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Hydrological analysis using geoelectrics on nickel mine slopes

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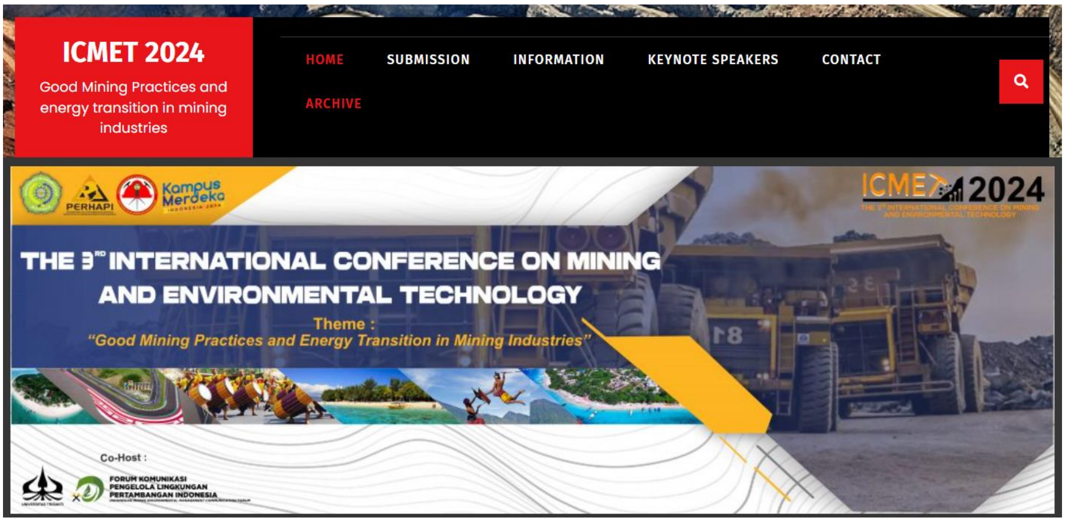

The 3rd International Conference on Mining and Environmental Technology (ICMET 2024) will be held|

The 3rd International Conference on Mining and Environmental Technology (ICMET 2024) is an international conference which covers **mining and environmental technology** issues. The 3rd will be held on August 22-24, 2024 in Mataram, West Nusa Tenggara, Indonesia. This conference organized by **Mine Engineering Department Muhammadiyah University of Mataram**, and **Association of Indonesia Mining Professionals (PERHAPI)**. The theme for this conference is "**Good Mining Practices and Energy Transition in Mining Industries**". The conference aims to keep abreast of the current development and innovation in the area of mining and environmental technology as well as providing an engaging platform for participants to share knowledge and expertise in related disciplines. all accepted and presented papers will be published at IOP EES (Indexed by SCOPUS).

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Hydrological analysis using geoelectrics on nickel mine slopes

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Abstract. The sudden emergence of groundwater levels has become a critical issue at PT. Makmur Lestari Primatama, a company operating in the nickel industry. Rainwater seeps into the soil, dominates the groundwater levels, and thus impacting the mining slopes. We conducted a geoelectric study to determine the presence of groundwater and its impact on the mining slopes. The slope safety factors ranged from 0.301 to 0.960, categorized as unstable and therefore, unsafe. Redesigning the slopes as a preventive measure is advised.

1. Introduction

A foundational paradigm in landslide science is that precipitation triggers landslides [1]. The rainy seasons raise the groundwater levels which, when combined with the influence of fractures, can affect the safety of single slopes in mining. This study focuses on a nickel mine located in Southeast Sulawesi, Indonesia, covering an area of approximately 407 hectares operated by PT Makmur Lestari Primatama, a company engaged in nickel resources using open-pit mining methods in the village of Langgikima, North Konawe Regency, Southeast Sulawesi. This open-pit mine is geologically situated within the high-pressure metamorphic rock zone, specifically the Pompangeo Schists. These schists exhibit foliated metamorphic structures along the Mendoke hills which significantly influence groundwater movement and groundwater level characteristics [2]. The sudden emergence of elevated groundwater levels, particularly during the rainy season, has become a critical issue, especially in the limonite layer within the mine. The implications for the mining site include potential direct landslides and operational delays.

The present study incorporates groundwater levels in slope analysis using geoelectric methods because this approach is crucial for accurately assessing slope stability. Investigating the influence of groundwater on internal pressure within the slope is essential, particularly since precipitation, specifically in the form of rainfall, is the most common cause of landslides [3]. Consequently, understanding these factors is vital for enhancing slope stability and mitigating potential risks.

2. Materials and methods

2.1. Materials

For stratigraphy analysis, the materials included the topsoil, limonite, saprolite, and bedrock. Additionally, nickel ore in this region is an ultrabasic rock of the serpentinite type, characterized by its coarse grains and composed of minerals such as olivine and pyroxene. Geoelectric research involved examining a specific scope and distance, analysing materials based on a single layer. The location for this study was determined based on previous research indicating the lowest safety factor at the mining site. This approach focused on assessing the strongest foundation of the mine, which, despite being critical, has a low safety factor.

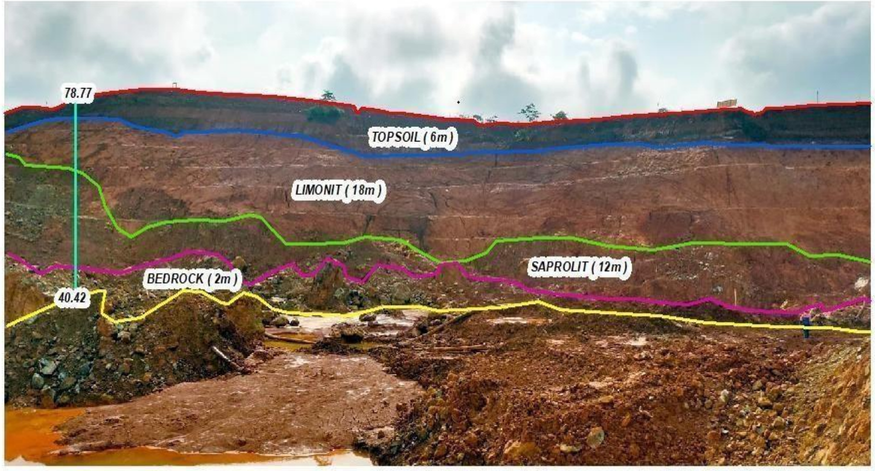

Figure 1. The stratigraphic layers of nickel at the mining

2.2 Methods

2.2.1 Creating survey location points with GPS

The research was conducted from March to May 2022, during which the survey locations were carefully mapped to ensure accurate and reliable data collection. Survey locations were determined using GPS devices to ensure high accuracy. Each location point was recorded with precise coordinates to ensure consistent and valid data for further reference.

2.2.2 Creating maps with ArcGIS

Data from the survey points was input into the ArcGIS to create accurate maps. Utilized ArcGIS weighted sum overlay strategy to create groundwater potential map using various layers [4].

2.2.3 Geoelectrical test

Quantitative reserach was conducted using the geoelectric method with the Schlumberger configuration, which is exceptionally capable of detecting the heterogeneity of rock layers on the surface by comparing apparent resistivity values when a change in electrode spacing occurs.This method utilizes the electrical properties of subsurface materials. Measurements are carried out by injecting direct current (DC) into the ground and measuring the resistivity of the materials below the surface [5]. The data sources were primary geoelectric data, including the voltage and current measurements from strategically selected survey points based on geological mapping and mining activity zones. The electrical resistivity of rock formation limits the amount of current passing through the formation when an electrical potential is applied [6]. The secondary data were location maps, situational maps, and rainfall data. Data analysis was run in Progress software and IP2Win to process the data, while laboratory tests determined the porosity and permeability. Quantitative tests ensured consistency through equipment calibration before each survey and repeat measurements. The selection procedure for survey points was based on geological features, accessibility, and the need to cover a representative area of the mine. We ensured data quality and validity include using high-precision equipment, standardized data collection protocols, cross-referencing results with other geophysical data, and performing statistical analyses. For slope stability analysis, the Slide software was used to evaluate safety factors and ensure reliable results.

2.2.4 Processing and modelling data with Progress software

The apparent resistivity results are then processed using PROGRESS software to get true resistivity [7]. Spacing input and observed data were utilized to create an accurate resistivity model. This process helped in visualizing the subsurface conditions more clearly. Error correction is performed to ensure a more accurate model that aligns with field data. The final model provides a detailed view of subsurface structures and potential groundwater level.

2.2.5 Correlating block models with geoelectric data using Surpac software
The results of the geoelectric model are compared with block models using Surpac software. This correlation helps identify areas with similar geological characteristics. This process is crucial to ensure the geoelectric data is consistent with the existing geological model

2.2.6 Processing and analysing correlation with mine slopes concerning groundwater levels using slide software
The correlation between geoelectric data and mine slope conditions was analysed to understand the impact of groundwater levels. This analysis helps determine the slope safety factor based on aquifer conditions. The results provide important information for safer mine planning and management.

3. Results and discussion

3.1. Research location point
The research location point is the best representation of the progress data at PT. Makmur Lestari Primatama's mine over the operational mining area. This area has the smallest slope safety factor points, making it hazardous and prone to landslides.

Table 1. Research location mining area

X	Y
S03°17'24.9" (GPS Essential)	E122°16'44.2" (GPS Essential)

Figure 2. Map of research location points

3.2 Rainfall intensity
This study used data of rainfall intensity from the past 3 years as presented in Table 2 below.

Table 2. Rainfall intensity

Year	Month												Rain hours per day	AVE daily rainfall hours	Rainfall intensity
	1	2	3	4	5	6	7	8	9	10	11	12			
2021	372	321	305	277	91	277	255	204	27	16.5	138	149	12.4	0.517	**243.25 mm/day**
2020	322	66	100	420	456	305	241	39	34	86	36	50	15.19	0.633	
2019	263	195	124	143	260	448	433	300	331	147	229	123	14.92	0.622	**10.14 mm/hours**
2018	208	361	268	209	493	321	329	670	320	57	120	131	22.35	0.931	

3.3 Parameters of analysing slope safety factor

The parameters for analysing slope safety factor include unit weight (γ), internal friction angle (ϕ), and cohesion (c). These analysis parameters consisted of limonite, saprolite, and bedrock for analysing slope safety factor (see Table 3).

Table 3. Parameters of material

Materials	Unit weight (kN/m)	Internal friction angle (°)	Cohesion (kPa)
Limonite	20	35	30
Saprolite	12	16	16
Bedrock	11.82	39.11	39.18

3.4 Result of progress software

Based on the rock resistivity values [8], we found that groundwater was present at the depth of 3-9 m, while surface water was at 1-2 m and 29-34 m.

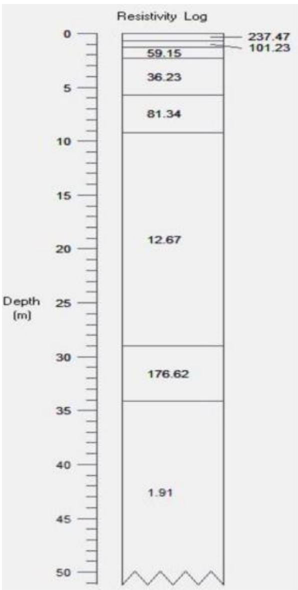

Figure 3. Analysis result of progress software

3.5. Slope safety factor analysis

Bishop and Morgenstern [9] developed a concept of obtaining FSfor any slope by determining its stability coefficients Following the application of the method, we incorporated groundwater as an additional parameter aiding the slope stability analysis using the Rocscience slide software. The results of slope stability analysis with the additional parameter of groundwater include the values of slope safety factors based on the Bishop's and Morgenstern-Price methods. After analysing the slope safety factors, we identified three slope cross sections that were unsafe and required attention, namely pit denver south section A-A', B-B', and C-C'.

Table 4. Safety factor in pit area

Number	Section	Safety factor	
		Bishop	M - P
1	A – A'	0.756	0.749
2	B – B'	0.978	0.979
3	C – C'	0.301	0.317
4	D – D'	2.328	2.327

3.6. New section BC-BC'

The creation of a new section is determined for correlating the results of geoelectric data with the area of one point. The section formed was positioned in the middle between Section B-B' and Section C-C' to obtain more representative results. The creation of the section was done using Surpac software processing.

3.7. Slope redesign

Slope inclination values are crucial factors in further slope analysis. Steep slope foundations can render safety factors unstable, necessitating actions or solutions to make the slope foundation gentler. Changing the slope angle from 33° to 28° results in a safety factor value of 1.24.

3.8. Porosity and permeability for hydrology analysis

Limonite and saprolite are porous in nature, capable of retaining groundwater volume with water filling the empty spaces in their structure due to numerous intergranular gaps. Limonite: 72.61% (porous) and saprolite: 65.70% (porous) [10]. Limonite and saprolite have low permeability, meaning few pore spaces are in place, preventing fluid and gas flow within their structure and causing them to settle within their layers. Limonite is 0.47 cm/hour (slow permeability class) and saprolite is 0.26 cm/hour (slow permeability class) [11].

4. Conclusion

Alongside the mine progress data for operational mining area, the slope is categorized as unsafe and may lead to landslides. The influence of groundwater at the depth of 3-9 m and surface water at depths of 1-2 m and 29-34 m may have contributed to the reduced slope stability. Limonite and saprolite have high porosity to accommodate groundwater volume, with water filling the void spaces in their structure. Limonite and saprolite have low permeability, demonstrating few pore spaces that prevent fluid and gas flow within their structure and cause them to settle within their layers. The layers at PT. Makmur Lestari Primatama are confirmed to be fractures, not aquifer layers, and the most dangerous slope in section C-C' is not affected by erosion. The slope in section C- C' is assisted by section D-D' due to the cohesion, which has a greater binding ability in limonite in section D-D'.

References

[1] Handweger A L, Fielding E J, Sangha S S, and Bekaert D P S 2022 Landslide Sensitivity and Response to Precipitation Changes in Wet and Dry Climates *Geophysical Research Letters* **49** 1-12 [doi.org/10.1029/2022GL099499]

[2] Hasria, Idrus A, and Armada I W 2021 Geologi Pegunungan Mendoke, Lengan Tenggara Pulau Sulawesi, Indonesia *Jurnal Geologi dan Sumberdaya Mineral* **22** 123-131 [doi.org/10.33332/jgsm.geologi.v22i3.581]

[3] Jagodnik, V. (2019). Rainfall infiltration and stability ana-lysis of an unsaturated slope in residual soil fromflysch rock mass.Proceedings of the XVII ECSMGE-2019: Geotechnical Engineering foundation of thefutureReykjavik, Island, 2019. p 1-8 [doi.org/10.32075/17ECSMGE-2019-09]
[4] Araffa S A S, Hamed H G, Alaa N, Sabet H S, AbuBakr M M, and Mebed M 2023 Assessment of Groundwater Aquifer Using Geophysical and Remote Sensing Data on The Area of Central Sinai Egypt *Sci Rep* **13** 18245 [doi.org/10.1038/s41598-023-44737-9]
[5] Aryanto R, Azizi M A, and Sumarjono E 2020 Analisis Tinggi Muka Air Tanah pada Daerah Longsoran serta Pengaruhnya terhadap Kestabilan Lereng dengan Metode Geolistrik di Bukit Kaliwadas Kedungwaru Karangsambung Jawa Tengah *Prosiding Seminar Nasional Pakar ke 3 Tahun 2020* 1-6 ISSN: 2615-33434
[6] Todd D K and Mays L W 2005 *Groundwater Hydrology Third Edition* (United States of America: John Wiley & Sons)
[7] Aryanto R, Fortian B, and Purwiyono T T 2019 Study of Aquifer Zone Using Geoelectric Vertical Electronic Sounding Method in Kedungwaru Village, Karangsambung District, Kebumen, Central Java *AIP Conf. Proc.* 2245, 070023 [doi.org/10.1063/5.0012110]
[8] Telford W M, Geldart L P, Sheriff R E, and Keys D A 1990 *Applied Geophysics Second Edition* (United State of America: Cambridge University Press)
[9] Bishop A W and Morgenstern N 1960 Stability Coefficients Forearth Slopes Géotechnique **10** 129–153 [doi.org/10.7939/R35M62D9F]
[10] Sutanto R 2005 *Dasar-dasar Ilmu Tanah Konsep dan Kenyataan* (Yogyakarta: Kanisius)
[11] Uhland R E, O'Neal A M 1951 *Soil permeability determinations for use in soil and water conservation* (Washington: U.S. Department of Agriculture, National Agricultural)