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ANALYSIS OF THE POSSIBILITIES FOR RECLAMATION AFTER AGGREGATE EXPLOITATION IN THE CRACOW'S QUARRY OF BRZEGI BY USING REMOTE SENSING AND GEOINFORMATICS

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Abstract

The paper presents a study referring to the bottom of a water reservoir formed after the exploitation of aggregates and the determination of its best possible direction of reclamation. The surveying reservoir is a part of the aggregate quarry "Brzegi", located on the border of Cracow and Wieliczka cities in the southern Poland. The owner Kruszywo S.A. is planning to develop this land for a water park that will make this areas available for people, but in harmony with nature as well. The aim of this research study is to analyze whether the water-recreation direction of reclamation is possible. If so, the second aim is to determine which is more practical and economical:

- the water – recreation reclamation in open swimming direction or
- the water – recreation reclamation in fishing direction.

To answer these questions three parameters are analyzed:

- the depth and gradients of underwater slopes near the side of the reservoir,
- the composition of the bottom,
- the vegetation quantity.

To analyze these parameters, special maps were made, such as: a bathymetric map, a composition map and a vegetation map. The depth measurements enable us to obtain gradient of underwater slopes. To determine the composition of the bottom, strength of the back echo-signal was analyzed. The vegetation analysis presents quantity and abundance of plants from bottom to surface. To determine the above-mentioned parameters, a self-constructed measuring device "The Smart SonarBoat" was used, which can be remote-controlled from the bank of the water reservoir. The article describes methods of obtaining geospatial underwater data and possibilities to analyze and interpret them using geoinformatics, statistics and related fields.

KOMPLEKSOWE WYKORZYSTANIE NOWOCZESNYCH TECHNIK POMIAROWYCH I NARZĘDZI GEOINFORMATYCZNYCH DO BADANIA DNA POEKSPLOATACYJNEGO ZBIORNIKA WODNEGO ZNAJDUJĄCEGO SIĘ W TRAKCIE PRAC REKULTYWACYJNYCH NA PRZYKŁADZIE KOPALNI KRUSZYWA „BRZEGI" W KRAKOWIE

Słowa kluczowe: batymetria, sondowanie zbiornika eksploatacyjnego, zdalny zestaw batymetryczny, twardość dna, struktura dna, pokrycie dna roślinnością, kruszywo naturalne, rekultywacja, kąpielisko, wędkarstwo, składowanie w zbiorniku, geoinformatyka, GIS

Abstrakt

Artykuł przedstawia analizę dna zbiornika poeksploatacyjnego kruszywa naturalnego (eksploatacja spod lustra wody) do określenia najlepszego możliwego kierunku jego rekultywacji. Celem badań jest przeanalizowanie czy możliwa jest rekultywacja w kierunku wodno-rekreacyjnym oraz który wariant jest bardziej korzystny: wodno-rekreacyjny jako kąpielisko czy wodno-rekreacyjny jako łowisko rybne dla wędkarzy.

Odpowiedzi poszukano, analizując następujące trzy parametry:

- nachylenie skarp podwodnych przybrzeżnych,
- stopień zamulenia dna w strefie brzegowej (struktura powierzchni dna),
- stopień pokrycia roślinnością dna w strefie brzegowej (wegetacja).

W celu przeanalizowania opisanych parametrów, wykonana została mapa batymetryczna zbiornika, mapa twardości struktury powierzchni dna oraz mapa pokrycia roślinnością. Do obliczenia nachylenia skarp przybrzeżnych wykonano pomiar batymetryczny, aby określić stopień zamulenia zbiornika, sporządzono pomiar twardości powierzchni dna, natomiast w celu analizy wegetacji, pomierzono ilość roślin znajdujących się na dnie akwenu. Zbiornik znajduje się na granicy Krakowa z Wieliczką w Kopalni Kruszywa „Brzegi", która należy do Krakowskich Zakładów Eksploatacji Kruszywa S.A. (rys. 1). Pomiar wykonano skonstruowanym przez autora zdalnym zestawem batymetrycznym Smart SonarBoat, umożliwiającym jego sterowanie z linii brzegowej (rys. 3). Opisano sposób pozyskania informacji geoprzestrzennych dla dna i skarp podwodnych oraz możliwości ich analizy i interpretacji, z wykorzystaniem dostępnych technologii geoinformatycznych. Przeprowadzone badania oraz analizy wyników umożliwiły stwierdzenie, który kierunek rekultywacji jest bardziej korzystny.

INTRODUCTION

Remote sensing and Geographic Information System have been enormous developed in recent years. The fields can support and increase abilities of variety scientific disciplines and technologies including geoscience, geomatics, spatial measurements or data collecting as well (Wright et al. 1997). The more analyzed data we have, the better computing algorithm we need and more problems to solve we have. The accessibility for the positioning technologies including satellite-based systems such as GPS, community map-

Fig. 1. The localisation of the studying object, openstreetmap.pl

Rys. 1. Położenie Kopalni Kruszyw Naturalnych „Brzegi" ping and ways of data collecting show directions of GIS is developing (Goodchild 2010). Laser scanning is a practical direction of monitoring in the mining reclamation (Madusiok & Maciaszek 2014), moreover, even remote drones are able to collect spatial data (Tolhurst 2016), but generally still only in outdoor space and surface. This paper describes the way of underwater geo-spatial data collection using a self-constructed measuring device "The Smart Sonar Boat" (fig. 2), which can be remote-controlled from the bank. The measurement was performed in 2016 after the first stage of the mine reclamation that includes depositing the soil and overburden in the reservoir. The surveying object (owned by Kruszywo S.A) is located on the border between Cracow and Wieliczka in the southern Poland (fig. 1).

The article describes methods of obtaining geospatial underwater data and possibilities of their analysis and interpretation, using geoinformatics, statistics and related fields. The aim of this research study is to an-

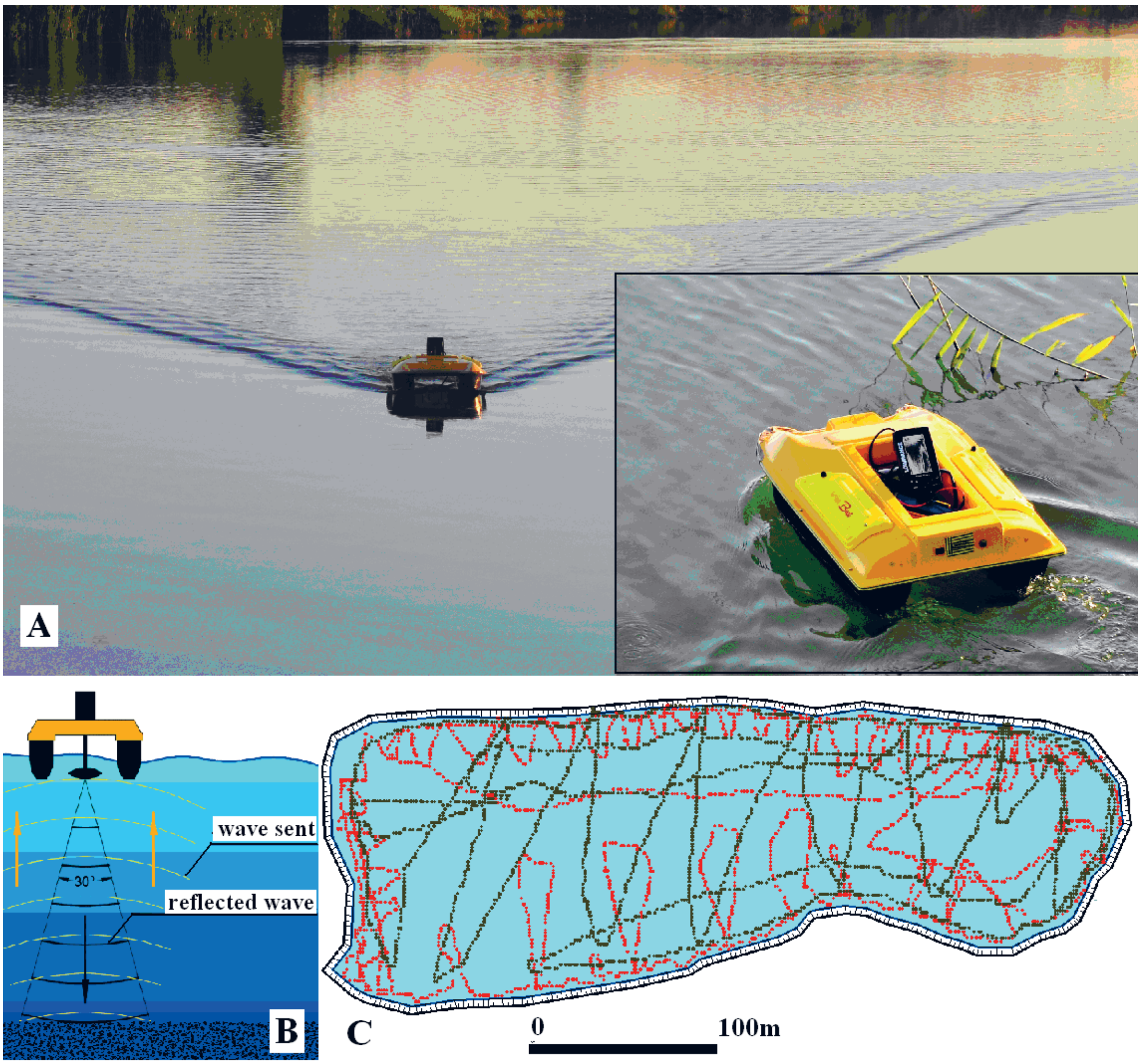

Fig. 2. Description of the measurement. **A**. The Smart SonarBoat device used in the study, **B.** Basics of hydroacoustic measurements, C. The map of the reservoir and waypoints

Rys. 2. Charakterystyka pomiaru. A. Łódka batymetryczna Smart SonarBoat wykorzystana do badań, B. Schemat działania sonaru ultradźwiękowego, C. Mapa zbiornika i punkty pomiarowe alyze whether the water-recreation direction of reclamation is possible or not. If it is possible, the second aim is to determine which is more practical and economical:

- the water – recreation reclamation in open swimming direction or
- the water – recreation reclamation in fishing direction.

To answer these questions three parameters were analyzed:

- the depth and gradients of underwater slopes near the side of the reservoir,
- the composition of the bottom,
- the vegetation quantity.

To analyze these parameters, special maps were charted, like a bathymetric map (fig. 3), a composition map (fig. 4) and a vegetation map (fig. 5). The depth measurements allowed us to count the gradient of underwater slopes. To determine the composition of the bottom, the strength of the back echo-signal was analyzed. Moreover, the signal penetrating underwater obstacle enabled us to obtain the information about the bottom vegetation. The exploitation in this area has already ended but the mine reclamation has not been finished yet. This is a process of restoring areas and lands that have been changed because of mining exploitation. The Polish legislation defines many directions of mine reclamation (Kasztelewicz 2010) (Anon 2002), one of them is water and recreational, so the paper focuses on this, as mentioned before.

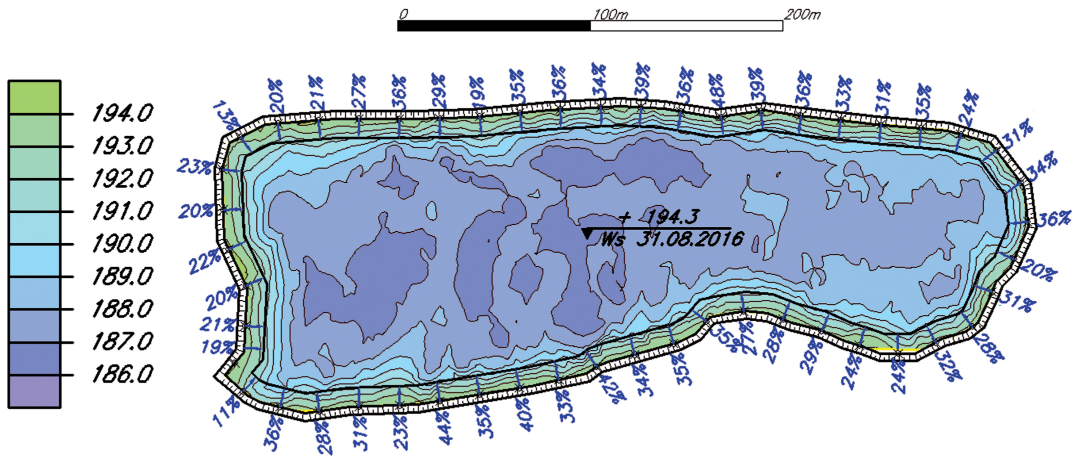

Fig. 3. The bathymetric map
Rys. 3. Mapa batymetryczna

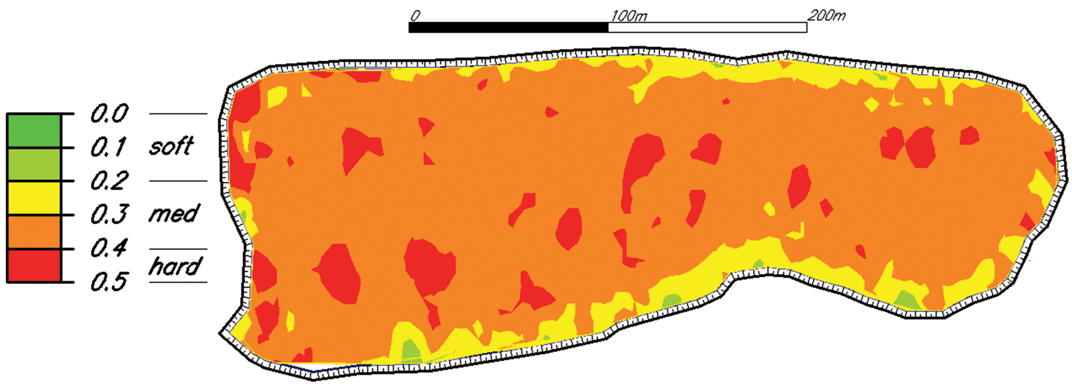

Fig. 4. The bottom composition map
Rys. 4. Mapa twardości struktury powierzchni dna

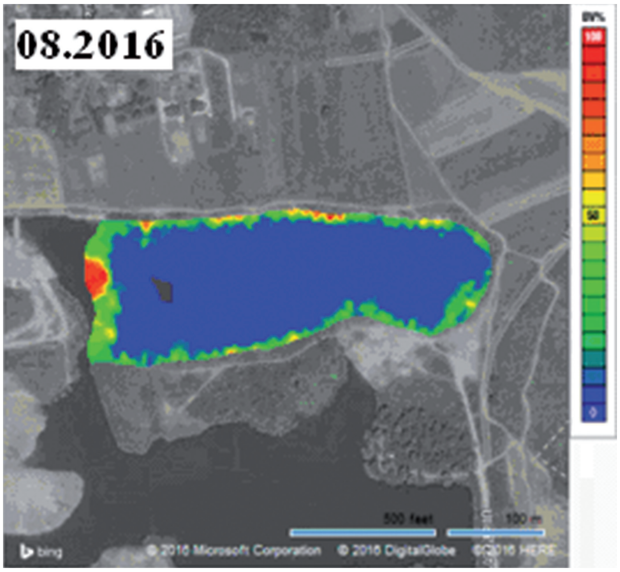

Fig. 5. Vegetation biovolume heat map, www.cibiobase.com © 2015 Navico, Inc.
Rys. 5. Mapy współczynnika biologicznego Biovolume

CHARACTERISTICS OF THE OBJECT

The "Brzegi" aggregate mine extracts sand and gravel that mostly lay below the water table, thus a special dredger machine is used (Migda 2015) to remove water and after the exploitation ends, the pit gets flooded. The layer of soil and overburden is only 2 meters thick, but the primary layer with sand and gravel below has over 8 meters of thickness (Migda 2016) so after extracting it there is a huge amount of space to fill out with water. When the aggregate reclamation is completed these ones areas will potentially become developable into recreational directions (Madusiok 2016). In 2016 there were two different working processes taking place at the same time: aggregate extracting and mine reclamation. In the southern area of the pit the sand and gravel are still being extracted but in the northern part the deposit has already been drained. Therefore, the mine reclamation must be done. The area development plan indicates the water – recreation direction of mine reclamation (Anon 2014) towards restoring green areas as much as possible. The mine owner is planning to develop this lands for a water park that will make this place available for people, but will not disturb the harmony of nature (Pająk 2009). To aim this target, scarping of the banks will be done (using mainly soil and sand). The area of the studied reservoir is 5 hectares, the length is about 400 meters, and the width 130 meters. It is rectangular-shaped, with depth reaching 9 meters (fig. 2C).

ANALYSIS OF THE RESULTS

There are a lot of hydroacoustic (Greenstreet et al. 1997) and seismoacoustic (Osadczuk 2007) methods of obtaining underwater data like depth, bottom morphology, composition, thickness of muck and silt. One of the useful and effective methods of bottom exploration is hydroacoustics, based on measuring, analyzing and interpreting of the reflected signals characteristics.

To perform graphic analysis of the results, three maps were charted:

- The bathymetric map.
- The aquatic vegetation map.
- The composition map.

To obtain the depths of the lake, the Smart Sonar Boat (fig. 2A) with a sonar GPS device, the Lowrance Mark-4 HDI and a 200kHz transducer with a 60 degree cone onboard (fig. 2B) were used. The elevation of the water was 194.3 m above sea level. The maximum measured depth was 8.67 m, but mostly it was about 6–7 m, which is presented on the map below (fig. 3). To analyze the costal bottom scarps 50 profiles were made with about 20 m distance one to another. Each of them was perpendicular to the bank and 10 m long. The average gradient of the slopes is 29.6% with the standard deviation of ±7.9%. The obtained values show that the costal bottom scarps are steep and dangerous in every part of the reservoir.

The analysis of the values of echo energy reflected from the bottom shows the following relationship (Orlowski 1984): the harder bottom composition, the bigger sound energy reflected, the softer obstacle (like muck or silt), the smaller energy coming back to the transducer. Acoustic reflectivity of bottom enables us to obtain the information on its hardness and composition. The sonar used in this study provides a relative and continuous scale of reflected sound energy that ranges from 0 to 0.5 (Valley 2014). The value between 0 and 0.2 means that the bottom is soft, from 0.25 to 0.4 is medium soft and between 0.4 and 0.5 is hard (Navico Inc. 2014). The soft bottom is loosely mixed with materials such as muck, loose silt or sand but the hard one contains dense sand, gravel or rock (fig. 4).

Analyzing the composition, the bottom structure is hard in the middle of the reservoir, but the closer to the bank, the softer bottom structure is. This observation may suggest that the costal bottom structure is loosely compacted with muddy material such as muck or loose silt.

The aquatic vegetation map is plotted to analyze the water availability especially at the edges (fig. 5).

The acoustic signal has also enabled us to obtain information about aquatic plants like canopy and height while it is intercepting and bouncing of the obstacle. The indicator of water clarity called Biovolume is expressed as a percent of the water column occupied by vegetation (fig.6). It is represented as the average depth to the plant canopy in a point paired to the average depth to real bottom from the same set of pings and its accuracy may be reached to 87.8% (Luczkovich 2013)

To illustrate the aquatic vegetation quantity a chart of percent vegetation cover is presented (fig. 7).

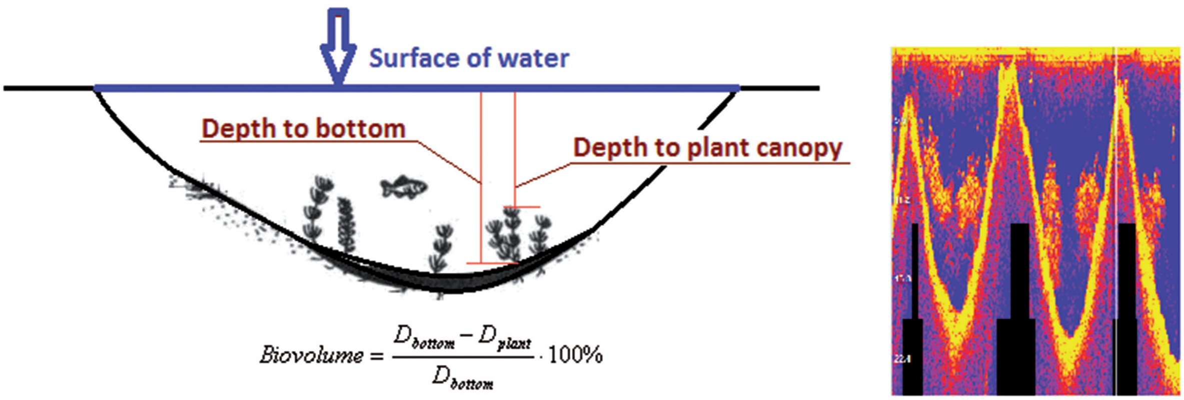

Fig. 6. Schame of Biovolume indicator (left), georeferenced sonar log (right)
Rys. 6. Schemat obliczania wskaźnika Biovolume (po lewej) oraz zapis z pomiaru (po prawej)

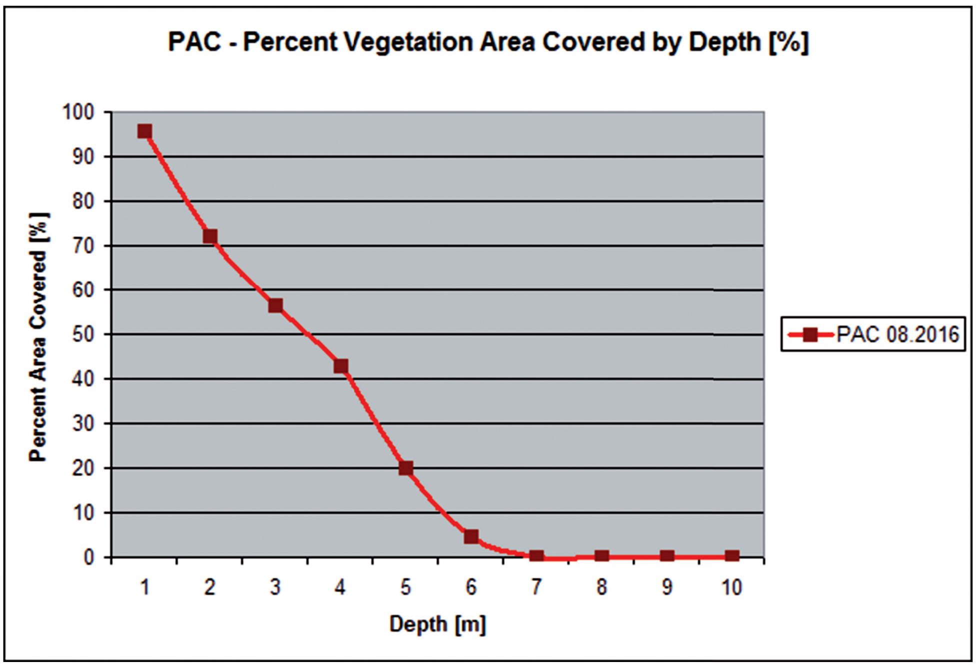

Fig. 7. Chart of vegetation cover
Rys. 7. Wykres procentowego pokrycia dna roślinnością względem głębokości

Analyzing the chart, it can be found that the deeper bottom, the less aquatic vegetation and finally it does not grow deeper than 7 m. The costal line and the bottom near the banks are covered over 90% by vegetation in every part of the reservoir (fig. 5), which makes it generally inaccessible and dangerous to swim.

CONCLUSIONS

The used method of spatial measurements and algorithms of data computing enabled us to obtain important parameters of the aggregate reservoir bottom, like depth, composition and vegetation. Analyzing the data allows us to answer the questions referring to the possibilities of the mining reclamation and to draw the following conclusions:

- The bathymetric measurement shows the expected maximum depth of the reservoir reaching to 8.7 m, but mostly between 6 m and 8 m (fig. 3).
- The average gradient of the bottom slopes near the bank is 29.6% with standard deviation of ±7.9%. Analyzing the obtained values, the costal bottom scarps are steep and dangerous in every part of the reservoir (fig. 3).
- Analyzing the composition; the bottom structure is hard in the middle of the reservoir, but the closer the bank, the softer the bottom structure (fig. 4). This observation may suggest that the costal bottom structure is loosely mixed with muddy material such as muck or loose silt. The costal bottom is dangerous, not only because of its steepness but because of its miry structure, too.
- Analyzing the chart (fig. 7), the deeper bottom the less aquatic vegetation quantity and finally it does not grow deeper than 7 m. The costal line and the bottom near the banks are covered over 90% by vegetation in every part of the reservoir (fig. 5), which makes it generally inaccessible and dangerous to swim.
- In conclusion, the water – recreation reclamation in fishing direction is more practical and economical because most of the works in this direction have been done. The costal bottom scarps are steep to over 8 m of depth with loose structure. Moreover, the vegetation is developed quite widely. This parameters are friendly for fish stocking but finally the chemical water analysis is needed to check the environment completely.
- The reservoir has big capacity to develop into swimming area in the future but a lot of works still must been done like costal slopes shaping, depositing sand and gravel, building sanitary facilities and so on, what is not analyzed in this paper.

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