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Numerical analysis of effects of an open-pit coal mine to groundwater

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Abstract. In this study we investigated the hydrogeological problems of an open-pit brown coal mine in the Borsod coal basin with Processing Modflow software. The coal mine is located in the valley of the Sajó-river with high transmissivity overburden layer where the traditional dewatering solutions were not encouraging due to inrush risks and low cost-efficiency. A new way of barrier forming was found out and numerically simulated to prove the efficiency of the solution. Since there are several contaminated sites in the surroundings it was a key factor to assure that the new mine dewatering technique has only a negligible effect on the groundwater regime that undisturbs the known contaminant plumes nearby.

Introduction

The history of the coal mining in Hungary goes back to 1759, meanwhile the last underground mine in Oroszlány closed in 2014. The total coal reserve of Hungary is approximately 10.5 billion tons (mainly lignite and brown coal). The Hungarian government aims to extend coal production and restart coal mining in Hungary. There are several deep mine sites under investigation but open pits are also in highlights. Since the simplest geological conditions rise at open pit mines, the planning is in that cases in the more advanced phase. Some of the best potential mine locations are in NE Hungary, in the Sajó-valley where the brown coal is covered by a fully saturated thick alluvial gravel layer with very high transmissivity (Püspöki et al, 2018). In this case the “barren” material can also be used as raw material that makes mining more cost efficient. But this special hydrogeological situation also carries the problem of groundwater inrush to the pits that needs special solutions. To be able to increase the local coal production the investigation of special dewatering techniques, solutions and also the calculation of their short- and long-term effects will be in focus in the near future. Since safety is a key factor during mine operation there are several investigations required and ordered by the future mine operators to assure the feasibility of special solutions. In such cases 3D groundwater flow modeling was found to be a useful tool to simulate and forecast the processes nearby new mine sites.

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1. The investigated area and the applied numerical simulations

1.1. The mining area

The investigated area is in NE Hungary, in the valley of the Sajó-river. In the region the surface is flat, the cover is Holocene flood plain clayey formation with 3m average thickness and $8{,}5 \cdot 10^{-4}$ m/d (Kovács et al, 2010) horizontal hydraulic conductivity. The underlying gravel aquifer is heterogeneous and an average of 6 m thick, it's measured hydraulic conductivity ranges between 3-104 m/d. The productive coal layers underlying directly the riverbottom sediments.

Due to the high transmissivity of the alluvial aquifer and since there are several contaminated sites in the surroundings of the mine, the concept of the brown coal production is to minimize the effects of the dewatering to the groundwater flow regime. Therefore, the coal deposit is planned to be extracted over 2 periods of three years (Phase I.: 49.000 m^2, Phase II. 49500 m^2).

Before each production phases, they planned to prepare trenches down to the bottom of the gravel formation and fill with compacted mine tailings (flood plain clayey formation). These trenches filled with low transmissivity clayey materials, act as hydraulic barriers around the mine. The mining area and the phases of production can be seen on Figure 1.

In the barrier-delineated open-pit the groundwater is lowered to the bottom of the gravel aquifer 4,5 m water level decrease is needed to start the coal production. The extracted water pumped into the Holt-Szuha riverbed, where the water is expected to infiltrate to the groundwater.

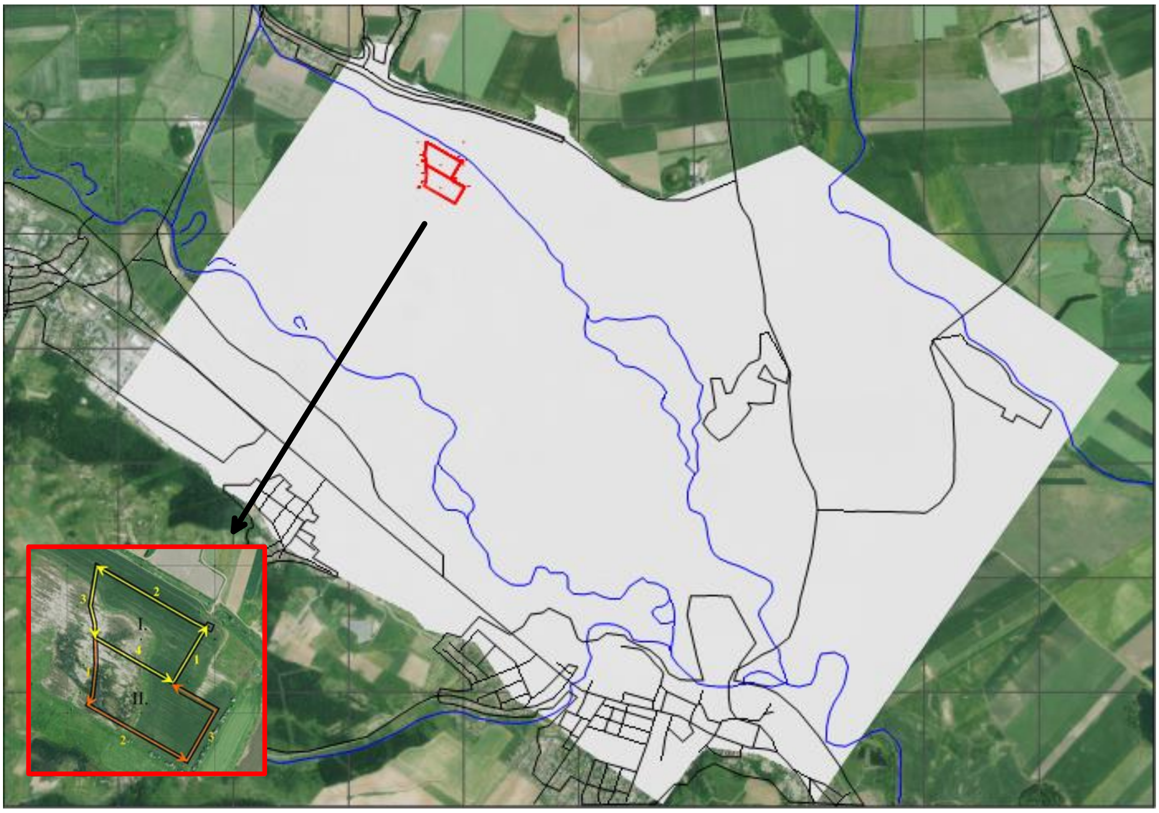

Figure 1. The investigated area with the model mesh and the coal production phases

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1.2. The applied numerical simulations

For the numerical three-dimensional groundwater-flow simulations through porous medium we applied Processing Modflow software that is based on finite difference method (Kovács-Szanyi, 2005). The extent of model grid is 5,5 km x 7 km (Figure 1.) The modelling area is relatively large, because in defining the area, we took into consideration the nearly Borsodszirák Water Plant.

The hydrodinamical simulations were performed by the combination of 17 transient and 1 steady state models: We have followed year by year the changing production periods of the open-pit mine with the transient models, while the equilibrium state after the mining activity (lakes in the pits) was simulated by the steady state model. The surface evaporation loss on the lakes of the abandoned pits also considered in the calculations (Tari et al, 2010).

The extracted mine-water (variable yield) is started to inlet 500 m away from the mine in the Holt-Szuha riverbed, thus reducing the impact of dewatering on mining activity.

2. Results and discussion

The results of the numerical simulations show, that the dewatering yield to reach the required groundwater level is maximum 1,2-1,4 m^3/min, depends on the production phase.

Due to the clayey barrier the risk of inrush is minimized and the effect of the dewatering to the groundwater levels is negligible: the maximum drawdown area is 160 m from the boundary of the pit (Figure 2.)

Figure 2. The dewatering influenced zone

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The open pit mine doesn't have any effect to the Borsodszirák Water Plant and even to the closer contaminated sites in the surroundings.

Mine water recirculation does not occur, due to the barrier and the distant water inlet section. The calculated maximum increase in the water level resulting from the mine water infiltration is 12 cm and the maximum influenced zone is 200 m from the Holt-Szuha riverbed (Figure 3.).

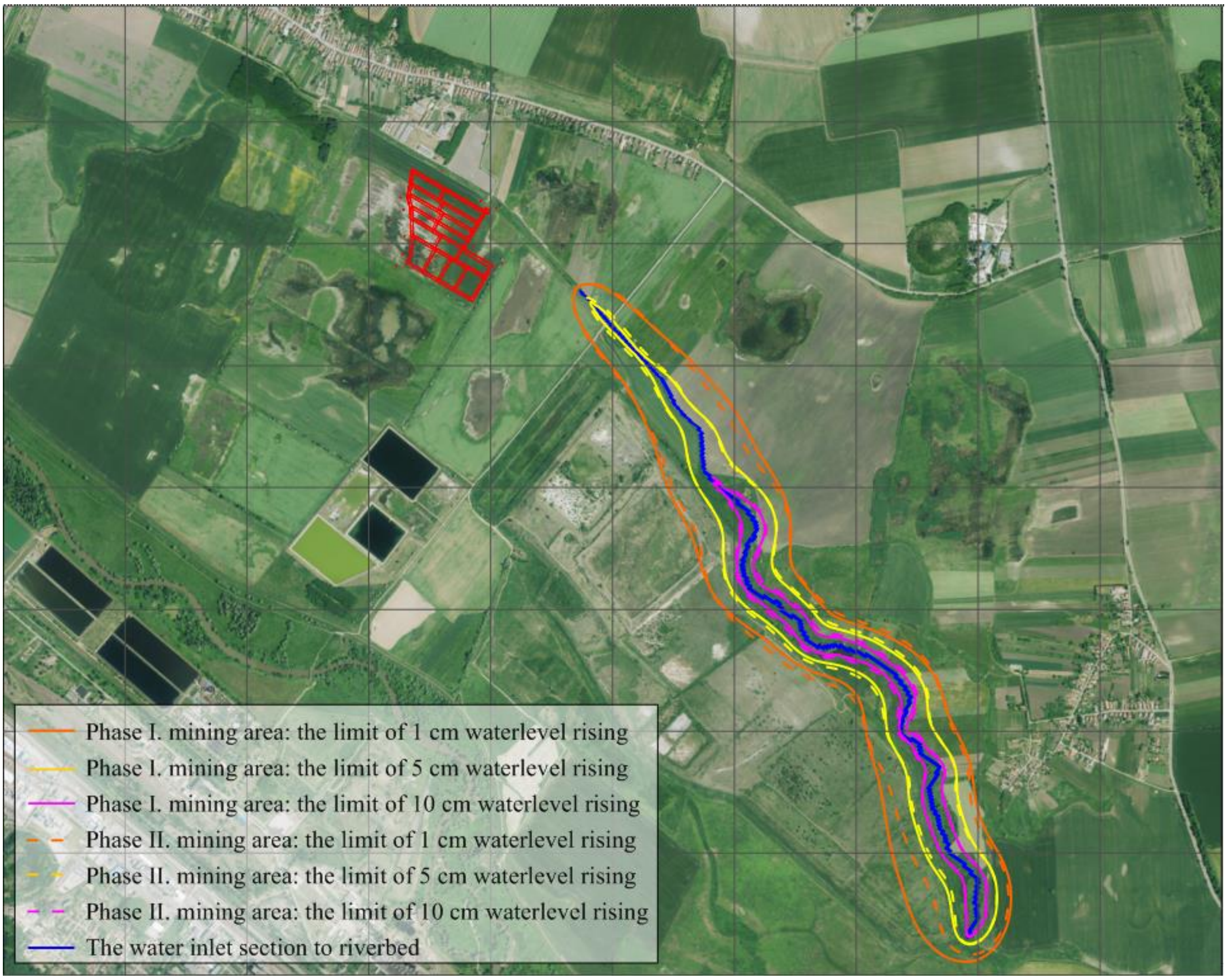

Figure 3. The mine water infiltration influenced zone

The evaporation loss of the lakes in the abandoned pits cannot be detected outside the protective barrier. According to the calculations, the amount of leaking waters which entering the lake can be less than the evaporation loss, therefore the barrier should be opened after the closure of the mine to ensure the appropriate water cycle of the lake.

3. Conclusions

This study proved that the use of compacted mine tailings as a material of barriers around the open-pit mine, is an innovative, cost effective and appropriate solution to minimize the effects of mining activity and the risk of water inrush in porous medium.

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There are several investigations required to ensure the mine safety. In such cases, especially in complex geological conditions and high transmissivity porous aquifers the 3D groundwater flow modelling was found to be a suitable tool for the estimation of the short- and long-term effects of the mining operations (especially dewatering).

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