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C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Impact of sediment transport of the Chellif River on silting of the Boughezoul reservoir (Algeria)

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Abstract

In this article, we discussed the effect of sediment transport in the Chellif catchment on the silting of Boughezoul reservoir. Since 1934, when the impoundment of the dam, nine bathymetric surveys were carried out by hydraulic services. Based on the last two bathymetric surveys (1986 and 2005), we assessed the average annual rate of silting 0.67 million $m^3 \cdot year^{-1}$. Is a filling rate of 70% of the total capacity of the reservoir in 2011. Storage capacity has decreased from 55 million m^3 in 1934 to 15 million m^3 in 2011. Concentrations exceeding 300 $g \cdot l^{-1}$, recorded in the river upstream of Boughezoul reservoir, caused formation of density currents.

Key words: *Boughezoul dam, Oued Chellif, sediment transport, siltation*

INTRODUCTION

The silting of dams poses operators enormous problems whose resolution cannot be that expensive. Deposits silt at the bottom of a reservoir are mainly from watershed erosion, gradually reducing the effective capacity of the dam. Very answered in the Mediterranean basin, especially in the northern Algerian erosion hydriqueest an indispensable factor in the assessment of the life of a dam. Unlike the northern part of the Mediterranean, the highest values of abrasion rates are recorded in the southern part of the Mediterranean. DEMMAK [1982] showed that erosion rates specific reaches 4000 $t \cdot km^{-2} \cdot year^{-1}$ on the chain of coastal Dahra. BOUCHELKIA *et al.* [2014] showed that the erodibility of watershed Chellif (Algeria) exceed the value of 4 million of $t \cdot year^{-1}$. The erosion is very important in the catchment of Tafna (Algeria), as it provides a solid throughput of more than the value of 6 million $t \cdot year^{-1}$. In Morocco, the average degradation of watershed Nekor approximates the value of 5900 $t \cdot km^{-2} \cdot year^{-1}$, one of the highest in the world [LAHLOU 1990]. On the catchment of Isere (France) specific erosion rate reached 652 $t \cdot km^{-2} \cdot year^{-1}$ [DUMAS 2008]. Even in other parts of the world, the erosion rate can reach high values such as the rate of erosion of the watershed of the Yellow River in China is 2650 $t \cdot km^{-2} \cdot year^{-1}$ [ICOLD 1976]. In Romania the specific erosion rate is close to the value of 500 $t \cdot km^{-2} \cdot year^{-1}$ [RADOANE, RADOANE 2005]. BĄK and DĄBKOWSKI [2013], studied the spatial distribution of sediments in the reservoir Suchedniow over a period of 33 years is exploitation. More than 32% of the sediments were deposited in the upper part of the reservoir.

According DEMMAK [1982], the average annual amount of eroded soil in Algeria is 180 million tones, part of which is deposited in the rivers and dams. WALLING [2008] showed that the dams are sediment trapping structures. They have an impact on the reduction of the sediment load in rivers. This erosion causes intense concentrations of fine particles very high in the drainage of a watershed, where the entry of a reservoir dam resulting in the formation of current densities. These attract a huge mass of fine particles that will settle to the bottom of reservoirs. This phenomenon often occurs during floods. Muddy deposits caused by the settling of particulate matter drained by these currents, thereby reducing the useful capacity of dams.

In Algeria, the Boughezoul dam classified as old dams is currently facing a high rate of siltation. With the completion of streams mega project for the new city of Boughezoul, Lake Boughezoul dam be the lungs of the city aesthetically and tourism.

In this study we treat the effect of sediment transport in the Chellif River the silting of Boughezoul. To maintain the capacity of the lake to its original state Boughezoul (1934), the services of hydraulic dredging planned the restraint and the raising of the dam to recover its initial capacity of 55 million m^3. In our opinion, these two options are insufficient to reduce the silting of Boughezoul. More extensive studies should be conducted to try to understand the mechanism of siltation and solve the problem.

STUDY SITE AND DATA USED

WATERSHED CHELLIF – ZAHREZ

The watershed upstream of the Boughezoul dam part of the watershed of Chellif Zahrez, which is ranked as the most erosive five watersheds of Algeria. It is located in the center west of Algeria northern region Cheliff – Zahrez is bounded on the north by the Mediterranean Sea, the west by the Oran region – Chott – Chergui, south through the desert and the is the region of Algiers – Chott – Hodna. Watershed Cheliff that spans 43 750 km^2, is the largest river basin in the north. Watershed Chellif Zahrez is divided into three watersheds; Basin Cheliff – Boughezoul upstream dam, the basin of the upper and middle basin Cheliff and low Cheliff and Mina.

The watershed upstream of Cheliff Boughezoul is drained by two major tributaries of the region namely Wadi Nahr Touil Ouassel whose confluence is the starting point of the largest wadi in Algeria, Chellif (759 km) at the dam of Boughezoul, where it controls more than 40% of the surface of the great watershed Chellif. Basin upstream of Chellif Boughezoul spreads over an area of 19 645 km^2 (Fig. 1).

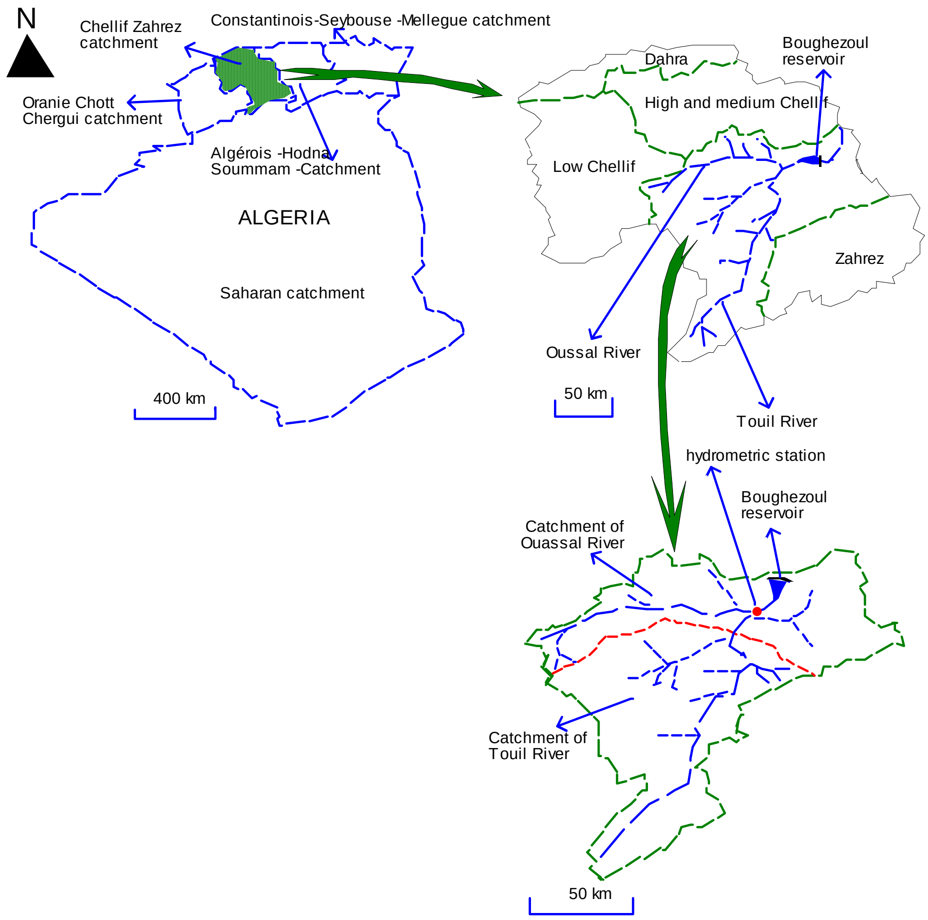

Fig. 1. Watershed upstream of the Boughezoul dam; source: NADT and NAWR, modified by the author

PRESENTATION OF DAM BOUGHEZOUL

Located on the river Chellif the Boughezoul dam stores a capacity of 55 million m^3 of water, inputs and wadis Touil Nahr Ouassel. Put water in 1934, the Boughezoul dam is located 150 km southwest of Algiers (Fig. 2). It has three distinct roles that are flood control, sedimentation tank to reduce sediment yield of the dam and Ghrib reservoir additional accumulation (Fig. 3).

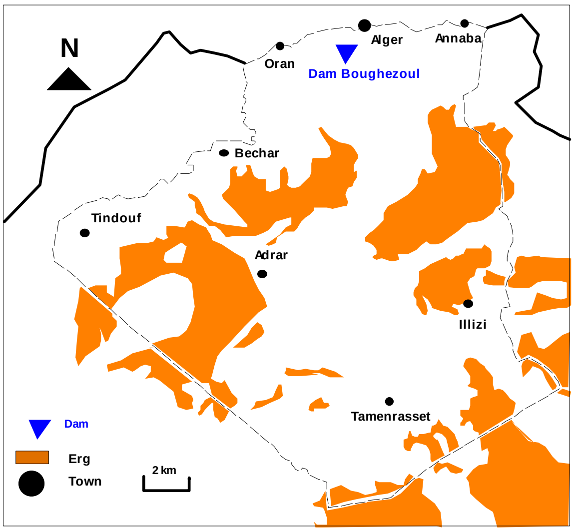

Fig. 2. Location of the Boughezoul dam; source: NADT modified by author

Fig. 3. An overview of the Boughezoul dam; photo: *B. Remini*

Fig. 4. The watershed upstream erosion of the Boughezoul dam; photo: *B. Remini*

Fig. 5. Banks erosion of the Chellif wadi; photo: *B. Remini*

RESULTS AND DISCUSSION

SEDIMENT YIELD DAM BOUGHEZOUL

The watershed upstream of the Boughezoul dam is divided into two sub-watersheds: Nahr Oussal in the north and Nahr Touil in the southern part of the watershed. Both wadis converge before the dam for the Chellif River form. Sediment from erosion of these two watersheds (especially the basin of Nahr Ouassal) and bank erosion caused by sudden changes in water level in the two wadis are drained in Chellif wadi before being trapped in the dam of Boughezoul (Fig. 4 and 5).

The total area of the sub basin of Nahr Touil is 11 450 km^2. The river originates Touil on the northern slopes of the mountains of Jebel Amont and Saharan Atlas. Along its course, the river crosses Touil as arid highlands and wetlands as closed depressions called Daia. The flow regime of Oued Touil is characterized by the absence of the water throughout the year and with torrential sudden increase in water level in flood periods, this situation causes erosion. The catchment area of Nahr Ouassal spreads over an area of 3 300 km^2. The river crosses Ouassal arid and mountainous and barren. Flash floods and rapids do not give enough time for infiltration, but rather it is the runoff prevails. Helped by steep slopes and terrain generally marly trickling erodes the soil and form gullies, which provide relatively large amounts of sediment into the river. During the year, the flow is almost zero, there is a net liquid in the wet season, the flow is apparent in the river during floods, the water level increases rapidly causing a power flow quite important sediment can drain large caliber up to tree trunks. The decline is rapid, rapid lowering of the water level causes landslides banks. The flow of the next flood carries lands settled to the bottom of the wadi. As shown in Figure 6, the sediment load of the Ouassal River, despite its small size of the watershed are largely greater than those of the Touil wadi which has a large area of the watershed.

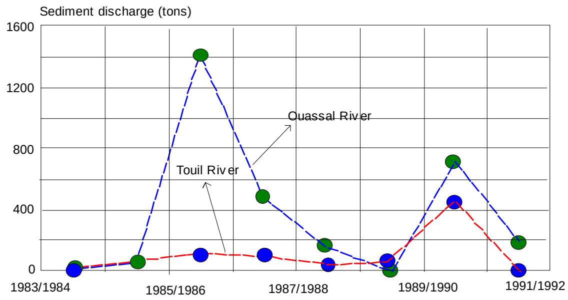

Fig. 6. Sediment yield in the Ouassal and Touil Rivers; source: NAWR

According to data from the NAWR, we found that during the flood sediment transport is important. In the case of watershed Nahr Ouassal the flood season had no effect on sediment transport as in the case of the northern regions of Algeria; autumn floods are the most loaded fine particles. In Oussal wadi, floods can occur at anytime and anywhere with a nice solid contribution. Average sediment yield drained by the floods are 150 times the sediment yield drained during low flow periods (Fig. 7). The flood of 1975, recorded solid contribution during the flood of 1975 far exceeded the threshold of 300 times the drained solid contribution throughout the year 1975.

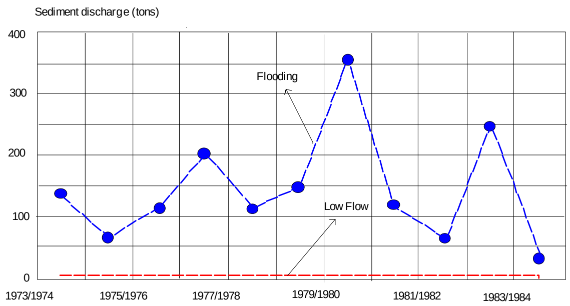

Fig. 7. Sediment yield during periods of high water in the Ouassal River; source: NAWR

Hydrometric station located on the Chellif River upstream of Boughezoul dam controlling sediment yield from Touil and Ouassal wadis, the sediment levels recorded by this station reached values spectacular 300 g·l^{-1}. This raw sediment laden causes the formation of density currents to the input of the retention Boughezoul. These density currents traverse easily the length of 7 km from the tail of the reservoir to the foot of the dam (Fig. 8). For information, a concentration of 30 g·l^{-1} can cause the appearance of a current density [REMINI 1997].

EVOLUTION OF THE CAPACITY OF THE BOUGHEZOUL DAM

No matter where the location of a dam, its capacity will never remain stationary and it decreases with alluvial deposits at the bottom of the reservoir. Since 1934, date of impoundment Bouighezoul dam, its

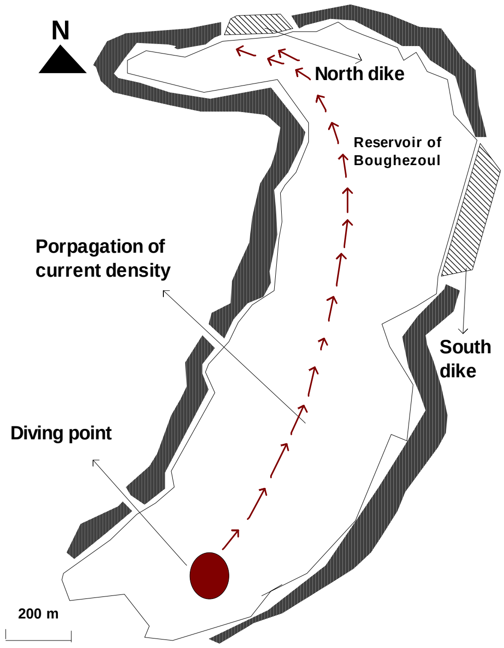

Fig. 8. Propagation of density currents in the Boughezoul reservoir; source: NADT, modified by author

capacity decreases in the time to reach the 2005 volume of 20 million m^3. A loss of capacity equal to 15 million m^3 in 2011. This decrease is caused by successive deposits of silt from erosion Chellif watershed and undercutting of banks led along the Chellif River. Figure 9 illustrates this decrease in the useful capacity of the dam due to Boughezoul to assess an annual loss of 0.5 million m^3.

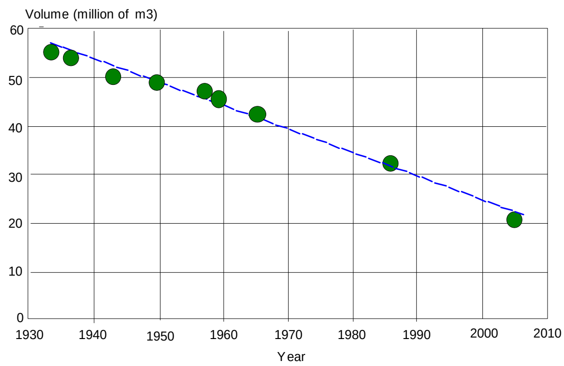

Fig. 9. Temporal evolution of the capacity (million m^3) of the Boughezoul dam (data NADT); source: own elaboration

Figure 10 shows the evolution of the capacity of the dam Boughezoul. She was initially equal to 55 million m^3 pure down to 33 million m^3 in 1986 and to 20 million m^3 in 2005. It is estimated only 16 million m^3 in 2011.

Based on bathymetric operated at the dam Boughezoul, we determined that the siltation rate during the period: 1986–2005: it is 0.67 million m^3·year^{-1}. The period 1965–1986 was estimated at 0.46 million m^3·year^{-1}. The siltation rate has significantly increased from 0.46 to 0.67 million m^3·year^{-1}.

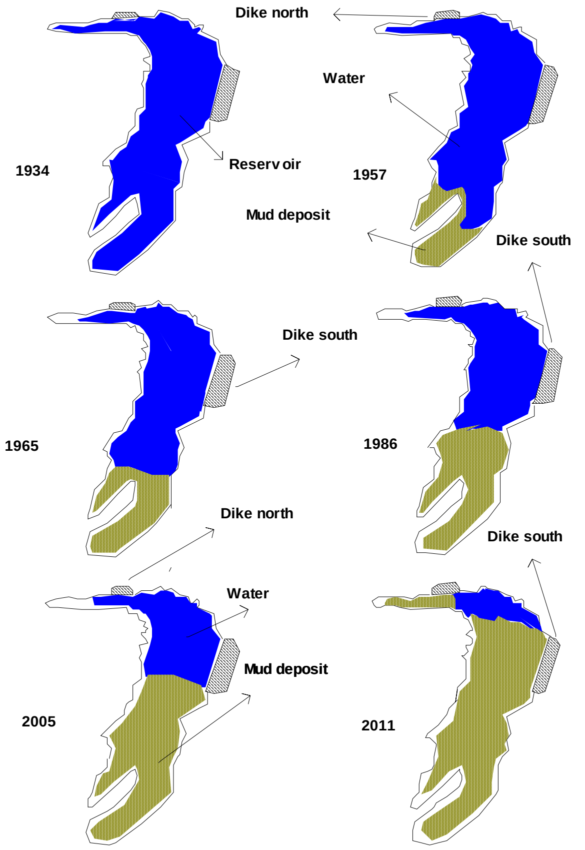

Fig. 10. Reduced capacity of the retention time Boughezoul; (realized by the data of NADT); source: own elaboration

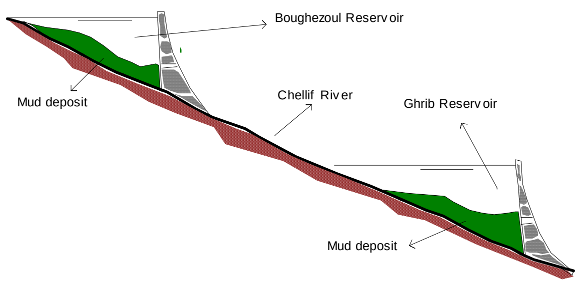

Fig. 11. Schematic diagram of the design hydraulic Boughezoul – Ghrib; source: own elaboration

This can be explained by the high watershed degradation and accelerating sapements banks of the Chellif River. Taking into account the last siltation rate (0.67 million $m^3 \cdot year^{-1}$), the amount of silt deposited in 2011 can be estimated at 40 million m^3, a filling rate of 73%. On these results, the dam will operate until 2033.

IMPACT OF THE BOUGHEZOUL DAM ON REDUCING THE SILTING OF GHRIB DAM

Ghrib dam with a capacity of 280 million m^3, is located downstream of the dam on the same wadi Boughezoul Chellif (Fig. 11). The dam was put into operation in 1939 just after the Boughezoul in 1934. In this case the Boughezoul dam can play the role of a settling dam; it can retain a volume of mud that is likely to be deposited in the Ghrib dam. It can have a positive effect on the extension of the term life Ghrib dam. For cons, the dam releases Boughezoul may have an adverse effect on the dam itself and that of Ghrib. Indeed, the dam Boughezoul acts as a sieve, the artificial flooding caused by maneuvers bottom valves drain the water not very busy fine particles. Sediments are retained in the enlarged dam Boughezoul. The mixture of high content of fine particles discharged from the Boughezoul dam causes the formation of density currents at the entrance to the holding Ghrib and therefore deposits silt at the bottom of the Ghrib tank is much greater.

By analyzing the data of bathymetric operated at dams of Boughezoul and Ghrib during their operation. Figure 12 represents the temporal evolution of the capacity of the Ghrib dam spared Boughezoul dam. It is interesting to note that the ability saved by the Boughezoul dam increased from 2.5% in 1957 to 12% in 2005. It is estimated at 15% in 2011. In 2005, we recovered Ghrib dam estimated at 35 million m^3 (Fig. 13).

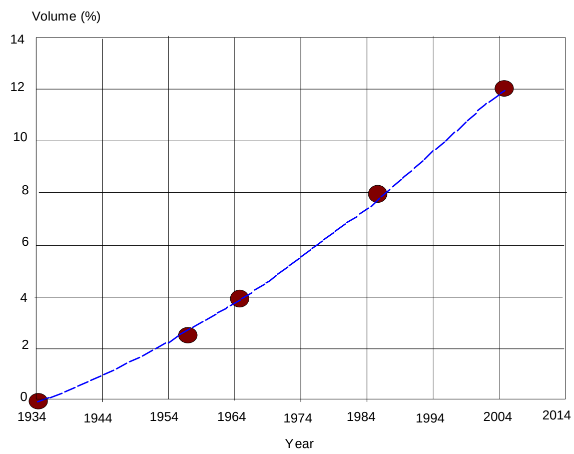

Fig. 12. Capacity (%) of the Ghrib reservoir spared by the Boughezoul reservoir (calculated from data of NADT) source: own elaboration

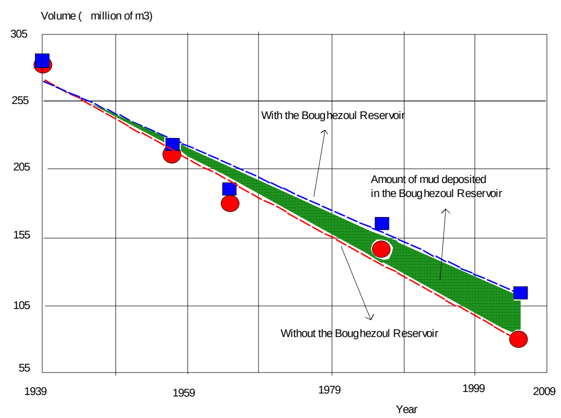

Fig. 13. Temporal evolution of the capacity (million m^3) of the Ghrib dam with or without the Boughezoul dam (calculated from data of NADT); source: own elaboration

CONCLUSION

This work has allowed us to get an idea of the mechanism silting of Boughezoul dam. Thus the high levels of fine particles cause the appearance of density currents in flood periods. Successive deposits of sediment drained by these streams were valued at more than 70% of the total capacity of the Boughezoul dam. It is currently ranked among the most silted dams in Algeria.

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Wpływ transportu rumowiska w rzece Chellif na zamulenie zbiornika Boughezoul (Algieria)

STRESZCZENIE

Słowa kluczowe: *transport osadów, ued Chellif, zamulanie, zapora Boughezoul*

W artykule opisano wpływ transportu rumowiska w rzece Chellif na zamulanie zbiornika Boughzoul. Badania były prowadzone w okresie eksploatacji zapory przez Narodową Agencję Zapór. Na podstawie danych na temat transportu osadów uedu Chellif uzyskanych w badaniach batymetrycznych z lat 1986 i 2005 prowadzonych powyżej zapory oceniono średnią roczną stopę zamulenia na 0.67 mln $m^3 \cdot rok^{-1}$. Ilość osadów zakumulowanych w zbiorniku oceniono na ponad 70% całkowitej pojemności. Pojemność ta zmniejszyła się z 55 mln m^3 wody w roku 1934 do 15 mln m^3 w 2011 r. Stało się tak z powodu stężenia zawiesin powyżej 300 $g \cdot l^{-1}$ notowanego w rzece powyżej zbiornika Boughzoul.