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Geometric Design Analysis of Pit X Mine Slope Koninis Area, Bunta District, Banggai Regency, Central Sulawesi Province

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ABSTRACTS

Research on the analysis of PIT X mine slope geometry was conducted by IUP PT. X in Koninis Village, which is administratively included in Bunta District, Bangggai Regency, Central Sulawesi Province, by designing the slope geometry statically and dynamically based on the Decree of the Minister of Energy and Mineral Resources No. 1827 K / 30 / MEM Year 2018. The analysis was conducted using the Bishop Simplified method using Rockscience's Slide 6.0 software. The results of static slope analysis of the overall slope in conditions without groundwater table are 2.00 and on the overall slope affected by the groundwater table is 1.77, the inter-ramp of the limonite section is 2.53 and on the inter-ramp slope the saprolite section is 1.92, the single slope of the limonite section is 5.35 and on the single slope the saprolite section is 4.10. While the analysis of the dynamic slope of the overall slope with the earthquake coefficient is 1.11, the inter-ramp of the limonite section with the earthquake coefficient is 1.77 and on the inter-ramp slope of the saprolite section with the earthquake coefficient is 1.35, the single slope of the limonite section with the earthquake coefficient is 2.75 and on the single slope the saprolite section with the earthquake coefficient is 4.679. Based on drill data, laboratory analysis results of UDS samples, and seismicity data, the FK value in limonite zoning is greater than the FK value in saprolite zoning. This design is to simulate slope geometry design modeling in PIT X research area.

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INTRODUCTION

Efforts to develop natural resources and energy, especially natural resources of Nickel Ore lately have increased their needs and become a prima donna. Ore excavated materials at this time in addition to meeting domestic needs are also export commodities and also make one of the potential natural resources in the mining sector. To meet the needs of increasing market share demand, the potential of nickel ore excavation materials needs to be pursued and developed optimally (Thamsi et al, 2019).

Mining activities often experience problems stemming from geotechnical problems. Excavation of a mass of soil and rock will cause a change in the distribution of stress on the slope which results in disruption of slope stability and ultimately can cause landslides. Other factors such as groundwater conditions can also affect the level of landslide vulnerability. The existence of a landslide on a mine slope will cause losses, including damage to operating heavy equipment, damage to facilities and infrastructure in the mine, disruption of production activities and loss of human life. Therefore, a slope stability analysis study is needed to be applied in the form of a singe slope geometry design *and* an overall *slope geometry design that* is optimal and creates safer working conditions (Munir et al, 2023).

The purpose of the study is to determine the geometry of the mine slope. The purpose of research activities on mining slope design is to design the geometry of mining slopes with static safety factors. Design mine slope geometry with dynamic safety factor. Knowing the comparison of FK in the laterization zone of the research area.

METHODS

The methods carried out in this research include several stages, namely Library Study, Data Collection stage which includes Field Data Collection stage, and Laboratory Data Collection. The next stage, namely the Data Analysis stage, includes the Field Data Analysis and Laboratory Data Analysis stages. The last stage is the Report Submission stage.

Literature studies are carried out by collecting basic information about the research area before taking data in the field. The information collected includes the geology of the research area, basic information including theories, studying literature from books, journals, previous researchers to a thesis or final project covering the research area.

Data collection is taken based on the results of literature studies, which include taking field data and laboratory data.

Field data collection includes slope geometry data collection and *Undisturbed Soil* (UDS) soil samples at 5 drill points. Soil samples are then processed using *direct shear tests* to obtain cohesion values and shear angles in the soil, as well as testing soil physical properties in the form of soil weight tests carried out in the Soil Mechanics Laboratory.

Processing field data derived from all recording, data collection and measurements made, in the form of coordinates of data retrieval stations, drill log descriptions, and documentation. Field data is then processed for further analysis and interpretation. The laboratory data work includes data analysis in the form of slope stability analysis with the Bishop method and weathering level analysis and using *software* assistance in the form of *Slide* 6.0 from *Rockscience.* *Slide* 6.0 software in analyzing slope stability against landslides. Data that have been analyzed in detail and interpreted and conclusions are drawn about the condition of the research area. During the preparation of this final project report, corrections and rechecks were carried out on all data and analysis results.

Regional Geology Research Area

Rusmana, et al (1993) explained that based on the regional geological nature of Sulawesi Island and its surroundings can be divided into several geological mandalas, one of which is the geological mandala of East Sulawesi. This mandala includes the Southeast arm of Sulawesi, the Eastern part of Central Sulawesi and the East arm of Sulawesi. The East Arm and Southeast Arm of Sulawesi are composed of malihan rocks, overburden sedimentary rocks and ophiolites that occurred from the process of *obduction* during the Miocene. Sulawesi and its surroundings are complex areas because they are the meeting place of three large plates, namely the Indo-Australian plate which moves towards the North, the Pacific plate which moves westward and the Eurasian plate which moves towards the south-southeast and the smaller plate, the Philippine plate.

Regional Geology of the study area based on rock assemblages and their characteristics, included in the regional geological map of the Luwuk sheet which is composed of oceanic crust / ophiolite deposits and alluvial deposits (Rusmana, et al., 1993). The research area is included in the hilly unit. The hilly unit is characterized as having an altitude of 50 meters to 700 meters above sea level. It is generally composed of ultramafic rocks and clastic sediments. This unit generally forms a parallel river flow pattern. (Rusmana, et al., 1993).

Ophiolite (Ku) rocks consist of peridotite, dunit and serpentinite. Serpentinite is dark gray to blackish in color; Solid and solid. This rock unit is estimated to be Cretaceous. Regionally, the Bangggai Regency area on the regional geological sheet is a subduction area associated with mafic and ultramafic rocks. The geological structure in this area is reflected by faults, folds and stocky. (Rusmana, et al., 1993).

The faults found are ascending faults, chunk faults and sliding faults. The ascending fault is represented by the Poh Fault, Batui Fault and Lobu Fault. All of them are thought to have a direction of force from the southeast. This force causes the formation of ascending faults and tile structures in the middle and sliding faults in the eastern part. The main fault is the Salodic Fault, westeast, involving Tertiary sedimentary rocks.

The crease structures found in this area are classified into open weak fold types i.e. folds with a maximum layer slope of 300 and closed strong folds with a layer slope of more than 300. The folding structure in this area forms an anticline and syncline with an easteast-southwest directional axis.

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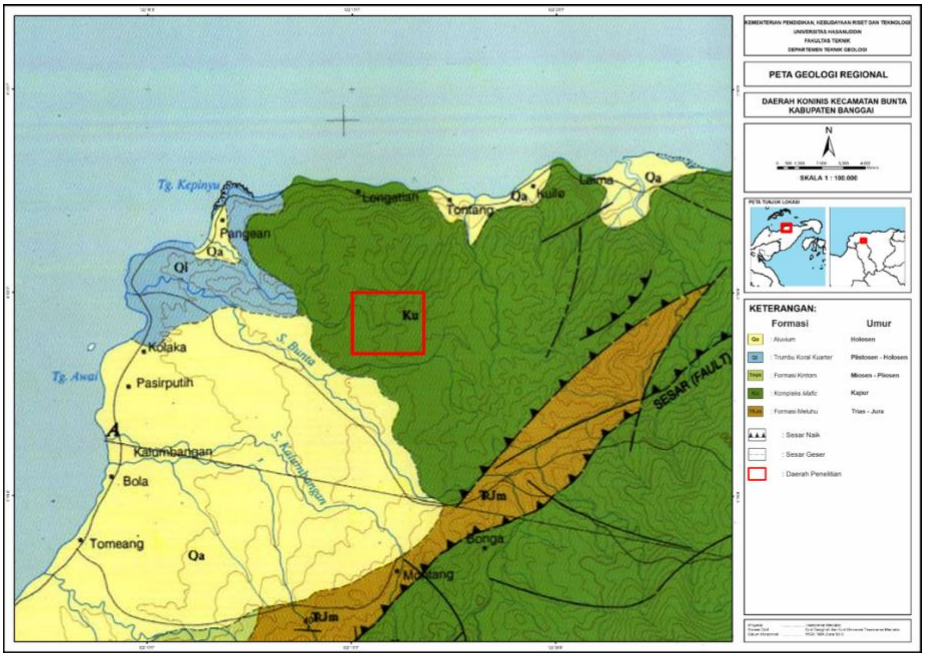

Figure 1. Regional Geologic Map of Lembar Luwuk, Sulawesi (Rusmana, dkk. 1993)

RESULTS AND DISCUSSION

In mining activities, the more upright the slope, the more excavated materials will be obtained. However, the more upright a slope is, the greater the possibility of landslides on the slope. Therefore, to determine the optimum slope, a geotechnical recommendation is needed, in the form of *a design geometry of a single slope (singe slope*), *Inter-ramp* and overall slope (*overall slope*), so that it will reduce the possibility of landslides and create safer working conditions. The study of the engineering geology of the research area was carried out by sampling soil and rock cores for laboratory analysis. The soil sampling location is shown in (Figure 2).

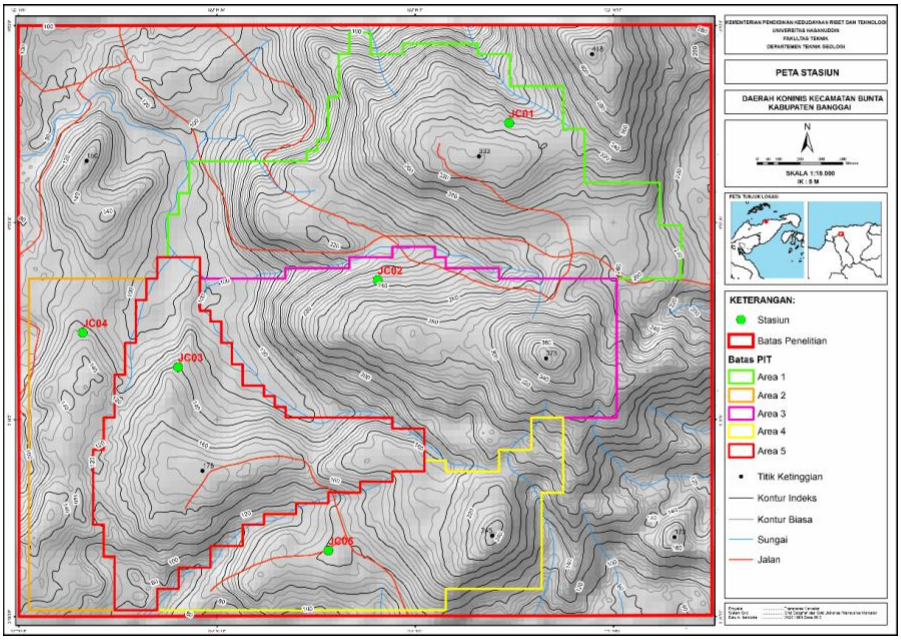

Figure 2. Drill Data Retrieval Location

Static Safety Factor

Slope Safety Factors are analyzed using soil parameters from laboratory analysis which are the average of the parameters most vulnerable to landslides to obtain critical avalanches that are likely to occur in mining areas, while these parameters are shown in Table 1.

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Table 1. Soil Parameters Used for FK Analysis Based on Soil Mechanics Laboratory Results (Results of Lab Analysis Sucofindo, 2022)

Lithology	Depth (m)	Description	Titik Bor					
			JC01	JC02	JC03	JC04	JC05	Mean
Upper Limonit	3	Wet Density (kN/m^3)	20.89	21.08	24.81	19.02	19.42	21.04
		Dry Density (kN/m^3)	14.71	12.85	18.63	11.08	12.55	13.96
		Bulk Density (kN/m^3)	20.95	18.97	25.75	18.40	17.69	20.35
		Void Ratio, e	0.42	0.64	0.33	0.72	0.55	0.53
		Porosity, n	0.30	0.32	0.28	0.40	0.29	0.32
		Cohesion(Kg/cm2)	56.87	17.65	50.01	20.59	47.07	38.44
		ϕ (o)	42.77	48.05	49.91	57.77	47.88	49.28
		q_u (kPa)	32.37	25.89	51.41	58.05	58.05	45.16
Lower Limonit	5	Wet Density (kN/m3)	24.32	16.28		18.24		19.61
		Dry Density (kN/m3)	17.95	10.10		11.77		13.27
		Bulk Density (kN/m3)	24.43	15.75		17.55		19.24
		Void Ratio, e	0.35	0.61		0.55		0.51
		Porosity, n	0.27	0.36		0.33		0.32
		Cohesion(Kg/cm2)	9.80	50.99		27.45		29.41
		ϕ (o)	41.01	56.76		53.40		50.39
		q_u (kPa)	51.79	51.60		38.56		47.32
Saprolit	9	Wet Density (kN/m3)	20.01	13.63		13.63		15.76
		Dry Density (kN/m3)	12.36	5.88		5.30		7.85
		Bulk Density (kN/m3)	19.69	9.79		9.08		12.85
		Void Ratio, e	0.62	1.32		1.57		1.17
		Porosity, n	0.37	0.40		0.42		0.40
		Cohesion(Kg/cm2)	42.16	18.63		30.40		30.40
		ϕ (o)	28.70	34.06		58.36		40.37
		q_u (kPa)	51.79	71.21		51.60		58.20

: Data yang digunakan

Overall Slope Static Safety Factor

The overall slope is designed from a combination of several single slopes, so modeling simulations are needed using *Rockscience Slide v.6.0* software to get the FK value so that it can be known whether the geometry of the overall slope is stable or not.

A stable slope design can minimize the possibility of landslides. There are several factors that can affect the stability of the slope, and there are certain criteria that a slope can be said to be stable or not. This study uses deterministic FK values, where the overall slope can be said to be stable / safe if the slope has a FK value of ≥ 1.2 according to predetermined rules.

The selection of overall slope geometry recommendations is based on several conditions, namely:

1. The overall slope is formed by a single slope geometry with a single slope tilt angle of 60o.
2. The overall slope modeling results are in a stable/safe condition if they have a FK value of ≥ 1.2.
3. MAT in the most pessimistic condition, namely in dry conditions (8H), this condition is found from the results of geoelectric analysis which shows the presence of groundwater aquifers in the JC04 area. High dry MAT was also modeled because dry conditions with no water occurred at some survey points.

Based on the results of the simulation analysis of the overall slope geometry model, it can be determined that the optimum overall slope geometry meets the above conditions.

From the results of the analysis, it is known that the FK for the overall slope without being affected by the groundwater table is **2.00** with *a bench height of* 4 m, a bench width of 1 meter, a slope angle of 35o and a ramp width of 12 meters (Figure 3). The geometric condition of this slope has met the Mining Slope Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

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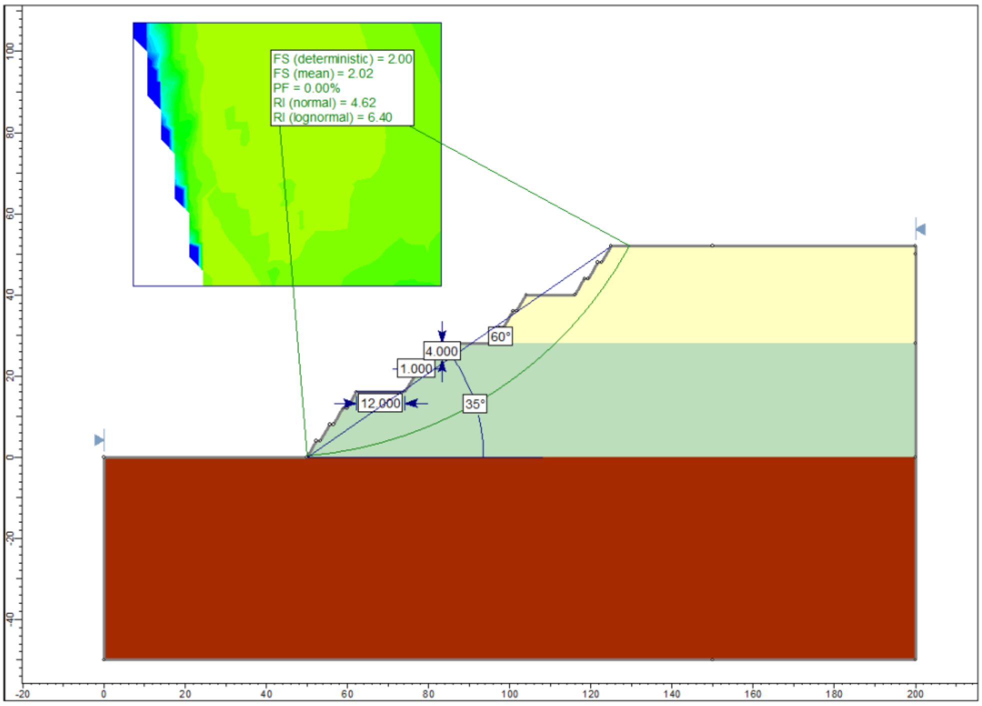

Figure 3. Overall Slope FK Analysis

From the results of the analysis, it is known that the FK for the overall slope affected by the groundwater table is **1.77** with a *bench height of* 4 m, bench width of 1 meter, slope angle of 35o and ramp width of 12 meters (Figure 4). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

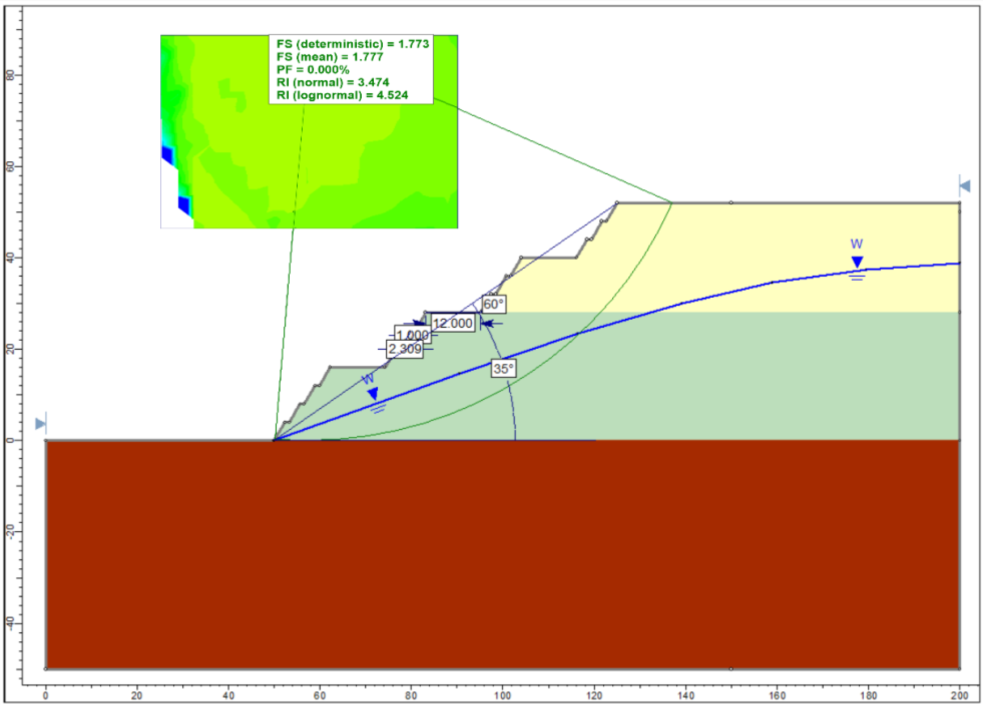

Figure 4. FK Analysis For Overall Slope With Ground Water Face

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Static Safety Factor *Inter-Ramp*

From the results of the analysis, it is known that the FK for *the Limonite Inter-Ramp* section is **2.53** with *a bench height of* 4 m, a bench width of 1 meter, a slope angle of 53o and a ramp width of 12 meters (Figure 5). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

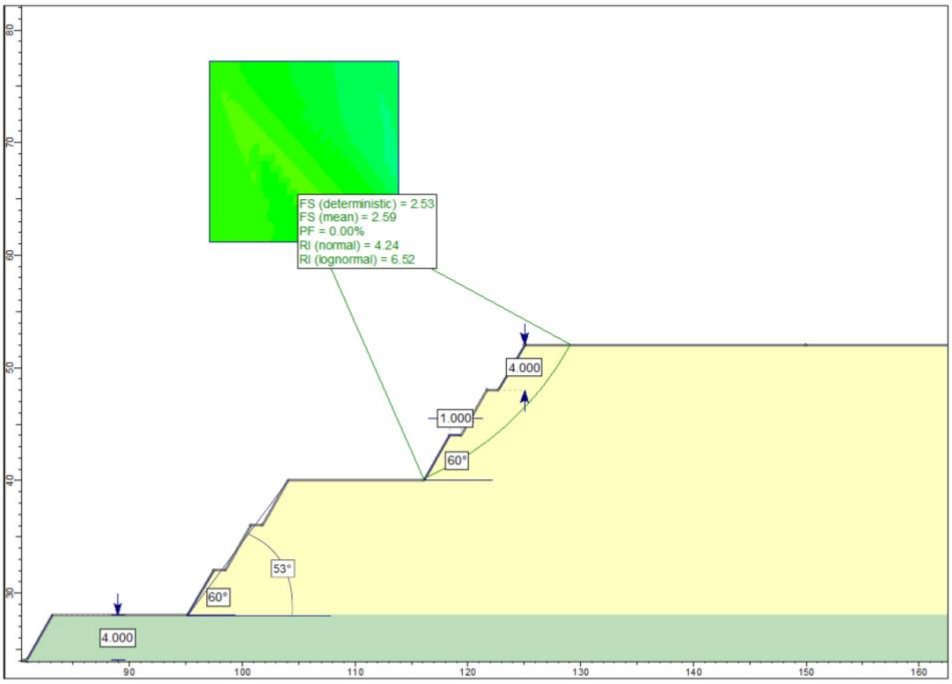

Figure 5. FK Analysis for *Limonite Section* Inter-Ramp

From the results of the analysis, it is known that the FK for *the Inter-Ramp* saprolite section is **1.92** with a *bench height of* 4 m, a bench width of 1 meter, a slope angle of 53o and a ramp width of 12 meters (Figure 6). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

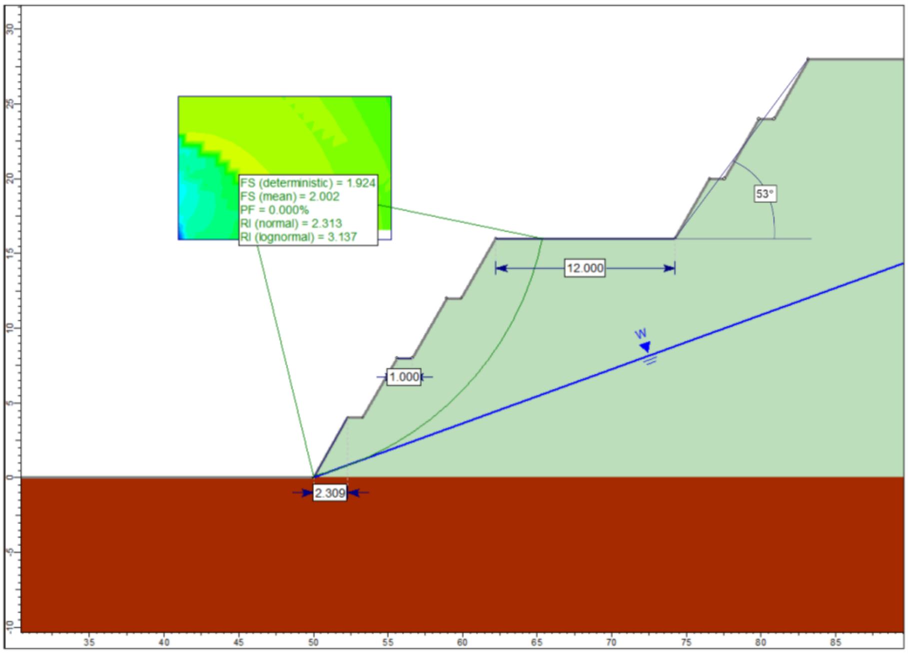

Figure 6. FK Analysis for *Saprolite Section* Inter-Ramp

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Single Slope Static Safety Factor

From the results of the analysis, it is known that the FK for the Single Slope of the limonite section is **5.35** with a *bench height of* 4 m, a bench width of 1 meter and a slope angle of 60o (Figure 7). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

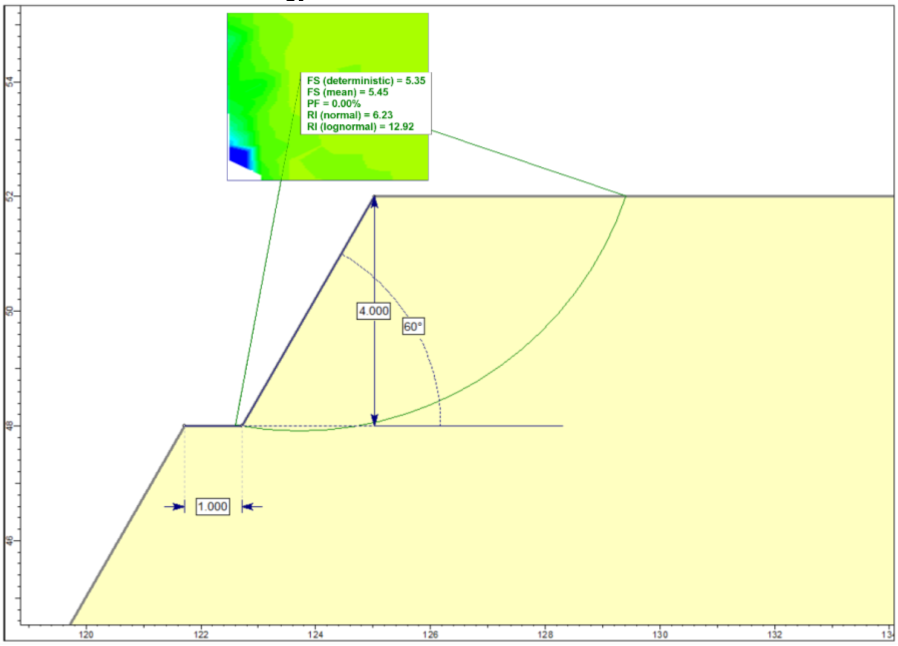

Figure 7. FK Analysis for Single Slope Limonite Section

From the results of the analysis, it is known that the FK for the single slope of the saprolite section is **4.10 with** a bench *height of* 4 m, a bench width of 1 meter and a slope angle of 60o (Figure 8). This condition is produced due to the high cohesion of laterite soils. The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

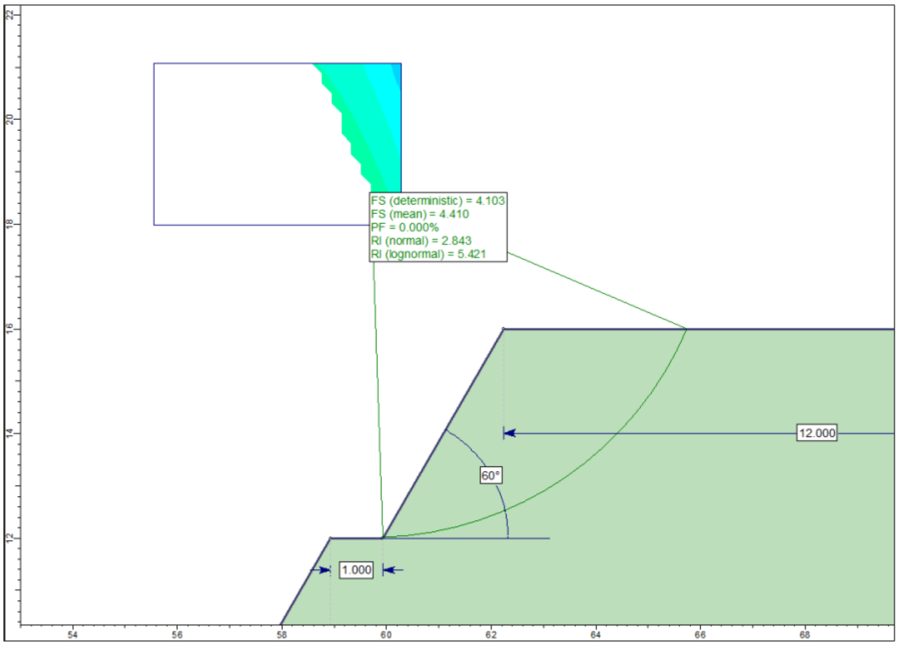

Figure 8. FK analysis for single slope saprolite section

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Dynamic Safety Factor

Determination of *peak ground acceleration* (PGA) is done by converting GPS coordinates to latitude and longitude. The coordinates 122°13'18.48"E and 0°50'8.18"S were obtained. Furthermore, the coordinates are entered on the http://rsa.ciptakarya.pu.go.id/2021/ page, obtained a PGA value of 0.465 which will then be used to calculate the value of the horizontal earthquake coefficient (kh). In the determination of the horizontal acceleration coefficient is assumed to be equal to the PGA value and the vertical acceleration coefficient is ignored.

Slope Safety Factors were analyzed using soil parameters from laboratory analysis that are most susceptible to landslides to obtain critical values of avalanches that are likely to occur in mine pits, while these parameters are displayed (Table 2) and Kh: PGA values: 0.465 g.

Table 2. Soil Parameters Used for FK Analysis Based on the Results of the Soil Mechanics Laboratory (Results of Lab Analysis Sucofindo, 2022)

Lithology	Depth (m)	Description	Titik Bor					
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Upper Limonit	3	Wet Density (kN/m^3)	20.89	21.08	24.81	19.02	19.42	21.04
		Dry Density (kN/m^3)	14.71	12.85	18.63	11.08	12.55	13.96
		Bulk Density (kN/m^3)	20.95	18.97	25.75	18.40	17.69	20.35
		Void Ratio, e	0.42	0.64	0.33	0.72	0.55	0.53
		Porosity, n	0.30	0.32	0.28	0.40	0.29	0.32
		Cohesion(Kg/cm2)	56.87	17.65	50.01	20.59	47.07	38.44
		ϕ (o)	42.77	48.05	49.91	57.77	47.88	49.28
		q_u (kPa)	32.37	25.89	51.41	58.05	58.05	45.16
Lower Limonit	5	Wet Density (kN/m3)	24.32	16.28		18.24		19.61
		Dry Density (kN/m3)	17.95	10.10		11.77		13.27
		Bulk Density (kN/m3)	24.43	15.75		17.55		19.24
		Void Ratio, e	0.35	0.61		0.55		0.51
		Porosity, n	0.27	0.36		0.33		0.32
		Cohesion(Kg/cm2)	9.80	50.99		27.45		29.41
		ϕ (o)	41.01	56.76		53.40		50.39
		q_u (kPa)	51.79	51.60		38.56		47.32
Saprolit	9	Wet Density (kN/m3)	20.01	13.63		13.63		15.76
		Dry Density (kN/m3)	12.36	5.88		5.30		7.85
		Bulk Density (kN/m3)	19.69	9.79		9.08		12.85
		Void Ratio, e	0.62	1.32		1.57		1.17
		Porosity, n	0.37	0.40		0.42		0.40
		Cohesion(Kg/cm2)	42.16	18.63		30.40		30.40
		ϕ (o)	28.70	34.06		58.36		40.37
		q_u (kPa)	51.79	71.21		51.60		58.20

: Data yang digunakan

Overall Slope Dynamic Safety Factor

From the results of the analysis, it is known that the FK for the overall slope is **1.11** with *a bench* height of 4 m, *a bench width of* 2 meters, a slope angle of 24o and a ramp width of 12 meters (Figure 4.8). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

Inter-Ramp Dynamic Safety Factor

From the results of the analysis, it is known that the FK for *the Inter-Ramp* limonite section is **1.77** with a *bench height of* 4 m, a bench width of 2 meters, a slope angle of 33o and a ramp width of 12 meters (Figure 9). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

From the results of the analysis, it is known that the FK for *the Inter-Ramp* saprolite section is **1.35** with a *bench height of* 4 m, a bench width of 2 meters, a slope angle of 33o and a ramp width of 12 meters (Figure 10). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

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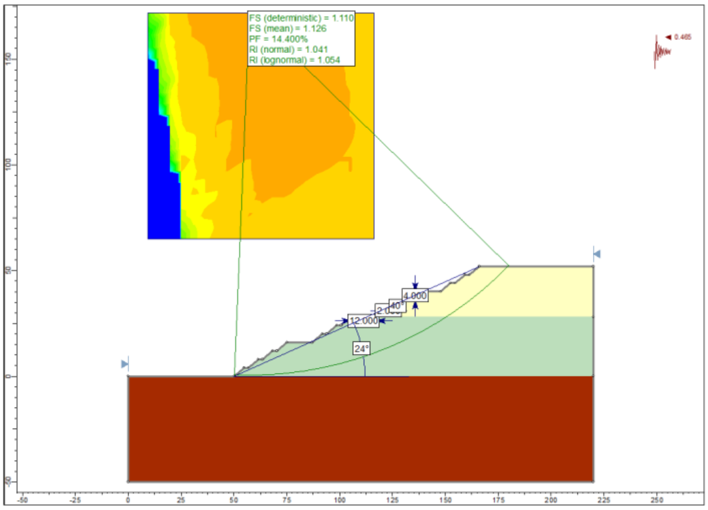

Figure 9. FK analysis for overall slope with earthquake coefficient

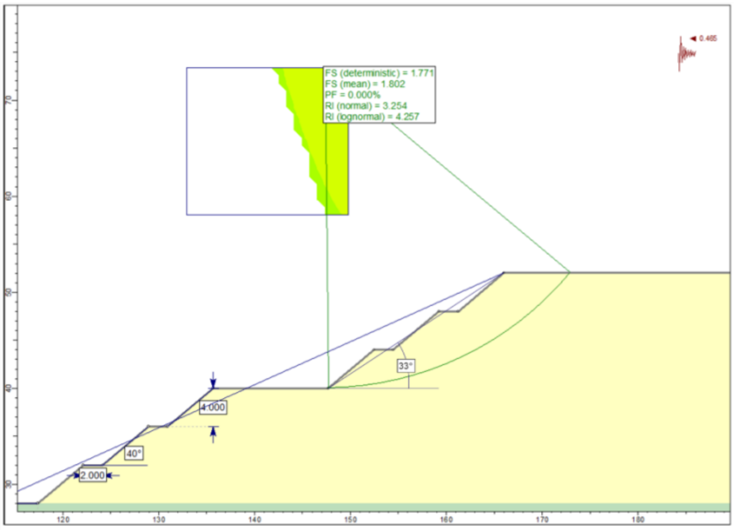

Figure 10. FK analysis for *inter-ramp* of limonite section with earthquake coefficient.

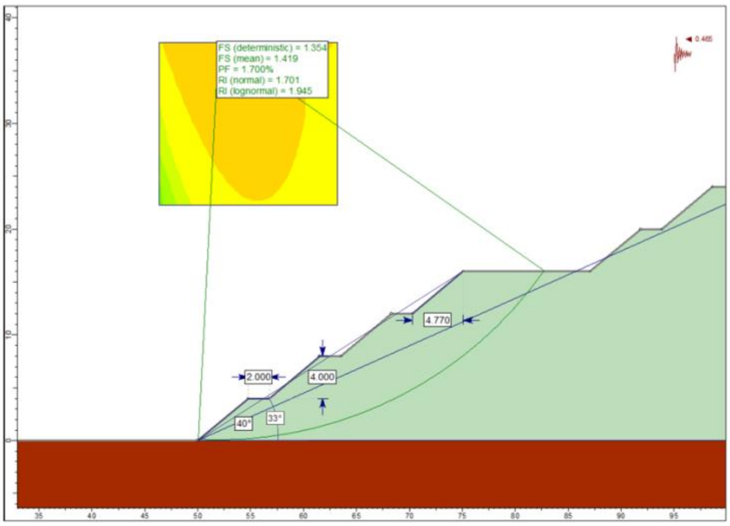

Figure 11. FK Analysis for *Saprolite Section Inter-Ramp* with Earthquake Coefficient

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Single Slope Dynamic Safety Factor

From the results of the analysis, it is known that the FK for Single Slope limonite section **2.75** with a *bench height of* 4 m, bench width of 2 meters and slope angle of 40o (Figure 12). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

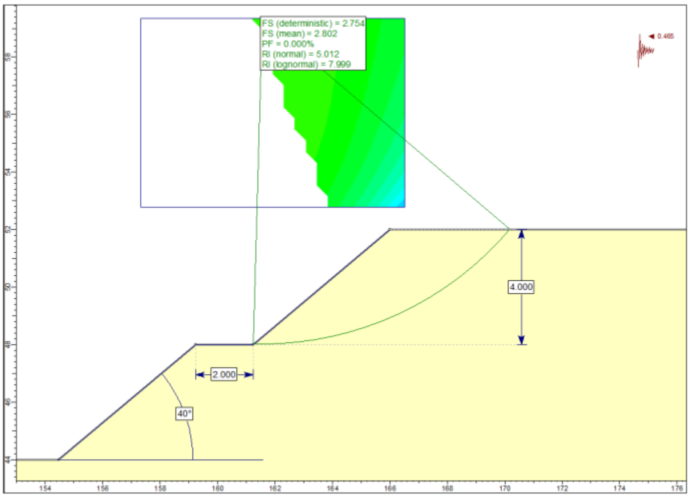

Figure 12. FK analysis for single slope limonite section with earthquake coefficient

From the results of the analysis, it is known that the FK for the Single Slope of the saprolite section is **2,516 with a** bench *height of* 4 m, a bench width of 2 meters and a slope angle of 40o (Figure 13). The geometric condition of this slope has met the Mine Slope Landslide Safety Factor Value based on the Decree of the Minister of Energy and Mineral Resources Number 1827 K 30 MEM 2018.

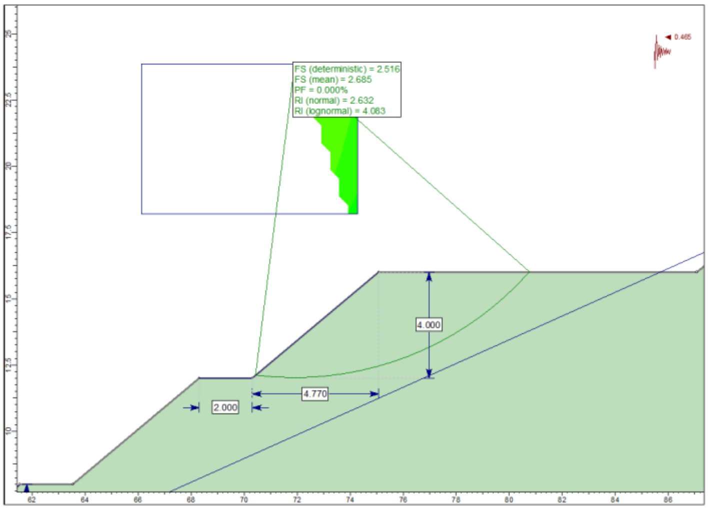

Figure 13. FK analysis for single slope saprolite section with earthquake coefficient.

Safety Factor Comparison

Based on observations from the drill data results, the investigation area consists of 4 laterite zones from bottom to top, namely *bedrock*, saprolite, limonite and top soil.

1. The top soil zone is dominated by *the minerals hematite* and *goethite*, with traces of plants still remaining.
2. Zone (Limonite) with a yellowish-brown to yellow physical appearance, with a very fine sand to clay grain size, in this zone a *leaching* process occurs leaving clay materials containing non-mobile elements (Al, Fe, and Mg) with a composition of *hematite*, *goethite* and manganese minerals with an average thickness of 7-10 meters.
3. Zone (Saprolite) with yellow-brown to greenish physical appearance. The material in this zone ranges in size from coarse sand to gravel. In this zone also found remnants of fractures and there

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are also silica veins. The mineral composition of *garnierite*, *serpentinite*, *hematite*, *goethite* and manganese with an average thickness of 9-20 meters.

Zone (*Bedrock*) physical appearance of greenish color, the size of gravel grains to chunks, with the mineral composition of *olivine*, *serpentinite*, and *pyroxine*. These rocks have fractures and are weakly serpentinized. Based on the laterization zone of the research area and the FK value in each slope geometry design, then:

Static Safety Factor

Based on drill data and laboratory analysis results of limonite zone UDS samples, resulting in a design with single slope FK 5.35 and *FK Inter-ramp* 2.53, this value is greater than the FK value in saprolite zoning. While the saprolite zone produces a design with a single slope FK of 4.10 and an Inter-ramp FK of 1.92. The Overall Slope Design is divided into two, namely FK Overall Slope 2.00 and FK Overall Slope with the influence of groundwater is 1.77. The FK value on the overall slope is greater than the FK value on the overall slope with the influence of groundwater.

Dynamic Safety Factor

Based on drill data, laboratory analysis results of UDS samples and limonite zone seismicity data, resulting in a design with single slope FK 2.75 and FK *Inter-ramp* 1.77, this value is greater than the FK value in saprolite zoning. While the saprolite zone produces a design with a single slope FK of 2.51 and an Inter-ramp FK of 1.35. The Overall Slope Design yields a value of FK 1.11.

CONCLUSION

The conclusions from the results of the study are based on the Decree of the Minister of Energy and Mineral Resources No. 1827 K / 30 / MEM of 2018 concerning Guidelines for the Implementation of Mining Engineering Rules, the static safety factor for the overall slope in conditions without groundwater table is **2.00** and on the overall slope affected by the groundwater level is **1.77**. The static safety factor for *the limonite section* inter-ramp is **2.53** and on the slope of the *saprolite section* inter-ramp is **1.92**. The static safety factor for single-slope limonite sections is **5.35** and for single-slope saprolite sections is **4.10**.

Based on the Decree of the Minister of Energy and Mineral Resources No. 1827 K / 30 / MEM of 2018 concerning Guidelines for the Implementation of Mining Engineering Rules, the dynamic safety factor for the overall slope with an earthquake coefficient is **1.11.** The dynamic safety factor for *the limonite section inter-ramp* with an earthquake coefficient is **1.77** and on the slope of the *saprolite section inter-ramp* with an earthquake coefficient is **1.35.** The dynamic safety factor for single-slope limonite sections with earthquake coefficient is **2.75** and for single-slope saprolite section with earthquake coefficient is **2.516.**

Based on drill data, laboratory analysis results of UDS samples, and seismicity data, the FK value in limonite zoning is greater than the FK value in saprolite zoning.

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