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Determination Coal Mine Ultimate Pit Limit based on Kepmen ESDM No. 227.K/MB.01/MEM.B/2023 and PP 26 2022

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Abstract
Economic factors and variables from geological resource models affect ultimate pit limit (UPL). Coal selling price, overburden stripping cost, coal mining cost, and royalties are among the economic factors taken into account in UPL. PP 26 2022 and Kepmen 227.K/MB.01/MEM.B/2023 both control the benchmark coal selling price and royalties. It takes a lot of time to determine UPL utilizing the Lerchs Grossman (LG) algorithm. UPL optimization is now feasible by integrating mining modelling software's Structured Query Language (SQL). The goal of this study is to determine UPL by maximizing coal resources at the site using the help of SQL in LG algorithm, which can optimize pits efficiently, precisely, and economically while taking the most recent laws into account. The study investigates a coal mine in Sanga-sanga, East Kalimantan. The study entails examining data processing using secondary data that was gathered for the study. Using the break-even stripping ratio (BESR) analysis approach, mining limitations are chosen. The chosen incremental stripping ratio (ISR) of 12.88 is in close proximity to the \$13.41/ton break-even stripping ratio (BESR). The grid OPT015 in the optimization grid contains the incremental stripping ratio (ISR) value and considered as the UPL for the coal mine.

1. Introduction

Mine planning is the initial activity in a mining activity that must be carried out by the company [1]. One of the stages in mine planning is pit optimization. Pit optimization is used to determine the ultimate pit limit (UPL) for obtaining excavated materials with respect to technical and economic conditions [2]. The UPL will generate the optimum reserve that provides the best economic return. The parameters that affect the UPL consist of economic parameters, i.e. coal price, break even stripping ratio (BESR), overburden stripping cost, coal mining cost [3]. Technical parameters consist of mining slope geometry, topography, and geological conditions [4].

Some pit optimization algorithms, i.e. floating cone, pseudoflow, and Lerchs Grossman (LG) widely use in determining UPL [5]. Among these three algorithms, LG brings the best result yet calculation process needs to be decreased with other improvements [6]. Determination and selection of the best UPL by optimizing the amount of coal resources effectively using the LG algorithm method. The LG algorithm method is carried out by making variations in the stripping ratio (SR) calculated based on the break-even stripping ratio (BESR) mathematical equation. The LG algorithm method helps optimize the extraction of valuable natural resources by considering various technical and economic factors [7]. Geovia Minex is a modelling software that has integrated LG algorithm in its pit optimizing [8].

Coal benchmark prices and royalties have been regulated in the Minister of Energy and Mineral Resources Decree (KEPMEN ESDM) No. 227.K/MB.01/MEM.B/2023 and PP 26 2022 [9][10]. Companies holding Mining Business License (IUP) must pay royalties and taxes to the government in accordance with the stipulated provisions. Based on PP 26 2022, the amount of royalty and tax rate entirely depends on the HBA and coal quality [11].

The creation of Structured Query Language (SQL) using software assistance aims to determine the optimization of coal resources based on the calculation of economic parameters [12]. SQL uses the calculation of the benchmark price of coal contained in the KEPMEN ESDM No. 227.K/MB.01/MEM.B/2023 and PP 26 2022 regarding royalty payments. The use of SQL in pit optimization is an appropriate and accurate system to determine the coal pit optimizer when compared to optimizer done manually [13]. The manual approach is done by making variations in stripping ratio (SR), which is the ratio of overburden volume to coal tonnage which takes a long time.

The use of LG algorithm in Geovia Minex combined with SQL integration in pit optimization will decrease the processing time when compared manually. In addition, the optimization results with SQL have more than one ultimate pit limit that follows the increase in a coal price [14]. Therefore, this research determines UPL using the LG algorithm method based on SQL and takes into account pit optimization by implementing KEPMEN ESDM No. 227.K/MB.01/MEM.B/2023 and PP 26 2022 as the main references in technical and economic payments. So as to get the results of fast, accurate and economical coal mining limits.

2. Methodology

Research methodology begins with problem formulation, data collection, data processing and data analysis. The data collection stage is divided into two, namely literature studies and collecting secondary data. The data used in this study are coal grid models containing information of calorific value (CV), total moisture (TM), total sulphur (TS), ash information (AS), KEPMEN ESDM No. 227.K /MB.01 /MEM.B/2023 for SQL code, reference coal royalties and taxes formula in PP 26 2022, one reference coal price (HBA), pit design geometry and the company's Financial Plan and Budget (RKAB). The data obtained from the company is then processed. The result from this process is a coal benchmark price (HPB). Furthermore, the HPB are integrated into mine modelling software, Geovia Minex, to produce series of grid data of optimized UPL containing in-situ resource report (Incremental Striping Ratio) that shows coal quality parameters and stripping ratio of each grid.

The company's Financial Plan and Budget (RKAB) data is entered into Microsoft Excel using break-even stripping ratio (BESR) equation to calculate the BESR. The BESR value is compared to the Incremental Stripping Ratio of optimized grid from previous process in Geovia Minex. The chosen optimized grid that must contain lower or equal stripping ratio value compared to BESR value is called the UPL. Figure 1 shows the workflow of SQL used in this research. Break-even stripping ratio follows below (subjects to coal CV, TM, TS, and AS). Royalties and taxes are set based on the coal CV and the coal reference price (HBA).

$$BESR = \frac{Coal\ Revenue - Total\ Operating\ Cost}{Total\ OB\ Removal\ Cost}$$

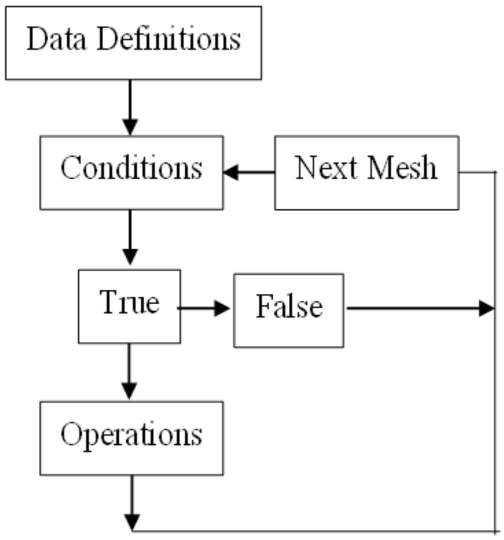

Figure 1. SQL workflow

3. Results and discussions

3.1. BESR Calculation

BESR uses economic parameters to determine the mining limit as a result of coal mine pit optimization. Based on the economic parameters seen in Table-1, the calculation of the BESR value can be done. The costs in Table 1 are based on the company's financial plan and budget (RKAB) report. The reference coal price (HBA) is 85 $/ton. Changes to the reference coal price follow the Kepmen 227.K/MB.01/MEM.B/2023 which refers to the equivalent calorific value of 6,322 kcal / kg GAR. The value of the reference coal price (HBA) in the break-even stripping ratio (BESR) parameter is based on the average calorific value of coal at the research location. Royalty fees included in the type of non-tax state opinion in accordance with PP 26 2022 which states that royalties for open-pit coal mines with a calorie level of 5200 Kcal/Kg GAR with an HBA value of 85 $/ton are charged at 11.5% of the sales price.

Table 1. Economic Parameters

Parameter	Unit	Price (USD)
HBA	$/ton	85,00
Fuel Cost	$/ltr	0,50
OB Stripping Cost	Bcm/ton	2.73
Coal Mining Cost	$/ton	1.54
Hauling Cost	$/ton	5.95
Coal Processing Cost	$/ton	0.70
Coal Barging & Shipping Cost	$/ton	6.88
Other Cost	$/ton	6.53
Tax	$/ton	15.11

The results of the calculation of BESR were obtained at 13.44 $/ton. This value is used as the best mining limit, BESR is a condition where revenue is equal to the cost of expenses made to obtain coal. If it exceeds the BESR value limit of 13.44 bcm/ton, the mining activity will not make a profit.

3.2. Ultimate Pit Limit Design

Coal mine pit optimization starts with determining economic parameters to decide the ultimate pit limit. These parameters are seen from the economic and financial aspects of the company which can be seen in Table 2. HBA 1-3 were generated from HBA based on Kepmen 227.K/MB.01/MEM.B/2023. The parameters that have been determined for coal mine UPL are entered into Structured Query Language (SQL) sections. In calculating the benchmark price of coal (HPB), the formula contained in the Kepmen 227.K/MB.01/MEM.B/2023 is entered into Structured Query Language (SQL). The snippet SQL-based UPL can be seen in Figure 2. Basically, all equations must be written in SQL code. LG algorithm was utilized using mining software Geovia Minex. Figure 3 shows combination economic and technical parameters and generates a set of pit-shell were generated. Table 3 shows 20 pit-shells and each pit-shell contains information of coal tonnage and overburden (OB) volume.

The results of SQL with the help of Geovia Minex are coal benchmark price (HPB), overburden stripping cost, and coal mining cost. These 3 parameters are utilized to generate pit optimizers using Geovia Minex. The output of the pit optimizer in Table 3 is a grid prefix with a start discount factor of 5% for each pit shell, overburden volume and coal tonnage used to calculate the incremental stripping ratio (ISR) and stripping ratio (SR) values. This accommodates coal price volatility with 5% incremented [15]. Pit optimizer results in mine modelling software can be seen in Table 3.

Table 2. Economic Parameters for UPL

Parameter	Unit	Price (USD)
HBA	$/ton	85,00
HBA 1	$/ton	65,00
HBA 2	$/ton	45,00
HBA 3	$/ton	25,00
OB Stripping Cost	$/bcm	2,725
Coal Mining Cost	$/ton	1,54
Coal Hauling Cost	$/ton	5,95
Coal Processing Cost	$/ton	0,72
Coal Barging & Shipping Cost	$/ton	6,88
Other Cost	$/ton	6,53
Total tax	$/ton	11,73
Royalty 1	$/ton	6,50
Royalty 2	$/ton	8,50
Royalty 3	$/ton	11,50

```
SELECT KALORI_6000
    WHERE K > 6000
    AND K # NULL
    AND TM # NULL
    AND TS # NULL
    AND AS # NULL

IF SELECT KALORI_6000
    KF = K/6322
    TMF1 = 100 - TM
    TMF2 = 87.7400
    TMF3 = TMF1/TMF2
    TSF1 = TS - 0.66
    TSF2 = TSF1*4
    ASF1 = AS - 7.94
    ASF2 = ASF1 * 0.4
    TSAS = TSF2 + ASHF2

    HPB = HBA * KF
    HPB = HPB * TMF3
    HPB = HPB - TSAS

    ROYALTY = HPB - CBSC
    ROYALTY = ROYALTY * ROYAL
END IF
```

Figure 2. A Snippet of SQL code

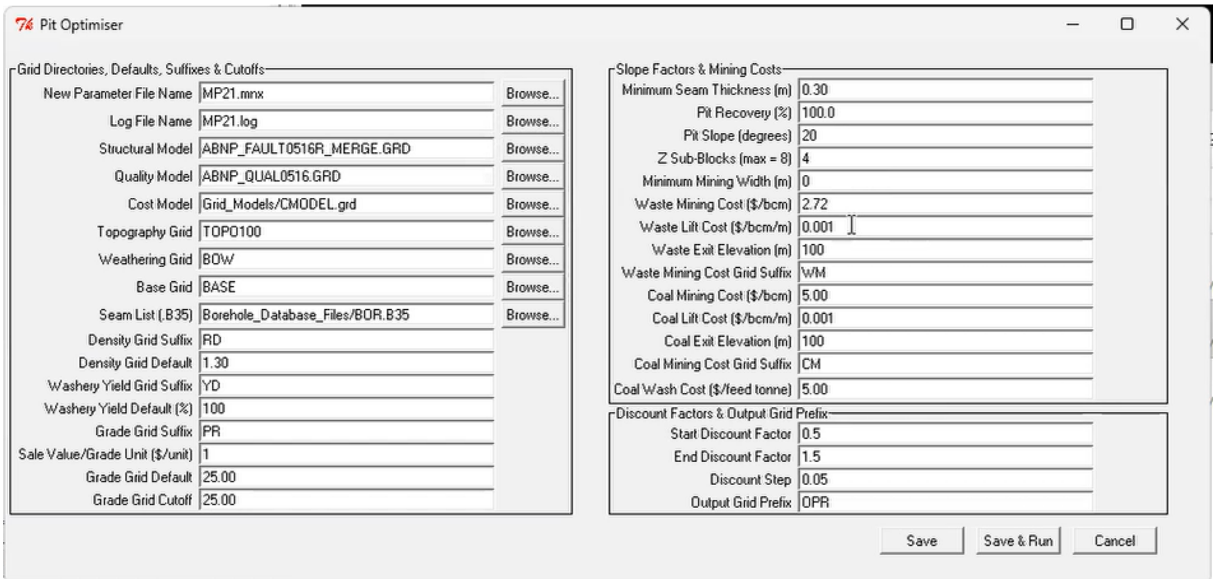

Figure 3. LG algorithm in Geovia Minex with technical and economic parameters

Table 3. Optimized UPL

GRID	OB Volume	Coal Tonnage	ISR
OPT-045	54.398.826	2.206.024	24,66
OPT-040	191.490.628	7.376.596	25,96
OPT-035	158.321.341	7.029.093	22,52
OPT-030	198.504.071	7.459.521	26,61
OPT-025	302.832.009	12.820.804	23,62
OPT-020	313.004.288	14.122.425	22,16
OPT-015	656.763.177	29.646.123	22,15
OPT-010	532.371.660	27.410.482	19,42
OPT-005	593.995.315	34.063.261	17,44
OPT-00	927.262.145	56.811.594	16,32
OPT005	1.699.651.273	113.330.901	15,00
OPT010	2.461.693.653	166.823.973	14,76
OPT015	**3.916.689.845**	**333.176.775**	**11,77**
OPT020	5.674.214.464	537.472.714	10,56
OPT025	3.407.472.869	351.893.285	9,68
OPT030	2.564.200.103	306.402.125	8,37
OPT035	1.071.104.121	162.062.944	6,61
OPT040	559.769.683	98.409.472	5,69
OPT045	167.696.458	26.522.107	6,32
OPT050	103.112.968	14.259.575	7,23

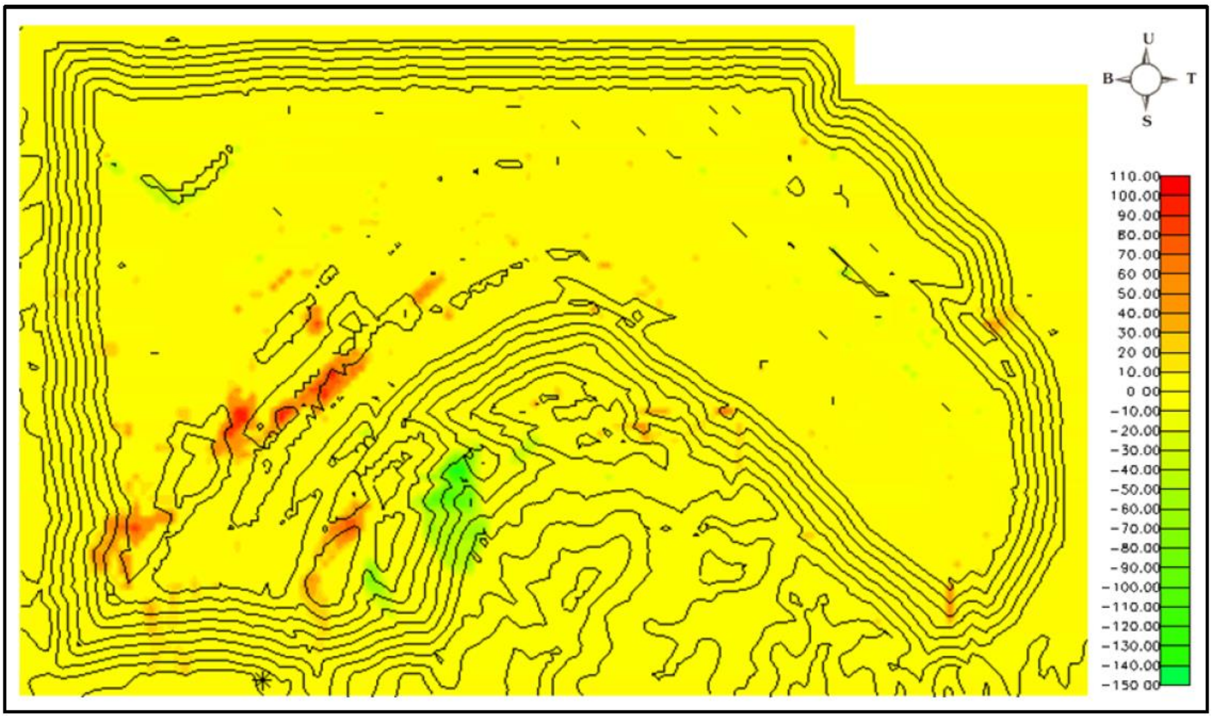

Figure 4. OPT015 as the UPL

The result of the pit optimizer in Table 3 is a layered pit shell or ultimate pit sequence generated by increasing the coal price around the base price value (Figure 4). The highest elevation in 85 AMSL and the lowest elevation is -200 AMSL. The results of the ultimate pit limit selection use a BESR analysis between net revenue and total operating costs, without considering production scheduling or discounting. The BESR analysis selects an incremental stripping ratio (ISR) value that does not exceed BESR value [16]. The BESR value is 13.44 bcm/ton, so the incremental stripping ratio (ISR) value selected is 11.77 bcm/ton (Figure-2). If it exceeds the BESR of 13.44 Bcm/Ton, the mining activity will not be profitable. The incremental stripping ratio (ISR) value is found in the optimization grid prefix OPT015. In other word, OPT015 is the UPL for this coal mine case.

4. Conclusion

The conclusions in this study are as follows that the BESR value using economic parameters of reference coal price, overburden removal cost, coal mining cost, coal hauling, coal processing, barging & shipping, other cost and tax is used to determine the mining limit as a result of optimization. The calculated break event stripping ratio (BESR) value is 13.44. Structured Query Language (SQL) based pit optimization through several stages, namely creating cross sections, macro types, variable definitions, statements, conditions selection, actions. Structured Query Language (SQL) results in the form of coal benchmark prices, overburden removal cost values and coal mining costs will be inputted into the pit optimizer. The pit optimizer results in the form of a series of pit shells are used to determine the mining design boundary. The selected pit shell uses break even stripping ratio (BESR) analysis, where the selected incremental stripping ratio (ISR) value does not exceed the BESR value. So that the optimized mining limit is obtained at 15% optimization with an incremental stripping ratio (ISR) value of 11.77.

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