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Analysis of Micro Hydro Potential as A New Renewable Energy Source (Case Study: Bangkong Waterfall, Kuningan Regency, Indonesia)

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Abstract:

Electricity demand in Indonesia is currently increasing along with population growth, economic growth, and development. This increase can lead to an energy crisis if it is not accompanied by the provision of additional power plants. This study aims to analyze the micro-hydro potential located at Bangkong Waterfall, Kuningan Regency. The research uses a quantitative approach that begins with field surveys and data collection from relevant agencies. Next, the dependable discharge analysis uses the Thiessen polygon method based on rainfall data and watershed area, as well as flow discharge analysis using the rational method. The results of calculations using the Thiessen polygon method and the rational method yield Q80 with a minimum discharge of 0.009 m^3/d and a maximum discharge of 1.160 m^3/d. For direct discharge analysis, the Float method is used to calibrate the calculation results with field conditions. The direct discharge analysis using the Float method yields 0.32 m^3/d. Based on the efficiency considerations of the micro-hydro power plant (MHPP) components such as a head of 20 meters, turbine type efficiency, water density, gravity factor, and flow discharge in the pipe of 0.109 m^3/d, the potential power that can be generated at the Bangkong Waterfall micro-hydro power plant is 16,097.23 Watts or 16.097 Kilowatts.

Keywords: (Micro-Hydro; Dependable Flow; Thiessen Polygon; Crossflow Turbine)

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INTRODUCTION

According to a report by the Ministry of Energy and Mineral Resources, electricity consumption per capita in Indonesia reached 1,337 kWh in 2023, up about 14% from the previous year and a record high in the last five decades (Lau, 2023). It is predicted that per capita electricity consumption by the end of 2024 will reach 1,408 kWh. This increase could result in an electrical energy crisis if not followed by additional power plants (Minister of Energy and Mineral Resources.

Energy use is still dominated by the use of non-renewable energy derived from fossils, especially petroleum and coal, but over time, the availability of fossil energy is running out and to anticipate it new renewable energy (EBT) is the best alternative, such as solar energy, wind energy, and water energy. The use of new and renewable energy is not only an effort to reduce the use of fossil energy but also to realize clean or environmentally friendly energy (Nurhidayah, Saputra, Hafid, & Faharuddin, 2022).

Water is an important source of energy that is not only to fulfill needs but also a source of energy for power generation. Indonesia is a country rich in water resources so it has the potential to produce electrical energy from water resources on both large and small scale (Marhendi, 2019).

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Micro Hydro (from the words "hydro" meaning water and "micro" meaning small scale) refers to electrical energy derived from moving water power, which is used to supply electricity for households or small villages (Anaza et al., 2017). MHPP is a type of hydroelectric power generation with micro-prone, which is to utilizes the height (head) - falling water with maximum water discharge (Negara, Nugroho, & Suprajitno, n.d.). The greater the flow discharge and head, the greater the energy capacity that can be utilized to produce electrical energy (Hameer & van Niekerk, 2015).

Based on the explanation above, the author made a research entitled "Analysis of Micro Hydro Potential as a Renewable Energy Producer" which focuses on the aim of knowing the amount of potential power generated by the Micro Hydro Power Plant at Bangkong Waterfall location, Kuningan Regency, Indonesia.

This article focuses on the impact of reward and punishment on the development of the Pancasila learner profile, particularly on the dimension of student independence at SD Negeri 1 Susukanlebak.

Previous research has shown that reward and punishment methods are effective in increasing students' motivation and independence (Kurniawati & Sobry, 2024). Reward can increase students' intrinsic interest, while punishment can reduce negative behavior (Bear, Slaughter, Mantz, & Farley-Ripple, 2017). However, inappropriate rewards and punishments can have negative impacts such as student dependency (Soleyadi, 2024).

This study presents a new perspective by examining the impact of rewards and punishments in the context of developing the Pancasila learner profile, particularly the dimension of student independence, in primary schools. The findings may provide new insights for applying these methods effectively in educational practice in Indonesia.

The results of this study can provide valuable input for teachers and school authorities in designing and implementing an appropriate reward and punishment system to develop the Pancasila learner profile, particularly the student independence dimension. The findings of this study can also contribute to the development of character education theory and practice in Indonesia.

RESEARCH METHODS

The research method used is quantitative, which produces facts based on data obtained and measurement results. The focus is on numerical data that can be processed and analyzed. The preparation process included administrative and licensing arrangements, as well as determining relevant agencies to obtain data and information. Field observations were conducted to calibrate the calculation results and ensure consistency with field conditions. Data collection includes primary data obtained from direct measurements and secondary data obtained from related agencies such as the PUPR Office of Kuningan Regency and the Cimanuk-Cisanggarung River Basin Center.

The best geographical areas for micro-hydro power generation systems are those where there are steep rivers, streams, creeks, or springs that flow throughout the year, such as in hilly areas with high rainfall throughout the year (Anaza et al., 2017). The research was conducted the upstream of Cisanggarung River, more precisely in Bangkong Waterfall, Kertawirama Village, Nusaherang District, Kuningan Regency. Bangkong Waterfall is one of the areas that has the potential to be built MHPP, thanks to its geographical conditions and close to the Darma Reservoir, it is estimated that the discharge that will later be utilized for this MHPP will be stable. This location is located at an altitude of 624-650 meters above sea level and geographically located at 7°13'47''S 109°23'20''E. The topography of Nusaherang Sub-district has a tropical climate, with a maximum temperature of 32°C and a minimum temperature of 22°C. The Cisanggarung River flow discharge from rainfall and the Darma Reservoir outflow discharge are the main sources of generating electrical energy in the MHPP. The location of the MHPP can be seen in Figure 1 below:

Figure 1. MHPP Site Watershed against 3 Rainfall Stations

Analysis of regional rainfall and discharge based on rainfall data from several stations aims to determine the availability of water in a watershed area. Polygon Thiessen is a method determined by making polygons between stations in an area and then calculating the average rainfall height by multiplying each polygon area and rainfall height divided by the entire area (Arianti & AW, 2021). With the following Thiessen polygon equation (Arianti & AW, 2021):

$$\mathbf{P} = \frac{A1\,.\,p1 + A2\,.\,p2 + A3\,.p3+\cdots+An\,.\,pn}{A1 + A2 + A3} = \sum_{i=1}^{n} \frac{Ai\,.\,pi}{Ai}$$

Where:
P = Area rainfall (mm),
P_1, P_2, P_3,....Pn = Rainfall height at post1,2,3,....n,
A_1, A_2, A_3,..., An = Area of influence of post1, 2, 3,....n.

The flow discharge in the river comes from the rain that falls in the watershed, so by knowing the depth of rain and water losses such as evaporation and infiltration. To estimate the amount of peak runoff (Qp), the rational method is one technique that is considered good (Ginting, 2014). The mathematical equation of the rational method to estimate the amount of water flow is as follows (Ginting, 2014):

$$\mathbf{Q = 0{,}00278.\ C.\ i.\ A}$$

Where:
Q = Peak water flow (discharge) (m^3/ seconds)
C = Flow coefficient
I = Rainfall intensity (mm/hour)
A = Watershed area (Km^2)

For direct debit measurement, the float method is used. The float method is a method that aims to determine the flow velocity with the principle of finding the time required by a float at a certain distance.

To find real-time discharge in the field with the buoy method, it can be calculated with the following equation (Ointu, Surusa, & Zainuddin, 2020):

$Q' = V \times A$
$V = a/c$
$A = b \times H$

Where:
Q' = Real-time discharge (m^3/ seconds)
V = Flow velocity (m/ seconds)
A = Cross-sectional area (m^2)
a = River length (m)
b = River width (m)
c = Average travel time (seconds)

The power generated in the MHPP turbine comes from the kinetic energy of water. The kinetic energy of the water that rotates the turbine to drive the generator can be calculated using the following formula (Hanggara & Irvani, 2017):

$P = \rho \times g \times Q \times H \times \eta$

Where:
ρ = Daya air (1000 Kg/m^3)
g = Gravitasi
Q = Debit aliran dalam pipa
H = Tinggi jatuh (*Head*)
ɳ = Efisiensi turbin

RESULTS AND DISCUSSION

Rainfall Analysis

The rainfall data used was obtained from the PUPR Office of Kuningan Regency. Rainfall data was taken from 3 rainfall stations, namely STA Ciniru, STA Cigugur and STA Darma in a period of 10 years, namely 2011-2020. These 3 stations were chosen because they are the closest stations to the research location and meet the requirements for use in the calculation of the thiessen polygon method. The monthly rainfall data can be seen in Table 1 and Figure 2 below:

Table 1. 10-Year Rainfall Data of 3 Stations

Year	Station Annual Average (mm)		
	Ciniru	Cigugur	Darma
2011	147,496	138,842	183,913
2012	103,758	91,802	168,177
2013	192,938	180,888	178,367
2014	131,304	150,004	217,063
2015	125,763	106,250	176,480
2016	143,329	168,825	140,158
2017	90,267	123,667	131,127
2018	106,000	127,838	196,450
2019	111,438	130,784	181,642
2020	134,667	184,288	181,708
Total	**1286,959**	**1403,186**	**1755,087**
Average	**128,696**	**140,319**	**175,509**

Source: Calculation Results

From the measurement results of the 3 rainfall stations above, the area of influence of rainfall based on the thiessen polygon method can be seen in Figure 3 and Table 2:

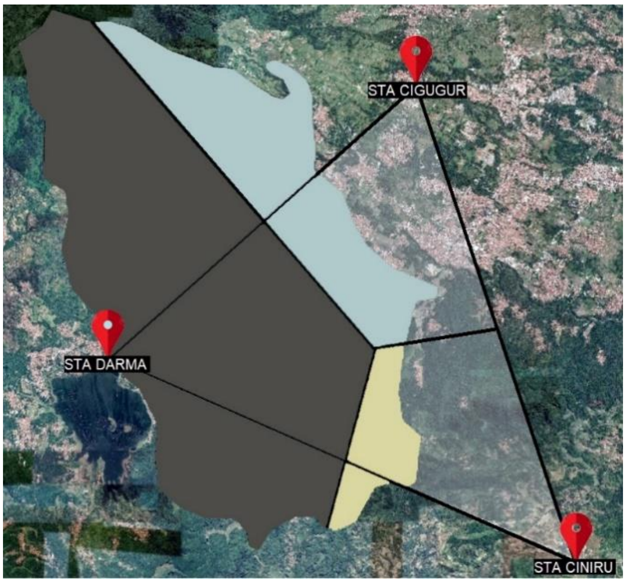

Figure 2. Thiessen Polygon influence on watershed Table

Table 2. Area of Influence of Rainfall Stations on Watershed

STA	Polygon Thiessen Faktor	
	Area (KM²)	**Percentage**
Ciniru	3.79	6.37
Cigugur	13.55	22.79
Darma	42.12	70.84
Total	**59,46**	**100**

Source: Calculation Results

The results of the regional rainfall calculation in the watershed are detailed in Table 3 below:

Table 3. Regional Rainfall 2011-2020

No.	Year	Value (mm)
1	2011	171,321
2	2012	146,666
3	2013	179,870
4	2014	196,315
5	2015	157,243
6	2016	146,893
7	2017	126,823
8	2018	175,049
9	2019	165,577
10	2020	179,298
Total		**1645,056**
Average		**164,506**

Source: Calculation Results

Potential Discharge Analysis

After obtaining the results of the calculation of regional rainfall using the thiesssen polygon method, the calculation of peak water flow discharge (Qp) is carried out using the rational method and the results of water flow discharge can be seen in Table 4 below:

Table 4. Calculation Result of Water Flow Discharge

No.	Year	Discharge (m^3/sec)
1	2011	0,708
2	2012	0,606
3	2013	0,743
4	2014	0,811
5	2015	0,650
6	2016	0,607
7	2017	0,524
8	2018	0,723
9	2019	0,684
10	2020	0,741
Total		**8.498**
Average		**0.850**

Source: Calculation Results

Reliable Discharge Analysis

From the results of the calculation of water flow discharge, the calculation of discharge with 80% reliability is carried out using the following formula:

N = 80% x n (number of years)
N $= \left(\frac{80}{100}\right)$ x 10 year
N = 8

The results of the calculation of discharge with 80% reliability are shown in Table 5 and Figure 3 as follows:

Table 5. Calculation Results of 80% Reliable Discharge

No.	Month	Discharge (m^3/sec)
1	January	0,931
2	February	1,097
3	March	1,160
4	April	0,780
5	May	0,361
6	June	0,131
7	July	0,065
8	Agust	0,009
9	September	0,013
10	October	0,135
11	November	0,457
12	December	0,824
	Average	**0,497**

Source: Calculation Results

Thus, a "flow duration curve" is obtained which shows the relationship between the average annual discharge and the percentage of occurrence. Using this curve, it is possible to It is easy to observe the Q80 discharge without having to use a table to calculate it. In this way, in addition to the Q80 discharge, the maximum and minimum discharge, as well as the fluctuation or variation of the discharge can also be observed. This is useful for finding the minimum flow for drainage planning and the maximum flow for determining flood conditions.

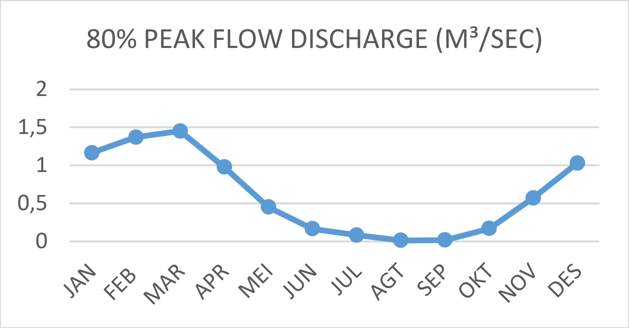

Figure 3. 80% Reliable Discharge

Based on the analysis of the rainfall area of Thiessen polygon method and the analysis of water flow discharge of the rational method, it can be estimated the availability of water from rainfall at the research site. Q80 is obtained with a minimum discharge of 0.009 m^3/second and a maximum discharge of 1.160 m^3/second, this value is a continuous reliable discharge to produce electrical energy.

Direct Flow Measurement Analysis

In addition to the Direct Flow Measurement calculated above, the discharge used in the MHPP must be compared with the measured discharge in the field. This is done to measure the accuracy of the calculation. Discharge measurements in the field are carried out using triangular thresholds and speed measurements to obtain the cross-sectional area and speed required for discharge calculations. The results of direct debit measurements in the field on March 19, 2024, obtained:

Table 6. Direct Flow Measurement Result

No	River Length (m)	River Widht (m)	Depth (m)	Travel Time (second)
1	7,5	3	0,2	14,54
2	7,5	3	0,2	12,82
3	7,5	3	0,2	14,97
			Averege	**14,11**

Source: Calculation Results

To find the real time discharge in the field with the buoy method, it can be calculated with the following equation:

Q = V x A
V = a/c
= 7,5/14,11
= 0,532 meter/second
A = b x H
= 3 X 0,2
= 0,6 m^2

$$
\begin{aligned}
Q &= V \times A \\
&= 0{,}532 \times 0{,}6 \\
&= 0{,}319\ m^3/\text{second} \\
&= 0{,}32\ m^3/\text{second}
\end{aligned}
$$

The discharge value obtained from both direct discharge calculations and the results of previous discharge calculations will be used as comparison data with the flow rate in the rapid pipe used to rotate the turbine.

Analysis of Water Drop Height

Waterfall height is obtained through direct measurement, which is the difference in elevation between the water level in the reservoir and the tailwater level (TWL). The method of measuring the height of falling water is done directly to obtain accurate results. The measurement results of the waterfall height can be seen in the following figure:

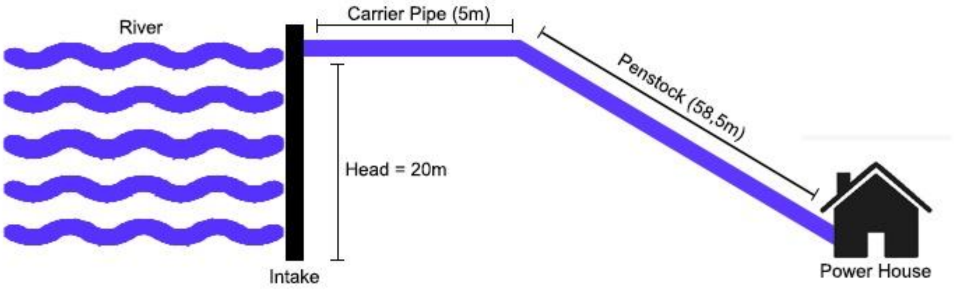

Figure 4. MHPP design

From the measurements taken, a waterfall height of 20 meters was obtained. The reference in this observation is seen from the water elevation to the tailwater level (TWL) so that the height of falling water can already be used in the calculation of the generated power. With a waterfall height of 20 meters, it can technically be used for MHPP.

Turbin Selection

Turbine selection in a Micro Hydro Power Plant (MHPP) is very important to ensure optimal efficiency and performance of the plant. Turbine selection is closely related to the type of generator that will convert hydropower into electrical energy.

The measurement results show that the effective fall height value is 20 meters. The turbine type selection is based on the Turbine Application Chart as follows:

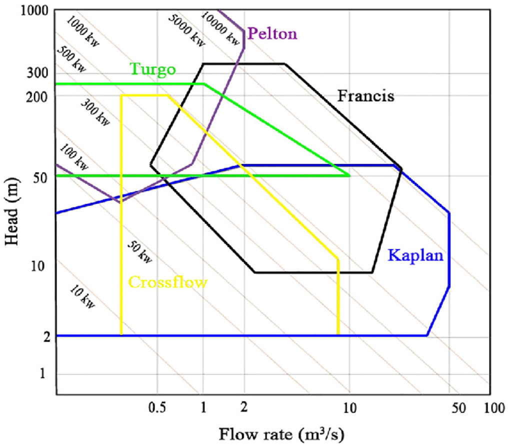

Figure 5. *Turbine Application Chart* (Chen, Lu, Hu, Lei, & Yang, 2018)

Based on the turbine application chart above, with an effective falling height (head) value of 20 meters and a river discharge of 0.320 m^3 / second, a Crossflow type turbine is used. In this study, the Crossflow T-14 D225 BO 25 turbine type is used with the following turbine drawings and specifications:

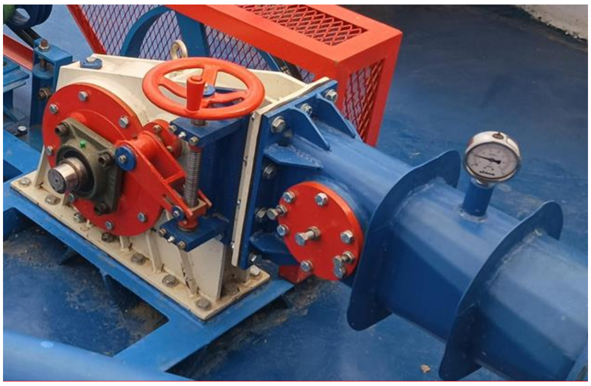

Figure 6. Turbin *Crossflow* T14 D225 BO 25

Table 7. Turbin Specifivations

Turbin Type	*Crossflow* T14 D225
Generator Type	Synchronous Generator
Voltage	380 Volts
Frequency	50 Hz
Round	± 1500 rpm
Head Design	1 – 200 meter
Design Disharge	10 l/s – 10 m^3/s
Eficiency	70 – 90 %

Source: Abdul Hafid, Andi Faharudin, 2020

Penstock Selection

The rapid pipe is a pressurized pipe used to drain water from the reservoir or reservoir directly into the turbine. The diameter and length of the penstock pipe are determined based on the flow rate that will flow in the pipe (Adamkowski, Janicki, Krzemianowski, & Lewandowski, 2019).

In this research, iron-based pipes are used which have a thickness of 1.5 mm and a diameter of 6 inches or equivalent to 15.24 cm. With such material thickness and diameter, the penstock pipe can direct water, both pipes that drain water from the weir to a 5 m long reservoir, followed by a rapid pipe installed with a steep slope from the reservoir to the turbine with a length of 58.5 m, as well as a pipe from the powerhouse that continues the flow of water back to the river with a length of 10 m. The length of the rapid pipe itself is obtained from observations and measurements in the field. The length of the rapid pipe itself is obtained from observations and measurements in the field.

Based on the results of the rapid pipe selection above, the flow rate in the pipe can be calculated with the following equation:

$$Q = A \times V$$

Where:
Q = Flow discharge in the pipe
A = Area of the rapid pipe
V = Flow velocity in the pipe

Calculated:

$A = \pi r^2$
$= 3{,}14 \times 7{,}62^2$
$= 182{,}32 \text{ cm}^2$
$= 0{,}018 \text{ m}^2$
$V = 6 \text{ m/sec}$
$Q = A \times V$
$= 0{,}018 \times 6$
$= 0{,}109 \text{ m}^3\text{/sec}$

From the results of the above calculations, the flow discharge value in the pipe is 0.109 m^3/second. This value will be used in the calculation of the generated power.

Calculation of Generated Power

The potential power generated from this Micro-Hydro power plant is the amount of power generated by considering the efficiency of all generating components such as flow discharge, turbines and generators (Nasir, 2014).

To obtain the amount of potential energy generated alone can be calculated by calculating the height of the fall (head), the flow rate in the pipe, the efficiency of the turbine which is estimated according to the capacity and condition of the Cisnggarung River used as the location of the MHPP and also the coefficient of gravity.

To obtain the amount of power generated can be calculated by the following equation:

$\mathbf{P = \rho \times g \times Q \times H \times \eta}$
$P = 1000 \times 9{,}81 \times 0{,}109 \times 20 \times 0{,}75$
$P = 16.097{,}23 \text{ Watts}$
$P = 16{,}097 \text{ Kilowatts}$

From the results of the above calculations, it can be concluded that the power generated by the Micro Hydro Power Plant (MHPP) in Bangkong Waterfall is 16,097.23 kilowatts or 16.097 Kilowatts.

CONCLUSIONS

The results of the analysis of all research results and calculations that have been carried out previously in the preparation of this Student Final Project (KITAM) entitled Analysis of the Potential of Micro-Hydro as a Renewable New Energy Producer can be concluded that: Based on the rainfall analysis of the Thiessen polygon method area and the rational method water flow discharge analysis, it can be estimated that the availability of water from rainfall at the research site. Q80 is obtained with a minimum discharge of 0.009 m^3/sec and a maximum discharge of 1.160 m^3/sec, this value is a discharge that can be relied on continuously to produce electrical energy. The effective falling height (head) obtained from observations and measurements in the field that can be used at the Bangkong Waterfall MHPP are 20 meters high. The turbine is selected based on consideration of various factors, so in this study the T14 D225 Crossflow turbine type is used with an effectiveness value of (0.7 - 0.9). The recommended penstock pipe based on consideration of various factors is selected iron-based pipe with a thickness of 1.5 mm and a diameter of 6 inches or equivalent to 15.24 cm. The length of the penstock pipe that drains water from the weir to the reservoir is 5 m long, followed by a rapid pipe that is installed with a steep slope from the reservoir to the turbine with a length of 58.5 m, followed by a pipe from the power house that continues the flow of water to the river with a length of 10 m. The power that will be generated by the Micro-Hydro Power Plant (MHPP) in Bangkong waterfall is 16.097 kilowatts or 16,097.23 Watt.

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