# LONG-TERM PLANNING OF MINING THE LEAD AND ZINC ORE DEPOSIT IN THE BRSKOVO ORE FIELD, THE REPUBLIC OF MONTENEGRO

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**Abstract**

*Profitable mining of mineral deposits requires some assessment and planning. The objective of these efforts is to determine the most profitable excavation plan and the highest rate of return on investment. These tasks are performed in the field of long-term planning.Using the Whittle software for strategic planning and optimization of excavation boundary and software Gems for construction the open pits, the long-term directions of exploitation the lead and zinc ore deposits in the Brskovo ore field are defined depending on the flotation processing capacity, quality of mineral raw material in terms of useful and harmful components. and making the maximum profits in that production process.*

***Keywords**: long-term planning, Brskovo ore field, optimization, Whittle and Gems software packages.*

## 1. INTRODUCTION

The basic, primary input in the planning and design process of the open pit is a geological block model of the ore body. It is very important to accurately calculate the block value in optimization, because the wrong calculation leads to the wrong optimal contour of the open pit [1].

The most commonly accepted objective, in complex production systems, in optimizing the open pit boundary is to maximize the net present value of future cash flows. To achieve this objective, the spatial relationship of variables in the deposit (such as the geographical location of deposit and its geological properties) as well as the temporal relationship of variables (including the order in which the ore will be mined and processed) must be taken into account, and consequently a derived cash flow.

The Brskovo ore field includes four lead and zinc deposits: Brskovo, Igrišta, ŽutaPrla and Višnjica. All deposits are located about 6 km east of Mojkovac and belong to the Municipality of Mojkovac.

Deposits of the Brskovo ore field were exploited in the period 1976-1987 using the open pit and underground mining methods. About 960,000 t of ore from the Brskovo deposit and about 2,020,000 t of ore from the ŽutaPrla deposit were excavated. The exploitation of mentioned deposits was suspended due to poor economic effects, caused by the high exploitation costs and low recovery of useful elements from the lead and zinc ore deposits.

## 2. SOFTWARE MODELING OF THE DEPOSIT

Block models for the lead-zinc ore deposits "ŽutaPrla-Višnjica" (hereinafter ZPV) and "Brskovo" were made in the Geovia Gems software package and represent the block models with regular blocks sizes 10x10x5. The economic value of the deposit is determined on the basis of the value of metals present in the ore, i.e. lead, zinc, copper and silver. The economic effects of ore exploitation are calculated on the basis of the selling price of payable metals in the ore, i.e. lead, zinc, copper and silver. Based on this, the cut-off grade of equivalent lead and zinc (Pb + Zn) metals in the ore was determined, which is GS = 0.6% Pb + Zn. Blocks with content for Pb + Zn below GS are treated as waste.

One of the key factors in creating an economic model for the ZPV and Brskovo deposits is the assessment of mercury content in concentrate, i.e. the value limitation to 900 ppm.

To estimate the mercury content in concentrate, the following formula was developed, on the basis of conducted experimental research:

$$Hg_{\_CON} = \left(\frac{Hg[ppm]}{Zn[\%] \times 0.01}\right) \cdot 0.406 \quad [ppm] \tag{1}$$

The formula is based on the mean contents of mercury (Hg, ppm) and zinc (Zn,%) in the run-of-mine ore. The next step is to create a new attribute of mercury content called ZnHg, which contains ≤900ppm Hg. A script is written using a scripting language that defines the ore with mercury content of ≤900ppm.

The panel in Figure 1 shows a script used by the Gems software to separate the ore with mercury content ≤900ppm and ore with mercury content > 900ppm.

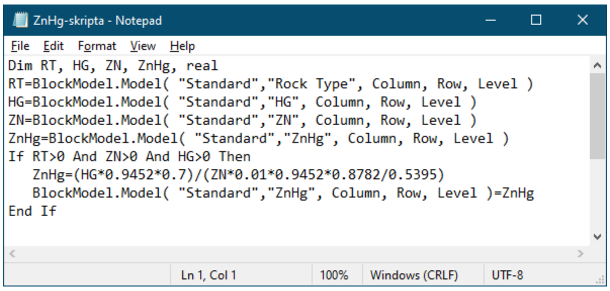


Figure 1. Script used by the Gemssoftware for separation the defined ore types

## 3. OPTIMIZATION THE BOUNDARY OF THE OPEN PTIS - SELECTION OF OPTIMAL FINAL CONTOURS AND PUSHBACKS

Optimization of the open pits at the Brskovo site was made on the basis of two block models of deposits and defined the input techno-economic parameters.

Optimization of the open pits was made on the balance reserves using the Whittle software that is the industry standard for this area. The Whittle software package uses a modified Lerch Grosmman algorithm in the optimization process, according to which the optimal contour of the open pit is obtained on the basis of economic value of individual mini blocks in the deposit. The software has the ability to change the size of revenue applying the revenue factor to the metal prices and thus generate more possible contours of the open pits [2].

Taking into account the amount of exploitation reserves affected by the open with a coefficient of revenue factor of 1, which corresponds to the optimal open pit based on undiscounted profit, the ore excavation capacity, minimum width between excavations of 50m, a decision was adopted to determine the final limit of optimal open pit for discounted profit based on the excavation of the final open pit in two pushbacks [3]. Based on this solution, the analysis of potential contours of the first pushback and optimal final contour of the open pit ZPV was carried out. The results of carried out analysis are shown graphically in Figure 2.

Analyzing the optimal development of the open pit ZPV, for the case of phase development with one Pushback (open pit 12 in the analysis), it was obtained that the optimal final contour of the open pit ZPV, the open pit under ordinal number 30 (revenue factor = 0.94). The open pit 30 provides the maximum Net Present Value ("Specified case") for the analyzed phase development.

Analyzing the optimal development of the open pit Brskovo, for the case of phase development with one Pushback (open pit 16 in the analysis), it was obtained that the optimal final contour of the open pit Brskovo, the open pit under number 33 (revenue factor = 0.96). The open pit 33 provides the maximum Net Present Value ("Specified case") for the analyzed phase development. Also, the result of analysis the Brskovo open pit showed a low sensitivity to the Net Present Values in the selection of potential Pushbacks, which is evident in the small difference in Net Present Value between the "Best case" and the "Worst case" analysis. The reason for small difference in the Net Present Values between the analyzed variants is a short service life for the Brskovo open pit [4].

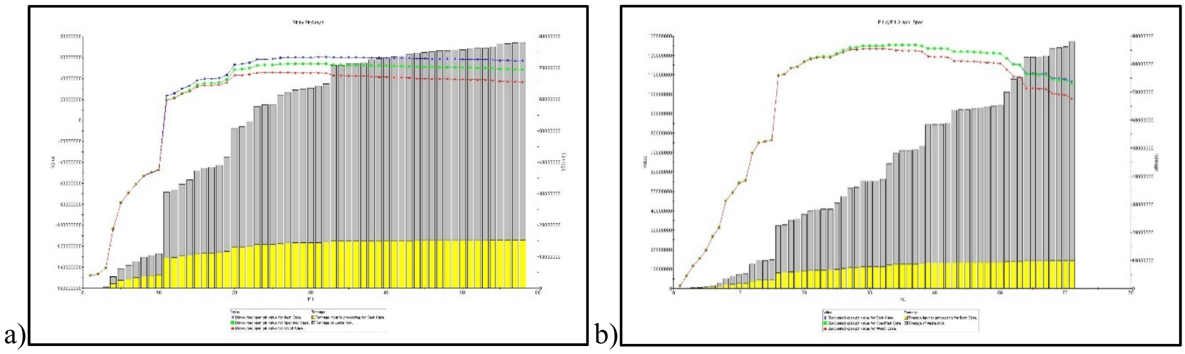

Figure 2. Pit by Pit graphs for the open pits: a) ZPVand b) Brskovo

## 4. OPTIMIZATION OF EXCAVATION DYNAMICS

After selection of pusbacks and final contours of the open pits, defining the order in which the blocks will be excavated is approached, i.e. the optimization of excavation dynamics is performed. This process was carried out in the Whittle software, using the Milawa algorithm-balancing mode, Figure 3. Excavation dynamics includes the period of excavation at the open pit ZPV (Period 0) and additional 7 years of excavation at the open pits ZPV and Brskovo.

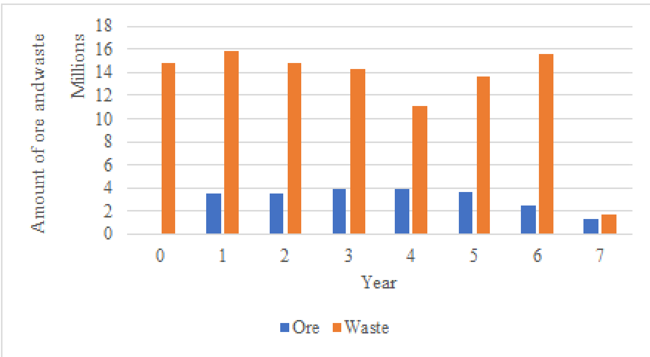


Figure 3. Dynamics of ore excavation at the open pits ZPV andBrskovo

## 5. NET PRESENT VALUE

Discounted cash flow analysis (DCF analysis) is a universally used method for evaluating the economic performances in a project. As such, it is often incorporated into algorithms, for optimization and production planning, commercial software packages (Whittle). The most common type of economic analysis comes down to the projection of cash flow during the project life.

The results of the carried out DCF analysis is shown in the graph of discounted cash flow, Figure 4. The realized net present value by exploitation of lead and zinc ore in the Brskovo ore field is 84,746,781 $ (discounted with 10%).

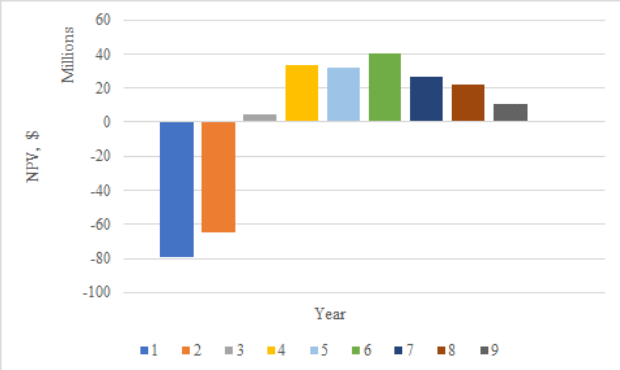


Figure 4. Graph of discounted cash flow

## 6. CONCLUSION

The applied approach of comprehensive understanding the process of planning the deposit exploitation in the Brskovo ore field using the modern software tools, which are based on the optimization algorithms such as the Lerchs - Grossmann algorithm, Milawa algorithm, and other procedures based on computer programs, provides a profitable exploitation. The result of such approach is the improvement of exploitation the lead and zinc ore deposits ŽutaPrla-Višnjica and Brskovo, which are characterized by the presence of high mercury content in certain batches of deposits in the complex working conditions, and which is reflected in better financial effects in the mine operations

The discounted cash flow analysis shows a net present value of $ 84,746,781 $. Based on that, the conclusion follows that the future exploitation of lead and zinc deposits in the Brskovo ore field is profitable.

## ACKNOWLEDGEMENTS

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