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A REVIEW OF BATHYMETRIC MEASUREMENTS FROM THE AUGUST 2018 CAMPAIGN ON THE LOWER COURSE OF THE DANUBE

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Abstract
The presented paper shows a combination of different methods and techniques for high precision depth measurements. The results show the procedures for collecting field data from the bathymetric measurement campaign of August 2018, developed along the lower course of the Danube. Measurements were made over a total distance of 20 km. The main purpose of the measurements is to create bathymetric maps and to generate depth maps. To achieve the main purpose of this research paper, single beam bathymetric measurements were made, and they were combined with GPS RTK mode determination, in local Stereo 70 coordinate system. Repeated measurements in different quarters of the year will determine the morphometric changes in time of the riverbed on this study area. Furthermore, based on the bathymetric maps, in the future, a coherent river terrain model can be created, and it can be used for other purposes, like 1D/2D or 3D hydrodynamic modeling and flood inundation mapping.

Keywords: bathymetric maps, water depth measurements, riverbed 3D model, flood mapping

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1. INTRODUCTION

Nowadays, the details of the bottom of a river or its detailed cartography play an important role in carrying out scientific research in the field of hydrology and hydrodynamics. In order to carry out the detailed mapping of the bottom of a river, it is necessary to make bathymetric measurements. Bathymetry is a hypsometry or topography branch, which deals with water depth measurement in seas, lakes, rivers, etc.

Bathymetric maps are made using depth measurements and they show the exact shape and elevation characteristic of the ground below the water level. Different methods and equipment are used to measure depths below water. Initially, the bathymetric measurements were made by a rudimentary method, by which the depth was measured with a strand thrown into the water, at the end of which a counterweight was attached [1]. By measuring the length of the rope, in various points, the real depth at that point was determined. This type of measurement was useful, but being made manually it is of very low accuracy, it involves a high cost of work and a very long time for the procedure.

As time went on, the progress of technologies was conducted to another type of bathymetric measurements which is now made with modern instruments that have a very high measurement accuracy. Modern bathymetric measurements are performed with the help of a single beam echosounder (SBES) or multibeam echosounder (MBES). The principle of the method is to determine the time at which the ultrasonic signal travels the distance from the transmitter to the bottom of the water and back to the receiver. Knowing the velocity of the ultrasound propagation in water, you can determine the depth of water. The depth value depends directly on the emission-reception time of the pulse.

Using this type of water depth measurements (SBES or MBES), what is dependent on the purpose of the project and the necessary accuracy, many interesting discoveries have been made over time. At ocean and sea levels submarines or sunken ships were discovered [3]. At the level of the rivers, with MBES type of measurements, we can determine different types of underwater shapes where different type of habitats exist [4, 5].

Other uses in river case are to determine the movement of the riverbed and the morphological differences during the time [6]. Another application of water depth measurement is the creation of 3D models of underwater terrain. The 3D model of the minor riverbed is essential for achieving hydrodynamic modeling and determination the risk areas that can be flooded [7].

The main purpose of this paper is to present a comparative analysis of the bathymetric measurements on the lower Danube section.

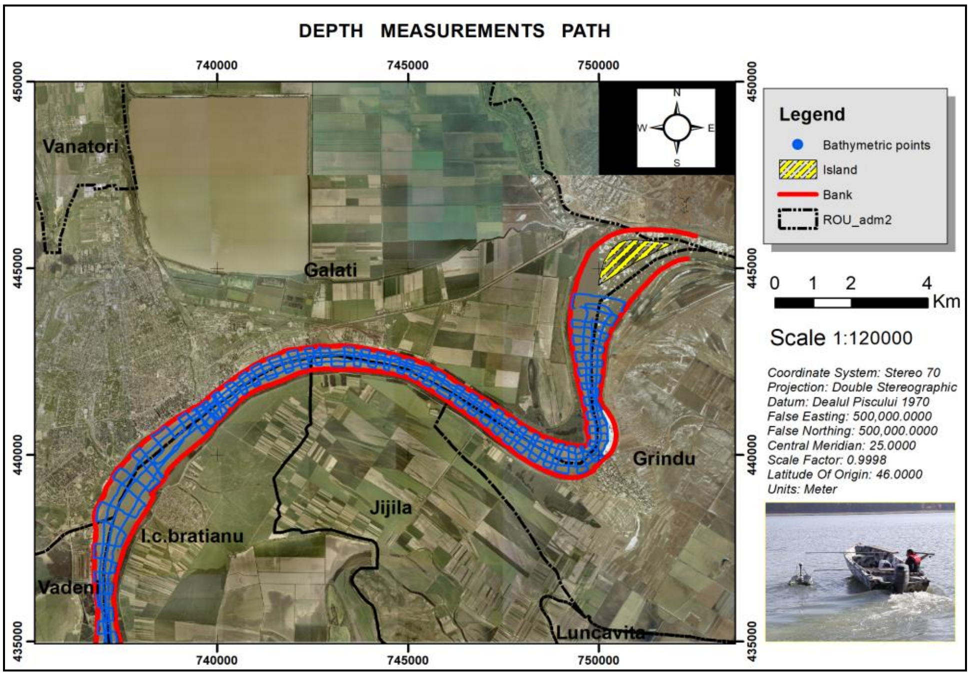

Fig. 1. Study area map and path of bathymetric measurements

During the August 2018 measurements campaign, different data related to the depth of water, its velocity rate in various cross-sections of the river, the water temperature at the time of the measurements (to apply the measurement corrections) and the flow rate in these sections, was recorded. Based on all these values and on the upcoming campaigns the spatiotemporal changes of the riverbed morphology as well as the observation of the change of the flow rate and velocity of water that depending on the water level will be analysed. It is also worth mentioning that these determinations are very important to be transposed into a validated bathymetric model, and together with the land surveying and photogrammetric measurements, they can be the basis of different hydrodynamic simulations intended to obtain flood risk and hazard map in the study area.

The study area is located on the Lower Danube River between Km 159 and Km 135 (Fig. 1).

This is an important area for monitoring the riverbed morphology, because this section of river has deep erosion processes at a large scale, influenced by the river course sinuosity and the Siret River that has an important flow rate addition to the Danube River with different type of sediments.

2. MATERIALS AND METHODS

The depth measurement was carried out with a 9-beam Sontek Hydrosurveyor M9 acoustic profiler. This type of system is designed to collect bathymetric, water column velocity profile, and acoustic bottom tracking data as part of a hydrographic survey. The total discharge through a measurement section is computed based on the average water velocity in the water column and the cross-sectional area. For the purposes of a measurement, the section is broken into three key components: the Start Edge, the Transect and the End Edge. These components are summed together to calculate the total discharge as shown in figure 2-a.

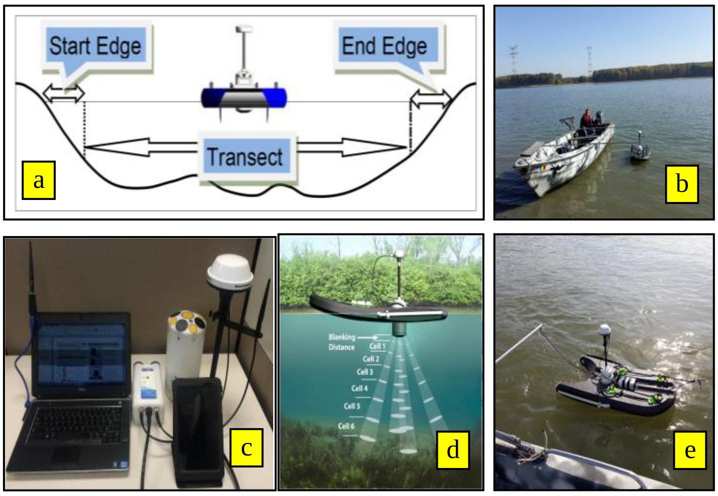

Fig. 2. Used methods and materials:

a) Cross section total discharge computing

b) Mounting method of Hydroboat II on a fiberglass boat

c) Sontek Hydrosurveyor M9 equipment with GPS system

d) 9 beam (cell) acoustic measurements

e) Hydroboard II with mounted Sontek Hydrosurveyor M9

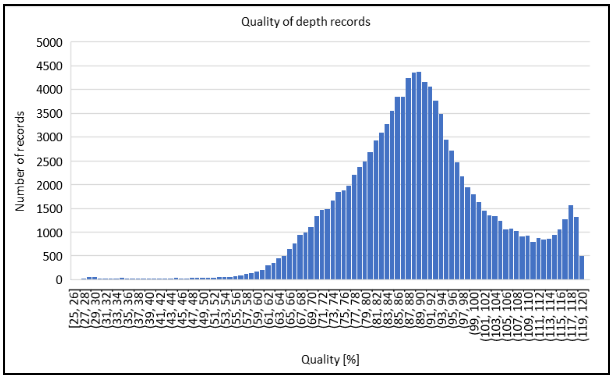

Fig. 3. Depth records quality histogram

3. RESULTS AND DISCUSSION

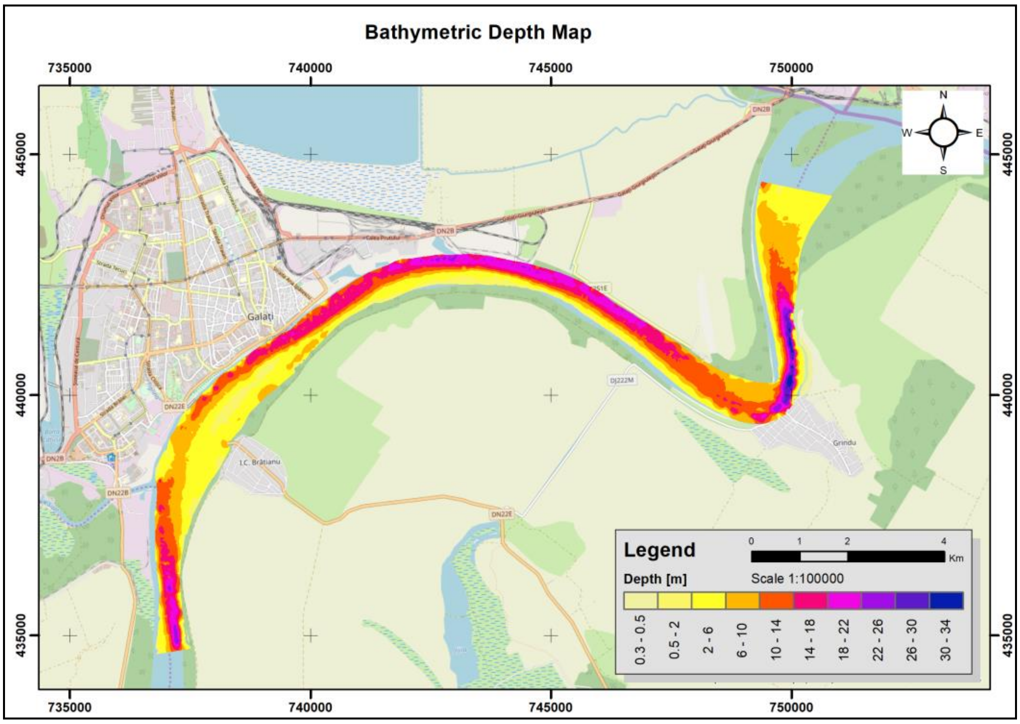

Fig. 4. Bathymetric depth map

To generate a continuous area of the bottom of the measured section the cell values in areas where data do not exist were interpolated by the Topo to Raster method.The analysis of quality of record conducted to the generation of a bathymetric depth maps using approx. 150000 records (Fig. 3). The maximum depth records were 34 m, and the minimum 0.3 m (Fig. 4).

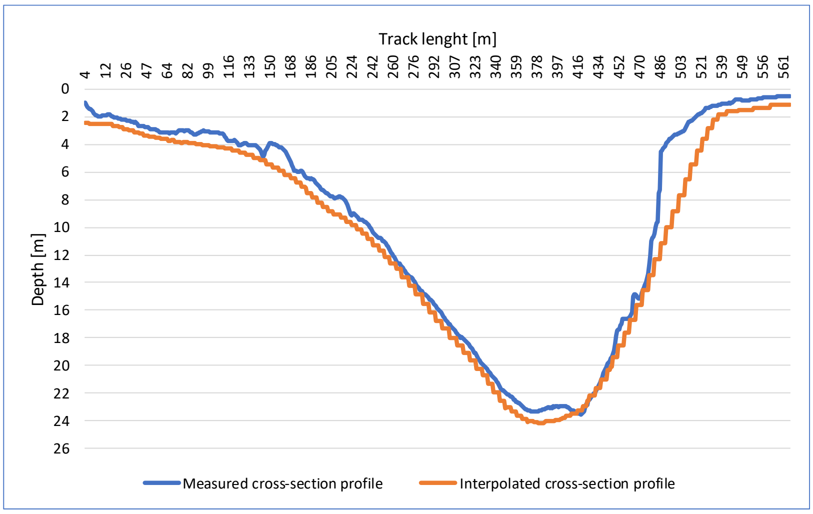

Fig. 5. Measured vs Interpolated cross-section profile

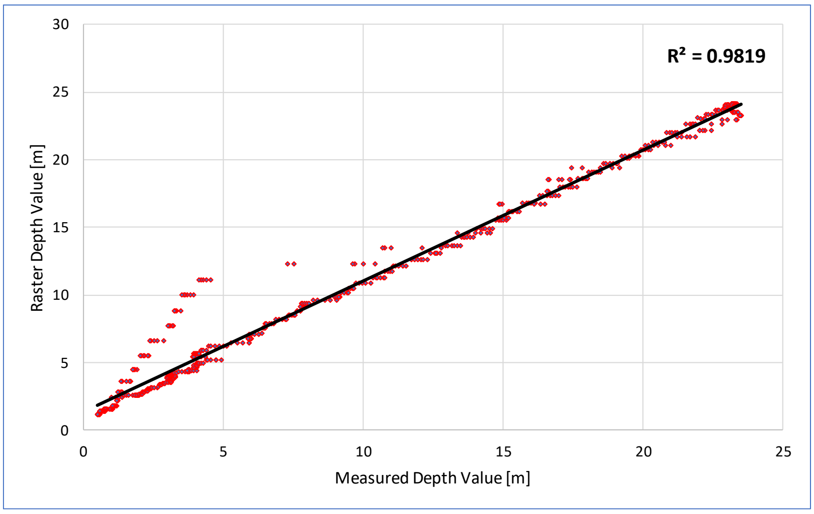

Fig. 6. Linear regression representation and coefficient of determination between measured and raster value depth

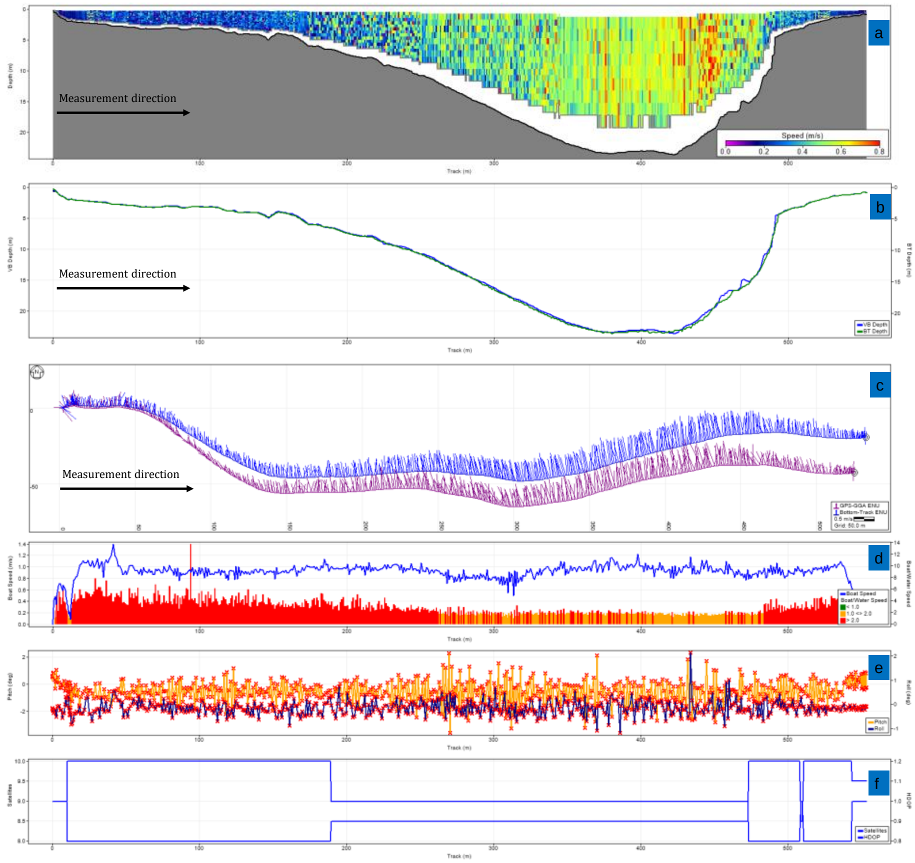

Fig. 7. Figure 5. Left – Right cross section measurements

a) *Mean water velocity - V_{water} = 0.441 m/s; Area - S = 5636.4 m^2; Discharge flow - Q_{total}=2487 m^3/s*
b) *Track distance = 565.70 m*
c) *Difference between GPS data and bottom tracking*
d) *Comparison between boat speed (mean value = 0.767 m/s) and water velocity (mean value = 0.441 m/s)*
e) *The oscillation of pitch and roll values*
f) *Number of satellites and horizontal dilution of precision*

Figure 4 represents a bathymetric map. It is a representation of the ground below the water level or the equivalent of the topography of the riverbed bed terrain. The digital terrain model (DTM) is a widely used product and provides a three-dimensional representation (X, Y, Z) of the studied terrain areas. In this research paper, the term DTM can be defined as "a regular matrix representation of continuous variations of space relief units" [8].

Following the collection of topo-bathymetric data and validation from the precision and quality point of view, a digital model was generated using the Topo to Raster interpolation method, with the help of the 3D Analyst Tools extension of ArcGIS geographic information program. The Topo to Raster method is a very accurate interpolation method, specifically designed to generate digital terrain models for hydrological analysis of the studied field [9]. This method is based on the ANUDEM program developed by Hutchinson (1988, 1989, 1996, 2000, 2011).

Compared to other interpolation methods like IDW, RBF or Kriging as it is described by Arseni et al. (2017), the Topo to Raster interpolation method has a much smoother and flatter graphic representation, with lower sinuosity elements.

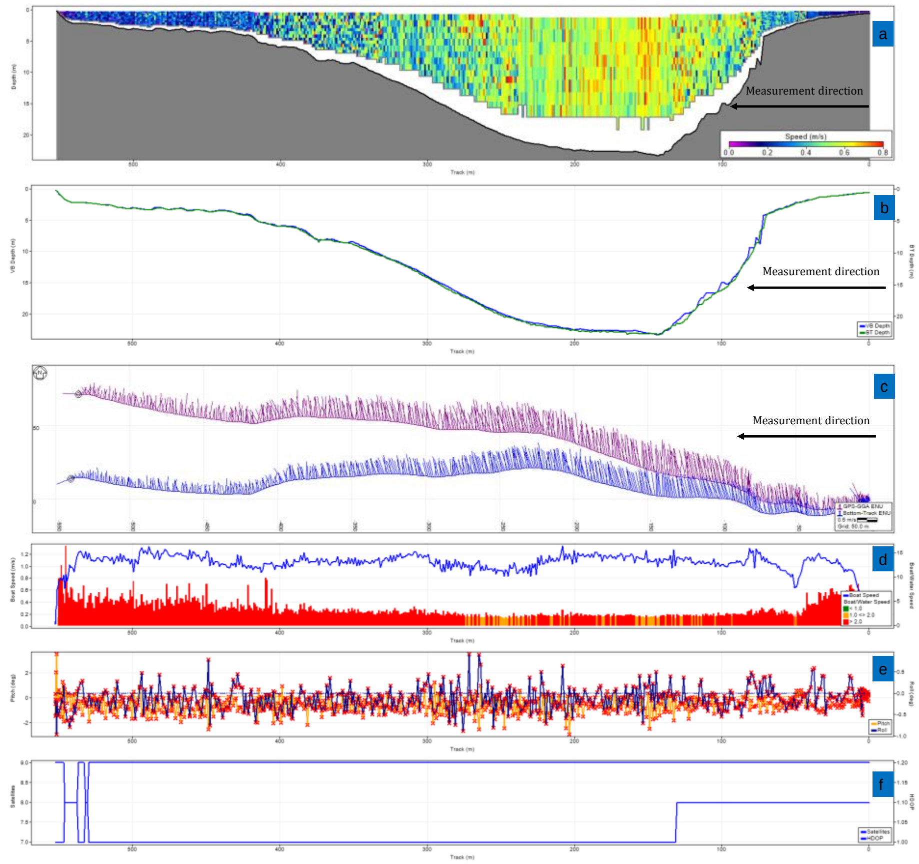

Fig. 8. Right – Left cross section measurements

a) Mean water velocity - V_{water} = 0.440 m/s; Area - S = 5779.7 m^2; Discharge flow - Q_{total}=2541 m^3/s
b) Track distance = 553.44 m
c) Difference between GPS data and bottom tracking
d) Comparison between boat speed (mean value = 0.953 m/s) and water velocity (mean value = 0.440 m/s)
e) The oscillation of pitch and roll values
f) Number of satellites and horizontal dilution of precision

The measured cross-section has a total distance of 561 m (Fig. 5). Figure 6 represents the differences between the Sontek M9 measured cross-section profile and the interpolated cross-section profile obtained by bathymetric measurements with the HydroSurveyor program. If we analyze statistically the value obtained by bathymetric determination and the values extracted from raster obtained by Topo to Raster interpolation it can be observed that the coefficient of determination tends to close to 1 (Fig. 6).

To determine the discharge on this section of Danube river, a cross-section was measured in two ways: from the left to the right bank (Fig. 8), and backward (Fig. 9). The total discharge value is important for another type of simulation, such as the validation of hydrodynamic models, in order to obtain the extent of the flooded area.

4. CONCLUSIONS

The depth measurement and total discharge depend on used instruments and its precision. The site selection is a critical part of a discharge measurement and is fundamental to its success. It needs to avoid possible obstructions and sites immediately downstream of bridges, gates, and weirs. Flow should be uniform with minimal turbulence. During the edge measurements, the vessel must be kept as stationary as possible. During the transect, the vessel speed and direction must be maintained constant, to obtain the same discharge flow from the left or right side. Ideally, any vessel movement should be slow relative to the water velocity, and changes in heading should be gradual and only when necessary.

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