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Satellite Technologies in Monitoring of Ecosystems

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Abstract. **The article provides a description of modern geodetic devices, which are used to solve several problems connected with environmental and hydraulic engineering. In particular, a non-conventional method of area measurement for ecosystems monitoring, which involves the usage of satellite navigation devices, is considered.**

Nowadays electronic tachymeters, digital levelling instruments, laser scanning systems and satellite systems are widely used for implementation of geodetic engineering works. In full extent it could be also applied to different environmental and hydraulic engineering problems solution.

The satellite navigators, especially with GPS+GLONASS system support, are the promising alternative to handle different planimetric tasks, particularly, water surface and drainage area measurement.

The paper presents an analysis of the results of research carried out in 2012-2014 years and comparison of them with the new field data. Moreover the obtained results are compared with the theoretical values of quadrates' areas and the dependence of the relative accuracy versus land plot area is built.

Based on a practical research, the accuracy of the method is being estimated. The analysis of different measuring conditions and factors, regarding their effect on accuracy, is made.

The suitable areas, where the method could be used, are mentioned. Particularly, the possibility of water surface and drainage area measuring is examined with the usage of previous theoretical base.

Keywords: **monitoring, engineering geodesy, satellite navigator, area measurement, GPS and GLONASS systems, measuring accuracy, water surface area, drainage area, ecosystems.**

I INTRODUCTION

To start with, geodetic works are the most important part of complex of tasks involving exploration, design, construction, exploitation and monitoring of different buildings and structures. The works are executed with accordance to a united schedule for certain building site, which also depends on time of civil and erection, fitter's and specific works. The costs and quality of construction, as well as engineering object maintenance conditions are mostly defined by geodetic works [1].

Nowadays electronic tachymeters, digital levelling instruments, laser scanning systems and satellite systems are widely used for implementation of geodetic engineering works. In full extent it could be also applied to different environmental and hydraulic engineering problems solution [2] – [4].

Electronic tachymeters and laser scanning systems are used in research of wind and wave weathering of water banks, areal and linear land-surveying and solution of other tasks [5]. For example, such devices can be used to determine the volume of heaps of different quick materials. Areas of land plots and water objects can also be determined by electronic tachymeters. Electronic tachymeters and levelling instruments are widely used in supervising of structures being built or operated, particularly to spot their subsidence.

II RESULTS AND DISCUSSION

The process of monitoring of fill dam, which was being erected in Ust-Luga trading sea port on soft foundation soils, is described in research [6]. The objects of monitoring were the hydraulic structures included in first stage of erection of dock frontage of condensed hydrocarbonic gas overloading complex.

The method of dam subsidence measurement consisted in levelling of control marks and comparison of the results of measurements in order to spot the deformation of structure or foundation soil [7].

The following calibrated geodetic devices were used for measurements:

- Digital levelling instrument Leica Sprinter 100m with bar-coded surveyor's pole GSS 111;
- Electronic tachymeter Pentax R 325NX with components.

As a result of geodetic works on approach embankment several features of the above-mentioned devices were determined [8], [9].

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Electronic levelling instrument Leica Sprinter 100m has the following advantages:

- impossibility of errors connected with human factor while reading and writing the measurement results;
- high speed of levelling caused by freedom from necessity for reading with the usage of both black and red sides of surveyor's pole;
- high accuracy of levelling (in precision mode up to 10-4 m);
- simplified device installation on the spot due to built-in compensator.

The disadvantages of the device are mainly connected with difficulties in measurement in certain conditions, such as:

- insufficient visibility (atmospheric pollution: dust, fog, hoarfrost etc.);
- temperature contrast (thin ice mound on the surveyor's pole);
- impact of sun rays into the lens of the device;
- windy weather;
- intensive operation of heavy building machines during the measurement process, which causes increased vibration and device automatic turning-off.

Some of the features of electronic tachymeter Pentax R-325 NX are:

- reflectionless mode availability, which allows to measure distances up to 200 m without a reflector pole;
- precision of angle measurements is 5";
- double-axis compensator.

In general, the advantages and disadvantages of the above-mentioned device are the same as of electronic levelling instrument.

Despite the mentioned disadvantages, such geodetic equipment allowed to execute the measuring process with required accuracy.

Recently the research concerning the availability of the usage of geodetic satellite systems in route levelling was performed on the Water resources and hydrotechnical engineering department (Saint-Petersburg State Polytechnical University). The comparison of the results acquired by different levelling devices (in particular, optical levelling devices, electronic digital levelling instruments and satellite systems) was established [10]. The result of the research indicates, that satellite navigation devices do not provide the required accuracy. Modern geodetic satellite receivers, however, practically have the same level of presicion as optical and electronic digital levelling instruments. Moreover, satellite receivers' accuracy is superior to the optical and digital devices in case of strong altitude difference of the measured route. This is demonstrated by the fact that surveyor's poles needed for differential levelling have a restricted length, while the satellite receiver does not require a pole. Therefore the usage of geodetic satellite receivers while levelling open-landscape routes in some cases could be the most effective method.

Another field of application of satellite technologies covers the problems connected with land plot area determination, as well as water surface and drainage area measuring.

In some cases such tasks can be accomplished with the usage of electronic tachymeters [11], [12]. For instance, in the research [12] the data concerning the measuring of lake water surface using an electronic tachymeter Pentax W-825NX is presented. Even though the result of the measurement was of high accuracy, it was mentioned, that the measuring process can be interrupted by the variety of external factors. For example, all points of the measured contour must be directly visible from the station (the spot where tachymeter stands), but dense vegetation or buildings could lessen the visibility. In addition to that, the process can be affected by weather conditions.

During the studies [13] – [15], the problem of determination of land plot and water surface areas with the usage of satellite navigators was being solved.

According to work [13], four quadrates with common vertex were divided on location, with their sides 10×10, 20×20, 40×40 и 80×80 meters. Each quadrate was repeatedly bypassed with satellite navigator Garmin GPSMAP 78S. In the process, the values of areas and perimeters were determined and recorded by a program installed on the device. Apart from that, the geographical coordinates of the quadrates' vertexes were fixed. Than, with the usage of this data and computer programs Photomod Geocalculator 4.2.490, Autocad 2008 и Gepath 1.4.4a, areas and perimeters of the polygons were additionally determined.

The diagrams of the relative accuracy as function of land plot size were built as a result of comparison of obtained practical results with the theoretical quadrate area and perimeter values. In addition, the trend line was built with the usage of logarithmic approximation.

Based on the analysis of the result, the following conclusion was made:

- When the land plot size reaches the value of 7 hectares, the usage of GPS navigator allows to obtain the result with same presicion as if an electronic tachymeter was used. In view of GPS navigator all-weather operation posibility, its capability of working without a free vision of measured polygon and reasonable price, the obtained result indicates, that it is efficient to use such device to solve some planimetric tasks. For instance, such tasks can include drainage area or agricultural land area measurement. Another advantages of GPS navigation device are pocket size and weight,

simplicity of use and long time of autonomous work without battery recharge.

– The method of determination of areas and perimeters with the usage of fixed coordinates and computer programs (conversion of geographical coordinates into the rectangular ones) do not have the advantages over immediate measurement (bypassing the area), furthermore, the additional error is inserted. However, in some cases, when determination of certain location of polygon is required, the coordinates' fixation is necessary.

The aim of the research [14] was to specify the relation between the accuracy of area measurement and land plot size (quadrate areas were increased by 3.5 times in comparison to former researches). This time GPS-navigator GPSMAP 78S and GPS+GLONASS navigator Garmin eTrex 30 were used. In addition, the aim was to indicate, which system has better accuracy and reliability.

To accomplish the task, three quadrates were divided on location with their sides 50×50, 100×100 and 150×150 meters, which also had one common vertex (Fig. 1). Each quadrate was repeatedly bypassed separately with navigators Garmin GPSMAP 78S and Garmin eTrex 30. The areas of the quadrates were determined with the usage of special programs installed on the devices. In addition to that, without a preliminary laying and in extreme conditions (darkness, rainy weather, high trees and buildings), the following areas were measured: rectangular woodlands with their areas 52460 m^2 and 163590 m^2 (the areas were additionally determined with the usage of satellite maps on www.yandex.ru) and two curvilinear lakes in Sosnovka park in Saint-Petersburg.

The obtained results were compared with the theoretical values of quadrates' areas and the dependence of the relative accuracy versus land plot area was built. As a result, trend lines were obtained for each system with the usage of methods of mathematical statistics (Fig. 2).

As a result of the diagram analysis and general supervision, the following conclusion was made:

– The relative error decreases on greater areas, but not as fast as was assigned in former research [13]. The accuracy of GPS navigator measurement can be compared with precision of electronic tachymeter if the measured area is larger than 15 hectares.

– Navigator supporting GPS+GLONASS system provides higher accuracy in comparison with navigator using only GPS system. Moreover, if the measured area is initially unknown, combined GPS+GLONASS system provides greater reliability (less rude errors during the measurement) and smaller quantity of bypasses is required.

– The relative error was not increased due to the extreme measuring conditions in case of GPS+GLONASS system, what confirms its reliability. The results, obtained during the measurement of the areas without preliminary laying, support the dependence achieved on the divided quadrates.

In work [15] navigator Garmin eTrex 30 with GPS+GLONASS system was used for testing the above-mentioned method while measuring a curvilinear area, in particular, Chornoye lake in Gatchina and its drainage area (Fig. 3).

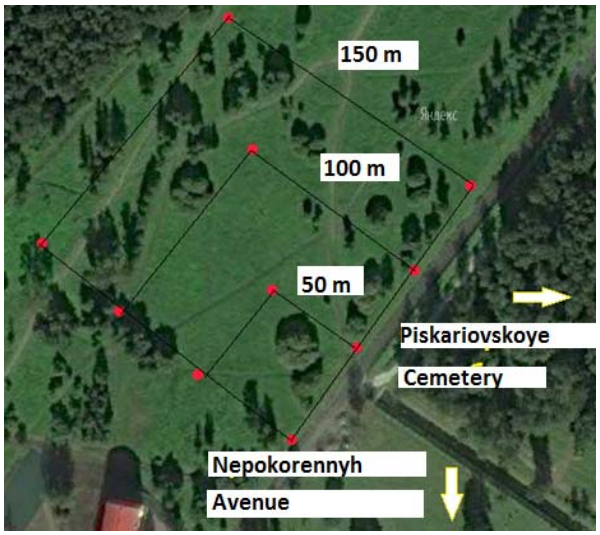

Fig. 1. Layout of quadrates

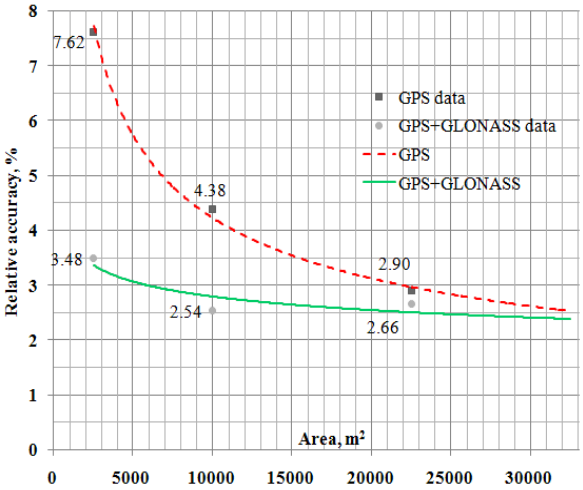

Fig. 2. Trend lines for the research [14]

To sum up, the following conclusions were made:

- When the curvilinear land plot size reaches the value of 10 hectares (Fig. 3), it is possible to obtain the results as accurate as if the graphical method was used, namely 1 % [15].
- The absolute accuracy of coordinate determination is more or less constant — approximately 3 meters in case of at least 10 satellites being within the navigator range [16]. In addition, in case of GPS+GLONASS system, the absolute accuracy faintly depends on measurement conditions and on dense vegetation presence around the water object in particular.

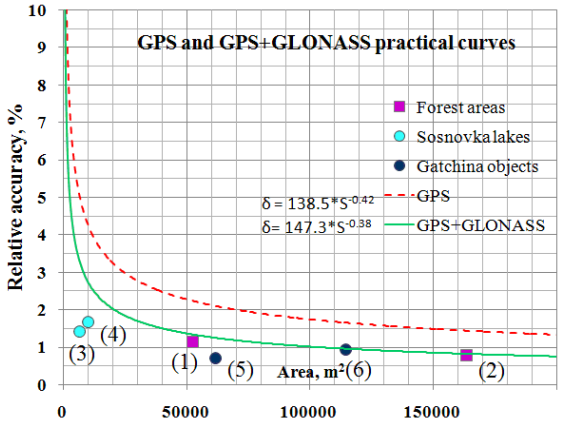

Fig. 3. Practical curves (trend lines) and real objects: 1, 2 – forest areas; 3, 4 – Sosnovka lakes; 5 – Chornoye lake; 6 – drainage area

III CONCLUSION

Taking everything into account, the satellite navigators, especially with GPS+GLONASS system support, are the promising alternative to handle different planimetric tasks, particularly, water surface and drainage area measurement in monitoring of ecosystems.

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