Lakes, reservoirs and ponds, vol. **4**(1): 52-69, 2010
©Romanian Limnogeographical Association

THE IRON GATES RESERVOIR – ASPECTS CONCERNING HYDROLOGICAL CHARACTERISTICS AND WATER QUALITY

Liliana ZAHARIA
University of Bucharest, Faculty of Geography
zaharialil@yahoo.com

Abstract

The paper makes a synthesis of the hydrological characteristics of the Iron Gates I reservoir and at the same time, it gives an account of its water quality state. A number of specific issues are revealed such as the feeding sources, level regime, water discharge, sediment load, and sedimentation processes. Likewise, the study highlights the alteration of the main hydrological parameters (levels, liquid and solid discharges) entailed by reservoir creation, by simply comparing the present day situation with that existing before the artificial lake came into being. The analysis of hydrological characteristics relies especially on the datasets provided by the "Romanian Waters" National Administration for the Baziaş, Orşova and Drobeta Turnu Severin gauging stations, which have different recording intervals for the period 1921 – 2006. At the same time, bibliographic sources have been taken into account in order to better understand the hydrological phenomena. As far as water quality is concerned, this has been established based on the quality indicators for the periods 2000 – 2004 and 2006 – 2009, which exist in the records of the National Water Monitoring System.

Keywords: Romania, Iron Gates, water quality

1. Introduction

The Iron Gates reservoir is by far the largest anthropogenic lake in Romania. It came into existence during the period 1964 – 1972, when the Iron Gates I Hydropower and Navigation System (H.N.S) was created, which is one of the most impressive engineering works in Europe and certainly the biggest on the Danube.

Through its dimensions, complexity and functionality the Iron Gates I H.N.S. has seriously impacted all the environmental components in the area. Hydrological alterations are the most significant and they refer to the following aspects: the raise of water level (as high as 27 m in the vicinity of the dam) and the flooding of tributary mouths, which have been turned into fluvial-lacustrine inlets; the expansion of water surface and the increase of water volume; the turning of fluvial flow into a fluvial-lacustrine one, with low velocities and level variations strongly influenced by human pressure; the alteration of solid flow regime, accompanied by changes in river dynamics and sedimentation; the modification of water's physical, chemical and biological properties and, consequently, of the living conditions of aquatic biocenoses, which in their turn have suffered alterations of structure and composition (Zaharia *et al*., 2003).

The present paper highlights the specific hydrological aspects and the water quality of the Iron Gates reservoir. It mostly presents the results of a type A research project funded by C.N.C.S.I.S. in the period 2005 – 2007. After mentioning some general data regarding reservoir creation and its morphometric features, various other aspects are revealed, which refer to the level regime, the liquid and suspended load discharges, and the sedimentation processes. Finally, an inventory of the pollution sources has been accomplished and comments about water quality have been made.

The presented results supplement and update the information about the hydrological characteristics of the reservoir and its impact on the environment, which are found in some previously published works, of which the most important are those authored by Ilie (1979), Trufaş and Simion (1982), Vespremeanu and Posea (1988), Şelău (1996, 2010), Manea (2003), Diaconu (2007) and Zaharia (2008). Other studies focus on landscape management in the area of the Danube Defile, as it is the case of the papers published by Pătroescu, Ghincea, Cenac-Mehedinţi, Toma and Rozylowicz (1999 – 2000), or by Pătroescu *et al*. (2002). Likewise, investigations concerning the impact of the Iron Gates reservoir on the landscape have also been undertaken with the occasion of two research projects coordinated by Pătroescu Maria. These are *The impact of land use changes on the biodiversity of the Iron Gates Natural Park*, funded by UNESCO (1996 – 1997), and the European project LIFE NATURE LIFE00/NAT/RO/7171, entitled *Iron Gates Natural Park – Habitat Conservation and Management* (2000 – 2004).

The paper relies mainly on statistical processing and analysis of the hydrological datasets (mean annual and monthly liquid and solid discharges) recorded at the Baziaş, Orşova and Drobeta Turnu Severin gauging stations, which have been kindly provided by the "Romanian Waters" National Administration, or which have been extracted from bibliographic sources (the work *Dunarea intre Baziaş şi Ceatal Izmail. Monografie hidrologică*, 1967, and the Hydrological Yearbooks for the period 1962 – 1974). An important part in the preparation of this paper has been played by the field investigations undertaken between 2005 and 2007, which allowed us to collect valuable information on the hydrological processes and phenomena on the basis of our own observations and measurements.

2. General data concerning the Iron Gates reservoir and its economic importance

The Iron Gates reservoir is part of the natural border that separates Romania (in the north) from Serbia (in the south) (Fig. 1). It overlaps the Danube Defile, the longest (135 km) and the most spectacular narrowing along the Danube watercourse, which runs on a general west – east direction between Baziaş and Gura Văii (on a length of 144 km if we consider as its eastern boundary the Transcarpathian reach of the Danube adjacent to Drobeta Tr. Severin City) (Sencu, 1987).

Figure 1. The geographical location of the Iron Gates (Porţile de Fier) reservoir

The artificial lake gradually developed behind the dam built along the Gura Văii – Şip alignment, which forced the waters of the Danube and its tributaries to accumulate. The entire retention structure includes a spillway dam (441 km long), with 14 spillway gates; two hydropower plants (on both sides of the dam, 214 m long each); two navigable locks (one on each side, 53 m wide), designed for a maximum level difference of 35 m; two non-overflow earth dams built between the locks and the river banks (117 m long on the left bank and 186 m on the right bank); control buildings and transformer stations on each side (Pop, 1996). The dam underlies a road that links the two neighboring countries. In addition, there is some room left for the construction of a future railway connection.

The development of the Iron Gates I H.N.S. was dictated by two major economic reasons: the necessity to facilitate navigation along the Danube Defile and the need to produce cheap electricity by harnessing the great hydropower potential of the river on this stretch. Consequently, as soon as the water level rose by 30 m behind the dam, the depths of navigable channel grew accordingly, so that at low waters the draught is three to five meters (therefore riverboats can be loaded at full capacity). Besides, the building of locks has encouraged navigation up and down the river. Under the circumstances, now it takes only 31 hours instead of 120 for a ship to cross the defile, and the transportation capacity of the Danube has grown from 12 – 14 million tons/yr. to more than 53 million tons/yr. The advantages deriving from the increased navigation capacity are supplemented by the hydropower production. The plant, which is appreciated as efficient and profitable (Ujvari, 1972; Pop, 1996), has a total installed capacity of 2136 MW and a hydropower production capacity of about 5.7 billion KWh/yr.

Water accumulation was accomplished in several successive stages in approximately two years (February 1970 – November 1971) (Hidroconstrucţia, 1984). At present, the lake is about 140 km long, covers 100 km^2, and at the maximum retention level (69.5 m a.s.l.) it can store a volume of 2400 million cubic meters of water. In some years, however, the retention level can drop to a minimum of 63 m a.s.l., which corresponds to a water volume of 1700 million m^3. When the level keeps at 68 m, as it usually happens, the equivalent volume of water stored in the reservoir is 2100 million m^3 (AQUAPROIECT, 1992). The depth ranges from 5 – 6 m to 110 m (the maximum value being found in a pit lying next to the *Tabula Traiana*) (Zaharia *et al*., 2003). The maximum widths are recorded within the depression-like basins that chain along the defile (Moldova Veche, Dubova, Eselnita, Orsova). In the Moldova Veche section, at the maximum retention level the reservoir has the highest width (4.6 km). By contrast, where the defile walls squeeze the Danube valley the reservoir width shrinks to 350 – 400 m. However, the lowest values of about 200 m are seen in the Cazane area.

3. Hydrological characteristics of the reservoir

Hydrological characteristics of the Iron Gates reservoir mirror the interaction between the natural and anthropogenic factors of the Danube river basin in general and of the reservoir area in particular. Of the natural factors, the main role is played by the climatic conditions of the upper and middle course of the Danube (and especially by precipitation and air temperature), whose temporal variability is highlighted by the water and solid discharges that feed the reservoir.

The reservoir levels and, implicitly, the water volumes, depend on the economic necessities that require either the retention of the water behind the dam or the draining of the reservoir. However, the main control of these variations is the operating regime of the hydropower plant.

3.1. The feeding of the reservoir

The most important feeding source of the Iron Gates reservoir is the Danube. During the period 1976 – 2003, the mean multiannual discharge of the river at Baziaş gauging station was 5352 m^3 /s, corresponding to a mean annual volume of 168909 million m^3. The annual discharges at the same station averaged between 3774 m^3/s (in 1990) and 6893 m^3/s (in 1980), values that account for water volumes of 119107 million m^3 and 217543 million m^3 respectively (both the discharges and the volumes have been computed based on the data provided by the "Romanian Waters" National Administration).

A low contribution to reservoir feeding is brought by the tributaries that flow into it upstream the dam, along the Danube Defile. The most important of them on the Romanian side is the Cerna River (87 km long and with a catchment area of 1360 km^2). Its mean annual discharge is 23.9 m^3/s, while the mean water volume corresponding to it is 754.3 million m^3/yr (according to the datasets recorded at Toplet gauging station during the period 1950 – 1995) (Sârbu, 2001).

With the exception of the Cerna River, the contribution of the other tributaries that drain the Romanian side of the reservoir is extremely low, inasmuch as most of them are very short and their mean multiannual discharge is less than 0.5 m^3/s. The only streams that exceed this value are Radimna (0.605 m^3/s) and Berzasca (2.19 m^3/s) (Table 1).

Table 1 Morphometric and hydrological data of the main tributaries of the Iron Gates reservoir

Current number	Stream	Length (km)	Elevation (m)		Mean gradient (m/km)	Area (km^2)	Mean elevation (m)	Discharge (mc/s)
			origin	mouth				
1.	Radimna	27	518	69	17	82	391	0.605*
2.	Boşneag	12	538	119	60	60	444	
3.	Cameniţa	14	480	69	29	86	349	
4.	Oreviţa	25	740	69	27	102	418	
5.	Berzeasca	46	1015	69	21	229	549	2.19*
6.	Sirina	22	720	69	30	74	550	
7.	Tişoviţa	16	730	69	41	33	527	
8.	Valea Morilor	11	700	69	57	20	427	
9.	Mraconia	19	820	69	40	113	508	
10.	Mala	12	695	69	52	18	436	
11.	Eşelniţa	26	1000	69	35	77	539	
12.	Cerna	87	2070	69	23	1360	737	23.9**
13.	Bahna	35	1060	69	28	137	559	

Source of morphometric data: Aquaproiect, 1992.
Source of hydrological data: * Zaharia, 1993; ** Sârbu, 2001.

The precipitation contribution to the direct replenishing of the lake is relatively low. At Drobeta Tr. Severin weather station, for instance, which lies close by the reservoir, downstream the dam, the mean multiannual amount of precipitation for the period 1961 – 2000 is 662 mm (Administraţia Naţională de Meteorologie, 2008).

3.2. The levels regime

Water level is the hydrological parameter that has suffered the most important alterations after the creation of the Iron Gates I Hydropower and Navigation System. The levels regime of the reservoir depends on the economic constraints, which require its exploitation either for hydropower generation or for mitigating the flood waves. As mentioned previously, water levels can oscillate between elevations of 69.5 m a.s.l. and 63 m a.s.l., which correspond to the maximum and minimum retention levels. The elevation of 68 m a.s.l. is the same with the natural high water level at Baziaş, whereas the elevation of 63 m a.s.l. corresponds to the Danube mean level under natural flow conditions.

The most dramatic alteration of the levels regime can be seen near the dam, but the amplitude of oscillations gradually decreases with the increasing distance from it. Thus, at Baziaş station, the mean multiannual level recorded after the reservoir came into operation (1976 – 2003) rose by only 35 cm (from 582 cm to 2146 cm) in comparison with the previous period (1921 – 1962). Figure 2 shows the influence of the reservoir on the variability of the mean annual discharges.

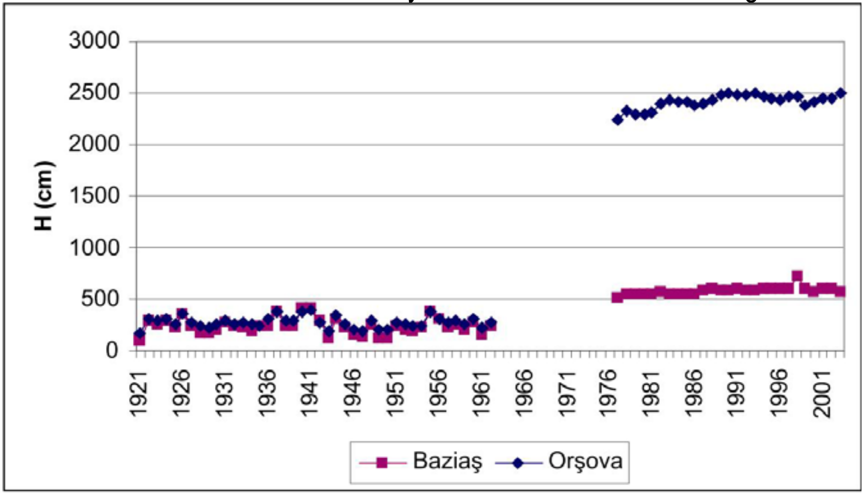


Figure 2. The variations of the mean annual levels of the Danube (1921 – 1962) and of the Iron Gates reservoir (1976 – 2003) at Baziaş and Orşova gauging stations

Before the creation of the reservoir, the annual levels regime mirrored, to the same extent as the discharges, the specific flow phases of the Danube. Once the huge impoundment appeared, the levels regime has been dictated by economic reasons. Consequently, during certain periods the water is stored in the reservoir, whereas other times it is released through the spillway gates. Generally, the levels are high at low discharges and drop during high water episodes, because according as the Danube discharges are rising the amount of released water increases. This is more obvious nearer the dam (at Orşova for instance), whereas upstream (at Baziaş) the level and discharge regimes become similar, both reflecting the natural flow conditions of the river (Fig. 3A and 3 B).

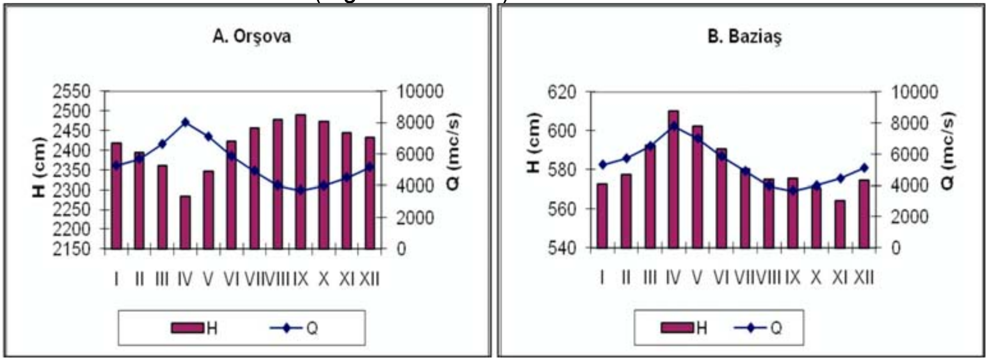


Figure 3. The variation of the mean monthly levels (H) and water discharges (Q) at Orsova (A) and Bazias (B) gauging stations (1976 – 2003)

Due to the controlled exploitation regime of the reservoir, level amplitudes (determined as the differences between the normal retention level of 69.5 m above the Black Sea level at Sulina and the mean monthly levels) vary significantly. For instance, in the period 1977 – 2005 they ranged from – 0.1 m to 6.2 m (Fig. 4).

A remarkable year from the point of view of the rapid and ample variations of the reservoir level was 2006, when water levels oscillated between 1853 cm (March 30) and 2553 cm (November 4), which means a maximum range of seven meters (Zaharia, 2008). From March to June 2006, the water level was very low, with negative ranges of more than 6 m compared to the normal retention level (Photo 1). This can be explained by the need to mitigate the high flood wave that was coming along the Danube from upriver. During this interval, the reservoir transferred a discharge that nearly matched the natural one.

The level variations (especially the rapid and ample ones) are among the major controls that alter the dynamics of the banks and slopes, rendering them unstable and causing collapses where the rocks are brittle. In 2006, between March 7 and 17, the water level dropped from 2445 cm to 2088 cm, which is a rate of 3.65 m in 10 days (or 0.36 m/day on an average). The maximum daily range was 1.3 m, a value recorded between March 23 and 24. As far as the rapid risings of water levels are concerned the period March 17 to 22 is the most significant, because in five days the level increased by 4.06 m (from 1900 to 2306 cm, or a mean rate of 0.81 m/day) (Zaharia, 2008).

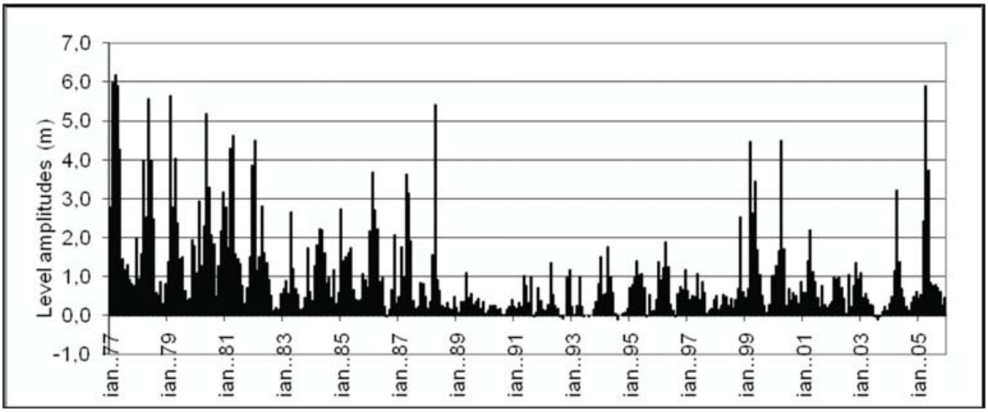


Figure 4. The range of the mean monthly levels at Orşova in relation to the normal retention level of the reservoir (69.5 m above the Black Sea level at Sulina), during the period January 1977 – December 2005)

3.3. Water discharge regime

The Iron Gates reservoir is mostly fed by the Danube. The variability of the river discharge at an annual scale mirrors the discharge regime of its main tributaries that flow into it upstream the reservoir: Inn, Drava, Sava, Morava, Tisa, etc. In short, this regime is characterized by high waters in spring, flood events that occur all year round, and low waters in summer, fall and winter (Trufaş and Simion, 1982).

The Hydropower and Navigation System transfers the Danube discharges through the reservoir, so that at annual scale inflows almost equal outflows. Under the circumstances, the variability of the mean discharges at multiannual scale, under a controlled regime, is almost the same with the natural flow. Thus, at Orşova, the mean multiannual discharge under a controlled regime (1972 – 2005) was 5419 m^3/s, whereas under a natural regime (1921 – 1960) it had been 5390 m^3/s. However, at annual scale one can note the regulating role of the reservoir manifested through the increase of discharges during low water periods and through their diminution when waters are high. As Figure 5 shows, during the intervals December – February and September – October the mean controlled discharges are higher than the natural ones, while in November and from May to August the situation is opposite. In terms of the seasonal distribution of the mean discharges, the highest share is specific for spring, both under controlled and natural regimes: 33.7% and 32.8%, respectively, from the mean annual volume. Summer and winter have rather similar percentages (22 – 24%), whereas in fall the river shows the lowest mean discharges and volumes under both types of regimes (about 19% of the mean annual volume). The analysis of the seasonal distribution of the mean discharge highlights a tiny diminution (approximately by 1%) during spring and summer under the controlled regime in comparison with the natural flow conditions and an increase during wintertime (by about 2%), whereas in fall the flow distribution under the two types of regimes is almost similar (Fig. 5).

The yearly regime of the mean discharges at Baziaş gauging station during the period 1976 – 2003 is controlled by the climatic conditions of the upper and middle course of the Danube. It shows a maximum during the spring high waters (7778 m^3/s in April) and a minimum in fall, when water level drops significantly (3686 m^3/s in September) (Fig. 3B).

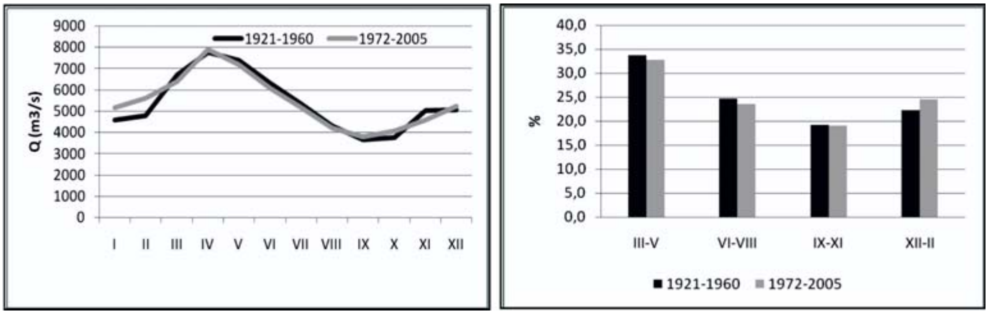


Figure 5. Mean monthly discharge variability of the Danube River at Orsova (left) and the seasonal flow distribution (right) under natural (1921 – 1960) and controlled (1970 – 2005) flow conditions

If at multiannual and annual scale there are no important differences between natural and controlled regimes, during high water periods and flood events the differences become significant, inasmuch as the flood mitigation role of the reservoir is more conspicuous, the inflows being inferior to outflows (Fig. 6). When flood waves menace the safety of the adjacent lands, water level is lowered to 63 m (the minimum elevation at which the turbines can operate), in order to retain the predicted excess water and protect the banks. When discharges top the turbines capacity (9600 m^3/s) the spillway gates are opened and water is released downstream (Şelău, 2010). As a rule, reservoir outflow is superior to inflow discharges in advance of the occurrence of spring high waters and floods, but during low water periods (in early fall) the process is reversed in order to bring the reservoir to its normal retention level. Generally, water use depends on the type of the year (rainy or dry), but also on the existence of the snow layer that feeds the upper course of the Danube. Irrespective of the situation, however, it is necessary to ensure a minimum outflow of 2000 m^3/s, in order to keep the channel navigable (Şelău, 2010).

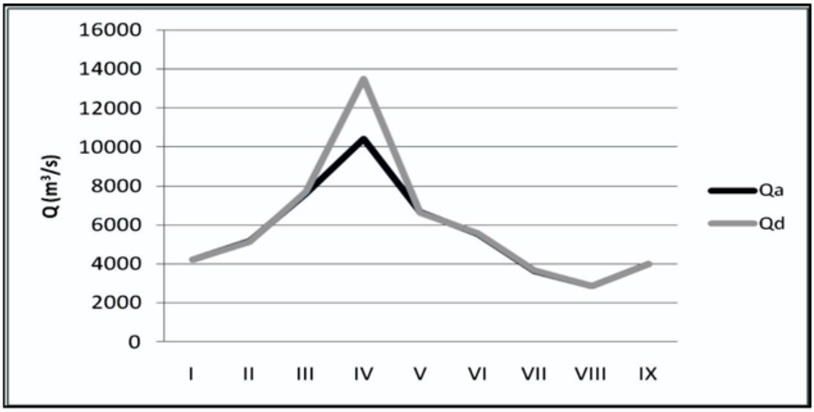


Figure 6. Inflow (Q_a) and outflow (Q_d) variability of the Iron Gates reservoir in the period January – September 1988 (based on the data Şelău, 1996)

From the standpoint of water discharge and levels regime, the reservoir can be divided into three sections, whose limits differ according to the transferred water volumes and retention elevations (Trufaş and Simion, 1982; Vespremeanu and Posea, 1988), as follows:

- *the lower section*, which at low waters (62 – 63 m) ends up at Ogradena, at mean elevations (65 – 66 m) extends as far as Şviniţa, and at high waters (68 – 69 m) reaches the Pescari village, is characterized by a lacustrine regime. However, because the flow is active enough the conditions are not exactly that of a lake.
- *the middle section,* whose boundaries are Ogradena – Şviniţa at low waters, Şviniţa – Moldova Veche at middle elevations and Pescari – upstream Moldova Veche at high waters, has a fluvial-lacustrine regime. The fluvial characteristics are obvious during high waters, whereas at low discharges lacustrine features prevail.
- *the upper section,* which at high waters ends up downstream of Baziaş village, at middle elevations downstream of Moldova Veche and at low waters downstream of Sviniţa, has a typical fluvial regime, although the backwater effect induced by the dam is still visible.

3.4. The solid discharge and sedimentation processes

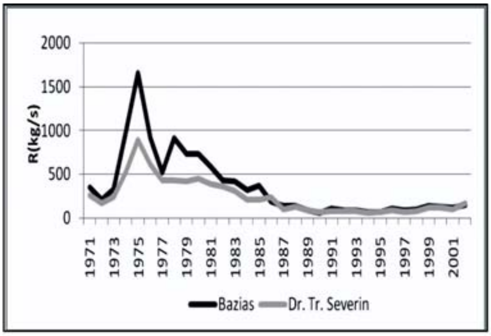
The Iron Gates reservoir undergoes a sedimentation process mainly because of the high amounts of solid load carried by the Danube. The streams that flow into the reservoir have a lower contribution and this is also true for the gradational processes induced by lacustrine dynamics, which affect the banks and slopes (Chiriac et *al*.,1976).

The reservoir creation has brought about significant alterations of sediment transport along the defile. Under a natural flow regime, the solid load of the Danube showed a slight increase from upstream to downstream. After the completion of the reservoir, however, the situation reversed and consequently the mean annual suspended load discharge decreased in the same way, more exactly from 170 kg/s on the Baziaş section to 128 kg/s at Orşova (values determined for the period 1981 – 2003 based on the data provided by the "Romanian Waters" National Administration). The sedimentation processes encouraged by the lower velocity of the flow led to a drastic reduction (by 88%) of the suspended load along the Orşova section. Thus, if prior to reservoir formation (1921 – 1962) the mean multiannual suspended load discharge on this section was 1112 kg/s (35 million tons per year), in the period 1981 – 2003 the value dropped to 128 kg/s (4 million tons per year), which proves the sedimentation processes are extremely active.

The decantation rate is also mirrored by the ratio between water and suspended load discharges, which increases from upstream to downstream, from 29.3 at Baziaş to 40.6 at Orşova (for the period 1981 – 2003), proving once again that the intensity of sedimentation processes increases in the mentioned direction.

The balance of the sediments deposited on the bottom of the Iron Gates reservoir during the period 1971 – 2002, computed based on the cumulated differences between Baziaş and Drobeta Tr. Severin sections, shows that the total volume of sediments amounted to 117.8 million tons (according to the data provided by "Romanian Waters" National Administration). At the same time, the mean multiannual suspended load outflow was 33% lower than the inflow, the values decreasing from 353.2 kg/s (at Baziaş) to 236.5 kg/s (at Drobeta Tr. Severin) (data provided by "Romanian Waters" National Administration). Significant reductions were recorded in the first decade after reservoir creation and especially in the years with major flood events (1975, 1978). After 1987, however, one can note a relative homogeneousness of the suspended load on the two sections of the reservoir, as well as a decrease of sedimentation rate (Fig. 7).

Although the solid load of the Danube dropped sharply because of the sedimentation processes, the mean monthly regime of suspended load discharges and their seasonal distribution did not suffer significant changes. Thus, the highest amounts of suspended load are specific for spring (March – April), a season characterized by high waters and flood events, which affect the upper and middle sections of the Danube river basin. By contrast, the lowest amounts of suspended load are carried from August till October (Fig. 8).



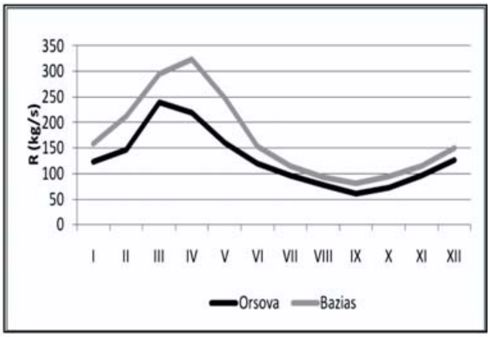


Figure 7 (left). The variability of the Danube mean annual suspended load discharges at Baziaş, Orşova and Drobeta Tr. Severin (according to the data provided by "Romanian Waters" National Administration Figure 8 (right). The variability of the mean monthly suspended load discharges on the Baziaş and Orşova sections (1981 – 2003)

If prior to reservoir accomplishment the regime, distribution and intensity of sedimentation processes were primarily influenced by liquid discharges, flow velocity and channel morphology, after H.N.S. came into existence an important role has been played by levels oscillations, which, as mentioned previously, may be as high as 7 m. The artificial lowering of water level in the reservoir during high waters periods makes the water surface tilt from upstream towards the dam. Consequently, flow velocity increases and drives the sediments downstream. Apparently, the most important removals occur along the section from Drencova to Şviniţa, where flow velocity exhibits the highest variations (Trufaş and Simion, 1982).

Sedimentation is more intense at the reservoir tail, within the small inlets formed at the mouth of its tributaries and in the depressionary lacustrine areas, where the course is sluggish. In the Dubova and Şviniţa inlets the sediment layer exceeds 11 m, while in the Cerna Gulf it is more than 6 m thick (Şelău, 2006). The measurements undertaken during the low waters period of June 2006 revealed that the sediments laid down along the banks of the Cerna Gulf, near the mouth of the Slătinic brook, are thicker than 2 m (Photo 2).

In the proximity of the dam, sedimentation is insignificant because the sediments carried by the Danube are permanently disturbed by the incessant movement of water, due to the overflow, the passing of ships through the locks or the use of water for hydropower generation. The high discharge of the Danube and the operating conditions of the hydropower plant have deterred the sedimentation processes along the thalweg, which explains why in the long profile this has almost the same features as during the initial flow conditions. The solid load is laid down somehow parallel with the main stream thus contributing to the silting of the former floodplains and lacustrine areas (Şelău, 2010).

4. Water quality of the Iron Gates reservoir

The quality of the water stored in the Iron Gates reservoir depends both on the water quality of the Danube (which in its turn is influenced by the riverain European countries lying upstream) and on the pollution sources that exist in the reservoir area. In 2004, the main point pollution sources on the Romanian bank were represented by the Moldova Nouă mining enterprise and the human settlements (Photo 3), which discharge into the reservoir wastewaters rich in suspensions and with a high content of fixed residue (Table 2).

Table 2 The main quality indicators of the wastewaters discharged into the Iron Gates reservoir in 2004

Pollution source	Total volume of wastewaters mil.m^3/yr	Quantities of pollutants discharged (t/yr)						
		Suspensions	Fixed residue	CCO-Mn/O_2	Ammonium	Phenols	Cu	Zn
Moldova Nouă mining enterprise	6.615	285.85	2308.42	44.575	0	0.012	2.312	0.814
IGOSERV Moldova Nouă	1.144	79.053	669.432	45.221	35.158	0.018	0	0
Township of Orşova	0.649	23.875	268.759	7.326	9.294	0.005	0	0
TOTAL	8.408	388.778	3246.61	97.122	44.452	0.035	2.312	0.814

According to the data provided by the ”Romanian Waters” National Administration, Bucharest

Other water pollution sources in the area are represented by domestic waste, which is disposed of on the reservoir shores or directly into the water. This phenomenon is especially common between Pescari and Moldova Nouă (where the town landfill is placed right on the reservoir shore). Consequently, the waters percolate the dump getting loaded with various contaminants, which are carried into the soil and the groundwaters, from where they reach into the reservoir. Sometimes, however, these impaired waters flow directly into the water body. The negative effects are more obvious into the inlets where algal bloom phenomena are common. Domestic waste can also be seen along the reservoir tributaries or right inside their channels, thus having a direct impact on water quality. The flood waves that travel down the streams (especially those produced by the Cerna River) bring into the reservoir large amounts of solid wastes. Another point pollution source is the Orsova shipyard. Besides, agricultural activities use phosphate and nitrogenous fertilizers, which turn into nonpoint pollution sources that impair the reservoir waters.

Photo 1. The lowered level of the waters in the Cerna Gulf in June 2006 (left), in comparison with the normal level recorded in June 2004 (right)

Photo 2. Alluvial deposits on the right bank of the Cerna Gulf (left) and at the junction of the Slatinic brook (right) in June 2006

Photo 3. The wastewater discharge pipe at the Sewage Treatment Plant in Orsova town (picture taken in June 2006 when the lowered levels of the reservoir exposed the pipe that normally is submerged). View from the reservoir to the shore (left) and from the shore to the reservoir (right)

The assessment of reservoir water quality has been accomplished for the period 2000 – 2004 according the *Normative regarding the reference indicators for the classification of surface waters quality 1146/2002* and on the basis of the analyses performed by the laboratories of the National Water Monitoring System. In order to assess water quality state the 90% method was used, because it has the advantage of eliminating extreme outliers, whereas for dissolved oxygen analysis the 10% method was employed. In Table 3, one can see the typical statistical values of the quality indicators determined for the Iron Gates reservoir (on the Şviniţa, Dubova, upstream Orşova and upstream the dam sections), as well as the quality class in which the waters fall according to the previously mentioned Normative and working method. The table analysis reveals the water of the Iron Gates reservoir is rich in nutrients (ammonium, nitrates, orthophosphates and total phosphorus), which explains why it belongs to quality Class 3. As far as the total coliforms content is concerned, the water belongs to the same class.

Beginning with 2006, the establishment of surface water quality has been done based on the provisions of *Order no. 161/2006 regarding the approval of the normative for surface water classification with the purpose of establishing the ecological state of water bodies*. According to this normative, from the point of view of nutrients (total nitrogen and total phosphorus) the waters of the Iron Gates reservoir fall into the following trophic categories: *Eutrophic* (in 2006 and 2007), *Eutrophic-Hypertrophic* (in 2008), and *Hypertrophic* (in 2009). From the biological standpoint, during the period 2006 – 2009 the reservoir waters were *Mesotrophic* (according to the Reports concerning the water quality, published by the Ministry of Environment and Forests, 2006 – 2009).

Table 3 The general characterization of the Iron Gates reservoir water quality for the period 2000 – 2004

Parameter	**U/M**	**No. of samples**	**Typical statistical values**				**Percent**	
			Minimum	**Mean**	**Maximum**	**Standard deviation**	**V (90%)**	**Class**
Water physico – chemical indicators								
Physical indicators								
Water temperature	^{0}C	79	3.9	16.3	28.0	7.37	-	-
pH		79	7.2	7.8	8.5	0.27	8.2	I-IV
Suspensions	mg/l	79	21.0	39.2	84.0	12.75	55.0	-
Oxygen regime								
Dissolved oxygen	mg O/l	78	4.79	7.75	10.63	1.396	6.05	II
CBO5	mg O/l	79	0.90	2.97	5.60	1.127	4.29	II
CCO-Mn	mg O/l	79	0.46	4.17	9.06	1.947	6.44	II
Nutrients								
Ammonium (N-NH4)	mg N/l	79	0.021	0.252	0.801	0.1831	0.534	III
Nitrites(N-NO2)	mg N/l	79	0.003	0.036	0.100	0.0198	0.061	III
Nitrates (N-NO3)	mg N/l	79	0.154	0.964	2.213	0.6462	1.951	II
Orthophosphates (P-PO4)	mg P/l	78	0.0233	0.0914	0.3400	0.06559	0.1853	III

Total phosphorus (P)	mg P/l	74	0.0090	0.1182	0.3600	0.6607	0.2070	III
General ions, salinity								
Filtered residue	mg/l	79	188.0	228.4	357.0	30.10	260.4	I
Chlorides(Cl)	mg/l	79	11.6	20.3	31.3	2.61	23.6	I
Sulphates (SO4)	mg/l	79	11.8	33.8	51.5	8.48	45.0	I
Calcium (Ca)	mg/l	79	4.4	48.3	68.4	8.15	57.1	I
Magnesium (Mg)	mg/l	79	6.8	12.8	64.0	6.30	15.5	I
Sodium (Na)	mg/l	56	8.0	15.1	27.0	2.88	18.5	I
Bicarbonates (HCO3)	mg/l	16	152.5	163.9	183.0	11.76	183.0	-
Total hardness	^{0}G	63	7.8	9.7	13.0	1.11	11.2	-
Total iron (Fe)	mg/l	78	0.01	0.18	0.62	0.151	0.38	II
Microbiological anlyses								
Total coliforms	nr/100 ml	12	1100	2326	4900	1394.1	4740	III

Source: ”Romanian Waters” National Administration, Bucharest

Conclusions

The hydrological characteristics of the Iron Gates reservoir are primarily the result of the natural conditions (especially the climatic ones) of the upper and middle sections of the Danube catchment, which are responsible for the variability of the liquid and solid flows that cross the reservoir. At the same time, the exploitation regime of the Iron Gates H.N.S. (either for hydropower generation or for flow regulation) plays an important part in this respect.

If prior to reservoir creation the levels regime of the Danube mirrored the river specific flow phases, once the reservoir came into existence the levels have been controlled by the needs to store or discharge the water. Level variations can have ranges as high as 7 m, with rates that sometimes exceed 1 m/day, which encourages the dynamics of the banks and slopes. Generally, the levels are high at low waters and low at high waters, inasmuch as the increased inflows require increased outflows. At the reservoir tail, the influence of water exploitation diminishes, so that the levels regime is rather similar with the discharges evolution under normal flow conditions.

Unlike the levels, the discharges regime has been less affected by reservoir creation. The operation of H.N.S. ensures the transfer through the reservoir of the Danube discharges, so that at multiannual, annual and seasonal scale the discharges variability under a controlled flow regime does not stray too much from the natural conditions. However, the analysis of the mean monthly discharge variability has emphasized the role of the reservoir in flow control, through the increase of discharges during low water periods (December – February and September – October) and through their decrease when the waters are high (May – August and November). Significant differences between the two types of regime are seen during the flood events, when flow mitigation process is more obvious, because outflow is superior to inflow.

The accomplishment of the Iron Gates reservoir has entailed significant alterations of sediment transport along the defile. The reduction of water flow velocity has encouraged sedimentation processes. Consequently, at Orşova, the amount of suspended load dropped by 88% during the period 1981 – 2003, in comparison with the interval 1921 – 1962.

The balance of the sediments laid down on the bottom of the reservoir during the interval 1971 – 2002, estimated on the basis of cumulated differences between Baziaş and Drobeta Tr. Severin sections, has shown a total sediment volume of 117.8 million tons. Silting processes are more active at the reservoir tail and within the inlets at the mouth of the tributaries.

As far as the water quality is concerned, it mirrors both the influence of pollution sources lying upstream the reservoir on the Danube waters, and the impact of the contamination sources located along the defile (particularly the domestic wastewaters and industrial effluents). During the period 2000 – 2004, the reservoir waters belonged to quality Class 2 according to the indicators reflecting oxygen regime and iron ions and to quality Class 3 according to most nutrients and total coliforms. Between 2006 and 2009, however, because of nutrients enrichment the water quality worsened, becoming from eutrophic in 2006, eutrophic-hypertrophic in 2008 and hypertrophic in 2009. At the same time, from the biological point of view the waters were mesotrophic. Under the circumstances, it is extremely important to take appropriate measures in order to protect the water quality of the Iron Gates reservoir.

References

Academia R.S.R., (1972), *Atlasul complex „Porţile de Fier*", Ed. Academiei R.S.R., 261 p.

Administraţia Naţională de Meteorologie, (2008), *Clima României*, Ed. Academiei Române, Bucureşti, 365 p.

AQUAPROIECT, (1992), *Atlasul Cadastrului apelor din Romania*, Bucuresti, 694 p.

Chiriac V., Filotti A., Teodorescu I., 1976, *Lacuri de acumulare*, Ed. Ceres Bucureşti, 213 p.

Diaconu, D.C., (2007), Caracteristici morfologice ale cuvetei Golfului Orşova*, Comunicări de Geografie,* IX, Ed. Universităţii din Bucureşti, pag. 327-331.

Grigore M., Sencu V., (1987), Defileul Dunării, in *Geografia României*, III, Ed. Academiei R.S.R., p. 406-412. Hidroconstrucţia, (1984), *A XX-a aniversare a S.H.E.N. Porţile de Fier I*.

Ilie, I., (1979), Direcţii noi în dezvoltarea proceselor morfogenetice şi a condiţiilor de solificare din zona Orşova – Plavişeviţa, după amenajarea lacului de retenţie Porţile de Fier I, *Analele Universităţii Bucureşti*, ser. Geografie.

Manea G, (2003), *Naturalitate şi antropizare în Parcul Natural Porţile de Fier*, Editura Universităţii din Bucureşti.

Ministerul Mediului şi Pădurilor, (2010), *Reports concerning the water quality*, published in 2006 – 2009, http://www.mmediu.ro/gospodarirea_apelor/rapoarte_ape.htm, http://www.mmediu.ro/gospodarirea_apelor/calitatea_apelor/raport_2009.pdf (consulted on 29.12.2010).

Pătroescu, M., Ghincea M., Cenac–Mehedinţi M., Toma, S., Rozylovicz, L., (1999 – 2000), Modificări antropice în coridorul fluvial al Dunării şi reflectarea lor în starea mediului, *Geographica Timisiensis*, VIII-IX, Timişoara.

Maria Pătroescu, Cristian Iojă, Laurenţiu Rozylowicz (2002), *Principii de management a ariilor protejate din România. Studiu de caz Parcul Natural Porţile de Fier*, Editura Altius Academy, Iaşi, pag. 136-146.

Pop Gr., (1996), *România. Geografie hidroenergetică*, Ed. Presa Universitară Clujană, Cluj Napoca, 237 p.

Sârbu I., (2001), *Valea Cernei. Studiu fizico-geografic, cu privire specială asupra hidrografiei*, Teză de doctorat, University of Bucharest.

Şelău N., (1996), *Studiul lacului de acumulare Porţile de Fier*, manuscris, 36 p.

Şelău N., (2010), Lacul de acumulare Porţile de Fier. Caracterizare fizico-geografică şi funcţională. Scurt istoric, *Comunicări de geografie*, vol. XIV, Bucureşti, p. 85 – 100.

Ujvári I., 1972, *Geografia apelor României*, Ed. Ştiinţifică Bucureşti, 591 p.

Trufaş, V., Simion, I., (1982), Modificarea unor caracteristici hidrologice ale Dunării, între Baziaş şi Gura Văii*, Analele Universităţii Bucureşti*, Anul XXXI, p. 65 – 82.

Vespremeanu, E., Posea, A., (1988), Sedimentarea şi sedimentele din lacul de acumulare „Porţile de Fier 1*”*, în *Probleme de geomorfologie*, vol. 2, Universitatea din Bucureşti, p. 25 – 101.

Zaharia L., (1993), *Câteva observaţii asupra scurgerii medii a unor râuri tributare Dunării româneşti*, Analele Universităţii Bucureşti, ser. Geogr., XLII, p. 73 - 80.

Zaharia L., Diaconu D., Sârbu I., (2003), *Activităţi practice de hidrologie în arealul „Porţile de Fier”* Editura CREDIS, Bucureşti, 56 p.

Zaharia L., (2008), Impactul lacului de acumulare Porţile de Fier I asupra morfodinamicii malului şi a versantului românesc, *Comunicări de Geografie*, vol. XII, Bucureşti, p. 223-228.

* * * (1967), *Dunărea între Baziaş şi Ceatal Izmail. Monografie hidrologică*, ISCH, Bucureşti, 369 p.