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Design and Planning of Mine Drainage Systems at PT. Pertama Mina Sutra Perkasa, Puger District, Jember Regency, East Java, Indonesia

Aldy Maulana Malik Ibrahim [*1], Avellyn Shinthya Sari [1], Fairus Atika Redanto Putri [1]
[1] Teknik Pertambangan Institut Teknologi Adhi Tama Surabaya
*E-mail: aldymaulanamalik02@gmail.com

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Abstract

PT. Pertama Mina Sutra Perkasa, a limestone mining company, operates in Grenden Village, Puger District, Jember Regency, East Java Province. Utilizing an open mining system, the company faces challenges related to mine drainage. Based on rainfall analysis from 2013 to 2020. the planned rainfall rate is 25.938 mm/hour, with a rainfall intensity of 5.712 mm/hour, resulting in a runoff water discharge of 0.599 m^3/second. The water discharge entering the well at the site is 2159.08 m^3/hour. The designed drainage channel has a discharge capacity of 3.109 m^3/second, a wet surface area of 0.5 m^2, a channel bottom slope of 0.03%, a hydraulic radius of 0.25 m, a Manning roughness coefficient of 0.011. a wet cross-section circumference of 2 m, and a flow depth of 0.5 m. The planned well dimensions are 60 m in length, 20 m in width, and 7 m in depth, with a volume of 8400 m^3. The current sludge settling pond has three compartments with a total capacity of 393.75 m^3. The proposed design for the sludge settling pond includes a length of 60.6 m, a width of 15 m, a depth of 7 m, and a volume of 5454 m^3. The actual mud dredging frequency is once every 2 days, while the proposed plan extends this interval to 9 days using a Doosan 340DX type excavator. This comprehensive drainage system design aims to efficiently manage runoff and sedimentation, ensuring sustainable mining operations

1. Introduction

PT. Pertama Mina Sutra Perkasa, which is located in Grenden Village, Puger District, Jember Regency, East Java Province, is currently carrying out its main activities, which focus on the limestone production stage. The mining system used by PT. Pertama Mina Sutra Perkasa is a mine in an open area that is in direct contact with the open air. The open mining system in mining activities will create an open area on the surface of a mining working area so that during mining activities there will be water problems, one of which is excessive amounts of rainwater.

PT. Pertama Mina Sutra Perkasa uses an open pit mining system, which will always face problems, especially drainage. Even though PT. Pertama Mina Sutra Perkasa already has a distribution system, but there are still problems that arise and affect the running of mining activities. The problem that often arises in drainage is the occurrence of water overflowing in the area around the well located in PT. Pertama Mina Sutra Perkasa. Even though the water overflow that occurred was relatively small, the signs of water overflow were not very visible. Several factors influence this, one of which is a water distribution system that is not optimal[1]. Therefore, in mining activities in this modern era, it is necessary to study the drainage system by calculating the amount of runoff water discharge, and rainwater discharge, and controlling mud deposits in mud-settling ponds as best as possible so that there is no overflow of water, can disrupt the progress of activity in the process of mining[2].

2. Methodology

2.1. Types of research

The research carried out was analyzing the capabilities of the distribution system at PT. Pertama Mina Sutra Perkasa. The research method that will be used is a quantitative research approach, by observing the drainage system in the research area to see whether it can obstruct mining activities. This method is carried out with several stages of activities carried out.

2.2. Research Implementation

Carrying out research regarding distribution system analysis at PT. Pertama Mina Sutra Perkasa will be divided into:

1. Preparatory stage before research.
2. Data collection stage.
3. Data processing stage.
4. Data Analysis Stages.

2.3. Research Preparation

Several things must be prepared before conducting research, including:

1. Literature study, the literature study method used was collecting the results of previous research related to the problems raised, reading reference books, and accessing research journals from the website. This study was carried out before data collection and during the research.
2. Field observations aim to determine the location for data collection and test problem formulation to make the research right on target.
3. Equipment preparation, namely preparing the tools needed during research including writing tools, personal protective equipment (PPE), and cameras.

2.4. Data retrieval

In this stage, data is collected that is considered useful in solving the problem. The data taken is as follows:

1. Primary data is data obtained directly in the field by research while in the field, such as data on the general condition of the research area, water discharge data, channel dimensions, well dimensions, and mud-settling pond dimensions.
    a. Water discharge data entering the mud-settling pond was taken using rainfall calculations using the Gumbel method (1954) for planned rainfall[3], the Mononobe method (1992) for rainfall intensity[4], and runoff water calculations using the Seyhan formula (1990)[5].
    b. Data on the dimensions of the drainage channel were taken by measuring using a rolling meter directly in the field carried out by researchers[6].
    c. Well dimension data was taken by measuring using a rolling meter directly in the field carried out by researchers[7].
    d. Data on the dimensions of the mud settling pond were taken by measuring using a rolling meter directly in the field carried out by the researcher and accompanied by the field supervisor[8].

2. Secondary data is data obtained through previous research studies and data taken from company reports as supporting data in writing research. This data includes rainfall data and equipment specifications[9].

2.5. Data processing

Once the data is obtained, the main data and supporting data are then processed through calculations and data processing. The data processing is as follows:

1. The calculation of water discharge, the total calculation of water inflow into the sedimentation pond can be determined by calculating the rainfall data obtained using several steps – calculating planned rainfall with the formula $CHR = X + \left(\frac{SD}{Sn}\right)(Yt - Yn)$[10], rainfall intensity with the formula $I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$[11], and runoff water discharge with the formula $Qr = C \times I \times A$[12]
2. The channel plan, calculation of the channel plan that enters the well can be known by calculating the data that researchers have obtained directly through measurements in the field and processed using $Q_s = \frac{1}{n} \times A_b \times S^{1/2} \times R^{2/3}$[13].
3. The capacity of the well, the calculation of the capacity of the well that the author has planned to accommodate runoff water can be determined by calculating the data that the researcher has obtained directly through measurements in the field and processed using the formula $V = p \times l \times t$[14].

4. The capacity the mud settling pond, calculation of capacity of the mud-settling pond that the author has planned to accommodate runoff water coming from wells can be determined by calculating the data that researchers have obtained directly through measurements in the field and processed using the formula $V = p \times l \times t$[15].
5. Mud dredging time, the calculation of the mud dredging time that the author has planned to overcome silting due to the deposition of runoff water from wells can be determined by calculating the data that researchers have obtained directly through measurements in the field and processed using the formula $WP = \frac{V.KPL}{TP}$[16].

2.6. Data analysis
After the data is processed through calculations, data analysis is then carried out, to compare the data obtained between actual data and data from the calculation process to provide solutions to solve problems as a reference to obtain answers to discuss problems as the final goal.

2.7. Research Flow Chart
The flow of activity implementation can be seen in the flow diagram image below.

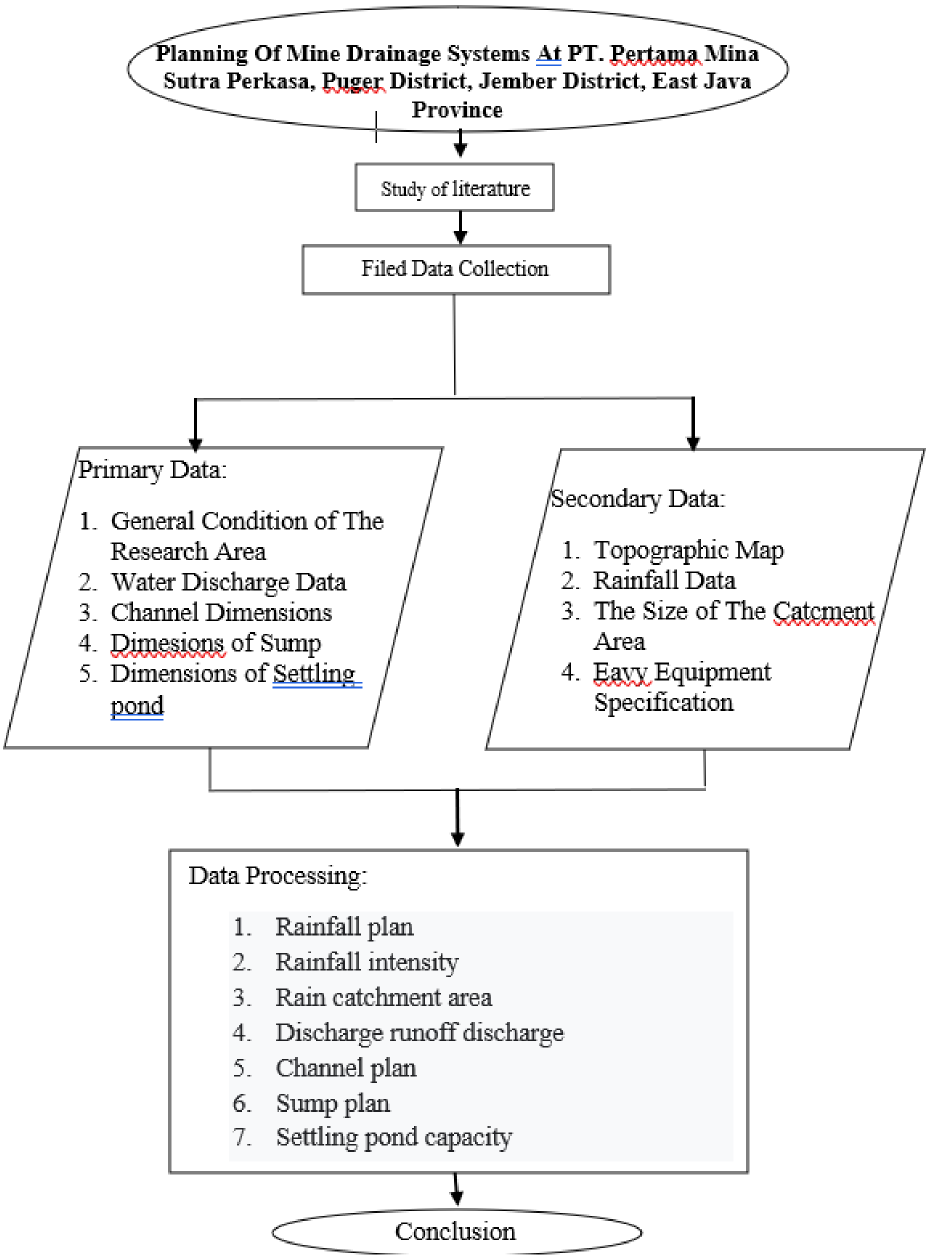

Figure 1. Research Flow Chart

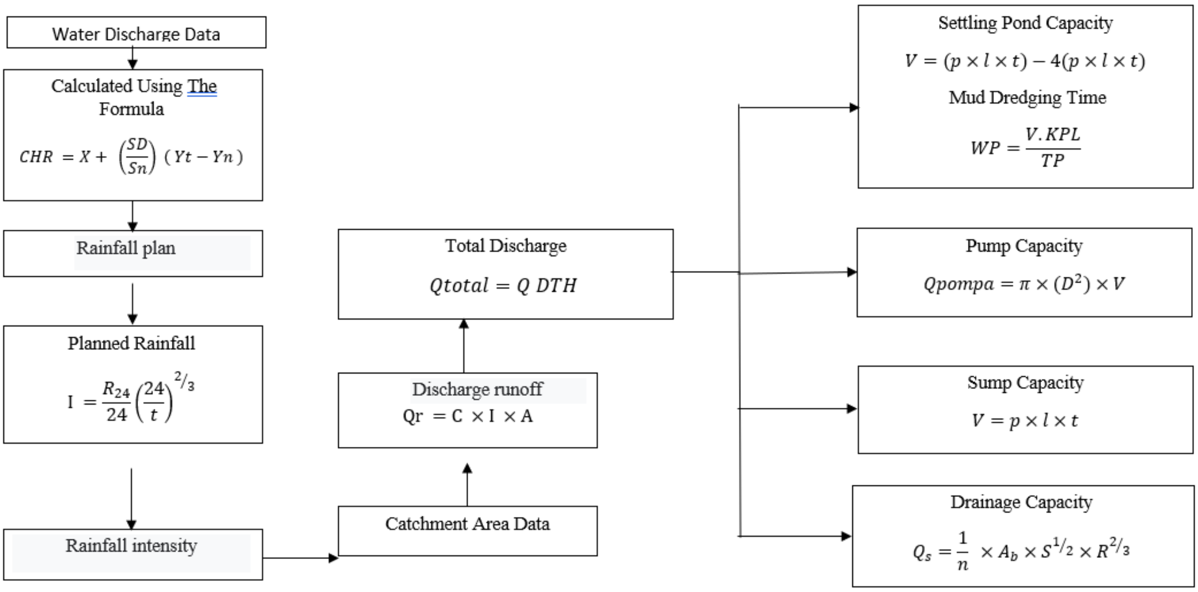

Figure 2. Data Processing Diagram

3. Results and discussions

3.1. Research Result

The results that have been obtained in conducting research are as follows:

1. The average incoming water discharge that enters the mud-settling pond is based on field research, there are several water discharges and their origins. For the mining area of PT. Pertama Mina Sutra Perkasa, the water flow that enters the mud settling pond comes from runoff water.

   Catchment Area Runoff Discharge

   $Qr = C \times I \times A$
   $Qr = 0.9 \times 0.171336 \text{ m/hours} \times 420000\ m^2$
   $Qr = 2159.08\ m^3/\text{hours}$
   $Qr = 0.599\ m^3/\text{second}$

2. Open channels, or ditches function to channel water from the catchment area to the well location. Mine drainage channels need to be made to channel runoff water into wells to reduce standing water in the mining area. At the research location, there are open channels, but they do not include the catchment area area. This causes flooding based on conditions in the field and data on sources of runoff water that occur in the mining area. So, the amount of runoff water that must be channeled into the well is.

   Catchment Area Runoff Discharge

   $Qr = C \times I \times A$
   $Qr = 0.9 \times 0.171336 \text{ m/hours} \times 420000\ m^2$
   $Qr = 2159.08\ m^3/\text{hours}$
   $Qr = 0.599\ m^3/\text{second}$

   From this data, the dimensions of open channels that can reduce inundation caused by runoff water are

Q_S	= Discharge of the conveyance channel (m^3/second)	= 3.109
A_b	= Wet cross-sectional area (m^2)	= 0.5
S	= Channel bottom slope (%)	= 0.03
R	= Hydraulic radius = A_b/P (m)	= 0.25
n	= Manning's roughness coefficient	= 0.011
P	= Wet cross-sectional perimeter (m)	= 2
h	= depth of flow	= 0.5

$$Q_s = \frac{1}{n} \times A_b \times S^{1/2} \times R^{2/3}$$
$$Q_s = \frac{1}{0.011} \times 0.5 \times 0.03^{1/2} \times 0.25^{2/3}$$
$$Q_s = 3.109\ m^3/\text{second}$$

A well is a place made to collect runoff water before it is channeled to the settling pond. Based on observations in the field, the well has not been able to accommodate the water that enters it, so repairs need to be carried out. According to field conditions at the time of the research, the wells were not yet able to accommodate water coming from the catchment area, based on calculations made on rainfall data samples for 2013-2020. The volume of the well cannot accommodate runoff water.

Catchment Area Runoff Discharge

$$\text{Qr} = \text{C} \times \text{I} \times \text{A}$$
$$\text{Qr} = 0.9 \times 0.171336\ \text{m/hours} \times 420000\ m^2$$
$$\text{Qr} = 2159.08\ m^3/\text{hours}$$
$$\text{Qr} = 0.599\ m^3/\text{second}$$

3. The mud-settling pond functions as a water reservoir and is also useful for settling solid materials that are washed away with the water from the mining area. The sludge-settling pond is made in a rectangular shape with a drainage pattern made meandering so that the rate of flowing water and materials entering the sludge-settling pond can be minimized. settling pond consists of 3 compartments.

Settling Pond Length	= 21.6 m
Settling Pond Width	= 7.5 m
Settling Pond Depth	= 2.5 m
Settling Pond Water Depth	= 2 m
Sealing Width	= 0.15 m
Sealing Height	= 2.5 m
Sealing Length	= 7.5 m
Settling Pond Volume	= 393.75 m^3
Settling Pond Water Volume	= 315 m^3

$$V = (p \times l \times t) - 4(p \times l \times t)$$
$$V = (21.6 \times 7.5 \times 2.5) - 4(7.5 \times 0.15 \times 2.5)$$
$$V = 315\ m^3$$

4. If the settling pond has a reduced flow rate, the time required for the water to leave the settling pond will take a long time so that the existing material has sufficient time for the settling process. The more material that settles in the mud-settling pond, the better the quality of the water that will come out of the settling pond. Based on the actual volume of the mud-settling pond, the time for dredging the mud from the bottom of the pond can be done every 2 days.

3.2. Discussion

The discussions that have been obtained in conducting research are as follows:

1. Based on research at PT. Pertama Mina Sutra Perkasa, for the water discharge that enters the mud settling pond, comes from runoff water which flows from the rain catchment area through open channels to wells so that the water discharge leading to the mud settling pond can be calculated in.

Catchment Area Runoff Discharge

$$\text{Qr} = \text{C} \times \text{I} \times \text{A}$$
$$\text{Qr} = 0.9 \times 0.171336\ \text{m/hours} \times 420000\ m^2$$
$$\text{Qr} = 2159.08\ m^3/\text{hours}$$
$$\text{Qr} = 0.599\ m^3/\text{second}$$

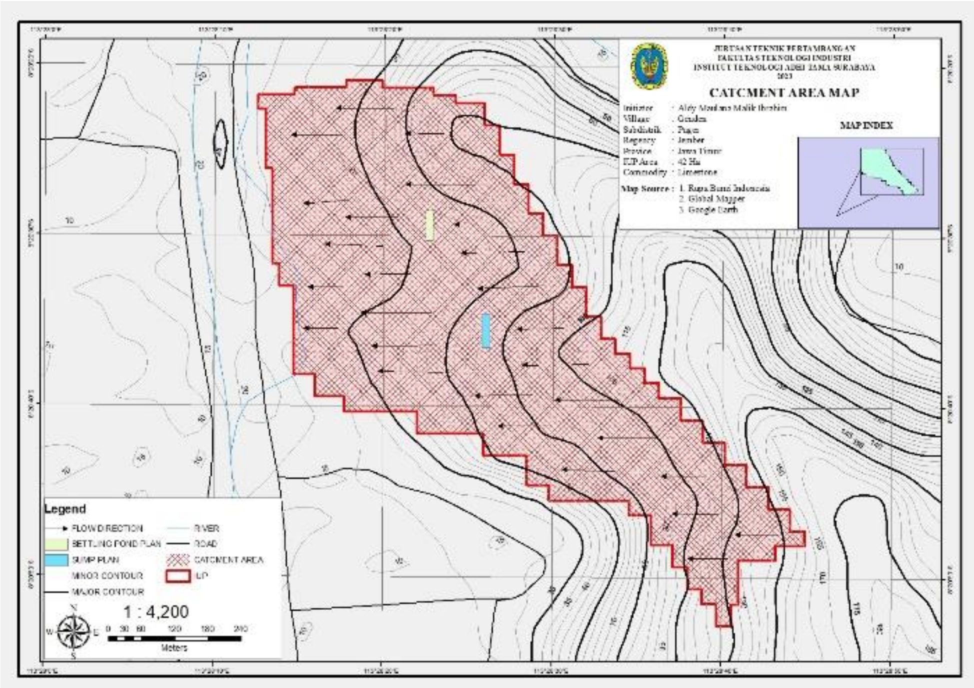

Figure 3. Catchment Area Map

Total Water Discharge
Q total $= $ Catchment Area Runoff Discharge
Q total $= 2159.08\ m^3/hours$
Q total $= 0.599\ m^3/\text{second}$

2. Trench Planning, Open channel planning is carried out to avoid overflowing water during the drainage process from the rain catchment area to the well. Open channels at PT. Pertama Mina Sutra Perkasa will be designed with a square shape. Open channels are created to channel runoff water originating from rain catchment areas. The discharge of runoff water that will flow through the open channel is 0.599 m3/second.

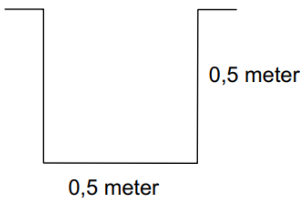

Figure 4. Open Channel Dimension Plan

Description:

Q_S	= Flow channel discharge (m^3/second)	= 3.109
A_b	= Wet surface area (m^2)	= 0.5
S	= Channel bottom slope (%)	= 0.03
R	= Hydraulic radius= A_b/P (m)	= 0.25
n	= Type of ditch material	= 0.011
P	= Wet cross-sectional perimeter (m)	= 2
h	= Flow Depth	= 0.5

$$Q_s = \frac{1}{n} \times A_b \times S^{1/2} \times R^{2/3}$$

$$Q_s = \frac{1}{0.011} \times 0.5 \times 0.03^{1/2} \times 0.25^{2/3}$$

$$Q_s = 3.109\ m^3/\text{second}$$

Figure 5. Actual Wells

3. Well Planning, after assessing the actual volume of the well, it was discovered that the well owned by PT. Pertama Mina Sutra Perkasa has not been able to handle the incoming water discharge. Planning of distribution system components needs to be done thoroughly to support other components. According to the conditions in the field, a well design needs to be carried out. The following is a design plan for the dimensions of the well. There are several reasons for designing the planned well in terms of the location of the planned well still being the same location as the actual well because it is an area that has a low elevation and the location itself is still wide enough for the planned well. There is also a reason to measure the dimensions of the planned well, namely looking at the specifications of the equipment at PT. Pertama Mina Sutra Perkasa, namely the Doosan 340 DX. And, for the direction of water flow from the catchment area towards the planned well because it doesn't change the location of the actual well, I just focus on one well.

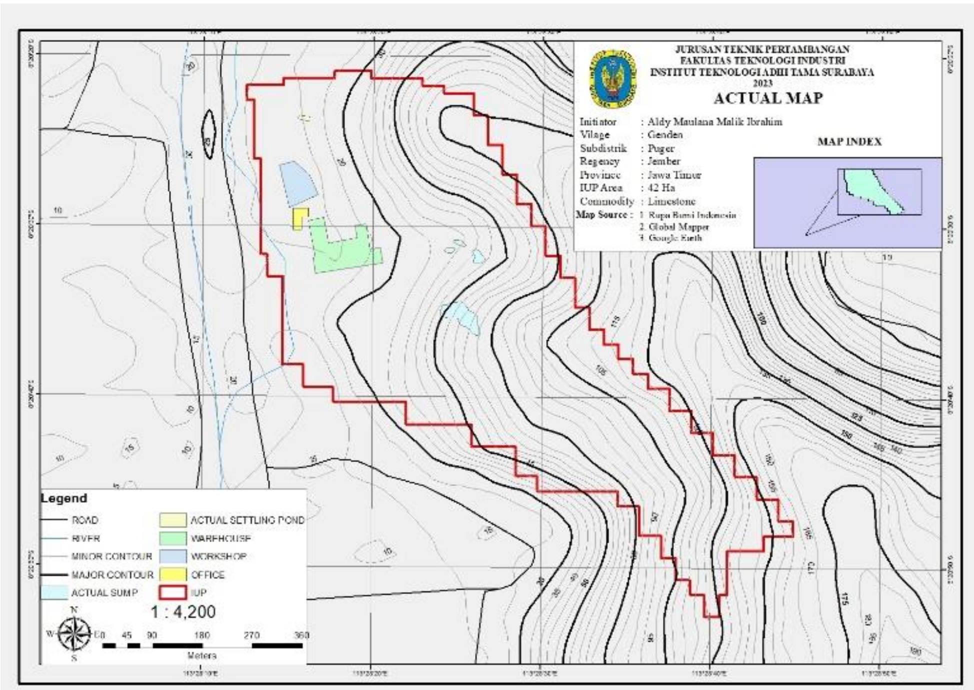

Figure 6. Actual Map

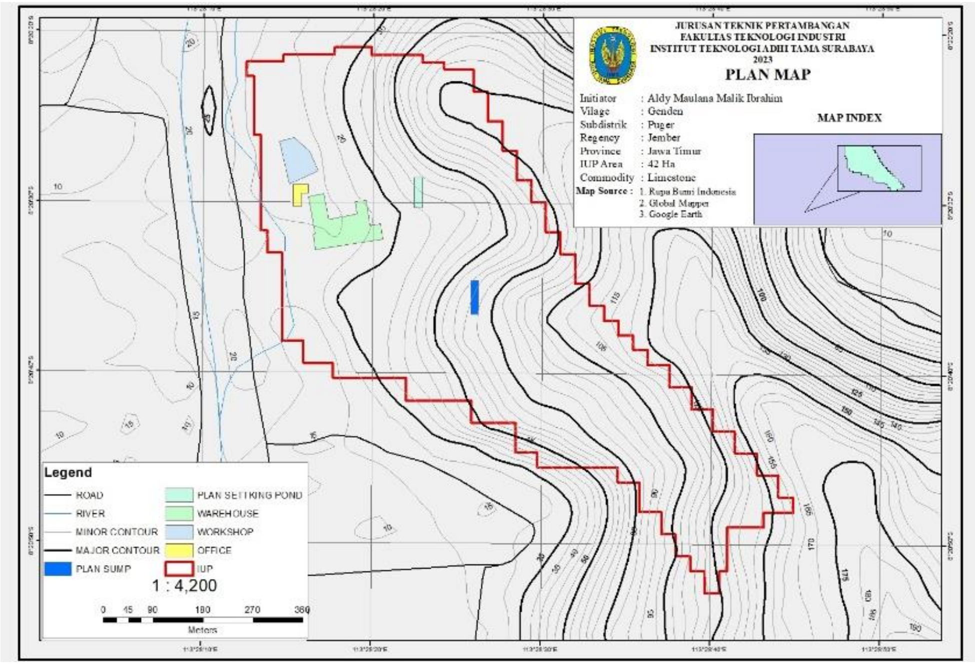

Figure 7. Plan Map

Description:
Pits length = 60 m
Pits width = 20 m
Depth of the pit = 7 m
Then the volume of the pit is:

$$V = p \times l \times t$$
$$V = 60 \times 20 \times 7$$
$$V = 8400\ m^3$$

4. Based on the volume of water flowed by a pump with a capacity of 2526.86 m3/hour for 1 pump, it is necessary to change the dimensions of the sludge settling pond. The aim of changing the mud settling pond is to increase the deposition of particles carried by the mine drainage process. Based on the analysis of mud-settling pond calculations.

Description:
Settling Pond Length = 21.6 m
Settling Pond Width = 7.5 m
Settling Pond Depth = 2.5 m
Settling Pond Water Depth = 2 m
Sealing Width = 0.15 m
Sealing Height = 2.5 m
Sealing Length = 7.5 m
Settling Pond Volume = 393.75 m^3
Settling Pond Water Volume = 315 m^3

$$V = (p \times l \times t) - 4(p \times l \times t)$$
$$V = (21.6 \times 7.5 \times 2.5) - 4(7.5 \times 0.15 \times 2.5)$$
$$V = 315\ m^3$$

There are several reasons for designing a planned mud settling pond in terms of the location of the planned mud settling pond in an area close to the planned well because the location is quite large for the planned mud settling pond. There is also a reason for the size of the recana mud settling pond, namely the specifications of the equipment available at the company, namely the Doosan 340 DX. And there is a reason for the large number of muds settling ponds, namely so that they can accommodate water from wells.

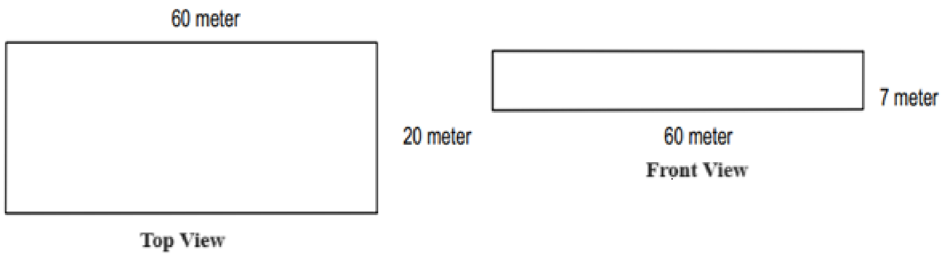

Figure 8. Dimensional Plan of the Well

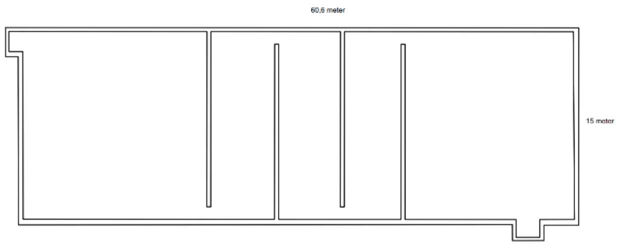

Figure 9. Sludge Settling Pond Dimension Plan

Description:

Settling Pond Length	= 60.6 m
Settling Pond Width	= 15 m
Settling Pond Depth	= 6 m
Settling Pond Water Depth	= 6 m
Sealing Width	= 0.15 m
Sealing Height	= 6 m
Sealing Length	= 15 m
Settling Pond Volume	= 5454 m^3
Settling Pond Water Volume	= 5400 m^3

$V = (p \times l \times t) - 4(p \times l \times t)$

$V = (60.6 \times 15 \times 6) - 4(15 \times 0.15 \times 6)$

$V = 5400\ m^3$

5. Based on information from PT. Pertama Mina Sutra Perkasa is known that every 1 liter of water contains 10% solids and 90% water. So the calculation of settling time is carried out using the Stokes formula, this is because the percentage of solids contained is less than 40% for the calculation of actual dredging of the settling pond for 2 days. The calculation results for sediment dredging are based on the dimensions of the mud settling pond which have been changed to 9 days for more details as shown in.

   Dredging time

   $WP = \frac{V.\text{Settling Pond}}{TP}$

   $WP = \frac{5400}{598{,}37}$

   $WP = 9.02\ days$

Figure 10. Dredging Process

4. Conclusion

With the planned rainfall calculation of 25.938 mm/hour, the rainfall intensity is 5.712 mm/hour, and the runoff water discharge is 0.599 m3/second. The water discharge enters the well at the PT Pertama Mina Sutra Perkasa obtained runoff water of 2159.08 m3/hour. The planned channel dimensions are drainage channel discharge 3.109 m3/sec, wet surface area 0.5 m2. channel bottom slope 0.03%, hydraulic radius 0.25 m, Manning roughness coefficient 0.011. wet cross-sectional perimeter 2 m, depth flow 0.5 m. The planned dimensions of the well with the total discharge entering the well are 2159.08 m3/hour, so the planned well volume is 8400 m3. The dimensions of the planned well are 60 m long, 20 m wide, and 7 m deep. Actual Mud Deposition Pond Capacity at PT. Pertama Mina Sutra Perkasa has 3 compartments and a capacity of up to 393.75 m3. The Sludge Deposition Pool Capacity Plan was redesigned with the following dimensions: pool length 60.6 m, pool width 15 m, pool depth 7 m, volume 5454 m3. The actual mud dredging time has a mud dredging time interval of once every 2 days. Meanwhile, the planned mud dredging time based on the dimensions of the planned mud settling pond is 9 days using a Doosan 340DX type excavator.

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