About control of industrial stability of dams of the fuel and energy complex facilities in Kuzbass on the basis of application of shallow-depth geophysical technologies

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Abstract. It has been established that the problem of using applied low-depth geophysical technologies to ensure the sustainability of industrial and civil construction in Kuzbass is as follows: on the one hand, there is a significant increase in measurement accuracy and efficiency, and on the other hand, there is the absence of new models that allow interpretation of not only base soils and geological objects, but also their condition. The research provides a generalization of practical experience in creating physical and geological models. Based on the studies, it was found that applied shallow geophysical technologies are more informative and automated than traditional ones. The practical use of this theory is to ensure the sustainability of industrial and civil construction, and, consequently, the development of the Kuzbass territory.

1. Introduction

The analysis performed by the authors indicates that the possibilities of geophysical technologies are much wider than prospecting or survey work [1-9]. Their use implements modern trends in the development of technologies such as improving the accuracy, efficiency and automation of processes in measurements and processing of received information. Therefore, they are in demand for the study of natural and technogenic geological processes in the development of the territory of the Kemerovo region to ensure safety (including objects of the fuel and energy complex). Region is characterized by high urbanization and concentration of production, which has important scientific and practical value for it. This is especially true for fuel and energy complex facilities that are disrupted by mining, which dramatically changes the natural characteristics of rock massifs and reduces the stability of the bases [10]. Information about these processes is essential to ensure the design of fuel and energy complex facilities, as well as their safety during operation [5; 7; 10]. The theory of digital geophysical support for the sustainability of industrial and civil construction of dams of fuel and energy complex facilities has not been developed yet [9]. Traditional technologies of geophysical surveys in areas of territorial development are currently focused on mapping and studying the signs of occurrence of mineral deposits. The development of digital geophysical support for the sustainability of dams of fuel and energy complex facilities is constrained by the lack of new mathematical models of deformation processes that ensure the adequacy of the condition of the base soils, as well as geological structures [1-9]. The main condition for such models is zoning of soils, identification of geological structures and identification of their state. The purpose of this theory is the collection, storage, processing and analysis of information on zoning of soils, the allocation of geological structures and identification of
their condition in areas of fuel and energy complex facilities. The results obtained in this way will provide an information basis for obtaining new knowledge about the state of soils and geological structures, which will not only solve the problem of sustainability of dams of fuel and energy complex facilities, but also a number of other national economic problems. The above allows us to consider the development of the theory and methods of the theory of usage of applied shallow geophysical technologies to ensure the industrial sustainability of dams of fuel and energy complex facilities in Kuzbass relevant. The practical use of its results is to ensure the industrial sustainability of dams of fuel and energy complex facilities for the development of territories. The main aspects of multi-purpose application of applied low-depth geophysical technologies to ensure the industrial stability of dams of fuel and energy complex facilities in Kuzbass will be considered on the example of taking into account the water content and seismicity of the territory of Kuzbass.

2. Materials and methods
Currently, the number of dams at fuel and energy complex facilities in Kuzbass is more than two hundred. The model of their industrial stability includes a subsystems of structure and water cut. Therefore, first of all, we will consider the role of information about the water content of dams of fuel and energy complex facilities obtained through the use of applied low-depth geophysical technologies. It is known that the regime of groundwater depends on many factors. The high level of underground water occurrence hinders the development of land development and construction growth, as well as increases the level of its seismicity. Waterlogged rock mass reduces its stability and requires preventive measures. The violation of a significant territory of Kuzbass by mining operations dramatically changes the natural hydrogeological regime [10]. Traditional technologies for searching for underground water are based on drilling wells, which is characterized by significantly higher time and financial costs, as well as the duration of research. These are discrete (spot) measurements with a rare network of exploration lines that make it difficult to build digital models of groundwater occurrence, which does not provide reliability and accuracy in determining their quantitative parameters. Traditional geophysics for the search for groundwater in the difficult geological conditions of mountainous areas and in urban areas is not always effective. Electrical exploration of the method of vertical electrical sounding (VES) in the search for groundwater of crack type in mountainous areas is laborious. The progressive method of pulsed electrical exploration in settlements often does not work due to strong electromagnetic interference.

3. Results
Consider the results obtained on the basis of these subsystems of the model in more detail on a number of examples. The analysis of electrical resistance during shallow applied geophysical studies is of great importance, since it is an indicator of the water content of soils and geological structures. The electrical resistance of most soils is determined mainly by porosity, water saturation and clay content. An increase in soil moisture and clay content leads to a decrease in specific electrical resistivity (SER). Moreover, an increase in the mineralization of the fluid in the pores also leads to a decrease in resistivity. The method of electrotomography allows you to explore the soil massif almost continuously. This makes it possible to fully explore any structure and determine the location of even small-irrigated areas. The method of electrotomography is the development of VES. In the method of electrotomography, first all electrodes are grounded, and then they are connected to current and measuring circuits using a switch. In other words, the same electrodes grounded on the profile are repeatedly used as the supply and measuring electrodes. The number of electrodes in the used equipment is 64, while the electrodes are structurally connected by a multicore cable, thereby forming an electrical reconnaissance spit.

A geoelectric section along profile 4 at one of the objects in the Kemerovo region is shown in figure 1.
Unlike conventional VES, where the interpretation is carried out in the framework of horizontally layered models of the geoelectric section, the data of electrotomography are interpreted in the framework of two-dimensional and three-dimensional models.

At a distance of 25–200 m from the beginning of the profile to a depth of 9–10 m a zone with resistivity is predominantly 20–35 Ohm·m, corresponding to clay soils. In the lower part of the section a zone with resistivity of 25–80 Ohm·m was identified, which corresponds to clay and sandy soils of the base of the object. At a distance of 150-200 m from the beginning of the profile, a region of reduced resistivity (less than 20 Ohm·m) corresponding to the zone with increased soil moisture was revealed.

4. Discussion
Based on the foregoing, we can conclude that traditional technologies for ensuring the industrial sustainability of dams of fuel and energy complex facilities in Kuzbass were based on the principle of minimum costs $C$, in other words, whose objective function was unambiguous and had the following form:

$$ C = \sum a_i x_i = \min $$

where $a_i$ is the factor; $x_i$ is the cost of the i-th technological process.

According to the authors, the mathematical basis of the proposed approach to ensure the stability of construction objects in Kuzbass is the following criterion that describes the zoning of territories:

$$ J_i \neq J_0 $$

where $J_i$ - investigated trait; $J_0$ - its normative value.

5. Conclusion
Based on the research, the following conclusions are made:

- It is established that the model of industrial sustainability of dams of fuel and energy complex facilities in Kuzbass includes subsystems of water cut and construction of territories.
- It has been established that the subsystem of water cut in the territories, implemented on the basis of the method of electrotomography, allows us to study the soil massif almost continuously, which makes it possible to monitor their condition and control the industrial safety of dams.
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