APPLICATION OF THE GPS TECHNIQUES FOR WATER STAGE MEASUREMENTS AND RIVER SLOPE CALCULATION IN WETLAND AREA OF UPPER BIEBRZA BASIN

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Abstract: In this paper a possibility of the DGPS RTK technique using for measure the river water stages, and consequently, for determination of the local river slopes in wetland areas is discussed. A part of the Biebrza valley between Jastrzębna and Jagłowo was selected as a research area. It forms a fairly undisturbed river-marginal peatland, located in the northern-south Poland. The advanced GPS equipment Legacy E made by TOPCON, which allows combination of GPS and GLONASS, was used with Differential RTK measurement mode. During measurements, the distance in straight line between Base and Rover was always lower than 6 km. The total 90 points were measured; the average vertical measurement error about 3 cm was observed. This accuracy, which is sufficient for river slopes calculation, could also be evaluate as very high, when we consider that the unstable organic valley bottom with many oxbows, and disturbance of natural vegetation makes classical levelling very difficult. The GPS technique allows performing high accuracy measurements of all three co-ordinates including the altitude, easy and fast way. The Differential GPS with RTK mode was found as perfect measurement tool, and could be recommending especially for hydrologic application in wetland environment.

INTRODUCTION

The slope of the river is very important hydrological data, especially from point of view of the hydrologic and hydrodynamic models calibration. These specific hydrological applications need calculation of the local changes of water level and slope. Slopes, which are calculated based on usually availably data - water stages observed in gauges, are always not sufficient. It is due to the long distance between gauges, which varies from few to several dozen of km. In the case of hydrodynamic model calibration, the river water stages should be determined based on water level measured with distance intervals at least a few hundred meters of the river length. In the natural river valley such detailed measurements are difficult to perform by use of classical geodetic leveling technique. In the

marginal river wetland it is even impossible, because of the harsh measuring condition: disturbance of natural vegetation, many oxbows and wetland areas, unstable organic ground and very few network coordination points. All these disturbances are noticeable in the Biebrza valley. The GPS technique seems to be optimal tool for altitude measurement in wetlands. This technique was successfully applied several times at the Biebrza wetlands for piezometers levelling (Mućka et al, 1999; Chormański et al., 2000; Orłowski and Chormański, 2000) and river measurements cross-sections (Chormański, 2000, Chormański, 2003). This paper describes application of the GPS RTK technique for the measurements of the water level stage, which consequently allows calculation of the local river slope.

GPS, DGPS, RTK

Global Positioning System (**GPS**) is a satellite system developed for localisation purpose. The original positions determined by GPS satellite signal have horizontal accuracy of about 18-30 (Wilkie and Finn, 1996 after Hurn, 1989). Location measured by the GPS technique is expressed in geography coordinates handled by a reference system named WGS84, which was specially created for the purpose of the GPS use.

A technique called differential correction (**DGPS**) is necessary to improve measurement accuracies. The accuracies within centimeters are possible to obtain with advanced – geodetic equipment. Differential correction requires a second GPS receiver called a Base station, which collects data in a stationary position at a precisely known point. Then, a correction factor can be computed by comparing the known location with the location measured by GPS Base station. In post-processing or in real-time transmission (Real Time Kinematics - **RTK**) the differential correction is performed by calculation a vector from the unknown position to the known and removing a most of the measurement errors at the Rover Receiver (Czarnecki K. 1994). This is made in fully automatic mode by advanced software.

The principal behind of the **RTK** surveying is collecting data with a receiver at a Base station and sending it to another receiver at an unknown location (Rover). In this application, the corrections are calculated at the Base and sent to the Rover at a time of measurement. The connection between them is through the radio antennas. The Base and Rover must also be tracking the same satellites at the same time. The advance of such an application is the measurement time: we can obtain very accurate results in seconds.

EQUIPMENT USED

The TOPCON **Legacy E** GPS receivers were used in this study. The TOPCON **Legacy E** receiver is a full function GPS/GLONASS receiver. Legacy offers the use of not only the American based GPS satellites, but also the additional Russian positioning system GLONASS. The most reliable RTK results can be obtained by using dual frequency GPS (L1/L2) and GLONASS systems. The combination of

GPS and GLONASS satellites always provides enough satellites for fast and reliable results. Legacy E can track 20 satellites at the same time without any channel switching. Using TOPCON technology it is possible that even satellites with weak signal can be tracked and used and lost satellites can be reacquired almost instantaneously. The operating temperature is from -40°C to 55°C. The operating distance – a distance between Base and Rover receivers – is limited by the radio modem power, and can be up to 15 km. The power output of radio modems used in this study was 1W, which allows sending of signals up to distance of 6 km from the Base.The combination of GPS and GLONASS as used in the TOPCON RTK-receivers provided us with coordinates within a horizontal accuracy of ±1-2 cm.

SITE DESCRIPTION

The research area is a part of the Biebrza valley between Jastrzębna and Jagłowo. The Biebrza valley between Jastrzębna and Jagłowo belongs to Upper Biebrza Basin (Żurek, 1984), which is located in the northern-south Poland. It forms a 25 km long, natural valley, which is 2 – 3 km wide in the beginning and basin-like widening close to Jagłowo, in the transition zone to the Middle Basin. In the middle of the area, in Sztabin the river gauge is located (Fig. 1). The Biebrza valley is a fairly undisturbed river-marginal peatland, containing endangered plant and animal species in a large variety of fully developed ecosystems. It is internationally recognised as a reference area for restoration of deteriorated peatlands.

APPLICATION

The GPS measurements of the Biebrza River water stages were performed in total of 90 points, located in the few hundred meters interval of the river length between the railway bridge in Jastrzębna and a Jagłowo village. Due to the limitation of radio-modem range, the proper use of GPS in RTK mode required installation of the Base stations in two spots. These were located in such a way that, the distance in straight line between Base and Rover not exceed 6 km (fig. 1). Since a key for river slope determination is an altitude, during measurements we are not focused on horizontal coordinates. In order to that Base station was located on moraine scarp with open horizon and precisely determined altitude (Fig. 1). The Rover receiver was installed on motorboat, which flowed from Jastrzębie to Jagłowo. The water level measurements were performed every few hundred meters. Next, the coordinates of collected points were transferred. The transformation of horizontal coordinates from WGS84 coordinate system into local Polish coordinate system “1965” was based on Helmert transformation, and elevation transformation based on a geoid model. Both the above-mentioned activities were processed with the use of Geotrans software (Geo-Systems, 1998).

The results of GPS measurements were next used for slopes determination, which were calculated in GIS. The Biebrza River main stream was digitized in ArcView GIS, and next, divided for numerous river segments according to location

measured by GPS. The slope was calculated for every river segment. The measurement error was automatically calculated by GPS receiver's serving software for each measurement point.

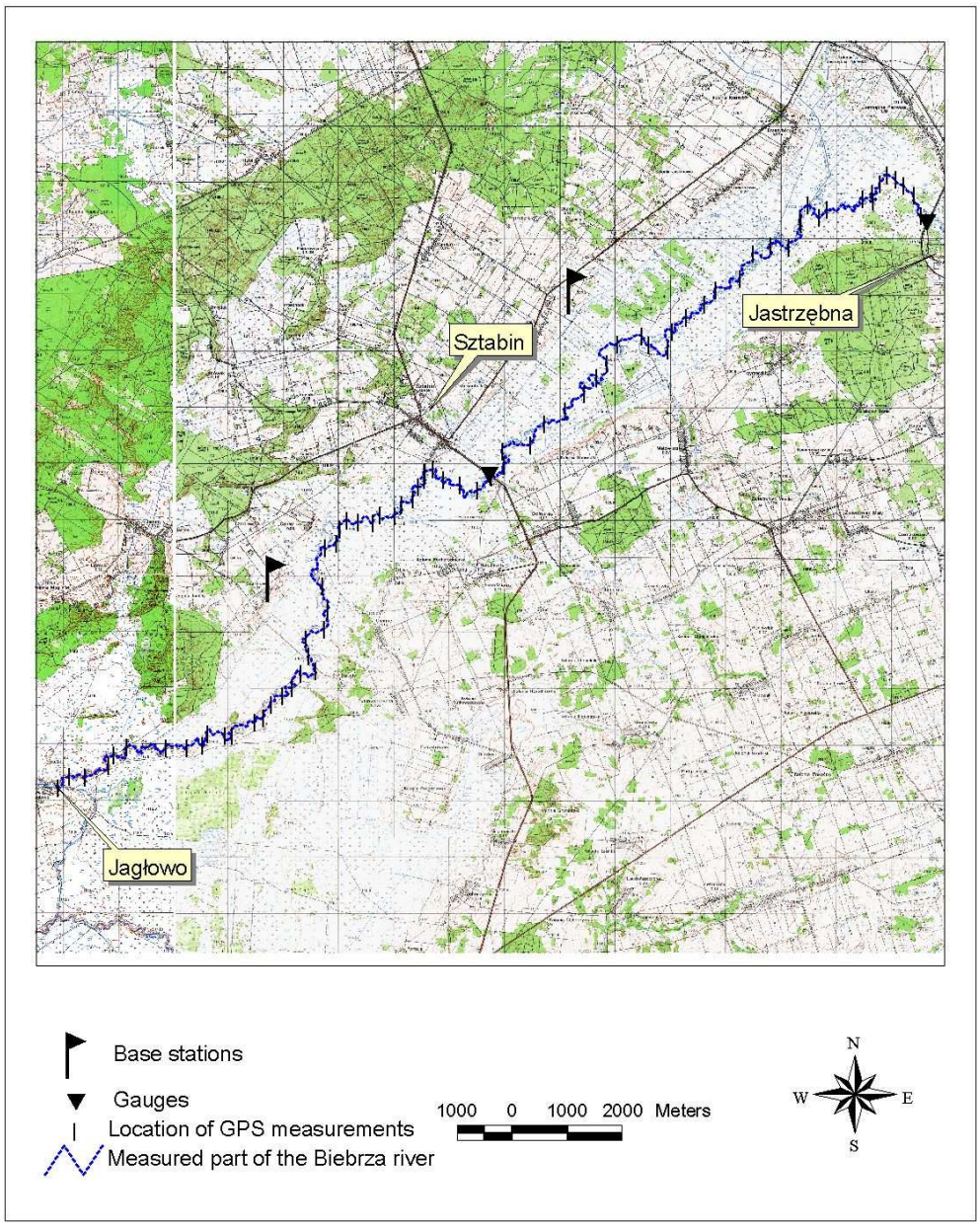

Fig 1 The research area. The location of Base stations.

RESULTS

The significant difference in river slope was observed between river segments located upstream and downstream Sztabin. The upstream Sztabin part was 16 km long, the downstream part was about 16.7 km long. The average distance of river segment in upper part of river, between Jastrzębna and Sztabin, was 467 meters and between Sztabin and Jagłowo was not exceed 400 meters (Tab. 1). Due to that, the results are presented and analyzed individually for each river part. The average slope of the Biebrza River between Jastrzębna and Sztabin is 0.107 ‰ and maximum 0.360‰, while between Sztabin and Jagłowo 0.252 ‰ and 1.481, respectively (Tab. 1). Fig. 2 presents the map of river slope between Jastrzębna and Jagłowo. On more then a half of a distance between Jastrzębna and Sztabin slopes were found less then 0.1‰. These low value of slope correspond to relatively wider peatland formed in the valley upstream Sztabin. Downstream Sztabin, the Biebrza river slope increases and exceed 0.5‰ in several places. The valley is narrow here and forms transition zones to Biebrza Middle Basin (Żurek, 1984).

Tab. 1 Statistics of the results of measurements and their accuracy.

River segment	Total measu-red points	Total distance [km]	Average distance between GPS measure ments [km]	Slope [‰]			Averag. vertical error [m]
				Avg.	Min.	Max.	
Jastrzębna-Sztabin	37	16.030	0.467	0.107	0.015	0.360	0.034
Sztabin - Jagłowo	43	16.765	0.399	0.252	0.032	1.481	0.029

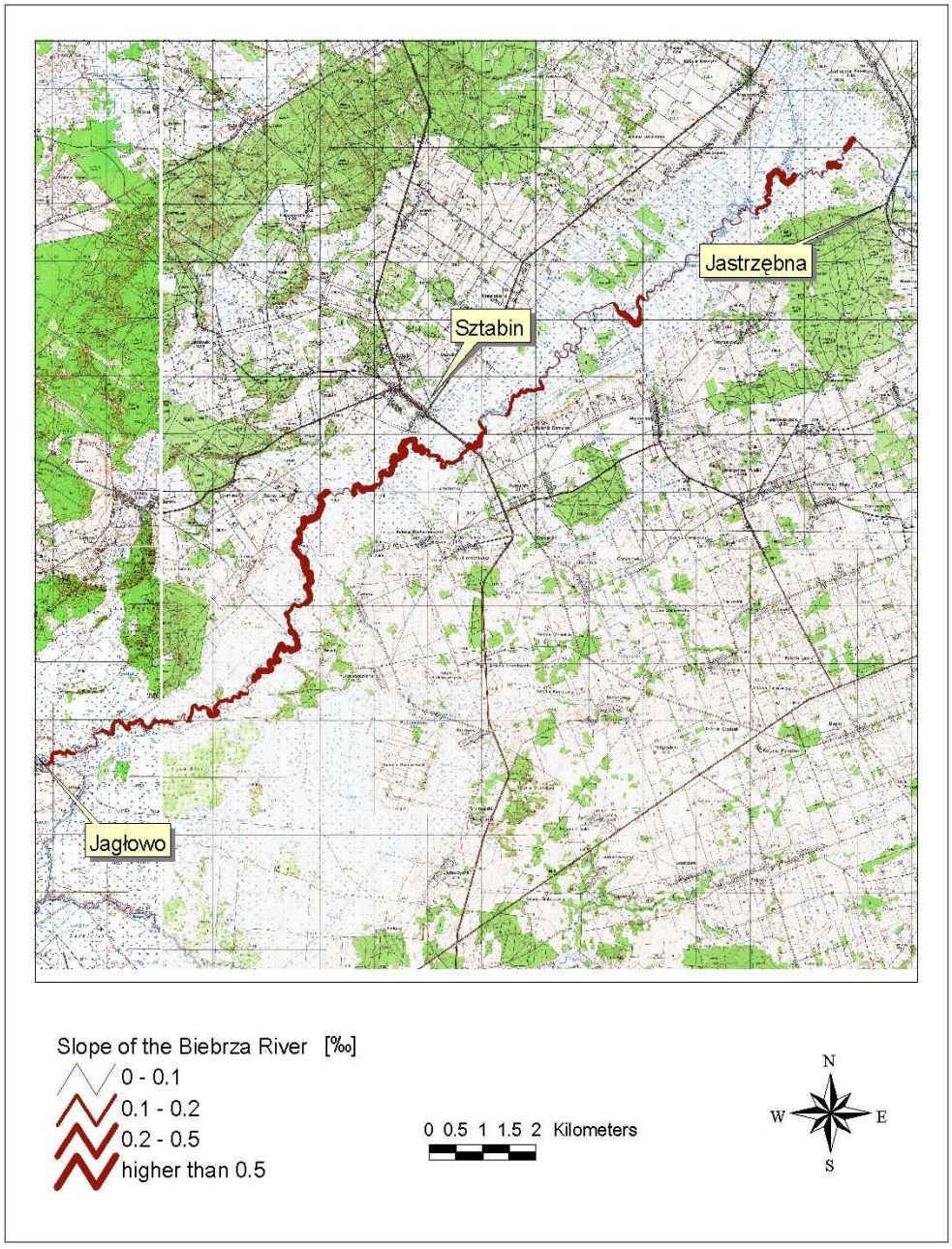

Fig 2. Slopes of the Biebrza River between Jastrzębna and Jagłowo calculated with use of the GPS measurements.

DISCUSSION AND CONCLUSIONS

The total 90 points were measured; the average vertical measurement error was observed about 3 cm. This accuracy, which is sufficient for river slopes calculation, could also be evaluate as very high, when we consider that the unstable organic valley bottom with many oxbows, and disturbance of natural vegetation makes classical leveling hard. Due to that the classical leveling is time consuming on wetland areas and also could decreases accuracy. All measurements described in this paper were performed during one working day. Taking into account the measured river distance, which was more than 32.7 km, the GPS become not only accurate but also very fast measurement technique. It is worth to write that using the GPS receivers is quite easy, it dos not require from a user to be geodesist.

Concluding, the GPS technique allows performing high accuracy measurements of all three co-ordinates including the altitude, easy and fast way. The Differential GPS with RTK mode was found as perfect measurement tool, and could be recommending especially for hydrologic application in wetland environment.

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