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HYDROLOGICAL STUDY ON LIMESTONE MINE DRAINAGE SYSTEM IN PT. ADS - SOUTH SUMATERA

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Abstract

The groundwater availability in an area with mineral deposits is measured by the geological and geomorphological characteristics of the area. The hydrological study on limestone mining in PT. ADS, South Sumatera aimed to acquire data and information regarding rainfall characteristics, drainage basin and catchment area, infiltration value, and surface water flow pattern at the limestone mining site and nearby area; this is to formulate a basis of reference in creating drainage system. The study employed Extreme Value Gumbel formula to analyze the expected daily rainfall. A calculation on the rainfall return period relied on two factors, i.e., the planned mining duration and natural events, such as seasonal flood per two years. Moreover, Mononobe formula was used to calculate and convert the daily rainfall intensity in the form of an hourly rate. The mine drainage system was regarded as necessary in the site since the watery area is the potential to hinder the production as well as to cause work accidents; on top of that, the terrain is dominated by relief of wavy hills with varying waves and slopes ranging from 10°-70°.

Keywords: Hydrological Study, Extreme Value Gumbel Formulation, Mononobe Formula, Mine Drainage System.

A. Introduction

Hydrology (derived from Greek: Υδρολογια, Υδωρ + Λογos, Hydrologia, "water science") is a branch of Geography that studies the movement, distribution, and quality of water throughout the Earth, including the hydrological cycle and water resources. Where water is a substance that is needed by all creatures in the world. The presence of water covers almost 2/3 of the entire surface area of the earth, such as the ocean. Water is composed of hydrogen and oxygen molecules, so it has the chemical formula H2O. However, the presence of this water is not desirable for mining activities. Because of the water in open and underground mining is very disturbing. Because it can cause mining areas to become slippery, wet, and cause fatal work accidents, such as lack of tools used in mining activities. Water sources that damage these mining areas, usually come from rain, dew, snow, and water in the pores of the soil. For this reason, it is necessary to conduct a hydrological study of limestone mining activities in South Sumatra to reduce standing water on the surface of the mining activity area using the Mononabe formula and The study employed Extreme Value Gumbel formula to analyze the expected daily rainfall, wherewith the formulation of the Mononabe formula we can determine the magnitude of the annual rainfall return period whether it is a rainy period during 2 years and 6 years. Where this can be adjusted to the duration of the mining operation. This means that if we know the amount of water that will enter the PIT mining area, we can plan a drainage system or mine drainage system so that the amount of water in the PIT mining can be reduced and can be overcome. The administrative coverage of PT ADS mining site in Ogan Komering Ulu regency, as stated in their mining exploration license and mining operation license, is 506.7 hectares and 148.9 hectares, respectively. The company's mining exploration site is accessible by plane, four-wheel vehicle, and two-wheel vehicle.

The exploration site has a population of 813 people, with a wet tropical climate and varying rainfall rate; in the site, dry months occur very rarely in a year. The overall size of Ogan Komering Ulu regency is 1,236,582.66 hectares; 66.5 percent of the regency consists of fertile lowlands with natural features, such as forests, rice fields, fields, rubber plantation sites, and other plantation sites. While there is no volcano in the region, the regency features narrow lowlands that share borders with the Bukit Barisan Mountains to the West; the region also stretches wider to the East. Due to the region's climate, the rainy season lasts longer than usual (around seven months), which usually starts from October to April. November is recorded as the month with the rainiest days, with an average of 17 rainy days and a maximum rainfall rate of 357 mm^3. The dendritic drainage pattern composes the main drainage pattern in the mining site of PT. ADS. The pattern has irregular shapes and develops with relatively similar rock composition, in which the river tributaries flow from the upstream with different directions and join together into the main river stem. Based on the site's geological and geomorphological conditions, the groundwater availability in the area is classified into two groundwater provinces; Plains groundwater province and Volcanic Groundwater Province. The hydrological study conducted by calculating the rainfall rate and intensity aimed to acquire data and information regarding rainfall characteristics, drainage basin and catchment area, infiltration value, and surface water flow pattern at the limestone mining site and nearby area; this is to formulate the basis of reference in creating drainage system.

B. Methodology

1. Research Design

Necessary data involved in the present study comprised primary and secondary data. Primary data were obtained from direct observation in the site like observing the rainfall that occurs in the field while secondary data were acquired from the existing literature and publications, including the rainfall data of 2015-2017 by the Agency for Meteorology, Climatology, and Geophysics (henceforth, BMKG) class I, South Sumatera, ultimate Pit Limit map, and other supporting documents. Moreover, direct observation was applied as the research method; the method involved interviews with the mineworkers; interviews to question whether rainwater flooded the surface where the mining operations are operating in field survey and geological exploration. This study was conducted in a quantitative descriptive manner, intending to elaborate on the phenomena by referring to numerical data in identifying the characteristics of a group or an individual (Syamsudin & Damayanti, 2011). The study evaluates such characteristics from apparent conditions. In other terms, this present study's objectives delimited itself only to describe the characteristics of the object as is.

C. Findings and Discussion

1. Findings

Rainfall data

The rainfall data are required as the basis to calculate the expected rainfall rate. Regarding this, this research refers to the rainfall data of three years from 2015 to 2017 obtained from the BMKG Class I, South Sumatera. The largest monthly average rainfall occurred in January 2015 with a 23.99 mm/month rate. Moreover, the rainfall condition in the research site consisted of heavy rain and very heavy rain (Gautama, 1984).

Discharge of runoff water entering the Pit (Q)

Runoff water discharge is the volume of rainwater per a particular time unit that does not infiltrate the soil and required to be drained through the drainage. The runoff water discharge is influenced by three factors: rainfall intensity (I), catchment area (A), and runoff coefficient (C).

Measurement of Rainfall Intensity (I)

Based on the theoretical principles, the measurement of rainfall intensity was conducted each day in the morning. The rainfall measurement instrument, or rain gauge, works by containing the rain within a particular time unit. The rainwater is then transferred by using a valve to the measuring cup. The rain gauge, or ombrometer, has a measuring cup that contains rainwater each day. If the rainwater exceeds the measuring cup's capacity, the excess water will drop into a container, and thus, the calculator is reset.

Determination of Rainfall Intensity Value

The average monthly rainfall rate is required to determine the dispersion value of rainfall from 2015 to 2017. Therefore, the following formula is applied to calculate the average monthly rainfall rate. Average monthly rainfall = $\frac{MonthlyRainfall}{RainyDays}$

Table 1. Average monthly rainfall date years from 2015 - 2017

Month	2015 (mm/day)	2016 (mm/day)	2017 (mm/day)	Maximum
Jan	23.99	18.83	18.07	23.99
Feb	21.47	23.67	8.67	23.67
March	18.83	7.39	23.78	23.78
April	7.46	6.14	9.11	9.11
Mei	4.72	5.46	2.45	5.46
June	4.81	1.00	4.00	4.81
July	0.13	4.77	1.60	4.77
august	0.00	0.00	0.00	0.00
Sept	0.00	0.00	0.00	0.00
Oct	8.52	4.50	0.00	8.52
Nov	10.00	12.53	3.55	12.53
Dec	12.73	12.30	8.11	12.73
Maks	23.99	23.67	23.78	23.99
Min	0.00	0.00	0.00	0.00
Average	9.39	8.05	6.61	9.39

Dispersion Measurement

The dispersion value of rainfall intensity during 2015-2017 is measured by statistical and algorithmic calculation to identify the skewness or lack of symmetry and the kurtosis of a distribution.

Table 2. The Results Dispersion Measurement

No.	Dispersion	The Result Dispersion	
		Statistical Parameter	Logathrim Parameters
1	S	7.6638	0.8711
2	Cv	0.2129	1.0484
3	Cs	0.1003	1.2675
4	Ck	2.8464	1.9300

Determination of Data Distribution Type

The dispersion value acquired from the prior process is compared to the required dispersion value in each distribution. Regarding this, the distribution that approaches the requirements is E.J. Gumbel distribution. E.J. Gumbel distribution is used to analyze the expected daily rainfall rate since the distribution is closest to the required dispersion values.

Table 3. Dispersion Requirement Each in Distribution

No.	Method	Terms	Results	Explanation
1.	Normal	Cs ≃0 Ck~3	Cs = 0.5770	Less Fulfilling
2.	Normal Log	Cv ~ 0.06	Cv = - 0.5115	Less Fulfilling
		Cs ~3 Cv + Cv^2 = 0.636	Cs = 3.2132	
3.	E.J.Gumbel	Cs ≤ 1.14	Cs = 0.1003	Fulfill
		Ck ≤ 5.40	Ck = 2.846	
4.	Pearson III Log	Cs ≠ 0	Cv = - 0.5115	Less Fulfilling
		Cv ~ 0.3	Cs = 0.5770	

Calculation of Expected Daily Rainfall

The study employed the Extreme Value Gumbel formula to analyze the expected daily rainfall. From the Gumbel distribution, the study generates the average value of maximum rainfall per day each year, obtained by sorting from the month with the largest rainfall rate to the smallest in each year. The average correction (Yn) is acquired from the number of data (n) and data sequence number (m) of annual rainfall sorted from the maximum rate to the minimum rate. The next step is, to sum up the values generated from the prior process to obtain average correction value. Also, to calculate variant correction value, one must generate rain return period data that are obtained from the data of the annual return period (T). 1.1 equation is applied in calculating the variant correction value (Yt). A calculation on the rainfall return period relies on two factors, i.e., the planned mining duration and natural events, such as seasonal flood per two years.

$$Yt = -\text{In}\ [-\text{In}\ [\frac{2-1}{2}] = 0.366 \ \textbf{......... Equation 1.1.}$$

Table 4. The Results From Standard Deviation, Average Correction

n	Month,Years	Rainfall (mm)	CH-Ch Average	CH^2	M	Yn	Yn-yn average	(Yn-yn Average)^2	S	Sn
1	Jan. 2015	23.99	15.97	255.14	1	3.60	2.99	8.95	7,66	1,06
2	Feb. 2015	21.47	13.45	180.96	4	2.17	1.56	2.44		
3	March.2015	18.83	10.81	116.91	6	1.73	1.13	1.27		
4	April. 2015	7.46	-0.56	0.31	16	0.57	-0.04	0.00		
5	Mei. 2015	4.72	-3.29	10.85	22	0.10	-0.50	0.25		
6	June. 2105	4.81	-3.20	10.25	20	0.25	-0.35	0.13		
7	July. 2015	0.13	-7.89	62.27	29	-0.43	-1.03	1.06		
8	August. 2015	0	-8.02	64.26	30	-0.51	-1.12	1.24		
9	Sept. 2015	0	-8.02	64.26	30	-0.51	-1.12	1.24		
10	Oct. 2015	8.52	0.50	0.25	14	0.74	0.14	0.02		
11	Nov. 2015	10	1.98	3.94	11	1.04	0.44	0.19		
12	Dec. 2015	12.73	4.72	22.24	8	1.41	0.81	0.65		
13	Jan. 2016	18.83	10.82	116.98	5	1.93	1.32	1.75		
14	Feb. 2016	23.67	15.66	245.09	3	2.47	1.87	3.48		
15	March.2016	7.39	-0.63	0.40	17	0.49	-0.12	0.01		
16	April. 2016	6.14	-1.88	3.53	18	0.41	-0.20	0.04		
17	Mei. 2016	5.46	-2.56	6.53	19	0.33	-0.28	0.08		
18	June. 2106	1	-7.02	49.22	28	-0.35	-0.95	0.91		
19	July. 2016	4.77	-3.25	10.56	21	0.18	-0.43	0.18		
20	August. 2016	0	-8.02	64.26	30	-0.51	-1.12	1.24		
21	Sept. 2016	0	-8.02	64.26	30	-0.51	-1.12	1.24		
22	Oct. 2016	4.5	-3.52	12.36	23	0.03	-0.58	0.33		
23	Nov. 2016	12.53	4.52	20.1	9	1.28	0.67	0.45		
24	Dec.,2016	12.3	4.28	18.35	10	1.15	0.55	0.30		
25	Jan. 2017	18.07	10.05	100.99	7	1.56	0.96	0.92		
26	Feb. 2017	8.67	0.65	0.43	13	0.84	0.23	0.05		
27	March.2017	23.78	15.76	248.46	2	2.89	2.28	5.22		
28	April. 2017	9.11	1.10	1.20	12	0.94	0.33	0.11		
29	Mei. 2017	2.45	-5.57	30.98	26	-0.19	-0.80	0.64		
30	June. 2107	4.00	-4.02	16.13	24	-0.04	-0.65	0.42		

31	July. 2017	1.60	-6.42	41.17	27	-0.27	-0.87	0.76		
32	August. 2017	0.00	-8.02	64.26	30	-0.51	-1.12	1.24		
33	Sept. 2017	0.00	-8.02	64.26	30	-0.51	-1.12	1.24		
34	Oct. 2017	0.00	-8.02	64.26	30	-0.51	-1.12	1.24		
35	Nov. 2017	3.55	-4.47	19.95	25	-0.12	-0.72	0.52		
36	Dec.,2017	8.11	0.09	0.01	15	0.65	0.05	0.00		
	∑=	**288.58**		**2055.67**		**21.79**	**0.00**	**39.86**		
	Average	**8.02**		**57.10**		**0.61**		**1.11**		
	Maximum	**23.99**								

Calculation of Rainfall Intensity using Mononobe Formula (i)

Mononobe formula is applied in the present study to calculate daily rainfall intensity in an hourly time unit. In calculating the rainfall intensity, the research refers to the data of rainfall intensity repetition during two years; this takes into account the mining age and progress as well as rainfall duration (T) in the area. Due to the lack of data in determining rain hour, the calculation of lowest rainfall duration (T) in the Pit Limit area applies 5 hours duration to simulate a large rainfall intensity that is assumed as the worst condition during rain. The calculation of rainfall intensity in the limestone mining operation plan in PT. SSM, South Sumatera refers to the data of expected rainfall of rain return period in a particular year as well as the rainfall duration.

2. Discussion

Settling Pond

Settling ponds are the containment area that catches any runoff and retain water during the sedimentation process of soils and other wastes. Settling ponds are mainly required in cases with output water containing total suspended solids that are higher than the quality standard of the output water. Settling ponds do not only function to settle suspended solids in the mining area but also serve as a container of wastewater that contains heavy metals and water with high acids (pH below six). The settling ponds neutralize the wastewater or polluted water to a normal level by the maximum quality standards allowed by the government. The settling ponds are constructed by several steps, e.g., creating retaining embankment or digging a hole for water/sediment embankment to retain water during the required duration to settle suspended solids. After the water is separated from the residue, the water is deemed clear enough to be drained. Treatments, such as liming, alum treatment, and aeration, are conducted in the settling ponds by adjusting to the waste contents.

Catchment Area and Run off Coefficient (C,A)

The next step is to determine the size of the catchment area by referring to the topographical map. Observation on the topographical map is carried out to determine areas in a lower position that are the potential to contain rainwater flowing to the mining site. Based on the process, this research applies four catchment areas in the Pit location. Further, the calculation of the runoff coefficient refers to the observation on the topographical map by considering the slope and field observation of land use. The runoff coefficient value depicts the comparison between runoff surface water towards the rainfall rate. As an instance, in the catchment area of Pit and Ex_A with 0.9 value, this indicates that 90 percent of the total rainfall will transform into surface water, while 40 percent of it infiltrates the soil. The runoff coefficient value in each location is present in the following Table 5.

Table 5. Catchment Area

No	Locations	Area (m^2)
1	CA1	258.911,39
2	CA2	74.911.16
3	CA3	45.845,62
4	CA4	81.008,92
Total		**460.677.09**

Runoff Water Discharge (Q)
The rational formula is implemented to identify runoff water discharge that enters into the Pit Limit. Such a method is deemed appropriate to calculate the runoff discharge and applies only in the area with a relatively homogenous surface and in an open mine area. The calculation of runoff discharge coming from pit applies the following equation: Total of water discharge that enters into pit limit equals to the runoff water, or Q Total = Total of runoff.

Q Total (m^3/second)	QTotal (m^3/hour)	Maximum Rain Time	Q Total (m3/day)
3,58	12702,99	5	63514,83

Runoff Water Prevention
The mine drainage is constructed based on the topography of the pit limit with the shape of the channel that generally follows the road surface, forming relatively straightforward water channels due to the lack of presence of slope base or foothills. The channel is constructed to prevent runoff water from infiltrating uncontrollably to the pit limit, as well as to drain the water that infiltrates the diversion channel towards a lower place. Further, the ditch is constructed stretching from the water spring or runoff water to different directions, e.g., to a containment basin, to an existing natural river, or the ditch along the access road to the main mining site. In constructing ditch, one adjusts with the condition in the mining site. A mining site can have more than one ditch. The dimension of the diversion channel is measured based on the maximum volume during periods of heavy rain by calculating the slope angle. The section of the diversion channel is constructed in the form of a trapezoid shape.

Management of water that enters into Pit limit
Calculation of sump capacity
The sump volume is calculated based on the total water discharge that enters into the mining site, i.e., 63,514.83 m^3/day. As the water always flows to the lower area, therefore, if rain occurs in the mine opening area, the water will flow into the lowest elevation of 80 m a.s.l. The sump will be constructed nearby the area within the twentieth year of mining in elevation of 80 on the North Pit.

Calculation of sump dimension
The sump's design and geometry are determined by referring to the amount of water entering it, or the total of water runoff discharge added with the groundwater discharge. The sump will be constructed in the shape of a trapezoid; hence, in containing the total volume, the study takes into consideration the maximum volume containable by the sump and the dimension.

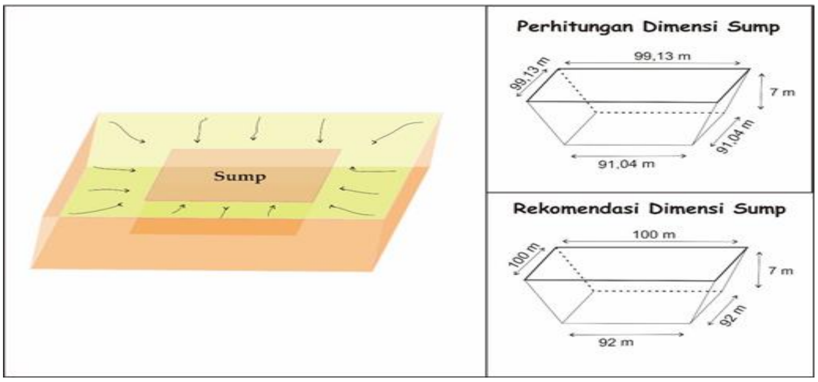

Figure 1. Sump Dimention

Pump Requirements
The mining site uses Mulia Flow 420 E pump to prevent the water from entering the pit. As an essential tool in mining, a pump functions to transfer fluids from one place to another. Based on the on-site measurement, the maximum discharge produced by the pump with a High-Density Polyethylene (HDPE) pipe of 8 inches is 0.3 m^3/second. Based on the observation, it is found

that the mining site requires four units of the Mulia Flow 420 E pump to prevent runoff water, each with an operation duration of 20 hours/ day.

D. Conclusion

The mine drainage system is considered necessary in the site since the watery area is the potential to hinder the production as well as to cause work accidents. On top of that, the terrain is dominated by relief of wavy hills with varying waves and slopes ranging from 10°-70°. This also takes into account the largest monthly average rainfall that occurred in January 2015 with a 23.99 mm/month rate. Moreover, the rainfall condition in the research site consisted of heavy rain and very heavy rain. The expected rainfall in the return period in the second, third, fourth, fifth, and tenth year is 6.30 mm/day, 10.15 mm/day, 12.62 mm/day, 14.44 mm/day, and 19.83 mm/day in respective order. The study applies five hours as the duration of the lowest rainfall in the Pit Limit area. By such duration, the study simulates a large rainfall intensity of 0.747 mm/hours in the second year. This number is assumed to be the worst rain condition. The largest catchment area is in the CA1, with a size of 258,911.39 m^2. The total water runoff discharge in the Pit Limit is 63,514.83 m^3/day.

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