Characterization of Former Coal Mining Ponds (voids) and Water Management System Planning

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> DOI: 10.29322/IJSRP.13.04.2023.p13603 http://dx.doi.org/10.29322/IJSRP.13.04.2023.p13603

> > Paper Received Date: 15th February 2023 Paper Acceptance Date: 27th March 2023 Paper Publication Date: 6th April 2023

Abstract. This study aims to examine the characteristics and volume of ex-coal mining pools that have been filled with water in the form of voids using River Surveyor M9 technology. The results of the void profile study become important data in planning a water management system which includes draining the pond with a pumping planning system and planning a sludge pond. From the results of a void study in Pit E, it was found that the area of pit E is 27.25 Ha, a depth of 57 m, a length of 820 m, a width of 205 m, and a volume of 6,479,241.5 m3. The company plans to drain 71,991.57 m³ of voids per day, so it is estimated that it will take 90 days of working time. The required pump capacity is 3,850 m3/hour. From the results of a field study and the efficiency of the pump, it will be placed in the southern part of the ex-mining pond which has a total capacity of 3,913 m3/hour and a total power of 1,181 HP. Sludge settling ponds are planned with a pond width of 18 m; Pool length of 45 m; pool depth of 4 m; many compartments of 5 pieces; compartment length of 8 m; settling capacity of 4000 m3; compartment capacity of 800 m3. Water is channeled using an open canal in the form of a trapezoid, made of earth, dug normally without hardening of the seams with a slope of 0.044%; channel bottom width 1.04 m; water level 1.04 m; top width of channel 4.12 m; guard height 0.5 m, slope 43°.

I. INTRODUCTION

PT. XYZ is a coal mining company that implements an open pit mining system, a mining system that is directly related to the outside weather and has 6 pits. Since 2000, namely pits A, B, C, D, E, and pit E, coal production has reached a cumulative production of 1,250,000 metric tons. In 2014, the company stopped all of its production activities due to the drastic decline in coal prices.

In 2021 the company plans to reopen its pits, as a result of a technical study there are coal reserves that are still economical, namely pit E, all abandoned mine openings are now mine ponds (voids).

Under these conditions, the mine pond must be drained so that it can dig back the coal in the mining pit. The drying or dewatering process will be carried out with careful planning so that an effective dewatering system plan can be carried out.

This research was conducted to know the characteristics and profile of mine water ponds (voids), analyze pump point locations, and select pumps so that the target of dewatering void pit v is achieved and analyze settling pond system planning in pit E.

In drying mine ponds, it is necessary to study the characteristics of the mine ponds. The study of hydrology includes flow groundwater, hydrometeorology (water in the air and the form of a gas), limnology (surface water that is relatively calm such as lakes and reservoirs), cryptology (water in the form of solids such as ice and

snow) [1].

The characterization of the mine pond includes the profile of the mine pond.

This publication is licensed under Creative Commons Attribution CC BY. http://dx.doi.org/10.29322/IJSRP.13.04.2023.p13603 The profile of the mining pond is obtained by measuring the dimensions in the form of coordinates (x, y), and the depth of the pond, using the m9 river surveyor technology. From the above data, it can be known and calculated the volume of mining ponds with Minescape 5.7 software. Obtaining the volume of mine ponds becomes a technical consideration for dewatering planning to be effective and efficient. [11]. The amount and intensity of rainfall in the ex-pit E mining area greatly determine the volume of mine pool water.

Planning to drain the volume of pond water in the former mine is carried out by calculating the planned water discharge, this is important for analyzing the selection of pumps that can meet the target, taking into account the pump head and pump efficiency at each location [2].

The open channel system in the drying process is used to predict the planned flow of water volume in dewatering activities [5].

The required design pump discharge can be found by calculating the volume of water entering the mine pond divided by the drying time. This type of soil pump is used to move the volume of mine water from one place to another through a continuous piping system [8].

Discharge based on pump specifications can be determined based on pump speed, efficiency, and desired pump head then linked in a pump specification graph [4].

The mining pond dewatering system is an effort or method to prevent, dry and remove water that is contained or inundated in a certain area. Meanwhile, drainage in an open pit is an effort to drain the mining environment which is carried out to prevent water from entering or removing water that has entered the mining area [3].

Evaluating the characteristics of mine ponds to determine the volume of water in mine ponds (voids) is done by analyzing

the local hydrological cycle as a basis for calculating the water discharge target [6].

This water discharge target is then used to analyze pump selection, starting from consideration of the available head for each location for pump placement, and pump efficiency at each location. [7].

All elements of open channel parameters must be known to prevent the water level from overflowing, so a guard height is needed in the channel. The guard is the vertical distance from the top of the canal to the water surface at the design discharge condition. The guard height is useful for raising the water level above the maximum water level and preventing damage to the canal embankment and is associated with the planned discharge of the canal [12].

II. METHODOLOGY

Research conducted at PT. XYZ. Pengaron District, Banjar Regency, South Kalimantan. Location of all mining activities based on contract No. KW 98 AGB064. follow the coordinates between 03°15'59,6" South Latitude to 03°19'04" South Latitude and 115°05'21" East Longitude to 115006'27" East Longitude.



Figure 1. Map of Research Locations

The initial stage of this research is to conduct a literature study related to data and information related to previous coal mining such as identifying former coal mining pools and mapping former coal mining ponds.

The next step is to prepare field observations and measurements to find out the site's general condition, including the number and characteristics of the 6 ex-coal mining pools.

Then from these data determine the ex-mining pond (void) that will be studied, namely in the ex-mining pond in pit E. After that measurements are carried out by determining the zero point to obtain detailed data on the characteristics and profile of the pond including coordinates, depth, volume, and water discharge.

To obtain characteristic data and void E profiles, direct measurements were made using the river surveyor M9 tool.

Figure 2 shows the river surveyor M9 technology used to directly measure the characteristics of void E in the field.





The River Surveyor M9 is a tool for measuring subsurface conditions using the Acoustic Doppler Current Profiler (ADCP) approach specifically designed to work in rivers, lakes, and seas. River surveyor m9 can measure the speed of water currents, water discharge in 2 or 3 dimensions, the depth of the water surface, the state of the particles below the water surface,d bathymetry. Processing of research data obtained from the field as well as data from companies is processed using the River Surveyor Live application, Minescape 5.7, Global Mapper, and Microsoft Excel. The data processing steps are as follows:

- 1. Compile and process closure data and void pit E grids from the river surveyor live application to Microsoft Excel.
- Input data from Microsoft Excel to calculate The volume of water in the voids using the Minescape 5.7 application.
- 3. Processing rainfall data in Microsoft excel.
- 4. Calculating the catchment area using the Global Mapper application.

Data analysis was carried out by evaluating the characteristics of the mine pond to determine the volume of water in the pit mine (*voids*) Pit E. Then analyzing the local hydrological cycle to calculate the target water discharge to be released (dewatering). This target water discharge is then used to analyze the selection of pumps that can meet the target, starting from consideration of the head for each location available for pump placement, and efficiency and ay at each location.

The next stage is to analyze the settling pond system. Settlement ponds (settling ponds) function as temporary water storage before flowing back into the river.

The sludge-settling pond is all a function as a place to control the quality of the water from the mixed mud or solid material which will be flowed out. In channeling water openly, planning the dimensions of the open channel needed to flow water to the nearest river body that meets environmental quality standards.

Calculation of the capacity of the drainage channel is done by using the Manning formula which is the basis for determining the channel. In designing channel dimensions, efforts must be made to obtain economical cross-sectional dimensions. Channel dimensions that are too large mean it is not economical, conversely channel dimensions that are too small the loss rate will be large. If the flow velocity and cross-section are known, then the flow rate can be calculated. Figure 3 describes the research flowchart from the field survey stages, measurement and analysis of the characteristics study and dewatering and pumping planning as well as the dimensions of the sludge settling pond plan.



III. RESULT AND DISCUSSION

The initial step in solving this case is through the following stages:

1. Evaluate the characteristics of the mine water pool (*void*) Pit E

a. Making a Mine Pool Profile

The first initial stage carried out in data processing in the Minescape 5.7 software is to enter closure data that has been taken with the river surveyor m9 which is tied to a rubber boat by walking along the edge of the mine pond (void). This aims to determine the shape of the mining pond (void), making

this closure based on boundary coordinate data (Table 1) obtained from river surveyor live software.

Table 1. Void River Surveyor coordinates

| Step | Track | DMG | Depth | UTM X | UTM Y |
|----------------|-------|------|-------|----------|---------|
| | m | m | m | m | m |
| Start Edge (1) | 0.36 | 0.36 | 12.94 | 296780.5 | 9648397 |
| Start Edge (2) | 0.74 | 0.74 | 12.9 | 296780.9 | 9648397 |
| Start Edge (3) | 1.09 | 1.08 | 12.77 | 296781.2 | 9648397 |
| Start Edge (4) | 1.44 | 1.43 | 12.86 | 296781.6 | 9648397 |
| Start Edge (5) | 1.74 | 1.73 | 12.66 | 296781.9 | 9648397 |

Source: Processed data, 2022

Profile data must be pre-processed in Microsoft excel software to change the depth to Z, by reducing the elevation with the depth obtained from the *river surveyor m9* tool.

The goal is that it can be loaded into the Minescape 5.7 software because the data that can be loaded in creating a mining pool profile (voids) must be in xyzfree form. After the X, Y, and Z coordinates (Table 2) are obtained, they are then loaded into the Minescape 5.7 software.

 Tabel 2. Koordinat Void Pit E
 Dari Perhitungan River

 Surveyor Live

| | - | | | | |
|----|----------|---------|--------|----------|------------|
| No | UTM X | UTM Y | Depth | Permukaa | Ketinggian |
| | | | | n air | |
| | m | m | m | m | m |
| 1 | 296780.5 | 9648397 | 12.937 | 66 | 53.04 |
| 2 | 296780.9 | 9648397 | 12.932 | 66 | 53.08 |
| 3 | 296781.2 | 9648397 | 12.768 | 66 | 53.20 |
| 4 | 296781.6 | 9648397 | 12.859 | 66 | 53.12 |
| | 296781.9 | 9648397 | 12.657 | 66 | 53.33 |





Figure 4. Pit E ex-mine pool (void).

b. Making Grid or Cross Section

This publication is licensed under Creative Commons Attribution CC BY. http://dx.doi.org/10.29322/IJSRP.13.04.2023.p13603 The next stage is gridding or the area division stage of the mining pool (*void*). The distance between each section is 25

meters. The distance of 25 meters was chosen not to have a certain standard but was chosen so that the results from the measurement of the mining pool (void) pit E were more optimal. The smaller the distance between sections, the greater the level of accuracy, and vice versa the greater the distance between sections, the greater the level of accuracy.

c. Making Contours with the Triangulation Method

The X, Y, and Z coordinate data that have been input into Minescape 5.7 are first processed into contour line data by clicking on the triangulation contour menu in Minescape so that the resulting contour lines are smoother, then processed into triangulation data. The figure shows the design of the triangulation model of the shape of the mining pool (Figure 4).

d. Calculation of the volume of mine pools (voids) Pit E

To calculate the volume, in addition to triangulation data from the mining pool, triangulation data from the water surface is also needed for additional data.

The volume calculation requires triangulation of water level data as the top layer and mining pool triangulation as the bottom layer (Figure 5).



Figure 5. Alternative locations for pump placement

Determination of the location where the pump is located is determined by comparing the size of the pump head, the number of alternative pumps to choose from, the amount of water discharge that can be pumped, and the power required for each pump installation.

The flow rate of each pump is obtained by plotting the head value on the head vs flowrate curve.





Figure 6. Pump installation plan in the northern part of the Mine Pond at Pit E

The pump installation plan in the coal mining pit as illustrated in Figure 6, shows that pump 03 cannot

be used as an alternative because the topography in the north of the pond is too large and steep for the ability of the pump head or commonly referred to as the shut-off head, where at that head the pump cannot flow water which will result in inefficiency and the pump will be damaged.



From the calculation results, it is obtained that the volume of the pit E mine pond is 6,479,241.5 m3 with a surface area of 32.224 Ha and an average pool depth of 12.817 meters.

2. Analysis of Pump Selection and Location

a. Water discharge

The volume of the mine pond is 6,479,241.5 m³. The dewatering target is carried out in 90 days, so the water discharge issued per day is 71,991.57 m³/day.

b. Pump Installation

For pump location placement, 2 locations can be used as pump installation placements, namely in the north of the void and in the south of the void (figure 4).

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The maximum pump capacity that can be achieved is 1,450 m3/h with an efficiency of 77% and the lowest power is 309 HP. Thus, there are only 5 pump installations that can be used, namely pumps 01A, 02B, 02C, 03A, and 03B as presented in table 3 below.

Table 3. Pump Installation North of the Mine Pond

| NORTH | | | | | | | | |
|------------|-----------------------|---------|---------------|-------|---------|------|-------|--|
| Pump | Tot | | Capasity | | Efisien | | Power | |
| Numb er | al He ad (m) | Setting | L/s | m³/h | cy % | RPM | (HP) | |
| 01 | 90 1512 | А | 200 | 720 | 7 0 | 1200 | 309 | |
| 01 | 80,1312 | В | 265 | 954 | 6 7 | 1300 | 428 | |
| | | С | 323 | 1.163 | 6 0 | 1300 | 583 | |
| 02 | 67,6253 | | Shut off head | | | | | |
| 03 | 73,3824 | А | 311 | 1.100 | 7 5 | 1000 | 405 | |
| | | В | 403 | 1.450 | 7 7 | 1000 | 520 | |

The pump installation plan in the southern part of the ex mine pond is designed as shown in Figure 6, where the topographical field analysis results in the southern part of the mine pond can be handled by all available pumps and there are 9 alternative pump installations.



Figure 7. Planned Pump Installation in the South of the Pit E Mine Pond

Pump installation in the south of the mine pond show3.d. Settling pond system planning analysis greater pump capacity and lower power and more selection of a. Settling pond dimensions alternative pumps compared to pump installation in the north of the mine pond (Table 4). From the results of field calculations and analysis, it is recommended that the pump installation be installed in the southern part of the Pit E ex-mine pond.

The largest pump capacity that can be achieved by the pump is 1,790 m3/h with an efficiency of 70% and the lowest power is 107 HP.

c. Pump Selection

From the results of the analysis of the pump installation above, it aims to be able to meet the target of removing void pool water of 71,991.57 m³/day, a pump capacity of 3,850 m³/hour is needed with 20 working hours.

Table 5. Calculation of Pump Capacity and Power

| PUMP | Setel an | Daya (HP) | Jumlah Pompa | Kapasit as total (m ³ /h) | Daya Total (HP) | Kapasitas per 1 HP | HP per 1 m3/ h |
|------|-------------|--------------|-----------------|--|-----------------------|-----------------------|----------------------------|
| 2 | Α | 169 | 0 | 2 0 2 0 | | 0.50 | 0.20 |
| 4 | С | 182 | 4 | 3.939 | 1.117 | 3,53 | 0,28 |
| 5 | В | 389 | 1 | | | | |
| 2 | | 317 | 0 | | | | |
| 4 | С | 182 | 4 | 4.029 | 1.209 | 3,33 | 0,30 |
| 5 | | 481 | 1 | | | | |
| 2 | _ | 235 | 2 | | | | |
| 4 | В | 152 | 3 | 4.145 | 1.315 | 3,15 | 0,32 |
| 5 | | 389 | 1 | | | | |
| 2 | | 317 | 1 | | | | |
| 4 | С | 182 | 3 | 3.897 | 1.344 | 2,90 | 0,34 |
| 5 | | 481 | 1 | | | | |
| 2 | | 317 | 2 | | | | |
| 4 | C | 182 | 4 | 3.900 | 1.362 | 2,86 | 0,35 |
| 5 | | 481 | 0 | | | | |

From the results of the study of alternative pump combinations in Table 5, all combinations meet the required minimum capacity. But from the results of the analysis of the effectiveness of the best alternative, combination 1 has the smallest power per 1 m3/hour and the largest capacity per 1 HP of power used compared to the other combinations. Thus, combination 1 is the most efficient choice.

The planning of the settling pond design aims to precipitate the sediments contained in the ex-mine pool water. Before planning a settling pond, the percentage of solids contained in the water must be calculated first. The total water discharge that enters the settling pond is 1.069 m³/second. The particle size of the precipitate is $5 \times 10-3$ m, which means that the particles are fine powders with a solid density of 5,100 kg/m³.

Suspended residue = TSS x Pumping discharge (5)

 $= 180 \text{ gr/m3} \text{ x} 1.069 \text{ m}^{3}/\text{s}$

= 192.42 gr/second

From the equation formula for the density of solids, it is known that the specific gravity of the solid is 5,100 kg/m³, then the volume of solids entering is the amount of suspended solid 192.42 gr/sec divided by the specific gravity of 5,100 kg/m³ so that the volume of solids entering is 0. ,00003773. For the

| South | | | | | | | | |
|------------------|-----------------|---------|--------------------|-----------------|-----------|--------------|-------------------|---|
| Pump Number | Total | | Capacity | y | Efisiency | | Power | |
| | Total | Setting | L/s | m³/h | % | RPM | (HP) | |
| | (m) | | | | | | | |
| Th | is nublicat | A | 162 | 583 ar Creat | 70 | 900 | 169 sibution (| |
| ² htt | 54,7376 | B B | 0.215 0.20222/1 | 774 | | 1000 1000 | 235 | Γ |
| | <i>.,,,</i> aao | Ċ | 260 | 936 | 60 | 1100 | 317 | |
| | | А | 185 | 665 | 75,5 | 900 | 107 | |
| 4 | 32,6856 | В | 250 | 900 | 72 | 1000 | 152 | 1 |

Table 4. Pump installation South of mine pond

percentage of solids that enter the total water, the % solids are obtained:

% Solids = $0.00003773 \ m^3/s \ x \ 100 \ \% \ 1.069 \ m^3/s = 0.003529 \ \%$

% Water =
$$100\% - 0.003529\%$$

= 99.99647 %

From the calculation results, the % solid is less than 40%

To calculate the settling velocity of the particles, Stokes' law is used. Calculations with Stokes' Law to find the speed of deposition of particles are as follows:

 $g.D2.(\rho\rho - \rho a)$

Settling Speed (Vt) =

$$= \frac{9.8 x (5.10^{-3}) 2 x (5.100^{-1}) 2 x}{18 x 0.801 \cdot 10^{-3}}$$

= 0,00697 m/s

The width of the settling pond is made by 18

meters with the depth of the settling pond adjusted to the vertical reach of the available backhoe equipment minus 1 meter, which is 4 meters.

After the pond depth is determined, the time it takes for the particles to settle to the bottom of the pond is obtained from the pool depth (H) of 4 meters divided by the sludge settling velocity (Vt): 0.00697 m/s in time per minute is 9.565 minutes.

The particles will settle to the bottom of the pool with a settling speed of 0.00697 m/s within 10 minutes. These results indicate that to precipitate 90% of the particles contained in the water, the settling pond must be given several compartments.

% % Precipitation =
$$\frac{th}{th+Vt}$$
 x 100%
90 % = $\frac{th}{th+9,565}$ x 100 %
0,9 (th + 9,565) = 1 th
Flowing water time (years) = 86.085 minutes

As a result, the particles settle by 90%, the water takes 86.085 minutes to flow out of the pool. The length of the water flow that must be taken is;

Water flow
$$=$$
 th x v.h

5,085 menit x 60 detik/menit x
$$\frac{1,069 \ m^{3}/detik}{60 \ m^{2}}$$

= 80

Number of compartments = 92,025 m / 18 m
= 5 compartments
Length of each compartment =
$$\frac{4000 m^3}{(18 m x 4 m)}$$
 :

= 11 m

5

From the calculation results above, the dimensions of the planned sludge settling pond to be made are described in Table 5 below

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Figure 8. Concept and Dimensions of the Sludge Settlement Pond (a) Side view (b) Upper view

| ruble 5. ruble of setting poild dimensions | | | | | |
|--|------------------------|------------|--|--|--|
| No | Dimension | Dimensions | | | |
| 1 | Pool width | 18 m | | | |
| 2 | The length of the pool | 55 m | | | |
| 3 | The depth of the pool | 4 m | | | |
| 4 | Number of compartments | 5 buah | | | |
| 5 | Compartment length | 11 m | | | |
| 6 | Pool capacity | 4.000 m3 | | | |
| 7 | Compartment capacity | 800 m3 | | | |

Table 5. Table of settling pond dimensions

e. Open Channel Dimensions

In planning the drainage, the trapezoidal shape was chosen, this is because it is easy to manufacture and maintain with soil material without talud pavement.

To calculate the wet cross-sectional area (A) obtained from the discharge value of the settling pond of 1.08 m³/hour divided by the flow velocity of 0.5 m/s, the resulting wet cross-sectional area is 2.16 meters.

Because the design of the embankment/salad is made without pavement, the slope of the talus must be designed at 45° and applies b/h = 1, so that the width of the canal is 4.12 m. After the width of the channel bottom and water level is known, the length around the wet cross section (P) can be calculated.

Circumference length (P) :

$$P = 0.82 \text{ m} + 2 \text{ x } 0.82 \text{ m } \sqrt{1 + 1^2}$$

 $= 3.98 \text{ m}$

The hydraulic radius can be calculated after the area and length, and the circumference of the wet cross sections are known. This hydraulic radius is useful for finding the slope of the channel so that the water discharge can flow as planned.

Hydraulic radius (R) =
$$\frac{2,16 m^2}{3,98 m}$$

R = 0,54 m

The slope of the channel is very important because, without a slope, water will not move. The slope is affected by the manning roughness, which is equal to 0.028. Because the channel will be made by regular and straight digging

Channel slope (I) = $(\frac{0.5 \text{ m/s x } 0.028)^2}{0.54^{2/3}})$ x 100% = 0.04425 %

To find out the parameters of the open channel that will be designed to prevent the water level from overflowing, it is necessary to have a guard height in the channel. Deflection height is the vertical distance from the top of the canal to the water surface at the design discharge condition. The guard height is used to raise the water level above the maximum water level and prevent damage to the canal embankment which is associated with the planned discharge of the canal. Because the design discharge made is 1.08 m³/second and the design height is 0.5 meters.

An open channel is made with a wet cross-sectional area of 2.16 m and a wet cross-sectional area of 3.98 m (Table 6).

Table 6. Planned settling pond dimensions

| No | Dimensions | Dimensions |
|----|-----------------------------|------------|
| 1. | Wet cross-sectional area | 2,16 m |
| 2. | Circumferential wet section | 3,98 m |
| 3. | Water level | 1,04 m |
| 4 | Channel base width | 1,04 m |
| 5 | Top width of the channel | 4,12 m |
| 6. | Channel slope | 0,04425 % |
| 7 | Flow rate | 0,5 m/s |
| 8 | Flow discharge | 1,08 m3/s |

The ideal cross-sectional dimensions of an open channel so that the target of water flow is achieved can be illustrated in Figure 8 below.



Figure 9. Sectional *drainage* plan

IV. CONCLUSIONS

From the results of the characterization study of ex-mining ponds, it was found that the profile of the pond in Pit E with the deepest depth of the pond is 58 m; the area of 26.72 Ha; the Pool length is 800 m; the pool width 200m; The water volume of the Pit E mine pond is estimated at 6,479,241.5m³. The total planned water discharge volume with 20 hours working hours in 90 days is 3,850 m³ per hour.

This publication is licensed under Creative Commons Attribution CC BY. http://dx.doi.org/10.29322/IJSRP.13.04.2023.p13603 The largest pump capacity in the south of the mine pond is 1,790 m³/h; efficiency is 70%; the smallest power is 107 HP. Pump installation is recommended to the South of the mine pond. The most pump combination efficient and meemeetse target, namely combination 1 with a capacity of 3,939 m³/h in total power 1,117 HP

Dimensions settling pond Appropriate plans are an 18 m wide pond; Pool length of 45 m; Pool depth of 4 m; many compartments of 5 pieces; Compartment length of 8 m; pool capacity of 4000 m³; compartment capacity of 800 m³.

ACKNOWLEDGMENT

Special thanks to Rektor Sriwijaya University and Tekmira Bandung for research assistance and collaboration

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