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PENGEMBANGAN METODE PENENTUAN AMBANG BATAS (THRESHOLD) INTENSITAS-DURASI HUJAN PEMICU KELONGSORAN
PADA LERENG TAMBANG TERBUKA MENGGUNAKAN PEMODELAN NUMERIS
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INTISARI

Kelongsoran lereng akibat hujan mengancam keselamatan operasional tambang nikel laterit terbuka di wilayah tropis Indonesia. Pendekatan peringatan dini saat ini masih bersifat reaktif karena mendeteksi pergerakan setelah deformasi terjadi. Di sisi lain, kurva ambang batas hujan empiris global atau regional tidak akurat diterapkan pada lereng tambang spesifik yang minim data historis longsor. Penelitian ini bertujuan untuk mengembangkan metode penentuan kurva ambang batas intensitas-durasi (I-D) hujan secara *site-specific* tanpa ketergantungan pada inventarisasi data historis longsor melalui pendekatan pemodelan numeris.

Metode penelitian dilakukan dengan mengekstraksi empat penampang lereng dari *block model* Surpac PT. X, Sulawesi Tenggara. Pemodelan numeris rembesan transien dan stabilitas lereng disimulasikan menggunakan program SEEP/W dan SLOPE/W berdasarkan parameter tanah tak jenuh hasil uji laboratorium. Sepuluh skenario intensitas hujan (10–350 mm/hari) diaplikasikan selama maksimum 90 hari dengan melibatkan kondisi *pre-wetting* anteseden sebagai kondisi awal yang realistis.

Lereng 1 dan Lereng 2 gagal pada kondisi *prewetting* (FK < 1,00), konsisten dengan laporan kelongsoran lapangan Januari 2026 dan berfungsi sebagai validasi *back-analysis* primer. Lereng 3 dan Lereng 4 menghasilkan kurva *threshold* dengan nilai eksponen $\beta = 2{,}832–3{,}756$, jauh lebih besar dari kurva global Caine (1980) $\beta = 0{,}39$ dan Guzzetti et al. (2008) $\beta = 0{,}44$, menunjukkan bahwa lereng nikel laterit ini jauh lebih rentan terhadap akumulasi hujan berdurasi panjang dibandingkan hujan intensitas tinggi sesaat. Berdasarkan hasil tersebut, direkomendasikan sistem peringatan dini tiga level berbasis kurva *threshold site-specific* yang dapat dioperasikan secara *real-time* menggunakan data stasiun curah hujan otomatis.

Kata kunci: ambang batas hujan, kestabilan lereng, nikel laterit, tanah tak jenuh, sistem peringatan dini, pemodelan numeris

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ABSTRACT

Rainfall-induced slope instability poses a major threat to the operational safety of open-pit nickel laterite mines in tropical regions of Indonesia. Current early warning approaches remain reactive, as they detect movements only after deformation has occurred. On the other hand, existing global or regional empirical rainfall threshold curves lack the accuracy required for application to specific mine slopes that suffer from a dearth of historical landslide data. This study aims to develop a method for establishing site-specific rainfall intensity-duration (I-D) threshold curves through transient seepage and slope stability numerical modeling, eliminating dependency on historical landslide inventories.

The methodology involved extracting four slope cross-sections from the Surpac block model of PT. X, Southeast Sulawesi. Numerical modeling of transient seepage and slope stability was simulated using SEEP/W and SLOPE/W software, based on unsaturated soil parameters obtained from laboratory testing. Ten rainfall intensity scenarios (10–350 mm/day) were applied over a maximum duration of 90 days, incorporating antecedent pre-wetting conditions to establish a realistic initial state.

The results demonstrated that Slope 1 and Slope 2 failed during the pre-wetting stage (Factor of Safety, FS < 1.00), which is consistent with the actual field landslide reported in January 2026, thereby serving as a primary back-analysis validation. Simulations for Slope 3 and Slope 4 yielded threshold curves with exponent values of \(\beta \) = 2.832–3.756. These values are significantly higher than the global curves of Caine (1980) (\(\beta \) = 0.39) and Guzzetti et al. (2008) (\(\beta \) = 0.44), proving that these nickel laterite mine slopes are highly sensitive to long-duration antecedent rainfall accumulation rather than short-duration high-intensity storms. Based on these findings, a proactive three-level early warning system utilizing site-specific threshold curves is recommended, which can be operated in real-time integration with automatic weather station data.

Slopes 1 and 2 reached failure (FS < 1.00) during prewetting, consistent with field supervisor reports of slope failures in January 2026 and serving as primary back-analysis validation. Slopes 3 and 4 produced threshold curves with exponent values β = 2.832–3.756, substantially larger than global empirical thresholds by Caine (1980) with β = 0.39 and Guzzetti et al. (2008) with β = 0.44, indicating that these nickel laterite slopes are far more vulnerable to prolonged moderate-intensity rainfall than to short-duration intense rainfall. Based on these results, a three-level early warning system is recommended, operating in real-time against site-specific threshold curves using data from an automatic weather station.

Keywords: *rainfall threshold, slope stability, nickel laterite, unsaturated soil, early warning system, numerical modelling*