GEODETIC WORKS IN THE RENOVATION OF THE RIVER MURA IN CROATIA

Mladen Zrinjski [1]
Đuro Barković [2]
Željko Kontak [3]

UDK: 528.74 : 627.4
DOI:10.14415/konferencijaGFS 2016.067

Summary: *In order to renovate the existing coastal fortification of the right river bank of the river Mura in the place Miklavec in Croatia, the surveying has been performed to provide the basis for the renovation project. The importance of geodesy in designing and construction of hydrotechnical objects is highlighted. The applied surveying methods and adequate instruments are described. The geodetic layout of the surveyed area is presented with the overlap in digital orthophoto and transversal profiles.*

Keywords: *Renovation project, geodetic layout, digital orthophoto, transversal profile, the river Mura*

1. INTRODUCTION

Rivers have always been in the focus of human activities. The importance of these activities is reflected in the benefits provided by rivers and in the necessity to protect the areas from floods and erosion. The imperative of environmental protection provides additional significance because the rivers contain a medium (water) that can transfer and spread the pollution very quickly in large areas. The preservation of natural beauty of the rivers is equally important. All these issues are related to the engineering tasks that can help in solving the problems [1].
Geodesy has an important role in solving the engineering tasks. It is indispensable in designing procedures, construction and usage of any structure. It is therefore necessary to be familiar with the accuracy that can be achieved by means of geodetic measurements. Such information combined with the knowledge about the possibilities of geodetic instruments and measuring methods may help a surveyor to complete the project successfully in the most efficient way and in the shortest possible time [2].
This paper describes geodetic measurement needed for the preparation of the documents related to the reconstruction of the existing revetment placed on the right bank of the

[1] Assist. Prof. Dr. Mladen Zrinjski, Faculty of Geodesy, University of Zagreb, Kačićeva 26, HR-10000 Zagreb, Croatia, tel: ++385 1 4639 337, e – mail: mladen.zrinjski@geof.hr
[2] Prof. Dr. Đuro Barković, Faculty of Geodesy, University of Zagreb, Kačićeva 26, HR-10000 Zagreb, Croatia, tel: ++385 1 4639 226, e – mail: djuro.barkovic@geof.hr
[3] Željko Kontak, Faculty of Geodesy, University of Zagreb, Kačićeva 26, HR-10000 Zagreb, Croatia, e – mail: zkontak@geof.hr.

river Mura (chainage rkm 58) in the settlement Miklavec in Međimurska County in Croatia.

2. THE RIVER MURA

Mura rises in Austria in Hohe Tauern and keeps running through Slovenia, Hungary and Croatia. Its distance is 465 km, and its 14 304 km^2 large basin joins the Danube river basin through the river Drava. With its lower course being about 100 km long, it makes a state border (35 km of Austrian-Slovenian border, 20 km of Croatian-Slovenian border, 45 km of Croatian-Hungarian border). It rises from several sources with Mururspprung being the most important with the outflow of 100 l/s, and it is located at the altitude of 1898 m. Receiving a few smaller sources, the stream turns into a headstream near the settlement St. Michel. The river Mura is a typical river of the Carpathian basin. It can change its bed very quickly, it is running in its alluvium and in the last two and a half centuries, it had several regulation periods [3].

3. REGULATION OF THE RIVER MURA

The regulation of Mura can be divided in three large periods. The first period includes the 16th and 17th centuries characterized by the influences protecting local interest. The maintenance works of that time were related only to the riverbed, but did not provide the flood protection for the settlements. Their efficiency was disputable, because only a smaller segment was „brought in order“, and the next flood swept away, knocked down or ran around the objects built for the purpose of the riverbed stabilization [3].
In the second period (at the time of Austro-Hungarian Monarchy), more coordinated works of larger extent were performed for the purpose of providing the sailing. In that period, the efforts were made to regulate the river with ditches and by means of building the flood embankments, but those interventions were not coordinated among each other. A preliminary design of the river Mura regulation was made, but the projects were never completed. In the process of digging the ditches, artificial channels of smaller size were built leaving the river to form its final bed profile. The cut meander was later managed as a backwater. Since the ownership structure of individual ditches changed, the technical works were always preceded by a long-lasting procedure of the agreement with the owners [3].
Today, the regulation of the river Mura is mostly intended for the flood protection. The system of flood prevention consists of the main embankment of the river Mura, the embankment Podturen and the embankment Sv. Martin. Upstream from Podturen to Čestijanec, the right bank of Mura is mostly high (apart from the area near Sv. Martin), and it is not necessary to protect the overall area from high waters. Before the construction of the flood prevention system for the river Mura, the river overflows already in the area of Novakovec and Podturen, submerging the lower land and flooding the fertile area as far as Kotoriba. Very often, the water from the river Mura flowed to the channel Bistrec – Rakovnica, and then further to Drava. The flood prevention in the area along the river Mura at the segment upstream to Podturen has been solved by

building the embankment. The embankment has reduced the flood area of 11 500 ha to 3800 ha (the area between Mura and the embankment). Apart from the main embankments, there were also the retarding embankments built along the tributaries with Trnava being the most significant one (left and right retarding 3.3 km long embankments were built). The system for flood prevention includes also the hydrotechnical interventions in the stream basins, as well as the elements of this system like retarding basins and channels [4].

4. STRUCTURES FOR RIVER REGULATION

The regulations of water courses include a set of constructions and measures applied to change the natural properties of a flowing water body and its basin for the purpose of: more rational water usage, more efficient protection from harmful effect of the water from streams and more efficient protection of water bodies from pollution. Depending on the regulation purpose, it is necessary to influence the change of natural properties of streams to a greater or lesser extent which defines the engineering tasks. However, one should be very careful in that matter bearing in mind that the watercourses are a part of nature guided by its own regularities. The success in solving the mentioned engineering tasks is related to the degree of understanding the nature of watercourses. Violent solutions lead to aggressive response, result in irrational and expensive solutions [1].
The structures intended for the regulation of watercourses are very expensive. It results from a large volume of works and from specific conditions of their performance. Therefore, cheaper technical solutions need to be found, i.e. in two directions. Firstly, natural materials are to be used that can be found nearby, and secondly, the abilities of a watercourse to build its own bed need to be used. It means that the watercourse will be directed with smaller interventions in order to erode a part of its bed that needs to be deepened (or enlarged), i.e. the course will be slowed down at the places where we want the bed to be filled up with the silting of the watercourse itself.
The regulation structures are very simple from the construction point of view, however, the selection of the type, their arrangement and formation belong to the group of more complex engineering challenges. The regulation structures should be understood not as independent objects but as a part of a watercourse that will acquire new properties in the system with regard to the new conditions. The water will flow in a different way, the silting will move differently, and the streambed will acquire a different shape. All this should be taken into consideration and these changes predicted with adequate calculations in order to make the final performance as it should be.
The regulations structures should be used to influence the undesired situations in the bed, and not the elimination of the consequences of such situations. The selection of the type of regulations structure that is to be used in some intervention depends primarily on the purpose of regulation.
The basic purposes of regulations are to increase the bed erosion and its deepening, to provide the transfer of silting without any obstacles (regular transfer of silting), to reduce the erosion and to encourage the subsidence at certain places, to increase the flow of the riverbed and to combine all previously mentioned measures.
The main regulation structures are the following [1]:

- deposits (stone deposits)
- revetments
- true parallel structures
- groynes
- partition walls
- ditches
- channels
- embankments.

5. PERFORMED GEODETIC AND CONSTRUCTION WORKS

The following surveying methods were used to prepare the improvement project:

- polar method (tacheometry)
- CROPOS (CROatian POsition System)
- acoustic depth measurement techniques
- trigonometric determination of height differences.

There are geodetic and construction works described further needed for the construction of revetments in Miklavec in Međimurska County in Croatia.

At the request of the investor "Hrvatske vode", there were 5 transversal profiles measured on the right bank of the river Mura, chainage rkm 58+000, near the settlement Miklavec. The bank of the existing reconstructed revetment was also measured upstream to the sandbank in the distance of about 200 m. The trasnversal profiles were numbered from the last upstream one PROF5 to the end downstream trasnversal profile PROF1 with the distance of about 40 m. The measurements were made with the single frequency echo sounder *Navitronic NS10* used for depth measurement, GNSS RTK receiver used for determining the coordinates using the link to CROPOS in the Croatian State Coordinate System (HDKS), and with the total station *Topcon GPT-7501*. The measurements were made for the purpose of preparing the documents needed for the improvement of the existing revetment in order to prevent the right bank of the river Mura to come closer to the settlement Miklavec due to the erosive activity of the water.

The works on the construction of revetment start with clearing off the construction site. In the process of clearing off the terrain, it is necessary to cut and remove the shrubberies and trees on the bank slope of the river Mura at the place where the revetment is to be built. After clearing off, the terrain is levelled, and after that the geodetic and hydrography survey of the bed profile and the bank is made as an „initial survey“. This geodetic survey („initial survey“) serves for the determination of the initial state of the bank and bed immediately before the construction works. After the „initial survey“, the layout is to be delineated on the designed structure elements, and then the differences should be detected that might appear in the material quantities needed for the construction and might result from the changes occurring in relation to the geometry of the banks and bed at the construction site. A river is a natural watercourse running under the influence of gravitation through the bed eroded and formed by the river itself. It is only natural to expect that the changes in geometry of transversal profiles in the observed area can occur due to the erosive activity of water. Due to its natural course, the river transports the silting along its bed under the influence of its tensile forces. The

river silting is naturally deposited in the bed and moved again under the influence of tensile forces and deposited at other locations. Possible morphological changes in the geometry of the bed and banks of the river Mura require the surveying of the banks and bed immediately prior to the construction of structures.

After the „initial survey“ and the delineation of the designed element on the surveyed transversal profiles, and after analysing the quantities, the staking out of the designed object elements is carried out. The stakeout documents and the staking out of the structure must be done by a person authorized to perform the state survey and real estate cadastre activities (chartered geodetic engineer).

It should be pointed out that the works on the construction of revetment need to be planned for the time of the year when lower water levels of the river Mura are registered in order to prevent the works, instruments and parts of the system to be threatened by the appearance of high water.

In order to build the designed elements of the revetment construction, it is necessary to make the excavation that defines the geometry of the construction foundation planned in the design. The excavation is done with an excavator, and the excavated material is immediately loaded onto the truck. The material is excavated partly from the high angle bank as deep as the ram of the excavator can reach, and partly from the working plateau defined by building the revetment toe. The excavated material is unloaded in the temporary deposit on the riverbank. This material shall be used for filling the parts of transversal profiles with available quantities in order to define the designed shape of the slope in accordance with the design blueprints of transversal profiles. If necessary, the needed material will be brought from the borrow pit.

The stone toe of the revetment made of crushed stone is laid directly onto the prepared ground within the bed of the river Mura. The works on the construction of this part of the revetment can be performed also by means of machines from the floating pontoon or directly from the plateau of the existing embankment, if the works are likely to be carried out from the bank by means of the access ramp on the slope of the future revetment.

The layers of the revetment are made with excavator, partly from the working plateau, i.e. the revetment toe, and partly from the high angle bank, all depending on the technological reaching possibilities of excavator ram. For such works, the machine with larger ram reach should be selected in order to facilitate the performance of the works.

Gravel layer is prepared with the thickness of 30 cm, grain size from 0 to 60 mm. The gravel grain size should not be smaller in order to prevent rinsing through the slope revetment. Gravel is transported by truck and placed into the bank slope with excavator being compressed and shaped to from the designed slope.

The stone is brought by truck to the location and spread with excavator on the bank slope. The stone evenly spread on the revetment slope should be rolled, i.e. arranged and levelled. In the process of manual rearrangement of the lining, manual tools, hammers and tampers are used to compress and arrange the stone as good as possible.

After the geodetic works are completed, the whole area is surveyed and the results delineated on the designed elements.

The survey of the entire area, except the channel, has been made with GNSS RTK receiver *Topcon V*. This instrument uses the link to CROPOS, and the surveying is done my means of the service VPPS (highly precise positioning service). The settlement Miklavec is located in Međimurska County in the 6th zone of Gauss-Krüger projection.

Thus, the parameters of transformation and the coordinate system are defined. The details were encoded in surveying for the purpose of quicker measurement and later data processing.
Polar method was used for channel surveying because there was no CROPOS signal in that area due to the forested terrain. The surveying of the channel was made with the total station *Topcon GPT-7501*. Out of the determined instrument station coordinates and orientation, as well as of measured quantities (angles and distances), the elements needed for the calculation of coordinates of detailed channel points were obtained.
The transversal profiles on the river Mura were measured by means of integrating single frequency echo sounder *Navitronic NS10* and GNSS RTK receiver *Topcon V*.
Before the surveying, it was necessary to mount the instruments onto the boat. After that, the height between the bottom of the echo sounder probe and the bottom of the antenna of the GNSS RTK receiver was recorded in the register of GNSS RTK receiver, and the sensitivity strength and echo sounder contrast were adjusted. The surveying of the riverbed bottom was made with the echo sounder mounted on the boat with the density of measuring points of 1 m to 5 m. The position of the boat and the coordinates of profile points were determined with GNSS RTK receiver *Topcon V*. The system of satellite positioning and the system of ultrasound depth measurement were connected so that the position obtained by means of the satellite positioning method was attributed to the discrete point at which the depth was measured [5].

6. MEASUREMENT DATA PROCESSING AND PRESENTATION OF RESULTS

The programme package AutoCAD Map 3D was used in the graphic data processing. The procedure was started by uploading the coordinates into AutoCAD and connecting them, depending on the sketch made in the field. The data were thematically organised into layers. Depending on the type, the data are attributed to the adequate layers.
As final result of surveying, the geodetic layout of the measured situation was made with the overlap in digital orthophoto at the scale of 1:500 (Figure 3) and with five transversal profiles at the scale of 1:100/100.
Figure 1 shows the transversal profile No. 1, and Figure 2 the transversal profile No. 3.

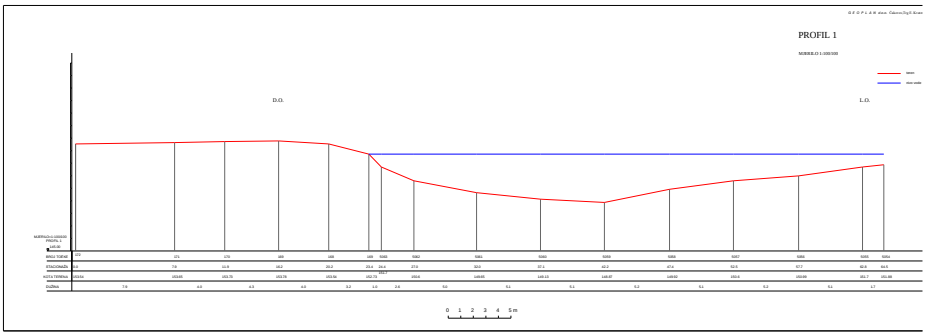

Figure 1. Transversal profile 1

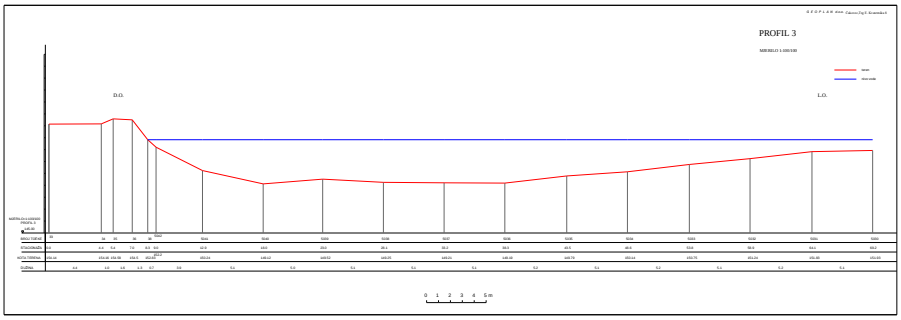

Figure 2. Transversal profile 3

Figure 3. Geodetic layout

7. CONCLUSION

The river Mura is one of rare remaining natural water courses among the lowland rivers in the Central Europe, and it is characterized by steep, collapsed and still undefined banks, and by gravel and sand sandbanks. High water that runs through the bed of the river Mura several times a year causes heavier erosion of the banks. Due to the erosion of the right bank of the river Mura (chainage rkm 58), the settlement Miklavec in Međimurska County will be threatened. In order to prevent further development of the erosion process that might endanger the settlement, the construction of the revetment of crushed stone has been planned.

According to the Law on the Protection of Nature, the course of the river Mura is protected in the category of regional parks. The process of carrying out, maintaining and using the mentioned intervention may have certain negative influences on the quality of water and soil, habitats, flora and fauna, the areas protected on the basis of the Law on Protection Nature. It is therefore to be concluded that the water course of Mura is the area of extraordinary natural values and has great significance at the regional, national and European level being an area spreading not only at the territory of the Republic of Croatia, but also across its borders constituting an ecological system in the neighbouring countries, which makes its protection an essential priority.

Geodesy has an important role in solving the engineering tasks. It is indispensable in designing, construction and usage of any structure, including also hydrotechnical object (revetments). The structures used for the regulation of watercourses are very expensive, which is caused by a large extent of works and by specific conditions of their performance. It is therefore very important to design and build the objects in such a way that they can meet all standards of ecology and construction with minimal costs, and geodesy can provide a significant contribution in this respect.

REFERENCES

[1] Kuspilić, N.: *Hidrotehničke građevine – 2 dio*, skripta, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, **2008**.
[2] Pribičević, B., Medak, D.: *Geodezija u građevinarstvu*, Građevinski fakultet Sveučilišta u Rijeci, Zagreb, **2003**.
[3] Toth, G., Engi, Z., Majdan, J., Fabian, S. A.: Historijsko-morfološka rekonstrukcija inundacije rijeke Mure. *Ekonomska i ekohistorija: časopis za gospodarsku povijest i povijest okoliša*, **2013**, Vol. 9, No. 1, p.p. 28–34.
[4] Hrvatske vode: *Dovođenje murskog nasipa u funkcionalno stanje (km 22+594–25+912)*, elaborat zaštite okoliša, Hrvatske vode, Zagreb, **2012**.
[5] Pribičević, B.: *Pomorska geodezija*, Geodetski fakultet Sveučilišta u Zagrebu, Zagreb, **2005**.

ГЕОДЕТСКИ РАДОВИ У ПОСТУПКУ САНАЦИЈЕ РЕКЕ МУРЕ У ХРВАТСКОЈ

Резиме: *За потребе санације постојеће обалоутврде десне обале реке Муре у месту Миклавец, у Хрватској, обављена је геодетски премер на основи које је израђен санациони пројекат. Наглашена је важност геодезије у пројектовању и градњи хидротехничких објеката. Описане су примењене методе геодетског премера и одговарајући инструментариј. Приказана је геодетска ситуација премереног стања с преклопом на дигиталном ортофоту те попречни профили.*

Кључне речи: *Санациони пројекат, геодетска ситуација, дигитални ортофото, попречни профил, река Мура*