The Use of Geodetic Methods in the Technical Examination of Hydraulic Structures from Soil Materials

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Abstract. In our country, particular attention is paid to the safety of operating hydraulic structures, operational reliability of which is an integral part of the overall security of the Russian Federation. The security and energetic efficiency of hydraulic structures is regulated by the Town Planning Code of the Russian Federation, federal laws, and the code of rules “Hydrotechnical Structures. Key Points” [1-4]. Recommendation on the implementation of federal state construction supervision by officials of Rostekhnadzor (Federal Environmental, Industrial and Nuclear Supervision Service of Russia) during the construction and reconstruction of hydraulic structures are contained in methodological recommendations [5, 6]. Investigation of the operational reliability of soil hydraulic structures issue and the development of measures to extend the established term of their operation is a pressing challenge. To solve this challenge, the technical examination of hydraulic structures from soil materials, which allows us to assess the state of strength properties and the stress-strain state of dams, dikes, etc. is of great importance. The vast majority of soil dams are checked only visually, which does not allow to reliably assess their strength properties. To determine the development of infractions in the body of the dam, to determine the amount of washed soil at hydraulic structures, etc. geodetic methods of research can be used, which, compared to the visual methods, are more accurate.

In order to determine the capabilities of geodetic methods for determining the volume of washed soils at hydraulic structures, the authors carried out experimental work to determine the volume of washed soils of the coast protection structure “Gluhaya Damba” (“Deaf Dam”) in the ash-disposal area near Zaimskiy island in the Omsk region.

1. Introduction
There is a huge number of dams, dikes and other hydraulic structures that are used on the territory of our country, which over the past decades have increased the risk of accidents due to various violations associated with not complying with a certain production technology and organization of work during their construction, operating rules and others.

Hydraulic structures from soil materials are the source of potential threat, since with their possible violation of the territory associated with the ablation of the soil by the wind, the flow, settlement of the structure, etc. settlements and other objects may be destroyed. Thus, the examination of the technical condition of soil dams and dikes is an integral part of the hydraulic structure safety monitoring.

Technical examination of the state of hydraulic structures from soil materials should be aimed at solving the following problems: assessment of the current state and operational reliability of hydraulic structures; forecast of possible changes in the state and safety of hydraulic structures over time. The
solution of these problems is based on the joint use of data analysis results from instrumental and visual field methods [7-9].

The aim of this research is to consider the use of geodetic methods for determining the volume of washed soils in hydraulic structures (for example, “Gluhaya Damba”) based on practical research.

2. Materials and methods
To achieve the aim of the research, it is necessary to solve the following tasks: to determine the actual amount of the washed-up soil of the coast protection structure “Gluhaya Damba” made on the basis of design estimation documentation of “Zolootval” (“Ash-disposal”); to determine the actual amount of the washed-up soil of the coast protection structure “Gluhaya Damba” taking into account the changes that have occurred with the structure in accordance with regulatory documents (the ablation of the soil by the wind, the flow, settlement of the structure); to determine the correspondence of the volume of the coast protection structure to the volume of the washed-up soil.

Scientific publications in Russian editions, departmental building codes and practical experience served as the informational basis of the research. Empirical, theoretical and quantitative research methods were used in the article.

The research was carried out by using visual inspection, photographing the object of the research, and through conducting necessary measurements using an electronic total station TRIMBLE 3305DR, computed roulette and by the method of calculations made on the basis of the results of an expert examination, the execution of drafts, the analysis of regulatory and technical documentation and the presented materials.

3. Results and discussion
The coast protection structure “Gluhaya Damba” is located in the ash-disposal area near Zaimskiy island on 1809-1810 km of the Irtysh River, below the city of Omsk. During expert inspections of this structure, a geodetic survey was carried out. The TGK-1 (H=70,78 m) and TGK-2 (H=71,97) were taken as the initial geodetic points.

The length of “Gluhaya Damba” is 70 m, the average width of the ridge is 50 m, the average mark of the top of the dam, taking into account the mark of TGK-1 is equal to 70,70 m, standing water level mark at the time of the research is 67,49 m.

The authors had the following tasks:
1. What is the actual amount of the washed-up soil of the coast protection structure “Gluhaya Damba”?
2. What was the actual amount of the washed-up soil of the coast protection structure “Gluhaya Damba” as of September 6, 2017?
3. Does the volume of the the coast protection structure “Gluhaya Damba” correspond to the volume of the washed-up soil?

As a result of a construction and technical examination, a geodetic survey was performed to determine the volume of the washed-up soil of the coast protection structure “Gluhaya Damba” with regard to the first task (Picture 1).

According to the survey results, the average length of the dam was 70,0 m, and the average width was 50,0 m. The mark of the TGK-1 benchmark in the dam area was taken to be 70.78 m, the average mark of the top of the dam was 70,5 m, standing water level mark at the moment of the survey was 67,5 m. as of 11.11.2018 and was 67,00 m. as of 26.11.2018.
The survey of LLC “Priboy” conducted in October 2016 was adopted as an initial survey. The volume of the coast protection structure “Gluhaya Damba” is $30276 \text{ m}^3 \pm 2725 \text{ m}^3$ according to the data of the expert survey (Picture 2).

The calculation of volumes was performed in the AutoCad Civil 3D 2010 RU software product. Triangulation with a side of a square of 10 m. was adopted as a method of calculation.

At the request of the Omsk branch of OS “TGC-11” the survey of LLC “NPF “GEO” conducted in October 2016 was researched as the initial survey, however according to the survey of LLC “NPF “GEO”, the duct was already blocked, because the markers in the center of the duct were 69 m., while the standing water level mark in Autumn does not exceed 68 m. This survey cannot be used as an initial, because it does not reflect the primary state of Zaimskaya duct.

**Figure 1.** “Gluhaya Damba” plan.

The survey of LLC “Priboy” conducted in October 2016 was adopted as an initial survey. The volume of the coast protection structure “Gluhaya Damba” is $30276 \text{ m}^3 \pm 2725 \text{ m}^3$ according to the data of the expert survey (Picture 2).

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Figure 2. Cartogram for calculating the volume of the mound taking into account the initial survey of LLC “Priboy” performed in October 2016.

The dam volume calculated in relation to this survey is only 18260±1643 m$^3$, excluding previously washed-up soil (Picture 3).

When solving the second task of the research, which is determining the actual volume of the washed-up soil of the coast protection structure “Gluhaya Damba” taking into account the changes that have occurred with the structure in accordance with regulatory documents [10, 11] (the ablation of the soil by the wind, the flow, settlement of the structure), the following results were achieved: the actual volume of the washed-up soil of the coast protection structure “Gluhaya Damba” as of September 6, 2017 was 11.5% more than the volume determined by the results of the expert survey, which was 33758±3038 m$^3$ if the survey of LLC “Priboy” is adopted as the initial, and 20360±1832 m$^3$ if the survey of LLC “NPF “GEO” is adopted as the initial.
Figure 3. Cartogram for calculating the volume of the mound taking into account the initial survey of LLC “NPF “GEO” performed at the end October 2016.

As for the third task, we can state the discrepancy between the volume of the coast protection structure and the volume of the washed-up soil, because a decrease in the volume of the coast protection structure happened during the year due to the ablation of the soil by the wind, the flow and settlement of the structure. The volume of the coast protection structure in accordance with the regulatory documents [12-15] decreased by about 11.5%. According to the expert calculations, in 2017 it was 33758±3038 m$^3$ and as of the research date 11.11.2018, 26.11.2018 – was 30276±2725 m$^3$ if the survey of LLC “Priboy” is adopted as the initial, and in 2016 it was 20360±1832 m$^3$ if the survey of LLC “NPF “GEO” is adopted as the initial.

4. Conclusion
1. The use of geodetic methods in combination with modern instruments and technologies make it possible to accurately determine the volume of hydraulic structures.
2. The accuracy of the washed-up soil volume calculation with a side of triangulation up to 10 m. is 10%. If higher accuracy is required, the side of the square must be reduced to 5 m.

5. Recommendations
1. These geodetic methods can be recommended for calculating the volume of any bulk materials (sand, coal, gravel, etc.), while it is necessary to have an accurate plan of the surface on which this material is stored.
2. For more expensive materials (e.g. coal), the accuracy of determining the volume can be 5%, which means that the side of the square should be no more than 5 m.
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