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STRATEGIC PLANNING, DESIGN AND MINE MANAGEMENT UNDER THE CONDITIONS OF ASAREL OPEN PIT MINE

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Abstract
Asarel-Medet JSC Mining and Processing Complex is the first, largest and leading Bulgarian mining company for copper ores open pit mining and processing.
Ore mining at the Asarel mine was initiated in 1976. The company has been implementing unique mining machines for the country, state-of-the-art flotation equipment and automated systems for management and control of technological processes ensuring top production indices ever since.
Open pit mining specialists at the Asarel mine have been using the software solutions of the company Datamine for mine planning, design and geological modeling since 2004.
The main planning and control activities according to the mining periods and purpose are:
- Long-term development, Medium-term mining plans, Short-term mining plans, Ten-day and daily mining plans.
Control over the design implementation and mining organization is conducted using data and records from the dispatch system modules and pit surveys and references.
***Keywords**: Asarel-Medet, open pit copper mine, mine planning, Datamine, mining periods*

1. INTRODUCTION

Asarel-Medet JSC Mining and Processing Complex is the first, largest and leading Bulgarian mining company for copper ore open-pit mining and processing.

The open-pit mining specialists at the Asarel mine have been using the software solutions developed by Datamine, including Studio OP, Studio RM and NPV Scheduler, for mine planning, design and geological modelling since 2004.

2. PRESENTATION

2.1. Geologocal Block Models

The major data set required for pit design using the software referred to above is the Geological Block Model. Two Geological Block Models are used at Asarel: Resource Geological Block Model and Updated Geological Block Model, the latter being used primarily for short-term planning.

The resource model is built only with data from the exploration core drilling. The block sizes within the geological model have been determined at 25/25/15m, respectively along the X, Y and Z axes through various geostatistical methods for analyzing the useful components variability. The 100/100 m exploration drilling pattern for the Asarel deposit has a significant impact on the block sizes within the model for most of the ore body. The block size in the vertical direction (15m) is determined by the height of the operational benches (mining levels) during the deposit mining. The model may also have smaller cells in places where there is contact between different ore bodies or in the contact zone at the surface.

The updated Geological Block Model is actually the Resource Model, but it is further adjusted with data from the detailed exploration taken from the chemical assays from the blast holes during

its updating on a regular basis. All analyses that are used have different weights in the model updating process. The results from the detailed exploration analyses have an impact on the uppermost part of the model which is closest to them and that will be subject to mining as soon as possible.

The Geological Block Models (obtaining values for useful and deleterious components for all blocks) are built at Asarel-Medet using the Ordinary Kriging method and Inverse Power of Distances method.

Comparative analysis is performed on the reconciliation between the Resource Model and the data from the continuous detailed exploration. It is the main database, a key factor for the accurate pit design and its subsequent operation.

2.2. Core Activities on Planning and Controlling the Ore Mining According to its Deadlines and Purpose

2.2.1. Long-Term Development

The long-term development designs are prepared using Studio NPVS (NPV Scheduler) which is one of the modules of the Datamine software at Asarel Medet JSC.

The main principle on which the NPV Scheduler software application for pit designing (optimizing) is based and developed is the Lerchs-Grossman method (LG-method). This is a mathematical algorithm belonging to the Network Flows method family and in this case it aims at determining the ultimate pit, the implementation of which will lead to a maximum profit over time (maximum Net Present Value). The Ultimate Pit designed using the software is the final boundary of the pit for a particular deposit. Some colleagues also call them LG Ultimate Pit.

The LG method is used to determine the "optimal ultimate pit" at certain expected commodity sales prices at known financial parameters for mining, processing and selling the commodity. Preliminarily calculated maximum theoretical values for the overall slope angles of the targeted optimal ultimate pit are also used to design the pit shell. The ultimate pit is a theoretically determined phase (shape) that will lead to the highest profit at the specified costs of extraction, processing and sale of the production. There are many factors that can influence the ultimate pit definition, the most important of which is the mineral distribution in the deposit: often "more valuable" blocks with higher mineral grade are located at depth, far below other smaller blocks of the ore body.

The price factor is used most often for optimal design and construction of the so-called "most profitable pit" where the study step is set to 1% and the optimal pit is searched for at 100% of the set sales price. This practice has been proven all around the world and has also been recommended the software authors. This study ensures a pit construction with maximum NPV and at the same time conducts a sensitivity analysis of the results when the price changes. The other factors are recommended in most analysis cases. The software generates an optimal sequence of geological block extraction (OES - Optimal Extraction Sequence) for each ultimate phase which is actually the foundation of the entire design process optimization. The optimal sequence of block extraction will be changing in all subsequent processes until the design is finalized.

The phases themselves are open pit mines embedded in each other with each phase being optimal when selling the commodity at a price corresponding to the percentage at which the given phase is built. This means the smallest phase (the smallest ultimate pit of a mine) will be optimal (will give the highest NPV) at a price equal to 1% of the set sales price. The next phase will be optimal at 2% of the set price, and so on until it reaches 100%. The analysis can be continued above 100%. Each subsequent phase is larger than the previous one and includes all the previous ones.

The following stages of the design development are quite long, but in general they aim to find a solution for the following:

- Ore mining at uniform rates and constant average grades of useful and deleterious components (as far as possible).
- Uniform mining of waste.
- Temporary mining limitations from the existing infrastructure perspective (if any).
- Compliance throughout the life-of-mine with engineering conditions during mining and processing – overall slope angles and parameters of the faces during the pit mining, parameters of the mineral ore dilution (losses and dilution during mining) and dilution parameters during ore processing.

Achieving all these goals (and not only) by the designers and mine planning specialists necessarily leads to a change in the block optimal extraction sequence (OES) in the already selected optimal pit and therefore to a change in cash flows and respectively in NPV.
For this reason, when working with this type of design software, it is incorrect to compare the NPV of designs for which only an optimal ultimate pit has been generated (ideal cash flows) with designs for which a practical calendar schedule has been developed (completely genuine and feasible cash flows).

2.2.2. Medium Term Mine Plans

Most often they are for a period of one to five calendar years. These plans are more detailed than the long-term ones and their monitoring and implementation ensures the accomplishment of the set ore mining and processing parameters: an optimal amount of waste and a precisely defined amount of ores with appropriate quality parameters are provided.

The actual development of the annual designs goes through several stages:

- Updating the current annual design for the last months of the year, if necessary. The update provides the baseline for the annual design or the expected pit state at the beginning of the next calendar year.

- Designing the mining operations for the next year – a plan with berms and roads is presented in the way the pit should look at the end of the design year.

- The distribution of the mined material throughout the year is presented by pit levels and ore type.

- The pit development is forecasted for two more subsequent years. This is done in order to prove the provision of the required ore for the periods after the year for which the main design is prepared. Most often, these plans are developed with both modules *Studio OP* and *Studio NPVS*. They show the mining sites in the respective year and again a tabular distribution of the mined material by levels and type.

- Finally, the average haulage distances by type of mined material to the various unloading locations are determined. The required number of dump trucks and other finishing works necessary for proper planning of the cost and provision of all main and auxiliary activities related to the pit development is determined.

2.2.3. Short-Term Mine Plans

These are quarterly and monthly plans which are also developed in detail. A large part of the material intended for mining is also assessed with current chemical assays from the detailed exploration, but not only according to the data from the block models. This makes these designs much more reliable than the long-term and medium-term ones considering the ore quality indicators. The block extraction sequence is indicated in this case in order to comply with the main parameters for optimal ore blending. The mined ore to be fed to the Concentrator Plant is ensured with its appropriate parameters: average copper, sulfur and copper dioxide grades and an optimal ratio at which the host rocks are blended. The latter is of a crucial significance for maximum efficient grinding of the ore at the Concentrator Plant at optimal throughput (processing of a certain

ore amount for a certain time). Grinding the ore to certain particle sizes, in turn, will ensure maximum extraction of the useful component from the entire process. The average grade of the deleterious components in the ore for the flotation process - sulfur and copper dioxide - also has a significant impact on the ore processing.

2.2.4. Ten Day and Daily Mine Plans

- A ten-day plan is prepared as a table. It reflects the available quantities and quality indicators of the already blasted or only drilled blocks. The outstanding drilling designs are also indicated and their quality indicators are calculated with the Geological Block Model. In these ten-day plans, a very large part (and sometimes 100%) of the ore to be mined is qualified with direct analyses and a very small part is qualified with assumed data from the Geological Block Model. This makes these plans very reliable in terms of the ore quality to be mined in the shortest possible period.

- The daily mining schedule is prepared for 24 hours and is even more detailed, foreseeing mining only from blocks with current chemical assays from the detailed exploration. It specifies the shovel that will be used and the exact block number and bench level from the mine fleet management dispatch system.

2.2.5. Provision of the Wenco Mining Dispatch System

The dispatch of the ore mining and all auxiliary activities carried out at the Asarel mine is performed by a software application developed by the WENCO company. The system hardware is installed on the available shovels, drill rigs, dump trucks, bulldozers, graders and all other auxiliary units for refueling, lubrication, water tank trucks, etc. All have high-end GPS receivers installed for positioning the units in real time. The shovels and drill rigs have two receivers each for accurate and precise positioning.

The main system administration in terms of mining, shovel relocation and ore blending is conducted by the specialists at the Mine Planning unit. The files of all work blasting fields are processed and imported according to the requirements of the dispatch software. Loading and unloading locations are created and updated on a daily basis, routes for mined material haulage are prepared, data on the blasted blocks with their quality parameters is imported, etc.

2.2.6. Control on the Design Implementation at the Asarel Mine

The Mine Planning Unit exercises daily control on the ore mining, implementation of blast patterns and the operation of loading equipment in the planned blocks. The control relies on numerous reports from the WENCO dispatch system software packages and survey measurements of the face lines. Control is also exercised on the implementation of long-term, medium-term mining plans and the mining technology in order to ensure an optimal ore blending. Control is performed over the implementation of all specific designs in the Asarel mine.

3. CONCLUSION

The design and updating of various options and development strategies is a dynamic and almost continuous process in the open pit mining of mineral deposits.

The optimal engineering conditions for ore mining and processing such as specified overall slope angles and face parameters during the pit mining, the mineral resources dilution parameters (losses and dilution), among others, have to be continuously monitored throughout the life-of-mine.