



Design of Mine Distribution System at Nickel Mining Front of Pt. Cipta Djaya Surya

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Abstract

Nickel mining activities at PT. Cipta Djaya Surya in Molore Village, North Konawe Regency, face a serious problem in the form of stagnant runoff in the mine front area due to the lack of an adequate drainage system and sedimentation pond. This condition not only disrupts smooth mining operations but also has environmental impacts, such as reddish discoloration of coastal waters and potential siltation. This study aims to analyze surface runoff discharge, design open channel dimensions, and design settling ponds appropriate to the hydrological and topographical conditions of the study site. The methods used include collecting rainfall data for the past 10 years from the Meteorology, Climatology, and Geophysics Agency (BMKG), hydrological analysis using the rational method, hydraulic calculations using the Manning equation, and planning channel and settling pond dimensions based on runoff discharge. The results indicate that the maximum runoff discharge in the study area can be managed by designing a trapezoidal open channel with dimensions appropriate to the flow capacity, while the designed settling pond can accommodate the runoff volume without overflowing. The implementation of a planned drainage system is expected to maintain smooth mining operations, minimize the risk of landslides, and mitigate the impact of coastal environmental pollution. Therefore, this research supports the implementation of Good Mining Practice (GMP) principles and can be used as a reference in sustainable mine drainage planning.

Introduction

The increasing utilization of nickel ore is evident in the numerous factories established domestically. This increase in nickel ore production has encouraged mining companies to explore and exploit it (Haryadi et al., 2024; Whitmore & London Mining Network, 2024; Laila & Simangunsong, 2023). This is one of the reasons driving entrepreneurs to actively seek out prospective nickel ore areas for development into nickel ore mines that can benefit the company, have a positive impact on the local area, and help create job opportunities for the surrounding community (Mudd & Jowit, 2022; Zainuddin Rela et al., 2020; Iskandar et al., 2019; Mudd & Jowitt, 2014). The mining sector in Southeast Sulawesi Province has considerable potential and is attracting the attention of both local and international investors focused on the mining sector. North Konawe is estimated to have highly potential mining properties, and so far, many companies are already exploiting them. This proves that North

Konawe does indeed possess superior mining resources, but they are not yet optimally utilized (FS PT. CDS, 2022).

PT. Cipta Djaya Surya is a national private company that mines nickel ore in Molore village, Langgikima District, North Konawe Regency, Southeast Sulawesi Province (FS PT. CDS, 2022). The system used is a mine drainage system. The mine drainage system is a method used to prevent water from seeping into the mine opening or the water from escaping from the mining front (the place or area where mining activities are carried out) where the mine drainage system at the PT. CDS mining front is not yet organized so that runoff water hits the PT. CDS mining front so that researchers feel the need to study the mine drainage system at the PT. CDS mining front so that mining activities can run smoothly. The mining method employed is an open-pit mining system, using a "strip mining" system. Ripping/dozing is performed using automated equipment such as bulldozers and excavators for overburden removal (FS PT. CDS, 2022). Several tiers (benches) are created to remove the overburden. The size of each tier, with a width of approximately 13-30 meters, is considered sufficient for the maneuverability of the mechanical equipment used, while the height of the tier's ranges from approximately 6-9 meters (FS PT. CDS, 2022).

Mining activities carried out by PT. Cipta Djaya Surya at the PT. CDS site begin with clearing the land to be mined, stripping the overburden using mechanical equipment (bulldozers), creating the topsoil layer using hauling equipment, and transporting the overburden material to the disposal area (RKAB PT. CDS, 2023). Mining area of PT. Cipta Djaya Surya does not yet have a good mining drainage system and does not yet have a sediment pond; runoff water hits the mining front and water from the mining area goes directly into the sea or coastal area so that mud or sediment material causes the coastal area to become red or shallow. In order to meet production quantity targets, work efficiency optimization needs to be developed by reducing various factors that could potentially hinder the mining process (Jalalian et al., 2023; Salieiev et al., 2024; Kulkov et al., 2024; Litvinenko et al., 2022). A major problem that frequently arises during nickel mining activities is increased runoff during the annual rainy season. This situation results in the cessation of some mining activities, disruption of mechanical equipment operations, and an increased risk of landslides in the mining area. Therefore, technical and managerial interventions are needed as mitigation measures to minimize these impacts (Abbass et al., 2022; Onita & Ochulor, 2024; Rohwer et al., 2022; Papakonstantinou et al., 2024).

The company's drainage system is considered unsystematic, resulting in the channels not functioning optimally. Furthermore, there is no sediment pond to treat runoff before discharging it into public waters. Therefore, the author will discuss the design of a mine drainage pattern directed toward the sediment pond to ensure that runoff does not disrupt mining activities, both in terms of quality and quantity. The design takes into account both rainfall and runoff discharge factors, achieving a balance between capacity and flow rate into the sediment pond. Thus, runoff can be optimally accommodated without overflow, which could potentially flow directly into the environment without prior treatment (RKAB PT. CDS, 2023). Similar research was conducted in 2025 by Erick Syarifuddin, entitled "Sediment Pond Design Concept for Environmental Management in Nickel Ore Mining Areas (Case Study of the North Block of PT. IFISHDECO, Tbk)."

This research was based on a Geographic Information System (GIS) system, utilizing rainfall data using rain gauges, weather radar, and satellite imagery (Kocsis et al., 2022; Silva et al., 2022; Amatebelle et al., 2025; Cho, 2023; Trigunasih & Saifulloh, 2022). This technical study of the mine drainage system is expected to address runoff issues, allowing mining operations to proceed more smoothly, minimizing the risk of landslides around the mine area, and achieving production targets. The reddish discoloration of the Molore Beach coastline due to the activities of several mining companies that failed to implement adequate drainage systems

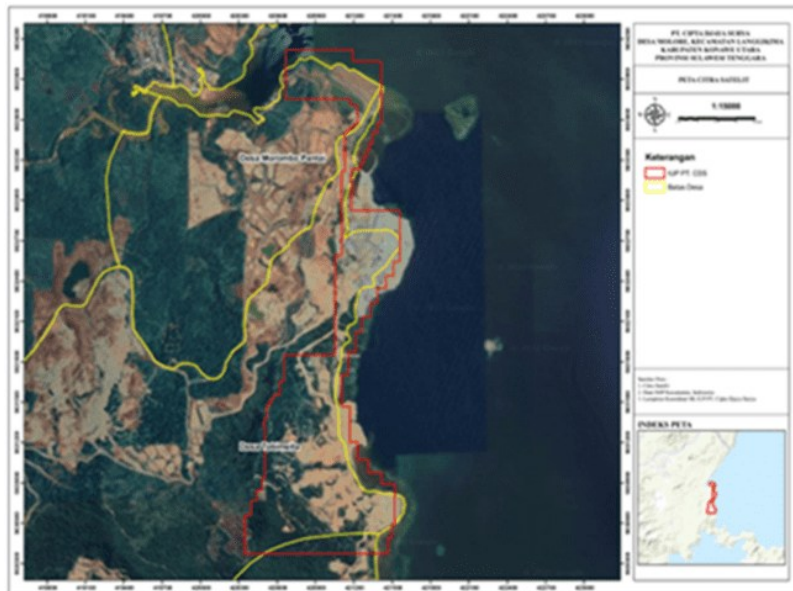


Figure 2. Map of PT. CDS's IUP OP (Researcher, 2025)

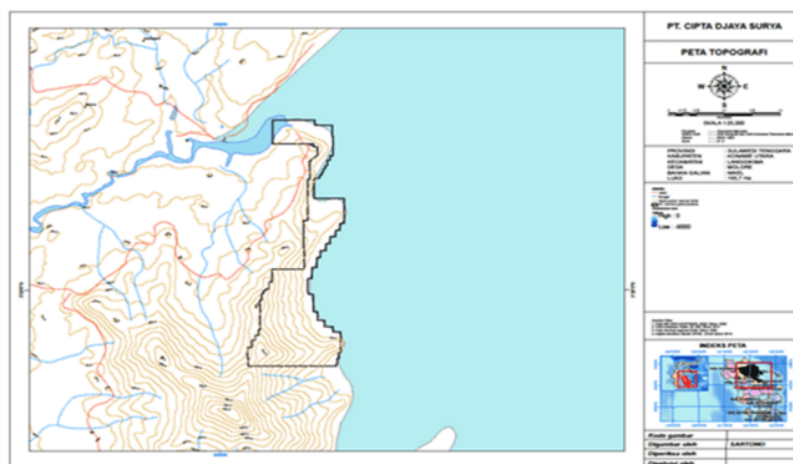


Figure 3. Topographic Map of PT. Cipta Djaya Surya (PT. CDS, 2022)

Study Area Conditions

Sulawesi Island covers approximately 172,000 km² and is dominated by mountainous terrain. From a tectonic perspective, the island lies at the convergence of three major plates: the Eurasian Plate to the northwest, the Indo-Australian Plate to the south and southeast, and the Pacific Plate to the north. The Indo-Australian Plate is actively moving northward, while the Pacific Plate moves westward, creating continuous tectonic activity in the region. Geologically, Sulawesi is divided into four main zones: the West Sulawesi Volcanic Zone, the Central Sulawesi Metamorphic Zone, the East Sulawesi Ophiolite Zone, and the Continental Fragment Zone. The study area, located in Southeast Sulawesi, belongs to the East Sulawesi Ophiolite Zone, dominated by ultramafic rocks. Topographically, the terrain varies from lowlands to steep mountainous slopes. Within the IUP PT. Cipta Djaya Surya, the morphology is classified into five slope categories: flat (0–5%), gentle (5–15%), moderate (15–25%), steep (25–40%), and very steep (>40%). This variation influences the direction of surface runoff and plays a crucial role in the design of drainage channels and sediment ponds.

Globally, from a tectonic perspective, Sulawesi Island is located at the confluence of three major plates: the Eurasian Plate to the northwest, the Pacific Plate to the north, and the Indo-Australian Plate to the south and southeast. Of these, the Indo-Australian Plate is actively moving northward, the Pacific Plate is moving westward, and the Eurasian Plate tends to be

passive. The interaction of these movements results in ongoing tectonic processes in Indonesia, particularly in these active plate convergence zones (FS PT. CDS, 2022).

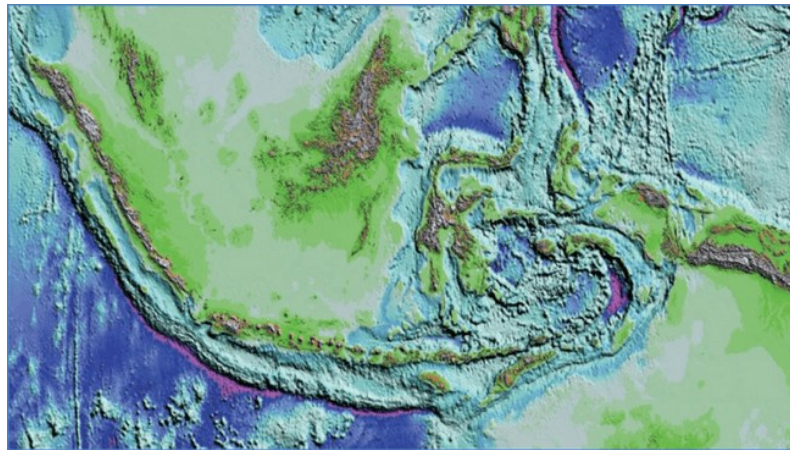


Figure 4. Topographic and bathymetric map of Indonesia based on (Hall, 2012)

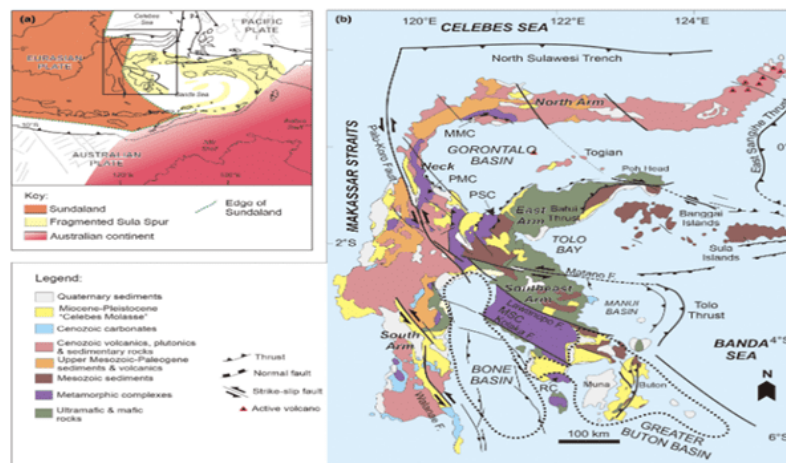


Figure 5. Regional Geological Map of Sulawesi Island (Nugraha and Hall, 2022)

Research Materials

The study utilized both hardware and software to support data collection and analysis. Hardware included a Dell Intel Core i5 laptop for data processing and map preparation, a Garmin GPS and geological compass for determining coordinates, a stopwatch for recording equipment cycle times, an Oppo A58 camera for field documentation, and vehicles for transportation during surveys. The software used comprised ArcGIS 10.8 for spatial data processing and map layout, as well as Google Earth Pro for location identification and map creation.

Research Design

This research adopts a quantitative method with an action research approach. The approach was chosen because the study aims not only to generate data but also to provide practical solutions for managing mining runoff. The methodology involves field surveys, rainfall and runoff measurement, and hydrological data analysis. The results are then used to determine the placement of drainage channels, establish their dimensions, and design a sediment pond (settling pond) capable of storing runoff and settling sediments before discharge into natural water bodies.

Data Analysis

The data analysis process in this study was carried out through several stages to ensure accurate hydrological and hydraulic design. The first stage involved rainfall calculation, where rainfall data from 2015 to 2024 were analyzed to estimate design rainfall values. Statistical approaches, including the Normal Distribution, Gumbel Distribution, and Log Pearson Type III methods, were applied to calculate rainfall corresponding to various return periods. Once the design rainfall was determined, rainfall intensity was calculated using the Mononobe formula, which considers rainfall duration and the 24-hour maximum rainfall to yield the average rainfall intensity required for runoff estimation. The next stage was the determination of the catchment area, where topographic data and the 2025 mining plan were analyzed to identify areas contributing runoff to the settling pond, with the Rational Method employed for calculation. Runoff discharge was then estimated using the Rational Method by incorporating rainfall intensity, catchment area, and runoff coefficient, producing the peak discharge expected in the mining area. Based on these results, drainage channel dimensions were designed using Manning's equation to ensure adequate capacity, with a trial-and-error approach applied to optimize the channel under varying flow conditions. Finally, the sediment pond design was carried out, determining appropriate dimensions and capacity to accommodate peak runoff and sediment load. The design was validated using literature guidelines and engineering standards to ensure functionality and reliability in managing water and sediment within the mining site.

Research Implementation

The research began with collecting rainfall data from the Meteorology and Climatology Agency, followed by statistical analysis using the Gumbel method to estimate design rainfall. Rainfall intensity was calculated with the Mononobe equation, while runoff discharge was determined using the Rational Method. Channel dimensions were then designed using Manning's equation. Finally, the sediment pond was sized based on peak runoff, ensuring its effectiveness in controlling water and sediment before discharge into natural waterways.

Results and Discussion

The PT. Cipta Djaya Surya mining area currently lacks an adequate drainage system and is not equipped with a sediment pond. This situation results in runoff inundating the mining front area, and some water from the mining area flows directly into the sea or the coast. This flow carries mud and sediment, which then causes environmental problems, such as reddish discoloration of coastal waters and potential siltation. Therefore, an effective analysis of the mine drainage system planning is necessary. The data required for research and design of the mine drainage system, particularly regarding open channels and sediment ponds, includes: mine plan maps, mining development maps, rainfall data, rainfall intensity, catchment area runoff coefficient, surface runoff discharge, condition and size of open channels, and sedimentation pond capacity.

Table 1. Rainfall Observation Data at PT. Cipta Djaya Surya (2014–2023)

No	Year	Rainfall (mm/24 hours)
1	2014	26
2	2015	27
3	2016	36
4	2017	44
5	2018	21
6	2019	28
7	2020	30
8	2021	25

9	2022	28
10	2023	25

Table 1 provides annual rainfall observation data recorded over a ten-year period, which forms the statistical basis for determining design rainfall values. The data shows that rainfall fluctuated between a minimum of 21 mm/day in 2018 and a maximum of 44 mm/day in 2017, with an overall variation between 21–44 mm/day. This fluctuation highlights the natural variability of rainfall patterns in the mining area and underlines the importance of statistical distribution analysis to capture both average and extreme rainfall conditions. By applying distribution methods such as Normal, Gumbel, and Log Pearson Type III, the study ensures that the selected design rainfall represents not only the central tendency but also the probability of extreme events. Reliable estimation of design rainfall is crucial, as underestimating values could lead to drainage system failure, while overestimating could cause unnecessary construction costs.

Table 2. Observation Data of PC 200/320 B Caterpillar Work Cycle

No	Digging (s)	Swing Loaded (s)	Dumping (s)	Swing Empty (s)	Moving (s)
1	8.32	4.15	3.61	2.00	14.25
2	5.27	4.38	3.22	2.15	10.25
3	7.43	4.50	3.30	2.13	18.73
...
30	6.29	3.40	3.81	3.11	10.81

Table 2 presents observation data of the PC 200/320 B Caterpillar excavator work cycle, which is an essential factor in determining excavation productivity for drainage channel construction. The work cycle includes five phases: digging, swing loaded, dumping, swing empty, and moving. Among these, the moving phase exhibited the greatest variability, ranging from 10.25 seconds to 18.73 seconds, while the other phases showed smaller variations. Such differences directly impact overall cycle time efficiency and, consequently, excavation productivity. A longer moving phase indicates potential inefficiencies caused by haul distance, terrain conditions, or operator technique. These variations are important for planning, as they affect the estimated time required for channel excavation and overall construction scheduling. Understanding cycle time behavior allows for more accurate projections of labor, fuel consumption, and machinery allocation, ensuring that channel excavation is both time-efficient and cost-effective.

Table 3. Maximum Daily Rainfall Data (2014–2023)

No	Year	Rainfall (mm/24 hours)
1	2014	26
2	2015	27
3	2016	36
4	2017	44
5	2018	21
6	2019	28
7	2020	30
8	2021	25
9	2022	28
10	2023	25

Table 3 provides maximum daily rainfall data for the ten-year observation period, which is critical for identifying extreme rainfall events used in hydrological design. The data confirms that the highest recorded rainfall was 44 mm/day in 2017, while the lowest was 21 mm/day in 2018. These extremes represent the range of rainfall conditions that could potentially occur

in the mining area. The peak value in 2017 is particularly important, as it indicates the likelihood of extreme runoff events that could place stress on the drainage system. Using these maximum daily values, statistical distribution methods were applied to estimate design rainfall for different return periods, which serve as the foundation for calculating rainfall intensity and runoff discharge. The emphasis on maximum daily rainfall ensures that the designed drainage infrastructure is resilient against peak conditions, reducing the risk of overflow, erosion, or sediment pond failure during extreme weather events.

Table 4. Design Rainfall for Specific Return Periods (Normal Distribution)

Return Period (Tr)	Probability (%)	Design Rainfall (mm)
1.25	80	21.56
2	50	24.63
5	20	32.11
10	10	40.51
20	5	57.17
25	4	59.11
50	2	64.67
100	1	69.66

Table 4 presents the design rainfall values calculated using the Normal Distribution method for different return periods. The results show that rainfall increases as the return period becomes longer, indicating that rarer events are associated with higher rainfall intensities. For a 1.25-year return period, which represents frequent rainfall events, the design rainfall is relatively low at 21.56 mm. Meanwhile, for a 10-year return period, commonly used in drainage and mining hydrology design, the design rainfall is 40.51 mm, reflecting a more severe rainfall event that must be accounted for in system planning. At the extreme 100-year return period, the design rainfall reaches 69.66 mm, representing rare but potentially catastrophic events. These results suggest that the Normal Distribution captures the expected variability of rainfall events over time, providing a basis for selecting an appropriate design standard. For this mining drainage system, the 10-year return period (40.51 mm) is typically chosen as a balance between safety and cost-effectiveness, ensuring that the system can handle reasonably extreme rainfall without excessive overdesign.

Table 5. Design Rainfall for Specific Return Periods (Gumbel Method)

Return Period (Tr)	Probability (%)	Design Rainfall (mm)
1.25	80	18.34
2	50	25.85
5	20	35.97
10	10	42.66
20	5	49.09
25	4	51.12
50	2	57.40
100	1	63.63

Table 5 shows the design rainfall values obtained using the Gumbel distribution method for various return periods. The results illustrate that rainfall depth increases with longer return periods, reflecting the higher magnitude of less frequent rainfall events. For a 1.25-year return period, which represents common rainfall, the design rainfall is 18.34 mm, slightly lower than the Normal distribution estimate. At a 10-year return period, the design rainfall is 42.66 mm, which is higher than the Normal method (40.51 mm), indicating that the Gumbel method tends to predict slightly more extreme rainfall values for medium to long return periods. For rare and extreme events, such as the 100-year return period, the design rainfall reaches 63.63 mm,

still below the Normal method's estimate (69.66 mm). This pattern suggests that the Gumbel distribution provides a more moderate estimation for extreme rainfall compared to the Normal distribution, but higher values for intermediate return periods such as $Tr = 10$ years. For practical purposes in mining drainage design, the 10-year return period (42.66 mm) is most relevant, as it offers a slightly more conservative estimate than the Normal method, ensuring adequate channel and pond capacity without overdesign.

Table 6. Design Rainfall for Specific Return Periods (Log Pearson Type III Method)

Return Period (Tr)	Probability (%)	K	Design Rainfall (mm)
1.25	80	1.0843	18.49
2	50	0.4572	22.43
5	20	1.0268	35.43
10	10	1.5642	41.81
20	5	1.8437	45.57
25	4	2.0237	48.17
50	2	2.2947	52.56
100	1	2.5892	57.34

Table 6 presents the design rainfall values calculated using the Log Pearson Type III method across different return periods. The results indicate that rainfall depth consistently increases with longer return periods, reflecting the occurrence of more extreme rainfall events at lower probabilities. For frequent rainfall events, such as the 1.25-year return period, the design rainfall is relatively low at 18.49 mm, closely comparable to the Gumbel method. At the 10-year return period, which is widely adopted in mining drainage planning, the design rainfall reaches 41.81 mm, slightly higher than the Normal method (40.51 mm) but lower than the Gumbel method (42.66 mm). For extreme cases, such as the 100-year return period, the design rainfall is 57.34 mm, significantly lower than the Normal distribution estimate (69.66 mm), suggesting a more moderate prediction of extreme values. These results show that the Log Pearson Type III method provides balanced estimates between the relatively higher values from the Gumbel method and the more extreme predictions from the Normal distribution. Its moderate and statistically consistent predictions, along with the lowest Chi-Square test value, indicate that it is the most reliable method for design rainfall determination in this study. Therefore, the 10-year return period design rainfall of 41.81 mm was adopted as the basis for subsequent rainfall intensity and runoff calculations in the mining drainage design.

Table 7. Chi-Square Test Results

Method	Chi-Square Value
Normal Distribution	3.70246
Gumbel	1.1355
Log Pearson Type III	0.9698

Table 7 presents the Chi-Square test results used to evaluate the goodness-of-fit of three statistical distribution methods: Normal, Gumbel, and Log Pearson Type III. The results indicate that the Log Pearson Type III method produced the lowest Chi-Square value of 0.9698, followed by Gumbel with 1.1355, and Normal Distribution with the highest at 3.70246. A lower Chi-Square value implies a closer fit between the observed rainfall data and the theoretical probability distribution. Therefore, Log Pearson Type III is considered the most accurate and statistically valid method for determining design rainfall in this study. For practical application, the 10-year return period rainfall intensity was calculated as 38.35 mm/hour, which then served as the key input for rainfall intensity and runoff estimation in the subsequent hydrological design process. This choice ensures that the drainage infrastructure is based on the most reliable and representative rainfall data.

Table 8. Catchment Area Division in Block XA–CB

Catchment Area	Area (m ²)
I	7,453.36
II	8,021.23
III	26,090.00
IV	9,546.50

Table 8 shows the division of catchment areas within Block XA–CB, which play a critical role in determining runoff contributions to the settling pond. The analysis identified four distinct catchment areas, with Catchment Area III covering the largest surface area at 26,090 m², which is more than half of the total block area. This indicates that Catchment Area III will likely contribute the greatest volume of surface runoff under uniform rainfall conditions, given its larger surface exposure. Conversely, Catchment Area I (7,453.36 m²) and Catchment Area IV (9,546.50 m²) represent the smallest contributors. Understanding this spatial distribution is essential for designing appropriate drainage channels, as the size and capacity of channels must align with the expected runoff volume from each catchment. The identification of Catchment Area III as the dominant contributor also highlights the need for special attention in channel alignment and sediment pond capacity planning.

Table 9. Rainfall Intensity for Each Catchment Area

Catchment Area	Intensity (mm/hour)
I	176.37
II	215.74
III	204.33
IV	258.14

Table 9 presents the calculated rainfall intensity values for each catchment area based on the design rainfall and catchment-specific characteristics. The results indicate a significant variation in rainfall intensity across the catchments, with Catchment Area IV showing the highest intensity of 258.14 mm/hour, despite not being the largest in area. Meanwhile, Catchment Area I recorded the lowest intensity of 176.37 mm/hour. These variations reflect the influence of local topography, catchment shape, and rainfall distribution factors. Interestingly, Catchment Area III, although the largest in area, recorded an intensity of 204.33 mm/hour, lower than both Catchment Areas II and IV. This suggests that larger areas do not necessarily correspond to higher rainfall intensities, but rather intensity is influenced by hydrological and meteorological dynamics. These differences are crucial, as they directly impact runoff discharge values and the dimensioning of drainage structures.

Table 10. Runoff Discharge by Catchment Area

Catchment Area	Runoff Discharge (m ³ /s)
I	0.9136
II	1.2027
III	0.7049
IV	0.1713

Table 10 summarizes the runoff discharge for each catchment area, highlighting how rainfall intensity and surface area interact to generate peak flows. The results reveal that Catchment Area II produces the highest discharge at 1.2027 m³/s, despite not being the largest in size. This outcome is primarily attributed to its relatively higher rainfall intensity of 215.74 mm/hour, which amplifies the runoff response. In contrast, Catchment Area III, the largest in terms of area, yields a lower discharge of 0.7049 m³/s, demonstrating that rainfall intensity plays a more critical role than area alone. Catchment Area IV, with the highest rainfall

intensity, still generates the lowest discharge (0.1713 m³/s) due to its relatively small size. This finding emphasizes the importance of considering both catchment area and rainfall intensity in hydrological modeling. The discharge results serve as the foundation for designing channels that can safely convey peak flows to the settling pond.

Table 11. Designed Dimensions of Channel A

Parameter	Value
Base width (b)	0.8193 m
Channel height (h)	0.3932 m
Side slope angle (α)	60°
Cotg α (Z)	0.58 h
Channel bed slope (S)	3.51 %
Freeboard height (w)	0.3932 m
Total channel depth (H)	0.8117 m
Channel top width (B)	1.4839 m
Cross-sectional area (A)	0.2926 m ²
Hydraulic radius (R)	0.2345 m

Table 11 presents the design parameters of Channel A, developed using Manning’s equation and trial-and-error optimization to ensure hydraulic efficiency. The results indicate that Channel A requires a base width of 0.8193 m and a total depth of 0.8117 m including freeboard, with side slopes set at 60° for structural stability. The cross-sectional area of 0.2926 m² and a hydraulic radius of 0.2345 m ensure sufficient capacity to convey the calculated runoff discharge. The channel slope of 3.51% facilitates adequate water velocity while minimizing erosion risk. With a freeboard height equal to the flow depth (0.3932 m), Channel A has been designed with a safety margin to accommodate sudden increases in discharge. The optimized top width of 1.4839 m provides structural stability against channel collapse. Overall, the design balances efficiency, stability, and safety, ensuring reliable runoff conveyance under peak flow conditions.

Table 12. Excavation Time for Drainage Channels

Channel	Length (m)	Excavation Time (hours)
A	199.62	3.28
B	274.14	4.64
C	185.11	2.40
D	139.68	2.00

Table 12 outlines the estimated excavation times for each designed drainage channel based on their lengths. The results show that Channel B requires the longest excavation time of 4.64 hours, as it is also the longest channel at 274.14 m. In contrast, Channel D requires only 2.00 hours due to its shorter length of 139.68 m, making it the fastest to construct. Channel A and Channel C require 3.28 hours and 2.40 hours respectively, aligning with their intermediate lengths. These excavation times are essential for project planning and resource allocation, ensuring that construction schedules are realistic and efficient. The results also highlight the importance of prioritizing longer channels such as Channel B in construction sequencing to avoid bottlenecks in the drainage network. Overall, the designed channel system ensures safe and efficient runoff conveyance to the sediment pond, while the excavation time estimates provide practical guidance for implementation in the field.

Table 13. Catchment Area Calculation in Mining Block XA–CB

No	Catchment Area	Area (m ²)
1	I	7,453.36

2	II	8,021.23
3	III	26,090.00
4	IV	9,546.50
	Total	51,111.09

The measurement results show that Catchment Area III is the largest, covering 26,090 m², or more than 50% of the total catchment area. In contrast, Catchment Area I is the smallest with 7,453.36 m². These differences in size significantly affect the runoff contribution from each area to the drainage channel and settling pond. Therefore, the channel design must give special attention to Catchment Area III, which dominates the total runoff volume.

Table 14. Maximum Runoff Discharge in Mining Block XA–CB

Catchment Area	Runoff Coefficient (C)	Rainfall Intensity (mm/hr)	Area (m ²)	Runoff Discharge (m ³ /s)
I	0.9	176.37	7,453.36	0.9136
II	0.9	215.74	8,021.23	1.2027
III	0.9	204.33	26,090.00	0.7049
IV	0.9	258.14	9,546.50	0.1713
Total			51,111.09	2.6581

The results show that Catchment Area II produces the highest runoff discharge of 1.2027 m³/s, despite not being the largest in size. This is because its rainfall intensity (215.74 mm/hr) is higher compared to other areas. Conversely, Catchment Area III, which is the largest, generates only 0.7049 m³/s due to its lower rainfall intensity. Catchment Area IV, although having the highest intensity (258.14 mm/hr), produces the lowest discharge (0.1713 m³/s) because of its smaller area. This indicates that runoff discharge is influenced not only by catchment size but also by rainfall intensity. The total runoff discharge from all catchments is 2.6581 m³/s, which forms the basis for designing drainage channels and settling pond capacity.

Table 15. Channel Gradient and Actual Length in Mining Block XA–CB

No	Channel	ΔH (m)	ΔX (m)	Plan Length (m)	Actual Length (m)	Gradient (%)
1	A	17	10	199.50	199.18	3.50
2	B	9	-16	273.00	274.14	9.16
3	C	-30	-45	184.50	185.11	8.13
4	D	-36	-43	139.50	139.68	5.02

The results show significant variations in channel gradients. Channel B has the steepest gradient (9.16%), allowing for faster water flow, while Channel A has the gentlest slope (3.50%), which may result in slower flow and a higher risk of sedimentation. In terms of length, Channel B is the longest at 274.14 m, whereas Channel D is the shortest at 139.68 m. These characteristics are critical for technical planning, as both slope and length influence flow velocity, erosion potential, and the need for structural reinforcement of channel walls.

Estimated Excavation Productivity of Backhoe PC 200/320 B Caterpillar

Based on field observations, the work cycle of the PC 200/320 B Caterpillar backhoe consists of several components: digging time, swing loaded time, dumping time, swing empty time, and moving time. Detailed data for each cycle component is provided in Appendix 8. The analysis of work cycle data was conducted to estimate the productivity of excavation for channel construction. The results indicate that the moving phase shows the greatest variability, significantly affecting the total cycle time. Longer moving times reduce overall productivity, while shorter times improve efficiency. This information is crucial for

estimating the excavation duration of each channel (see Table 12), as well as for planning construction schedules, equipment deployment, and resource allocation to ensure efficient implementation of the drainage system.

Runoff, Drainage System, and Settling Pond Design in Block XA–CB

The hydrological conditions in Block XA–CB play a crucial role in determining the effectiveness of mining operations, as rainfall runoff is the main source of water entering the site. This runoff originates both from surface flow, where rainwater does not infiltrate into the ground but directly enters the mining area, and from subsurface flow, where infiltrated water re-emerges as groundwater seepage. Both components pose risks to mining activities if not properly managed, ranging from sudden flooding to long-term water accumulation within the pit.

To address this, a comprehensive drainage plan was designed to regulate runoff and direct it into a settling pond. The total mineable area in Block XA–CB is 51,111.09 m², divided into four catchment zones with varying sizes: Catchment I (7,453.36 m²), Catchment II (8,021.23 m²), Catchment III (26,090.00 m²), and Catchment IV (9,546.50 m²). While Catchment III is the largest in area, the smaller catchments, particularly Catchment IV, demonstrate higher rainfall intensities, which can generate proportionally higher runoff.

Historical rainfall data highlight the variability of hydrological conditions. The lowest annual rainfall, recorded in 2001, was 1,274 mm over 80 rainy days, with a maximum daily intensity of 21 mm/day, whereas the highest was in 2008 with 3,954 mm across 174 rainy days and a maximum intensity of 44 mm/day. Such variations necessitate a drainage system that is capable of handling both typical and extreme rainfall events. Using three analytical approaches Normal Distribution, Gumbel Method, and Log Pearson Type III the Log Pearson Type III method was selected as the most reliable for a 10-year return period. Based on this, rainfall intensities were calculated as 176.37 mm/hour (Catchment I), 215.74 mm/hour (Catchment II), 204.33 mm/hour (Catchment III), and 258.14 mm/hour (Catchment IV).

Runoff discharge calculations yielded maximum flows of 0.9136 m³/s (Catchment I), 1.2027 m³/s (Catchment II), 0.7049 m³/s (Catchment III), and 0.1713 m³/s (Catchment IV). These results emphasize that Catchment II, despite its smaller area compared to Catchment III, contributes the highest discharge due to its greater rainfall intensity. To safely accommodate these flows, drainage channels were dimensioned with specific parameters. For example, Channel A was designed with a base width of 0.8193 m, height of 0.3932 m, side slope of 60°, bed slope of 3.51%, and total depth of 0.8117 m, ensuring sufficient hydraulic capacity. Excavation using Backhoe PC 200/320 B Caterpillar was estimated to require practical working times, ranging from 2.00 hours for Channel D (139.68 m) to 4.64 hours for Channel B (274.14 m).

The final component of the system is the settling pond, designed to manage both water volume and sediment load before discharge. The pond has a capacity of 157.00 m³, with dimensions of 13.08 m in length, 4 m in width, and 3 m in depth, and a cross-sectional area of 52.34 m². With a calculated inflow of 2.6581 m³/s and an average rainfall duration of 138.92 seconds, the pond incorporates a zig-zag layout to slow water velocity, thereby enhancing sediment deposition. This ensures that suspended solids are effectively removed before water exits the mining site.

Overall, the integrated system of runoff analysis, channel design, and settling pond construction provides a comprehensive solution for water management in Block XA–CB. By addressing both surface and subsurface inflows, as well as accommodating variable rainfall conditions, the design minimizes flooding risks, enhances sediment control, and supports sustainable mining operations.

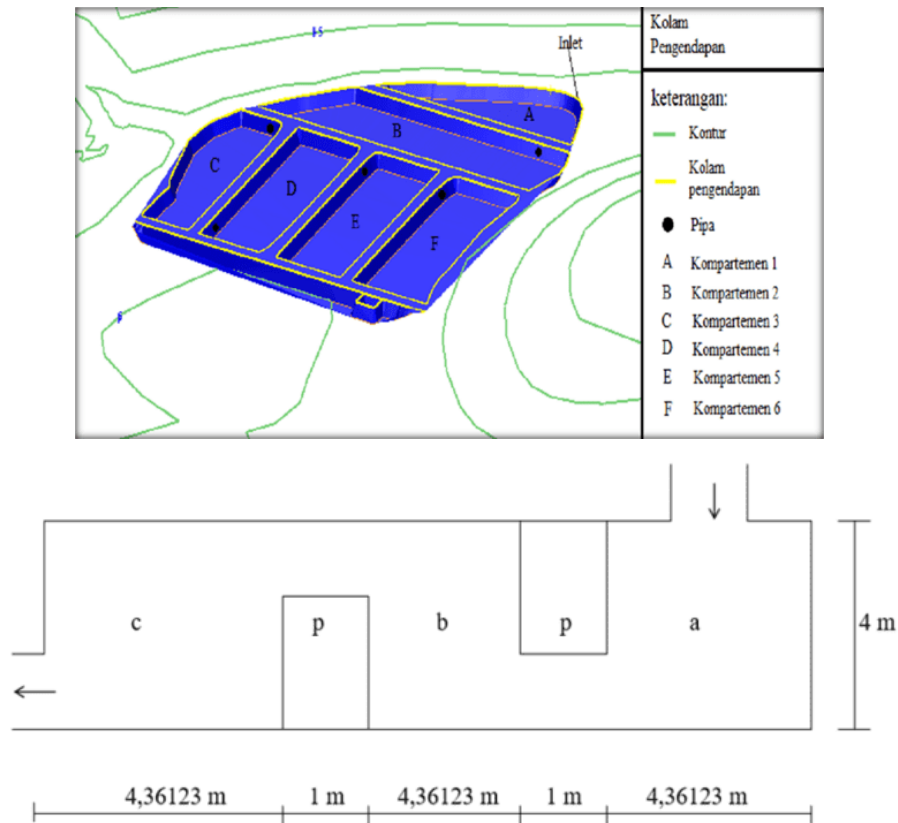


Figure 5. Design Dimensions of Settling Pond

The layout of the settling pond is divided into three sedimentation zones (a, b, c), which function sequentially to maximize the deposition of suspended particles before the water is discharged. Each zone is separated by a partition wall (P) that slows down the water velocity and allows more time for the sediment to settle. The pond is equipped with an inlet channel (→) that directs runoff water into the first zone, ensuring that larger and heavier particles are deposited at the beginning of the process. After passing through the partitions, the flow continues into the subsequent zones where finer particles can gradually settle. Finally, the clarified water is released through the outlet channel (→) located at the end of the pond system. This staged arrangement effectively improves sediment control, prevents excessive siltation within the mining area, and ensures that water leaving the site meets the required environmental standards (Peneliti, 2025).

Conclusion

Based on the results of observations, data processing, and analysis at the PT. Cipta Djaya Surya research site, several important conclusions can be drawn. The calculation of runoff water discharge shows variations across different influence areas, with Influence Area I producing $0.91359 \text{ m}^3/\text{sec}$, Influence Area II $1.20271 \text{ m}^3/\text{sec}$, Influence Area III $0.7049 \text{ m}^3/\text{sec}$, and Influence Area IV $0.17127 \text{ m}^3/\text{sec}$. Altogether, the total runoff discharge passing through Blocks A–B reaches $2.65806 \text{ m}^3/\text{sec}$, which becomes the basis for drainage and settling pond planning. The dimensions of channels A, B, C, and D that direct water to the settling pond have been designed according to hydraulic requirements and are proven to meet the standards needed to accommodate and safely transport runoff. Furthermore, the settling pond has been constructed in a zigzag shape with three compartments to optimize sedimentation efficiency. Its design includes a total pond area of 52.335 m^2 , a length of 13.0837 m , a depth of 3 m , and each zone width of 4.36123 m with a pond side width of 4 m . This arrangement ensures that water entering the pond experiences a controlled flow, allowing

sediment particles to settle effectively before the water is discharged, thereby supporting both mining operations and environmental protection.

References

- Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental science and pollution research*, 29(28), 42539-42559. <https://doi.org/10.1007/s11356-022-19718-6>
- Alviansyah, N. (2019). *Perencanaan desain kolam pengendapan pada Bukit 7 PT. Antam Tbk UBP Bauksit, Tayan, Kabupaten Sanggau, Provinsi Kalimantan Barat*. [Undergraduate thesis, Universitas Tanjungpura].
- Amatebelle, C. E., Owolabi, S. T., Ogundeji, A. A., & Okolie, C. C. (2025). A systematic analysis of remote sensing and geographic information system applications for flood disaster risk management. *Journal of Spatial Science*, 1-27. <https://doi.org/10.1080/14498596.2025.2476973>
- Cahyadi, T. A., Butungan, J., Sudiyanto, A., Amrin, D., Siri, H. T., & Nusanto, G. (2019). Rancangan sistem penyaliran pada lokasi disposal tambang nikel. *Jurnal Teknik: Media Pengembangan Ilmu dan Aplikasi Teknik*, 18(1), 27-37. <http://www.jurnalteknik.unjani.ac.id/index.php/jt/article/view/92>
- Cho, Y. (2023). Comparative application of rain gauge, ground-and space-borne radar precipitation products for flood simulations in a Dam Watershed in South Korea. *Water*, 15(16), 2898.
- Gautama, R. S. (1991). *Hidrologi dan hidrogeologi* [Lecture notes]. Departemen Pertambangan, Institut Teknologi Bandung.
- Haryadi, L., Hartiwingsih, H., & Hermawan, S. (2024, February). Legal Protection for Communities Affected by Nickel Mine Exploitation Amidst Increased Exploration for Electric Battery Needs. In *International Conference On Law, Economic & Good Governance (IC-LAW 2023)* (pp. 68-76). Atlantis Press. https://doi.org/10.2991/978-2-38476-218-7_12
- Iskandar, Z. R., Awang, A. H., & Ramli, Z. (2019). An analysis of the community perceptions of well-being: Special reference to nickel mining and processing industry. *Management of Environmental Quality: An International Journal*, 30(1), 211-226. <https://doi.org/10.1108/MEQ-02-2018-0042>
- Jalalian, M. H., Bagherpour, R., & Khoshouei, M. (2023). Environmentally sustainable mining in quarries to reduce waste production and loss of resources using the developed optimization algorithm. *Scientific Reports*, 13(1), 22183. <https://doi.org/10.1038/s41598-023-49633-w>
- Kocsis, I., Irimuş, I. A., Patriche, C., Bilaşco, Ş., Maier, N., Roşca, S., ... & Bartók, B. (2022). A GIS-Based Methodology to Combine Rain Gauge and Radar Rainfall Estimates of Precipitation Using the Conditional Merging Technique for High-Resolution Quantitative Precipitation Forecasts in Țibleş and Rodnei Mountains. *Atmosphere*, 13(7), 1106. <https://doi.org/10.3390/atmos13071106>
- Kulkov, I., Kulkova, J., Rohrbeck, R., Menvielle, L., Kaartemo, V., & Makkonen, H. (2024). Artificial intelligence-driven sustainable development: Examining organizational, technical, and processing approaches to achieving global goals. *Sustainable Development*, 32(3), 2253-2267. <https://doi.org/10.1002/sd.2773>

- Kurnianda, A., Alkatiri, H., Haya, A., & Halil, A. (2022). Evaluasi sistem penyaliran tambang di PT. Sinar Karya Mustika IUP PT. Fajar Bhakti Nusantara Kecamatan Pulau Gebe Kabupaten Halmahera Tengah Provinsi Maluku Utara. *Geomining*, 3(1), 33–49. <https://ejournal.unkhair.ac.id/index.php/geomining>
- Laila, N. B. A., & Simangunsong, F. (2023). Corporate Responsibility Due to Nickel Mine Exploitation Activities. *SCHOOLAR: Social and Literature Study in Education*, 2(4), 238-243. <https://doi.org/10.32764/schoolar.v2i4.3647>
- Lesmana, D. M. M., Waterman, W., & ... (2019). Kajian teknis sistem penyaliran tambang terbuka pada PIT Alpha PT. Timah Investasi Mineral, Kecamatan Kabaena Barat, Kabupaten Bombana, Sulawesi. *Prosiding Seminar Nasional Sains dan Teknologi*, L, 501–506. <https://ejurnal.itats.ac.id/sntekpan/article/view/614>
- Litvinenko, V., Bowbrick, I., Naumov, I., & Zaitseva, Z. (2022). Global guidelines and requirements for professional competencies of natural resource extraction engineers: Implications for ESG principles and sustainable development goals. *Journal of Cleaner Production*, 338, 130530. <https://doi.org/10.1016/j.jclepro.2022.130530>
- Mudd, G. M., & Jowitt, S. M. (2014). A detailed assessment of global nickel resource trends and endowments. *Economic Geology*, 109(7), 1813-1841. <https://doi.org/10.2113/econgeo.109.7.1813>
- Mudd, G. M., & Jowitt, S. M. (2022). The new century for nickel resources, reserves, and mining: Reassessing the sustainability of the devil's metal. *Economic Geology*, 117(8), 1961-1983. <https://doi.org/10.5382/econgeo.4950>
- Murad, M. (2021). Rancangan sump dan sediment pond Bukit 13 PT. Antam Tbk UBP Bauksit Tayan Kalimantan Barat. *Jurnal Sains dan Teknologi: Jurnal Keilmuan dan Aplikasi Teknologi Industri*, 21(2), 163–170. <https://doi.org/10.36275/stsp.v21i2.386>
- Onita, F. B., & Ochulor, O. J. (2024). Technological innovations in reservoir surveillance: A theoretical review of their impact on business profitability. *International Journal of Applied Research in Social Sciences*, 6(8), 1784-96. <https://doi.org/10.51594/ijarss.v6i8.1426>
- Papakonstantinou, G. I., Voulgarakis, N., Terzidou, G., Fotos, L., Giamouri, E., & Papatsiros, V. G. (2024). Precision livestock farming technology: applications and challenges of animal welfare and climate change. *Agriculture*, 14(4), 620. <https://doi.org/10.3390/agriculture14040620>
- Partanto, P. (1993). *Pemindahan tanah mekanis*. Departemen Pertambangan, Institut Teknologi Bandung.
- Partanto, P. (1993). *Pengantar penirisan tambang*. Pusat Penambangan, Jurusan Teknik Pertambangan, Institut Teknologi Bandung.
- Rohwer, E., Flöther, J. C., Harth, V., & Mache, S. (2022). Overcoming the “Dark Side” of Technology—A scoping review on preventing and coping with work-related technostress. *International journal of environmental research and public health*, 19(6), 3625. <https://doi.org/10.3390/ijerph19063625>
- Roni, A., Partama, M., & Misdiyanto, M. A. M. (2022). Kajian teknis sistem mine drainage pada tambang terbuka batubara di PT. SIMS Jaya Kaltim. *Mining Insight*, 3(1), 33–42.
- Salieiev, I. (2024). Organization of processes for complex mining and processing of mineral raw materials from coal mines in the context of the concept of sustainable

development. *Mining of Mineral Deposits*, 18(1), 54-66.
<https://doi.org/10.33271/mining18.01.054>

- Sandrio, F., & Har, R. (2023). Perencanaan sistem penyaliran tambang batubara dalam perancangan main sump Block B PT Harmoni Panca Utama Jobsite PT Tambang Damai, Kalimantan Timur. *Jurnal Mining Engineering: Bina Tambang*, 8(1), 1–11.
<https://ejournal.unp.ac.id/index.php/mining/article/view/121965>
- Sianturi, P. R., Yusuf, M., & Iskandar, H. (2019). Technical assessment of water management system settling pond North 3 to reach standard quality water based on Governor Regulation of South Kalimantan No. 36 of 2008. *Jurnal Pertambangan*, 3(1), 1–9.
- Silisa, L. J., Rande, S. A., & Misdayantana, P. (2022). Rencana teknis pemeliharaan kolam pengendapan di area Efo PT. Gag Nikel Provinsi Papua Barat. *Mining Insight*, 3(1), 11–20.
- Silva, E. J. R. D., Alves, C. N., Campos, P. C. D. O., Oliveira, R. A. A. C. E., Marques, M. E. S., Amorim, J. C. C., & Paz, I. (2022). Comparison of Rain Gauge Network and Weather Radar Data: Case Study in Angra dos Reis, Brazil. *Water*, 14(23), 3944.
<https://doi.org/10.3390/w14233944>
- Sistem, K., Tambang, P., Smart, P. T., Berkah, R., Amir, M. K., Dzakhir, L. O., & Shaddad, A. R. (2023). Pengaruh DBR (Debit Banjir Rencana) terhadap perancangan model saluran. *Jurnal Teknologi Pertambangan*, 11(1), 54–63.
<https://doi.org/10.33096/geomine.v11i1.146>
- Sukamto, P., Widodo, S., Nawir, A., & Thamsi, A. B. (2023). Pemantauan dan pengelolaan air pada tambang batubara PT. Bukit Makmur Mandiri Utama, Kabupaten Berau, Provinsi Kalimantan Timur. *Journal of Mining Insight*, 1(1), 1–7.
<https://doi.org/10.58227/jmi.v1i1.32>
- Towansiba, N., & Pangkung, Y. G. (2020). Rancangan settling pond terhadap laju endapan sedimen pada area Arafah dan waste dump pada front penambangan PT. GAG Nikel Kab. Raja Ampat, Provinsi Papua Barat. *Jurnal Penelitian Tambang*, 3(1), 35–39.
<https://doi.org/10.56139/intan.v3i1.53>
- Trigunasih, N. M., & Saifulloh, M. (2022). The investigating water infiltration conditions caused by annual urban flooding using integrated remote sensing and Geographic Information Systems. *Journal of Environmental Management & Tourism*, 13(5), 1467-1480. [https://doi.org/10.14505/jemt.v13.5\(61\).22](https://doi.org/10.14505/jemt.v13.5(61).22)
- Utamakno, L., & Budiarto, T. S. R. P. (2020). Rancangan pemodelan settling pond pada daerah Imkasu di PT. Gag Nikel, Pulau Gag, Kabupaten Raja Ampat, Papua Barat. *Prosiding Seminar Teknologi Kebumihan dan Kelautan (SEMITAN II)*, 2(32), 95–104.
- Whitmore, A., & London Mining Network, U. K. (2024). "Blood on the floor": The nickel commodity frontier and inter-capitalist competition under green extractivism. *Journal of Political Ecology*, 31, 568.
- Zainuddin Rela, I., Awang, A. H., Ramli, Z., Taufik, Y., Md Sum, S., & Muhammad, M. (2020). Effect of corporate social responsibility on community resilience: Empirical evidence in the nickel mining industry in Southeast Sulawesi, Indonesia. *Sustainability*, 12(4), 1395. <https://doi.org/10.3390/su12041395>