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Application of SNI 7280:2022 in Overburden Dumping Mechanism for PAF-NAF Material Management

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ABSTRACT. The management of overburden containing Potentially Acid Forming (PAF) and Non-Acid Forming (NAF) materials is critical to preventing acid mine drainage (AMD). This study aims to analyze the spatial distribution of PAF and NAF materials based on lithological characteristics and to design a safe overburden dumping mechanism complying with the SNI 7280:2022 standard. Utilizing data from 90 borehole points at PT X in East Kutai, the spatial analysis revealed a total overburden volume of 11,528,194 bank cubic meters (bcm). The lithology is dominated by sandstone and siltstone, resulting in a composition of 84.13% PAF and 15.87% NAF materials. To mitigate AMD risks, an encapsulation dump design was developed using a 1-3-7 block configuration (NAF-PAF-NAF), successfully isolating PAF materials from air and water exposure. Geotechnical assessment of this design using the Bishop method yielded a Factor of Safety (SF) of 1.545. In conclusion, the proposed encapsulation mechanism not only meets the national standard for environmental protection against AMD but also ensures structural slope stability. This integrated approach provides a practical framework for sustainable mine waste management.

Keywords: Acid mine drainage · PAF · NAF · SNI 7280:2022 · overburden.

1 INTRODUCTION

Managing mining waste, particularly overburden dumping, is a critical pillar of environmental sustainability in the mining industry (Yin *et al.*, 2026; Farhan & Nugraha, 2021). A primary challenge in open-pit operations is the formation of acid mine drainage (AMD), which occurs when Potentially Acid Forming (PAF) materials are exposed to atmospheric oxygen and moisture (Agustin *et al.*, 2020; Zhang *et al.*, 2026). The oxidation of sulfide minerals within these materials lowers the pH of the surrounding water, potentially leaching heavy metals into the ecosystem (Win *et al.*, 2020; Matsumoto *et al.*, 2016). Effective prevention strategies often involve strategically placing Non-Acid Forming (NAF) materials to neutralise acidity or act as physical barriers (Abfertiawan *et al.*, 2020).

Recent scholarship has extensively explored the geochemical characterization of mine waste (Sandan & Nurcholis, 2024); Hicks *et al.*, 2026). However, many studies focus exclusively on either the chemical prevention of AMD (Sandan & Nurcholis, 2024b; Barroso *et al.*, 2026) or the mechanical stability of waste dumps (Singh *et al.*, 2023; Yang *et al.*, 2023). There remains a significant research gap regarding the integration of spatial material distribution with standardized encapsulation protocols and concurrent geotechnical verification. This study addresses this gap by utilizing the SNI 7280:2022 standard to develop a comprehensive dumping mechanism.

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The novelty of this work lies in its holistic approach: combining 3D spatial modelling of PAF/NAF ratios with a 1-3-7 block encapsulation system and verifying the resulting structure's stability using the Bishop method. The authors chose this topic because precise material distribution is essential for effective encapsulation, yet it is often overlooked in standard operational designs. By bridging the gap between geochemical prevention and geotechnical safety, this research provides a validated model that meets Indonesian national standards while ensuring long-term environmental and structural integrity (Yang *et al.*, 2023).

2 REGIONAL GEOLOGY

This research was conducted in Bengalon, East Kutai Regency, East Kalimantan. The study area is characterized by undulating morphology and is situated at an elevation of approximately 325 meters above sea level. The coal formations in this region of East Kalimantan are part of the Kutai Basin, which was formed during the Tertiary period. The overburden in the study area predominantly consists of siltstone and sandstone (Figure 1).

3 METHODOLOGY

3.1 Data collection

The data used in this study are secondary data obtained from the company, including 90 sets of borehole data, topographic data, and pit design. Borehole data were utilized to identify lithological types and the distribution of PAF/NAF materials. Volume calculations were carried out using mining software (Geovia Minex) based on the lithological information in the borehole data using Insitu Resource Module (Warda *et al.*, 2020). Figure 2 shows the borehole location across the whole area of the proposed pit. Each drillhole will be cored and tested for PAF/NAF classification using the paste pH procedure. The composite data will be set for every 1 m-long core sample (Hadi *et al.*, 2024).

3.2 Dump design

The dumping design was developed based on the encapsulation principle in accordance with SNI 7280:2022 (Figure 3). The design composition follows a 1-3-7 system, consisting of one base block of NAF, three core blocks of PAF, and seven cover blocks of NAF. The dumping is carried out in layers and compacted to prevent water infiltration. This layered and controlled compaction process enhances the physical stability of the dump structure and reduces permeability. By minimizing permeability, the likelihood of water seeping through and initiating chemical reactions is significantly lowered. This approach aims to minimize the exposure of PAF materials to oxygen and water, thereby reducing the potential for acid mine drainage (AMD) formation.

Figure 3. Design Based on SNI 7280:2022

3.3 Slope stability analysis

The Safety Factor (SF) was calculated using the Bishop method. This method assumes that the failure plane is curved and that the resultant shear force across the sections is zero (Figure 4). The Bishop method satisfies the vertical force equilibrium for each slice and the moment equilibrium for the entire structure about the centre of the circular test surface. Geotechnical parameters, including unit weight, cohesion, and internal friction angle, were obtained from laboratory test results. Simulations were conducted to model the stability of the dump under shear forces and additional loading. The SF is calculated using the equation below.

$$FK = \frac{\sum [c + (\gamma_r h - \gamma_r h_w) \tan \phi] \, (\frac{\Delta x}{\cos \psi_b}) / (1 + \tan \psi_b \tan \frac{\phi}{FS})}{\sum \gamma_r h \Delta x \sin \psi_b + \frac{1}{2} \gamma_w z^2 (\frac{\alpha}{R})}$$

Note:
H = slope height (m)
h = water height (m)
R = radius (mm)
Δx = slices in circular failure (m)
Z = crack depth (m)

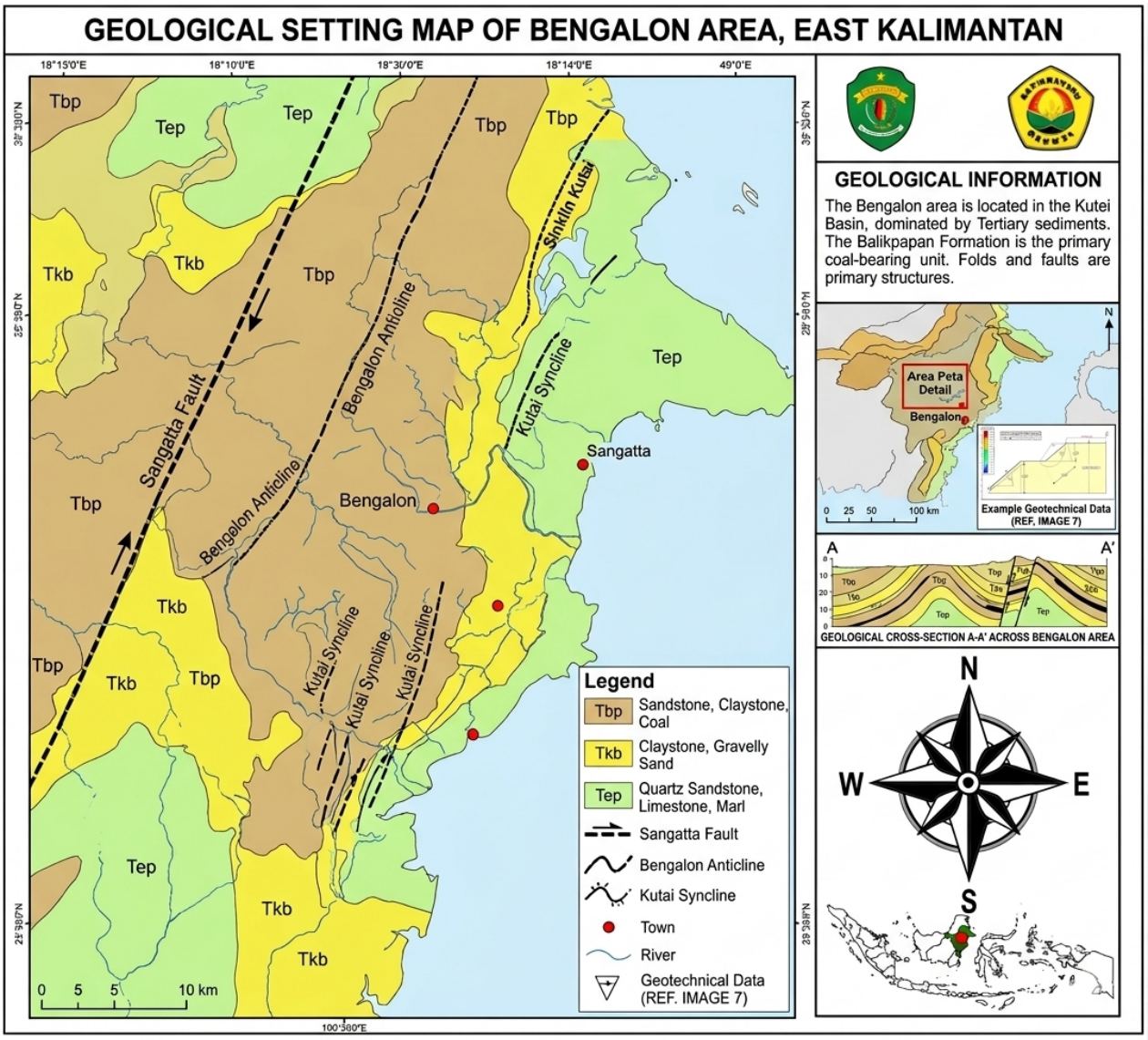

FIGURE 1. Geological setting map.

γ = unit weight (gr/m^3)
ψ = base angle (°)
ϕ = friction angle (°)
α = normal stress (kPa)
τ = shear stress (kPa)

These simulations help evaluate potential failure surfaces and assess the dump's overall structural integrity. The analysis ensures that the designed dumping system meets the required safety standards under varying field conditions.

4 RESULTS AND DISCUSSION

4.1 Distribution of PAF and NAF materials

Table 1 presents the analysis results for 90 boreholes using the in situ report module of Geovia Minex. It indicates that the overburden material consists of 84.13% Potentially Acid Forming (PAF) and 15.87% Non-Acid Forming (NAF) materials. The PAF material is predominantly composed of sandstone and claystone lithologies, with pH values below 4.5 as determined by the Net Acid Generation (NAG) test. NAF material is unevenly distributed and is generally found in the upper sections of the borehole profiles. Figure 5 shows a lithological representation derived from four borehole data points: 1503R, 1683R, 1458R, and 1498R. The researcher utilized geological software to model the lithological distribution based on the data obtained from the 90 boreholes points, which indicates that the overburden.

The higher proportion of PAF material com-

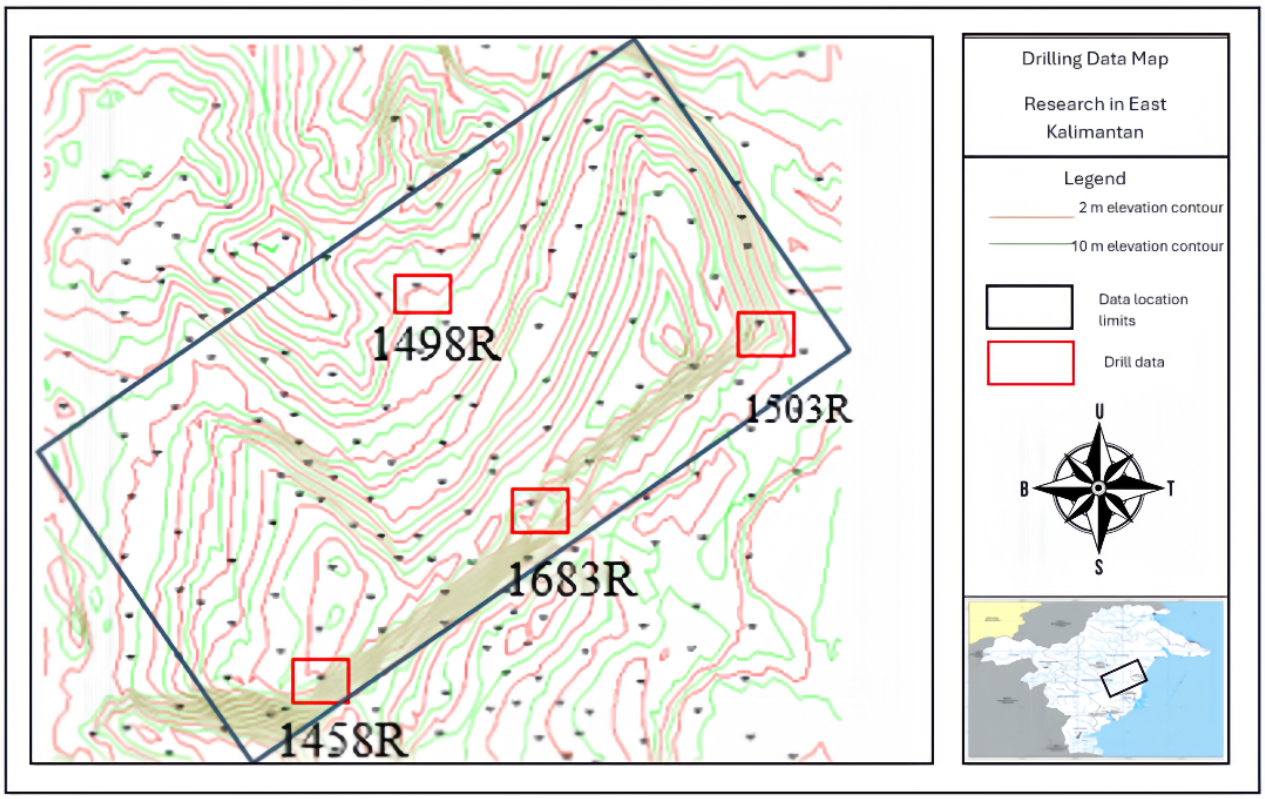

FIGURE 2. Borehole locations.

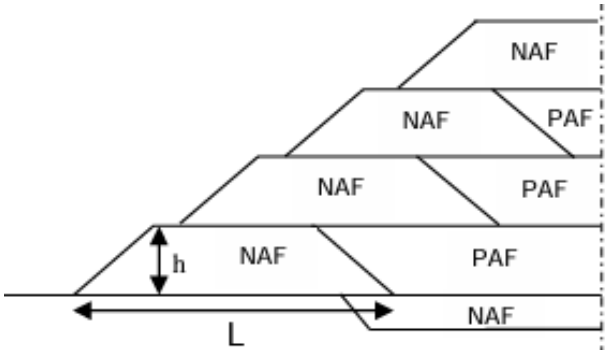

FIGURE 3. Design based on SNI 7280:2022.

TABLE 1. Borehole analysis.

No.	Material	Volume (m^3)
1	Coal	2,378,736
2	Waste (PAF)	9,699,228
3	Waste (NAF)	1,828,966

pared to NAF indicates an imbalance in the distribution of acidic and neutralizing materials, which requires the implementation of a more effective dumping strategy to prevent potential environmental degradation and mitigate the long-term contamination. NAF material was found only in limited quantities and was restricted to certain sections of a few specific boreholes.

4.2 Dump design according to SNI 7280:2022

The total overburden volume amounts to 11,528,194 BCM, consisting of 9,699,228 BCM of PAF material and 1,828,966 BCM of NAF material. The encapsulation system design places the PAF at the core of the dump, with NAF layers at the base and top. Each block is specifically designed to minimize contact between PAF and free water. Visualization of rock distribution was carried out using data from four selected boreholes: 1503R, 1683R, 1458R, and 1498R. These boreholes were chosen due to their low coal content, ensuring that the focus remained on waste material intended for dumping. The model considered a dumping depth of 28 meters, revealing that sandstone and mudstone dominate the lower to middle layers, ranging from approximately 2 meters to 28 meters, where most of the material is distributed. These lithologies are classified as PAF material based on their Net Acid Generation

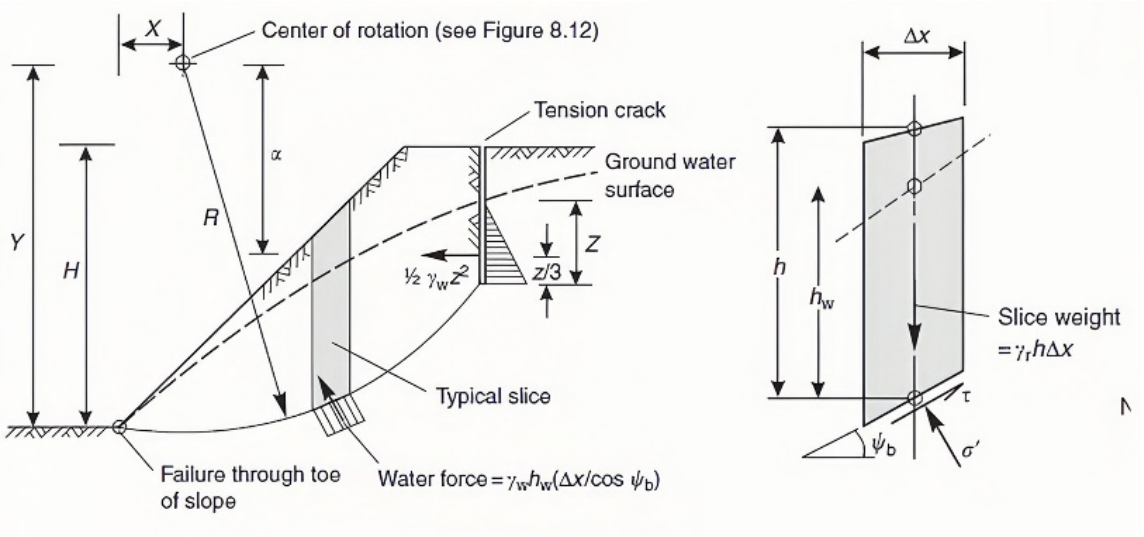

FIGURE 4. All forces on the Bishop method.

(NAG) test results, which showed pH values below 4.5, in accordance with SNI 6597:2021.

The dump design illustrated in Figure 6 considers not only chemical aspects, namely the analytical results indicating dominant PAF and NAF zones, but also geotechnical factors. PAF and NAF materials generally differ in texture, density, and shear strength. When mixed, these differences can significantly affect the overall stability of the dump. By adopting the 1-3-7 structure (one base block of NAF, three core blocks of PAF, and seven cover blocks of NAF), the design ensures that potentially contaminating materials are managed in a controlled manner and in accordance with national regulations.

4.3 Slope stability analysis

As shown in Figure 7, the dump location poses a slope stability concern, a critical aspect in mining operations, particularly for ensuring occupational safety and environmental sustainability. In this context, the overburden dump consists of Potentially Acid Forming (PAF) and Non-Acid Forming (NAF) materials, each possessing distinct material and geotechnical characteristics. These characteristics directly influence the slope behaviour and overall structural integrity. Therefore, slope stability analysis is essential to assess safety levels, which is conducted by calculating the Safety Factor (SF) using the Bishop method.

Figure 8 illustrates the slope stability analysis using the Bishop method, indicating a Safety Factor (SF) of 1.545, exceeding the minimum static SF standard of 1.3. The geotechnical parameters used in the analysis include a unit weight of 18 kN/m³, cohesion of 52 kPa, and an internal friction angle of 10.3°. The Bishop method calculation confirms that the SF value of 1.545 is above the required safety threshold (SF > 1.3), indicating that the slope is considered stable under current conditions. The simulation also accounted for surface loading and external forces to assess the potential for failure under operational conditions. The presence of the groundwater table influences pore water pressure and shear strength within the slope. PAF material also poses a risk of generating acid mine drainage (AMD) due to chemical reactions with oxygen and water. These reactions can lead to the gradual weakening of material strength over time. Therefore, management strategies such as encapsulation and compaction of the dump, runoff water control, and continuous monitoring of water quality and slope stability must be strictly implemented. From both technical and environmental perspectives, the Safety Factor (SF) value of 1.545 indicates a stable condition. However, this result is considered temporary and must be reassessed periodically to account for dynamic field conditions. The SF value also reflects that the slope remains within safe limits according to geotechnical criteria, particularly under an additional load scenario of 55 kN/m² applied to the slope crest. The shear strength parameters

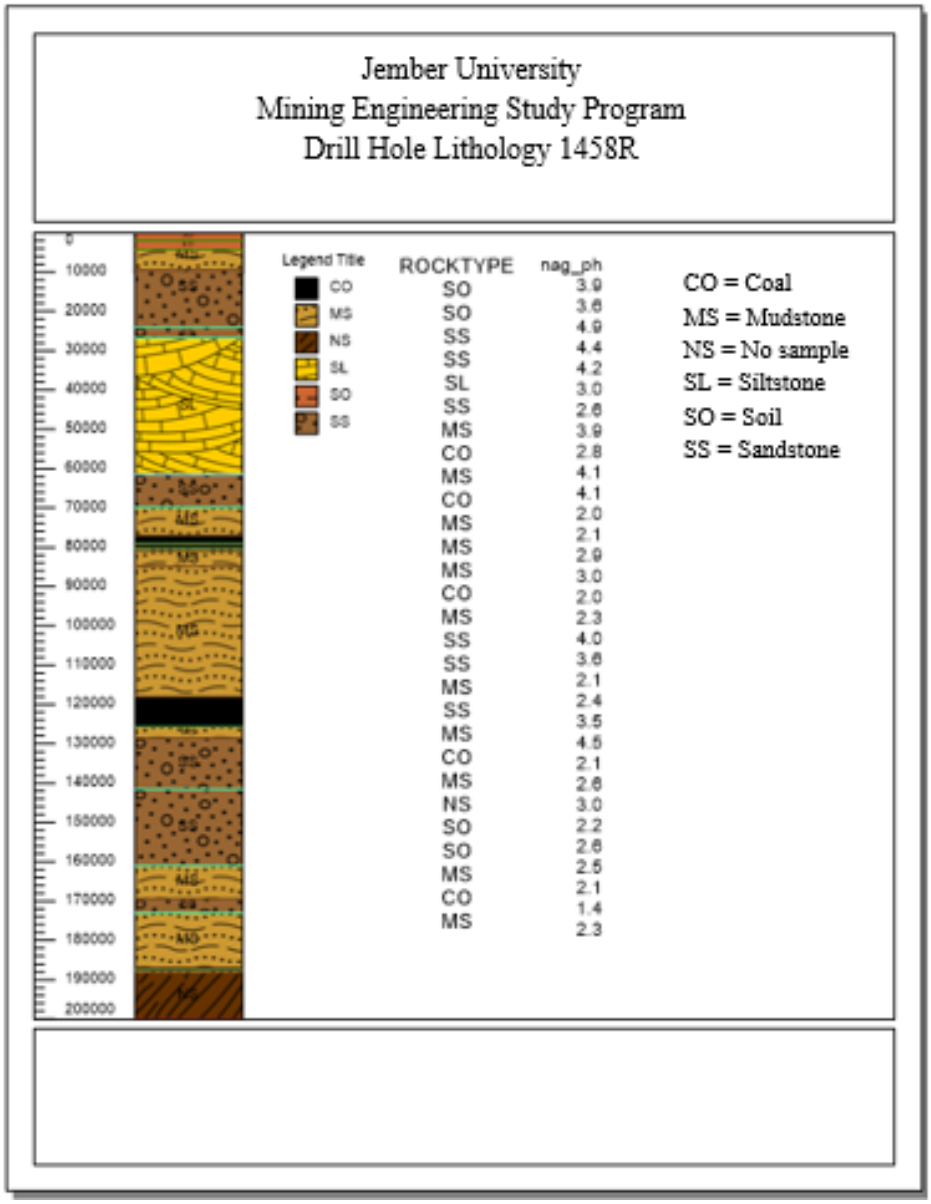

FIGURE 5. Borehole lithology overview.

used in the analysis—cohesion of 52 kPa and internal friction angle of 10.3°—significantly contribute to maintaining slope stability under constant groundwater table conditions.

5 CONCLUSION

Based on the analysis of 90 borehole points, the geochemical area is predominantly composed of PAF material (66.67%), indicating a high potential for acid mine drainage (AMD) formation, as evidenced by an average NAG pH value of less than 4.5. In contrast, NAF material accounts for only 33.33% and is unevenly distributed. The overburden dump design refers to SNI 7082:2022, applying an encapsulation method using a 1-3-7 system to minimize environmental impacts. The slope stability analysis, conducted using the Bishop method, yielded a Safety Factor (SF) of 1.545, which exceeds the minimum standard requirement and confirms the overall stability of the dump structure.

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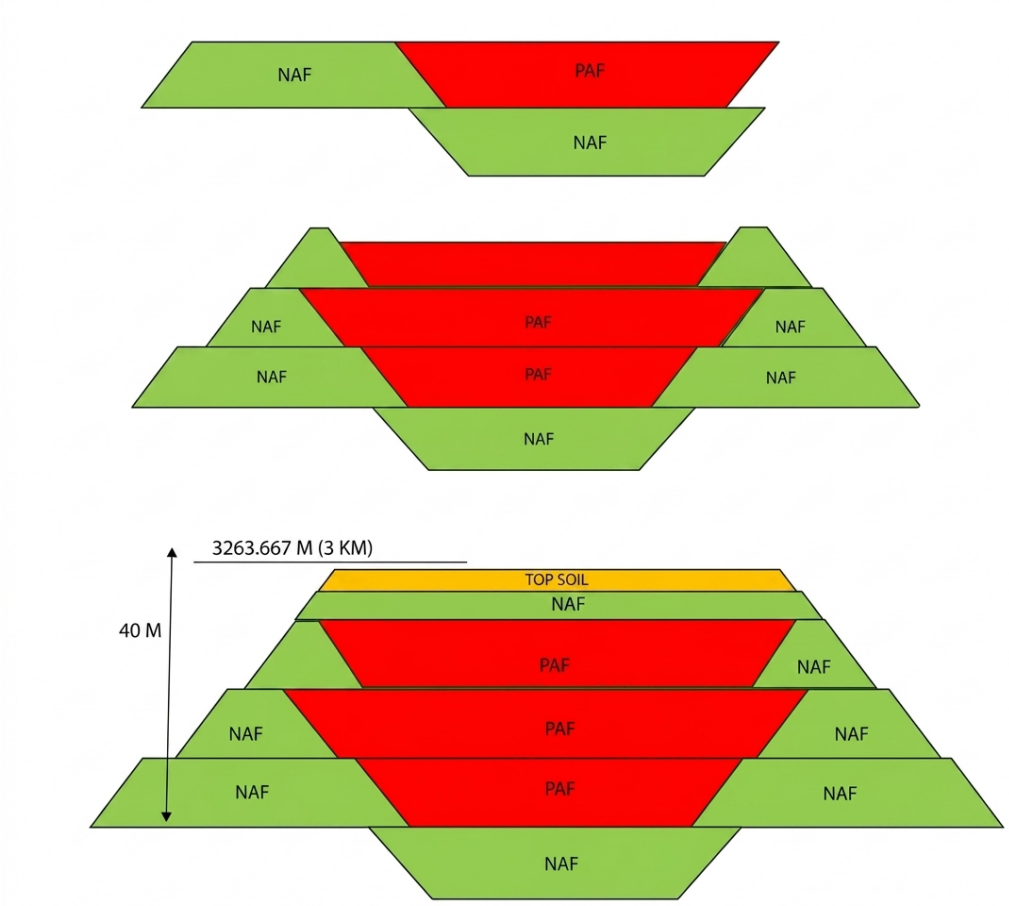

FIGURE 6. Dumping mechanism.

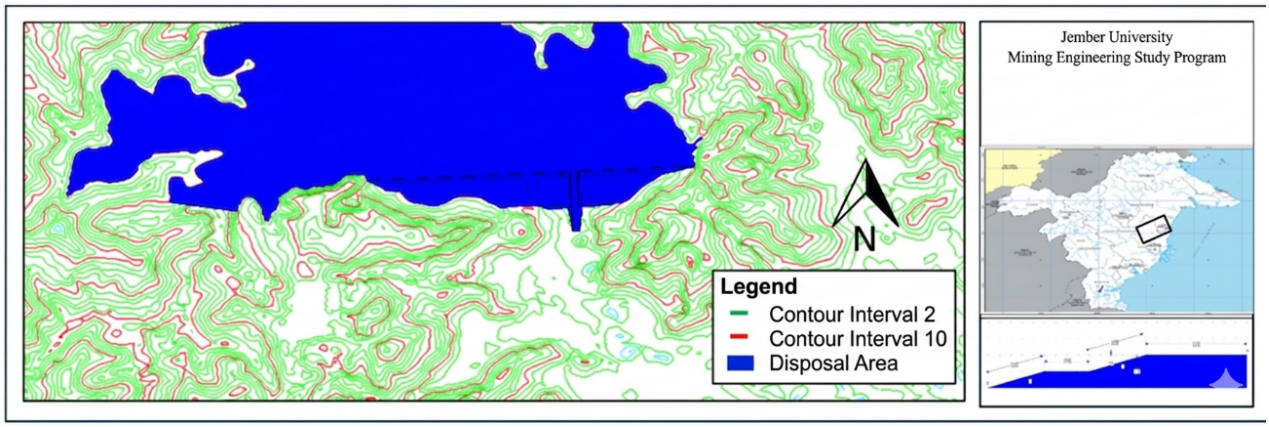

FIGURE 7. Disturbed area for disposal dump.

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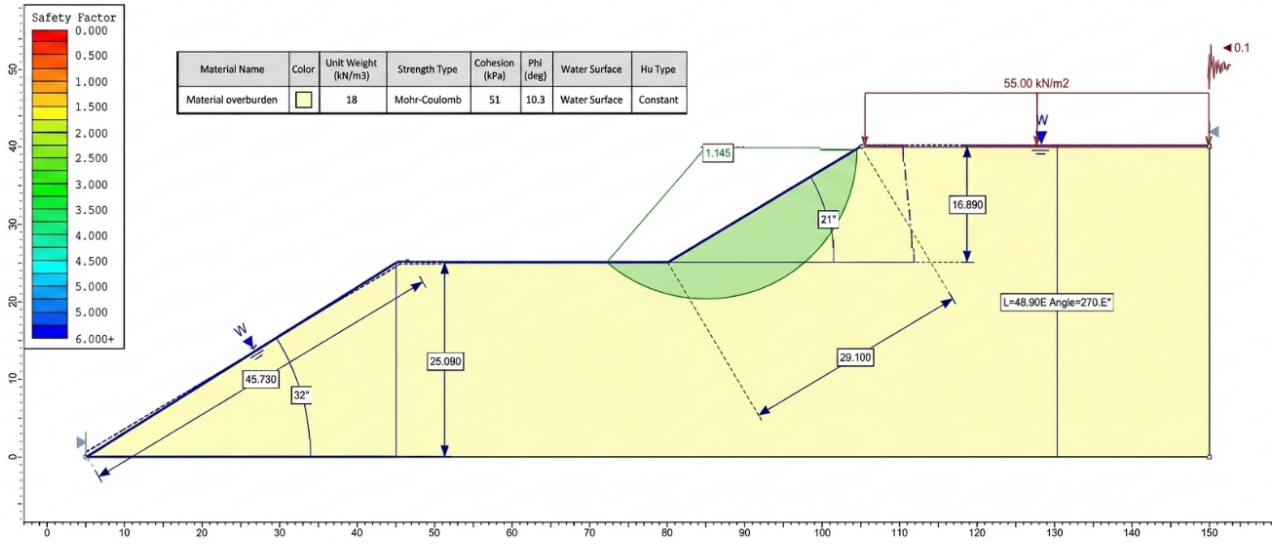

FIGURE 8. Dump modeling.

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