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HYDRODYNAMIC MODELING OF THE VALJA FUNDATA FLOTATION TAILINGS POND IN MAJDANPEK, SERBIA

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Abstract

In order to obtain reliable design solutions for the overburden of the Valja Fundata flotation tailings pond in Majdanpek, Serbia, geotechnical investigations were integrated with detailed hydrogeological investigations. A key segment of the paper is the development of simulation models, which include two cases: the current state of the tailings pond and the future designed state upon reaching the maximum overburden elevation. This approach allows the precise definition of the groundwater regime and flow directions within the tailings pond body, which, along with geomechanical parameters, are crucial factors for confirming the stability of the facility in all phases of its exploitation.

Keywords: *flotation tailings, geotechnical research, hydrogeological model, hydrodynamical model*

1. INTRODUCTION

The flotation tailings pond Valja Fundata in Majdanpek, Serbia, is the main tailings pond where the flotation of the Majdanpek Copper Mine deposits its tailings and has a dual purpose: the first is the disposal of all tailings from the copper mine flotation, and the second is to supply the flotation with process water.

The area of the Valja Fundata tailings dump in Majdanpek has been the subject of intensive geotechnical and hydrogeological research in the period 2019-2025, Figure 1.

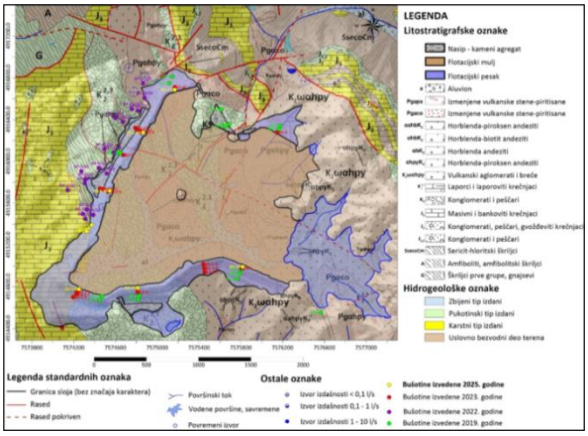


Figure 1. *Hydrogeological map of the Valja Fundata tailings dump research area with a view of the drilled boreholes*

The tailings dump was formed in the former karst lake of Valja Fundata, formed at the contact of karst and non-karst rocks [1].

In order to enable further elevation of the flotation tailings pond and its exploitation in safe and stable conditions to the designed elevation of K+545 m above sea level, given that the stability coefficients in this part of the tailings pond are below the legally prescribed minimum, due to the wide seepage front through the outer slope of the embankment, its rapid rehabilitation is necessary. [2]

2. EXPERIMENTAL

During the research process, it was shown that knowledge of both the tailings pond body itself such as: geometry, filtration characteristics, geomechanical parameters, groundwater level regime, and the geotechnical and hydrogeological characteristics of the native environment were of exceptional importance.

Research methods were applied, including terrain mapping, exploratory drilling with coring, installation of piezometers, preparation of geoelectric profiles, observation of groundwater levels, and preparation of a conceptual hydrogeological and hydrodynamic model.

A network of eight observation piezometers with continuous remote readings has been established.

To understanding the internal boundary conditions, the study of tectonic and karst formations on the hydrodynamic model was important. Based on the results of previous and current research, the tectonic formations were observed and shown on the map in Figure 2.

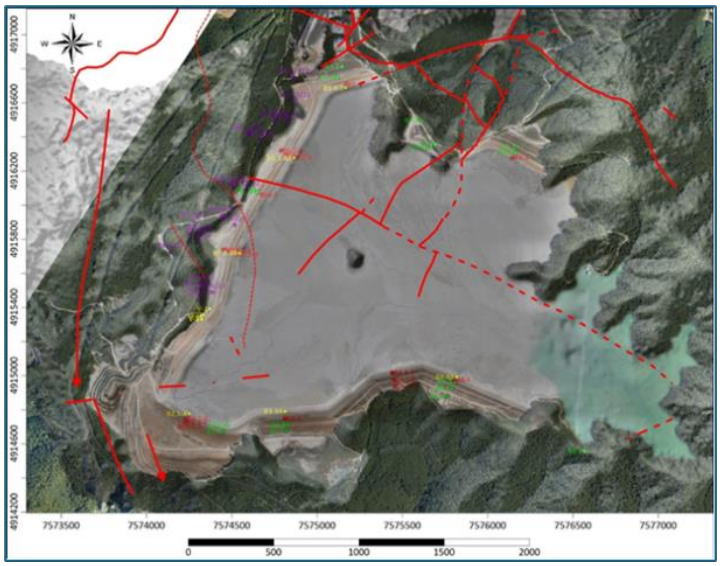


Figure 2. *Tectonic structures in the research area*

The spatial position of the tectonic structures is generally NW-SE. These are younger tectonic structures compared to the regional tectonics, which is N-S according to [1].

An inseparable part of the rupture phenomena on the surface of the research area, but also below the surface of the terrain, was the analysis of karst phenomena and forms within the upper jurassic limestones, with all their geomorphological forms and phenomena, where sinkholes are dominant, but caves and caverns are present as underground forms.

3. RESULTS AND DISCUSSION

A hydrogeological model was first formed, shown in Figure 3, by synthesizing all data from the terrain surface, lithological composition of the boreholes, the bottom of the tailings body, rupture structures. Then a hydrodynamic (mathematical) model was formed.

Synthesizing the results of field and laboratory tests, as well as calibrating the hydrodynamic model, and by the used of model given in [3], hydraulic conductivity was determined for different lithological units. Results are shown in Table 1.

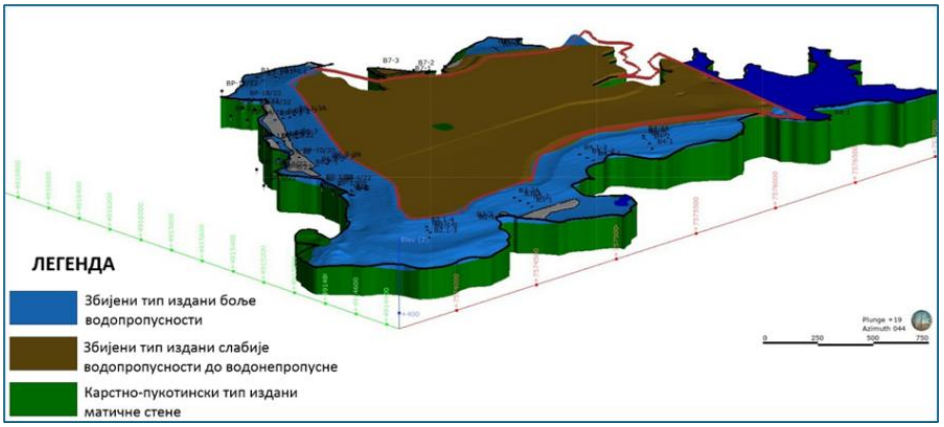


Figure 3. *3D view of the hydrogeological model of the Valja Fundata tailings pond*

Table 1. *Hydraulic conductivity calculated through synthesis of all investigations*

Lithological unit	Hydraulic conductivity (m/s)
Gneiss	$1 \times 10^{-11} – 3 \times 10^{-11}$
Fractured gneiss	$1,5 \times 10^{-5} – 4,2 \times 10^{-5}$
Limestone	$1,2 \times 10^{-10}$
Fractured limestone	$5 \times 10^{-4} – 5 \times 10^{-3}$
Sandstone	$6 \times 10^{-10} – 1 \times 10^{-9}$
Fractured sandstone	$3 \times 10^{-6} – 5 \times 10^{-5}$
Andesite	1×10^{-11}
Deluvium (clay)	$1 \times 10^{-9} – 2 \times 10^{-8}$
Flotation sand	$2,06 \times 10^{-5}$
Flotation slit	$2,7 \times 10^{-7}$

The hydrodynamic model was developed using the finite difference method - modflow according to [4]. The flow area was discretized using a homogeneous grid with dimensions of 20 x 20 m, which makes a grid of 18.404 cells per layer, or 55.212 cells in a total of three model layers (L1 flotation sand, L2 flotation mud and L3 bedrock). Most of the boundary conditions in the model were set in a logical way to be in a logical connection with the natural conditions of groundwater recharge and drainage. The solver within the modflow 6 package was used. The map of hydroisohypses and residual differences (for stationary flow conditions) is shown in Figure 4.

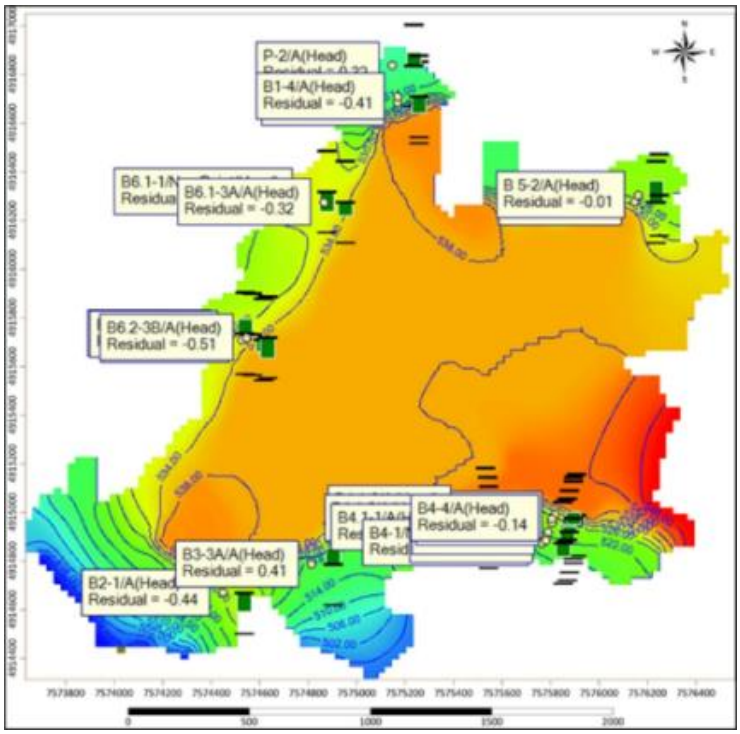


Figure 4. *Hydroisohypses map with residual difference at piezometers*

The groundwater level forecast, based on the hydrodynamic model, is based on the forecast of all elements from which the hydrodynamic model is formed. With a maximum elevation for the final designed elevation of the sand embankment of the tailings pond of 560 m, or 555 m above sea level, the calculated groundwater level is shown on the map in Figure 5.

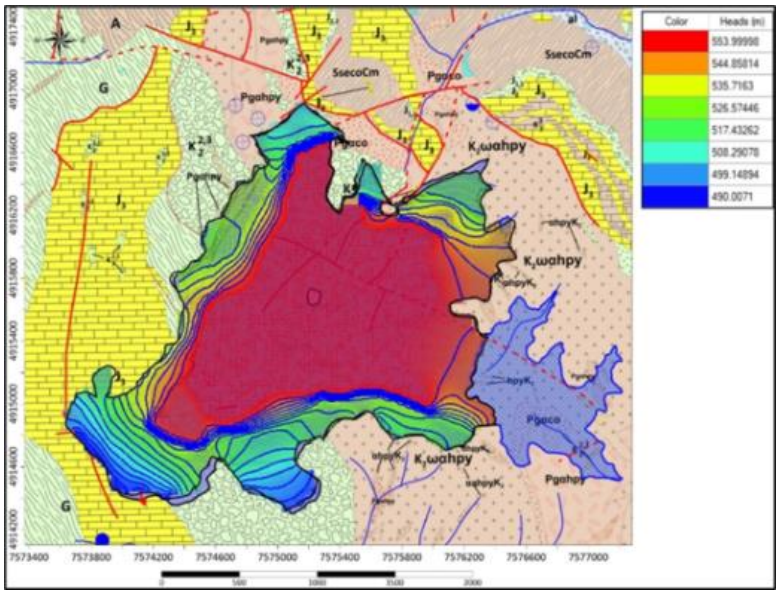


Figure 5. *Forecasting groundwater levels using a hydrodynamic model*

4. CONCLUSION

The calibrated hydrodynamic model was used to analyze the stability of the tailings pond in its current state, as well as to assess the lateral flow of groundwater into the host environment.

By forecasting the elements of the hydrodynamic model formation, forecasts of changes in the groundwater regime (groundwater levels, groundwater gradients, changes in inflow and outflow into the host environment) were made for the purposes of analyzing the maximum overhang of the tailings pond. Also, the forecast elements from the hydrodynamic model were used to forecast the stability of the tailings pond body for the maximum possible overhang.

Further research from the aspect of environmental protection and possible remediation measures were planned through the geotechnical and hydrogeological investigations themselves, as well as the development of the hydrodynamic model.

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