considered floods at Orşova in the period 1840-1920. Certainly, these correlations and extrapolations should be considered approximations, not being homologated (tab. 4. and 5.).

Tab.4. The monthly maximum discharges for the period 1840-1990 at Ceatal Chilia (C. Bondar)

month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
Q (m³/s)	13870	15690	16110	14500	15540	20940	20940	12250	11350	11940	11800	11700	20940
year	1879	1879	1871	1981	1970	1897	1897	1876	1926	1972	1974	1961	8.VII. 1897

Note: the maximum discharge of 15900 m³/s has occurred in April 2006

Tab.5. The maximum discharges (floods) at Orşova in the period 1839-1920, > 11000 m³/s (C. Bondar)

Q (m³/s)	11500	14000	13700	14100	13000	15500	15900	15400	13600	13600	14000
date	4VI 1839	1V 1845	7V 1853	1IV 1876	24V 1879	17IV 1888	1895	7VI 1897	26IV 1907	1IV 1914	8V 1918

From the analysis of **multiannual decadal average discharges,** it is noted that only the decade 1961-1970 is highlighted through slight higher values due to the high water in the year 1970, when floods were produced. The floods of the year 1970 affected, especially, the floodplain and the Danube Delta downstream of Brăila, the upstream floodplain being embanked in the proportion of 73.7%, but requiring consolidation and surveillance. In the decade 2001-2010, although the annual average discharges were higher in 2005, 2006 and 2010, the decadal averages were attenuated by the lower discharges of the years 2007 and 2008. In the opposite situation, there is the decade 1941-1950 with lower multiannual decadal average discharges in this decade being the years 1943, 1946, 1947, 1949 and 1950, with lower annual average discharges throughout the lower Danube sector. It should be mentioned, that the years 1946-1947 were of the most dry years which affected the Romanian territory (tab. 6., Fig.4).

Tab.6. Decadal and multiannual average discharges (period 1931-2010)

period	Baziaş	Gruia	Giurgiu	Olteniţa	Chiciu Călăraşiai	Vadu Oii	Brăila	Ceatal Chilia
1931-1940	5836	5831	6373	6426	6379	6410	6302	6547
1941-1950	5273	5208	5690	5698	5724	6152	5632	5991
1951-1960	5782	5703	6167	6221	6157	6165	6153	6455
1961-1970	**5830**	**6026**	**6484**	**6561**	**6554**	**6562**	**6492**	**6885**
1971-1980	5678	5773	6058	6176	6225	6376	6433	6843
1981-1990	5442	5154	5614	5668	5751	5811	5809	6047
1991-2000	5294	5305	5910	5938	5971	6050	6064	6417
2001-2010	5585	5558	6148	6232	6299	6430	6471	6896
average	**5590**	**5570**	**6056**	**6115**	**6133**	**6245**	**6170**	**6510**

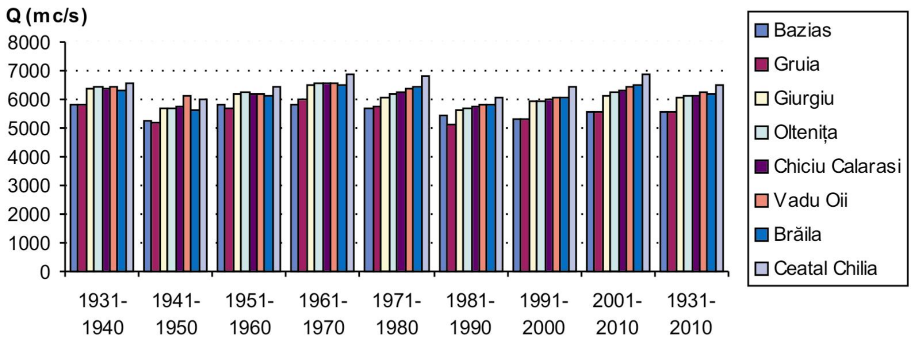
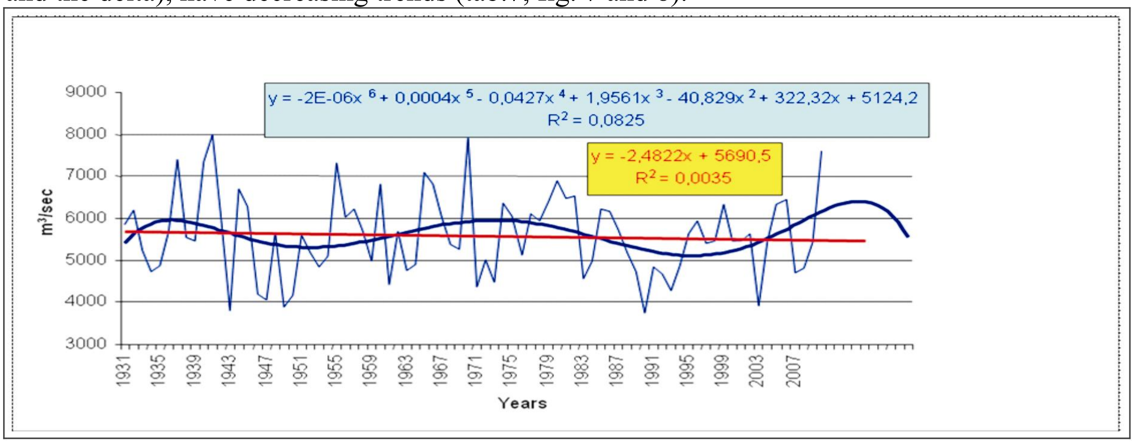


Fig.4. Decadal and multiannual average discharges at the gauging stations on the lower Danube sector

Analyzing the annual average, maximum and minimum discharges variation at the two extreme gauging stations, respective Baziaş – the entry into the Iron Gates gorge and Ceatal Chilia – before the Danube Delta, it is noted the trends of these hydrological parameters for the period 1931-2010.

Thus, the **annual average discharges** at the Baziaş station have registered a slight decreasing trend, as the polynomial analysis shows, comparing with those obtained at Ceatal Chilia station,where the trend is slight increasing (fig.5 şi 6).

The minimum discharges, as it could be seen for the both geographical positions (entry into the gorge and the delta), have decreasing trends (tab.7, fig. 7 and 8).



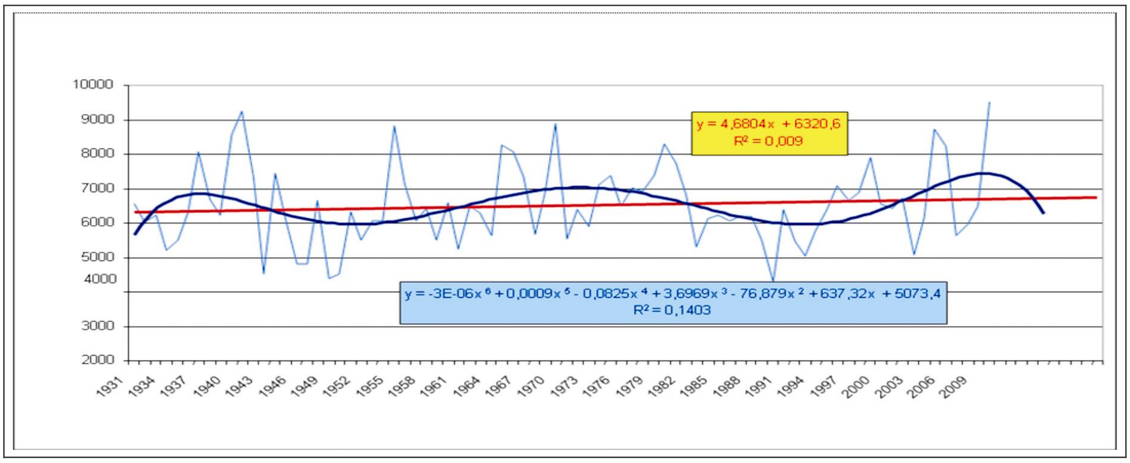


Fig.5 and 6. The variation of the annual average discharges at Baziaş and Ceatal Chilia (1931-2010)

Tab.7. The annual minimum discharges <1500 m^3/s in the period 1931-2010, at Baziaş*

year	Baziaş	Gruia	Giurgiu	Olteniţa	Chiciu Călăraşi	Vadu Oii	Brăila	Ceatal Chilia
1947	1280	1300	1560	1570	1530	1540	1550	1790
1949	1040	1650	1820	1830	1900	1910	1920	2180
1953	1360	1350	1650	1660	1610	1620	1630	1910
1954	1200	1260	1485	1490	1710	1720	1460	1820
1985	1400	990	1800	1890	1930	1880	2030	2110
2003	1470	1420	1690	1700	1800	2080	2100	2030

*the minimum discharge <1500m^3/s was registered (before 1931) at Ceatal Chilia station in 1921 (1350 m^3/s).

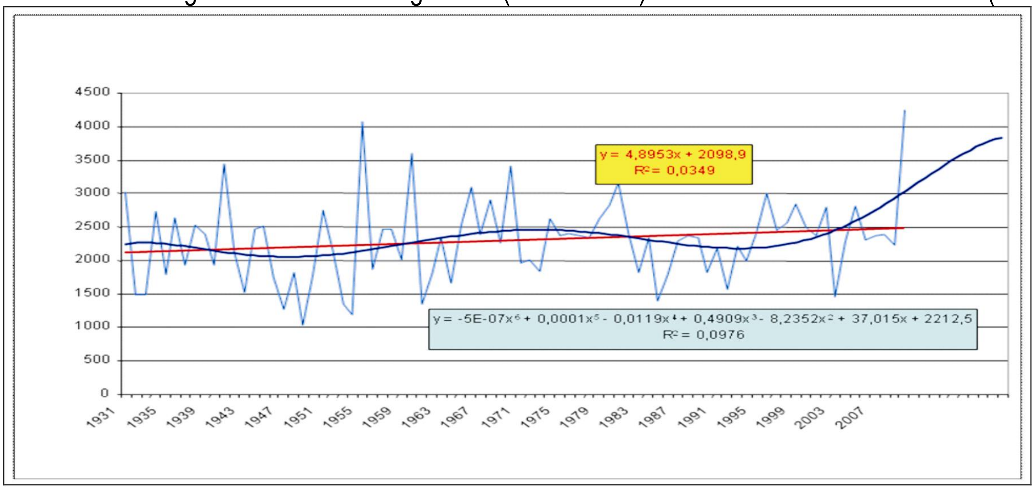


Fig.7 and 8. The variation of the annual minimum discharges at Baziaş (1931-2010)

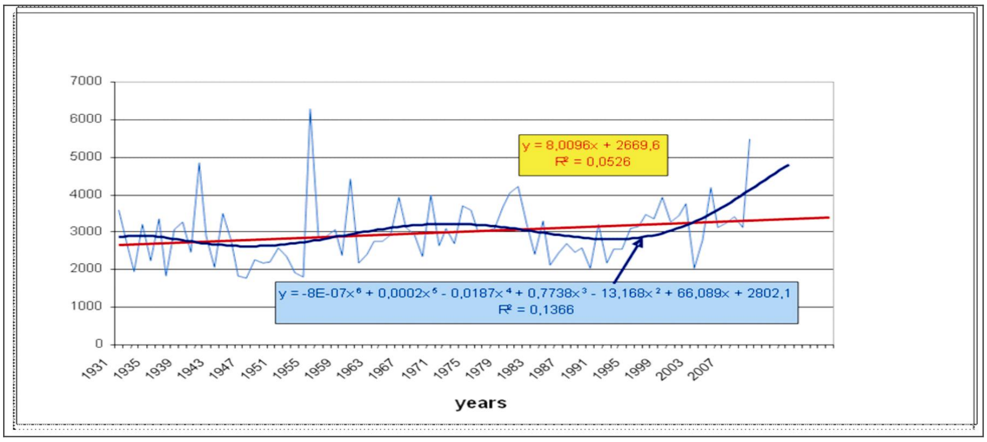
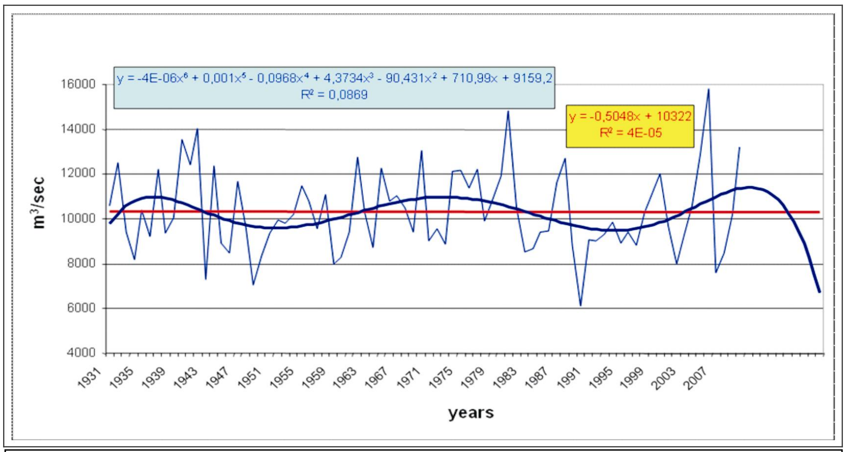


Fig. 8. The variation of the annual minimum discharges at Ceatal Chilia (1931-2010)

The maximum discharges for the Danube River take place, especially, in the spring – summer seasons, due to the overlapping effects of snows melting and spring rains from the entire catchment, which generates high discharges. From the analysis done at the gauging station Orşova, there was noted that in the period 1841-1965, 52 floods events had been produced, with a discharge >10000 m^3/s (*The Danube River between Baziaş and Ceatal Izmail – hydrological monograph,1967*). If at the 52 floods events we are adding other 23 which were registered in the period 1968-2010, it results a number of 75 flood events (for this period, the discharge at Baziaş was taken into consideration, as the one from Orşova was no longer representative due to the Iron Gate reservoir influence). Comparing with the mentioned situation, we highlight that not any flow exceeding 10000 m^3/s is producing floods in the lower sector of the Danube River.



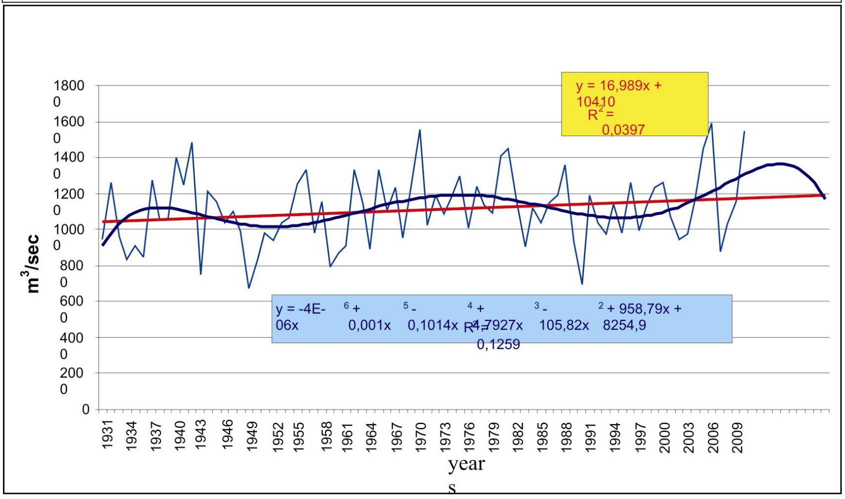


Fig.9 and 10. The variation of the annual maximum discharges at Baziaş and Ceatal Chilia (1931-2010)

Coming back to the **annual maximum discharges** during 1931-2010, as it is resulting from the polynomial analysis, they have a slight decrease at Baziaş gauging station and a sensible trend of increasing at Ceatal Chilia station (tab.8, fig.9 and 10).

Tab. 8. The annual maximum discharges >13000 m^3/s period 1931-2010, at Baziaş

Year	Baziaş	Gruia	Giurgiu	Olteniţa	Chiciu Călăraşi	Vadu Oii	Brăila	Ceatal Chilia
1940	13520	13150	14970	15020	14880	14950	15020	14000
1942	14020	13100	15370	15290	14680	14750	14820	14880
1970	13040	13900	14930	14640	15800	14790	15000	15540
2006	**15800**	**15800**	**16300**	**16200**	**16200**	**16200**	**15800**	**15900**
2010	13200	12900	14340	14490	14620	15410	15150	15500

4. HYDROLOGICAL YEAR 2006

As it results from the presented maximum validated discharges and floods, in 2006 there have registered the highest flows on the entire Danube lower sector (Baziaş-Ceatal Chilia) for the period 1931-2010, inclusive the decade 1921-1930 and floods downstream the Ostrovul Mare reservoir. The 2006 flood is estimated to occur once every 100 years (1%), the flow, level, duration of flooding over the floods level (CI). The maximum discharge at the entry into the Iron Gates gorge had 15800 m^3/s, being the highest from the entire monitoring period 1840-2010 (tab.9).

Tab.9. The average, maximum and minimum discharges (m^3/s) registered at Baziaş in 2006*

Discharge/ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average discharge (2006)	6150	4340	9600	14100	10600	9590	5210	4480	4240	2850	3200	3150
Maximum discharge (2006)	8100	8200	11700	15800	13200	11800	7400	6200	5900	3400	4000	3700
Minimum discharge (2006)	4000	3300	7500	11800	7500	7400	3100	3100	3200	2400	2400	2700
Multiannual average discharge	4900	5300	6800	7900	7350	6450	5500	4450	3750	3800	4800	5200

*South East Europe,Danube Floodrisk, 2010

With the exception of 2006 flood, floods with maximum floods >15000 m^3/s have been registered in the years: 1888 (Q=15500 m^3/s), 1895 (Q=15900 m^3/s), 1897 (Q= 15400 m^3/s), 1940 (Q=15100 m^3/s), 1942 (Q=15370 m^3/s at Giurgiu), 1970 (Q=15500 m^3/s at Ceatal Chilia), , 2010 (Q=15500 m^3/s at Ceatal Chilia). The 2006 flood with long duration (March-May) was produced due to snow melting in Alps, affecting even the middle sector with consequences in Budapest. The high flows of the Drava, Sava, Tisa and the Serbian Morava have determined the increasing of flow at Baziaş in the 19th February from 3600 m^3/s (below the multiannual average 5590 m^3/s) at 8500 m^3/s at the end of the same month (fig.11.).

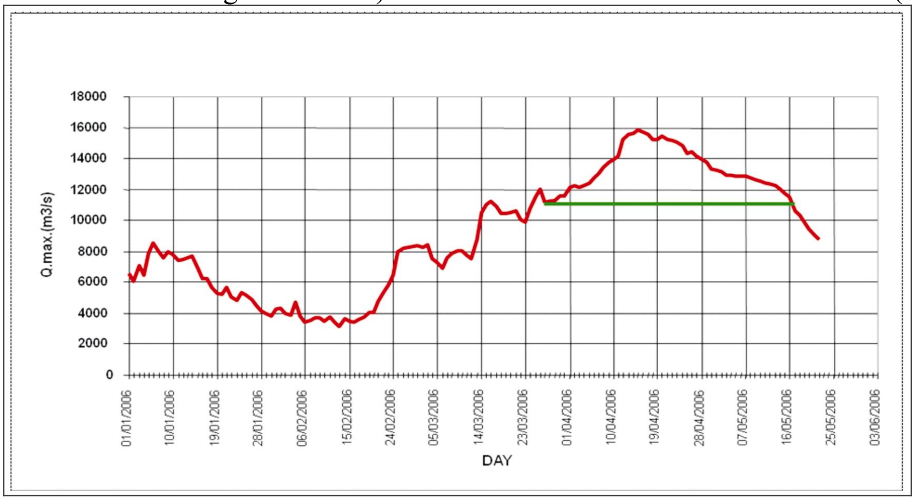


Fig.11. The variation of the Danube discharge downstream of Iron Gates reservoir dam during flood event (March-May 2006)

The highlighting high waters magnitude with associated floods in 2006 can be noted from the comparison with the floods from the 1970, 1981 and 1985, produced downstream to Iron Gate reservoir/dam (tab.10).

Tab.10.The discharges and levels from the years 2006, 1970, 1981 and 1985*

Year/ Station	2006		1970		1981	1985
	Q.max (m^3/s)	H.max (cm.mira)	Q.max (m^3/s)	H.max (cm.mira)	Q.max (m^3/s)	Q.max (m^3/s)
Gruia	15800	898	14700	823	14700	12920
Calafat	16140	861	14100	776	14100	13100
Bechet	16000	845	14250	784	14250	12500

Corabia	16800	800	14300	756	14300	12260
Tr. Magurele	16560	790	14400	710	14400	12650
Zimnicea	16600	839	14800	800	14800	13550
Giurgiu	16500	822	15000	795	15000	13000
Oltenita	16500	809	14600	772	14600	13140
Calarasi	16200	737	14800	703	14800	13630
Harsova	16000	764	15100	727	15100	13200
Braila	15800	699	13700	639	13700	12900
Isaccea	16100	524	14500	514	14500	13300

* South East Europe,Danube Floodrisk, 2010

As it can be observed, the highest flows were registered for the sector Turnu Măgurele-Oltenița. Downstream of this sector the flows decreased, as a consequence of floods in the floodplain through the dykes breakings, including those deliberately caused by the authorities for avoiding/defense of some important downstream localities (Brăila, Galați) and from the Danube Delta. (fig.12.).

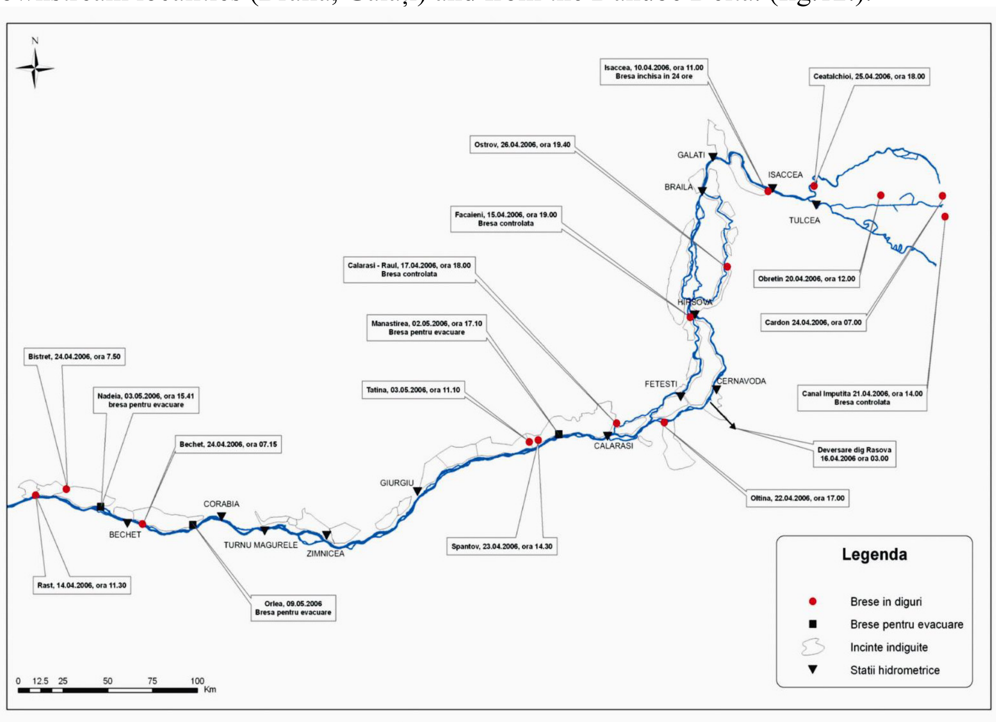


Fig. 12. Dykes breakings produced during 2006 floods

Tab.11. The levels, discharges and exceeding the flood levels (CI) during 2006 floods*

Gauging station	Hmax (cm)	Qmax (mc/s)	Date	Exceeding of flood levels (CI) and attention levels (CA) (cm)
Gruia	899	15775	16/04	CI+199
Calafat	861	15495	21/04	CI+261
Bechet	845	15825	23/04	CI+245
Corabia	801	15730	23/04	CI+251
Tr. Magurele	790	16500	24/04	CI+240
Zimnicea	840	16900	23/04	CI+230
Giurgiu	822	16500	23/04	CI+182
Oltenita	809	16422	25/04	CI+179
Calarasi	737	15760	23/04	CI+117
Hârşova	764	15580	25/04	CI+154
Braila	699	14670	26/04	CI+89

Gauging station	Hmax (cm)	Qmax (mc/s)	Date	Exceeding of flood levels (CI) and attention levels (CA) (cm)
Galati	661	14220	26/04	CI+61
Isaccea	524	14325	27/04	CA+114

*South East Europe, Danube Floodrisk, 2010

The levels and discharges exceeded the flood levels (CI) at all gauging stations on the lower Danube sector downstream to Iron Gate producing dykes breakings and flooding the plain and also of some localities totally or partially. (tab.11.). From the levels hydrograph at Baziaş (Danube entrance in the Iron Gates Gorge) and Gruia (downstream of gorge), it is noted the exceeding the attention levels (CA) and flood levels (CI) and corresponding flow drawing between 13 March and 13 June 2006 (fig.13).

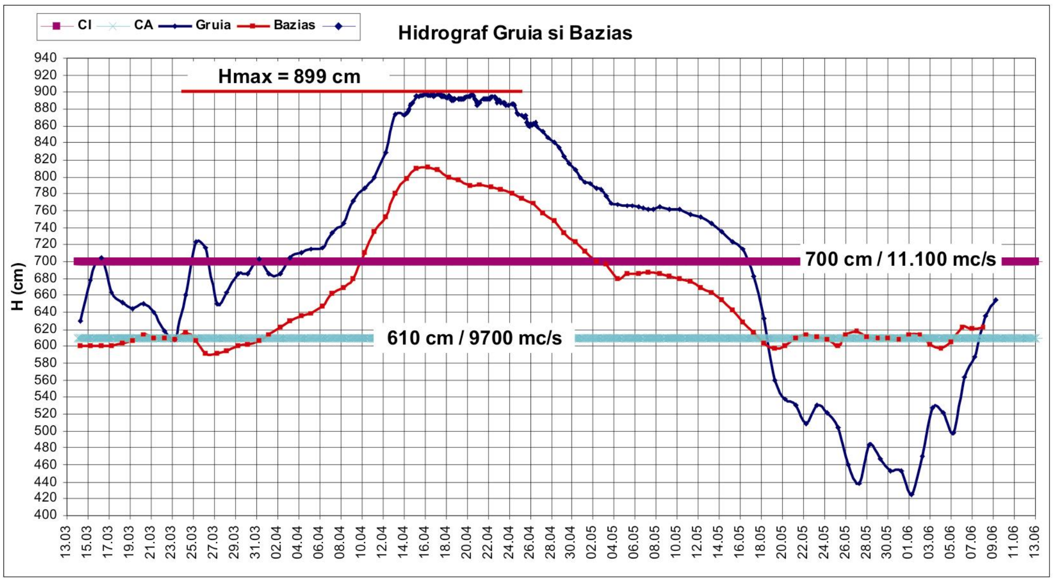


Fig.13. The level hydrograph at Baziaş and Gruia gauging stations with drawing the exceeding the attention (CA) and flood levels (CI)

Tab.12. The minimum levels and discharges registered in 2006

Gauging station	Hmin (cm)	Qmin (m^3/s)	Date	Navigable low water line (cm)
Gruia	-10	2390	30.10, 4-6.11	34
Calafat	-26	2460	9.10	50
Bechet	22	2530	24.10, 6.11	42
Corabia	-42	2730	24.10	23
Tr. Magurele	34	2910	6.11	34
Zimnicea	39	3000	6.11	51
Giurgiu	-27	3020	25.10, 6.11	44
Oltenita	-10	2550	7,8.11	44
Calarasi	-27	3060	7,8.11	-1
Cernavodă	-88	628	9.11	-39
Hârşova	8	3020	9,10.11	19
Braila	84	3060	8,9.11	46
Galati	93	3430	8-10.11	52
Isaccea	71	3320	9,10.11	42

In contrast with the flood from the spring season, in the second part of the 2006 year, the levels and discharges decreased, especially in October and November, both due to the normal phase of the natural discharge regime, and retention in the two reservoirs – Iron Gates and Ostrovul Mare. Thus, the levels dropped below the low-water line, downstream Gruia, with influence on river navigation (tab.12).

5. CONSEQUENCES, PROJECTS/SOLUTIONS

The floods produced in April- May 2006 affected downstream Ostrovul Mare dam, differentiate the dammed floodplain area and some riparian localities, through the breakings produced by high water discharges and levels. The flood maximum levels were higher with 60 cm comparing with the levels registered from the floodplain embankment period 1960-1970. The flood effects through the natural caused breakings (Rast, Bechet, Dăbuleni, Modelu, Spanțov, Ostrov, Isaccea), water level exceeding the dykes height (Oltina, Vederoasa) and controlled dykes breakings (Rast, Călăraşi-Răul, Făcăeni-Vlădeni) had consequences as the flooding of the plain (about 73000 ha) and retention of about 1,5 km^3 water.

Among the fully affected localities were Rast and Negoiu from Dolj county, partially Bechet, Spanțov, Stancea, Mânăstirea – Călăraşi county, Oltina, Baciu, Vederoasa - Constanța county, Tudor Vladimirescu, Ceatalchioi, Ilganii de Jos, Mila 23, Uzlina-Tulcea county.

Given the lower Danube expressions at high waters/floods phase due to the floodplain embankment and reduction of "free space" with 73% , of 2006 floods consequences, some strategists of the National Administration „Apele Române" has proposed solutions for remediation of the situation, based on the National Strategy of Risk Management taking into account the European principles, considering the aquatic habitate conservation, wetlands rehabilitation, creation of cascade retention modules, for temporary retaining the water volumes during floods period. (Mihailovici and colab., 2006) (fig.14).

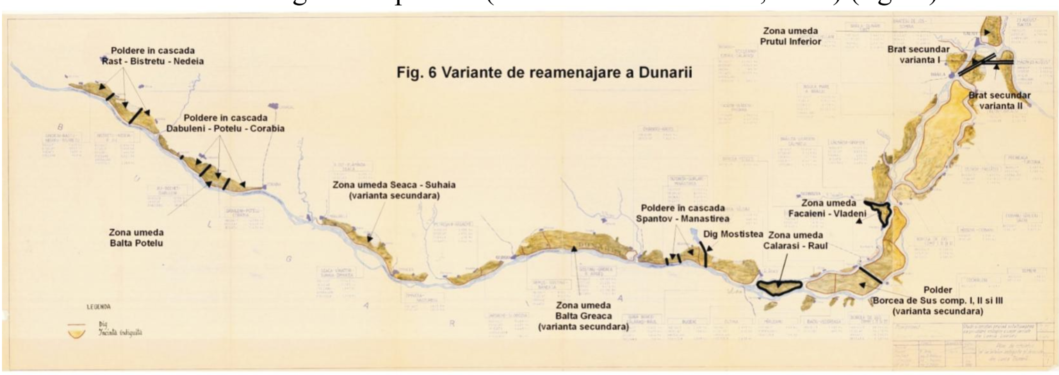


Fig. 14. Proposed solutions for redevelopment of the Danube River -after 2006 floods

CONCLUSIONS

Through the latitudinal development of the Danube River Basin, in the Western and Central European space with different climate conditions (ocean and continental temperate), the liquid discharge regime, with high waters during spring and early summer is reflecting a moderate variation (K=Qmax/Qmin-8.9 at Ceatal Chilia). From the analysis of average, maximum and minimum flows for the period 1931-2010, the significant increasing/decreasing trends are not noticed. The floods, usually pluvio-nival, occur in the high discharges phase. The high discharges of the 1970, 2006 and 2010 years, which produced floods, were also caused by the limitation of *free space* of the lower Danube sector through floodplain embankment. The Iron Gate reservoir and even the Ostrovul Mare reservoir do not play a flood attenuation role due to low retention volume in relation to their maximum flow. However, both reservoirs have a significant influence, in low discharges phase, summer – autumn, through retention of certain volumes for hydropower needs. The reconsideration of the complex function of the lower sector Danube Floodplain it is necessary from many points of view - hydrological, ecological, economical and human safety.

REFERENCES

Antipa, Gr. (1910), *Regiunea inundabilă a Dunării*, Bucureşti

Antipa, Gr. (1921), *Dunărea şi problemele ei ştiințifice, economice şi politice*, Bucureşti

Bondar, C. (1993), *Secular evolution of some components of the hydrological Danube regime and of the mean level of the Black Sea,*Proceed. World Coast Conf.

Constantineanu, M. (1958), *Hidrografia şi hidrologia Deltei Dunării*, Hidrobiologia, nr. 1
Gâştescu, P.(1998), *Danube River: hydrology and geography*, Encyclopedia of hydrology and water resources, edited by R.W.Herschy and Rh.W. Fairbridge, Kluwer Academic Publishers, Dordrecht/Boston/London
Ioaniţoaia, H., Dobre, V., Moraru, N.(2007), *Un secol (1906-2006) de lucrări de îndiguiri şi amenajări hidroameliorative în Lunca Dunării*, Hidrotehnica vol..52, nr.1-2
Hartley, Ch. (1856-1939), *Colecția de rapoarte, memorii şi protocoale ale Comisiei Europene a Dunării*

Mihailovici, J. and colab.(2006), *Soluții propuse pentru pentru reamenajarea fluviului Dunărea pe* sectorul românesc, Hidrotehnica, vol. 51, nr. 5
Mirică, Gh. (1957), *Debitul Dunării în zona deltei,* Bul. Inst. Cercet. Piscicole, nr. 4
Mociorniță, C. *(1961),O metodă aproximativă de determinare a debitelor maxime pe râurile din R.P.Română*, ISCH, Studii de hidrologie, I
Penck, A. (1991), *Die Donau*, Wien
Şerban, P. şi colab.(2006), *Analiza viiturii produse pe Dunăre în perioada aprilie-mai, 2006*, Hidrotehnica, vol. 51, nr. 5
***(1963), *Zona de vărsare a Dunării. Monografie hidrologică*,I nstitutul de Studii şi Cercetări Hidrotehnice, Bucureşti, Institutul de Cercetări Oceanografice, Moscova
***(1967), *Dunărea între Baziaş şi Ceatal Izmail. Monografie hidrologică*, Institutul de Cercetări Hidrotehnice, Bucureşti
***(1969), *Geografia Văii Dunării româneşti*, Edit. Academiei Române
***(1983), *Geografia României*, vol. I, *Geografie fizică*, Edit. Academiei Române
***(2010), *Analiza regimului hidrologic al fluviului Dunării pe teritoriul României, South Eas*t *Europe, Danube Floodrisk* (după Studii şi caracterizări hidrologice INHGA, 2010)

**published in Riscuri si Catastrofe, vol. 10, nr. 1/2012*