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Estimation of Parameters in Tank Models Analysis From a Discharged Simulation in Sibundong Hydropower

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ABSTRACT

In the planning of hydroelectric power plant requires sufficient discharge data for the purpose of hydrology analysis of the watershed. In the Sibundong watershed encountered incomplete discharge measurement problems, many empty discharge observations, and prolonged discharge data. With the tank model, it is expected to be able to perform a discharge simulation to find out the amount of discharge in the river. The purposes of this study are to apply the tank model in the estimation of river discharge and calculate the dependable discharge on the Sibundong river, in addition, it is also to analyze the potential power of Sibundong hydropower. From the result of the generator discharge analysis, it can be analyzed the probability of discharge reliability based on Flow Duration Curve that is Q = 9.29 m3/s, P = 60 %. The selected Francis turbine has a sensitivity of operating variation from 35 % to 105 % of the discharge design of the generator, the turbine operating discharge pattern is between 60 % and 100 % with consideration of dependable discharge. The power potential that can be generated for the hydro power operation pattern is 2 x 6.26 MW and the energy is 1,489.96 GWh/year.

KEYWORDS

Discharge Simulation, Hydro Power, Tank Model.

INTRODUCTION

The unexpectedly growing population causing the circumstance of herbal sources, specifically land and water assets around the watershed. inside the Sibundong Watershed for Sibundong hydro power is influenced by means of the increasing populace in Sumatra Island and the power delivery has reduced the capacity because of the age of the older plant and the addition of latest generating ability is noticeably small. Hydropower generation is the maximum difficulty in electricity global. Hydropower is taken into consideration to be one in all essential renewable energy resources. Renewable electricity are the second largest contributor to the global energy manufacturing after fossil gasoline [1]. Hydro energy technology affords several benefits over most other assets of electrical strength. It is encompass a high stage of reliability, validated era, high efficiency (approximately 90 %), very low working and preservation prices, flexibility and large storage capacity [2].

Sibundong watershed also skilled problems of incomplete discharge measurements, observations debit empty lot. Below those situations, the country strength agency planned Sibundong hydropower development to fulfill the power wishes of everyday people. This observe objectives to transform and determine discharge mainstay at the river with a purpose to be used as a power deliver the usage of a tank model is anticipated on the way to answer this trouble by doing a discharge simulation to understand the amount of discharge in the river.

The method used in the search for missing rainfall data is Normal Ratio Method with the provisions here in after least 2 stations using curved double mass to test the data consistency rain. The average regional rainfall estimates using methods mean algebra. Data rainfall averages calculated area is in the year 2004 to 2013. The average regional rainfall data is used as input data on flow tank model simulation. To search for a discharge in the watershed Sibundong used tank model. The data used is the rainfall data of 6 years starting from 2006 until 2011, climatological data and Sibundong watershed area is 282 km2. Calculation of evapotranspiration using climatic data such as temperature, relative humidity, solar radiation and wind speed. In the calculation of evapotranspiration using Penman method.

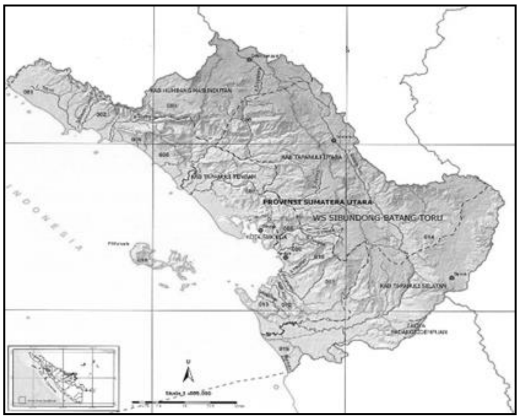

Figure 1. Location of Sibundong hydro power

The demand for electricity has been continuously growing with the ever-increasing international populace and rapid industrialization. the use of fossil fuels is becoming less attractive because of their unfavorable environmental impacts and the role they play in international warming through greenhouse gas emissions [3 - 5]. Hydropower is a dependable and renewable source of power to generate strength. Like In Indonesia, because of its low environmental influences, flexibility, and occasional operation and protection costs, hydroelectric manufacturing is apparently growing around the globe, specifically in growing international locations [6, 7].

The rainfall-runoff model is a growing research subject. One altogether rainfall-runoff models may be a tank version, delivered by means that of Sumatra, Japan hydrologist, to clarify the water flow phenomena of a watershed [10]. At the start, the use of tank models entirely in vogue in Japan, however, the tank fashions had been thought of sincere and valid to deliver tight simulation outcomes to invite many researchers from outside Japan victimization tank model to research the rainfall-runoff relationship. Several researchers reported the tank version has incontrovertible its potential to model the hydrology response of an incredible vary of watershed. Researches on the usage of tank models in Asian Country [8 - 17], created countless literature on the link Associate in Urinalysis of rain-runoff of the watershed. The researchers used the tank model to expect flood and conjointly the supply of water is an unbelievable watershed. A budget tank model plan has been ready to form a case for the event of water flow through victimization rain power (as entering) and manufacture discharges as output. A tank model is a sincere thought that uses one or larger tanks are illustrated as reservoirs in Associate in Nursing unbelievably watershed that considering rain as a result if they enter and generate the output because the surface runoff, below ground drift, intermediate float, molding float, and base flow as output, furthermore, because the improvement of infiltration, percolation, deep percolation, and water storage within the tank are frequently outlined with the help of the model. The development of performances of tank version performed by means that of trial and errors or robotically, by contrast, the traditional discharge (observed discharges) with simulated discharge ensuing from tank model [11]. If the simulated discharges received from the tank version and historical discharges have fashion and important correlations, the simulation is taken into account roaring, and additionally, the tank version is usually accustomed to appraise the waft phenomena for the watersheds[18].

MATERIAL AND METODE

Data collection

Study Location is in Aek Sibundong River, North Tapanuli District, North Sumatra Province (Figure 1). The data used in this study are as follows:

- 10 years of rainfall data from 3 stations (Sarula rain station, Sibolga rain station and Balige rain station).
- Balige region climatology data in 2004-2013.
- The 50 km2 of Dolok Sanggul Watershed area and Sibundong Watershed area of 282 km2.
- AWLR Data of Dolok Sanggul for 6 years.

The climatology data used in this study is Balige region climatology data from 2004-2013. This data contains a record of monthly climatological data in 2004-2013 consisting of wind speed data, humidity, sun brightness, temperature and vapor pressure.

Preliminary analysis of this study is calculations the loss of rain data using the method Normal Ratio Method. Although, filling of the gaps generated through inconsistent facts is crucial, and distinctive tactics and processes are to be had to perform this venture. The most common technique used to estimate lacking rainfall statistics is ordinary Ratio approach [6]. Equation rainfall data Eq. (1).

$$Dx = \frac{1}{n}\sum_{i=1}^{n} d_i \frac{An_x}{An_i} \qquad (1)$$

where:

Dx : Rainfall data in the station of x
N : Number of stations around x to find rainfall data at x
At : daily rainfall data at station i
Anx : Average annual rainfall data at station x
Ani : Average annual rainfall data at stations around x

Before rainfall data is used for further data analysis, the first consistency test of rainfall data in the rain gauge station is used. Consistency test is done by using double mass curve. In this study the calculation of the average rainfall area using the average method of algebra. The potential evapotranspiration calculations use the Penman method, and the discharge data is calculated using the tank model. This study also conducting calibration between Automatic Water Level Recorder (AWLR) measurement data from 2006 to 2011 with a simulation of tank model in 2006 until 2011.

2.2. Concept of Sugawara Tank Model

The tank model may be a really truthful version, composed 1, 2, three and four tanks set vertically in collection [10]. Precipitation is region inside the pinnacle tank, and evaporation or evapotranspiration is deducted from the best tank. If there's no water in the top tank, evaporation or evapotranspiration is subtracted from the second tank; if there may be no water in each the pinnacle and also the second tank, evaporation or evapotranspiration is subtracted from the 1/3 tank then on. The output from the side outlets are the calculated runoff. The output from the top tank is taken under consideration as floor runoff and sub-surface runoff, output from the second one tank as intermediate waft, from the 1/3 tank as sub-base drift and output from the fourth tank as base go with the flow. the method of water flow to soil is taken into account as infiltration and if the infiltration is steady the percolation is seemed. Supported the general of water stability is then normal among the water balance for tank version by way of considering quite a number land makes use of of watershed [19] as shown ini Eq. (2).

$$\frac{dS}{dt} = P - ET - Q \qquad (2)$$

Where, dS/dt = fluctuation of water storage (mm/day), P = precipitation (mm/day), ET = evapotranspiration (mm/day), Q = discharge (mm/day) A watershed has typically comprises several types of land use such as settlement, paddy area, gardens, vacant area and forests. The unit for all components of the water balance is in mm/day.

2.3. Calculation of Nash-Sutcliffe

In this study, the calculation calibration is analyzed by the combination. In this case, the calibration is performed to determine the range of values of a parameter (Eq. (3)).

$$Nash - Sutcliffe = 1 - \frac{\sum_{i=1}^{N} (Q_{si} - Q_{mi})^2}{\sum_{i=1}^{N} (\overline{Q} - Q_{mi})^2} \qquad (3)$$

Where
Qsi : Run-off counted at time interval i
Qmi : Run-off measured at time interval i
: Average measured run-offs for the period used
i : Time interval
N : Number of time intervals

2.4. Broad Comparison Method

In the broad comparison method, the concept used is a rational method in Eq. (4).

$$\frac{Q_I}{Q_{II}} = \frac{C_I I_I A_I}{C_{II} I_{II} A_{II}} \qquad (4)$$

where:
QI : discharge of watershed I (m3/s)
QII : discharge of watershed II (m3/s)
CI : flow coeficient of watershed I
CII : flow coeficient of watershed II
AI : area of watershed I
AII : area of watershed II

RESULT AND DISCUSSION

3.1. Consistency Rainfall Test

Before the rainfall data used for the analysis of more data, then the first test the consistency of rainfall data at stations rainfall measuring wear. Testing the consistency of the performed with the use of the way the curve of the mass of double (double mass curve). Having obtained the annual rainfall at each station, the rain, and then compare the prices on a station that was tested with the price at the station around by doing plots on the curve of the mass of double (double mass curve).

3.2. Discharge simulation of tank model

This simulation will be divided into two stages, Namely phase 1 and stage 2, where simulation phase 1 using the width of Dolok Sanggul sub-watershed with the width of the watershed is 50 km2 because the Sibundong Watershed does not have AWLR station. One of the example of the first phase of discharge simulation using tank model (in January 2006) can be seen in Figure 2.

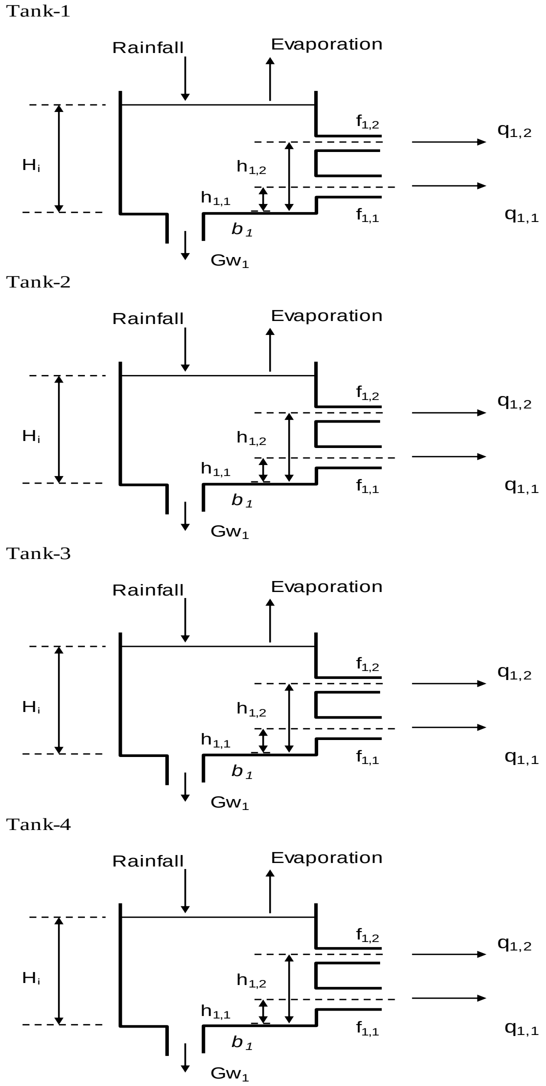

Figure 2. Arrangement of discharge simulation using tank model

The simulation analysis has been calibrated with the help of the solver program on excel (see Figure 3 and Table 1) obtained the value of tank coefficient parameters. The constraint limits used in the calculation with the solver program as follows:

Hi ≥ 0, hi2 ≥ 0, hi1 ≥ 0
Hi ≥ hi2 ≥ hi1 ≥ 0
1 ≥ fi1 ≥ 0
1 ≥ fi2 ≥ 0
1 ≥ b1 ≥ 0

Table 1. Parameter and coefficient of tank model.

	tank-1	*tank-2*	*tank-3*	*tank-4*
H_i	9,817.461	4,776.958	4,695.886	373.288
$h_{i.2}$	218.549	249.233	158.691	140.803
$f_{i.2}$	0.005	0.002	0.001	0.001
$h_{i.1}$	48.977	23.278	11.298	0.000
$f_{i.1}$	0.002	0.023	0.133	0.253
b_i	0.249	0.610	0.998	0.987

3.4. Broad comparison method

By knowing the discharge of Sibundong River at the upstream at Dolok Sanggul station with the total area of its watershed is 50 km2, and the total area of Sibundong watershed is 282 km2. Assuming the characteristics of the watershed and climatology are the same, then it can calculate the discharge of Sibundong River. The concept used is a rational method QII = 95.93 m3/s

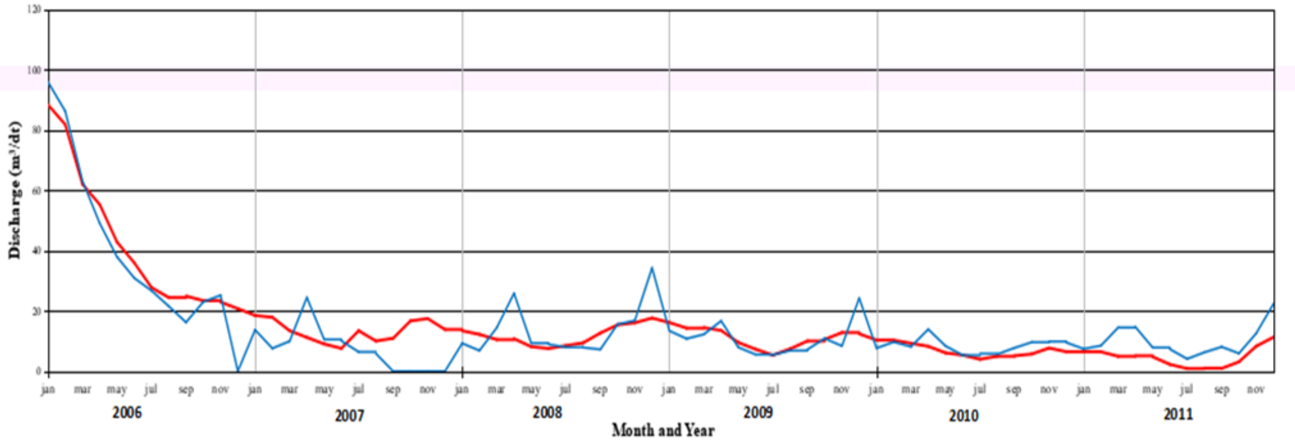

Figure 3. Calibration Tank Model

3.3. Calculation of Nash-Sutcliffe correlation value for calibration

The calculation calibration is analyzed by the combination. The parameters which are then used trial nd error to determine the optimal combination of details are parameters Hi, hi1, hi2, fi1, fi2 and b1. The Nash-Sutcliffe correlation value of phase 1 simulation:

$$Nash - Sutcliffe = 1 - \frac{78,98}{636,55}$$

$$= 0.88$$

The Nash-Sutcliffe correlation value of phase 2 simulation:

$$Nash - Sutcliffe = 1 - \frac{3331,37}{23604,45}$$

$$= 0.86$$

Based on the correlation values between two simulations, it shows a positive relationship where the correlation value is in category 0.6 <R <1.

3.5. Flow duration curve

The flow duration curve is calculated using the Weibull equation by entering the result data of the tank model simulation method. The result can be seen in Table 2.

3.6. Analysis Of Discharged Simulation And Operation

Sibundong hydroelectric power generation can generate draft turbine operation based on the probability of discharge reliability. The draft is based on turbine capability and sensitivity to operating discharge variations.

Table 2. Discharge Probability

	Final Calibration			Final Calibration			Final Calibration	
m	**P=m/(n+1)**	**Q (m³/s)**	**m**	**P=m/(n+1)**	**Q (m³/s)**	**m**	**P=m/(n+1)**	**Q (m³/s)**
1	1.37 %	88.36	26	35.62 %	13.44	51	69.86 %	7.59
2	2.74 %	81.79	27	36.99 %	13.43	52	71.23 %	7.56
3	4.11 %	62.04	28	38.36 %	12.84	53	72.60 %	7.43
4	5.48 %	55.28	29	39.73 %	12.67	54	73.97 %	7.31
5	6.85 %	42.85	30	41.10 %	12.39	55	75.34 %	6.49
6	8.22 %	35.97	31	42.47 %	12.22	56	76.71 %	6.47
7	9.59 %	27.76	32	43.84 %	11.29	57	78.08 %	6.44
8	10.96 %	24.94	33	45.21 %	11.23	58	79.45 %	6.12
9	12.33 %	24.44	34	46.58 %	10.95	59	80.82 %	5.72
10	13.70 %	23.39	35	47.95 %	10.80	60	82.19 %	5.36
11	15.07 %	22.96	36	49.32 %	10.56	61	83.56 %	5.36
12	16.44 %	20.77	37	50.68 %	10.52	62	84.93 %	5.14
13	17.81 %	18.51	38	52.05 %	10.38	63	86.30 %	5.13
14	19.18 %	17.89	39	53.42 %	10.28	64	87.67 %	4.99
15	20.55 %	17.65	40	54.79 %	10.04	65	89.04 %	4.99
16	21.92 %	17.47	41	56.16 %	10.03	66	90.41 %	4.79
17	23.29 %	16.70	42	57.53 %	9.54	67	91.78 %	3.98
18	24.66 %	16.16	43	58.90 %	9.42	68	93.15 %	3.13
19	26.03 %	16.09	44	60.27 %	9.29	69	94.52 %	2.29
20	27.40 %	15.39	45	61.64 %	9.05	70	95.89 %	1.03
21	28.77 %	14.48	46	63.01 %	8.49	71	97.26 %	0.95
22	30.14 %	14.32	47	64.38 %	8.31	72	98.63 %	0.89
23	31.51 %	13.87	48	65.75 %	8.27	73	100.00 %	0.00
24	32.88 %	13.53	49	67.12 %	8.15			
25	34.25 %	13.45	50	68.49 %	7.70			

Table 3. Discharge draft and turbine operation.

Pattern	Total discharge	Probability	Operation pattern	
			Turbine 1	Turbine 2
	m³/s	(%)	m³/s	m³/s
1,0 Q	9.29	60 %	4.65	4.65
0,9 Q	8.36	70 %	4.65	3.72
0,8 Q	7.43	77 %	3.72	3.72
0,7 Q	6.50	86 %	3.25	3.25
0,6 Q	5.57	93 %	2.79	2.79
0,5 Q	4.65	97 %	2.32	2.32
0,4 Q	3.72	99 %	3.72	0.00

Table 4. The simulation results of the discharge by using the tank model in stage 1

Year	Month	Discharge Simulation m^3/s	Year	Month	Discharge Simulation m^3/s
2006	Jan	17.00	2009	Jan	2.30
	Feb	15.30		Feb	2.20
	Mar	11.20		Mar	2.10
	Apr	8.90		Apr	2.10
	May	6.80		May	1.70
	Jun	5.50		Jun	1.60
	Jul	4.20		Jul	1.40
	Aug	3.60		Aug	1.50
	Sep	3.40		Sep	1.80
	Oct	3.00		Oct	1.80
	Nov	3.00		Nov	2.00
	Dec	2.70		Dec	2.00
2007	Jan	2.50	2010	Jan	1.80
	Feb	2.50		Feb	1.90
	Mar	2.00		Mar	1.70
	Apr	1.80		Apr	1.70
	May	1.60		May	1.50
	Jun	1.60		Jun	1.50
	Jul	2.00		Jul	1.30
	Aug	1.70		Aug	1.40
	Sep	1.90		Sep	1.50
	Oct	2.30		Oct	1.50
	Nov	2.40		Nov	1.70
	Dec	2.10		Dec	1.60
2008	Jan	2.10	2011	Jan	1.60
	Feb	2.00		Feb	1.70
	Mar	1.80		Mar	1.40
	Apr	1.80		Apr	1.50
	May	1.60		May	1.40
	Jun	1.60		Jun	1.30
	Jul	1.60		Jul	1.10
	Aug	1.70		Aug	1.10
	Sep	2.00		Sep	1.20
	Oct	2.20		Oct	1.30
	Nov	2.30		Nov	1.70
	Dec	2.40		Dec	2.00

Table 5. The simulation results of the discharge by using the tank model in stage 2

Year	Month	Discharge Simulation m^3/s	Year	Month	Discharge Simulation m^3/s
2006	Jan	88.40	2009	Jan	16.20
	Feb	81.80		Feb	14.30
	Mar	62.00		Mar	14.50
	Apr	55.30		Apr	13.50
	May	42.90		May	9.50
	Jun	36.00		Jun	7.30
	Jul	27.80		Jul	5.40
	Aug	24.40		Aug	7.40
	Sep	24.90		Sep	10.00
	Oct	23.40		Oct	10.60
	Nov	23.00		Nov	12.80
	Dec	20.80		Dec	12.40
2007	Jan	18.50	2010	Jan	10.40
	Feb	17.90		Feb	10.30
	Mar	13.40		Mar	9.30
	Apr	11.20		Apr	8.30
	May	9.00		May	6.10
	Jun	7.60		Jun	5.40
	Jul	13.40		Jul	4.00
	Aug	10.00		Aug	5.00
	Sep	11.00		Sep	5.10
	Oct	16.70		Oct	5.70
	Nov	17.50		Nov	7.70
	Dec	13.90		Dec	6.50
2008	Jan	13.40	2011	Jan	6.50
	Feb	12.20		Feb	6.40
	Mar	10.50		Mar	5.00
	Apr	10.80		Apr	5.10
	May	8.10		May	4.80
	Jun	7.60		Jun	2.30
	Jul	8.50		Jul	0.90
	Aug	9.40		Aug	1.00
	Sep	12.70		Sep	0.90
	Oct	15.40		Oct	3.10
	Nov	16.10		Nov	8.30
	Dec	17.70		Dec	11.30

CONCLUSION

According to the calculations, simulations discharge part 1 in January to December 2006, the min discharge of 2.7 m3/s and max discharge of 17 m3/s. Simulation discharge in January to December 2007, the min discharge of 1.6 m3/s and a max discharge of 2.5 m3/s. Simulation discharge in January to December 2008, the min discharge of 1.6 m3/s and a max discharge of 2.4

m3/s. Simulation discharge from January to December of 2009, the min discharge of 1.4 m3/s and a max discharge of 2.3 m3/s. Simulation discharge in January to December 2010, the min discharge of 1.3 m3/s and a max discharge of 1.9 m3/s. Simulation discharge from January to December of 2011, the min discharge of 1.1 m3/s and a max discharge of 2.0 m3/s. Discharge simulation part 2 in January to December 2006, the min discharge of 20,8 m3/s and a max discharge of 88.4 m3/s. Simulation discharge in January to December 2007, the min discharge of 7.6 m3/s and a max discharge of 18.5 m3/s. Discharge simulation in January to December 2008, the min discharge of 7.6 m3/s and a max discharge of 18.7 m3/s. From January to December of 2009, the min discharge of 5.4 m3/s and a max discharge of 16.2 m3/s. Simulation discharge in January to December 2010, the min discharge of 4.0 m3/s and a max discharge of 10.4 m3/s. Simulation discharge from January to December of 2011, the min discharge of 0.9 m3/s and a maximum discharge of 11.3 m3/s. The standardization method between the discharge tank model with the mensuration results supported calculations Nash-Sutcliffe efficiency simulated at stage 1 and 2 obtained the worth of R = 0.88 and 0.86. The correlation value within the class of 0.6 < R > selected Francis turbin contains a sensitivity in operation variation from 35 % to 105 % of the discharge style of generator, the rotary engine in operation discharge pattern is between 60 % and 100 % considerately of dependable discharge. The potential power which will be generated for hydropower operation pattern is 2 x 6.26 MW and electricity is 1,489.96 GWh / year.

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Author Contributions

R. D.L (Lecturer & Researcher) designed the research plan, wrote the manuscript, submitted the paper to the EER Journal, and is the corresponding author. S.M. (Lecturer & Researcher) accomplished its processes and reviewed the manuscript. R.H (Lecturer & Researcher) reviewed, edited the paper, and M.A.S (Lecturer & Researcher) reviewed, edited the paper.

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