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FEASIBILITY ANALYSIS OF MICRO-HYDRO POWER PLANT DEVELOPMENT TO ACHIEVE THE ELECTRICITY INDEPENDENCE AT MONGIILO VILLAGE-BONE BOLANGO DISTRICT-GORONTALO PROVINCE

Komang Arya Utama*, Rawiyah Husnan

Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Gorontalo, Gorontalo

ABSTRACT

Mongiilo Village has a population of 165 families with low electrification rate. This village has the potential of river flow that is available throughout the year. Therefore, we conducted a study to determine the development feasibility of hydro-electric power plants infrastructure that takes advantage of the source from river flow. The purpose of this research is to determine the Q_{90} dependable discharge, the potential of power generation, the type of turbine and the proper type of power plant, and also the number of home connections that can be served.

The dependable discharge of the river was analyzed by using the Nreca flow model with 90% dependable. The value of evapo-transpiration potential was analyzed by using Penman Method. The determination of the magnitude of the generated power is carried out by using an empirical formulation, where the efficiency level is obtained by adjusting the type of turbine to be used based on the available of the dependable discharge.

The research results showed that the average dependable discharge (Q_{90}) was 0.72 m^3/sec for the River Butaiyo Daa and 0.55 m^3/sec for the River Butaiyo Kiki. The potential of electric power that can be generated from both rivers are 91.03 kW. Based on the available dependable discharge, the selected type of Turbine is Banki/Crossflow type. The power plant type is a Micro-Hydro Power Plant. The number of home electricity connections that can be served is 202 units and provide a surplus of electricity supply by 22.42% of the needs of the community.

Keywords: Dependable discharge, Electricity independence, Micro-hydro power plant

1. INTRODUCTION

Electrical issues become the most important things, especially for the remote and isolated areas in some parts of the Republic of Indonesia. There are still many areas in the republic that are still unable to enjoy and be served by electricity needs for the community. One of the areas that experienced it is Mongiilo Village in Bone Bolango District, Gorontalo Province.

Mongiilo Village is one of the villages in Bulango Ulu District Bone Bolango District, Gorontalo Province. The population of this village amounts to 165 families and since independence of Indonesia, this village has never served by electricity supply from the State Electricity Company or PLN mainly fulfill the need for electricity for lighting (Amali, 2016). However, this village has the potential of a river, the River Butaiyo Daa and River Butaiyo Kiki, which flows throughout the year that can be utilized by the community. Therefore, the construction of hydroelectric power can be a

*Corresponding author: E-mail: arykomang@yahoo.com

solution in overcoming the problem of electricity supply. A hydroelectric plant is a power plant system that utilizes water and head water as the main factor of the plant.

The objective of this research are: 1) analyzing the dependable discharge Q_{90} of River Butaiyo Daa and Butaiyo Kiki; 2) determine the magnitude of the potential power that can be generated by the available dependable discharge; 3) determine the type of turbine that suitable for the power plant to be planned; and 4) calculate the number of units of home connections that can be served.

Therefore, this research is expected to provide another point of view so that it can provide benefits to stakeholders who can take decisions in solving the problem of electricity supply for the people in Mongiilo Village. In addition, the results of this study are expected to provide an example of an appropriate model of analysis in solving electrification problems for remote community area in Gorontalo Province.

2. METHODOLOGY/ EXPERIMENTAL

2.1. Approach and Formulation

The approach in this research applies a quantitative analysis that refers to the empirical formulations which has been commonly used. The analysis of the region's rainfall data was applied the Average Algebra Formulation. Where this analysis is particularly suitable for remote areas and inadequate distribution of rainfall station data. The average method of algebra is the simplest method of calculating average rainfall in a region. Measurements made at multiple stations at the same time are summed and then divided by the number of stations. The rain stations used in these calculations are usually those within the watershed, but stations outside the adjacent catchments can also be taken into account.

The Penman method is needed to calculate the evapotranspiration which will be used as a variable of discharge flow analysis later in the Nreca Method. Climatological data required are: air temperature (t), sun brightness (n/M), wind velocity (u) and relative humidity (R_H) with the formula:

$$Eto^{*} = W(0.75Rs - Rn_1) + (1-W)\,f(u)(ea - ed) \quad (1)$$

The Nreca model has been widely applied in analyzing the availability of water discharge in various watersheds in Indonesia. This is because the model parameter needs quiet fewer parameters and easy to implement as well as delivering reliable results. In general the basic equation of this model is formulated as follows:

$$Q = P - Eto + \Delta S \quad (2)$$

Where:

Q = runoff (mm)
P= average rainfall watershed (mm)
Eto = actual evapo-transpiration (mm)
□S = water storage

The reliability of hydropower infrastructure design results is highly dependent on the determination of the dependable discharge that used as the design discharge. The dependable discharge is an expected dischargethat will be available through the year with the greatest risk of failure that can be used for various purposes (such as irrigation, raw water, hydropower and others).

A dependable discharge is a discharge which associated with a certain probability where the value is expected to be equal or exceeded than the expected. The reliability based on frequency/ probability of occurrence, formulated as follows:

$$P_{(Xm)} = \frac{m}{(n+1)} 100\% \quad (3)$$

Where:
$P_{(Xm)}$ = probability
n = number of years
m = serial number of events

If 90% of the debit is set, it means that there will be less discharge than 10% of observations. According to observation by Soemarto, C.D. (1987) the amount of reliability that is taken for optimum water utilization in some projects is as presented in the table below:

Table 1. Dependable discharge for various purposes

Needs	Dependable Discharge (%)
Water for Domestic used	99
Irrigation	95-98
1) Irrigation for humid area	70-85
2) Irrigation for dry climates	80-95
Hydro power plants	85-90

Source: Soemarto, C.D. 1987

The main principle of hydroelectric power system is to utilize the high drop or head water discharge. Therefore, it is endeavored to obtain the high water fall and large discharge effectively and economically. Generally, large discharges require facilities, such as water intake buildings, drains and turbines (Arismunandar and Kuwahara, 1991). Classification of hydroelectric power based on capacity or output generated by hydroelectric power ie;

Table 2. Classification of hydro power plant

No	Type of Hydro power	Productivity
1	Large-hydro	>100 MW
2	Small-hydro	1 - 15 MW
3	Mini-hydro	100 kW - 1 MW
4	Micro-hydro	5 kW -100 kW
5	Pico-hydro	<5 Kw

The result of theoretical power can be calculated by using the empirical equations as shown (Arismunandar and Kuwahara, 1991):

$$P = gQH_{eff}\eta_{tot} \quad (4)$$

Where :
P = Theoretical generated power (kW)
Q = Generating discharge (m^3/sec)
H_{eff} = High fall effective (m)
G = Acceleration of gravity (m/s^2)
η_{tot} = Total efficiency of tubin and generator (%)

Turbine is one of the important elements in the process of analyzing the amount of power generation that can be generated. The selection of the proper turbine strongly influences the results of the hydro power plant. Determining the type of turbine can be done by plotting the amount of head water and the dependable discharge. This can be seen in the picture below:

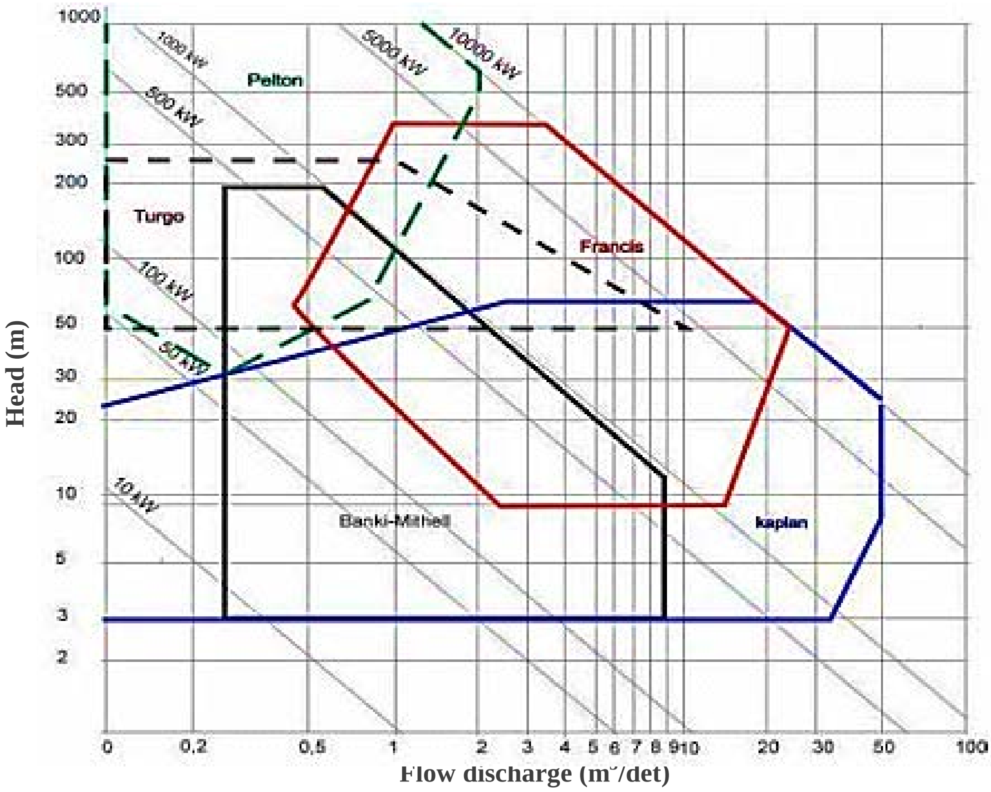

Figure 1. Determining the turbine type

2.2 Research Loction

The location of the current study is included within sub-watershed of Mongiilo, which is at coordinates 0°39'02" North Latitude and 123°8'58" East Longitude. The location of the study is presented in Figure 2 below:

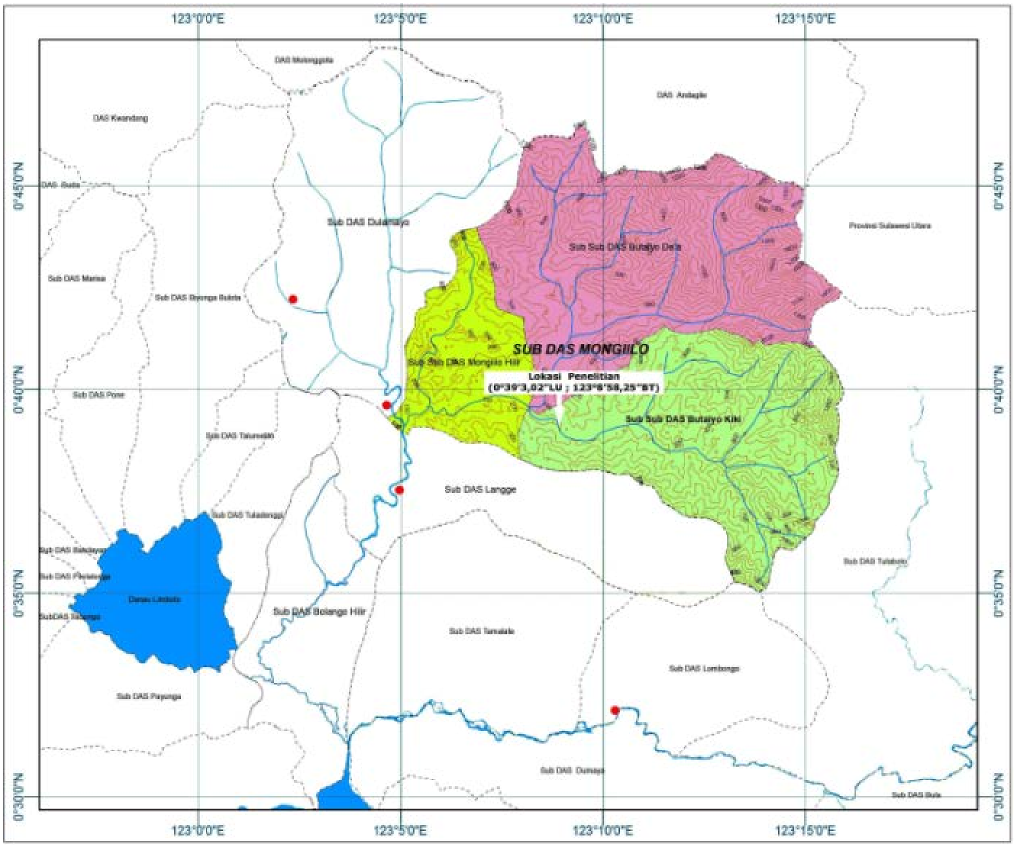

Figure 2. Location of the research

2.3 Research Methods

The research method which applied in this research is done by following the stages as follows:

a. Data collection. The primary data was measurements as well as site topographic conditions. The secondary data were collected form releted goverment agencies.
b. Hydrological analysis. This analysis includes analysis of the area's rain, potential evapo-transpiration analysis, water availability analysis, river mainstream discharge and flood discharge analysis.
c. Analysis of potentional elctric power generation. This analysis includes analysis of potential head water, suitable turbine type analysis, determination of turbine and generator efficiency levels and power generation analysis.
d. Analyze the number of home connection units. This analysis is to calculate how many houses can be serviced and what percentage of electrification levels will be available.

3. RESULTS

3.1 Rainfall area

The characteristics of rainfall in Mongiilo Sub-Basin area are presented as histogram below:

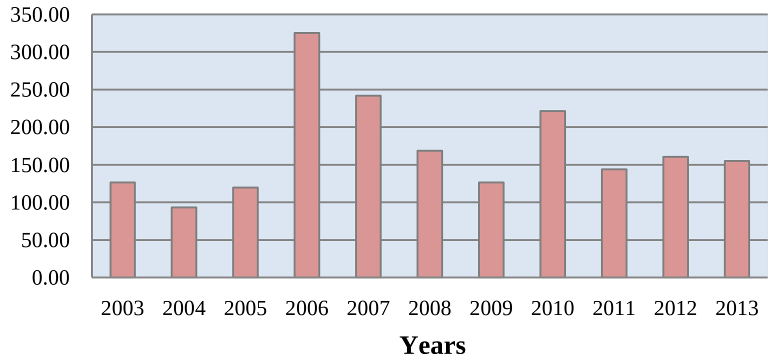

Figure 3. Annual maximum rainfall histogram

Figure 3 above is a graph of rainfall area that is processed from five rain gauge stations closest to the research location. The graph shows that rainfall characteristics as a hydrological input are very varied. So it can be stated that the availability of water in the area is relatively fluctuating from year to year. This is the reason why it is necessary to conduct water supply analysis as well as establish its reliability according to the water fulfillment requirement to be achieved by using hydrological model.

3.2 Potential Evapo-transpiration (ETo)

Potential spatial evaporation analysis is performed to complement the data input in hydrological modeling that will be made. The data used are climatological data obtained from the nearest recording station. The method used is Penmann Method. The results of the analysis are presented in the table below:

Table 2. Amount of daily potential evapotraspiration between 2003-2013 (mm/day)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	5,14	5,26	4,65	4,62	4,62	5,40	4,59	6,13	5,72	5,78	4,96	3,96
2004	4,68	4,49	5,07	4,90	4,46	5,01	4,50	6,27	11,89	6,21	4,88	4,63
2005	4,83	4,96	5,44	5,17	4,73	3,94	4,16	5,20	6,03	5,81	5,35	4,08
2006	4,38	4,68	5,38	5,24	4,64	3,77	4,64	6,11	6,31	6,19	5,82	4,18
2007	4,41	4,61	5,17	5,27	4,91	3,72	4,06	4,61	6,00	5,63	5,52	4,08
2008	4,87	4,71	3,71	4,48	4,39	4,02	3,72	4,29	4,76	4,82	5,35	3,82
2009	4,14	4,71	4,86	4,50	4,57	4,36	4,75	6,35	6,69	6,13	4,62	5,18
2010	4,69	5,54	5,53	4,95	4,59	3,71	3,81	4,23	4,31	4,40	4,75	3,84
2011	4,18	4,13	4,20	4,11	4,21	4,29	5,01	5,22	5,27	4,72	4,13	4,02
2012	4,39	4,59	4,56	4,27	4,38	3,92	3,81	5,40	5,10	5,14	4,28	5,01
2013	3,99	4,82	5,22	4,70	17,41	17,85	3,88	5,00	5,67	5,55	4,89	4,23
Average	**4,52**	**4,77**	**4,89**	**4,75**	**5,72**	**5,45**	**4,27**	**5,35**	**6,16**	**5,49**	**4,96**	**4,28**

Table 2 above shows that the average daily potential evapotraspiration (Eto) value ranges from 4.27 to 6.16 mm/day. This value is relatively normal for the tropics as we are in Indonesia.

3.3 River flow discharge with Nreca Model

The amount of water available is needed to determine the hydrological potential of a river. The potential can be simulated by using hydrological model, one of them is Nreca Model. The result of Nreca Model analysis is to knowing the availability of water discharge in Mongiilo Sub basin, that is in River Butaiyo Daa and River Butaiyo Kiki. The result is presented in the following table:

Table 3. Average flow discharge of River Butaiyo Daa (m^3/sec)

Tahun years	Bulan month												Rerata ave
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Des	
2003	1.16	1.67	2.36	2.34	2.10	0.51	1.59	0.70	0.85	0.72	1.66	3.24	1.58
2004	2.70	1.69	1.78	1.25	1.06	0.47	0.96	0.02	0.02	1.10	1.62	1.11	1.15
2005	0.41	2.53	1.76	1.60	1.36	1.45	0.61	0.31	0.10	2.02	2.46	3.27	1.49
2006	5.87	3.44	3.03	6.82	4.77	7.18	0.12	0.02	3.01	0.12	9.32	5.83	4.13
2007	2.75	3.37	2.08	2.50	2.19	6.19	3.15	3.25	1.79	1.29	2.25	5.89	3.06
2008	1.56	1.26	4.55	2.65	1.31	1.67	2.34	1.15	1.45	3.18	2.30	1.90	2.11
2009	2.50	1.51	2.02	3.80	1.80	0.32	0.98	0.08	0.07	1.55	2.83	1.43	1.57
2010	2.17	1.14	0.72	3.38	3.35	3.38	3.46	3.00	3.97	3.03	2.30	3.51	2.78
2011	2.28	3.42	2.79	2.46	1.38	1.24	0.36	0.35	0.84	2.27	1.80	2.54	1.81
2012	1.83	1.99	2.15	2.39	1.69	0.59	3.19	0.76	0.27	2.01	3.42	3.82	2.01
2013	1.38	2.34	1.49	2.33	3.74	1.29	2.41	1.84	0.78	0.77	1.81	2.82	1.92

Table 4. Average flow discharge of River Butaiyo Kiki (m^3/sec)

Tahun years	Bulan month												Rerata ave
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Des	
2003	0.89	1.28	1.80	1.80	1.61	0.39	1.22	0.54	0.65	0.56	1.27	2.49	1.21
2004	2.07	1.30	1.36	0.96	0.81	0.36	0.74	0.01	0.01	0.85	1.24	0.85	0.88
2005	0.32	1.94	1.35	1.22	1.05	1.11	0.46	0.24	0.08	1.55	1.88	2.51	1.14
2006	4.49	2.64	2.32	5.22	3.65	5.50	0.10	0.01	2.30	0.10	7.14	4.47	3.16
2007	2.11	2.58	1.60	1.92	1.68	4.74	2.41	2.49	1.37	0.98	1.72	4.51	2.34
2008	1.20	0.97	3.49	2.03	1.01	1.28	1.79	0.88	1.11	2.43	1.76	1.45	1.62
2009	1.91	1.15	1.55	2.91	1.38	0.24	0.75	0.06	0.06	1.19	2.17	1.09	1.21
2010	1.66	0.87	0.55	2.59	2.56	2.59	2.65	2.30	3.04	2.32	1.76	2.69	2.13
2011	1.74	2.62	2.14	1.89	1.06	0.95	0.28	0.27	0.64	1.74	1.38	1.95	1.39
2012	1.40	1.53	1.65	1.83	1.30	0.45	2.44	0.58	0.20	1.54	2.62	2.92	1.54
2013	1.06	1.79	1.14	1.78	2.87	0.98	1.85	1.41	0.60	0.59	1.39	2.16	1.47

Table 3 and Table 4 above show the amount of water availability in the form of the average discharge at the two rivers that analyzed during the Years 2003 - 2013. After that, in order to determine the reliability of dependable discharge, analysis will be performed with a reliability level of 90%. This is done because in addition to in accordance with common planning references, also to increase the range of the success of the prediction of discharge predictions. Thus, it is hoped that the results of the design of the power plant will have a sustainable supply of water throughout the year without being severely affected by wet and dry season situation.

3.4 Dependable discharge (Q_{90})

Subsequently, a flow curve (Flow Duration Curve) is created between the two rivers which is the relationship between the reliability/probability level with the average discharge.

Table 5. Average river flow discharge (m^3/sec)

No	M/N+1	Discharge	
		Butaiyo Daa	Butaiyo Kiki
1	8.33	4.50	3.94
2	16.67	4.19	2.84
3	25.00	2.94	2.21
4	33.33	2.27	1.72
5	41.67	2.04	1.56
6	50.00	1.83	1.41
7	58.33	1.62	1.23
8	66.67	1.40	1.04
9	75.00	1.18	0.90
10	83.33	0.97	0.74
11	91.67	0.66	0.51

The table above is presented in graphical form as shown below:

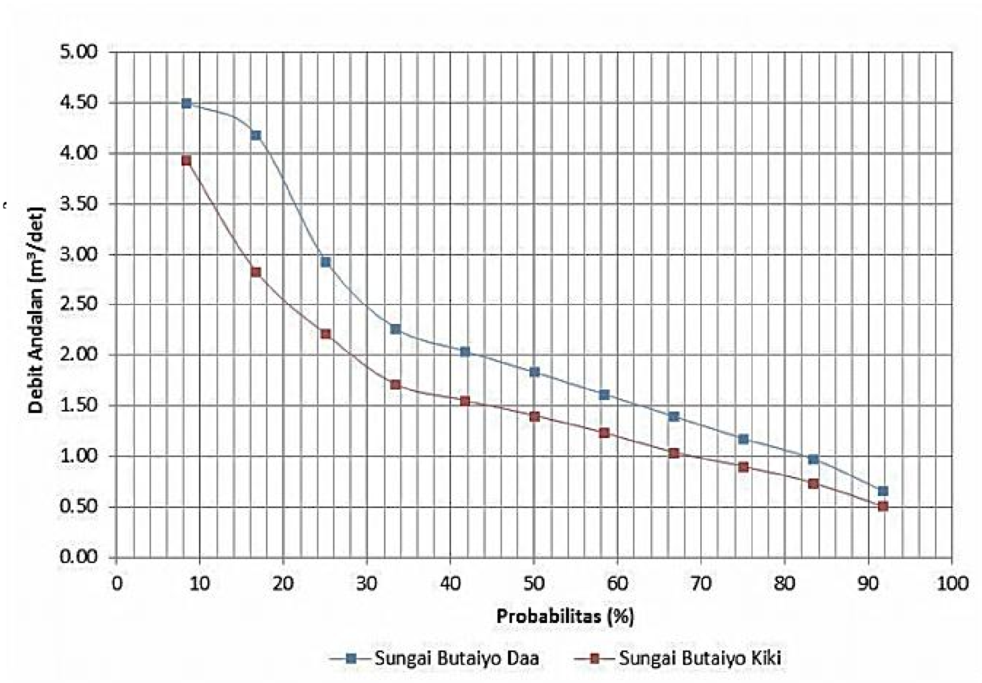

Figure 3. River flow duration curve

Through Table 5 or Figure 4, we obtain the dependable discharge (Q_{90}) of the Butaiyo Daa is 0.72 m^3/s; and the dependable discharge (Q_{90}) of the Butaiyo Kiki is 0.55 m^3/s. This is a design discharge that will be used to determine the size of the intake, the fore bay channel, the penstock pipe dimension as well as the predicted power potential that can be generated.

3.5 Potential of electric power

Power that can be generated depends on design of the discharge, head water and total efficiency of turbine and generator. Based on the result of field survey of condition on research location, hence position which possible to place the location of building of plant have different head 8.2 meter for source of Butaiyo Daa River and head 11.32 m for source of Butaiyo River Kiki. The determination of the turbine type employed shall be made by considering the design discharge and the head water available according to the possible topographical conditions of the study site. Therefore, based on the graph according to Figure 1, the suitable turbine type is a Banki/Crossflow turbine. The efficiency values used are 0.9 for turbine efficiency and 0.85 for generator efficiency. So by using Formulation 4, then obtained the potential of electrical power that can be generated as presented in the table below:

Table 6. Generated potential hydro power (kW)

No.	Location	Head	Dependable Discharge	Generated Power
		(m)	(m^3/sec)	kW
1	S. Butaiyo Daa	8.2	0.72	44.31
2	S. Butaiyo Kiki	11.32	0.55	46.72

Based on Table 6 above, the generated power shows that for the Butaiyo River Daa of 44.31 kW and for the Butaiyo Kiki River is 46.72 kW. Thus, the total power that can be generated derived from the utilization of both rivers is 91.03 kW. The type of hydroelectric power that suitable to be built or applied in this place is a type of Micro Hydro Power Plant. This type of plant is suitable to be applied in remote areas with a considerable position and not yet served by electricity, but has enough water potential.

3.6 Potential of electric power

The result analysis of generated power which has been obtained before, indicating that the potential that can be raised is 91.03 kW, hence next will be analyzed how many units of home connection that can be served by available power potency.

The assumption of electricity needs per house is assumed to be 450 VA. Therefore, with the potential of this existing power plant, it is expected that this plant can serve about 202 units of houses. The number of connections that can be served is greater than required. So in other words, this power plant will provide a surplus electricity supply of 22.24% of the required needs.

4. DISCUSSION

The results of the research that has been done on the River Butaiyo Daa and River Butikyo Kiki will be explained as follows:

a. Related to annual rainfall conditions that exist in the area looks fluctuate. This is the reason for using the Nreca Model. This model is considered suitable, because after controlled by using the test method in the form of direct measurements in the field of instantaneous flow, the measurement gives good results. This proves that the dependable discharges obtained provide an excellent level of satisfaction. Thus, if the results of this analysis are used, then we have great confidence that at the time of operation, this plant will be operate in good performance.

b. Determination of power house location. The penstock location is determined by considering the topographical condition and available of the site. It is known that the head of water greatly determines the amount of power that can be generated, so that with consideration of topography, location, availability of land, trace channel plan / carrier and the optimum value of power that can be raised, then selected a location that gives a head value of 8.2 m For the Butaiyo Daa River and 11.32 m for the Butaiyo River Kiki.
c. The type of plant that can be built is very suitable for remote and isolated areas to provide the community's independent needs for electricity. This type of power plant includes buildings that are technologically relatively inexpensive in terms of cost. The supporting infrastructure buildings can be built by utilizing locally available resources. Thus, the development process can also utilize local manpower.
d. Finally, with a generating power of 91.03 kW, the area at the site of this study not only can be fulfilled by electricity but also can obtain a surplus of electricity supply from the pambangkit. So by installing an energy storage device (battery) then this area could have sufficient electricity reserves in case of shortage of river water supply in extreme dry seasons and or anomalous weather in the years to come.

5. CONCLUSION

The results of this study can be summarized as follows:

1) The dependable discharge analysis of Q_{90} obtained for the Butaiyo Daa River is 0.72 m^3/s and the Butaiyo Kiki River is 0.55 m^3/s.
2) The potential power that can be generated by the Butaiyo Daa River is 44.31 kW and the Butaiyo Kiki River is 46.72 kW. So the total of the two rivers can provide a potential power that can generate is 91.03 kW.
3) The type of turbine that suitable for use, if referring to the major discharge and the head water of water discharge available is the type of Turbine Banki/Crosflow.
4) The number of units of home connection that can be served is 202 units. These results provide a surplus of electricity supply by 22.42% of the total electricity needs of the community in the village.

REFERENCES

Amali, L.M.K.; Mohamad, Y.; Utama, K.A., (2016), “Perancangan Bangunan Sipil PLTMH Kapasitas 62 kW di Desa Mongi’ilo Induk Kecamatan Bulango Ulu Kabupaten Bone Bolango”, In: Proceedings of 2016 seminar of science and Technology, pp. 1-4, Jakarta: Engineering Faculty, Universitas Muhammadiah Jakarta.

Arismunandar, A. and Kuwahara S., (1991), *Teknik Tenaga Listrik Jilid I Pembangkitan dengan Tenaga Air*, Jakarta: PT. Pradnya Paramita.

Patty, O., 1995, *Tenaga Air*, Jakarta: Erlangga.

Soemarto,C.D., (1987), *Hidrologi Teknik. 1st Edition*, Surabaya: Usaha Nasional.

Triatmodjo, B., (2013), *Hidrologi Terapan*, Yogyakarta: Beta Offset.