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Assessment of Drainage Efficiency in the Backfill Disposal Area of East Air Laya Mine Field at PT. Bukit Asam; A case study from Tanjung Enim, South Sumatera, Indonesia

Fitri Indah Dwi Suci *[1], Yazid Fanani [1], Yudho Galih Dwi Cahyono [1]
[1] Department of Mining Engineering, Institut Teknologi Adhi Tama Surabaya
*e-mail: fitriindahdwisuci1901@gmail.com

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Abstract

This research undertakes a thorough evaluation of the drainage systems in the disposal areas at PT. Bukit Asam during the October 2023 sequence, with the objective of understanding the factors that influence the capacity and efficiency of disposal mounds, the density of materials used, the geometric structure of disposal sites, and the design dimensions of open drainage channels. Utilizing the trapezium volume formula, the study meticulously calculated the planned disposal volumes at various elevations—2,289,155 Bank Cubic Meters (BCM) at 36 meters, 1,004,112 BCM at 42 meters, and 669,892 BCM at 48 meters—comparing these against an actual obtained volume of 1,799,111.4 BCM. The substantial variance between the planned and actual volumes highlights the critical challenges in achieving predictive accuracy in disposal management. Further assessments were conducted using the Dynamic Cone Penetrometer (DCP) with a 60-degree cone to determine the density and sub-grade California Bearing Ratio (CBR) of the barrier materials, which were found to be suitable for road construction, falling under sub-grade C classification. Moreover, the Gumbel method was applied to devise the dimensions of a trapezoidal open channel, designed to facilitate a drainage capacity of 100,432.996 cubic meters per hour over a length of 3000 meters. The channel dimensions included a bottom width of 1.1 meters, a top width of 2.3 meters, a depth of 2.4 meters, and a 45-degree slope, with a Manning's coefficient (n) of 0.03. This detailed inquiry not only provides vital insights into the operational adjustments required for effective drainage but also promotes the adoption of sustainable and safe disposal management practices in the mining industry. The findings from this study serve as a pivotal reference for future improvements in the design and management of mine waste disposal systems

1. Introduction

PT Bukit Asam is a company engaged in the coal mining business, a critical sector within the global mining industry. The management of overburden material and coal waste generated during the mining process is vital, as these materials must be moved, managed, and disposed of efficiently. This not only meets technical requirements but also minimizes environmental impacts [1]. Overburden in coal mining can consist of soil, rocks, sand, clay, and other materials covering coal deposits [2], [3]. It is typically placed in designated areas known as disposals.

At PT Bukit Asam specifically in the east TAL (abbreviated from *Tambang Air* Laya / Air Laya Mine) backfilling disposal area, the overburden material from the Air Laya Mine is varied, including clay, sandy clay, and ordinary soil [4], [5]. The management of these disposals is crucial, often referred to as dump sites, spoil dumps, spoil disposals, or disposal dumps. The proximity of the TAL east backfilling disposal to the mining site plays a significant role in the efficiency of the disposal process [6], [7].

The disposal design includes geometric structures such as overall slopes, adhering to guidelines such as KEPMEN ESDM No.1827K/30/MEM/2018, which provides standards for implementing good mining engineering practices [8], [9]. Additionally, the presence of trenches within the disposal geometry is essential to prevent issues such as flooding, erosion, and hindrance to the monthly sequence targets in the stockpile area [10], [11].

The mining and disposition of materials involve diverse material characteristics such as type, moisture, and texture, which affect the density of the fill, the compaction process, and even the swell factor of the fill material [12], [13]. These factors significantly impact the backfilling capacity of the disposal area. At the TAL East backfilling disposal, materials are often stockpiled randomly, making originally heterogeneous materials become homogeneous, which affects both the compaction process and the volume at the disposal [14], [15].

Such challenges require thorough analysis and careful management, incorporating aspects of engineering hydrology [16], [17], soil mechanics [18], and foundation engineering [19] to ensure that the disposal sites effectively manage the materials without adverse environmental impacts. The backfilling and drainage systems must be designed to handle the runoff and prevent waterlogging, which are closely related to rainwater management and material characteristics [20].

2. Methodology

This study employs a multi-faceted approach to analyze various data sets crucial for evaluating the efficiency of drainage systems in the disposal areas of PT. Bukit Asam Our methodology integrates hydrological modeling, geotechnical testing, and volumetric analysis to ensure comprehensive assessment of the disposal and drainage systems. The primary data analyzed include runoff water discharge, the volume and capacity of open channels, the California Bearing Ratio (CBR) values, and the total disposal volumes.

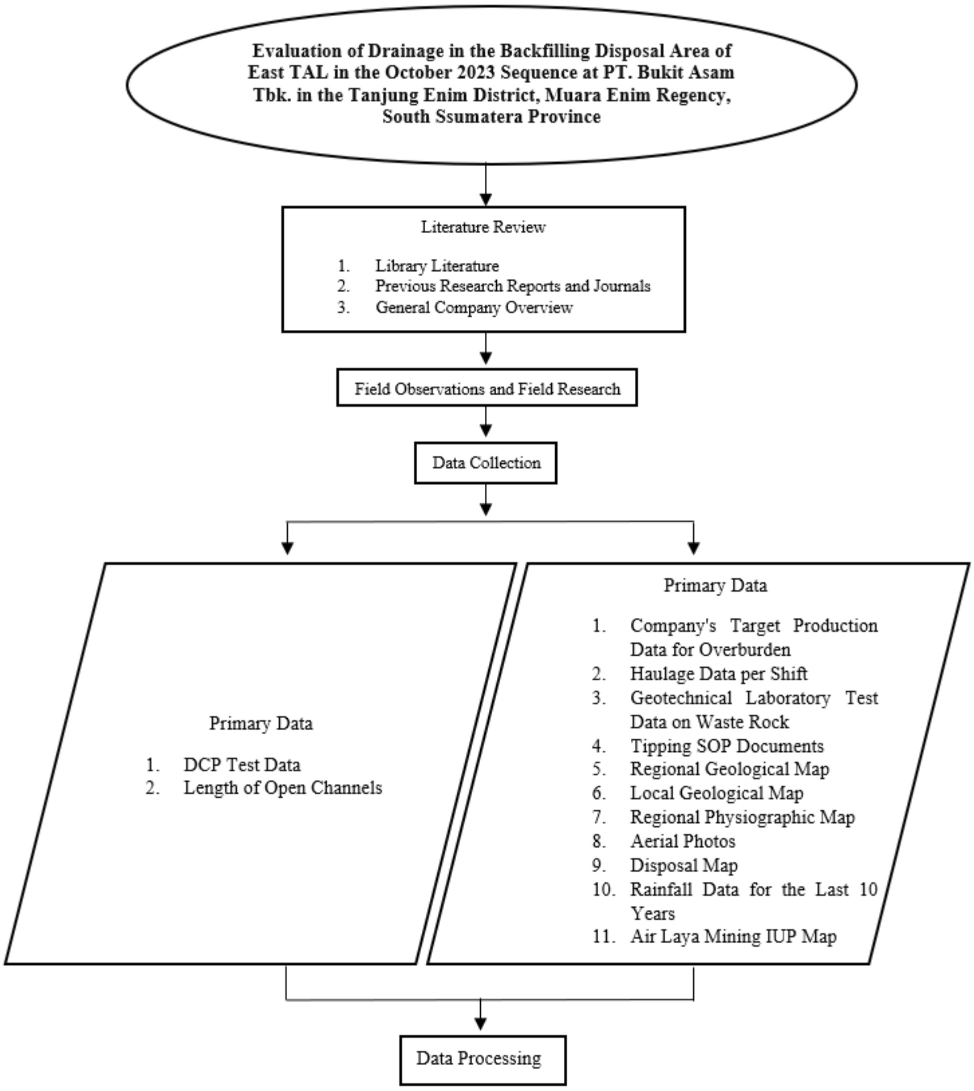

Figure 1. The research flowchart

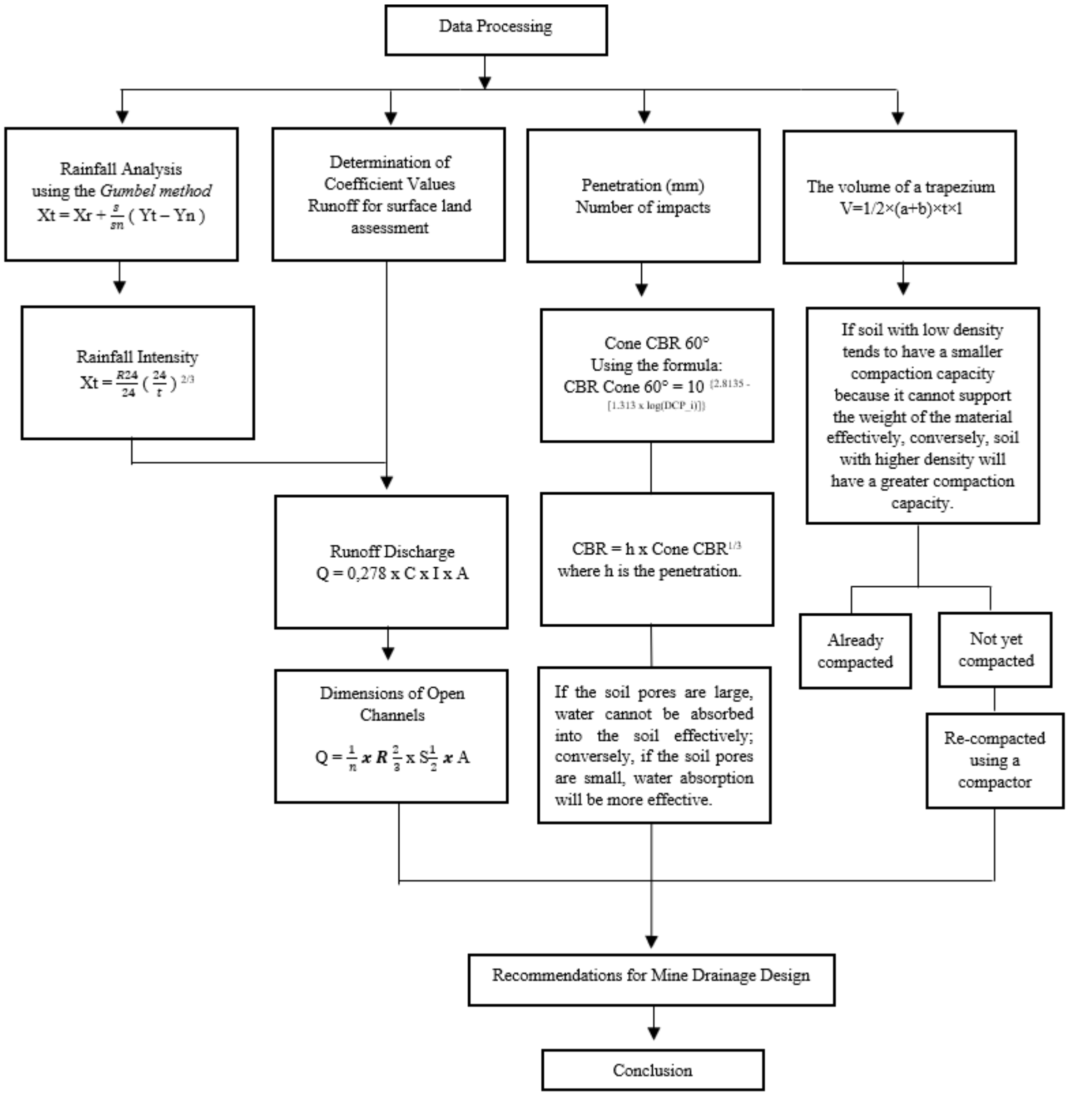

Figure 2. The data flowchart

2.1 Hydrological Analysis

The hydrological aspects of the disposal sites are analyzed using the Gumbel method to estimate peak water discharge rates, which are crucial for designing efficient drainage systems [12]. This method helps in determining the dimensions of open channels necessary to accommodate potential maximum runoff during heavy rainfall events. Hydrological data collection involved measuring rainfall intensity and runoff coefficients from the surrounding catchment areas, with analysis facilitated by the principles laid out by Soermarto [9] and Suripin [10].

2.2 Geotechnical Testing

Geotechnical properties of the disposal materials are assessed using the Dynamic Cone Penetrometer (DCP) test, which provides critical data on the bearing capacity and density of the disposed materials [6]. This test is instrumental in classifying the sub-grade characteristics of the disposal material, which directly impacts the stability and effectiveness of the disposal site in terms of load-bearing and erosion resistance as outlined by Sosrodarsono and Nakazawa [4].

2.3 Volumetric Calculations

Volumetric analysis of the disposal areas was performed using the trapezium volume formula, an established geometric method for calculating volumes based on surveyed cross-sectional areas [19]. This method was used to ascertain both the planned and actual volumes of the disposal sites at different elevations, thus helping in the evaluation of the disposal practices in terms of accuracy and efficiency.

2.4 Capacity Analysis of Open Channels

The design and capacity analysis of open channels was conducted adhering to the Manning formula to determine the hydraulic radius and flow rate capabilities of the channel structures [11], [18]. The Manning coefficient was adjusted based on the channel lining materials and slope conditions, ensuring accurate predictions of flow capacity and channel stability to prevent overflows and sedimentation issues.

2.5 Data Processing and Analysis

All collected data were processed using statistical software to analyze the relationships between the hydrological and geotechnical characteristics of the disposal sites. This analysis was pivotal in establishing correlations between material properties, disposal site design, and environmental impact, aligning with the methodologies proposed by Gautama [8] and Pfleider [14].

3. Results and discussions

3.1 Disposal site configuration

The Torino disposal site, covering 48.55 hectares, was planned with elevation levels set at 36, 42, and 48 meters above sea level. Field measurements, however, showed actual elevations at 36, 40, and 45 meters. This discrepancy indicates a deviation in construction or erosion post-construction, which could impact both volume capacity and environmental control measures [19]. Such discrepancies underscore the challenges in large-scale earthworks where precision is crucial for maintaining structural integrity and environmental safety [14], [19].

3.2 Disposal system efficiency

The necessity for effective drainage systems in such disposal areas cannot be overstated. The assessment of the slope, using a formula to calculate a moderate slope percentage of 5%, supports the open land type and a runoff coefficient of 0.7. These figures are critical in designing drainage systems that can efficiently handle water flow without causing erosion or saturation, which could lead to structural failures [9], [10]. Observations of the irregular slopes and their gradual formation suggest a dynamic landscape that requires adaptable management strategies to mitigate potential risks [14].

3.3 Volume and material management

The planned versus actual volume data highlight a significant shortfall in material management, with only 1,799,111.4 BCM achieved out of the 3,963,159 BCM planned. This variance can be attributed to estimation errors, material compaction differences, or unforeseen site conditions, which could impact the site's environmental and operational efficiency [12]. This finding calls for a review of current volume estimation techniques and possibly the integration of more advanced geospatial and volumetric analysis tools to enhance accuracy in future projects [2], [19].

3.4 Open channel design and functionality

Our analysis confirmed that the single open channel designed for the Torino site has an operational discharge capacity of 1,868,610.3 m³ per hour, far exceeding the incoming water discharge, thus providing a robust system capable of managing extreme hydrological events. The design parameters, including a Manning coefficient of 0.03 and a bottom slope of 5%, are aligned with industry standards to reduce siltation and maintain flow efficiency [11], [18]. These specifications are vital for ensuring that the drainage system remains functional over time, despite sediment load variations and potential hydrological changes [10], [17].

Table 1. Comparison Table of Channel Discharge and Runoff Water Discharge

Description	Incoming Water Discharge		description
Q in	56,427	(m³ / hour)	**Accommodated**
channel capacity	100.433,9	(m³ / hour)	

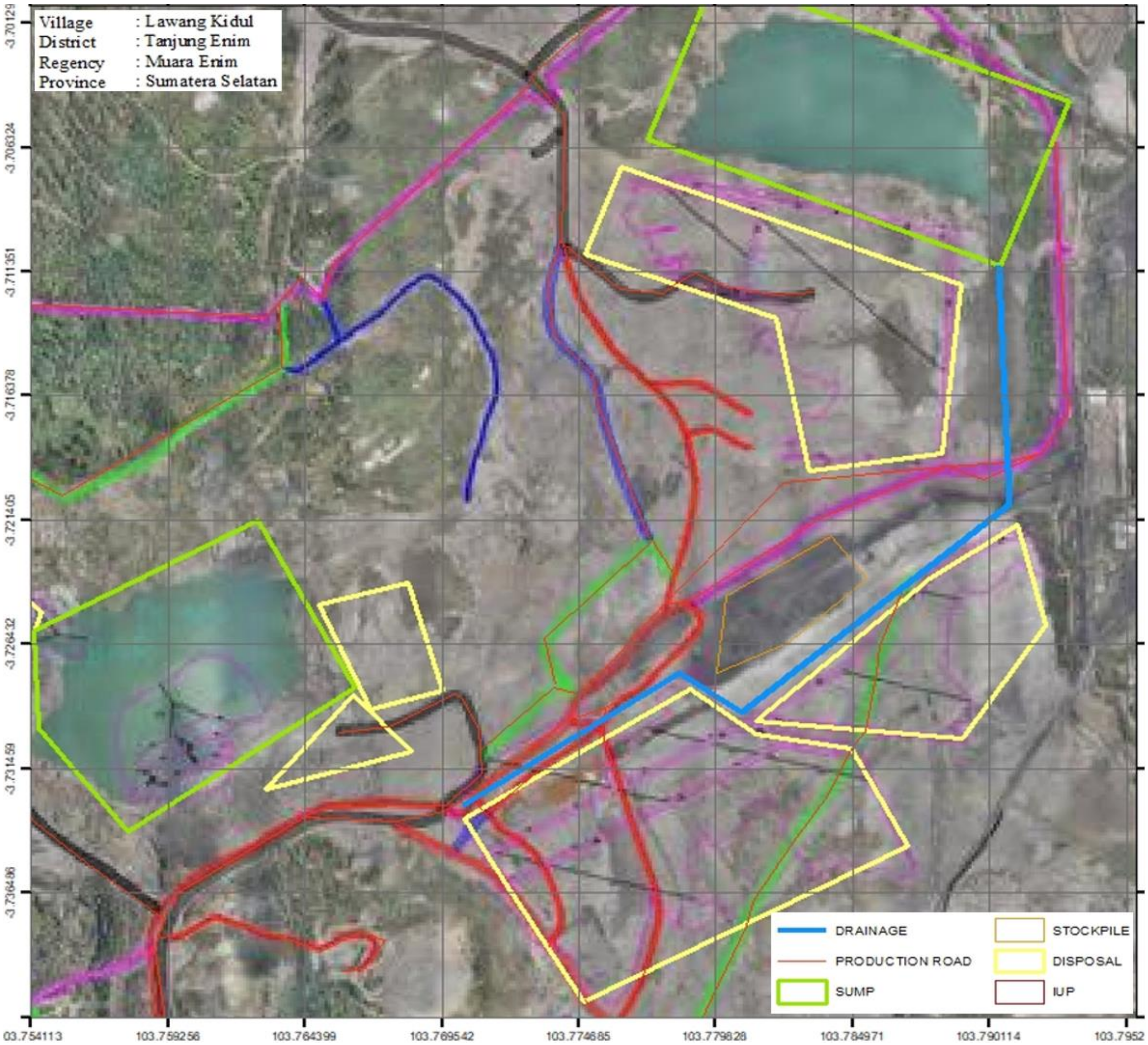

Figure 3. The Drainage Plan Map

3.5 Maintenance and Operational sustainability

The maintenance strategies implemented, such as regular clearing and sediment management, are critical in preventing blockages and erosion within the channel. These strategies not only help maintain the design capacity of the drainage system but also extend its operational life [7], [15]. Effective maintenance is crucial for ensuring that the drainage system can continue to perform under varying environmental conditions and load demands [8], [18].

3.6 *Comparative analysis and further directions*

Comparing these findings with other studies such as those by Pirmani et al. [18] and Gautama [8], it is evident that the challenges faced at the Torino site are not unique. However, the approach to solving these issues can serve as a case study for similar disposal sites worldwide. Future research should focus on improving predictive models for volume and drainage capacity and integrating more flexible, adaptive site management practices that can respond to the dynamic nature of such large-scale engineering projects [5], [16].

Table 1. Channel Discharge Comparison and Figure 3: Drainage Plan Map further illustrate the operational parameters and the design efficacy, providing a visual confirmation of the theoretical calculations and supporting the discussion with empirical evidence.

4. Conclusion

This study has provided important insights into the management and operational dynamics of the east TAL (Tambang Air Laya) backfilling disposal area. Detailed calculations and data processing revealed a substantial discrepancy between the planned and actual volumes of the disposal area for the October sequence. While the planned volume was 3,963,159 BCM distributed across various elevations, the actual volume achieved was significantly lower at 1,799,111.4 BCM, indicating operational inefficiencies or miscalculations during the planning phase. The actual elevations, recorded at 36, 40, and 45 meters, further underscore the dynamic nature of such large-scale operations and the challenges inherent in maintaining precise control over disposal volumes.

Material management within the disposal area showed a homogeneous distribution of various material types, including clay, sandy clay, and soil. Despite the diversity in material types, the disposal area maintained a relatively stable density, with CBR values of 6.089% at point 1 and 5.203% at point 2 as determined by DCP testing. These values suggest adequate bearing capacity and density for the backfill, contributing to the structural integrity and operational stability of the disposal area.

The drainage system, designed as a trapezium-shaped open channel, was able to support a substantial flow capacity of 100,432.996 m^3 per hour. The dimensions and slope of the channel were optimized to minimize erosion and siltation, ensuring efficient water management during high rainfall events. This effective design underscores the importance of careful planning and implementation of drainage systems in preventing environmental damage and enhancing the sustainability of mining operations.

Future efforts should focus on refining volume estimation techniques to improve the accuracy of initial projections and reduce discrepancies in actual outcomes. Additionally, ongoing monitoring and adaptive management strategies should be developed to respond to the dynamic conditions at the site, ensuring that both environmental and operational targets are met. The lessons learned from the east TAL disposal area can serve as valuable benchmarks for similar projects worldwide, promoting more sustainable and efficient mining practices.

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