Study and Design of Mine Drainage systems at open Mine with Extre,me Rainfall Study Case

by Peter Eka Rosadi

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Study and Design of Mine Drainage Systems at Open Mine with Extreme Rainfall Study Case

Tedy Agung Cahyadi[1,a)], Rafif Mahrus Khalik[1)], Abdul Rauf[1)], Peter Eka Rosadi[1)], Untung Sukamto[1)], Indra Wahyu Murtyanto[2)]

[1]Mining Engineering, Faculty of Mineral Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, 5528 Sleman, Indonesia
[2]PT. Studio Mineral Batubara, 55283 Sleman, Indonesia

[a)]Corresponding author: tedyagungc@upnyk.ac.id

Abstract. Research on coal mining that uses an open pit system shows that during the rainy season with extreme rainfall intensity causes water puddles in the mining area that cannot be flowed out of the area. The purpose of this study is to analyze rainfall and study and design a system of mine flow every mine progress. The method used to calculate plan rainfall, and runoff water flow into open channels, sumps, and settling ponds, using the Modification Gumbell, Mononobe, Empirical and Rational methods. Based on the results of the study, the planned rainfall is 285.03 mm with a return period of 8 years of rain and the hydrological risk is 86.51%. The catchment area and runoff water flow every year is getting bigger because the opening of the mine area is getting wider. Water entering the mining area is accommodated using sumps and then flowed using a pump through an open channel to the settling pond. The planning pump used is Multiflo 420EX, with a maximum discharge capacity of 440 l/sec. The need for pumps and sumps every mine progress continues to grow because the incoming runoff water flow is getting bigger.

INTRODUCTION

Mining companies that use an open pit mining system will be in direct contact with the atmosphere. Then while rainfall, water will go into the mining area [1]. The main sources of water that go into the mining area are surface and groundwater [2]. The high rainfall that enters the mining area can affect mining activities, so it must be to study the drainage system for handling water go into the mining area [3]. The system used to discharge water in mining is called the mine drainage system [4, 5].

The problem in mining companies that use an open pit mining system is that during the rainy season with high rainfall intensity, it causes puddles of water on the mining front that cannot be flowed out of the area. It is important to study the mine drainage system of runoff water discharge, open channel dimensions, sumps, and settling ponds, as well as pumping and piping systems to solve this problem. With the study of the mine drainage system, it is hoped that mining activities can run smoothly, and production targets can be met. The purpose of this research is to analyze rainfall and to study and design a mine drainage system that includes open channels, sumps, pumps, pipes, and settling ponds.

LITERATURE REVIEW

Handling water problems in an open pit can be divided into two, i.e.:

1. Mine Drainage
   Mine drainage system is an attempt applied to a mining area to prevent water that entering the mining area. This effort aims to prevent disruption of mining activities due to excessive amounts of water, especially during the rainy season. The mine drainage system also aims to slow down damage to equipment, and machine tools used in the area have a long life [6].

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2. Mine Dewatering
   The purpose of mine dewatering is to drain water outside the mining area, and mining activities can be proceed safely. The main objective of this effort is to treat water originating from rainwater, groundwater seepage, and water generated from mining activities [7].

Rainfall

The determination of rainfall data is aims to obtain the value of the planned rainfall. The rainfall plan can be the basis for designing a mine drainage system. Rainfall data would be analyzed the maximum rainfall in one year in the last few years [8].

Rainfall data processing uses the Modified Gumbell method. The Gumbell method is a method based on the normal distribution (extreme price distribution). Gumbell assumes that the variables of hydrological have an infinite spread, so it must use the largest spread value [9]. Calculation of the rainfall plan using the Gumbell method generally using the average daily rainfall, while in the Modified Gumbell method using the maximum daily rainfall. The Modified Gumbell equation, i.e.:

$$X_t = \mathrm{X}_{\mathrm{maks}} + \frac{\mathrm{SD}}{\mathrm{Sn}}(\mathrm{Y}_t - Y_n) \qquad (1)$$

Information:
Xt = Rainfall plan (mm/day)
Xmaks = Maximum daily rainfall (mm/day)
SD = Standart deviation
Sn = Reduce standart deviation
Yt = Reduce variate
Yn = Reduce mean

The degree of rainfall is usually expressed by the amount of rainfall in units of time and is called the intensity of rain. So the intensity of rain is the total of rain expressed in terms of volume of rain per unit time, which is relatively short. Usually, the unit used is mm/hour. Determination of rainfall intensity using the Mononobe formula because it uses daily rainfall data [10].

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \qquad (2)$$

Information:
I = rainfall intensity (mm/hour)
R_{24} = maximum rainfall (mm)
t = time (hour)

Runoff Water

Runoff water is water that flows due to rain and moves from a higher place to a lower place before reaching an open channel. The runoff discharge that will enter the pit can be calculated using the parameters of concentration time, rainfall intensity, runoff coefficient, and catchment area. The calculation of runoff water discharge uses rational equations to determine runoff water discharge [4].

$$Q = 0.278 \times C \times I \times A \qquad (3)$$

Information:
Q = discharge of runoff water (m^3/sec)
I = rainfall intensity (mm/hour)
C = runoff coefficient
A = runoff area (km^2)

The runoff water coefficient is a number that shows the ratio between the amount of rainwater flowing above the ground and rainfall. Runoff coefficients are determined based on observations in the field, depending on soil conditions and vegetation [11]. From the observation results, then adjusted to the runoff coefficient table, according to [8] is shown in **TABLE 1**.

TABLE 1. Multiple Price Runoff Coefficients [8]

Slope of Land	Use of Land	Runoff Coefficient
Flat Slope < 3%	Rice fields, swamps	0.2
	Forest, plantation	0.3
	Settlement	0.4
Slightly Slope (3-15%)	Forest, plantation	0.4
	Settlement	0.5
	Light vegetation	0.6
	Barren land	0.7
Steep Slope > 15%	Forest	0.6
	Settlement	0.7
	Light vegetation	0.8
	Barren land, mining	0.9

Mine Drainage System

Open Channel

The basis for determining the dimensions of the open channel is the amount of runoff water that entering the open channel from rainwater [1] and flows it to water collection points such as sumps, rivers, or other places. In an open channel the most important thing in determining its dimensions and shape is that the channel must be able to drain the planned water, be easy to manufacture, in accordance with the direction of runoff and according to the topography of the area as well as economical and effective in its shape and dimensions. The Manning formula is used to calculate the flow capacity or the runoff flow rate of an open channel, with the following formula:

$$Q = \frac{1}{n} \times A \times S^{\frac{1}{2}} \times R^{\frac{2}{3}} \tag{4}$$

Information:
Q = discharge of maximum drainage (m^3/sec)
n = wall roughness coefficient of channel according to Manning
A = area of cross sectional (m^2)
S = the channel base slope (%)
R = radius of hydraulic (m)

Sump

The function of the sump is a reservoir for water before it is drained out of the mine area. Thus, the dimensions of the sump are very dependent on the amount of water entering and leaving the sump. The amount of water that enters the sump comes from runoff water, which directly enters the pit then flowed through an open channel to the sump. The water in the sump will be discharged using a pump to the outside of the pit area. The calculation of the sump volume is to combine a graph of the rain intensity that calculated by the Mononobe theory versus time, and a graph of pumping discharge versus time is shown in **FIGURE 1** [8].

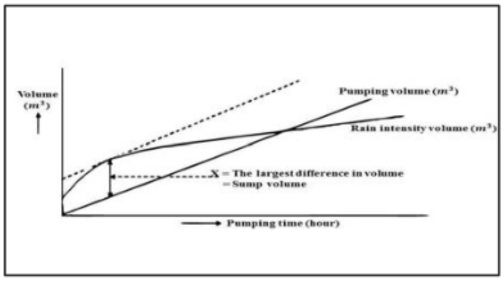


FIGURE 1. Graph of Determination of SumpVolume

Settling Pond

A settling pond is an area specially made to accommodate runoff water before being discharged directly into a public drainage area. Design of settling ponds to accommodate and settle runoff water from mining and around the mine area, and later the water will flow back into the river or lake [10]. Meanwhile, a settling pond for mining areas or commonly called WMP (Water Monitoring Point).

Calculation of the rate of settling using Stokes' law. Stokes' law applies when the solid is less than 40%.

$$V_t = \frac{g \times D^2 \times (\rho_v - \rho_a)}{18 \times \mu} \quad (5)$$

Information:
V_t = The rate of particle settling (m/sec)
G = Acceleration due to gravity (m/sec^2)
D = Solid particle diameter (m)
ρ_p = Density of solid particles (kg/m^3)
ρ_a = Specific gravity of water (kg/m^3)
μ = Dynamic viscosity of water (kg/m.sec)

The calculation of the percentage of deposition aims to determine whether the settling pond to be created can serve to settle solid particles contained in mine runoff water.

$$P_v = \frac{\text{the time it takes water to come out}}{(\text{time required for water to come out} + \text{settling time})} \times 100\% \quad (6)$$

The settling pond area can be counted using the formula:

$$A = \frac{Q_{total}}{V_t} \quad (7)$$

Information:
A = Settling pond area (m^2)
Q_{total} = The water discharge entering the settling pond (m^3/sec)
V_t = Settling speed (m/sec)

The time of dredging the settling pond is very important in the result of the deposition of solid material from the mine before being discharged into the river. The percentage of solid material deposition from the mine can be maintained, if the mining company performs regular dredging. The following is the calculation of the time for the dredging of the settling pond:

$$T = \frac{\text{the volume of the settling pond}}{\text{volume of solids}} \quad (8)$$

METHODOLOGY

This research method is carried out based on several stages. The first stage is determining the facts that found at the research location, then looking for problems that faced at the research location, then determining the problem formulation and collecting the primary and secondary data needed, then analyzing the research and determining the criteria. The last stage, if the results of the analysis are in accordance with the required criteria, it is necessary to make a conclusion regarding the results of the analysis. The research method is shown in detail in **FIGURE 2**.

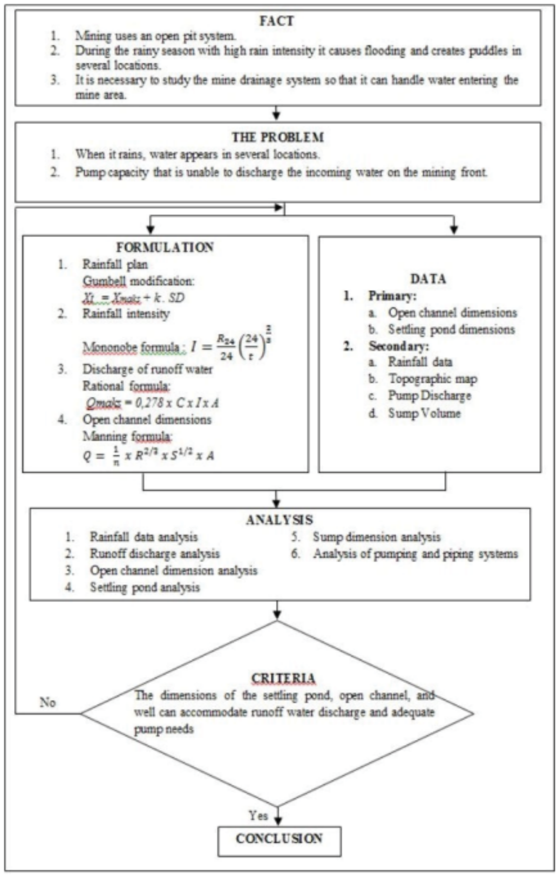


FIGURE 2. Research Methodology Flowchart

RESULT AND DISCUSSION

Field research is carried out based on several stages, starting with field observations. At this stage, the researcher conducted direct observations at locations that experienced flooding during the rainy season, and carried out observations on the technical conditions of the drainage system, which included open channels, sumps, settling ponds, pumping systems and piping. The next step is collecting field data, primary data that measures of the open channel, and settling pond dimensions. The company provides secondary data in the form of rainfall data, topographic maps, sump volume, and pump discharge. From existing primary and secondary data, the next step is processing and analyzing data using methods that have been determined based on literature studies or similar research. The following are the results of data processing and analysis.

Rainfall Data Analysis

The rainfall data used comes from the research location for seven years (2013-2019). Rainfall every year has a different intensity. The highest rainfall intensity was in 2018 in October, which was 748 mm, and the lowest rainfall intensity was in 2018 in January and June, which was 24 mm. The graph of rainfall data is shown in more detail in **FIGURE 3**.

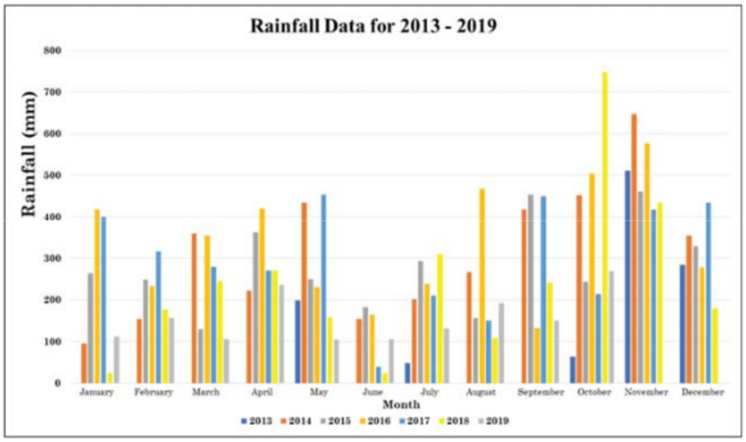


FIGURE 3. Graph of Annual Rainfall

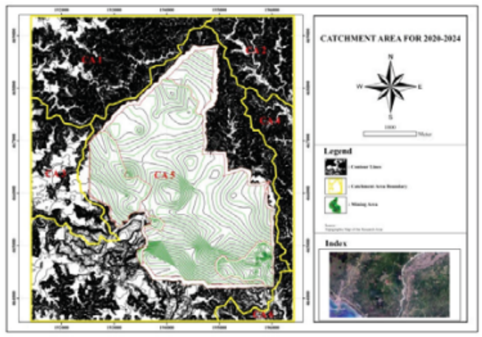
From these data, the maximum daily rainfall is 193 mm/day. To calculate the planned rainfall data can use the maximum daily rainfall data. The calculation of the rainfall plan uses the formula from the Modified Gumbell equation, previously determining the hydrological risk to get the return period of rain. From the existing data, the planned rainfall is 285.03 mm/day, with a hydrological risk of 86.51% and a return period of 8 years of rain. After getting the amount of rainfall planned, the calculation of rainfall intensity uses the Mononobe formula. At the research location, the average rain duration was 3.19 hours, so the planned rainfall intensity value obtained was 45.54 mm/hour.

Empirical Prediction of Surface Water Quantity

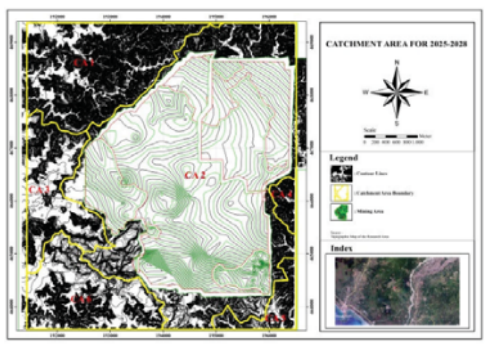
Rain Catchment Area and abbreviated as "CA", is the surface area where rain occurs, then the rainwater will flow from a higher area to the lowest point. The rain catchment area determination is by connecting the highest contour points around the mine area to form a closed polygon by looking at the possible direction of airflow. The rain catchment area varies annually due to mining progress. The area of each rain catchment area every mine progress can be seen in **TABLE 2,** and in **FIGURE 4** is the determination of the catchment area every mine progress.

TABLE 2. Area of Rainfall Catchment Area Every Mining Progress

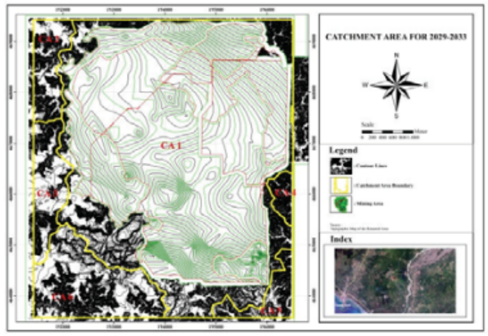
No	Location	Area of Rain Catchment Area Every Mining Progress (km^2)				
		2020-2024	2025-2028	2029-2033	2034-2035	LOM
1	CA 1	4.70	4.78	2.85	2.,94	27.25
2	CA 2	1.99	17.84	1.21	1.07	0.99
3	CA 3	2.40	2.59	1.46	0.90	1.15
4	CA 4	1.47	0.37	0.37	0.25	0.26
5	CA 5	17.87	0.82	0.83	1.56	0.31
6	CA 6	0.63	3.02	3.02	0.74	0.75
Total		29.07	29.43	29.74	30.46	30.70



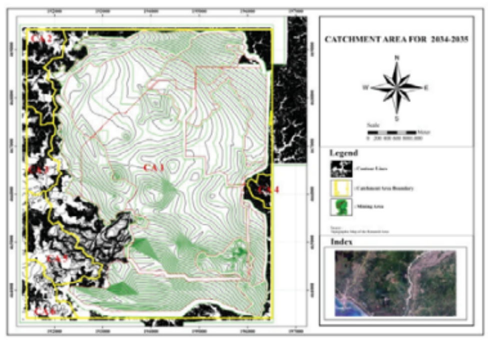
(a)



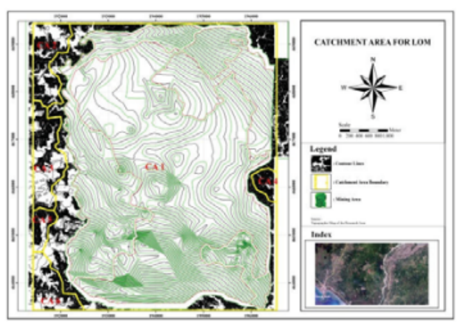
(b)



(c)



(d)



(e)

FIGURE 4. Rain Catchment Area in 2020-2024 (a) 2025-2028 (b) 2029-2033 (c) 2034-2035(d) LOM (e)

The calculation of runoff discharge uses a rational formula. The parameters to obtain runoff water discharge are rainfall intensity, rainfall catchment area, and runoff coefficient value. The amount of runoff discharge in each study area is shown in **TABLE 3** to **TABLE 7**.

TABLE 3. Calculation of Runoff Water Discharge for 2020-2024

Discharge of Runoff Water for 2020-2024						
No	Location	Runoff Coefficient (C)	Rain Intensity (I) (mm/hour)	Open Area (A) (km^2)	Runoff Discharge (Q) (m^3/secon)	Runoff Discharge (Q) (m^3/hour)
1	CA 1	0.6	45.54	4.70	35.74	128,647.55
2	CA 2	0.6	45.54	1.99	15.13	54,478.33
3	CA 3	0.6	45.54	2.40	18.27	65,764.31
4	CA 4	0.6	45.54	1.47	11.15	40,130.63
5	CA 5	0.9	45.54	17.87	203.66	733,166.02
6	CA 6	0.4	45.54	0.63	3.20	11,535.89

TABLE 4. Calculation of Runoff Water Discharge for 2025-2028

Discharge of Runoff Water for 2025-2028						
No	Location	Runoff Coefficient (C)	Rain Intensity (I) (mm/hour)	Open Area (A) (km^2)	Runoff Discharge (Q) (m^3/secon)	Runoff Discharge (Q) (m^3/hour)
1	CA 1	0.6	45.54	4.78	36.31	130,731.40
2	CA 2	0.9	45.54	17.84	20332	731,968.50
3	CA 3	0.6	45.54	2.59	19.67	70,822.49
4	CA 4	0.6	45.54	0.37	2.83	10,193.21
5	CA 5	0.4	45.54	0.82	4.18	15,039.85
6	CA 6	0.4	45.54	3.02	15.30	55,097.89

TABLE 5. Calculation of Runoff Water Discharge for 2029-2033

Discharge of Runoff Water for 2029-2033						
No	Location	Runoff Coefficient (C)	Rain Intensity (I) (mm/hour)	Open Area (A) (km^2)	Runoff Discharge (Q) (m^3/secon)	Runoff Discharge (Q) (m^3/hour)
1	CA 1	0.9	45.54	22.85	260.40	937,443.04
2	CA 2	0.6	45.54	1.21	9.20	33,103.61
3	CA 3	0.6	45.54	1.46	11.06	39,829.13
4	CA 4	0.6	45.54	0.37	2.83	10,204.61
5	CA 5	0.4	45.54	0.83	4.19	15,082.24
6	CA 6	0.4	45.54	3.02	15.31	55,102.21

TABLE 6. Calculation of Runoff Water Discharge for 2034-2035

Discharge of Runoff Water for 2034-2035						
No	Location	Runoff Coefficient (C)	Rain Intensity (I) (mm/hour)	Open Area (A) (km^2)	Runoff Discharge (Q) (m^3/secon)	Runoff Discharge (Q) (m^3/hour)
1	CA 1	0.9	45.54	25.94	295.56	1,064,005.00
2	CA 2	0.6	45.54	1.07	8.16	29,374.83
3	CA 3	0.6	45.54	0.90	6.86	24,704.28
4	CA 4	0.6	45.54	0.25	1.87	6,715.65
5	CA 5	0.6	45.54	1.56	11.85	42,672.68
6	CA 6	0.6	45.54	0.74	5.63	20,273.11

TABLE 7. Calculation of Runoff Water Discharge for LOM

Discharge of Runoff Water for LOM						
No	Location	Runoff Coefficient (C)	Rain Intensity (I) (mm/hour)	Open Area (A) (km^2)	Runoff Discharge (Q) (m^3/secon)	Runoff Discharge (Q) (m^3/hour)
1	CA 1	0.9	45.54	27.25	310.47	1,117,685.48
2	CA 2	0.6	45.54	0.99	7.51	27,046.85
3	CA 3	0.6	45.54	1.15	8.72	31,382.16
4	CA 4	0.6	45.54	0.26	1.95	7,006.39
5	CA 5	0.6	45.54	0.31	2.38	8,560.78
6	CA 6	0.6	45.54	0.75	5.70	20,516.74

Mine Drainage Facility Infrastructure Study

1. Open Channels
   The planned open channel is trapezoidal, the slope of the channel wall is 60°, and the guard height is 20% of the flow depth. Following are the results of the dimensional design of each open channel:
   a. Eastern Open Channel and East Coal Getting
   The discharge that enters the open channel comes from CA 4 and 6 with a discharge of 14.35 m^3/second. The channel walls are designed from cementless soil, and the manning roughness coefficient is 0.03. The open channel design is shown in **FIGURE 5** and the results of the calculation of the dimensions of the eastern open channel and east coal getting, i.e.:

Depth of water (*d*)	= 2.17 m
Channel depth (*h*)	= 2.61 m
The basic channel width (*b*)	= 2.50 m
The width of channel surface (*B*)	= 5.01 m
The outer side length of the channel (*a*)	= 2.99 m

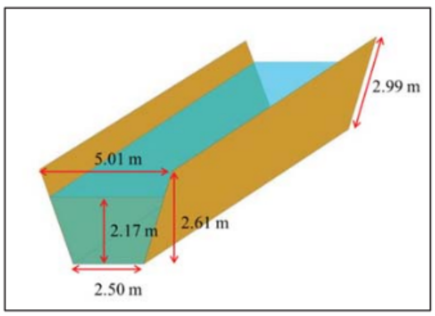


FIGURE 5. Dimensions of the Eastern Open Channel and Open Channel for East Coal Getting

   b. Western Open Channel
   The discharge that enters the open channel comes from CA 3 with a discharge of 18.27 m^3/second. The channel walls are made of soil without any cement so that the manning roughness coefficient is 0.03. The open channel design is shown in **FIGURE 6** and the results of the calculation of the dimensions of the western open channel, i.e.:

Depth of water (*d*)	= 2.38 m
Channel depth (*h*)	= 2.85 m
The basic channel width (*b*)	= 2.73 m
The width of channel surface (*B*)	= 5.49 m
The outer side length of the channel (*a*)	= 3.28 m

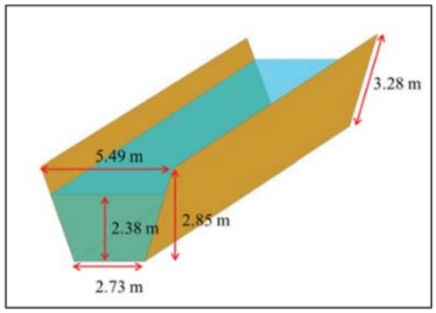


FIGURE 6. Dimensions of the Western Open Channel

c. Northern Open Channel

The discharge that enters the open channel comes from CA 1 and 2 with a discharge of 50.87 m^3/second. The channel walls are made of soil without any cement so that the manning roughness coefficient is 0.03. The open channel design is shown in **FIGURE 7** and the results of the calculation of the dimensions of the northern open channel, i.e.:

Depth of water (*d*)	= 3.49 m
Channel depth (*h*)	= 4.19 m
The basic channel width (*b*)	= 4.01 m
The width of channel surface (*B*)	= 8.06 m
The outer side length of the channel (*a*)	= 4.81 m

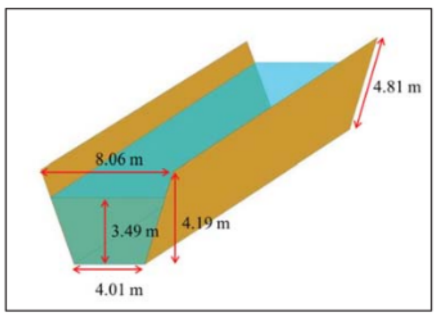


FIGURE 7. Dimensions of the Northern Open Channel

2. Sumps

How to determine the sump volume is by combining a graph between the intensity of rain in a certain period and the volume of the pump in a certain period. The highest difference between the volume of runoff and the volume of pumping will be obtained. The biggest difference is the recommended volume of the sump to be made. Following are the results of the sump design every mine progress:

a. Sump for 2020-2024

The area of mine openings in 2020-2024 is 10.03 km, and the discharge of runoff water is 114.26 m^3/second. The number of sumps planned is five sumps, the sump design is shown in **FIGURE 8**. The results of the calculation of the sump dimensions, i.e.:

The length of the sump surface	= 223 m
Sump surface width	= 211 m
The length of the base of the sump	= 211 m
Sump base width	= 200 m

Depth = 10 m
Volume = 421,303.84 m^3

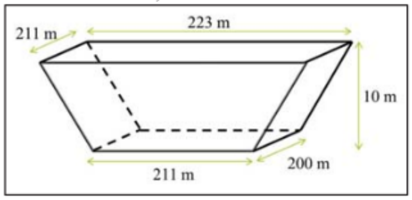


FIGURE 8. Dimensions of the Sump for 2020-2024

b. Sump for 2025-2028
The area of mine openings in 2025-2028 is 13.91 km, and the discharge of runoff water is 158.52 m^3/second. The number of sumps planned is seven sumps, the sump design is shown in **FIGURE 9**. The results of the calculation of the sump dimensions, i.e.:

Sump surface length	= 222 m
Sump surface width	= 210 m
The length of the base of the sump	= 210 m
Sump base width	= 199 m
Depth	= 10 m
Volume	= 415,621.59 m^3

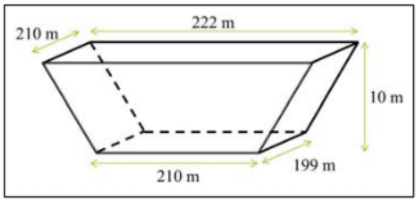


FIGURE 9. Dimensions of the Sump for 2025-2028

c. Sump for 2029-2033
The area of mine openings in 2029-2033 is 18.73 km, and the discharge of runoff water is 213.44 m^3/second. The number of sumps planned is nine sumps, the sump design is shown in **FIGURE 10**. The results of the calculation of the sump dimensions, i.e.:

The length of the sump surface	= 229 m
Sump surface width	= 217 m
The length of the base of the sump	= 217 m
Sump base width	= 206 m
Depth	= 10 m
Volume	= 445,155.92 m^3

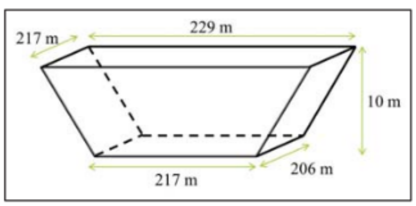


FIGURE 10. Dimensions of the Sump for 2029-2033

d. Sump for 2034-2035

The area of mine openings in 2034-2035 is 22.19 km, and the discharge of runoff water is 252.85 m^3/second. The number of sumps planned is ten sumps, the sump design is shown in **FIGURE 11**. The results of the calculation of the sump dimensions, i.e.:

The length of the sump surface	= 240 m
Sump surface width	= 228 m
The length of the base of the sump	= 228 m
Sump base width	= 216 m
Depth	= 10 m
Volume	= 490,066.10 m^3

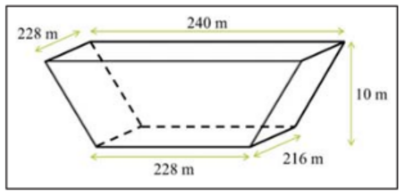


FIGURE 11. Dimensions of the Sump for 2034-2035

e. Sump for LOM

The area of LOM mine openings is 23.84 km, and the discharge of runoff water is 271.67 m^3/second. The number of sumps planned is eleven sumps, the sump design is shown in **FIGURE 12**. The results of the calculation of the sump dimensions, i.e.:

The length of the sump surface	= 236 m
Sump surface width	= 224 m
The length of the base of the sump	= 224 m
Sump base width	= 212 m
Depth	= 10 m
Volume	= 473,088.76 m^3

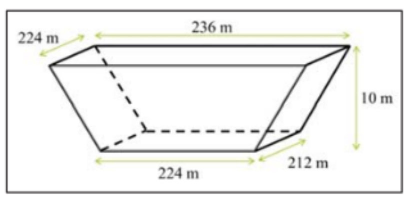


FIGURE 12. Dimensions of the Sump for LOM

3. Pumps and Pipes

Researcher plan the pumping and piping systems at the research location as follows, the type of pump to be used is the Multiflo 420 EX (maximum flow of 440 l/s). The pumped water will be flowed using a suction pipe (Rubber Horse) with a length of 6 m and then exit through the HDPE exhaust pipe (12 inches in diameter) with the longest length of pipe required is 690 m on the sump to the open channel and the highest elevation difference between sump and elevation the outlet is 41 m. In this pump, there is a suction valve which functions as a protection for the pump from damage in case of backflow. In addition to the suction valve at the end of the pipe connection, there is a reducer. Multiflo 420 EX pump head, i.e.:

a. Static head = 41 m
b. Friction head in suction pipe = 0.47 m
c. Friction head at outlet pipe = 39.83 m
d. Accessories friction head
   1. Suction Valve Head = 3.27 m

2. Head exit speed = 1.86 m
3. Head turn = 0 m

The efficiency of the Multiflo 420 EX pump in operation is determined based on the Pump Performance Curve. The total pump head is 86,43 m, and the maximum flow rate is 440 liters/second, and the pump efficiency is 65% with 1,400 rpm. The capacity of the Multiflo 420 EX pump is 1,584 m^3/hour and the pumping time is 20 hours/day, then the number of pumps required per mine progress as follows:

a. Number of Pumps in 2020-2024
In 2020-2024 with a recommendation of 5 sumps, the average discharge of runoff water entering each sump is 22.85 m^3/second, the number of pumps needed to remove runoff water at each sump is three pumps and the total 15 pumps required.

b. Number of Pumps in 2025-2028
In 2025-2028 with a recommendation of 7 sumps, the average discharge of runoff water entering each sump is 22.65 m^3/second, the number of pumps needed to remove runoff water at each sump is three pumps and the total 21 pumps required.

c. Number of Pumps in 2029-2033
In 2029-2033 with a recommendation of 9 sumps, the average discharge of runoff water entering each sump is 23.72 m^3/second, the number of pumps needed to remove runoff water at each sump is three pumps and the total 27 pumps required.

d. Number of Pumps in 2034-2035
In 2034-2035 with a recommendation of 10 sumps, the average discharge of runoff water entering each sump is 25.29 m^3/second, the number of pumps needed to remove runoff water at each sump is three pumps and the total 30 pumps required.

e. Number of Pumps in LOM
At the mining LOM with a recommendation of 11 sumps, the average discharge of runoff water entering each sump is 24.70 m^3/second, the number of pumps needed to remove runoff water at each sump is three pumps and the total of 33 pumps required.

4. Settling pond
The suspended soil material (Total Suspended Soil) ranges from 106 mg/l. The rate of settling is calculated using Stokes' law because % solids are less than 40%. Based on the calculation, the value of the settling speed is 0.00283 m/sec. The following is the calculation result of the recommended dimensions and volume of each settling pond at the research location.

a. WMP 11
The discharge of runoff water that enters WMP 11 is 3.20 m^3/s, and the required pool area is 1,132.30 m^2. The design of the settling pond is shown in **FIGURE 13** and the results of the calculation of the planned settling pond dimensions, i.e.:
Pool width (*L*) = 20 m
Pool length (*p*) = 60 m
Number of compartments = 6
Pond depth (*h*) = 3 m
Baffle width = 10 m
Baffle length = 30 m
Pool volume = 21,600 m^3
Dredging time = 173 days

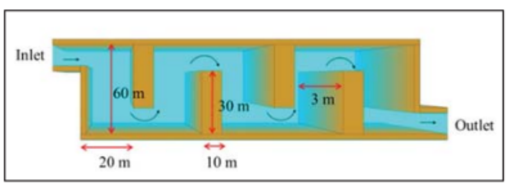


FIGURE 13. Dimensions of WMP 11

b. WMP 13
The discharge of runoff water that enters WMP 13 is 18.27 m^3/s, and the required pool area is 6,455.07

m². The design of the settling pond is shown in **FIGURE 14** and the results of the calculation of the planned settling pond dimensions, i.e.:

Pool width (L)	= 35 m
Pool length (p)	= 185 m
Number of compartments	= 10
Pond depth (h)	= 3 m
Baffle width	= 15 m
Baffle length	= 100 m
Pool volume	= 194,250 m³
Dredging time	= 259 days

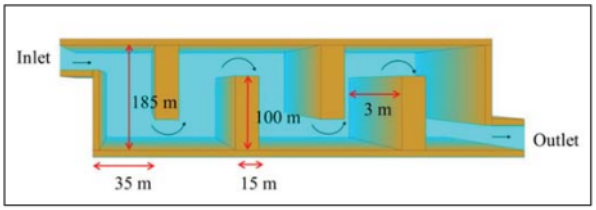


FIGURE 14. Dimensions of WMP 13

c. WMP 14

The discharge of runoff water that enters WMP 14 is 18.27 m^3/s, and the required pool area is 6,455.07 m^2. The design of the settling pond is shown in **FIGURE 15** and the results of the calculation of the planned settling pond dimensions, i.e.:

Pool width (L)	= 35 m
Pool length (p)	= 185 m
Number of compartments	= 5
Pond depth (h)	= 3 m
Baffle width	= 15 m
Baffle length	= 100 m
Pool volume	= 97,125 m^3
Dredging time	= 142 days

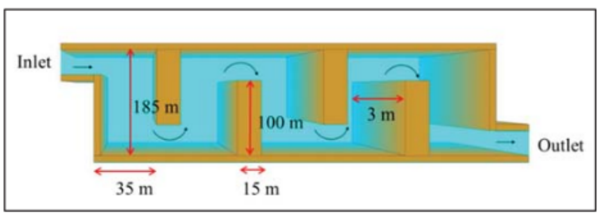


FIGURE 15. Dimensions of WMP 14

d. WMP 15

The discharge of runoff water that enters WMP 15 is 14.35 m^3/s, and the required pool area is 5,071.31 m^2. The design of the settling pond is shown in **FIGURE 16** and the results of the calculation of the planned settling pond dimensions, i.e.:

Pool width (L)	= 35 m
Pool length (p)	= 150 m
Number of compartments	= 7
Pond depth (h)	= 3 m
Baffle width	= 15 m
Baffle length	= 80 m
Pool volume	= 110,250 m^3

Dredging time = 194 days

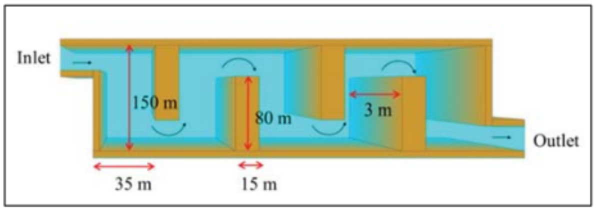


FIGURE 16. Dimensions of WMP 15

CONCLUSIONS

Very high rainfall at the research location causes flooding. Therefore, in this study for rainfall data processing used the Modified Gumbell equation. The goal is to get the value of the planned rainfall, rain intensity, and maximum runoff water discharge. The results of this data processing make the design of open channels, sumps, and settling ponds bigger, and the number of pumps used is more than the actual conditions in the field. The design of mining incineration facility infrastructure will prevent flooding in the mining area.

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