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ECONOMIC EFFECT OF MODIFICATION THE OPTIMAL CONTOUR OF THE OPEN PIT SOUTH MINING DISTRICT MAJDANPEK, REPUBLIC OF SERBIA[**]

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Abstract

The Open Pit South Mining District is a unique unit that operates within the company Copper Mine Majdanpek, which is a part of the company Serbia Zijin Copper doo (former Mining and Smelting Basin Bor Group). The capacity of the Open Pit is 9.9 million tons per year and is of a great importance for copper production in the company system. As a result of natural and technical factors, a landslide occurred on the eastern side of the open pit, so it became necessary to define a new final contour of the open pit. In this paper, the effect of modification the optimal contour of the Open Pit South Mining District on the net present value (NPV) was analyzed.

Keywords: *optimization, modification of optimal contour, NPV*

1 INTRODUCTION

The mining industry is a specific and risky industry compared to the other industries because it depends primarily on the engineer's ability to see all the issues related to the production process in terms of the number of alternatives related to the natural-technical factors, resources and quality of resources, required investments for the adopted mining technology, administrative norms and restrictions, defined by the legal acts, etc.

Design and planning of the open pits is a significant and complex problem in the mine planning. The dominant driving factor in the modern mining is to ensure that the ore body is exploited in such a way as to maximize the value realized from the mine.

In the conditions of the global market economy over the years, the necessity of forming a unique methodology for evaluation the mining projects was imposed. Profitable exploitation of mineral deposits requires a certain economic assessment and exploitation planning. First, it must be determined which part of the deposit is

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economical for the mine and which mining methods can be applied under the given conditions. The next step is to define the final boundary of the mine and dynamics of mining the exploitable ore reserves. The goal of these efforts is to determine the most profitable mining plan and the highest rate of return on investment [1].

The most commonly accepted goal, in the complex production systems, in the optimization of the open pit boundary is maximization the net present value of the future cash flows. To achieve this goal, the spatial association of variables in the deposit (such as the geographic location of the deposit and its geological properties) as well as the temporal association of variables (including the order in which the ore will be mined and processed) must be taken into account, and accordingly the resulting cash flow [2,3].

Optimization, reliable estimation of exploitation reserves, planning and design are realized using the Geovia Whittle™ and Geovia Gems™ software, which in the modern mining represent the standard for strategic planning and design of the open pits.

The significance of analyzing the modification of the optimal contour, depending on the natural and technical factors, is multiple and can greatly contribute to making the crucial decisions regarding the economics of the open pit mining.

2 METHODOLOGY

Modification of the optimal contour of the Open Pit South Mining District is carried out with a strict respect the geomechanical and technological factors, and at the same time, the minimum deviation from the elements of the optimal contour is sought. In this way, the conditions are created for transformation the optimal contour into the final contour.

2.1 Defining the geotechnical characteristics of the eastern side of the open pit

In the eastern part of the Open Pit South Mining District there is a landslide, which is characterized by the complex geometry and dynamics of movement.

On the basis of the engineering geological explorations, conducted at the open pit, the geotechnical profiles were defined and modeling of the sliding body was carried out. A part of the terrain with an area of 826,309 m^2 has been set aside as the unstable terrain. The material affected by the colluvial process are: a complex of medium and completely degraded slates and gneisses and medium and completely degraded andesites

Figure 1 presents a characteristic engineering-geological section of the eastern slope of the Open Pit South Mining District that shows the landslide.

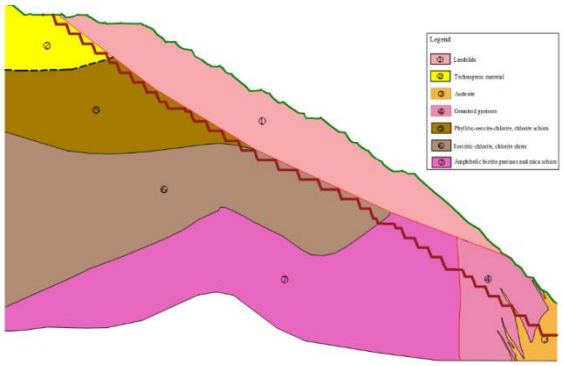

Figure 1 *Engineering geological section in the landslide zone on the eastern side of the Open Pit South Mining District*

2.2 Modeling of landslide solids in the eastern side of the open pit

The final boundary of the eastern side of the open pit was constructed on the basis of a defined landslide solid in the area limited by the terrain topography, as the upper surface and boundary of the sliding plane, as the lower limiting surface.

Solid is generated in the Geovia Gemstm software on the basis of defined vertical geotechnical profiles, which represent the closed polygons (3D rings). The solid was formed using the TIN (Triangle Irregular Network) method - it represents a triangulation with a network of irregular triangles, based on the geotechnical interpretation of landslides with vertical profiles, and the solid characteristics (solid volume, surface area (envelope), number of nodes in the formed surface, number of triangles, etc.) [4].

Figure 2 presents the generated landslide solid in the northwestern zone of the Open Pit South Mining District in the Geovia GemsTM software.

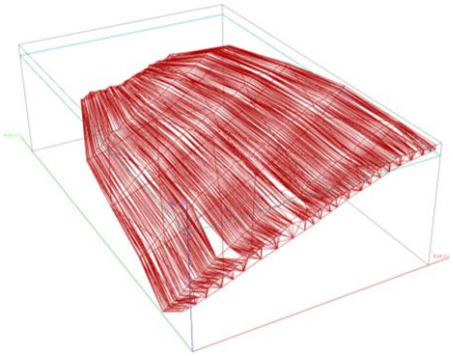

Figure 2 *View of the network of irregular triangles of the landslide solid*

Figure 3 shows the view of the landslide solid in the eastern side of the Open Pit South Mining District.

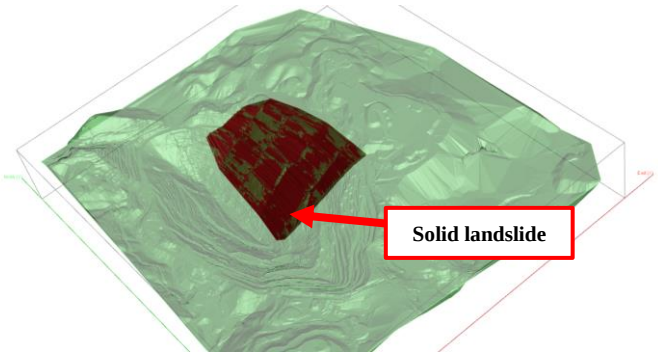

Figure 3 *3D view of the position of the solid landslide in the eastern side of the Open Pit South Mining District*

2.3 Optimal boundary of the open pit

The optimal boundary of the open pit was defined using the Geovia WhittleTM software, and based on the block model of the deposit, created by the geostatistical modeling method, Figure 4.

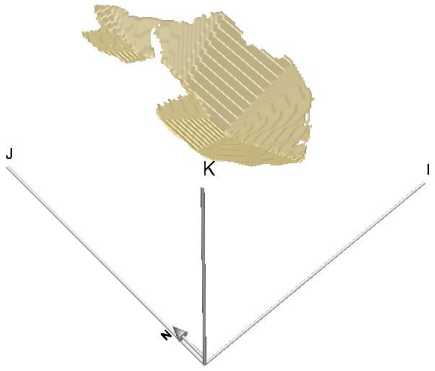

Figure 4 *Optimal contour of the Open Pit South Mining District, Geovia WhittleTM software*

2.4 Modification of the optimal contour of the eastern slope of the open pit

Modification of the optimal contour of the open pit was carried out with respecting the basic condition - to ensure a stable slope of the eastern side of the open pit. On the basis of defined conditions, the adopted geometric elements of the open pit and generated landslide solid, the final contour of the reconstructed northwestern part of the Open Pit South Mining District was constructed. The final contour of the grip was constructed in the Gems software, [4].

Figure 5 presents a characteristic profile showing a deviation of the modified (final) contour from the optimal contour of the open pit.

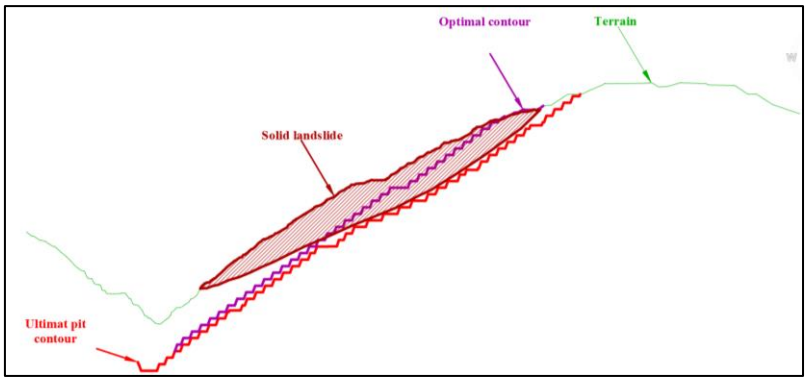

Figure 5 *View of a deviation of the modified contour from the optimal contour in the eastern side of the Open Pit South Mining District*

3 RESULTS AND DISCUSSION

Figure 6 presents the resulting graph with the economic optimization parameters, which was formed on the basis of annual production of the Open Pit South Mining District of 9.9 million tons of ore.

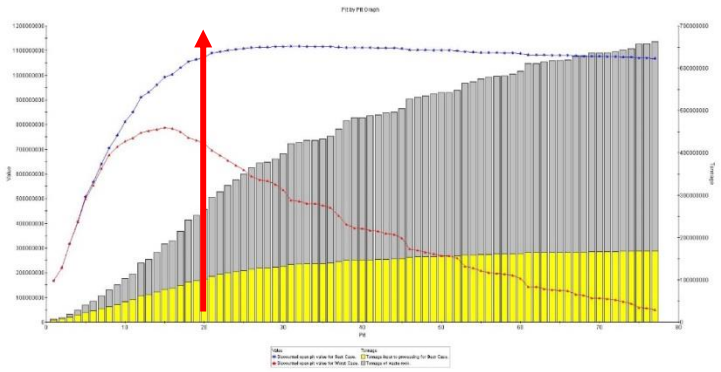

Figure 6 *Graphic presentation of the results of the Whittle economic optimization of the Open Pit South Mining District*

The maximum NPV is given by the shell of open pit no. 32, so it was chosen as the optimal contour of the Open Pit South Mining District.

Parameters of the optimal contour of the Open Pit South Mining District are shown in Table 1.

Table 1 *Techno-economic parameters of the optimal Open Pit South Mining District*

Parameter	Unit	Value
Ore	tons	124,061,159
Waste	tons	286,629,364
Overburden coefficient	t/t	2.09
Average copper content	%	0.356
Average gold content	g/t	0.189
Average silver content	g/t	1.578
NPV	$	896,643,015

A graphic representation of the final, modified contour of the Open Pit South Mining District designed in the Geovia GemsTM software, is given in Figure 7.

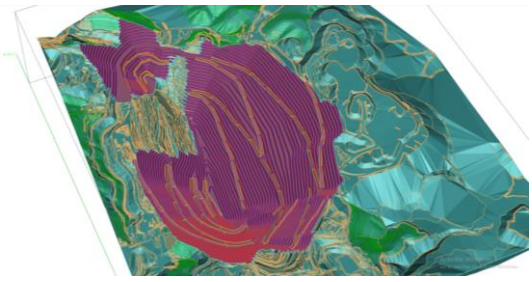

Figure 7 *3D view of the final contour of the Open Pit South Mining District*

Parameters of the final, modified optimal contour of the Open Pit South Mining District are presented in Table 2.

Table 2 *Techno-economic parameters of the modified optimal Open Pit South Mining District*

Parameter	Unit	Value
Ore	tons	124,061,159
Waste	tons	396,891,145
Overburden coefficient	t/t	3.20
Average copper content	%	0.356
Average gold content	g/t	0.189
Average silver content	g/t	1.578
NPV	$	585,932,261

On the basis of presented results, the following can be concluded:

1) The life of ore exploitation at the Open Pit South Mining District is 13.5 years.

2) 124,061,159 t of ore and 286,629,364 t of waste are captured by the optimal open pit contour. The overburden coefficient is 2.09 t/t.

3) 124,061,159 t of ore and 396,891,145 t of waste are captured by the modified optimal open pit contour. The overburden coefficient is 3.20 t/t.

4) The NPV for the optimal contour of the open pit is $896,643,015.

5) The NPV for the modified optimal contour of the open pit is $585,932,261.

4 CONCLUSION

Due to the occurrence of a landslide in the eastern side of the Open Pit South Mining District, there was a need to modify the optimal contour of the open pit in order to ensure the necessary stability for smooth development of the mining process.

Modification of the optimal contour of the Open Pit South Mining District was carried out so that the deviation from the optimal contour is minimal, i.e. to the extent that the geomechanical and technological factors are satisfied.

Due to the modification of the open pit optimal contour, the amounts of waste, which will be excavated, were increased and compared to the optimal contour, they are greater by 110,261,781 t.

The economic effect of modification the optimal contour is reflected in realization a lower NPV by $310,710,754.

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