Morphometric and hydrological features of the lakes of the Sergachsky municipal district (Nizhny Novgorod region, Russia)

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Abstract. The article presents the results of a study of the morphometric and hydrological features of the lakes of the Sergachsky municipal district (Nizhny Novgorod region, Russia), lying in the north of the Privolzhskaya upland. A bathymetric survey was carried out on the lakes of the researched territory from the board of an inflatable boat, using an echo sounder, combined with a navigator. The results of the field research were processed using the geographic information program QGIS, digital models of the relief of the six researched lakes were created, and their main morphometric and hydrological characteristics were calculated. Based on the analysis of the morphometric characteristics of the lakes and data on the landscape features of their surroundings, conclusions were drawn about the origin of the lake basins. Two genetic groups of lakes within the researched area are identified: karst and riverbed (oxbow lake).

1 Introduction

The history of the research of lakes on the territory of the Nizhny Novgorod region (Russia) began in the XVIII century and is associated with the works of P. S. Pallas and I. I. Lepekhin. In the XIX century some aspects of the research of the lakes of the Nizhny Novgorod province were affected by the expedition of V. V. Dokuchaev. However, until the XXI century, the research of morphometric features of lake basins was practically not carried out, and therefore conclusions about their genesis were often speculative. Currently, reliable data on the relief of lake basins are available only for some parts of the Nizhny Novgorod Region [1].

Lakes are a major element of the hydrographic network and a structural component of the landscape. Determining the features of the relief of the lake basin is an important step towards determining the age of the lake, its origin, its current state and developing a forecast for future development. Morphometric and hydrological features of lakes are of interest to hydrologists [2], biologists [3-5], ecologists [6-7], as well as tourists, visiting

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lakes for recreation. Reliable data on the relief of the lake basin and the main hydrological characteristics of the lakes of the Sergachsky municipal district have not yet been obtained.

This paper solves the problem of determining the genesis of lake basins, lying within the Sergachsky municipal district of the Nizhny Novgorod region of the Volga Upland on the basis of their morphometric characteristics.

2 Materials and methods

Aim: to establish the morphometric and hydrological characteristics of lake basins within the Sergachsky municipal district of the Nizhny Novgorod region (north of the Volga Upland).

Tasks:

- To analyze the physical and geographical features of the surroundings of the lake basins of the Sergachsky municipal district.
- To conduct a bathymetric survey.
- To create bathymetric maps of lake basins of the Sergachsky municipal district.
- On the basis of GIS analysis of bathymetric maps of lake basins of the Sergachsky municipal district, calculate their main hydrological and morphometric characteristics.
- To hypothesize the origin of the lake basins of the Sergachsky municipal district.

Object of the research: lakes, lying within the Sergachsky municipal district of the Nizhny Novgorod region.

Subject of the research: morphological and hydrological characteristics of the lake basins within the Sergachsky municipal district of the Nizhny Novgorod region.

Research hypothesis: the researched lakes have a diverse genesis, determined by landscape conditions.

In 2020, the authors carried out work on the research of the relief of lake basins within the Sergachsky municipal district.

The research was conducted on the basis of the analysis of thematic maps, literature sources, remote sensing data, and the results of our own field research. In the preparation of the research work, the following methods were used: expedition, cartographic, analysis of remote sensing data, analysis of literature and thematic maps, geoinformation, mathematical. Depth measurements were carried out from the side of an inflatable boat, using an echo sounder, combined with a navigator. To build a digital model of the lake topography and calculate their hydrological characteristics, the QGIS was used.

3 Results

The lithogenic base of the researched area is represented by Quaternary deposits (limestones, dolomites, marls, sands). The most widespread deposits in the area are those of the Jurassic system (marl clays, limestones and sandstones) [8]. Quaternary deposits are represented by eluvial-deluvial and alluvial deposits (yellow-brown loams with boulders, dark and red-brown clays of Mezhpyanye and river sediments) [9]. The terrain is complicated by a dense ridge-and-ravine network.

Climate is temperate continental, humid, with moderately severe and snowy winters and warm summers.

The main rivers of the researched area are Piana, Urga, Anda, Pica.

On the territory of the Sergachsky municipal district dark gray and gray forest soils predominate, which, due to the long-standing economic development of the territory, are subject to water erosion over a significant area.

The forest area of the region is 17.7%. The researched lakes are located in the forest-steppe zone (the northern forest-steppe subzone) [10] on the right bank of the Volga River within the forest-steppe region, the Pyansko-Volzhsky and Pyansko-Sursky subdistricts [11]. The territory of the Sergachsky municipal district lies within two landscape regions: the eastern part within the landscape region of the Prisurskaya forest–steppe, the western part in the Central steppe landscape region [12]. There are 8 types of landscapes within the Sergachsky municipal district [13].

The digital terrain model is based on depth measurement data. Based on the results of field researches, digital bathymetric maps of lake basins were created (Figures 1-5) and the main hydrological and morphometric characteristics were calculated (Table 1).

Table 1. Morphometric characteristics of the lakes of the Sergachsky municipal district.

Lake	Number of depth measurement points	Maximum depth, m	Average depth, m	Lake length, m	Maximum width, m	Average width, m	Mirror area, m^2	Water volume, m^3	Shoreline length, m	Shoreline development	Absolute height of the water surface in the lake above sea level, m	Shape of the basin	Indicator of openness
Bezdonnoe	1020	12.6	3.2	484	290	201	97317	314917	1277	1.15	131	0.25 conical	3.0 open
Lopatino	707	10.8	4.6	386	317	208	80471	376650	1133	1.13	145	0.43 parabolic	1.7 open
Tepseskul'	335	4.5	2.3	164	139	112	18428	42517	490	1.01	88	0.51 parabolic	0.8 open
Dolgoe	9544	6.3	1.8	1505	100	84	125988	238231	3237	2.57	76	0.29 conical	7.0 Well open
Western Staritsa	485	2.9	1	89	310	256	22809	22371	1493	2.81	78	0.34 conical	2.3 open
Eastern Staritsa	534	2.7	1	808	64	30	24010	21578	1665	3.03	78	0.37 conical	2.4 open

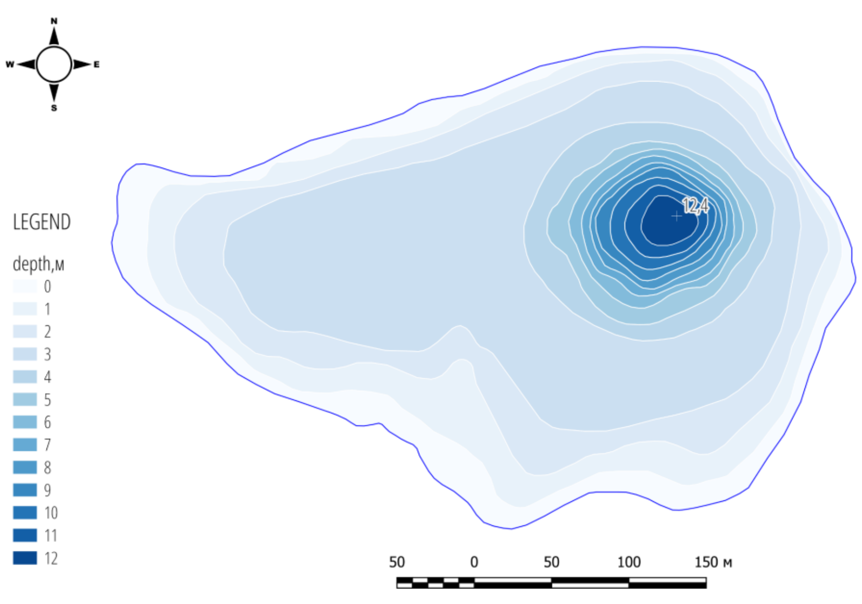

Fig. 1. Bathymetric map of the lake Bezdonnoe.

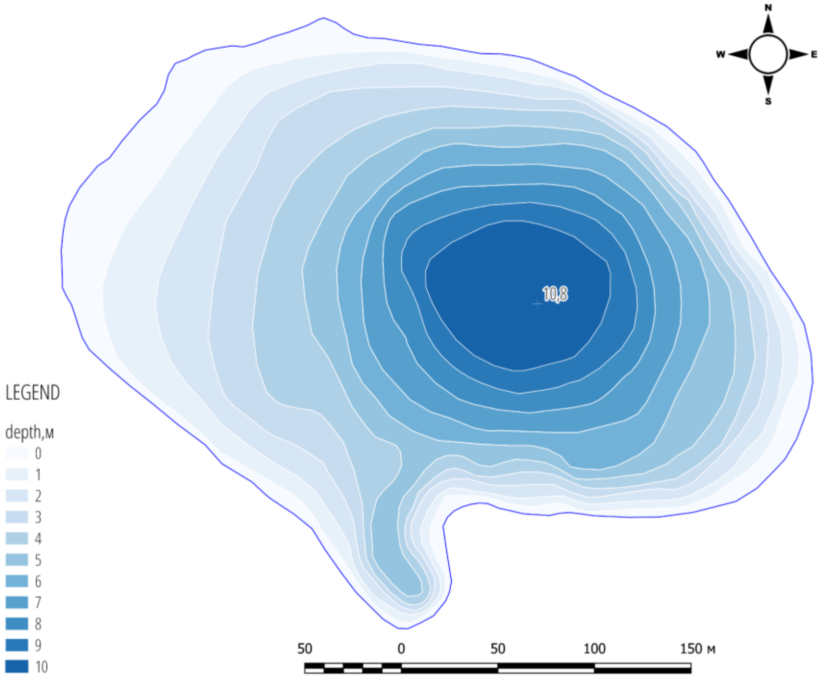

Fig. 2. Bathymetric map of the lake Lopatino.

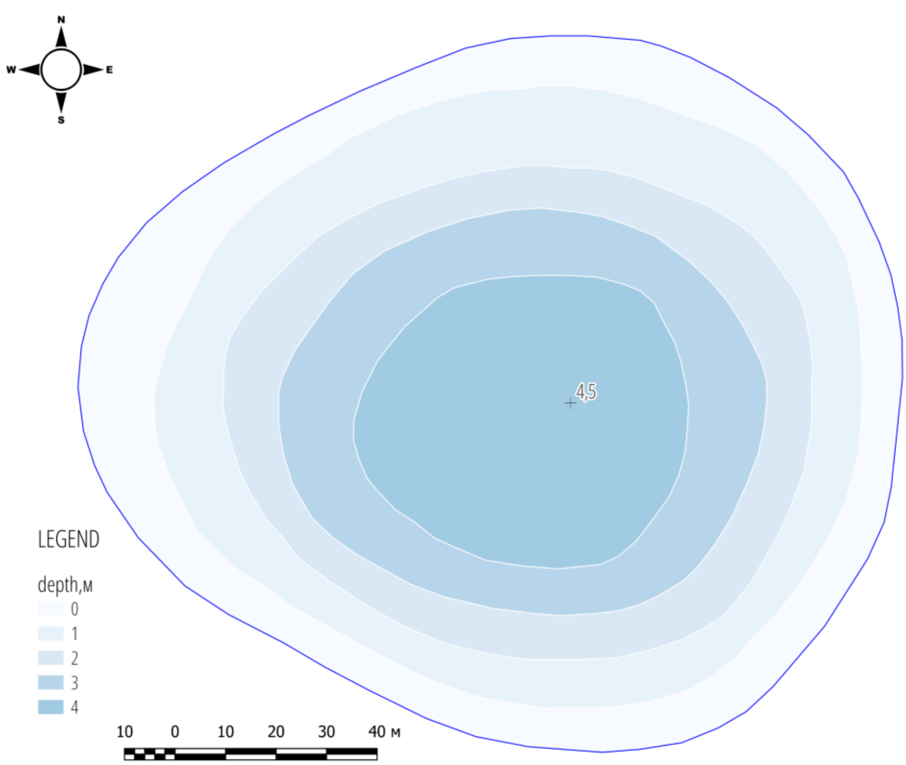

Fig. 3. Bathymetric map of the lake Tepseskul'.

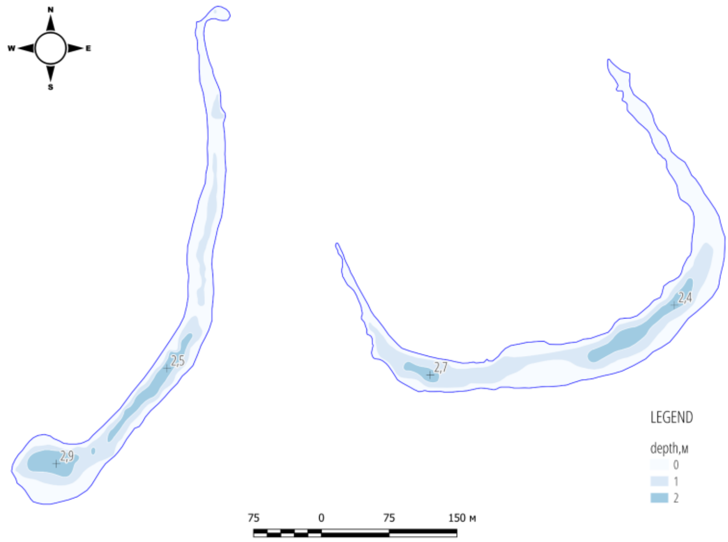

Fig. 4. Bathymetric map of the lakes Western and Eastern Staritsa.

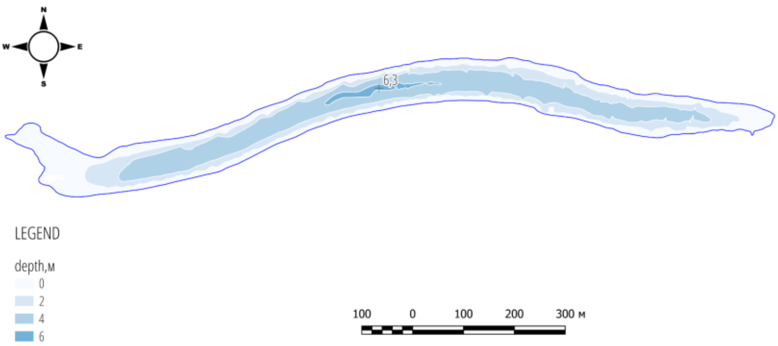

Fig. 5. Bathymetric map of the lake Dolgoe.

4 Discussion

The morphometric features of a part of the researched lakes have features, characteristic for karst lakes: a funnel-shaped basin, rounded shoreline configuration, weak shoreline development, large depth differences and steep slopes of the sides of the basin, relatively large average depths (lakes Bezdonnoe, Lopatino, Tepseskul').

The lakes Dolgoe, Western Staritsa, and Eastern Staritsa have another characteristic: insignificant average depths, a strongly developed coastline, a linear configuration, and relatively smooth depth amplitudes (Table 1).

The position of the researched lakes on the floodplain, the nature of the lithogenic base and the geomorphological features of the lake basins and the adjacent territory allow us to conclude that the lakes Dolgoe, Western Staritsa, and Eastern Staritsa are oxbow lakes.

5 Conclusion

The genesis, morphometric and hydrological characteristics of lakes are interrelated with the landscape features of the territory. Spatial patterns of the origin of the genesis of lake basins are determined by the landscape structure of the territory and can be reliably established only in close connection with landscape researches. The lakes of the researched area were formed under the strong influence of local landscape conditions – the development of karst and riverbed processes.

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