RTK/GPS WATER LEVEL DETERMINATION DURING LAKE KAMIENNE BATHYMETRIC MEASUREMENTS

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ABSTRACT

The paper presents application of real time RTK/GPS positioning technique for determination of water level changes during bathymetric measurements on Lake Kamienne – the upper water reservoir of the Pumped-Storage Power Station in Żydowo. The bathymetric measurements were carried out on the bases of GPS/RTK satellite positioning using the Ashtech X-Treme receivers while hydroacoustic sounding was conducted using the Simrad EA501P single beam hydroacoustic system. The article describes the basic stages of the work and methods for water level determination during bathymetric surveys.

INTRODUCTION

A vertical datum used in hydrography is typically related to a physical surface, such as lowest astronomical tide (LAT) (FIG, 2006). In inland bathymetry these physical surface is usually stable and can only change slightly in time. Exception to the rule can be a reservoir of a hydro-electric power station, where the water level changes significantly over time.
An example is Lake Kamienne. It is a tunnel valley lake ca. 2800 m in length (north-south) and maximum ca. 600 m in width. The estimated maximum area of that lake in case of the maximum water level (162.20 m) is approx. 99 ha, and at minimum water level (158.50 m) 78.5 ha. The power Station work causes up to 3.7 m movement of vertical reference surface in aspect of local bathymetry surveys.

OBJECTIVE OF THE PROJECT

The primary objective of the bathymetric project was to develop of the digital elevation model of the bottom and calculate the capacity of the upper reservoir of the Pumping-Storage Power Plant Żydowo. Especially the capacity between minimum (158.50 m) and maximum (162.20 m) water level is crucial for proper and effective work of the power plant.

INTEGRATED GNSS AND HYDROACOUSTIC TECHNOLOGIES

The bathymetric measurements were conducted using hydroacoustic sounding and GPS/RTK satellite positioning technique.
Before commencement of measurement works on Lake Kamienne the following preparatory works were conducted:

- **the local geodetic control points were established (including RTK/DGPS reference station),**
- **the methodology of study was defined,**
- **the major measurement profiles were designed.**

After familiarizing with the object, immediately prior to the field measurements, the following works were carried out:

- **the coordinates of measurement control network were determined (using the static GPS technique, according to POLREF 5206 control point),**
- **the local reference station was configured,**
- **the Integrated Bathymetric System was calibrated.**

The local RTK/DGPS base station was set up only for the dedicated project. The differential positioning system used two Ashtech Z-Xtreme GPS receivers. The first of them, placed at a known mark is a stationary receiver called base or master reference station. There can be used the permanent reference station also (e.g. ASG-EUPOS). The base station receiver were sent corrections and raw data (using Ashtech dbn format) via radiomodem to the rover GPS receiver in unknown location.

BATHYMETRIC MEASUREMENTS

To achieve high accuracy of depth measurement conducted using single beam echo sounder (SBES) it is necessary to conduct the measurement system calibration. The vertical distribution of ultrasound waves speed in water should be measured using the calibration probe or the so-called calibration plate (calibration board). On the first day of measurements, before commencement of sounding, the tests of water parameters were conducted to determine the sound propagation speed in water. The sound speed in water has fundamental influence on the accuracy of depth measurements using hydroacoustic methods. Before hydroacoustic sounding of Lake Kamienne the YSI 600R device was used for testing the conductivity and temperature and the YSI2SS software was used for computation of sound speed in water on the basis of the formula developed by Medwien in 1977 (Clay, 1977). **On the basis of the results from sound speed in water tests and bar check calibration, the Simrad EA 501P system was calibrated for depth measurement in Lake Kamienne.**
After testing correctness of reference station and precise GPS/RTK positioning operation on Lake Kamienne, and following calibration of depth measurement system the field survey work was started.
Ashtech Z-Xtreme receiver operating in the RTK (Real Time Kinematic) mode was used for determining the boat position during sounding. During the measurements the file with the position and raw data for post-processing mode were also recorded. ArcMap v. 8.3 by ESRI Inc. was used for navigation through the measurement profiles. The basic measurement profiles were designed in the East-West directions at the interval of 20 m. The boat position, determined in real time, allowed precise navigation of the boat along the earlier designed measurement profiles. During measurements

satellite navigation was conducted depending on the variability of the reservoir bottom along the profiles at the distances of from 5 to 20 m.

Fig. 1. The trajectory of hydrographic measurements.

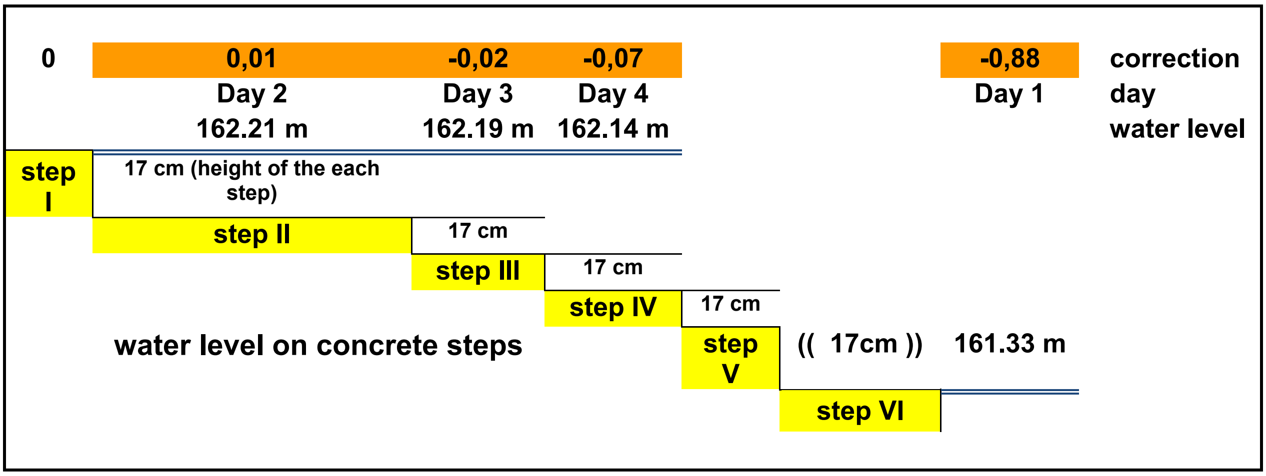
WATER LEVEL CALCULATION

During bathymetric measurements on Lake Kamienne the water level was changing significantly over time. Verified hydrographic data had to be brought to the common water level. The specific characteristics of the upper reservoir of the pumping-storage power plant caused that during the measurement campaign the water level changed depending on the operational schedule of the power plant in Żydowo.
To determine the final water level on a given measurement day the digital readings from the power plant water level indicator, data on the height of the GPS antenna positioned on the boat during hydroacoustic sounding computed in OTF post-processing mode and data from own readings of water level on concrete steps at the outlet of the channel to Lake Kamienne were considered.

Table 1. Computation of depth adjustments for each day of measurements

Zero level: 162.20 m	Day 1	Day 2	Day 3	Day 4
Direct readings (steps)	161.33	162.21	162.19	162.14
RTK/OTF	161.35	162.23	162.19	162.14
Digital water level indicator	161.32	162.21	162.18	162.13
Adjustments made [m]	0.87	-0.01	0.02	0.07

Table 2. Direct readings of water level from concrete steps



For conversion of ellipsoid heights to the system of ordinary heights the values of computed distances of the geoid from the ellipsoid within the range of from 32.46 m (northern part of Lake Kamienne) to 32.50 m (southern part of Lake Kamienne) were applied.

BATHYMETRIC RAW DATA ELABORATION

After conducting the field measurement campaign on Lake Kamienne the bathymetric data recorded was processed. Data from hydroacoustic sounding along individual measurement profiles was recorded as echograms in the form of binary files containing the following data: echogram image recorded for printing under office conditions, depths, position and basic setup data of the echosounder. All echograms were used for verification of the numeric data recorded from the measurements: position with the depth. The raw data from hydroacoustic sounding was processed using the software by the authors called Echo Converter and Echo View. As a result of processing the raw measurement data the set of staff points of the reservoir bottom converted to one water level that formed the database for development of the Digital Elevation Model of Lake Kamienne Bottom.

CREATION OF THE DIGITAL BOTTOM MODEL. CAPACITY CALCULATION

As a result of bathymetric survey conducted for basic profiles designed at 20 m interval 59,973 spot heights were obtained. The minimum depth measured was -0.4 m, while the maximum depth was -35.8 m. The average depth was determined at the level of -7.5 m, and the standard deviation at – 7.2 m. The resulting set of elevation data points was used for construction of the digital TIN model containing the triangulated irregular network characterizing the water reservoir bottom surface.

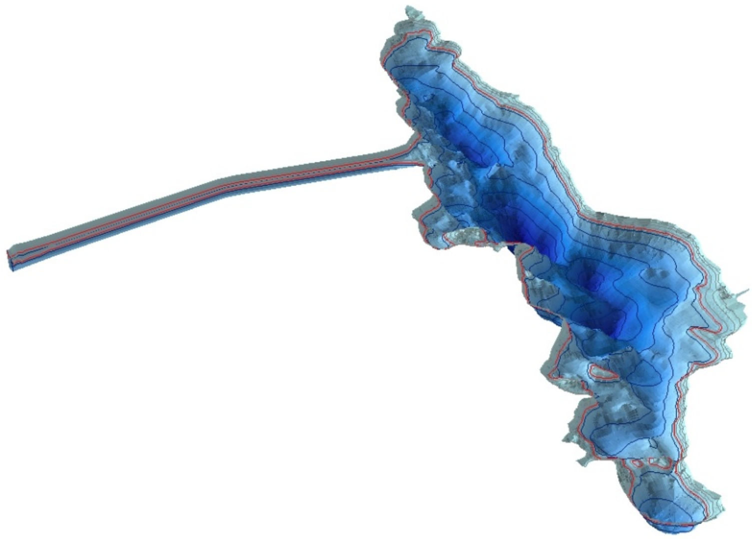


Fig. 2. TIN model of Lake Kamienne with coastline and contour line -3.70 m marked in red.

On the basis of the developed Digital Elevation Model of the bottom the capacity of the upper reservoir of the Pumping-Storage Power Plant Żydowo was calculated.

Table 3. Capacity calculation

		Method I	Method II	Method III	Average	Standard deviation % Method I	Method II	Method III
Total capacity of Lake Kamienne	m3	12470973	12512130	12520314	12501139	0,24	-0,09	-0,15
Working capacity between 162.20 m and 158.50 m (-3.7)	m3	3762919	3763474	3779386	3768593	0,15	0,14	-0,29
Total area of Lake Kamienne (162.20 m)	ha	110,26	110,49	110,49	110,41	0,14	-0,07	-0,07
Minimum area of Lake Kamienne (158.50 m)	ha	89,76	90,47	90,54	90,25	0,55	-0,24	-0,31
Area between 162.20 m and 158.50 m	ha	20,50	20,03	19,96	20,16	-1,69	0,67	1,02

Calculations were made by three independent scientists with the use of three methods. The achieved results are very coherent with each other (Popielarczyk et al., 2007).

CONCLUSION

As a result of survey and hydrographical works conducted on Lake Kamienne – the upper reservoir of the Pumping-Storage Power Plant Żydowo, the Digital Elevation Model of the bottom were elaborated.
Hydroacoustic sounding was carried out on the basis of single beam echo sounder (SBES). Processing of the data from bathymetric survey required adjustments to the depth measurements as a consequence of changing water level at different stages of the

work. The adjustments were computed on the bases of the height computations by means GPS OTF technique and verified by the readings from the digital water level indicator of the power plant. The water level changes were also compared with direct readings on concrete steps at the outlet of the channel to Lake Kamienne.

The Digital Elevation Model of the bottom of the reservoir was used for computation of the total capacity of the upper reservoir of the Pumping-Storage Power Plant Żydowo.

REFERENCES

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