MINING AND METALLURGY INSTITUTE BOR
UDK: 622

ISSN: 2334-8836 (Štampano izdanje)
ISSN: 2406-1395 (Online)

UDK: 622.79(282.1)(045)=111
DOI: 10.5937/mmeb2401021T

Received: 08.05.2024.
Revised: 20.05.2024.
Accepted: 23.05.2024.

Original Scientific Paper
Mining

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PROJECT SOLUTION OF INTERVENTION MEASURES AT THE DAM OF THE "ŠAŠKI POTOK" TAILING DUMP[**]

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Abstract

There was an increase in the groundwater level and increased waterlogging of the terrain at the "Šaški potok" flotation tailing dump in Majdanpek, due to a damage of drainage collector. The stability of man-made materials of the landfills is directly dependent on the position of the free water surface in the body of the landfill. The rise of the underground water level leads to a decrease in the strength parameters of the materials from which the dam is built, which reduces the safety factor of the outer slope. For the purpose of interventional lowering the high level of underground water in the main dam body of the landfill, a hydrodynamic terrain model was created and various conceptual solutions were evaluated, using the hydrodynamic analysis. A group of wells was selected as the most optimal technical solution for lowering the groundwater level below the designed elevation.

Keywords: *flotation tailing dump, high groundwater level, hydrodynamic model, group of wells*

1 INTRODUCTION

The “Šaški potok” tailing dump is located 3 km south of Majdanpek. It serves as a retention tailing dump, which receives tailings from the “Valja Fundata” flotation tailing dump in emergency cases.

For the purpose of draining the tailing dump, a drainage system of pipelines, wrapped in geotextile, was installed in the basement. During January 2024, the main collector was damaged. Shortly after that, the observation piezometers showed an increase in the underground water level, as well as an increase in the water level on the terrain surface. The last applied geological surveys were conducted in 2022. As a part of them, the hydrogeological surveys of the site in question were also carried out. Since there was a need to define a technical solution for lowering and regulating the underground water level, the continuation of numerical interpret-

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[**] *This work was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract on realization and financing of the scientific research work of the Mining and Metallurgy Institute Bor in 2024, Contract No.: 451-03-66/2024-03/ 200052.*

tation of the collected and presented research results with the analyses of various technical solutions was undertaken.

This paper presents the basic concept and technical solution of groundwater level regulation and expected effects of the system [1]. The aim of this paper is to present a variant of solution for lowering the groundwater level, using the method of hydrodynamic analysis

2 DEVELOPMENT OF A HYDRODYNAMIC MODEL

Due to the need to develop a technical solution for intervention defense of the dam on the accidental tailing dump, the development of a hydrodynamic (mathematical) model of this area was started [2]. The model itself was created using the finite difference method, using the MODFLOW package. The space of the hydrodynamic model is along the Y axis from 7,576,300 to 7,576,880 that is along the X axis from 4,917,240 to 4,917,602. The model has a rectangular shape with dimensions of 580×362 m, i.e. a total area of 0.21 km^2. Discretization the area of water flow was done with 5×5 m cells. The total number of cells per model layer is 8,352.

On the basis of everything stated, and from the aspect of the issued regime, it can be concluded that the largest underground water reserves are formed in the body of flotation sand with the mean value of filtration coefficient of $2.5*10^{-5}$ m/s. The depth to water ranges from about 14 to about 38 m, measured from the ground surface. The geometry of flotation sand is predisposed by the paleomorphology of terrain.

Drainage of flotation sand is artificial, that is, via a built-in drainage system. By analyzing the level of underground water and reconnaissance in the field, it can be concluded that the drainage system was very functional, from the aspect of hydrogeological profession.

The general conclusion is that a spring with a free level is formed within the flotation tailings on the entire area of retention tailing dump. The other hydrogeological collectors with different filtration characteristics are also registered, but they are sparsely distributed, so they do not significantly participate in the total reserves of underground water. Also, conditionally waterless parts of the terrain are separated, which are represented by the compact or crushed shale, andesites and clayey material.

Analyzing the conditions of recharge and drainage of groundwater, the boundary conditions were set on the hydrodynamic model that most closely describe the natural flow conditions. The applied boundary conditions are shown in Figure 1.

The so-called external boundary conditions that define the flow area and conditions of recharge and drainage and **internal boundary conditions** were used for the hydrodynamic model.

The following types were used for the external boundary conditions:

- CHD (Constant Head) – this type of boundary condition was used on the western part of the model, which simulates the constant flow of fluid into the tailing dump body;

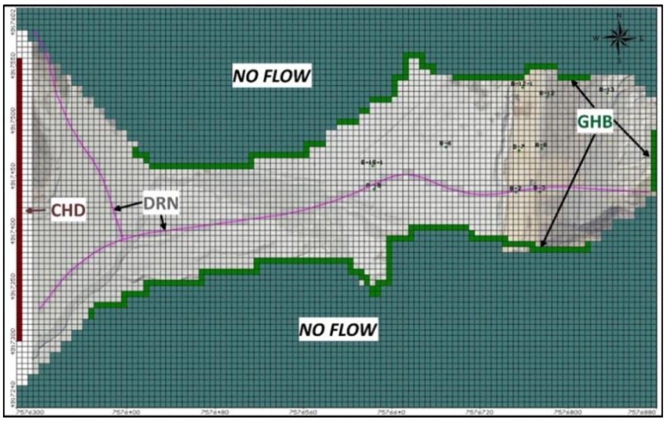

Figure 1 *Applied boundary conditions*

- GHB (General Head Boundary) – used for the northern and southern part of the model, which simulates the lateral inflow and outflow of groundwater; it was also used as a boundary condition on the east to simulate runoff to the lake;

The following types were used for the internal boundary conditions:

- DRN (Drain) which simulates runoff along the drainage collector.

By calibrating the model, this set of used boundary conditions proved to be the most reliable.

As for the filtration characteristics for the entire body of flotation sand, the mean value was used $k_x = k_x = k_z = 2{,}5 \times 10^{-5}$ m/s.

The calibration result of this model is shown on the hydroisohypse map and residual difference between the calculated and measured groundwater levels for the period 2022-2023, shown in Figure 2.

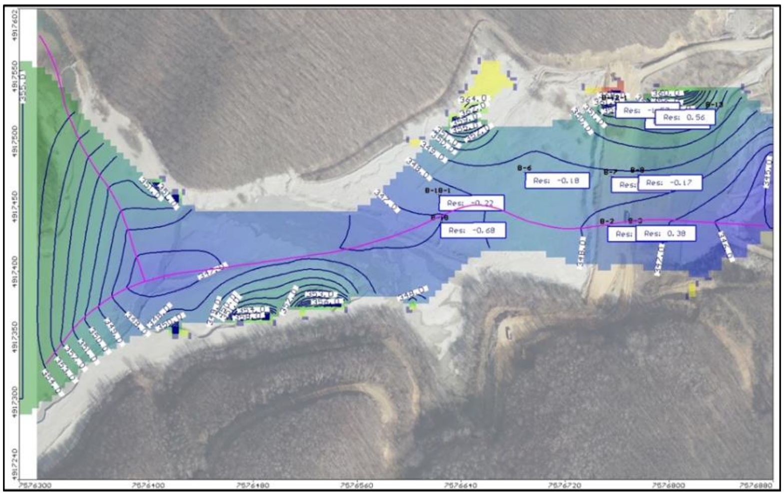

Figure 2 *Hydroisohypse map with residual difference on piezometers for the measured groundwater level based on the observation results from 2022 and 2023*

After it was observed in the field in 2024 that there was a breakdown of the drainage collector, i.e., filling of material inside the drainage itself, daily monitoring of the groundwater level on piezometers was started. A trend of increasing groundwater levels was observed on average of 4-13.5 m on the piezometers B-7, B-8 and B-18.

Based on the analysis of surface and underground water regime, and based on the ortho-photograph and measurement the groundwater level, it is completely clear that there has been a worsening of the groundwater drainage, and thus the danger of dam on the emergent tailing dump.

After that, a new hydrodynamic analysis was carried out, where the same hydrodynamic model was used, but the permeability of drainage collector was reduced. This type of calibration resulted in the following map of hydroisohypsis with the residual difference on piezometers, as shown in Figure 3.

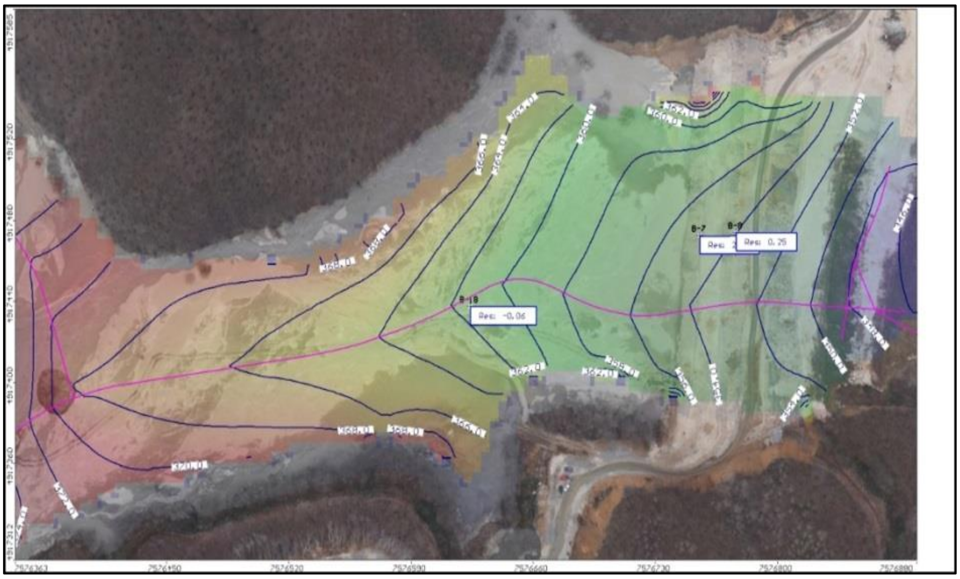

Figure 3 *Map of hydroisohypsis and residual differences based on measurements from April 2024*

Practically, the calibration of model [3] after the drainage collector failure was carried out only by reducing the filtration characteristics of the drainage collector (boundary condition of the DRN type). The model analysis showed an atrophy of the drainage collector permeability, inhomogeneous along its length, ranging from 30-70%.

The change in the groundwater level from 2022 to April 2024 is shown on the map in Figure 4.

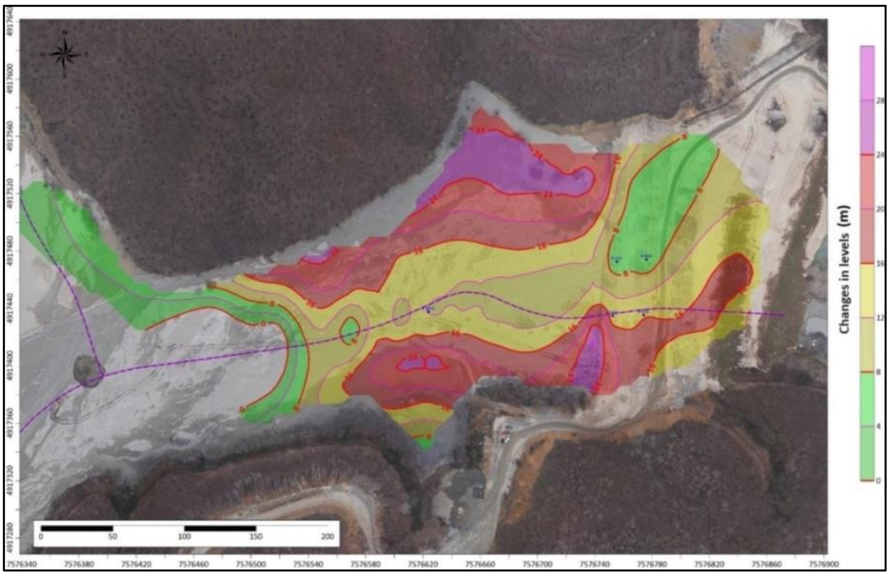

Figure 4 *Change in the groundwater level (in m) for the period November 2022-April 2024*

The highest intensity of groundwater level rise was in the part of contact between the flotation sand and parent rock, but it was also not small along the drainage collector. From all of the above, it is clear that there was a redistribution of the groundwater recharge and drainage conditions as a result of the drainage collector failure.

3 PROJECT SOLUTION OF THE INTERVENTION PROTECTION OF THE DAM

The process of changing the level of underground water was observed, after the failure drainage collector at the tailing dump. It was necessary to find a technical solution that could, in a short period of time, lower the level of underground water, as close as possible to the level before the drainage collector failure, especially immediately around the dam. On the other hand, it needs to have the ability to capture larger amounts of groundwater, if the unfavorable trend of rising levels continues.

The groundwater reduction is done in different ways, the choice of which depends on the specific geological conditions at the location. In choosing the water reduction technology, numerous factors are taken into account: conditions of groundwater occurrence, soil characteristics, thickness of aquifer, volume of drained soil, soil filtration coefficient, duration of water level reduction procedure and technological parameters of technical equipment [4].

Analyzing the different conceptual solutions, it can be concluded that the most suitable facilities for quick intervention on lowering the groundwater level and maintenance at a given elevation are a group of wells. The wells, as objects, are dimensioned so that they can respond to the problem even if the unfavorable trend of underground water level increase continues, and in terms of dam protection.

The designed position (Figure 5) and expected depth of the well are shown in Table 1.

Table 1 *Designed wells*

Well designation	Y	X	Prognostic depth (m)
EB-1	7576759	4917434	50
EB-2	7576758	4917459	52
EB-3	7576763	4917484	50
EB-4	7576734	4917459	45

The wells are dimensioned so that they have the possibility of a wide range of exploitation with capacities from 0.5 l/s to over 10 l/s depending on a further increase of the groundwater level, with the aim of maintenance the groundwater level at the given elevation.

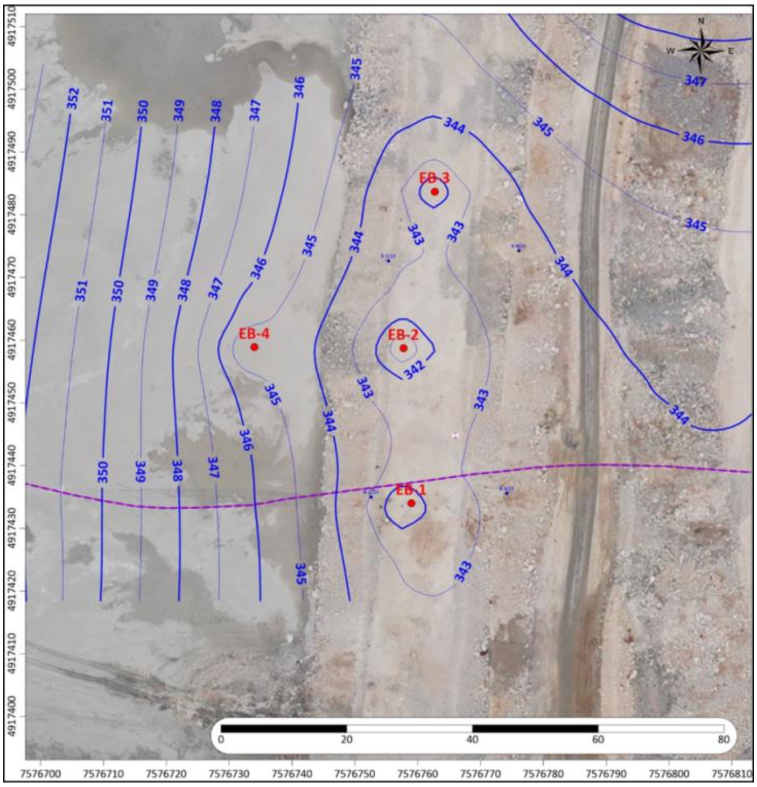

Figure 5 *Map with expected hydroisohypses after four wells are put into operation*

The expected lowering of the groundwater level after the well is put into operation is shown on the map in Figure 6.

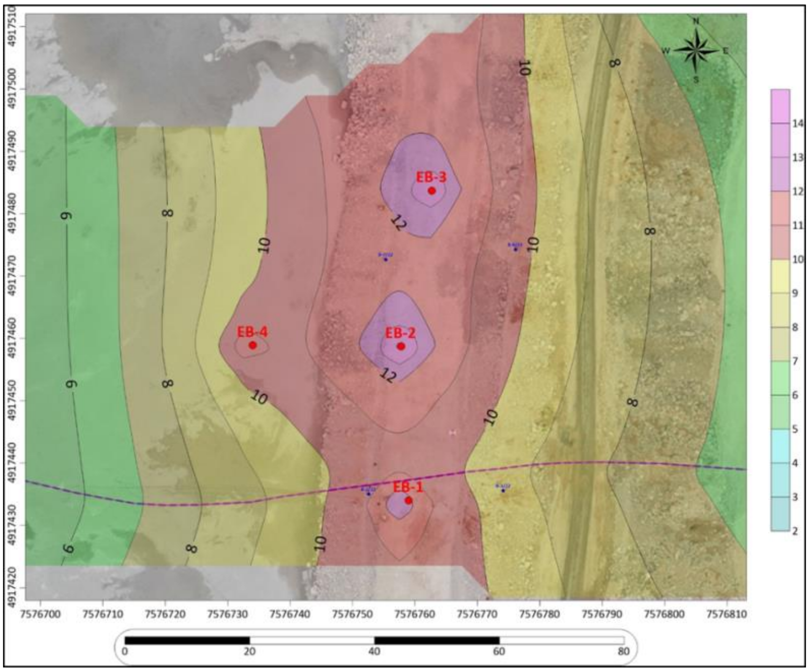

Figure 6 *Expected lowering of the groundwater level*

After construction, the contractor must use his equipment to perform the individual testing of wells and test exploitation (group test of wells), in order to procure the well pumps and electronic equipment for maintenance the level of groundwater at the given elevation after calculation the optimal capacity.

Drainage from the well should be to the nearest receiver, that is, to the pumping station. At the end of all field work, it is necessary to evaluate the technical solution [5] on the effects of dam protection, dimensioning and procurement of well pumps, electrical equipment, and water drainage to the receiver.

CONCLUSION

The predicted hydrogeological measures to lower the level of underground water were designed right next to the main dam of the tailing dump. These measures cannot replace the function of drainage collector in the entire area of the emergent tailing dump "Šaški potok", but represent the intervention measures, in order not to endanger the dam, as a result of the rise in the level of underground and surface water.

Using the hydrodynamic analysis, it was determined that in order to achieve the effects of lowering and regulating the underground water level, it is necessary to build four wells. Their position and expected effects of their installation were modeled and determined. The work presented is the basis for some of the multi-criteria optimization methods and selection the optimal variant of the groundwater defense system.

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