ASSESSMENT OF HYDROMORPHOLOGICAL AND HYDRODYNAMIC ALTERATIONS CAUSED BY ANTHROPOGENIC INTERVENTIONS ON THE RIVERBED.
CASE STUDY DANUBE BALA BRANCH NEW BOTTOM SILL

Constantin CÂRSTINOIU, Eng. - National Institute for Research and Development in Environmental Protection Bucharest, Romania, catalincc90@yahoo.com
Gyorgy DEAK, Eng. PhD. - National Institute for Research and Development in Environmental Protection Bucharest, Romania
Bogdan URIȚESCU, Geogr. - National Institute for Research and Development in Environmental Protection Bucharest, Romania
Georgeta TUDOR, Eng. - National Institute for Research and Development in Environmental Protection Bucharest, Romania
Alina-Florina NICOLAE, Eng.PhDStud. - National Institute for Research and Development in Environmental Protection Bucharest, Romania &"Dunărea de Jos" University of Galati, Romania
Adrian-Ștefan ZAMFIR, Eng.PhDStud. - National Institute for Research and Development in Environmental Protection Bucharest, Romania &"Dunărea de Jos" University of Galati, Romania
Tiberius DĂNĂLACHE, Ecol. PhDStud. National Institute for Research and Development in Environmental Protection Bucharest, Romania & University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Marius OLTEANU, Eng. - National Institute for Research and Development in Environmental Protection Bucharest, Romania
Marius RAISCHI, PhDStud. National Institute for Research and Development in Environmental Protection Bucharest &"Dunărea de Jos" University of Galati, Romania

Abstract: *The necessity for navigation conditions improvement on the Lower Danube lead to the construction of a submerged bottom sill on the Bala branch. This paper presents differences that occurred between riverbed bathymetry and water current velocity values recorded in measurements campaigns using multibeam and ADCP techniques carried out before and after the bottom sill was built (June 2013 and March 2016). The comparative hydromorphological analysis showed the emergence of erosion areas up to -17.4 m and deposition areas up to 9.5 m. As for the hydrodynamic alterations, above the new built bottom sill, the water current velocity values of over 3.0 m/s were recorded.*

Key words: *bathymetry, water current velocity, multibeam, ADCP*

1. Introduction

With a length of 2783 km, of which 2414 km are navigable, the Danube is the second longest river in Europe. The Danube is of particular importance for Romania, the country covering about one third of the basin surface and of the total watercourse length (*ICPDR, 2009*).The segment between Calarasi and Braila (km 375 – km 175) connects the Danube River to the navigation channel Danube - Black Sea and the maritime Danube. Taking into account the recommendations of the Danube Commission on the above-mentioned sector, hydro-technical works have been carried out to ensure the optimal conditions for navigation on the Old Danube - the Danube main branch. Thus, in order to improve the navigation conditions on the Lower Old Danube, in the Bala Branch – Old Danube bifurcation area, a bottom sill, a guiding wall and a bank protection were constructed to redistribute the flows between the two branches (INCDPM, 2011-present).

The assessment for the variation of hydrodynamic parameters in the context of anthropogenic intervention (INCDPM, 2015) is needed in order to determine the hydrological and/or morphological pressures on the structural characteristics of the water body and on the existing habitats, especially for the sturgeon populations (INCDPM, 2016).

Data processing involving spatial information on hydrodynamic and hydromorphological parameters require the use of Geographic Information Systems (GIS) technique (INCDPM, 2017).

2. Material and method

The datasets used in the comparative analysis presented in this paper resulted from two in situ measurement campaigns conducted in the pre-construction (June 2013) and post-construction (March 2016) phases on the Danube Bala branch using the Acoustic Doppler Current Profilers (ADCP) technique.

In this paper, there are used longitudinal transects recorded on the same track in both measurement campaigns, as shown in Fig.1.

Fig. 1. Longitudinal control sections location on Danube Bala branch

The ADCP mounted on a moving boat is one of the most widely-used tools for measuring streamflow with a history of use of over 30 years for its capabilities to measure water current velocity and to compute discharge values (Christensen and Herrick, 1982; Simpson and Oltmann, 1993) on a spatial and temporary scale unattainable before.

Being used in a moving boat-mounted system, the recorded water velocity values are relative to the boat, so the ADCP uses bottom tracking or a global positioning system (GPS) in order to account for the velocity of the boat. Thus, the technique is also used for determining the transect bathymetry and therefore, the discharge value can be accurately computed using velocity and section data.

In the measurement campaigns on the Bala branch, there has been used the ADCP SonTek RiverSurveyor M9 (SonTek, 2013) that has four 3-MHz and four 1-MHz profiling beams angled at 25 degrees, and one 500-kHz vertical beam that measures depth only and an auto-adaptive configuration algorithm that supports use of multiple frequencies, variable depth-cell sizes, and pulse-coherent, broadband, and incoherent ping configuration and processing techniques.

Using the GGA string from the GPS, essential fix data which provide 3D location and accuracy data [NMEA, 2008], the recorded bathymetry data was used for the comparative analysis of riverbed bathymetry from June 2013 and March 2016.

Multibeam bathymetry is based on the fact that more beams are better than one. They map the riverbed by generating several hundred beams over a crosstrack profile for each ping, and each beam generates at least one depth sounding. While the survey platform sails forward the river bed is covered with a dense pattern of soundings producing high-resolution bathymetry data and georeferenced high resolution seabed imagery throughout the survey area and thus providing 100% coverage of the riverbed.

3. RESULTS

Comparative analysis has been carried out on the hydromorphological and hydrodynamic conditions along the longitudinal control sections for the 2013 (pre-construction period) and 2016 (post-construction phase) recorded data sets for riverbed bathymetry and water current velocity.

In order to highlight the morphological changes that took place in the area of the new built bottom sill on the Bala branch, using multi-beam bathymetric measurements, in Fig.2 is represented the riverbed bathymetry from June 2013 vs. March 2016.

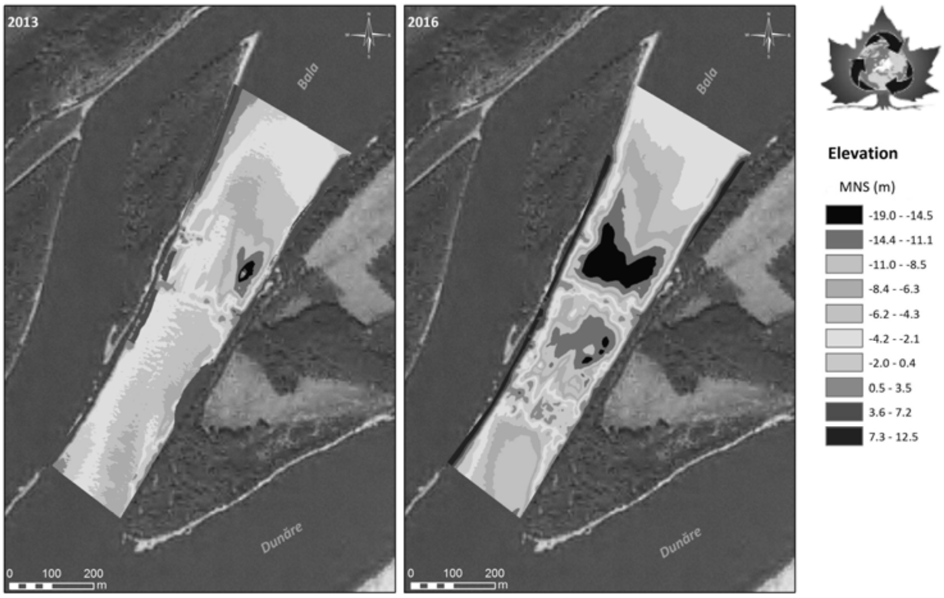

Fig. 2. Riverbed bathymetry – Bala branch – pre and post - construction period

In order to obtain a clearer picture of the comparison results for the riverbed geometry before and after the construction of the new bottom sill, these representations were overlapped, with the resulting differences presented in Fig.3.

Fig. 3. Changes in riverbed bathymetry 2013 vs 2016

As can be seen in Fig.3, erosion up to -9.2 m is evident in the upstream area of the new bottom sill, value recorded towards the right riverbank. In Fig.3, the new bottom sill appears as a deposition area of up to 9.5 m. The sector between the two bottom sills is characterized by erosion areas of up to -10.5 m.

Erosions also resulted in the area of the old bottom sill, the values being around -5.4 m. Immediately downstream of the old bottom sill can be noted, towards the left bank, an area with erosions up to -17.4 m. The fact that before the hydraulic works began in June 2013, downstream of the old bottom, there was an erosion pit at the right bank, it can be said that at the level of 2016 it has deepened and extended to the right bank.

SLCB1 longitudinal control section

Figure 4 shows the 2013 vs 2016 riverbed geometry resulted from the bathymetry measurements on the SLCB1 longitudinal section, located along the right riverbank.

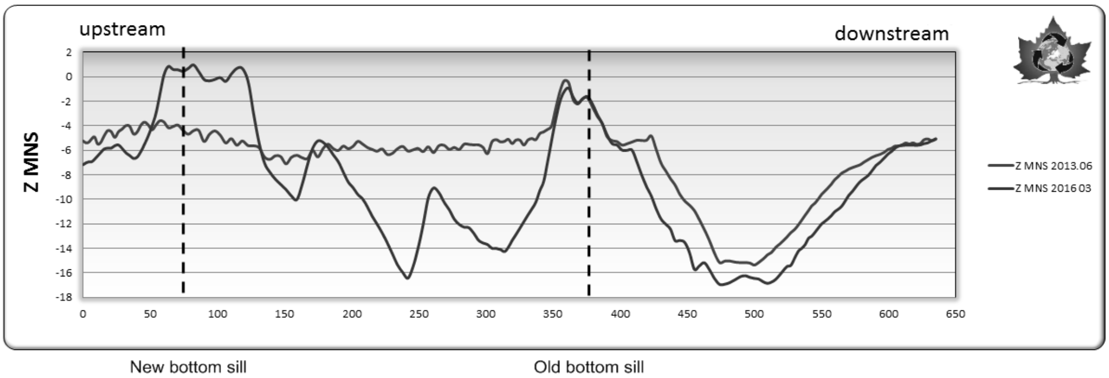

Fig. 4. Riverbed bathymetry SLCB1– June 2013 vs March 2016

On this section we can see that, in 2016, erosion zones were formed upstream and downstream of the new bottom sill. Also, the scour hole formed downstream of the old bottom sill, has widened compared to the period before the start of hydrotechnical works.

As for the water current velocity distribution on the SLCB1 longitudinal section (Fig.5) in the pre-construction phase, peak values of approx. 2.0 m/s were recorded above the old bottom sill.

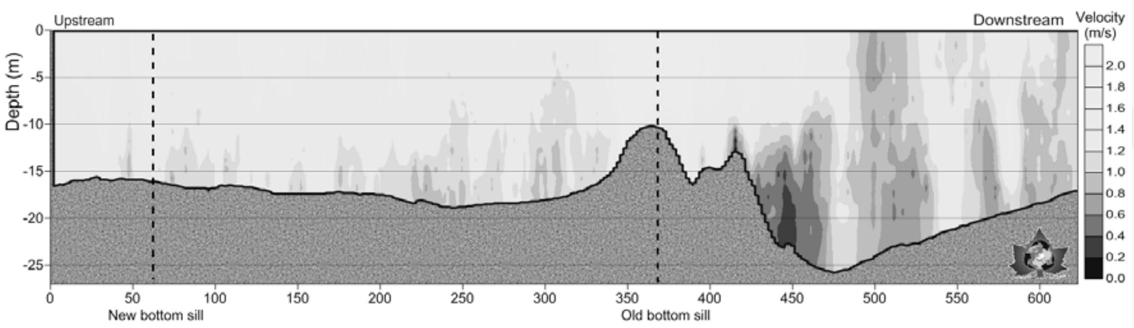

Fig. 5. Water current velocity distribution – pre-construction phase 2013- SLCB1

Fiure. 6 shows the distribution of water current velocity in the post-construction phase with maximum values of over 3 m/s above the new bottom sill.

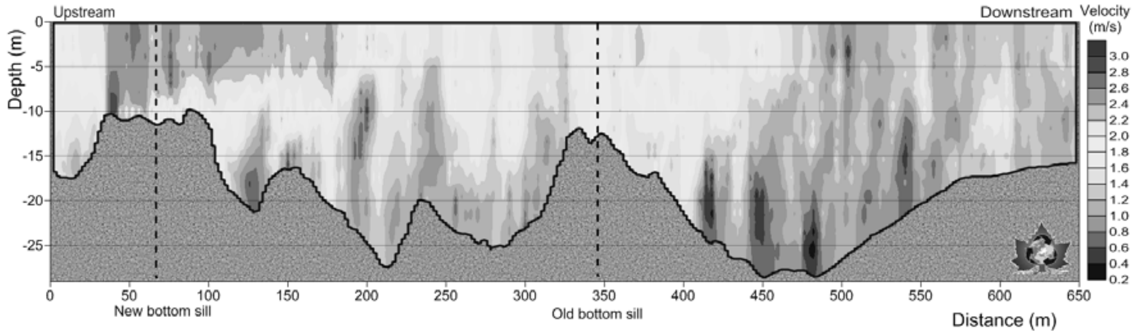

Fig. 6. Water current velocity distribution – post-construction phase 2016- SLCB1

In order to further the comparative analysis, using the results obtained from the field measurements carried out at comparable discharge values, velocity frequency histograms were represented (Fig. 7 - 8) for the bottom and top 1m water layers.

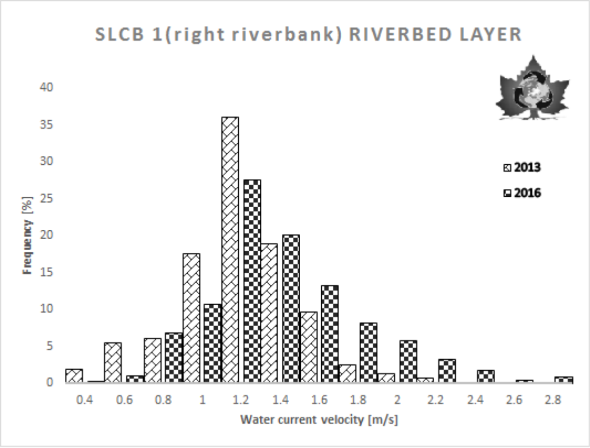

Fig. 7. Water current velocity frequency distribution – SLCB1 - June 2013

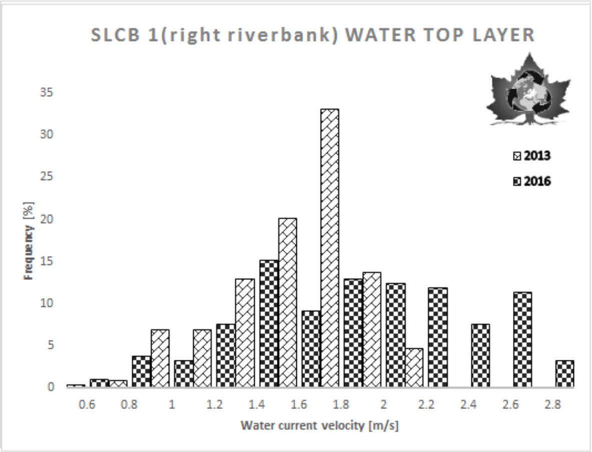

Fig. 8. Water current velocity frequency distribution – SLCB1 - March 2016

For SLCB 1 control section, it can be noted that for both the riverbed layer and the water top layer, the histogram shape differs between the two periods. Thus, for 2016 the recorded velocity range increased from maximum values of 2.2 m/s for 2013 to water current velocity values of 2.8 m/s for both considered layers.

SLCB2 longitudinal control section

The SLCB2 control section is located at the center of the Bala arm (Fig.1). According to Fig.9, it can be noticed that a scour hole was formed immediately downstream of the new bottom sill. At the same time, upstream of the new hydraulic construction, it can be noted one erosion area of up to 5 m. Downstream of the old bottom sill, the scour hole that was located in the pre-construction phase near the right bank has expanded until 2016.

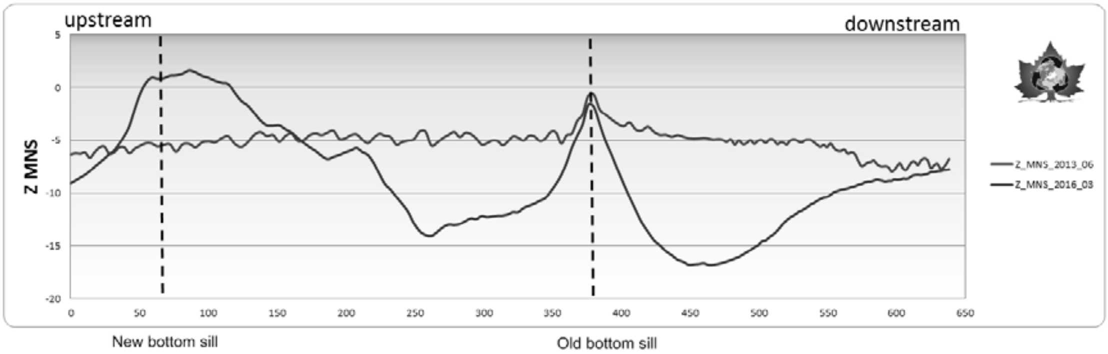

Fig. 9. Riverbed bathymetry SLCB2– June 2013 vs March 2016

As for the distribution of the water current velocity, as in the case SLCB1 control section, it is worth mentioning that during the pre-construction period the maximum values were approx. 2.0 m/s, the maximum being recorded at the old bottom sill (Fig.10).

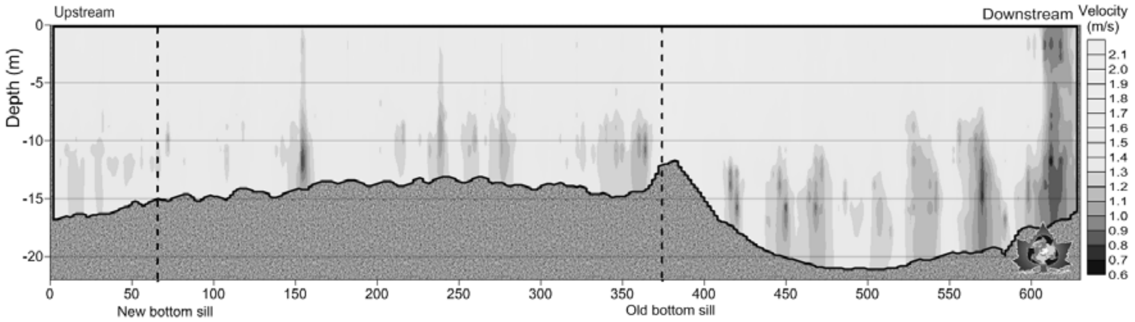

Fig. 10. Water current velocity distribution – pre-construction phase 2013 - SLCB2

In the post-construction period, as a result of flow section reduction, the maximum values of the water current velocity values are about 3.2 m/s (Fig.11).

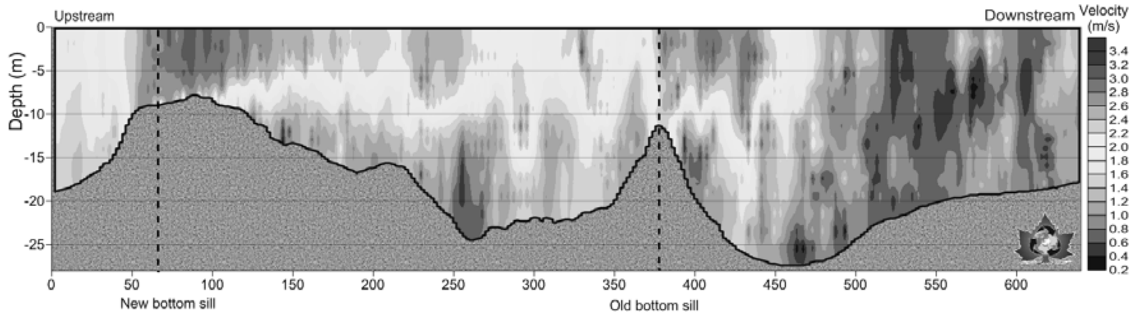

Fig. 11. Water current velocity distribution – post-construction phase 2016- SLCB2

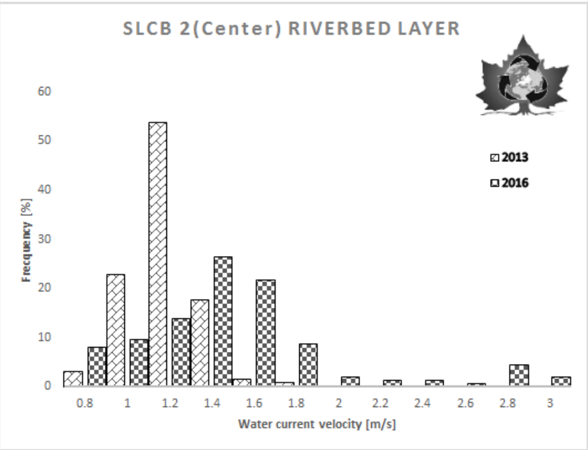

Fig. 12. Water current velocity frequency distribution- SLCB2 - June 2013

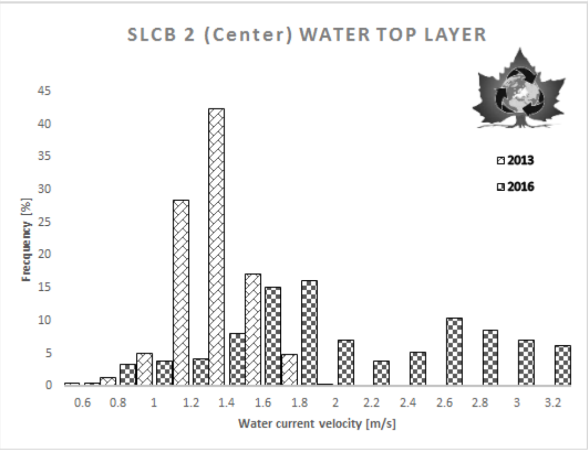

Fig. 13 Water current velocity frequency distribution- SLCB2 - March 2016

As can be seen in Fig.12 - 13 for SLCB 2 control section, in 2016 the maximum velocity values range from 3-3.2 m/s, compared to the 2013 maximum values of around 2 m/s. The highest frequency velocity values are about 1.2 m/s (riverbed layer - 2013), 1.4 m/s (riverbed layer - 2016 and water top layer - 2013) and 1.8 m/s respectively (water top layer - 2016).

SLCB3 longitudinal control section

In the case of the ***longitudinal SLCB3 control section*** located near the left bank of the Bala branch (Fig.1), from the point of view of the riverbed geometry, it can be observed that in 2016, similar to the analysis shown for SLCB2, a new scour hole was formed by the new bottom sill, and downstream of the old bottom sill is visible the scour hole that extended from the right bank (see Fig.14).

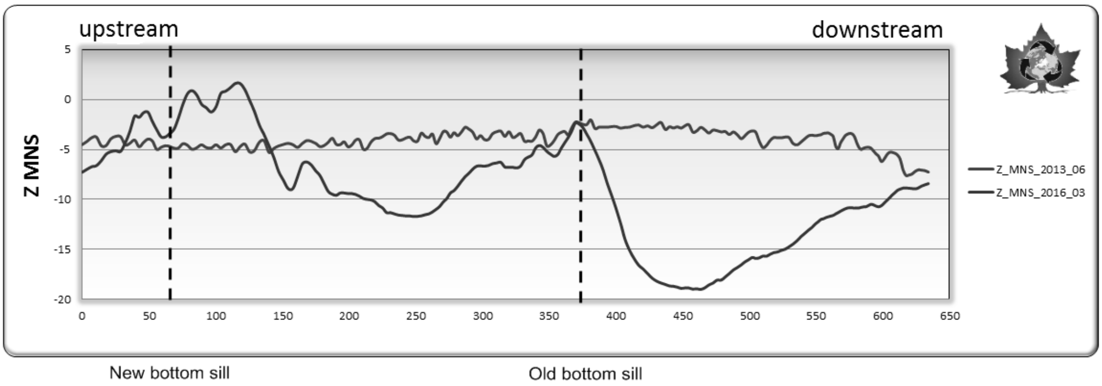

Fig. 14. Riverbed bathymetry SLCB3– June 2013 vs March 2016

Unlike the other two sections, in the longitudinal section near the left bank, during the pre-construction period, higher water current velocities were recorded, the maximum values being about 2.5 m/s (Fig.15).

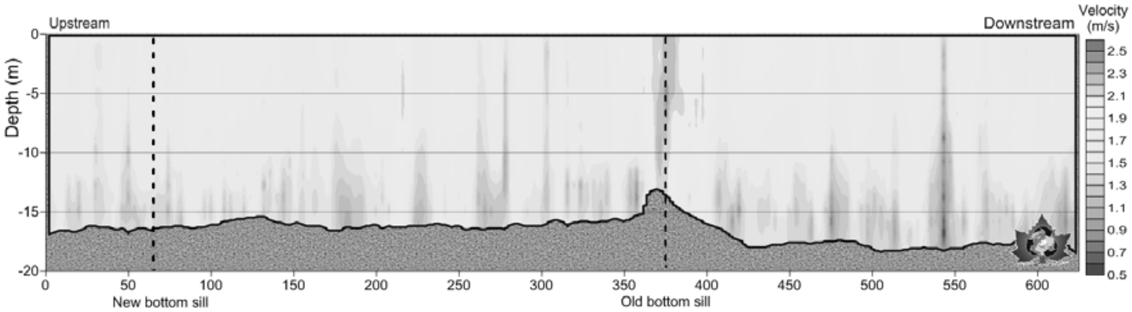

Fig. 15. Water current velocity distribution – pre-construction phase 2013- SLCB3

In the post-construction period, there were recorded maximum values of the water current velocities of approx. 3.2 m/s, above the new bottom sill (Fig.16).

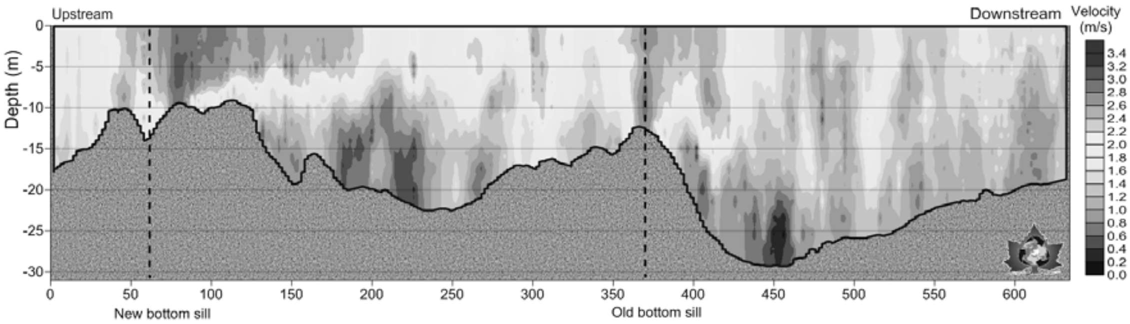

Fig. 16. Water current velocity distribution – post-construction phase 2016- SLCB3

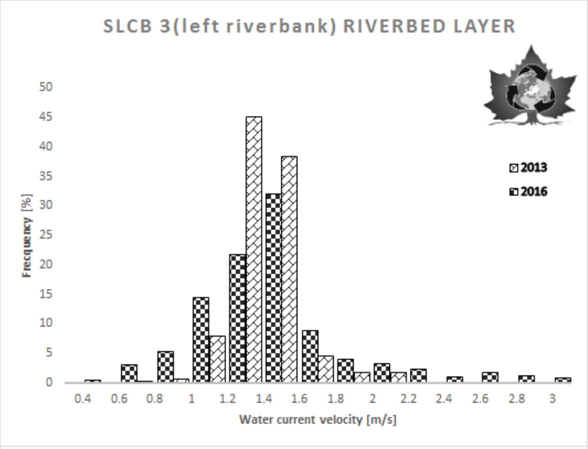

Fig. 17. Water current velocity frequency distribution - SLCB3 - June 2013

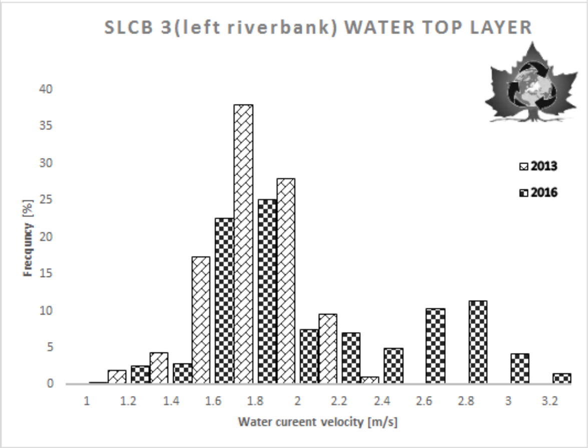

Fig. 18. Water current velocity frequency distribution - SLCB3 - March 2016

For SLCB 3 longitudinal control section, as shown in Fig. 17 - 18, in 2013 the maximum recorded velocity values were around 2.2 m/s (riverbed layer) and 2.4 m/s respectively (the water top level), and for 2016 these values increased to approx. 3 m/s (riverbed layer) and approx. 3.2 m/s (the water top level).

For the riverbed layer, the highest frequency for the water current velocity was recorded for the 1.4 m/s values for both 2013 and 2016. The same trend is also observed for the water top layer with values around 1.8 m/s presenting the topmost frequency.

4. Conclusions

As the presented results from two measurements campaigns in June 2013 and March 2016 shown, the construction of the Bala new bottom sill led to a series of morphological and hydrodynamic changes.

The riverbed bathymetry changed immediately downstream the new bottom sill, forming a new scour hole. Also, upstream of the new hydraulic construction an area with erosions up to -9.2 m was formed towards the right riverbank and downstream of the old bottom sill can be noted, towards the left bank, an area with erosions up to - 17.4 m.

As can be seen in the previous representations, compared to the pre-construction phase, the scour hole downstream of the old bottom sill has expanded. By implementing the new construction the flow section has decreased, so the water current velocity values have increased significantly compared to those recorded during the pre-construction period.

5.Acknowledgement

The results presented in this paper were obtained thanks to the research conducted by INCDPM in the development of the project entitled: 'Monitoring the environmental impact of works regarding the improving of the navigation conditions on the Danube River between Calarasi and Braila, km 375–175' financed by national and European funds (2011 – present).

5. References

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