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ASSESSMENT OF THE ACTUAL WATER BASIN CAPACITY WITH THE USE OF GIS

OCENA RZECZYWISTEJ POJEMNOŚĆ ZBIORNIKA WODNEGO Z WYKORZYSTANIEM GIS

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Abstract. The water basin bottom relief during its lifetime is shaped by the acumulation of the sediments, cleaning processes or the abrasive effects of the water flow. These modifications of the relief leads to the changes of the water basin acumulation capacity.
The usage of the GIS for this task means the usage of digital terrain model (DTM), which represents the bottom of surveyed basin. The proposed method for the assessment of the basin capacity uses the poin-type objects. For the collecting of the point coordinates (*x*, *y*, *z*), we used the arrangement of the measuring equippment consisting of the GPS receiver and sonar, which was mounted to the raft boat. The data collection was done during the sailing on the water basin Golianovo. Final DTM was used for the calculation of the water basin capacity with the usage of zonal statistics in ArcGIS 10.

Streszczenie. Urzeźbienie dna zbiornika wodnego podczas jego eksploatacji kształtowane jest przez akumulację osadów, proces oczyszczania lub abrazję powodowaną przepływem wody. Te modyfikacje rzeźby dna prowadzą do zmian zdolności akumulacyjnej zbiornika wodnego.
Wykorzystując GIS, korzystano z cyfrowego modelu terenu (DTM), który reprezentuje dno badanego zbiornika. Proponowana metoda oceny zdolności pojemnościowych zbiornika wykorzystuje obiekty typu punktowego. W celu zgromadzenia współrzędnych punktów (*x*, *y*, *z*), użyto urządzenia pomiarowego składającego się z odbiornika GPS i sonaru, które umieszczonego na tratwie. Dane zgromadzono podczas żeglowania po zbiorniku wodnym Golianovo. Ostatecznie DTM użyto do obliczenia pojemności zbiornika z wykorzystaniem strefowych statystyk z programu ArcGIS 10.

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Key words: water reservoir, digital terrain model, GIS

Słowa kluczowe: zbiornik wodny, cyfrowy model terenu, GIS

INTRODUCTION

The common economical and ecological problem of the water management structures, especially the water dams, is the gradual siltation with the eroded material, as the product of the accelerated water erosion in the catchment [Bendíková and Švecová 2005].

Bottom sediments of the water structures are the eroded parts from agricultural and forest soils, catchments of the main water-course and influx that are feeding the water structure or the arrangement of the water structures. This material has the basic attributes of the surface layers of the eroded soils [Holobradý and Iľka 1997].

The water capacity of the basin is decreased of the amount of the acumulated sediments, which can vary in the wide range interval of the values, depending on the more natural factors (for example erosion resistance of the soils and the terrain configuration in the catchment, rain intensity, etc.), but also the antropogenic factors (deforestation, soil protection, cleaning of the water basin bottom, etc.). Muchová and Konc [2010] mentions the water basins as the key elements of the water management framework, because of their potency of the harmonization of the natural water source capacity with the demands of the users, therefore the reduction of the capacity of the water basins can be crucial factor for the assessment of the proper functions of the water basin (flood-protection, irrigation basins, fish production, etc.).

This work deals with the possibility of the water basin capacity assessment with the use of non-contact measuring of the points of the basin bottom. The measuring was done with the arrangement of the GPS receiver with the single beam sonar, the arrangement was mounted to the raft boat with electric engine. Collected data, representet as the points with *x*, *y* coordinate and altitude, was used in ArcGIS 10 software to create the digital terrain model (DTM) of the basin bottom, which was used for the final calculation of the volume of the water mass with the water level at the common value.

MATERIAL AND METHODS

We used GPS receiver Leica 1200+ connected with the Garmin GPSmap 421s sonar (200kHz probe with 14°/45° beam), the connection was made via the NMEA cable.

NMEA interface (National Marine Electronics) categorizes the ASCII data flow as the comma-separated sentence based on the information included in the information code [Thota 2006].

Collected data was processed in ArcGIS 10 software. Geographic information systems (GIS) is the tool for the production of the quality map base and for the providing of the necessary information about the area. GIS provides the connection of the graphic and text-numerical data about objects, also as it provides the consequential analyses of the phenomena and processes in the area of interest [Grešová 2011].

Data sources for the DTM creation are the materials, from which the data for the creation of the model can be gained. These data can be obtained in more ways:

- field survey – direct measuring (theodolite, total station, GPS),
- photogrametry methods,
- digitalization of the existing maps [Li et al. 2004].

Input data is the first, and most crucial part of the DTM creation. DTM can be affected by the input data in more ways, as mentions Halva [2009].

The description of any of the geoelements must contain at least the horizontal position data and mostly also the elevation data (for DTM purposes) [Rapant 2005].

The research was done at the water basin Golianovo located in the Golianovo village (10 km far from the Nitra city). The basin was built in the years 1965–1968 for the purposes of flood protection, decrement of maximum water discharge under the water basin, improvement of the minimal water discharge during growing season and fish production. Total mass in water level 150,10 AMSL is 477 000 m^3 / 31 ha, effective mass in water level 149,50 AMSL is 336 000 m^3 / 27 ha. Area of the basin catchment is 38,5 km^2. Lenght of dam crest is 305 m with elevation 4,5 m over the terrain (geodetic elevation 151,00 AMSL). Water basin has two parts: first part is functional, second part (from the inflow to water basin) is silted to the level of the water level. This work does not deals with the possibilities of the reduction of the siltation, the siltation reduction fundaments are mentioned for example in Jurík et al. [2011]. The measurings were done only at the functional part.

RESULTS AND DISCUSSION

Creation of the navigation lines

Data collection was done during the sailing across the water basin (direction: parallel with basin dam, distance 20 m between lines). These lines was created in the ArcGIS 10, then we moved them to the Leica GeoOffice, where we processed the data for the export to the GPS receiver.

Data collection

Data source of this work was the points laying at the bottom of the water basin. The measuring was done in the march and april of 2011. The measuring equippment was mounted to the back side of rafting boat. GPS receiver was set to mode for collecting the data each 5 m of the sailing. The direction of swimming was made across the basin in accordance to the navigation lines. One person was operating the measuring and navigated the second person, who operated the engine and direction. Coordinates of the measured points were stored in the CF memory card in the GPS receiver. The connection with sonar provided the data storage of all data in one place, that means that the each point contained the data of GPS position and the depth from sonar measuring. During the field survey, there were 1347 points collected as the result of measuring with GPS receiver and sonar.

Processing of the collected data

Data was imported from the receiver to the Leica GeoOffice. The points with the accuracy worse than 50 mm was excluded from the set for the further use. The points were consequently moved to the MS Excel for the calculation of the altitude of the points. The calculation of the elevation, or more precisely, the *Z*-coordinate is described with the following equation:

$$Z_{bottom} = Z_{GPS} + H_{mount} - H_{measure} - D_{sonar} \quad (1)$$

where:

- Z_{bottom} – *Z*-coordinate of the point at the bottom (point used for the model creation),
- Z_{GPS} – *Z*-coordinate of the tip of the GPS pole.
- H_{mount} – heinght of the mount plate above the tip of the GPS pole,
- $H_{measure}$ – distance from the top of mount plate, from which is sonar measuring done,
- D_{sonar} – depth measured by sonar.

The graphic representation of the formula is describet at the Figure 1.

At this place, there was second selection of the proper measured points. This selection was based on the assessment of the sonar measuring. The sonar we used is capable of measuring the depth larger tham 300 mm. The depth smaller than this value was displayed as the depth in range 750–1500 mm. To detect these depths, we used the MS Excel to

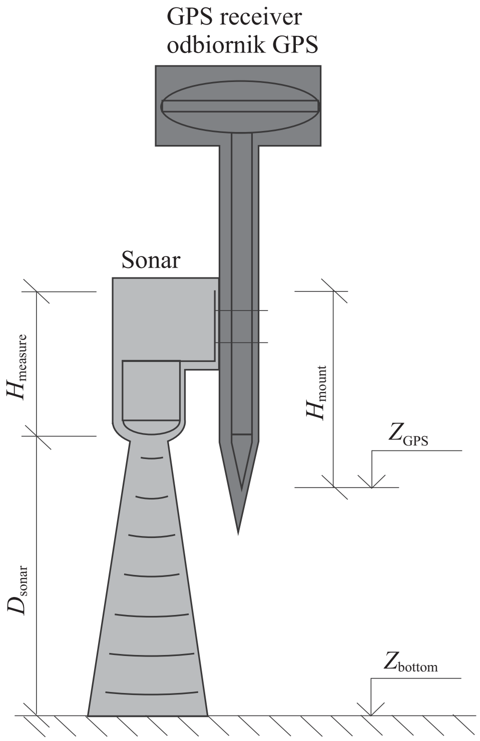

Fig. 1. Scheme for the calculation of the *Z*-coordinate of the point of basin bottom in accordance to Equation (1)
Rys. 1. Schemat obliczania współrzędnej punktu dna basenu, zgodnie z równaniem (1).

evaluate the differences between the depths of the sequential points. The points with incorrect measurings of the depth was excluded. Then the calculations with the equation (1) was processed.

In the group of the 1347 collected points there was 27 points with accuracy worse than 50 mm (horizontal and vertical accuracy) and 43 points with incorrect depth measuring.

The rest of the 1277 points that left we imported to the ArcGIS 10, where we created three themes for creation of DTM of water basin bottom (301 + 292 + 287 points) and one theme (397 points) for assessment of the accuracy of created DTM's. Points for DTM creation were selected manually, that the distance in x and y direction was approximately 20 m.

Creation of the DTM of the Golianovo water basin bottom

We used the tool „Topo to raster" to interpolate the values of the raster model of the terrain. The points with known coordinates were divided to the three themes for creating of the DTM and one theme for verification of the accuracy of the models. The border of the DTM was obtained from the orthophotomap. Final result of the DTM creation with the „Topo to raster" tool were three DTM: DTM 201 created from the first theme of the measured points, DTM 202 created from the second theme of the measured points, DTM 203 created from the third theme of the measured points, as shown at Figure 2.

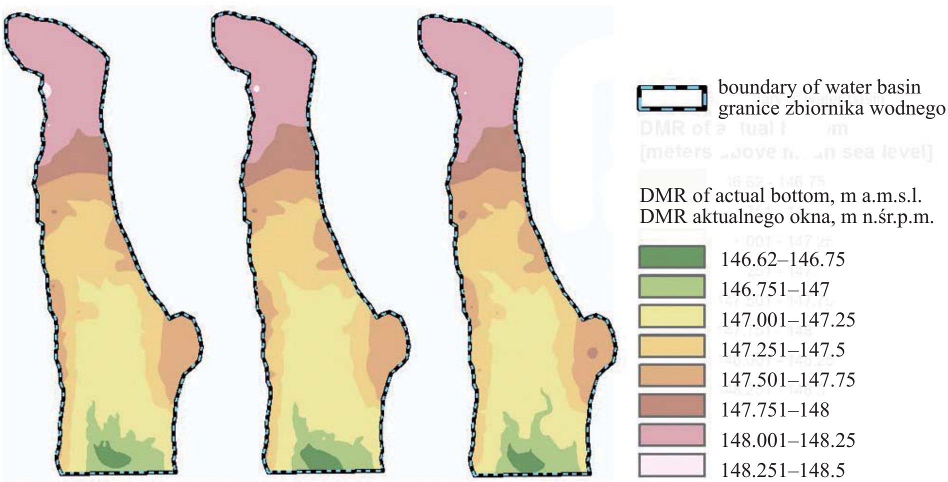

Fig. 2. Three models of the Golianovo water basin bottom – each model made from different theme of the measured points

Rys 2. Trzy modele dna zbiornika wodnego Golianovo – każdy wykonany model z innego zbioru pomierzonych punktów

The assessment of the accuracy was done with the „Zonal statistics as table" tool, where the each DTM was used to calculate the altitude of the points from the verification theme of points. The calculated and measured altitudes of points for accuracy assessment theme were compared and the differences were assessed as shown in Table 1. The differences were classified (1 = best; 4 = worst) and then was calculated the average grade for each DTM. The best classification grade had the DTM 201 and this model was used for the further calculations.

Table 1. Assessment of the characteristics of the DTM
Tabela 1. Ocena charakterystyk DTM

Classified value Wartości sklasyfikowane	Value of ΔH Wartości ΔH ($\Delta H = H_{zonal.} - H_{real.}$) m			Classificationof the accuracy of the particular DTM Klasyfikacja dokładności w szczególności DTM grade – klasa		
	DTM 201	DTM202	DTM203	DTM201	DTM202	DTM203
Average ΔH Średnia ΔH	0.0013	0.0028	0.0047	1	2	3
ΔH > 0,1m	15 points	15 points	19 points	1	1	2
ΔH > 0,05m	44 points	41 points	44 points	2	1	2
Median of ΔH Środkowa ΔH	–0.0005	–0.0019	0.0010	2	3	1
Standard deviation of ΔH Odchylenie standardowe ΔH	0.0502	0.0523	0.0522	1	3	2
Min. – Min. ΔH	0.0001	0.0001	0.0003	1	1	2
Max – Maks. ΔH	0.2199	0.3781	0.3070	1	3	2
Global classification – Klasyfikacja globalna				1.29	2.00	2.00

Calculation of the water mass volume

The principle of the water mass calculation is in the calculation of the sum of the water mass at all cells of the raster. This task was solved as an calculation of the mass of the cuboid, where each pixel is the base and the height of the water column at the pixel is the height of the cuboid. The height of the water column can be calculated as the difference between altitude of two points with same *x*- and *y*-coordinates. That means the first point is laying at the water level and the second point is laying beneath the first point at the bottom of the water basin. The principle of this subtraction in the raster solution is described at the Figure 3.

For the calculation of the water column height we used the „Raster calculator" tool, where we subtracted the altitude of basin DTM cell from the altitude of the water level (148,996m – altitude of the safety fall of the water basin).

For the water mass calculation we used the „Raster calculator". The raster of water column height was multiplied by 4 (area of the cuboid base: 2 m × 2 m).

Final step was the calculation of the total water mass in water basin Golianovo. This quantity was calculated as the sum of the water volumes at each cell of the raster. We used the tool „Zonal statistics as table", that sumarizes the data of volume (from raster of water mass) to the polygon, which is copying the raster of the DTM. This polygon was created with the conversion toll „Raster to polygon". This polygon copies the exact boundaries of the cells at the edge of the raster.

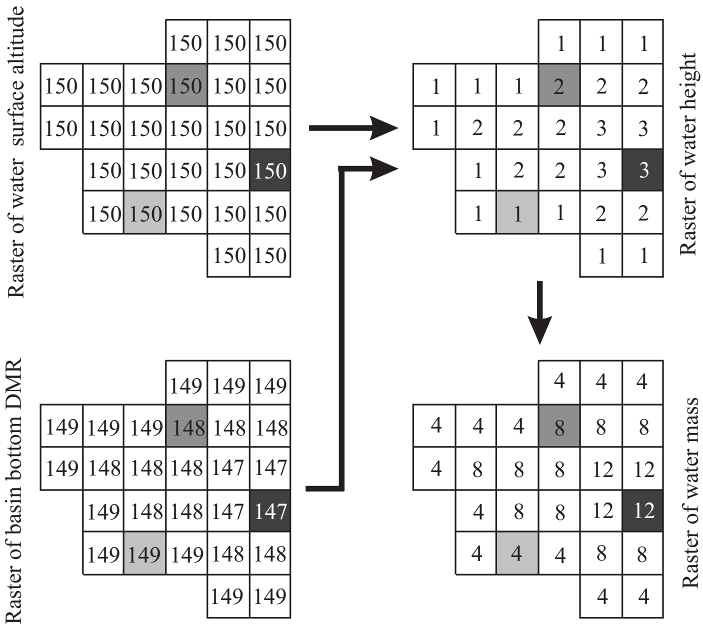

Fig. 3. Calculation of the water column height
Rys. 3. Obliczanie wysokości słupa wody

With the zonal statistics there is calculated the total amount of water in the value 299724,84 m^3 at the area of 200240 m^2 when the water level is at the altitude 148,996 above mean sea level (altitude of the safety fall of the Golianovo water basin). Largest depth of the water basin is 2,37 m.

The method of creation of the DTM of the water basin bottom is an usefull tool for the assessment of the capacity of the water basin. The usage of this assessment can be done for the evaluation of the flood protection functions of the basins, capacity for the irrigation water reservoirs or for the measuring of the water depth in the fish production basins. Results of the assessment of the capacity can be used for the evaluation of the next steps of the maintenance of the water basins. This method for the creation of the bottom DTM can be also used for the creation of the bottom DTM of the rivers or streams. The maintenance of the river bottom can be done in accordance to the Halaj and Božoň [2010].

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