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ANALYSIS OF PIT XZ DRAINAGE SYSTEM GEOMETRY IN X BLOCK AT PT ABC

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ABSTRACT

PT ABC is a lateritic nickel mining company located in Bungku Pesisir Subdistrict, Morowali Regency, Central Sulawesi. The research location, Pit XZ, lacks an adequate drainage system, resulting in water accumulation that disrupts mining operations. This study aims to design a drainage system consisting of open channels, culverts, and sedimentation ponds. A quantitative method was employed, involving rainfall data analysis, identification of the catchment area, calculation of runoff discharge using the Rational Method, and channel design using the Manning formula. The calculation results show a runoff discharge of 0.35 m³/second. Based on these results, open channels were designed at four locations: Location 1 with a base width of 0.84 m, top width of 1.46 m, and height of 0.60 m; Location 2 with a base width of 0.42 m, top width of 0.93 m, and height of 0.25 m; Location 3 with a base width of 0.49 m, top width of 1.08 m, and height of 0.30 m; and Location 4 with a base width of 0.40 m, top width of 0.89 m, and height of 0.24 m. The total channel length is 2,742 meters. The culverts are designed using iron material with a diameter of 0.50 m and lengths of 13 m, 19 m, 22 m, and 55 m, installed across mining roads. Meanwhile, the sedimentation pond is designed with three compartments, each measuring 27 m in length, 18 m in width, and 4 m in depth, with a total volume of 5,037.56 m³ and a dredging interval of every 120 days.

Keywords: culvert, drainage system, open channel, runoff discharge, sedimentation pond

Introduction

Mining is part or all of the stages of activities in the management and exploitation of mineral or coal resources, which include general investigation, exploration, feasibility study, construction, mining, processing and/or refining, development and/or utilization, transportation and sales, as well as post-mining activities [1]. In Indonesia, mining is a critical industrial sector that plays a significant role in national economic development [2]. With abundant mineral and coal reserves, Indonesia hosts a wide range of mining operations across multiple regions. One of the most extensively mined commodities in Indonesia is nickel. Lateritic nickel is formed through the weathering of ultramafic rocks exposed at the surface [3]. Laterite nickel deposits are generally found in tropical to subtropical climates, in accordance with the ideal sequence of nickel deposit formation, which typically includes a sequential profile (horizons or zones) consisting of topsoil, limonite, saprolite, and bedrock [4]. In Indonesia, laterite nickel deposits are distributed across various regions such as Central Sulawesi, South Sulawesi, Southeast Sulawesi, North Maluku, Papua, and West Papua.

Nickel mining operations in Indonesia predominantly employ open-pit mining methods. As a consequence, mining activities are directly exposed to atmospheric conditions, including variations in weather, such as rainfall [5]. Rainfall is one of the challenges in open-pit mining operations. Without proper water management, it can disrupt operational activities, increase the risk of infrastructure damage, and lead to workplace accidents. Additionally, unmanaged surface water may result in ponding, flooding, erosion, and even environmental contamination. Therefore, an effective drainage system is crucial for managing and discharging water from the mining area. Drainage systems are engineering measures applied in mining areas to prevent, dewater, or remove water entering the mine site [6].

PT ABC is one of the nickel mining companies operating in

Indonesia, with its project site located in Bungku Pesisir Subdistrict, Morowali Regency, Central Sulawesi. The company utilizes an open-pit mining method, which renders its operations highly sensitive to atmospheric and weather conditions. However, in its mining area—particularly at Pit XZ, which serves as the study location—PT ABC currently lacks an adequate drainage system. As a result, rainfall is not effectively managed, leading to disruptions in mining operations and contributing to environmental pollution in the surrounding area.

In response to the identified issues, it is necessary to design an appropriate and effective drainage system capable of accommodating the total surface runoff within the study area. This research aims to calculate the geometric dimensions of the drainage system components—including open channels, culverts, and a sediment pond—within the study site located at Pit XZ, X Block, PT ABC.

Materials and Methods

This study was conducted at a lateritic nickel mining company, PT ABC, located in Bungku Pesisir Subdistrict, Morowali Regency, Central Sulawesi. The study employs a quantitative method, involving the processing of numerical data. The data processing includes analysis, calculations, and evaluations to obtain results that align with the research topic.

The primary data used in this study are rainfall data. This data is utilized to determine the design rainfall intensity, surface runoff discharge, and the hourly rainfall intensity. The processed data directly influences the geometric calculations of the drainage system designed to accommodate the runoff discharge within the study area. The following section outlines the calculation procedures.

Rainfall Return Period is a hypothetical time interval during which a specific magnitude of rainfall is expected to be equaled or exceeded once within that duration [7]. The selection of an appropriate return period can be adjusted based on the intended application and the projected lifespan of the min.

Table 1. Rainfall return Period [8]

Condition	Period (years)
Open area	0 - 5
Mining facilities	2 - 5
Mine slope and stockpile	5 - 10
Main sump	10 - 15
Perimeter mine drainage	25
River diversion	100

Planned Rainfall refers to the amount of rainfall associated with a specific return period, representing the likelihood of occurrence once within a given time interval [8]. Prior to calculating the planned rainfall, an appropriate method must be selected based on the following parameters:

1. Mean (X)

$$X = \frac{\sum Xi}{n} \quad (1)$$

Description:
X = Mean value of annual maximum rainfall (mm)
ΣXi = Total of annual maximum rainfall values (mm)
n = Number of data points (year used)

2. Standard Deviation (S)

$$S = \sqrt{\frac{\sum(Xi - X)^2}{n-1}} \quad (2)$$

Description:
X = Mean value of annual maximum rainfall (mm)
Xi = Maximum rainfall (mm)
S = Standard deviation
n = Number of data points (year used)

3. Coefficient of Variation (Cv)

$$Cv = \frac{S}{X} \quad (3)$$

Description:
X = Mean value of annual maximum rainfall (mm)
S = Standard deviation
Cv = Coefficient of variation

4. Coefficient of Skewness (Cs)

$$Cs = \frac{n^2 \, x \, \sum(Xi - X)^3}{(n-1) \, x \, (n-2) \, x \, S^3} \quad (4)$$

Description:
X = Mean value of annual maximum rainfall (mm)
Xi = Maximum rainfall (mm)
n = Number of data points (year used)
S = Standard deviation
Cs = Coefficient of skewness

5. Coefficient of Kurtosis (Ck)

$$Ck = \frac{n^2 \, x \, \sum(Xi - X)^4}{(n-1) \, x \, (n-2) \, x \, (n-3) \, x \, S^4} \quad (5)$$

Description:
X = Mean value of annual maximum rainfall (mm)
Xi = Maximum rainfall (mm)
n = Number of data points (year used)
S = Standard deviation
Ck = Coefficient of kurtosis

Table 2. Distribution Selection Criteria [9]

No	Distribution Type	Requirement
1	Gumbel	Cs ≤ 1.1396 Ck ≤ 5.4002

2	Log Normal	Cs = 3 Cv + Cv^3 Ck = Cv^8 + 6 Cv^6 + 15 Cv^4 + 16 Cv^2 + 3
3	Normal	Cs ≈ 0 Ck ≈ 3
4	Log Pearson Type III	Other than the values mentioned above

In this study, the Gumbel distribution method is utilized with the following equations:

$$\boldsymbol{Yt} = [-\ln(-\ln\frac{T-1}{T})] \quad (6)$$

Description:
Yt = Reduced variate
T = Rainfall returns period (years)

$$\boldsymbol{K} = \frac{Yt - Yn}{Sn} \quad (7)$$

Description:
K = Gumbel correction factor
Yt = Reduced variate
Yn = Reduced mean
Sn = Reduced standard deviation

$$\boldsymbol{Xt} = X + K\,x\,S \quad (8)$$

Description:
Xt = Planned rainfall with a return period of T years
X = Mean annual maximum rainfall
S = Standard deviation
K = Gumbel correction factor

Rainfall Intensity is defined as the amount of rainfall per unit of time over a relatively short duration, usually expressed in mm/hour, mm/minute, or mm/second [10]. Rainfall intensity is typically denoted by the symbol "*I*". The unit of rainfall intensity, expressed in mm/hour, indicates the depth or height of rainfall in millimeters (mm) accumulated over one hour. The calculation of rainfall intensity in this study uses the Mononobe formula, as follows:

$$\boldsymbol{I} = \frac{R_{24}}{24}\,x\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad (9)$$

Description:
I = Rainfall intensity (mm/h)
R_{24} = Planned rainfall (Xt) from rainfall data processing
t = Duration of rainfall (h)

Surface Runoff is defined as rainwater that flows over the land surface from higher elevations to lower areas before reaching an open channel [11]. To determine the runoff discharge, the rational formula is applied as follows:

$$\boldsymbol{Q} = 0{,}278\,x\,C\,x\,I\,x\,A \quad (10)$$

Description:
Q = Runoff discharge (m3/s)
C = Runoff coefficient
I = Rainfall intensity (mm/h)
A = Catchment area (km2)
0,278 = Conversion constant (used when units are in mm/h and km2)

The Runoff Coefficient is a number that indicates the ratio between the amount of rainwater flowing over the ground surface and the rainfall that is infiltrated [11]. A higher coefficient value indicates that more rainwater becomes runoff.

Table 3. The Runoff Coefficient [8]

Slope	Land Cover	Coefficient
< 3%	Rice fields, swamps	0.2
	Forests, plantations	0.3
	Residential area with a garden	0.4
3% - 15%	Forests, plantations	0.4
	Residential area with a garden	0.5
	Sparse vegetation	0.6
	Barren land, stockpile area	0.7
> 15%	Forest	0.6
	Residential area, garden	0.7
	Sparse vegetation	0.8
	Barren land, mining area	0.9

If the observed location or catchment area has different characteristics, the following formula can be used to obtain the runoff coefficient value:

$$\boldsymbol{C} = \frac{(C1\,x\,A1) + (C2\,x\,A2) + (C3\,x\,A3) + ..+(Cn\,x\,An)}{A1 + A2 + A3 + ..+An} \quad (11)$$

Description:
C = Runoff coefficient
A = Catchment area (km2)

An Open Channel is a channel in which water flows with a free water surface, because surface flow has the same pressure as atmospheric pressure [12]. Open channels are constructed to reduce production disruptions caused by runoff entering the mine. The shape of an open channel is generally selected based on water discharge, the type of channel-forming material, and based on construction [8]. The flow rate in an open channel can be calculated using Manning's formula, which is:

$$\boldsymbol{Q} = \frac{1}{n}\, x\, R^{\frac{2}{3}}\, x\, S^{\frac{1}{2}}\, x\, A \tag{12}$$

Description:
Q = Runoff water debit (m3/s)
n = Wall roughness coefficient value according to Manning
S = Open channel base slope (%)
R = hydraulic radius
A = Cross-sectional area of flow (m2)

The determination of the base slope (S) is based on the ratio of the difference between the highest and lowest elevations and the length of the planned channel. The following formula is used in the calculation:

$$\boldsymbol{S} = \frac{H}{L} \tag{13}$$

Description:
S = Open channel base slope (%)
H = The difference between the highest and lowest elevation (m)
L = Open channel length (m)

Culverts are designed to connect open channels to sediment ponds, serving to convey water across haul roads. They are constructed to address issues of rainwater accumulation caused by the inability of surface runoff to flow from open channels into the sedimentation ponds.

Sediment Ponds are an essential component of mine drainage systems. Their primary function is to settle solid particles carried by surface runoff resulting from mining activities or erosion processes [13]. In the design, the sedimentation pond is constructed in a zig-zag configuration and equipped with baffles to slow down water flow, thereby allowing sufficient time for sediments to settle. The area of the sediment pond can be calculated using the following formula:

$$\boldsymbol{A} = \frac{Q}{V} \tag{14}$$

Description:
A = Catchment area (km2)
Q = Runoff water debit (m3/s)
V = Settling velocity (m/s)

The settling velocity in the sediment pond can be calculated using either Stokes' Law or Newton's Law. Stokes' equation is applicable when the solid concentration is less than 40%, whereas Newton's equation is used when the solid concentration exceeds 40% [14].

1. Stokes Law

$$\boldsymbol{Vt} = \frac{g\, x\, d^2\, x\, (\rho p - \rho a)}{18\mu} \tag{15.1}$$

2. Newton's Law

$$\boldsymbol{Vt} = \left(\frac{4\, x\, g\, x\, d^2\, x\, (\rho p - \rho a)}{3\, x\, Fg\, x\, \rho a}\right)^{0,5} \tag{15.2}$$

Description:
Vt = Settling velocity (m/s)
g = Acceleration due to gravity (m/s2)
ρp = Specific gravity of the solid particles (kg/m3)
ρa = Specific gravity of water (1000 kg/m3)
μ = Dynamic viscosity of water (kg/m.s)
Fg = Resistance coefficient value
d = Solid particle diameter (m)

The amount of time it takes for a particle to settle vertically downward in the pool can be calculated using the following formula:

$$\boldsymbol{Tv} = \frac{H}{Vt} \tag{16}$$

Description:
Tv = Settling time of the particle (s)
H = Depth of the channel (m)
Vt = Settling velocity (m/s)

The speed required to exit the horizontal settling tank can be calculated using the following formula:

$$\boldsymbol{Vh} = \frac{Q}{A} \tag{17}$$

Description:
Vh = Horizontal velocity of the particles (m/s)
Q = Runoff water debit (m3/s)
A = Surface area of the sediment pond (m2)

The amount of time required for water to flow horizontally can be calculated using the following formula:

$$\boldsymbol{Th} = \frac{P}{Vh} \tag{18}$$

Description:
Th = Horizontal residence time in the sediment pond (s)
P = Length of the sedimentation basin (m)
Vh = Horizontal velocity of particle (m/s)

Particles can settle effectively if the settling time (Tv) is not greater than the horizontal flow time (Th). In other words, if the time required for a particle to settle is shorter than the time it takes for water to flow out of the pond, the sedimentation process can occur successfully [14]. The larger the solid particles, the faster the sediment process, and the higher the percentage of solids that can be successfully deposited.

$$\% = \frac{Th}{Th + Tv} \, x \, 100\% \quad (19)$$

The maintenance or dredging interval of the sediment pond is crucial for controlling the discharge of solid materials from mining activities before being released into nearby rivers. Regular dredging helps maintain the sedimentation efficiency and ensures that a high percentage of suspended solids are deposited within the pond [15]. The dredging interval can be estimated using the following equation:

$$T = \frac{Sediment\ pond\ volume\ (m^3)}{Total\ volume\ od\ solid\ per\ day\ (m^3/hari)} \quad (20)$$

Results

Rainfall Data

This study utilizes rainfall data collected over a 10-year period (2014-2023), sourced from Morowali Regency rainfall records maintained by PT ABC.

Table 4. Rainfall Data

No	Month	MONTHLY RAINFALL (mm)									
		Year									
		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	January	146.2	192	107	231	231	275	290.5	387	196.2	220.5
2	February	52.2	304	323	224	224	176	174.4	516.5	252.7	139
3	March	216.7	122	243	332	332	236	261.9	660	229.5	323.5
4	April	409.9	308	174	330	330	434	242	472	190.6	281.2
5	May	538.8	329	204	316	316	131	222.8	526	181.89	284.9
6	June	318.6	489	241	223	223	553	223.2	488	287.8	176.9
7	July	193.9	239	269	186	185	148	291.4	715	646.4	317.4
8	August	130	51	243	329	321	51	125	500.5	300	117
9	September	88.3	99	137	131	52	58	249.1	220	98.5	176.5
10	October	44.5	13	311	72	77	124	407.6	80.5	156.5	226.9
11	November	460.5	42	208	262	333	66	256.8	125	98.5	271.4
12	December	157.5	106	255	320	248	104	63.1	216.5	31	161.3
	Max	538.80	489.00	323.00	332.00	333.00	553.00	407.60	715.00	646.40	323.50

Based on the obtained data, it is known that the average maximum rainfall is 466.13 mm, with the highest rainfall recorded in July 2021 at 715 mm.

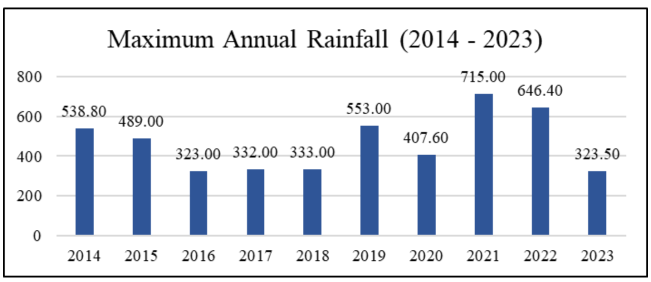

Figure 1: Maximum Annual Rainfall Graph (2014-2023)

Planned Rainfall

To determine the appropriate method, a statistical test was conducted by calculating statistical parameters including the standard deviation (S), skewness coefficient (Cs), kurtosis coefficient (Ck), and variation coefficient (Cv) [16].

Table 5. Rainfall Data Processing

No	Year	Xi	Xi - X	$(Xi - X)^2$	$(Xi - X)^3$	$(Xi - X)^4$
1	2014	538.80	72.67	5280.93	383765.10	27888210.05
2	2015	489.00	22.87	523.04	11961.85	273567.60
3	2016	323.00	-143.13	20486.20	-2932189.36	419684263.43
4	2017	332.00	-134.13	17990.86	-2413113.64	323670932.00
5	2018	333.00	-133.13	17723.60	-2359542.46	314125887.07
6	2019	553.00	86.87	7546.40	655555.50	56948106.17
7	2020	407.60	-58.53	3425.76	-200509.79	11735837.74
8	2021	715.00	248.87	61936.28	15414081.23	3836102396.23
9	2022	646.40	180.27	32497.27	5858283.39	1056072745.94
10	2023	323.50	-142.63	20343.32	-2901567.29	413850542.49
	Total	**4661.30**		**187753.64**	**11516724.55**	**6460352488.72**

Based on the calculation result, the following statistical parameters were obtained:

Mean (X) = 466.13 mm
Standard deviation (S) = 144.44 mm
Coefficient of variation (Cv) = 0.31
Coefficient of skewness (Cs) = 0.53
Coefficient of kurtosis (Ck) = 2.94

Based on the calculation results, an adjustment was then made by comparing the statistical parameters with the applicable test criteria. The result of the comforting assessment is as follows:

Table 6. Result of Frequency Distribution Fitting

No	Type of Distribution	Criteria	Result	Conclusion
1	Gumbel	$Cs \leq 1.1396$	0.53	Satisfies
		$Ck \leq 5.4002$	2.95	Satisfies
2	Log Normal	$Cs = 3\ Cv + Cv^3$	0.96	Does not satisfy
		$Ck = Cv^8 + 6\ Cv^6 + 15\ Cv^4 + 16\ Cv^2 + 3$	4.68	Does not satisfy
3	Normal	$Cs \approx 0$	0.53	Does not satisfy
		$Ck \approx 3$	2.95	Does not satisfy
4	Log Pearson Type III	Other than the values mentioned above		

Table 7. Chi-Square Test Result

No	Method	X^2	X^2 cr	Conclusion
1	Gumbel	5	5.991	Satisfies
2	Log Normal	3	5.991	Satisfies
3	Normal	3	5.991	Satisfies
4	Log Pearson Type III	3	5.991	Satisfies

Table 8. Smirnov-Kolmogorov Test Result

No	Method	Δp max	Δp cr	Conclusion
1	Gumbel	0.13	0.41	Satisfies
2	Log Normal	0.20	0.41	Satisfies
3	Normal	0.33	0.41	Satisfies
4	Log Pearson Type III	0.90	0.41	Does not satisfy

Based on the statistical analysis, the Gumbel distribution was determined to be the most suitable method for design rainfall estimation. Using this method, the 5-year return period design rainfall was calculated to be 618.95 mm.

Table 9. Planned Rainfall Calculation Result

PUH	Yn	Sn	Yt	K	Xt
2	0.4952	0.9496	0.37	-0.14	446.56
5	0.4952	0.9496	1.50	1.06	618.95
10	0.4952	0.9496	2.25	1.85	733.09
20	0.4952	0.9496	2.97	2.61	842.58
50	0.4952	0.9496	3.90	3.59	984.30
100	0.4952	0.9496	4.60	4.32	1090.50
		Mean			**786.00**

Rainfall Intensity

The rainfall intensity in this study was calculated using the Mononobe method. This calculation requires the duration of rainfall occurring in the study area. A rainfall duration of 3.65 hours was used, based on the average rainfall duration in the area. Since the rainfall value obtained from the previous calculation was in monthly units, it was divided by 30 days to convert it into rainfall before proceeding with the intensity calculation.

Table 10. Rainfall Intensity Calculation Result

PUH	Rainfall Intensity	
2	2.18	mm/hour
5	3.02	mm/hour
10	3.58	mm/hour
20	4.11	mm/hour
50	4.80	mm/hour
100	5.32	mm/hour
Mean	**3.83**	**mm/hour**

Based on the calculation result, the rainfall intensity for a 5-year return period was determined to be 3.02 mm/hour.

Catchment Area

The catchment area in Pit XZ was delineated by the highest and lowest elevation contours, forming a closed polygon. In this study, the area was determined using Digital Elevation Model (DEM) data processed in ArcGIS software. The catchment area is divided into three sub-areas, as illustrated in the figure below. This division is based on differences in land characteristics and vegetation cover. Such categorization facilitates the determination of appropriate runoff coefficients for each sub-area.

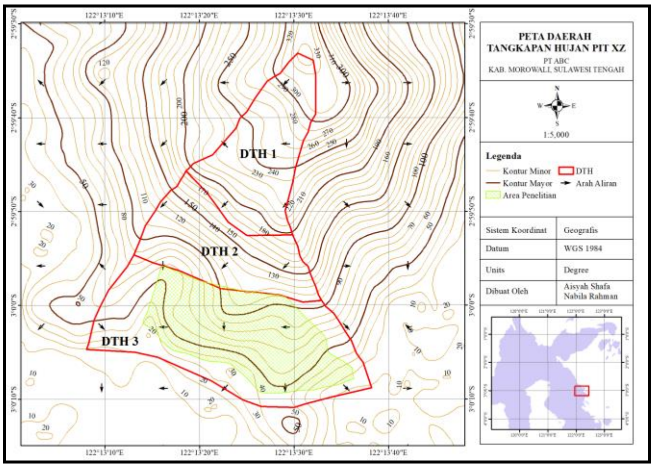

Figure 2. Catchment Area Map

From the map above, the flow direction toward the Pit XZ area can be observed. The total catchment area in this region in identified as 51.90 hectares, which is further subdivided as follows:

Table 11. Division of The Rainfall Catchment Area

Name	Area (ha)	Area (m2)
DTH 1	13,21	132.081,43
DTH 2	12.31	123.061,13
DTH 3	26.38	263.857,40

Runoff Coefficient

In this study, the runoff coefficient was determined based on the field conditions and by analyzing landform and slope gradient maps. These maps were used to classify the area into groups according to established classifications in order to assign appropriate runoff coefficients. The landform map revealed that the study area consists of four landform types: hills, low hills, inland lowlands, and lowlands.

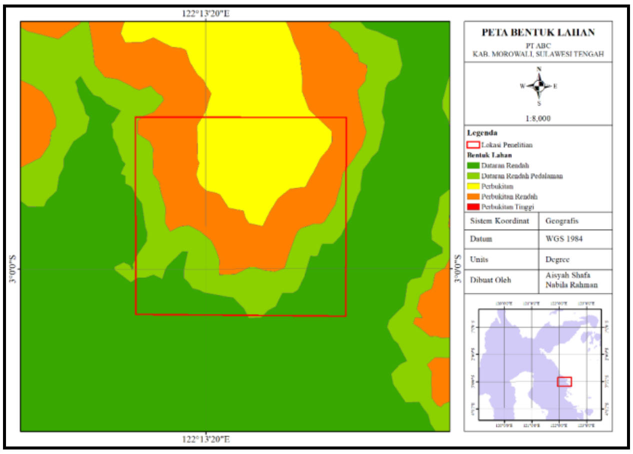

Figure 3. Landform Map of the Pit XZ Area

Based on the slope gradient map, the study area is classified into several slope categories, ranging from very steep, steep, moderately steep, gentle, to flat.

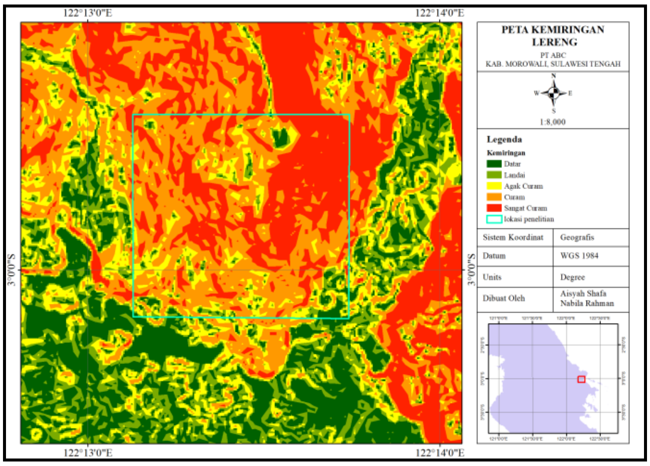

Figure 4. Slope Gradient Map of the Pit XZ Area

Based on the conducted observations, the classification of runoff coefficients in the study area is determined as follows:

Table 12: Runoff Coefficient Classification Based on the Land Use Type

Location	Classification	Coefficient
DTH 1	Slope ±20%, categorized as hilly area, composed of sandy clay material, and sparsely vegetated	0,80
DTH 2	Slope ±20%, categorized as hill area, composed of a sandy clay material, and located in a forested region.	0,60
DTH 3	Slope 15-20%, categorized as lowland area, composed of sandy clay material, and identified as a mining area (bare land)	0,90

With the known area and runoff coefficients for each section, the runoff coefficient for Pit XZ was calculated using the above equation, resulting in a value of 0.80.

Runoff Discharge

The runoff discharge was calculated using three variables: runoff coefficient (C), rainfall intensity (I), and catchment area (A). The calculation employed the rational method. Based on the results, the runoff discharge for the study area was determined to be 0.35 m3/s or 1,260.01 m3/h.

Discussion

Open Channel

In this study, the open channel was designed with a trapezoidal shape. This shape was selected because it is commonly used in mining areas, easier to construct and maintain, less prone to landslides, and capable of conveying larger flows compared to other shapes. The geometric design of the open channel was calculated using Manning's formula. Four types of open channels were designed in this study, differentiated as follows:

Table 13. Open Channel Parameters

Location	Q	n	a	S
1	$0{,}35\ m^3/s$	0,03	60°	0,25%
2		0,04	45°	16,81%
3		0,04	45°	7,42%
4		0,04	45°	21,24%

Another distinction in the designed open channels lies in the Manning's roughness coefficient applied. The first channel is constructed entirely from native soil, while channels 2 through 4 are constructed using soil with a rock lining at the base. The presence of rock at the bottom of the channels serves to reduce erosion and scouring rates, providing greater durability and stability to the channel structure.

1. Open Channel at Location 1

This channel is located along the hauling road leading to the sedimentation pond. The channel dimensions at this location are designed based on hydraulic calculations, with the following specifications.

Table 14. Geometry of Channel 1

Description	Result	Unit
Flow depth (h)	0,47	m
Freeboard (d')	0,10	m
Channel depth (d)	0,60	m
Channel bottom width (b)	0,81	m
Water surface width (B)	1,35	m
Channel top width (T)	1,46	m
Side slope length (a)	0,65	m
Hydraulic radius (R)	0,27	m
Wetted perimeter (P)	1,89	m
Area (A)	0,50	m^2

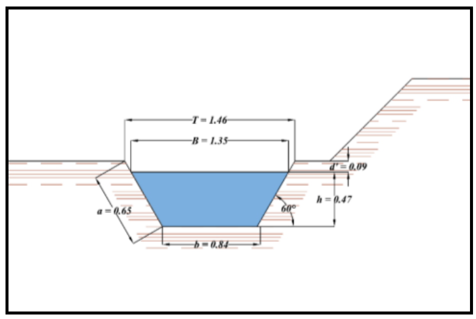

Figure 5. Design Profile of Open Channel at Location 1

2. Open Channel at Location 2

This channel is located on the left side of Pit XZ, leading towards the hauling road. The channel exhibits an elevation difference that can be used to determine the bed slope, with the highest elevation at 69.026 m and the lowest at 41.027 m. Based on this difference, the calculated bed slope for the open channel at location 2 is 16.81%. furthermore, based on the hydraulic calculations, the geometric dimensions of the channel are as follows:

Table 15. Geometry of Open Channel 2

Description	Result	Unit
Flow depth (h)	0,21	m
Freeboard (d’)	0,04	m
Channel depth (d)	0,25	m
Channel bottom width (b)	0,42	m
Water surface width (B)	0,84	m
Channel top width (T)	0,93	m
Side slope length (a)	0,36	m
Hydraulic radius (R)	0,13	m
Wetted perimeter (P)	1,02	m
Area (A)	0,13	m^2

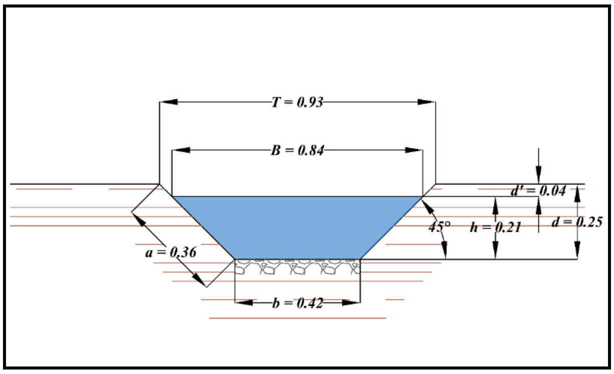

Figure 6. Design Profile of Open Channel at Location 2

3. Open Channel at Location 3

This channel is located on the right side of Pit XZ, with the highest elevation at 81.339 m and the lowest at 20.097 m. Based on the elevation difference, the bed slope of the channel was calculated. From the calculations, it is determined that the bed slope for the open channel at location 4 is 21%. Furthermore, the geometric characteristics of the open channel are obtained as follows:

Table 16. Geometry of Open Channel 3

Description	Result	Unit
Flow depth (h)	0,25	m
Freeboard (d’)	0,05	m
Channel depth (d)	0,30	m
Channel bottom width (b)	0,49	m
Water surface width (B)	0,98	m
Channel top width (T)	1,08	m
Side slope length (a)	0,42	m
Hydraulic radius (R)	0,15	m
Wetted perimeter (P)	1,18	m
Area (A)	0,18	m^2

4. Open Channel at Location 4

This channel is located on the right side of Pit XZ, with the highest elevation at 81.339 m and the lowest at 20.097 m. Based on the elevation difference, the bed slope of the channel was calculated. From the calculations, it is determined that the bed slope for the open channel at location 4 is 21%. Furthermore, the geometric characteristics of the open channel are obtained as follows:

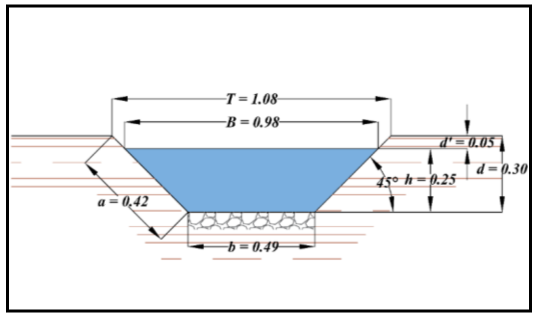

Figure 7. Design Profile of Open Channel at Location 3

Table 17. Geometry of Open Channel 4

Description	Result	Unit
Flow depth (h)	0,20	m
Freeboard (d’)	0,04	m
Channel depth (d)	0,24	m
Channel bottom width (b)	0,40	m
Water surface width (B)	0,80	m
Channel top width (T)	0,89	m
Side slope length (a)	0,34	m
Hydraulic radius (R)	0,13	m
Wetted perimeter (P)	0,97	m
Area (A)	0,12	m^2

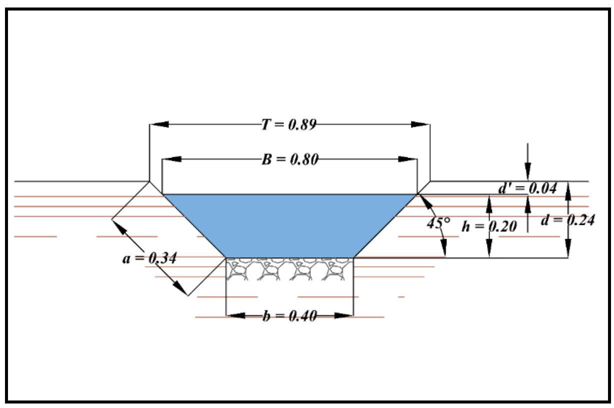

Figure 8. Design Profile of Open Channel at Location 4

Culvert

Culverts are utilized as an auxiliary structure to convey water across the hauling road. The geometric calculation of the culvert was performed using Manning’s equation. The culvert is designed to operate under free-flow (open channel) conditions, where the flow depth is 90% of the culvert’s diameter. In this study, the culvert is designed using steel material; thus, the Manning’s roughness coefficient adopted is 0.041. Additionally, the culvert is designed with a bed slope of 1% to ensure the water flows properly toward the sedimentation pond. Based on the parameters mentioned, the geometric dimensions of the culvert can be calculated. The results of the culvert geometry calculations are as follows:

Table 18. Culvert Geometry Calculation Result

Description	Result	Unit
Diameter (D)	0,50	m
Radius (r)	0,25	m
Depth of flow (h)	0,44	m
Area (A)	0,18	m^2
Wtted perimeter (P)	1,22	m
Hydraulic radius (R)	0,15	m
Flow velocity (V)	1,97	m/s

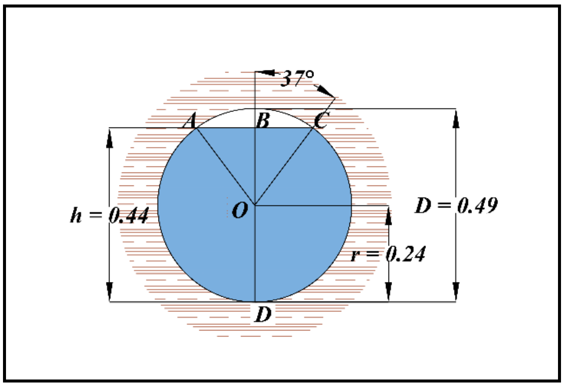

Figure 9. Culvert Design Based on Geometric Calculation

Sediment Pond

A sediment pond is utilized as a facility for the collection and treatment of water contaminated by suspended solid particles transported from mining activities. Water that has undergone sedimentation and meets the discharge quality standards is released into nearby rivers or water bodies. The sedimentation process aims to prevent turbidity and siltation caused by excessive sediment loads.

At Pit XZ, X Block, operated by PT ABC, a proper sediment pond has not yet been provided. Therefore, this study includes the design of a sediment pond system. To determine the geometry of the sediment pond, the settling velocity was calculated using Stokes' Law, as the solid particle concentration in the runoff water is assumed to be less than 40%, specifically estimated at 1%. Based on the calculation results, the settling velocity of suspended particles was obtained at 0.0027 m/s. In this study, the sediment pond is designed to accommodate runoff discharge for a rainfall duration of 3.65 hours/day, resulting in a required pond area of 479.77 m2 to hold a total discharge of 4,594.05 m3/day.

The construction of the sediment pond is planned using a PC200-10M0 excavator, which has a maximum digging depth capacity of 6.5 m. Referring to this specification, the designed pond dimensions are as follows:

1. Length = 27 m
2. Width = 18 m
3. Depth = 4 m
4. Number of compartments = 3

With these dimensions and compartment configuration, the total volume of the sediment pond is calculated to be 5,037.56 m3. The settling time required for the particles is 25.06 minutes, while the total detention time of water in the pond is 274.45 minutes or approximately 4.57 hours. Based on the daily sediment load and the pond's total volume, the maintenance interval for dredging was also calculated. This study concludes that the sediment pond should be dredged every 120 days

Table 19: Sedimentation Pond Geometry Calculation Result

Description	Result	Unit
%Solids	1	%
Settling velocity (Vt)	0,0027	m/s
Sediment pond surface area	479,77	m^2
Sediment pond volume	5.037,56	m^3
Particle settling time (Tv)	25,06	minutes
Horizontal particle velocity (Vh)	0,005	m/s
Particle retention time (Th)	274, 45	Minutes
%sedimentation efficiency	91,63	%
Number of compartments	3	
Sediment pond depth (h)	4	m
Sediment pond width (l)	18	m
Sediment pond length per compartment (p)	27	m
Baffle length	16	m
Baffle width	3	m
Total sediment pond length	87	m

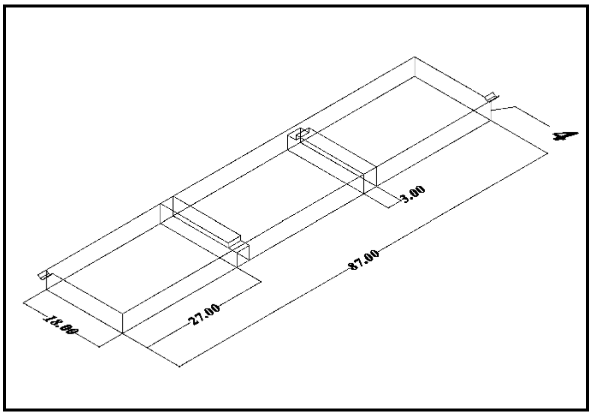

Figure 10. Sedimentation Pond Design

Conclusion

Based on the results of the analysis conducted, it can be concluded as follows:

1. The runoff discharge occurring in the study area was calculated using the rational method based on planned rainfall. The runoff discharge obtained was 0.35 m^3/s, which became the main basis for planning the dimensions of the channel and sedimentation pond.

2. The most suitable open channel design uses a trapezoidal shape, designed based on the elevation and slope differences at four locations. The dimensions at location 1 are 0.84 m at the bottom, 1.46 m at the top; 0.60 m in height, made of soil material; and with a slope of 60°. At location 2, it has a bottom width of 0.42 m, a top width of 0.93 m, and a height of 0.25 m. At location 3, it has a bottom width of 0.49 m; a top width of 1.08 m, and a height of 0.30 m. Location 4 has a bottom width of 0.40 m; a top width of 0.89 m, and a height of 0.24 m. Locations 2-4 are designed with a slope of 45° and made of soil material with a rock base to efficiently channel water flow without causing excessive erosion or sedimentation. In the closed channel, a circular culvert with a diameter of 0.50 m and a flow height of 0.44 m is designed, using iron material. The length of the culvert is adjusted to the width of the haul road, which is 13 m, 19 m, 22 m, and 55 m.
3. The settling pond is designed to collect runoff water and settle solid particles (sediment) before it is discharged into the downstream channel. The pond is designed with dimensions of 4 m in depth, 27 m in length, and 18 m in width, and has a dredging cycle of once every 120 days. The pond's location was chosen to avoid interfering with mining activities, is close to the main channel, and has a suitable slope for efficient inflow and outflow.

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