62
Professional paper
Doi 10.7251/stp202401074DJ
ISSN 2566-4484

Bojan Đurin, University North, bojan.durin@unin.hr
Nikola Kranjčić, University North, nkranjcic@unin.hr
Vlado Cetl, University North, vcetl@unin.hr
Danko Markovinović, University North, danko.markovinovic@unin.hr
Ana Frntić, ana.frntic@gmail.com

APPLICATION OF GEODETIC AND HYDROMETRIC MEASUREMENTS FOR THE PURPOSES OF DEFINING THE WATER BALANCE – THE EXAMPLE OF “DEDIN MLIN” NEAR SVETI ĐURĐ ON THE PLITVICA RIVER, CROATIA

Abstract

This paper presents the application of geodetic and hydrological measurements to define the water balance in the example of a lake in an alluvial medium. The purpose of the above is to provide insight into parts of the lake's water balance since evaporation from the water surface (evaporation) and precipitation, along with infiltration and surface inputs and outputs from the lake, represent input data for the water balance calculation. An example of a modern approach to geodetic and hydrometric measurements on a lake created by damming the Plitvice watercourse for water inflow to the former mill for grinding grain, called "Dedin mlin", is presented.The emphasis of the work is on the field part, which includes measuring the flow and speed of the Plitvice River on the profile at the exit from the lake, as well as determining the lake's surface using an unmanned aerial vehicle. Using a mini-submarine, insight was obtained into the lake's shape, i.e., the conditions at the bottom and along the edges of the bed. Quality analysis of the water balance is essential for calculating the volume of new reservoirs that will be designed and built and for analyzing the water balance of existing reservoirs and natural lakes.

Keywords: lake, Plitvica river, hydrometry, geodetic measurements, balance sheet

ПРИМЈЕНА ГЕОДЕТСКИХ И ХИДРОМЕТРИЈСКИХ МЈЕРЕЊА ЗА ПОТРЕБЕ ДЕФИНИРАЊА ВОДНЕ БИЛАНЦЕ – ПРИМЈЕР “ДЕДИНОГ МЛИНА” КОД СВЕТОГ ЂУРЂА НА РИЈЕЦИ ПЛИТВИЦИ, ХРВАТСКА

Сажетак

У овом раду приказана је примјена геодетских и хидролошких мјерења за потребе дефинисања водне биланце на примјеру језера у алувијалном медију. Сврха наведеног је увид у дијелове водне биланце језера, будући да испаравање са водне површине (евапорација) и оборине, уз инфилтрацију те површинске улазе и излазе из језера, представљају улазне податке за прорачун водне биланце. Приказан је примјер модерног приступа геодетских и хидрометријских мјерења на језеру насталом преграђивањем водотока Плитвица за потребе дотока воде на некадашњи млин за мљевење житарица, назван "Дедин Млин". Нагласак рада је на теренском дијелу, који обухваћа мјерење протока и брзине тока ријеке Плитвице на профилу код излаза из језера, као и одређивање површине језера кориштењем беспилотне летјелице. Кориштењем мини подморнице добивен је увид у облик језера, односно увјете на дну и уз рубове корита. Квалитетна анализа водне биланце важна је за прорачун волумена нових акумулација које ће се тек пројектовати и градити, као и за анализу водне биланце постојећих акумулација и природних језера.

Кључне ријечи: језеро, ријека Плитвица, хидрометрија, геодетска мјерења, биланца

1. INTRODUCTION

The alluvial substrate is a porous soil created by erosion and accumulation, resulting in sand and gravel particles deposition. River valleys have an erosive character, and their development can be monitored by knowing the morphological and hydrogeological properties of the river terraces. The Plitvica River was formed by depositing sedimentary material from the Drava terraces on alluvial deposits. The processes of deposition of material resulted in a decrease in the flow capacity and volume of the channel, further erosion of the coast and flooding of the terrain, and ultimately, the formation of water bodies that have the characteristics of stagnant water[1].

The Plitvica River began to form on the alluvial deposits of the heterogeneous composition of gravel and sand of the Drava River. The thickness of the sediment increases from west to east, and the amounts of gravel, sand, and pebbly sand are transported by wind and strong water flow. Due to erosion in the higher areas, sediments are transported to the lowlands and deposited during the flood period, which causes the water level in the area to rise..This reduces the volume of the channel, resulting in the creation of meanders and erosion of the channel. Another consequence of accumulation actions is alluvial fans, which are characteristic of wet environments and mountain terrains. Due to the continued deposition of sediment, the channels are prone to clogging, so due to breakthrough, the flow moves to a part of the fan that has a steeper slope. The Plitvica River is a torrential river characterized by a small catchment area, steep falls, and a torrential and short-term inflow. Heavy precipitation as well as sudden melting of snow, contribute to the rapidly rising level of large waters[1]. It should be emphasized that the hydrology and geomorphology of the river Plitvica have not been investigated in the literature. .

In the continuation of the work, the artificial lake created by damming the course of the Plitvice River will be analyzed. The purpose of the field measurements, as well as of the analysis of obtained results was to determine the balance of the lakes in the alluvium media. It is important to get information about the amount of water that can be lost in a way of infiltration or evaporation. This is of importance due to the sizing and building of the accumulations or retentions for the purposes of flooding protection, irrigation, and similar. The hydrological cycle of the lakes or accumulations usually consists of the input and outputs into the volume.[2]. Evaporation and precipitation can be calculated from data from meteorological stations if they are near the observed locations. Also, there is a need to calculate the area of the lake surface, which the drone will do. Because the evaporation and precipitation are expressed in millimeters, i.e., liters per square meter, the amount of evaporated water and precipitation will be calculated by multiplying these values. The same goes for the inflows and outflows in and out of the analyzed accumulations. If such data are unavailable, then field measurements must be provided. The biggest problem is to determine the volume of the accumulation, i.e., the available volume which can store a certain amount of the water. .

2. FIELD MEASUREMENT METHODOLOGY

The methodology for determining the water balance of the lake generally consists of analytical and field research.

The calculation of the water balance is meticulously derived from the inputs and outputs from the lake. At the observed location of the lake, there are no entrances and exits, or natural and/or artificial watercourses. Our comprehensive field survey, coupled with the available basic geological map, reveals that the dominant entrances and exits in the lake itself are not expected, and for a more comprehensive understanding of the lake's profile and geometric characteristics, a mini-submarine will be deployed.

The entrance and exit to the lake are made by the flow of the Plitvice River and precipitation, while the exit is made by evaporation and infiltration. Due to the small areas that gravitate to the lake, i.e., that make up the lake's basin, the flow from the surrounding areas into the lake will be ignored. Since the remaining inlet, i.e., the outlet to that lake is the flow of the Plitvice River, the flows obtained as a result of the application of the FlowTracker2 ultrasonic meter will be used there.

The surface of the lake will be determined using the AUTEL EVO II dual drone. To verify the area obtained by the drone, the area determined using the Geoportal will be compared.

2.1. LOCATION

The rivers Bednja, Drava, Lonja, and Plitvice are located on the territory of Varaždin County. The source of the Plitvice River is connected to the Macelj Mountains, i.e., Vinica Breg, and to the

Bednja River with its tributaries. It belongs to the Drava River basin, which flows into it north of Mali Bukovec Figure 1 [3].

Figure 1. Location of the research area

The Plitvica River is a lowland river that stretches west-east. This paper recorded all photos on May 26, 2023, when the field flow measurement was performed with the FlowTracker2 ultrasonic meter. Figure 2 shows the lake and its left side of the shore, which is visibly more neglected than the right side.

Figure 2. Analyzed lake from the right side of the shore

The input assumption is a constant volume of the lake despite the change in the water flow in the Plitvica River, which is visible in Figure 14. Since the flow is always enabled, the only changes in the water levels in the lake are visible at the dam and the threshold or waterfall. As shown in Figure 2, the change in water flow into the Plitvica River does not change the lake's volume despite the higher flow in a certain period of the year.

2.2. GEODETIC MEASUREMENT

Field research was carried out on 05/22/2022. The surface of the lake was obtained using a drone measurement image that was overlaid with an image from the DGU Geoportal [4]. Since determining the lake's surface is a critical step in defining the amount of evaporation, the recording was done with a drone for this work. The procedure begins with assembling the equipment in protected boxes. Along with the device being in a protected box, there is a remote control for the drone, an additional battery, and a USB connection to transfer data to a computer. The Global Navigation Satellite System (GNSS) receiver used for this measurement was the Trimble R12, designed with increased accuracy and efficiency in demanding GNSS conditions. This device provides at least 30% better accuracy in challenging GNSS areas where the receiver has enough satellites to achieve minimum accuracy requirements but where that signal may be obstructed or reflected by trees or buildings [5]. The drone used to record the lake's surface was Autel EVO II DUAL 640T (Figure 3). This device is equipped with 19 types of sensors that enable the creation of 3D maps and easier route planning through more demanding terrain.

Figure 3. Drone Autel EVO II DUAL 640T [6]

After the equipment is ready, it is necessary to mark the control points above which the drone will record the surface. This procedure was carried out so that the point above which the GPS device is placed was drawn with a spray. In this field recording, more points were determined for more accurate results and to reduce deviations in the final model. Figure 4 shows one of the marked points on the shore of the lake at the revision shaft

Figure 4. Marked point - example on the cover of the inspection window

Two recordings were made with the drone at two different heights. The first height of the flight was 60 meters, and the second height was 100 meters. The reason for shooting at two different heights was to overlap the shots so that a more accurate data cloud could be developed later. Figure 5 shows the result of the recording by an unmanned aerial vehicle, i.e., the obtained recording. The total area of the lake obtained with this model is 747.65 m^2.

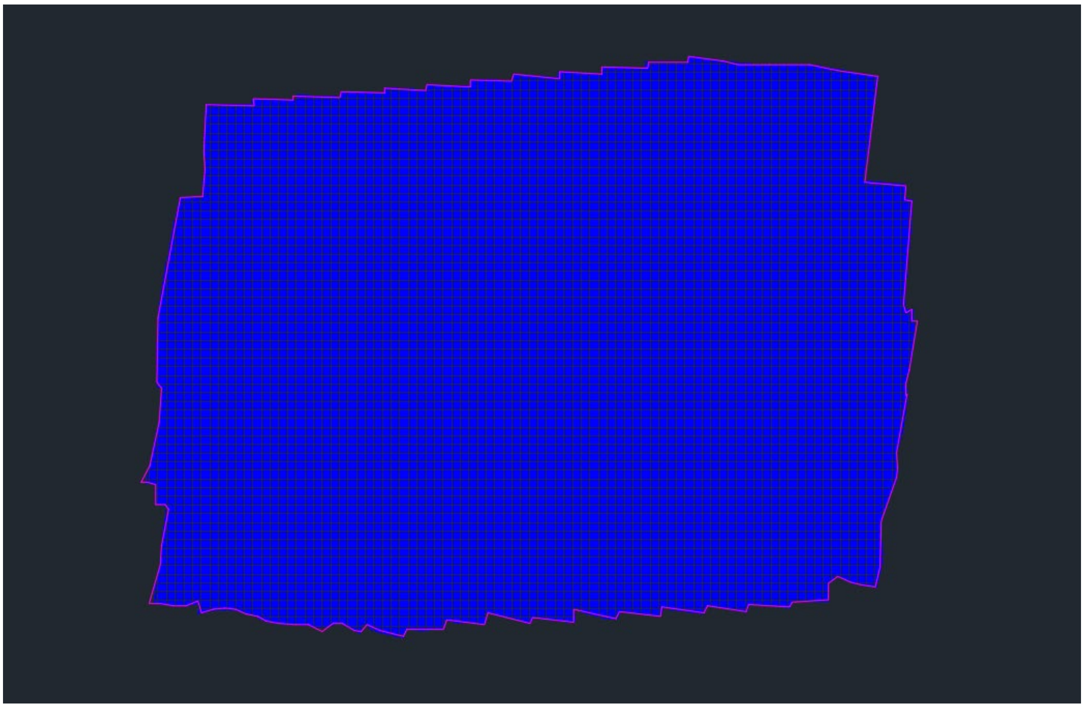

Figure 5. A model of the lake surface obtained by drone imaging

As the drone recording included part of the coast and the surrounding terrain, the area of the lake itself was calculated by overlaying the obtained model with the base taken from the Geoportal page. Figure 76 shows the overlay of the model and the Geoportal base, based on which the area of the surrounding terrain was determined, which is 427.25 m^2.

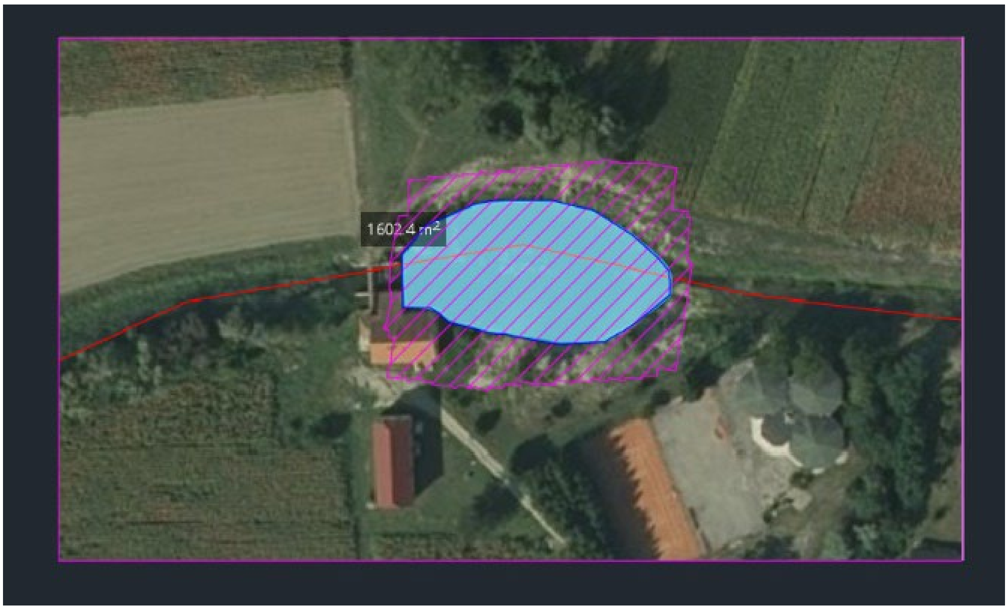

Figure 6. Overlay of images obtained by an unmanned aerial vehicle and the Geoportal digital ortophoto [4]

In the picture, the lake's area is marked with a blue line, which is 1602.4 m^2 on a scale of 1:500 and 320.4 m^2 on a scale of 1:1. The adopted authoritative area of the lake is 320.4 m^2, and it was obtained after processing the drone footage and the Geoportal base in AutoCad.

2.3. HYDROMETRIC MEASUREMENT

For this work, one measurement was performed on May 26, 2022. where the FlowTracker 2 Handheld-ADV portable field device was used, Figure 7.

Figure 7. FlowTracker 2 Handheld-ADV [7]

This instrument belongs to the ultrasonic meters, which obtain flow rates, velocities, water temperatures, and possible deviations. The collected data were transferred via a USB connection to a computer where the FlowTracker2 application was used for their analysis. Figure 8 shows the graph of flow values obtained on 5/26/2022 for each measured point.

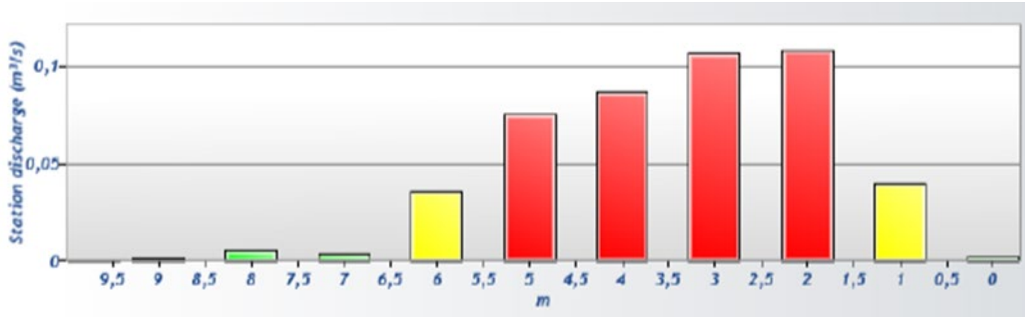

Figure 8. Display of obtained flow values, measurement on May 26, 2022

Figure 9 shows the speed values for each measurement point, while Figure 10. graphically shows the depths of individual points on the field measurement on May 26, 2022.

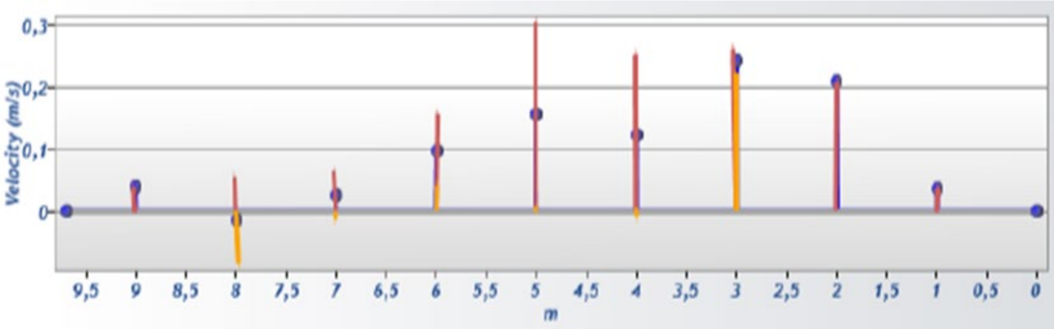

Figure 9. Velocity values for each measured point

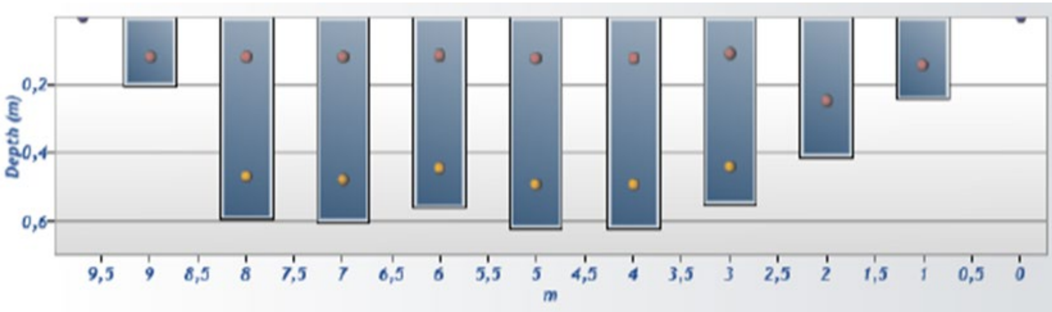

Figure 10. Depths of individual points

Due to the ISO standard of the measurement procedure, an under 0.5 m measurement is provided at one point, between 0.5. and 1 m in two and above the 1 m in three points. Also, the ISO standard defines, as well as procedure rules, the distance between the stations in cross profiles, which is 20 percent of the total width.

2.4. BATIMETRIC MEASUREMENT

The bathymetric measurement took place on June 21, 2022, at the analyzed location near St. Đurđ, near the Ludbreg. The measurement aimed to determine the depth of the lake with a mini-submarine. A bathymetric map was to be created based on the submarine images, showing the relief of the bottom of the observed lake. On bathymetric maps, depths are marked with different shades of a specific color to distinguish changes in terrain height.

The Chasing M2 Mini Submarine is an underwater drone that can move in all directions. The weight of the device is 4.5 kg, which makes it easily portable. The length of the submarine is 380 mm, the width is 267 mm, and the height is 165 mm. This type of mini-submarine performs recordings in temperature conditions with a limit of -10 °C to 45 °C. This mini-submarine's highest speed of movement is 3 knots or 1.5 m/s, and the largest horizontal radius is 200 m. A 4K/1080p camera and an additional EIS camera for image stabilization are installed in the device itself. An LED light on the front of the device is equipped with four propellers on each side. The device can be lowered into water up to 100 m deep. On the remote control, there is an insert for the device on which the Chasing GO1 application is installed, through which the path of the mini-submarine can be seen. [8].

The measurement began by marking the spot on the shore of the lake where the mini-submarine would be lowered into the water. After that, we started assembling the device, which is in a protective box (Figure 11). After attaching the cable to the mini-submarine, we started our measurements. Results were not obtained due to the bad visibility of the lake bottom due to the underwater grass and all other vegetation. Great blurred bottoms also go in favor of that.

Figure 11. Mini submarine Chasing M2

Due to unfavorable water turbidity conditions, the bathymetry could not be entirely performed. Problems encountered during the bathymetry also included raising material from the bottom of the lake, such as fine gravel and sand, which prevented the operation of the device's propellers. In other words, insight into the spatial characteristics of the lake's shape and volume was not possible.

3. DISCUSSION

Calculating the evaporation and precipitation amount is possible because data about it exists and is available from the Croatian Meteorological Service, i.e., from the meteorological stations. Inflow and outflow values in and out from the observed lake can be obtained only from the hydrometry measurements, i.e., by using the measurement device. Unfortunately, continued river flow data does not exist because no limnigraph station is near the analyzed locations. Because the inflow and outflow water flow was almost equal at the measurements, it was concluded that the infiltration into the ground was neglected. Also, for this preliminary analysis, because the surrounding relief does not have a sloping area that is too big or the surface area, the inflow of precipitation from these areas will not be considered.

Because determining the lake's volume by mini-submarine has not been possible, the total water balance of the lake could not be determined.

4. CONCLUSION

Geodetic and hydrometric measurements are vital when defining water balance. Numerous developed models for the above are unreliable unless compared with the measurement results obtained in the field. Also, input data for models are often assumed or estimated. Reliable measurements also increase the precision of modeling outputs. Also, the accuracy of the water balance of the observed lake is higher.

Due to the complexity of hydrological tasks, an interdisciplinary approach to solving the problem, including other scientific branches, is necessary to apply the correct procedures in the management of water assets. Continuous monitoring of changes in the water level and flow of the analyzed rivers, along with the analysis of hydrometeorological data, represents the basis of all such further research.

ACKNOWLEDGEMENT

This research is supported by the scientific project The role of geodesy and geomatics in the development of smart spaces from the University North, Croatia.

LITERATURE

[1] C. G. Survey, “Basic geological map,” 2014. [Online]. Available: https://www.hgi-cgs.hr/wp-content/uploads/2020/07/Koprivnica_tumac.pdf.

[2] V. T. Chow, D. R. Maidment, and L. W. Mays, *Applied hydrology*. 1988.

[3] “Google Maps,” *Google*, 2020. google.maps.com/croatia (accessed May 30, 2021).

[4] S. A. Geodetic, “Geoportal,” *Geoportal*, 2024. https://geoportal.dgu.hr/ (accessed Apr. 07, 2024).

[5] Trimble, “Trimble R12,” 2024. https://geospatial.trimble.com/products-and-solutions/trimble-r12 (accessed Apr. 07, 2024).

[6] A. Robotics, “Autel Robotics,” 2024. https://www.autelrobotics.com/productdetail/evo-ii-dual-640t-drones/ (accessed Apr. 04, 2024).

[7] XYLEM, “XYLEM - Let’s solve water,” 2024. https://www.xylem.com/en-us/products--services/analytical-instruments-and-equipment/flowmeters-velocimeters/flowtracker2-handheld-adv/ (accessed Apr. 07, 2024).

[8] CHASING, “CHASING M2 PRO MAX,” *CHASING*, 2024. https://www.chasing.com/en/chasing-m2pro-max.html (accessed Apr. 07, 2024).