International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 4
ISSN: 2088-5334

Analysis of The Pipelines Headrace of Micro-Hydropower Plant

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***Abstract*— The area around Andalas University has the potential for renewable water sources that have not been utilized optimally. This can be used to meet the electricity needs of Andalas University. University requires electricity costs of 720 million per month. With the Micro Hydro Power Plant, the campus can save electricity costs for this purpose. This research aims to study the most optimum headraces and the generated power capacity. A hydrology analysis is needed to obtain a reliable discharge as a reference for potential river flow in determining the electric power capacity; the dependable discharge is used with a percentage of events throughout the year of 85%. The dependable discharge analysis is carried out by the F.J Mock method and the NRECA model, where the calculation results of these two methods are almost close to 1.1 m^3/s. This study uses EPANET 2.0 software in modeling the water distribution network to the MHP turbine. The rainfall data used is for 11 years (2008-2018), where the data is taken from Batu Busuk station, Ladang Padi station, Simpang Alai station and Gunung Nago station. The climatological data needed is the climatological data for the city of Padang. In this study, several alternative channel traces were used to make it easier to determine the most optimum channel trace. Based on the EPANET simulation results, an alternative D is obtained as the best trace with a carrier channel along 1692.82 m using HDPE pipe Ø720. The discharge that can be passed is 1,098 m3/s, and the power generated is 0.6 MW. Alternative D trace is superior to others because it does not pass-through steep slopes, so it is safe and easy to install.**

***Keywords*— Micro-hydropower plant; carrier channel; dependable discharge; EPANET.**

Manuscript received 20 Apr. 2021; revised 29 Sep. 2021; accepted 14 Jan. 2022. Date of publication 31 Aug. 2022.

I. INTRODUCTION

Andalas University requires electricity costs of 720 million per month. Of which 600 million are for electricity needs for the Andalas University academic community's activities, and 120 million are for electricity payments for the Andalas University Teaching Hospital (RSP). The area around Andalas University has the potential for renewable water sources that have not been utilized optimally, for example, the Limau Manis river. This can be used to meet the electricity needs of Andalas University. Therefore, Andalas University submitted a request to use the Kuranji Check dam to become a Multipurpose Check dam for Raw Water and Microhydro power plant to be utilized in the Andalas University area. However, the water access path from the intake to the calming basin is still a problem due to the steep slopes of the topography. Therefore, a special study is needed regarding the placement of distribution pipelines (carrier channels) and the required discharge. Conditions in the field can be seen in Figures 1,2,3, and 4.

This study aims to conduct a hydrological study of the Limau Manis watershed to determine the dependable discharge for Micro Hydropower plants to meet the university's electricity needs. Determine the optimum carrier pipeline alignment based on the planned dependable discharge. Analyze the power capacity of the generator based on the planned dependable discharge [1], [2]. From the results of this study, it is hoped that it can provide accurate information in determining the dependable discharge, carrier pipelines, and pipe dimensions that will be used in planning Microhydro power plant to meet the electricity needs of Andalas University.

Fig. 1 Penstock and Turbine House,

The limitation of the problem in this study is the calculation of water discharge based on rainfall data in the Limau Manis River watershed; the rainfall and climatological data used in the dependable discharge analysis are data recorded for 11 years (2008–2018), rainfall data is obtained from four stations. Namely, rotten stone stations, paddy field stations, Simpang Alai stations, and Gunung Nago stations; analysis of the discharge that can be flowed in pipes is carried out using the EPANET Model [3].

Fig. 2 Intake and Settling Tub

Fig. 3 Pipe Installation Inlet and Raw Water

Fig. 4 Pipe Network Conditions on Slopes

II. MATERIALS AND METHODS

Micro Hydro Power Plant is a power plant that utilizes power from water flow/falls, reservoirs/dams, or irrigation canals whose construction is multipurpose with a capacity of less than 1 MW [3], [4]. A microhydro power plant has three main components: water as an energy source, turbines and generators [5]-[7]. The microhydro power plant utilizes the potential energy of waterfall (head) from water flows that have a certain height difference [5], [8].

Loss of rainfall data occurs due to equipment damage or observation errors. Rainfall loss was calculated using the normal ratio method [9,10].

$$\frac{P_x}{N_x} = \frac{1}{n}\left(\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \cdots + \frac{P_n}{N_n}\right) \quad (1)$$

Px: Rainfall lost at station x
Nx: Annual rain at station x
P1, P2,P3: Rainfall around station x
N1, N2,N3: Annual rain around station x
n: Number of stations around the station x

Regional rainfall is calculated using the average arithmetic method because all four stations are outside the catchment area.

$$R = \frac{R_1 + R_2 + R_3 + \cdots + R_n}{n} \quad (2)$$

Where; R is Rainfall average, and then n: Number of stations.

A. *Potential Evapotranspiration and Dependable Discharge*

The calculation of potential evapotranspiration uses the FAO-modified penman method. In summary, the calculations can be seen in the diagram in Figure 5.

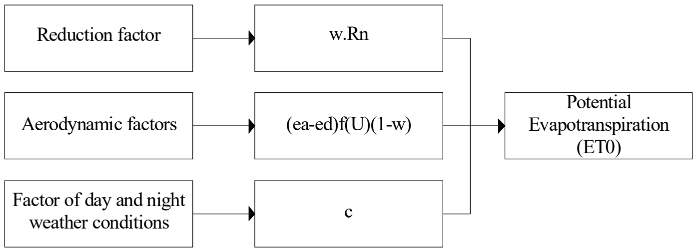

Fig. 5 Potential Evapotranspiration (ET0).

Fig. 6 F.J Mock Method

For a power plant centre's needs, the dependable discharge used is the discharge, which has a percentage of occurrence throughout the year of 85-90% [11], [12]. Dependable discharge probability analysis is calculated using the interval and ranking statistical methods [13]. The interval method is calculated based on the Flow Duration Curve (FDC), which graphs the curve of the discharge relationship with the frequency of its occurrence [14], [15]. For reliable discharge using the ranking statistical method, each percentage's analysis of the discharge probability is calculated using the Weibull formula [16], [17]. Dependable discharge analysis was carried out using the F.J Mock [18]-[20] and the NRECA Model [21]-[23]. The dependable discharge calculation follows the diagrams in Figure 6 and Figure 7.

Fig. 7 NRECA Model

B. Carrier Channel

The water-carrying channel (headrace) has the function of flowing water from the intake/settling basin to the forebay and maintaining the stability of the discharge. In Figure 8, 4 alternative alignment channels are planned, but in this study, only an analysis of alternative 1, alternative four, and additional alternatives is the result of the author's planning. Alternative two is not analyzed because it has to build a new weir for its intake, so it requires a large amount of money. Whereas alternative 3 has a head that is not sufficient to drain water.

C. Hydraulics Analysis

The hydraulic analysis was carried out with the EPANET 2.0 software [24]-[26]. Where the hydraulic system components in the field will be simulated in EPANET, then run the simulation to get the discharge value of each tested alternative.

D. Generating Power Capacity Analysis

The output produced by the Microhydro power plant depends on the discharge and the height of the water drop [28-30].

$$Pmax = g \times Heff \times Q \times \eta \qquad (3)$$

Which is:

Pmax	: Maximum output power	(kW)
g	: Acceleration of gravitational force	(m/s^2)
Q	: Dependable discharge	(m^3/s)
Heff	: Effective head	(m)
η	: Maximum efficiency	(%)

In the implementation of this research, the stages carried out can be seen in Figure 8 below:

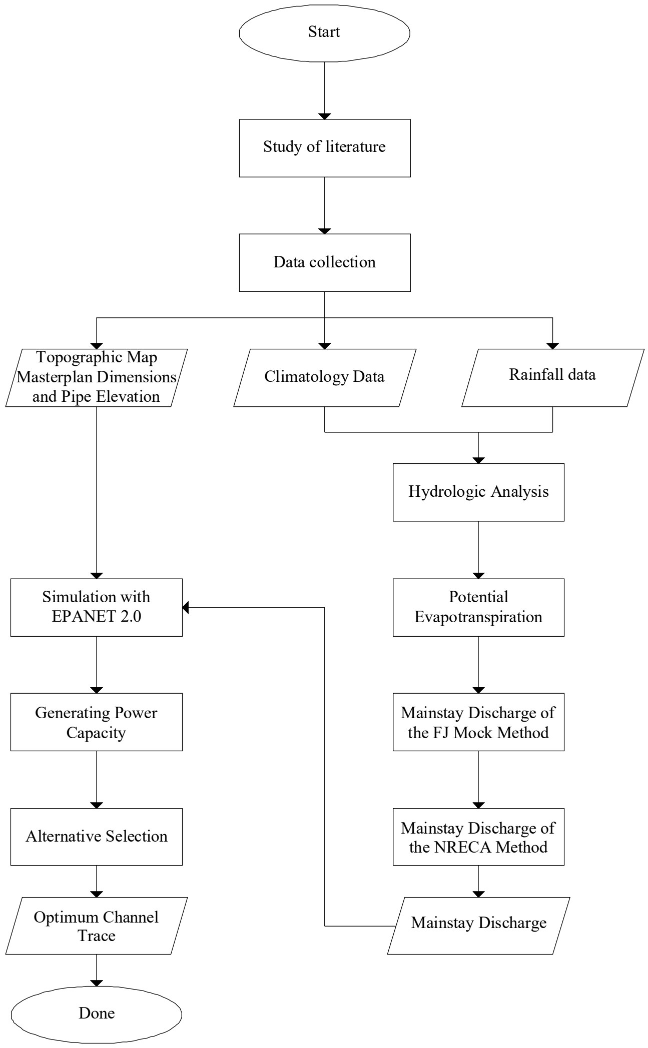

Fig. 8 Research Flowchart

III. Results and Discussion

A. Description of the Case Study

The case study chosen was the Micro Hydro Power Plant on the Limau Manis river. The components needed in this research are as follows:

1) Dam: This Microhydro power plant utilizes the existing Kuranji Check dam as its intake building.

2) Settling tub: In modeling, the settling basin is the source of water entering the distribution network. The water level in the soaking tub is +357.05 masl.

3) Carrier channel: The planned carrier line is a closed channel (pipe) with varying diameters and lengths based on the alternatives tested. The carrier channel has upstream of the settling tank with a pipe elevation of +352.55 masl.

Meanwhile, downstream from the carrier channel is in a calming tub with an elevation of +345.73 masl.

4) Soothing tub: The calming tub has a water level equal to the downstream elevation of the carrier channel, which is +345.73 masl.

5) Rapid pipe: The rapid pipe has a diameter of 800 mm with a pipe length of 196.53 m. The rapid pipe connects the calming basin and the turbine housing, with the pipe elevation in the calming tub at +339.705 masl and the elevation at the turbine housing at +266.88 masl.

6) Turbine house: The turbine house is located at an elevation of +266.88 masl. At the beginning of the planning, it was planned that the Microhydro power plant would use three turbines, but currently, the pipeline is still installed for one turbine. Therefore, this study's modeling and alignment planning were to rotate just one turbine.

7) Exhaust Channel: The exhaust channel functions to drain water that has been used to turn the turbines into the river. The exhaust channel has a pipe length of 11.83 m.

Fig. 9 Components of Microhydro power plant Andalas University

B. Estimated Loss of Rainfall Data

Of the four stations, there are seven missing rainfall data, namely rainfall data from June to December 2008 at the Ladang Padi station.

TABLE I
RAINFALL DATA FOR 2008

Month	Station			
	Batu Busuk	Ladang Padi	Simpang Alai	Gunung Nago
Jan	190	122	150	155
Feb	390	266	146	428
Mar	401	204	513	354
Apr	383	242	502	548
May	155	120	19	223
Jun	287	-	12	384
Jul	623	-	45	601
Aug	275	-	239	179
Sep	103	-	59	277
Oct	312	-	44	361
Nov	401	-	8	289
Dec	414	-	80	662
Total	3934	954	1817	4461

Therefore, the normal ratio method (1) is used to fill in the missing rainfall data. So that the results of Px each from June to December, namely 53 mm, 101 mm, 77 mm, 38 mm, 59 mm, 54 mm, and 95 mm could be obtained.

C. Analysis of Regional Average Rainfall

Rainfall and rainy-day data will be averaged using the arithmetic average method (2), as can be seen in Table II and Table III.

TABLE II
THE MAXIMUM RAINFALL DATA

No	Observation Year	Maximum rainfall (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2008	154.30	307.40	367.95	418.75	129.30	183.97	342.41	192.46	119.35	193.81	188.06	312.67
2	2009	163.88	163.30	161.65	202.95	140.10	202.68	215.68	264.25	329.30	239.13	337.65	237.75
3	2010	278.65	369.05	477.30	243.63	235.58	268.25	308.50	145.83	288.45	208.15	333.20	266.45
4	2011	153.90	172.65	163.38	230.35	236.75	276.95	148.25	221.53	186.70	220.65	365.50	253.03
5	2012	159.28	161.85	333.70	184.10	331.95	245.45	394.83	202.55	230.25	232.75	354.38	454.20
6	2013	273.60	228.35	414.55	362.30	162.00	159.95	225.48	325.95	217.08	315.93	672.28	429.95
7	2014	357.65	142.40	145.50	505.53	290.00	380.30	160.00	374.08	293.35	510.65	652.90	417.58
8	2015	279.65	166.98	213.05	335.75	275.73	241.40	123.63	267.63	121.13	191.88	675.23	367.93
9	2016	221.33	166.55	486.95	361.20	438.20	476.60	196.65	477.00	361.23	912.33	355.03	409.90
10	2017	412.30	270.61	429.45	331.05	419.10	237.40	312.68	487.58	487.43	314.93	839.04	450.05
11	2018	133.00	328.25	324.75	209.00	323.00	235.00	251.50	152.50	329.50	574.75	633.00	596.00

TABLE III
POTENTIAL EVAPOTRANSPIRATION (MM / MONTH)

Observation Year	Potential Evapotranspiration (ETo)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	124.56	124.38	129.67	122.25	123.83	114.11	109.11	125.33	121.78	124.20	114.20	112.24
2009	117.10	101.25	134.47	117.26	129.50	108.62	118.94	121.39	115.81	103.90	98.63	109.86
2010	124.16	120.17	118.31	121.67	124.03	107.27	107.84	126.93	121.12	106.12	101.70	117.54
2011	114.08	120.60	125.69	121.08	128.23	116.58	130.53	121.10	112.45	103.36	91.49	93.32
2012	138.90	121.81	136.50	128.58	121.77	119.65	126.96	127.74	109.99	128.80	107.99	101.46
2013	128.94	107.45	118.01	121.88	131.57	122.52	123.38	125.51	118.09	111.05	111.65	110.68
2014	135.76	133.37	121.59	125.25	123.27	116.02	132.20	124.85	121.13	119.03	104.84	112.61
2015	131.04	135.64	143.17	120.46	131.12	120.24	131.68	132.75	113.91	85.68	111.18	108.42
2016	127.96	141.84	146.41	122.97	117.74	110.02	133.38	124.18	121.09	109.29	112.80	99.13
2017	114.54	119.63	135.69	127.16	121.01	121.30	121.06	122.16	111.02	130.59	96.68	114.79
2018	10.42	126.83	128.32	125.29	112.86	113.05	120.66	126.73	115.79	106.47	108.70	121.86

D. Analysis of Potential Evapotranspiration

The measured data presented are air humidity, temperature, wind speed, and average solar radiation from 2008 to 2018. The results of the potential evapotranspiration analysis recapitulation can be seen in Table III.

E. Dependable Discharge Analysis

In addition to data from Table II, Table III, and Table IV, other data needed in the analysis are:

Watershed Area : 26.6 km²
Infiltration coefficient (i) : 0.3
Ground flow recession factor (k): 0.4
Open land surface (m): 30 %
Moisture capacity (SMC) : 200 mm

1) The dependable discharge of the F.J Mock method: The recapitulation results of reliable discharge calculations using the F.J Mock method can be seen in Table IV.

TABLE IV
DEPENDABLE DISCHARGE USING F.J MOCK METHOD

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	0.75	1.92	2.27	2.96	0.79	0.98	2.17	1.06	0.41	0.79	0.90	1.87
2009	0.85	0.94	0.55	0.96	0.41	0.98	1.09	1.43	2.16	1.53	2.30	1.50
2010	1.67	2.62	3.31	1.76	1.43	1.77	2.02	0.70	1.69	1.23	2.19	1.69
2011	0.83	0.89	0.59	1.12	1.18	1.68	0.64	1.09	0.95	1.20	2.51	1.77
2012	0.96	0.73	1.84	0.92	1.99	1.56	2.52	1.19	1.42	1.21	2.30	3.17
2013	1.97	1.69	2.73	2.54	0.89	0.72	1.09	1.89	1.27	1.93	4.92	3.38
2014	2.64	0.96	0.62	3.27	1.93	2.66	0.89	2.27	1.92	3.45	5.10	3.42
2015	1.95	1.01	0.96	2.03	1.63	1.47	0.43	1.28	0.47	1.06	4.78	2.90
2016	1.58	0.88	2.96	2.51	3.03	3.65	1.33	3.22	2.59	6.85	3.24	3.24
2017	3.28	2.25	2.92	2.32	2.92	1.69	2.03	3.36	3.77	2.32	6.54	3.80
2018	1.96	2.50	2.09	1.25	1.98	1.53	1.45	0.65	1.96	3.99	4.97	4.73
Maximum	3.28	2.62	3.31	3.27	3.03	3.65	2.52	3.36	3.77	6.85	6.54	4.73
Minimum	0.75	0.73	0.55	0.92	0.41	0.72	0.43	0.65	0.41	0.79	0.90	1.50
Average	1.68	1.49	1.89	1.97	1.65	1.70	1.42	1.65	1.69	2.32	3.61	2.86

Based on the data obtained, it is necessary to calculate the river's dependable discharge with a probability of 85%. The interval method produces Q85% of the total sorted discharge data, while the ranking statistical method will produce Q85% every month based on the Weibull formula. The results of the calculation of the interval method can be seen in the graph in Figure 9, while the statistical method of ranking is in the graph in Figure 109.

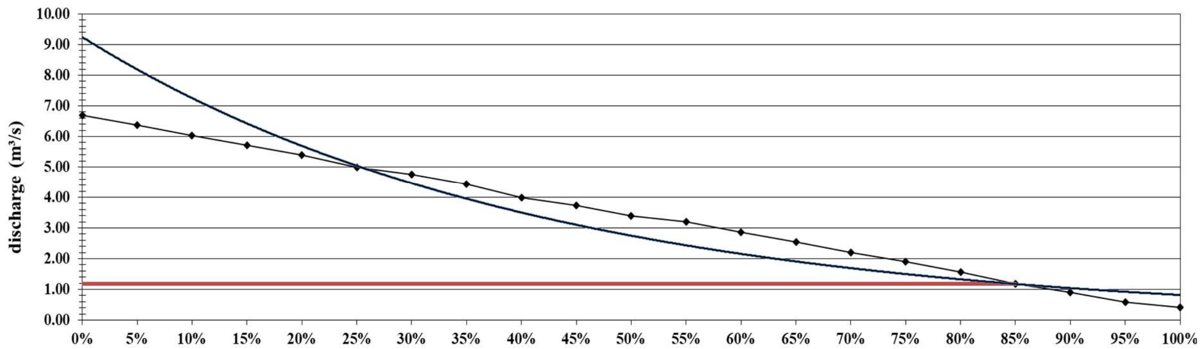

Fig. 80 Graph of Q85% Interval Method (Mock)

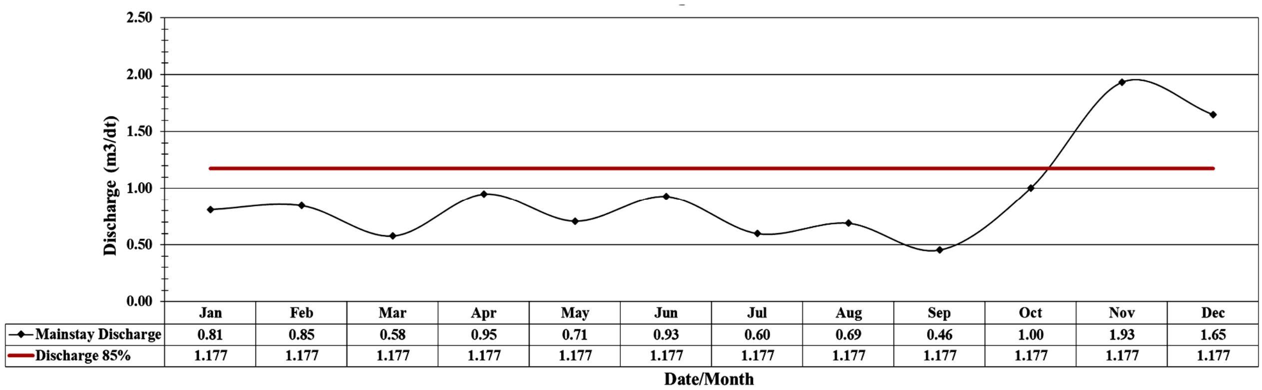

Fig. 9 Q85% for 1 Year Statistical Ranking Method (Mock)

2) The dependable discharge of the NRECA method: The recapitulation results of reliable discharge calculations with the NRECA model can be seen in Table V. The results of the calculation of the interval method can be seen in the graph in Figure 10, while the statistical method of ranking is in the graph in Figure 11.

TABLE V
DEPENDABLE DISCHARGE RECAPITULATION OF NRECA MODEL

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	0.11	0.20	1.54	2.32	0.63	1.10	2.22	1.34	0.41	0.79	0.90	1.87
2009	0.11	0.16	0.17	0.40	0.21	0.68	0.81	1.20	2.16	1.53	2.30	1.50
2010	0.13	1.21	2.61	1.44	1.45	1.95	2.32	1.28	1.69	1.23	2.19	1.69
2011	0.11	0.15	0.17	0.46	0.76	1.27	0.50	1.05	0.95	1.20	2.51	1.77
2012	0.10	0.12	0.28	0.50	1.52	1.24	2.27	1.24	1.42	1.21	2.30	3.17
2013	0.13	0.56	1.81	2.03	0.82	0.93	1.36	2.12	1.27	1.93	4.92	3.38
2014	0.14	0.17	0.24	2.40	1.55	2.44	1.04	2.56	1.92	3.45	5.10	3.42
2015	0.13	0.24	0.43	1.36	1.25	1.29	0.57	1.46	0.47	1.06	4.78	2.90
2016	0.12	0.14	0.71	1.89	2.62	3.37	1.53	3.59	2.59	6.85	3.24	3.24
2017	0.16	1.19	2.17	1.94	2.71	1.84	2.41	3.77	3.77	2.32	6.54	3.80
2018	0.12	0.63	1.42	0.92	1.81	1.48	1.61	1.04	1.96	3.99	4.97	4.73
Maximum	0.16	1.21	2.61	2.40	2.71	3.37	2.41	3.77	3.77	6.85	6.54	4.73
Minimum	0.10	0.12	0.17	0.40	0.21	0.68	0.50	1.04	0.41	0.79	0.90	1.50
Average	0.12	0.43	1.05	1.42	1.39	1.60	1.51	1.88	1.69	2.32	3.61	2.86

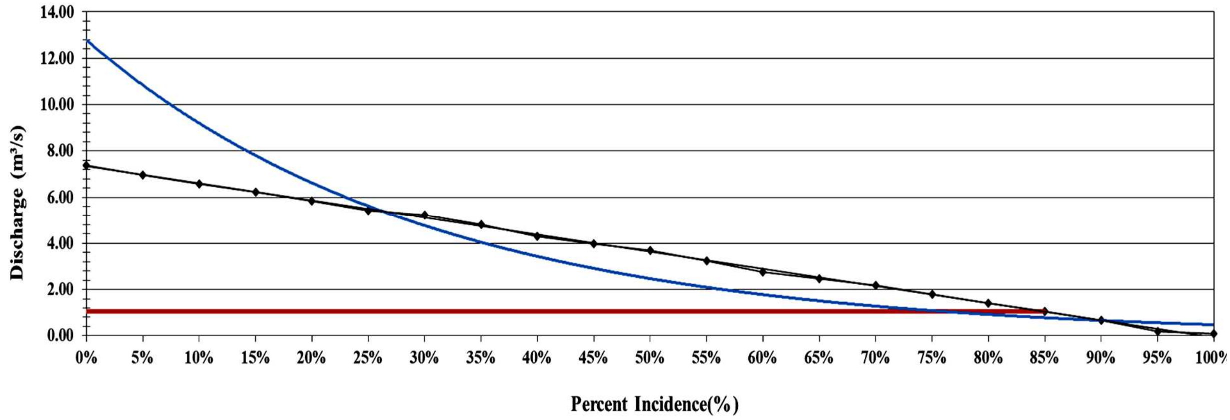

Fig. 102 Graph Q85% Interval Method (NRECA)

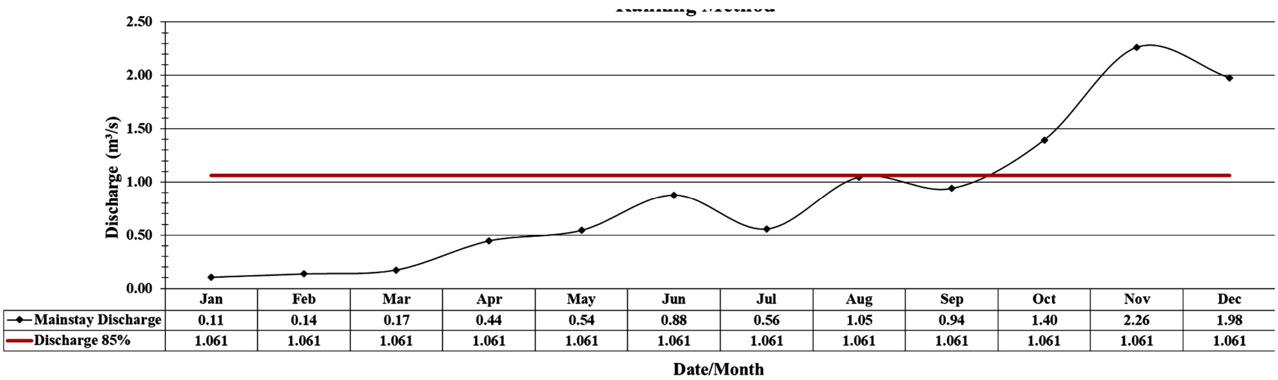

Fig. 113 Q85% for 1 Year Ranking Statistical Method (NRECA)

F. Planned Discharge Distribution

The turbine is installed and requires a discharge of 0.7 m^3/s for operation. According to the Guidebook for the Construction of a Micro Hydro Power Plant, the calming bath capacity should be secured at a range of 120 to 180 times Qd.

$Qr = Q \times 120\%$
$Qr = 0.7 \times 120\%$
$Qr = 0.84\ m^3/s$
$Q85\% > Qr$
$1.1\ m^3/s > 0.84\ m^3/s$

G. Trace of Carrier Channels

1) Alternative A: Alternative A is an alternative that has been designed since the beginning of planning to build MICROHYDRO POWER PLANT. However, this alternative requires further analysis because the placement of the carrier channel is in a steep area. This alternative is planned with an HDPE pipe with a diameter of 800 mm. Alternative A flows the water from the settling bath to the soaking tub with a constant slope of 0.004, a head of 78.85 m, and a channel length of 1718.00 m.

2) Alternative B: Alternative B is the alternative that planners most recommend because this alternative has a safer path and is in a more gentle place, but it has a disadvantage, namely that the previously installed penstock pipe becomes unused because this alternative directly becomes the penstock pipe to the turbine. Alternative B is planned with a GIP pipe with a diameter of 950 mm, a head of 85.67 m, and a channel length of 1741.91 m to obtain the pipe slope at 0.049 m.

3) Alternative C: Alternative C is one of the alternatives planned by the researcher with a horizontal pipe elevation and descending continuously from the settling bath to the soaking tub. This track line has the same head as alternative A, but the length of the channel is shorter, namely 1699.34 m, with the channel's slope on the pipe decreasing by 0.00485. Alternative C is planned with an HDPE pipe with a diameter of 700 mm. HDPE pipe was chosen because this pipe is made of a polymer that is lighter than GIP pipe, which is made of steel, so this type of pipe is suitable to be placed on the slope.

4) Alternative D: Alternative D is an alternative planned by researchers who consider steep slopes. The channel alignment is not placed directly through a steep area like alternative A but instead decreases to a more gentle elevation with a channel slope of 0.0393 and then rises with a slope of 0.001433 towards a calming basin. This track line is planned to use an HDPE pipe with a diameter of 720 mm, a channel length of 1692.18 m, and the same head as the previous alternative.

H. Hydraulics Analysis

EPANET Modelling follows the conditions in the field as described in the description of the case study; the components required are as follows:

1) Reservoir: Reservoirs represent water sources entering distribution networks, reservoirs, and rivers. The input required is the water level.

2) Pipe: The pipeline consists of several junctions and pipes. The pipe simulates the conveyor line, penstock, and tailrace. The input required is the pipe length and elevation for each junction.

3) Valve: The operating turbine is simulated as general-purpose valves (GPV). The valve requires a head-flow rate curve in operation. The curve used is a single-point curve that combines the head-discharge with one debit and head data only. Discharge data uses the dependable of discharge, while the data head adjusts for each alternative. The head required is the head between the water level from the reservoir upstream of the penstock with the turbine head.

I. Modeling Results with EPANET 2.0

The output on running EPANET is a table with different parameters for nodes and links. An example of modelling for Alternative A is shown in Figure 12 below. The results of running EPANET Alternative A can be seen in Table VI and Table VII.

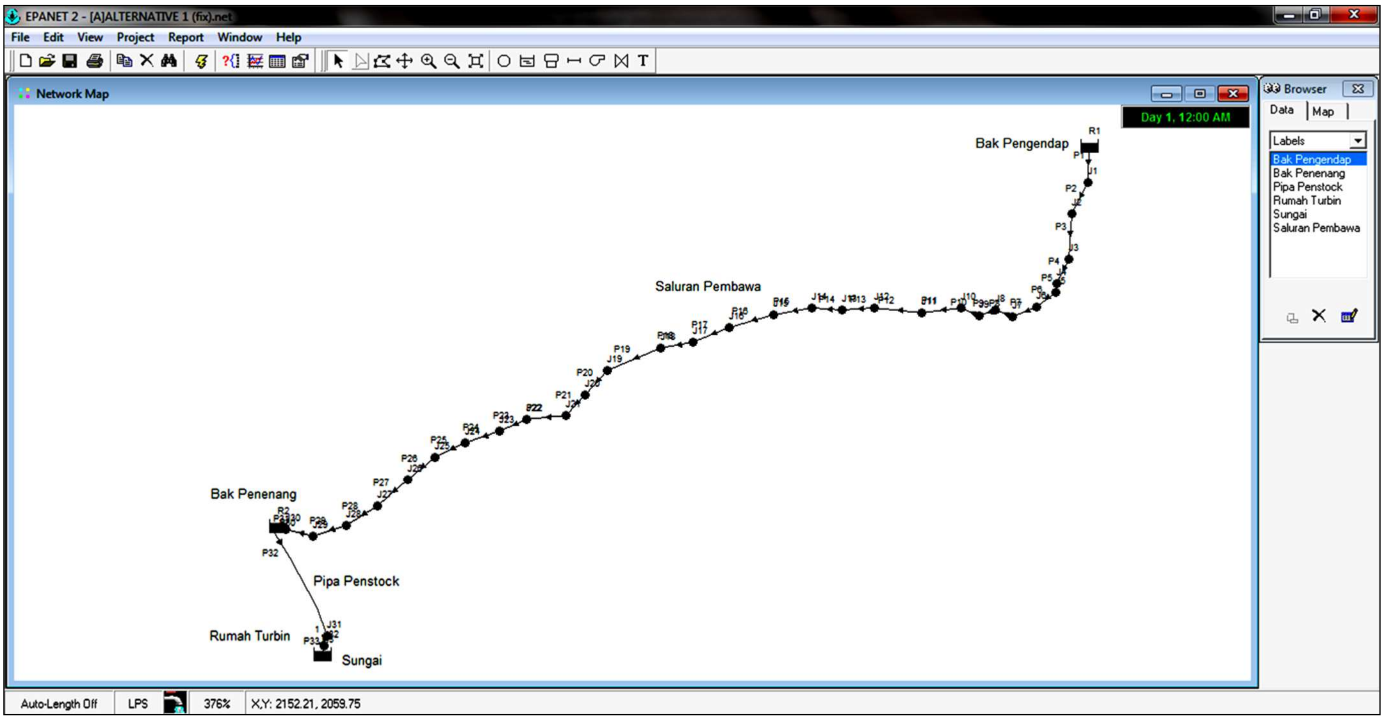

Fig. 124 Alternative Simulation A.

TABLE VI
ALTERNATIVE NODES A.

Node ID	Elevation	Demand	Head	Pressure	Node ID	Elevation	Demand	Head	Pressure
	(m)	(LPS)	(m)	(m)		(m)	(LPS)	(m)	(m)
Junc J1	354.73	0	356.64	1.91	Junc J19	350.25	0	350.05	-0.2
Junc J2	354.46	0	356.24	1.78	Junc J20	349.98	0	349.67	-0.31
Junc J3	354.1	0	355.71	1.61	Junc J21	349.72	0	349.35	-0.37
Junc J4	353.88	0	355.4	1.52	Junc J22	349.47	0	348.91	-0.56
Junc J5	353.76	0	355.3	1.54	Junc J23	349.24	0	348.58	-0.66
Junc J6	353.54	0	355.03	1.49	Junc J24	348.92	0	348.18	-0.74
Junc J7	353.35	0	354.74	1.39	Junc J25	348.92	0	347.79	-1.13
Junc J8	353.19	0	354.54	1.35	Junc J26	348.35	0	347.4	-0.95
Junc J9	352.99	0	354.34	1.35	Junc J27	348.08	0	346.95	-1.13
					Junc J28	347.8	0	346.53	-1.27
Junc J10	352.84	0	354.12	1.28	Junc J29	347.22	0	346.14	-1.08
Junc J11	352.58	0	353.68	1.1	Junc J30	347.13	0	345.83	-1.3
Junc J12	352.28	0	353.15	0.87	Junc J31	266.879	0	300.39	33.51
Junc J13	352.08	0	352.79	0.71					
Junc J14	351.69	0	352.45	0.76	Junc J32	266.879	0	267.88	1
Junc J15	351.51	0	352.02	0.51	Resvr R1	357.05	-1543.02	357.05	0
Junc J16	351.19	0	351.5	0.31	Resvr R2	345.73	-8980.73	345.73	0
Junc J17	350.78	0	351.06	0.28	Resvr R3	265.15	10523.75	265.15	0
Junc J18	350.49	0	350.69	0.2					

TABLE VII
ALTERNATIVE LINKS A.

Link ID	L	Ø	C	Q	v	HL	Link ID	L	Ø	C	Q	v	HL
	(m)	(mm)		(LPS)	(m/s)	(m/km)		(m)	(mm)		(LPS)	(m/s)	(m/km)
Pipe P1	62.93	800	150	1543.02	3.07	6.59	Pipe P17	66.4	800	150	1543.02	3.07	6.59
Pipe P2	59.95	800	150	1543.02	3.07	6.59	Pipe P18	55.48	800	150	1543.02	3.07	6.59
Pipe P3	79.98	800	150	1543.02	3.07	6.59	Pipe P19	97.8	800	150	1543.02	3.07	6.59
							Pipe P21	48.81	800	150	1543.02	3.07	6.59
Pipe P4	46.85	800	150	1543.02	3.07	6.59	Pipe P22	67.34	800	150	1543.02	3.07	6.59
Pipe P5	16.25	800	150	1543.02	3.07	6.59	Pipe P23	50.55	800	150	1543.02	3.07	6.59
Pipe P6	40.31	800	150	1543.02	3.07	6.59	Pipe P24	60.29	800	150	1543.02	3.07	6.59
Pipe P7	44.27	800	150	1543.02	3.07	6.59	Pipe P25	58.57	800	150	1543.02	3.07	6.59
Pipe P8	31.03	800	150	1543.02	3.07	6.59	Pipe P26	59.34	800	150	1543.02	3.07	6.59
Pipe P9	30.09	800	150	1543.02	3.07	6.59	Pipe P27	68.59	800	150	1543.02	3.07	6.59
Pipe P10	32.77	800	150	1543.02	3.07	6.59	Pipe P28	63.15	800	150	1543.02	3.07	6.59
Pipe P11	66.93	800	150	1543.02	3.07	6.59	Pipe P29	60.47	800	150	1543.02	3.07	6.59
Pipe P12	81.2	800	150	1543.02	3.07	6.59	Pipe P30	46.14	800	150	1543.02	3.07	6.59
Pipe P13	54.26	800	150	1543.02	3.07	6.59	Pipe P31	15.33	800	150	1543.02	3.07	6.59
Pipe P14	51.54	800	150	1543.02	3.07	6.59	Pipe P32	196.53	800	150	10523.75	20.94	230.68
Pipe P15	65.48	800	150	1543.02	3.07	6.59	Pipe P33	11.83	800	150	10523.75	20.94	230.69
Pipe P16	78.8	800	150	1543.02	3.07	6.59	Valve 1	#N/A	800	#N/A	10523.75	20.94	32.51

A summary of the simulation results of each alternative can be seen in Table VIII.

TABLE VIII
SIMULATION RESULTS FOR EACH ALTERNATIVE

Parameter	Pipe	L	v	Q	Heff
		(m)	(m/s)	(m^3/s)	(m)
Alternative A	HDPE Ø800	1718.00	3.07	1.543	78.85
Alternative B	GIP Ø950	1741.91	1.67	1.062	90.17
Alternative C	HDPE Ø700	1699.34	2.83	1.089	78.85
Alternative D	HDPE Ø700	1692.18	2.70	1.098	78.85

J. Generating Power Analysis

Analysis of generating power using formula (2.3) with the required calculation parameters in the form of discharge and effective head of the penstock pipe. η = 70% is used for each type of Crossflow turbine in Indonesia because the turbine efficiency in Indonesia is not too high due to the quality of the fabrication. The results of the calculation of generating power can be seen in Table IX.

TABLE IX
GENERATING POWER FOR EACH ALTERNATIVE

Parameter	Q	Heff	eff	P
	(m^3/s)	(m)		(kW)
Alternative A	1.543	78.85	70%	834.647
Alternative B	1.062	90.17	70%	656.714
Alternative C	1.089	78.85	70%	589.249
Alternative D	1.098	78.85	70%	593.917

IV. CONCLUSION

From the results of the research conducted, the following data were obtained: The dependable discharge obtained from the F.J Mock method is 1.177 m3 / s and can be fulfilled in November and December. Meanwhile, the dependable discharge obtained with the NRECA model is 1.061 m3 / s and can be fulfilled in October, November and December. Alternative D is the most optimum line because it has the shortest channel length of 1692.18 m, and the resulting power is 0.6 MW. Alternative tract D is superior to other alignments because it does not pass-through steep slopes, so it is safe and easy to install.

The suggestions that can be given from this test are as follows: To get more valid results, further research is needed on constructing the carrier pipe supports. Rainfall data is expected to use complete data and from reliable sources. It is advisable to conduct a field survey in advance to study the conditions in the field, and the results will be by the actual conditions.

ACKNOWLEDGEMENT

This research was supported by Faculty of Engineering, University of Andalas We thank our colleagues from Department of Civil Engineering who provided insight and expertise that greatly assisted the research.

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