PERFORMANCE AND DESIGN OF THE BIFURCATION STRUCTURE AT TOILI RIVER

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ABSTRACT
One of The flooding of June 18, 2019 caused damage to the check dam structure on the Toili River branch, causing flooding during the rainy season and water being unable to flow into the Mansahang River which irrigates the Toili irrigation network and the Moilong irrigation network during the dry season. The purpose of this study is to design a bifurcation structure by modeling river hydraulics so that water can be supplied to the Moilong Irrigation Area and Toili Irrigation Area and to provide a sense of security from the threat of water damage. The data needed are: hydroclimatological data, watersheds, and river situation maps. Based on the results of the HEC-RAS analysis and simulation, the bifurcation structure of alternative-2 was chosen. This condition is very satisfying, where during floods the water can flow proportionally to the river branches and during the dry season the water needs are met.

Keywords: Bifurcation Structure, Hydraulics Modeling, Toili River

1. INTRODUCTION
Rivers as a source of water are very useful in meeting community needs, for example for agricultural irrigation, drinking water raw materials, as a drainage channel for rainwater, even as a tourist attraction. The condition of the river in the upstream is usually in the form of forest vegetation density, in the middle part it is heavily influenced by agricultural cultivation and some settlements, and in the downstream part of the river is dominated by the impact of dense settlements with all their sediment and waste problems.
Rivers in the Province of Central Sulawesi, Indonesia generally carries a large amount of sediment at the time of flooding so that it has an impact on changes in river morphology. The result is the overflow of river water when it rains and the area around the river is threatened during floods. To reduce the impact of the flood, it is necessary to plan for flood control infrastructure structures in the upstream, middle and downstream of the river.
The Toili River is one of the rivers in Central Sulawesi Province which has the characteristics of a river branching downstream (about 6 km from the river mouth) so that the flow is divided into two directions, namely, the Toili River/Moilong River on the left and the Mansahang River on the right. Before the river forks (±100 m) there is a free intake to irrigate the Moilong Irrigation Area of 1007 ha. While on the Mansahang River there is a Toili Weir to irrigate an area of 2410 ha.
The flood incident on June 18, 2019 resulted in the destruction of check dam structure at the river's branches, submerging seven villages in Moilong District, Banggai Regency, Central Sulawesi. With the collapse of this structure, in July and August 2020 there was another flood and submerged several villages in Moilong District. This happens

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repeatedly during the rainy season. On the other hand, due to the damage to this structure, the flow of water does not flow into the Mansahang River so that it interferes with the Toili irrigation network system, where the water requirement needed for rice processing is 5.061 m3/s and the water requirement for the Moilong Irrigation Area is 2.115 m3/s.

The aim of this study is to create a sense of security in the community from the threat of danger due to the destructive power of water, especially in the downstream part of the river branches and to ensure water supply for the Moilong Irrigation Area and Toili Irrigation Area. To achieve this goal, the purpose of this research is to design a bifurcation structure by modeling river hydraulics so that water is supplied to the Moilong Irrigation Area (free intake Moilong) and to the Toili Irrigation Area (Toili dam) and to provide a sense of security from the threat of water damage, especially in downstream part of the river. For this reason, river hydraulics modeling is needed. The river hydraulics modeling uses the HEC-RAS 6.0 model with variations in the location of the bifurcation structure, the cross-sectional shape of the bifurcation, the dependable flow and the design discharge.

2. METHODOLOGY

2.1 *Description of study*

The location of the work is in Toili District and Moilong District, Banggai Regency, Central Sulawesi Province, Indonesia with coordinates 01°23'28" south latitude and 122°20'10" east longitude. Area of catchment Toili is 191.450 km2 and the long of main river around 31.97 km. For more details, the location of the research is presented in the Figure 1.

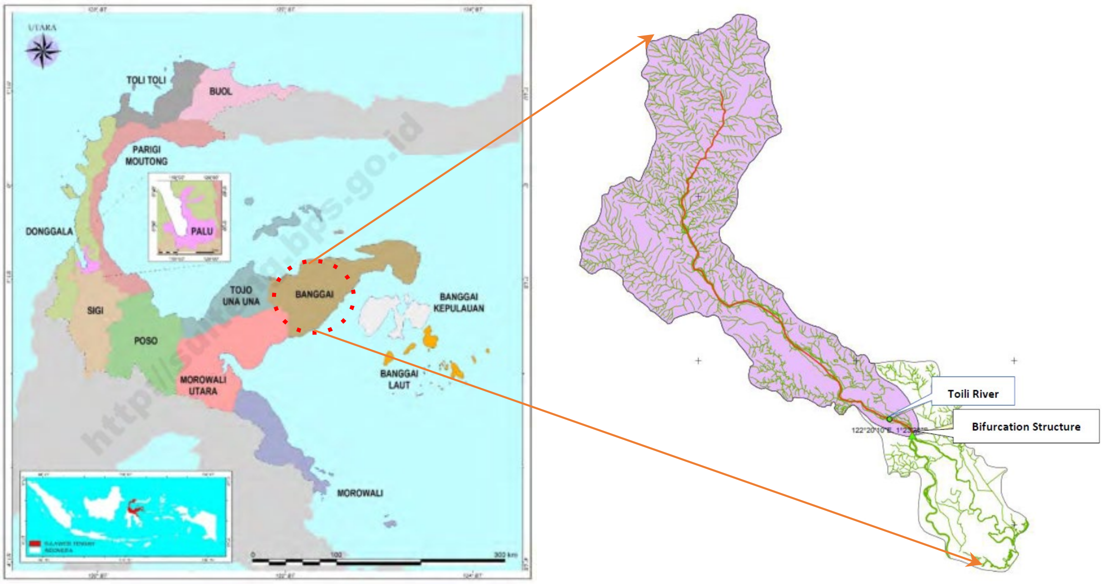

Figure 1. Map of location and Toili watershed

2.2 *Model description*

2.2.1 Frequency analysis

Rain frequency analysis is very necessary in calculating the design flood event if at the planned location there is no recording of the maximum long-term and continuous discharge. Some of the methods that are often used include normal distribution, log normal distribution, Pearson type III distribution, and Gumbell distribution. The choice of the method depends on the statistical parameters except the Pearson type III log distribution which is not implied. Therefore, in this study, the Log Pearson type III method was used III ((Hadisusanto, 2011), (Soemarto, 1978)). Furthermore, the distribution was tested using the Chi Square and Smirnov-Kolmogorov methods to ensure that the selection of frequency analysis was appropriate. The input data is in the form of maximum daily rain during the 20-year observation period (2000-2019). The data was obtained from the Office of Human Settlements and Water Resources of Central Sulawesi, Indonesia.

2.2.2 Design flood discharge analysis

Planning flood analysis is very important for planning water structures, for example weirs, flood protection structures, bridges and others. Flood discharge analysis was carried out by various methods, including frequency analysis of maximum discharge data. This condition is carried out if the discharge data is available in the measuring structure on the river. If discharge data are not available, the analysis can be carried out using the Synthetic Unit Hydrograph (HSS) method or the rational method (Irawan, 2011).

Factors causing flooding include high rainfall, reduced land cover in the upstream area and reduced river channel capacity, especially in the downstream area due to sedimentation and the topography of the area. In order to protect the danger of flooding in the river, a structure plan can be carried out which aims to reduce the damage caused by flooding to the minimum level. The control planning can be carried out properly if the rainfall data at each rain station can be known and the discharge calculated using a synthetic and rational hydrograph unit or using frequency analysis if discharge data is available (Siby,2013).

Rain characteristics change, daily rain and rainfall intensity tend to increase, followed by increasing flood discharge, resulting in more people at risk and increasing damage, loss, and losses(Suripin,2016).

The design flood is determined based on an analysis of the maximum daily rainfall recorded. The maximum discharge frequency is rarely applied because of the limited observation period. So, the analysis is carried out using empirical equations taking into account the related natural parameters. To determine the design flood discharge, the peak flood discharge analysis was carried out with several different methods. Some of the methods used in this study are: the Nakayasu HSS Method, the Haspers Method and the Snyder HSS Method. Input data in the form of design rain calculation results of frequency analysis and watershed characteristics (watershed area, river length, river slope). The watershed map was obtained from the Bakosurtanal Office in Bogor, Indonesia.

2.2.3 Evapotranspiration

Evapotranspiration is the event of water loss from plant tissue and the soil surface used as a place to grow plants. Many methods can be used to calculate evapotranspiration. Potential evapotranspiration is calculated by the Penman Monthiet: (Ansari, 2017) The input data is in the form of climatological data for Singkoyo Station for 2000-2019 which was obtained from the Department of Human Settlements and Water Resources of Central Sulawesi.

2.2.4 Water availability

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Analysis of water availability using the F.J. model. mock. The principle of the Mock method in his paper, land and capability appraisal and water availability appraisal, (1973) explains that the rain that falls on the watershed will partly be lost as evapotranspiration, some will directly become surface runoff and some will enter the soil (infiltration). The infiltration process in the first stage will saturate the surface soil and become percolation to form ground water which will then come out in the river as base flow [28-30]. (Input data in the form of monthly rain data, number of rainy days, evapotranspiration and watershed area.

2.2.5 Dependable flow

Dependable flow is a discharge that is expected to be available throughout the year with the smallest possible calculated failure risk (Richard,1998). The input data is the result of calculating the availability of water which is ranked and the probability is calculated using the Weibull equation (Hadisusanto, 2021).

2.2.6 Bifurcation structure preliminary design

Sediment retaining structure (BPS) is one of the sediment controls structures that functions to accommodate and control the flow of sediment in rivers and to hold sediment deposits that have settled upstream of the structure. In addition, BPS controls the flow velocity and controls the sediment discharge so as not to cause damage to the river environment and other water resource infrastructure, property losses and loss of life due to excess sediment flow. BPS can also be used for other purposes as long as it does not interfere with its main functions, including pedestrian bridges, water collection and others (Hadisusanto, 2018).

The first step in making a bifurcation structure model is to adopt the check dam equation. The purpose of making a check dam is to resist bottom erosion, accommodate and control sediment flow so that the peak discharge of sediment flow can be reduced. While the benefit is that sediment flows downstream in a controlled manner little by little so as not to damage the river structure or downstream area (Hasan, 2022)

The dimensions of the check dam structure spillway must be designed to be able to pass the design discharge. The water level above the check dam spillway should be designed to be no more than 2.50 m to avoid over dimensioning the dam body. The width of the spillway is recommended to be 60% to 80% of the river width. Dam height is determined based on the planned holding capacity and sediment control. The dimensions of the check dam body, wings, protected floor and others are determined based on the check dam structure design criteria (Hasan, 2022). Input data in the form of design flood discharge calculation results from design flood discharge analysis and cross-sectional geometry of the river.

2.2.7 Hydraulic modeling (HEC-RAS)

The water level profile analysis uses a non-steady flow approach because one of the things that affects the water level is the flow rate which is not constant in the time dimension. Calculation of the water level profile with unsteady conditions using the HEC RAS (Hydraulic Engineering Center – River Analysis System) program package from the US Army Corps of Engineers. The river hydraulics modeling is carried out with variations in the location of the bifurcation structure, the cross-sectional shape of the bifurcation, the dependable flow and the design discharge. Data on longitudinal and transverse sections of the Toili River were obtained from the Office of Human Settlements and Water Resources of Central Sulawesi.

3. METHODS

The complete research methodology is presented in Figure 2.

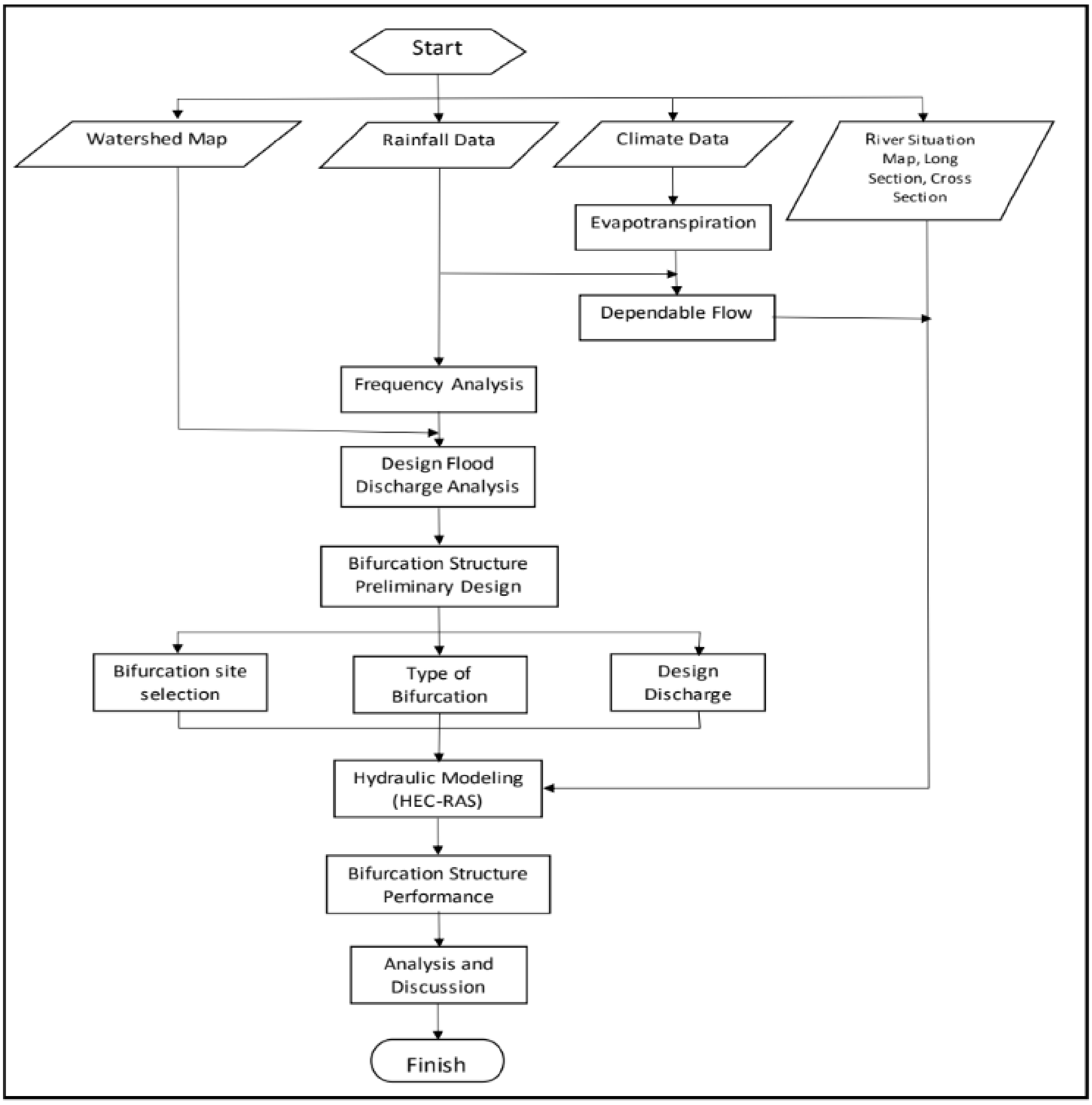

Figure 2. Research flow chart

4. RESULT AND DISCUSSION

4.1 *Frequency analysis*

For design purposes, the frequency analysis using the Log Pearson III method is calculated at a return time of 1.01; 2; 5; 10; 25; 50; 100; 200 and 1000 years. The results are presented in Figure 4. It can be seen that the magnitude of the return period and the design rain form a straight line except for the 1.01-year return period.

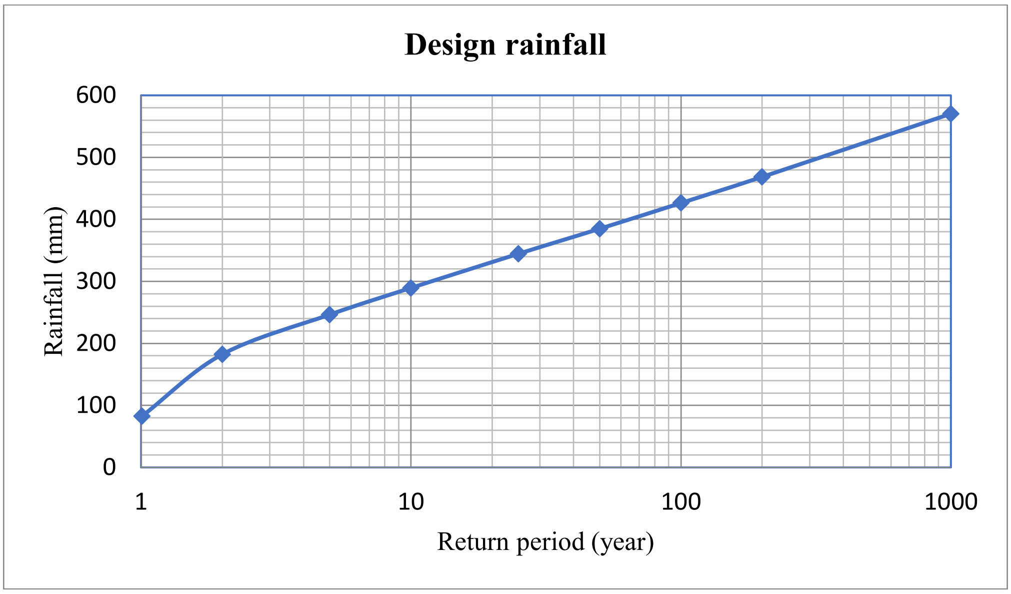

Figure 3. Design rain graphics

4.2 *Design flood discharge*

The results of the calculation of the design flood discharge with several methods are presented in Table 1 and Figure 4. The calculation results of the three methods look very much different. The HSS Nakayasu method showed the greatest results, followed by the HSS Snyder method and the Haspers method. While the average results are between HSS Snyder and HSS Nakayasu. With various considerations, in designing the bifurcation structure using the Snyder HSS Method because this method results are closer to the reality on the ground. Meanwhile, according to existing regulations, the design of the bifurcation structure uses a design flood discharge with a return period of 25 years.

Table 1. Recapitulation of the calculation of the design flood discharge

Return Period (year)	Methods			Discharge (m3/s)	
	M. Haspers	HSS Nakayasu	HSS Snyder	Max	Average
1.01	168.96	385.01	239.69	385.01	264.55
2	371.93	847.52	527.64	847.52	582.36
5	502.62	1145.34	713.05	1145.34	787.00
10	590.41	1345.40	837.60	1345.40	924.47
25	702.66	1601.18	996.84	1601.18	1100.22
50	785.04	1788.89	1113.70	1788.89	1229.21
100	869.67	1981.74	1233.76	1981.74	1361.72
200	955.63	2177.63	1355.72	2177.63	1496.33
1000	1163.30	2650.85	1650.33	2650.85	1821.49

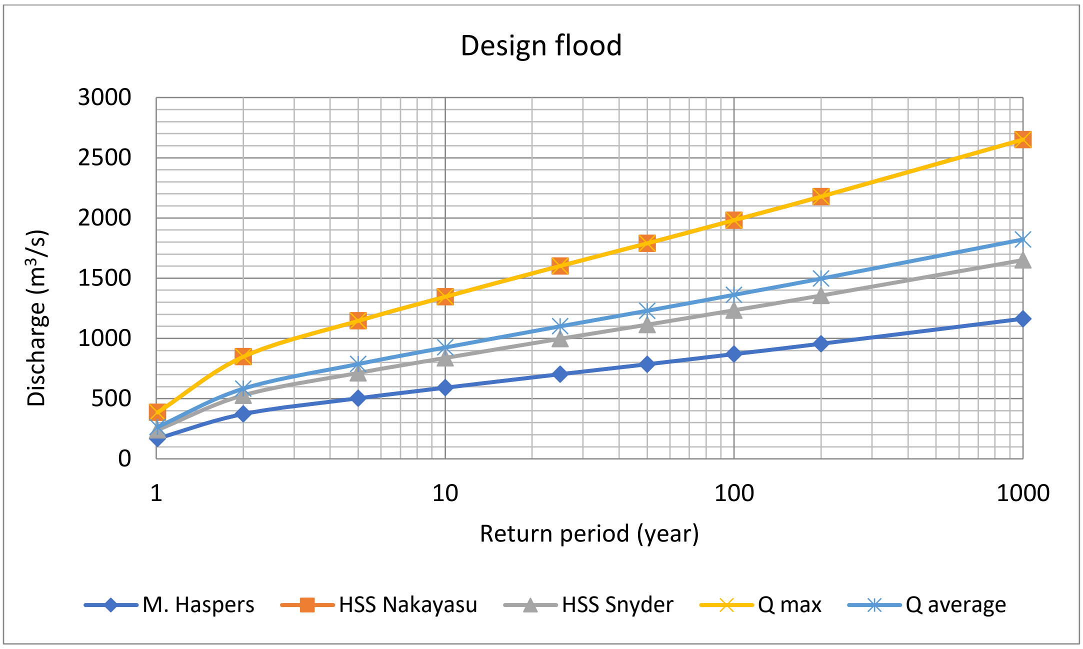

Figure 4. Graph of the calculation of the design flood discharge

4.3 *Dependable flow*

The results of the dependable flow calculation (Q80) using the Weibull method are presented in Figure 6 below. The dependable flow of the Toili River forms an inverted V, where the largest dependable flow occurs in July. There is a fairly long drought from January to April and November to December.

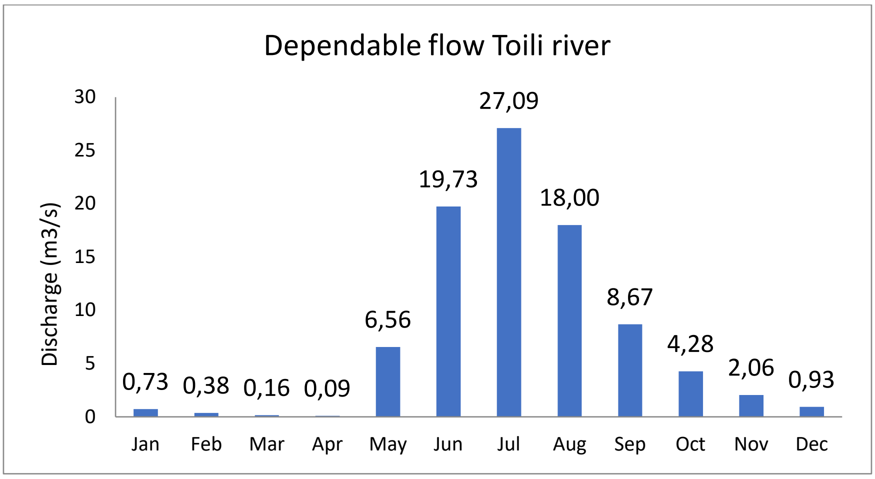

Figure 5. Toili River dependable flow graph

4.4 *Preliminary design of bifurcation structure*

The data and considerations made in designing the bifurcation structure include:

1. Technical requirements
   a. Flood height above spillway 2.50 m
   b. Spillway width is recommended 60% to 80% of the river width
2. The width of the river in the bifurcation structure plan

3. Location and width of the old check dam (B = 2 x 60 m)
4. Design discharge (Q25 = 996.84 m3/s)
5. Moilong free intake threshold elevation +41.89
6. The discharge required for the Moilong free intake is 2.115 m3/s
7. The water requirement of the Toili Irrigation Area is 5.061 m3/s, it is planned that 120% = 1.2 x 5.061 = 6.073 m3/s
8. Fair distribution of water during the dry season and a sense of security to residents downstream of the Bifurcation structure from the threat of flooding during the rainy season.

4.5 *Design concept*

Based on the bifurcation structure planning criteria, two alternative locations for the bifurcation structure are made as follows:

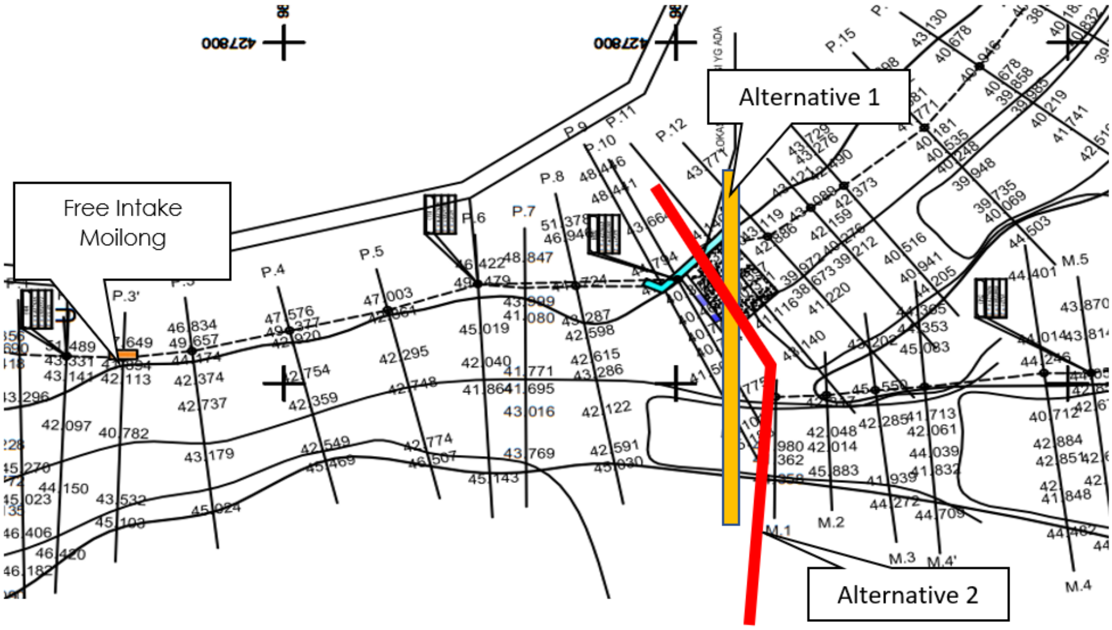

Figure 6. Alternative bifurcation structure location

The bifurcation structure is planned on the site of an old structure that has been destroyed. Two alternatives are planned for the placement of the bifurcation structure, namely alternative-1 is made perpendicular to the river upstream and alternative-2 is planned at an angle with the structure position perpendicular to the direction of the water flow downstream. The chosen alternative will be based on the results of river hydraulics modeling (HEC-RAS) to determine the pattern of river flow that occurs.

4.6 *The initial design of the bifurcation structure*

4.6.1 *Overflow planning*

Based on technical considerations, the dimensions of the bifurcation structure can be calculated as follows:

- The design discharge is divided into two, namely towards the Moilong River and to the Mansahang/Toili River = 996.84/2 = 498.42 m3/s

- A gap was created in the bifurcation structure leading to the Mansahang/Toili River with the aim of irrigating the Toli Irrigation Area. It is planned that the size of the gap is 10 m wide and 0.5 m high. Check the discharge flowing into the gap:
  Q = 1,771 b h^3/2 (1)
  = 1.771 x 10 x 0.5^1.5 = 6.261 m3/s > 6.073 m3/s (water demand for Toili Irrigation Area)
- Bifurcation structure overflow dimensions
  Q = 1.771 B + 1.42 h) h^(3/2) (2)
  The slope of the slope is planned to be 1 : 1
  The water level above the spillway is planned to be 2.5 m
  498.42 = (1.771 x B + 1.42 x 2.5)x 2.5^1.5
  B = 69.2 70 m
  So the bifurcation structure is planned to be B = 2 x 70 m with a gap in the Mansahang/Toili River section

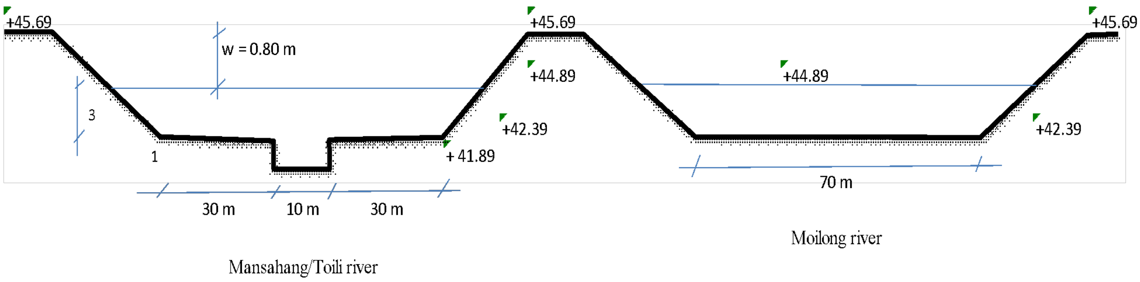

Figure 7. Cross-sectional sketch of the bifurcation structure

4.6.2 *sub dam and floor design*

Sub dam location and height

L = lw + X + b2

(3)

Calculation:

$$Vr = \sqrt{2g(H1 + h1)} = \sqrt{2x9.81(2.58 + 2.50)} = 9.98.....m/s$$

$$q = \frac{Q_{25}}{B} = \frac{498.42}{70} = 7.12....m^3/s/m$$

$$hr = \frac{q}{Vr} = \frac{7.12}{9.98} = 0.71......m$$

$$Fr = \frac{Vr}{\sqrt{(gxhr}} = \frac{9.98}{\sqrt{9.81x0.71}} = 3.78$$

$$hj = \frac{hr}{2}(\sqrt{(1 + 8.Fr^2} - 1 = \frac{0.71}{2}(\sqrt{(1 + 8x3.78^2} - 1) = 3.45....m$$

X = β . hj = 5 x 3.45 = 17.25 ≈ 18.00 m

$$Vo = \frac{q}{h1} = \frac{7.12}{2.50} = 2.848....m/s$$

$$lw = Vo\left[\frac{2(H1+1/2h1)}{g}\right]^{1/2} = 2.848\left[\frac{2(2.58+1/2x2.5)}{9.81}\right]^{0.5} = 2.52 \cong 2.60...m$$

L = lw + X + b2 = 2,6 + 18 + 1,5 = 22,1 ≈ 23 m (Distance to main dam to sub-dam)

Floor thickness

t = 0.2 (0.6H + 3h1 – 1)

(4)

$$t = 0.2\ (0.6 \times 2.58 + 3 \times 2.5 - 1) = 1.61\ \approx 1.70\ \mathrm{m}$$

Sub dam cross section design:

1) The sub dam standard design follows the main dam design standard as follows:
2) The width of the sub dam lighthouse is the same as the width of the main dam crest
3) The slope of the sub-dam embankment is the same as that of the main dam
4) The water level above the sub dam crest is the same as the main dam

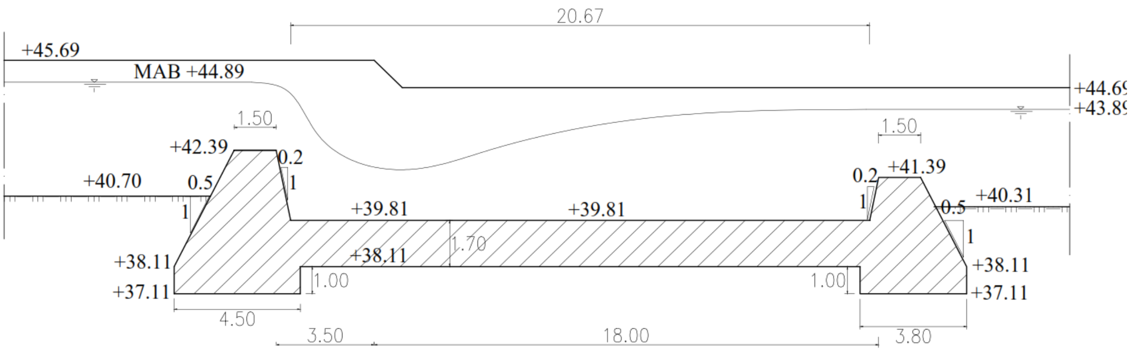

Figure 8. Longitudinal section of the bifurcation structure

4.7 *HEC-RAS running results*

The data and considerations made in designing the bifurcation structure include:

a. River geometry

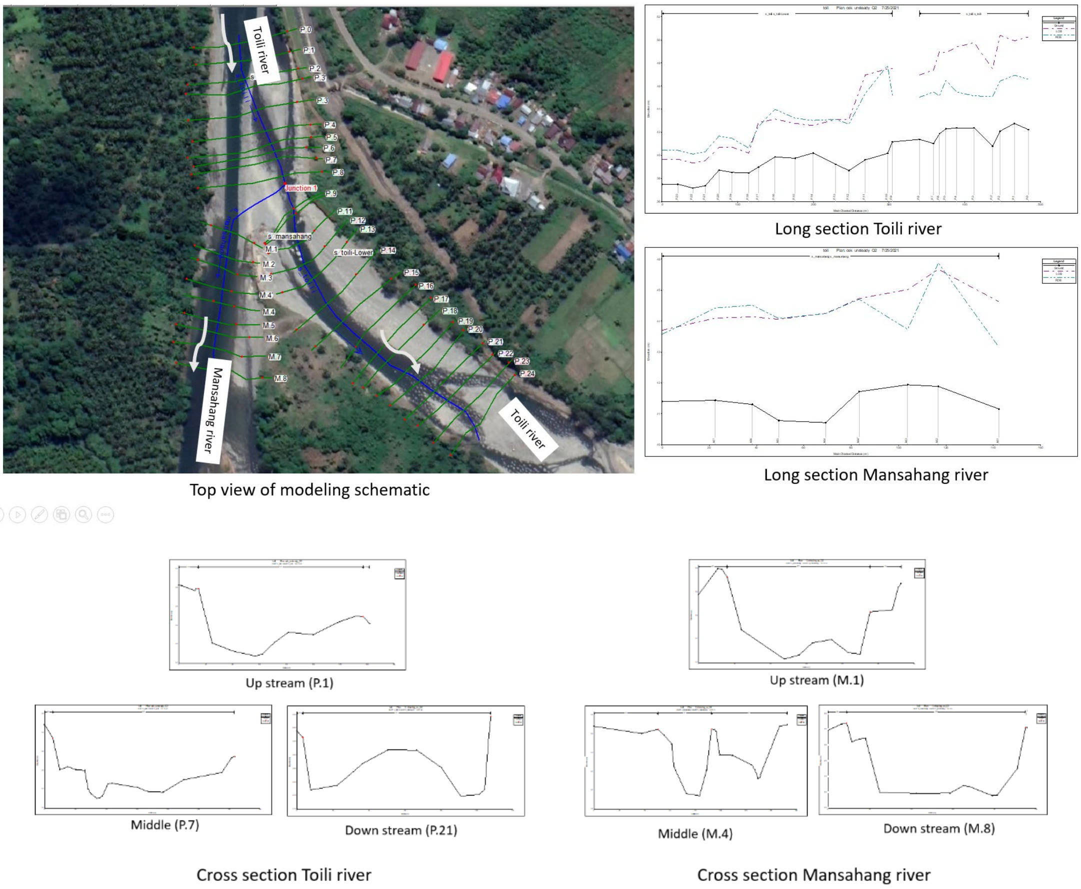

Figure 9. Geometrics of the Toili and Mansahang Rivers

b. Boundary conditions

Figure 10. Simulation boundary conditions

c. Results of running HEC-RAS on existing conditions

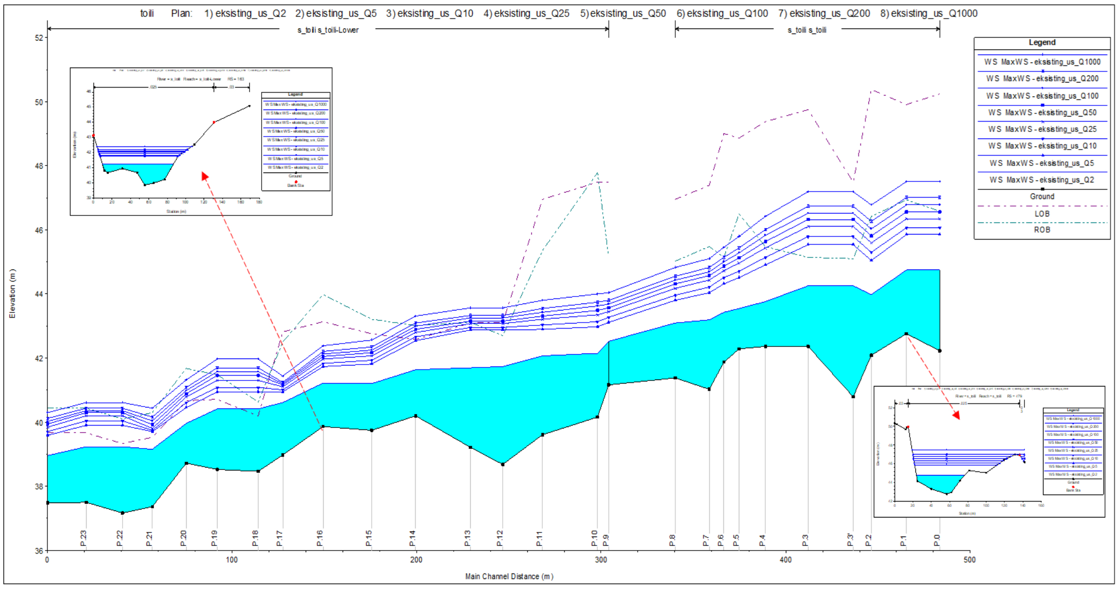

Figure 12. The results of running HEC-RAS on the existing condition of the Mansahang River

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Table 2. Results of running HEC-RAS on the existing condition of the Toili River

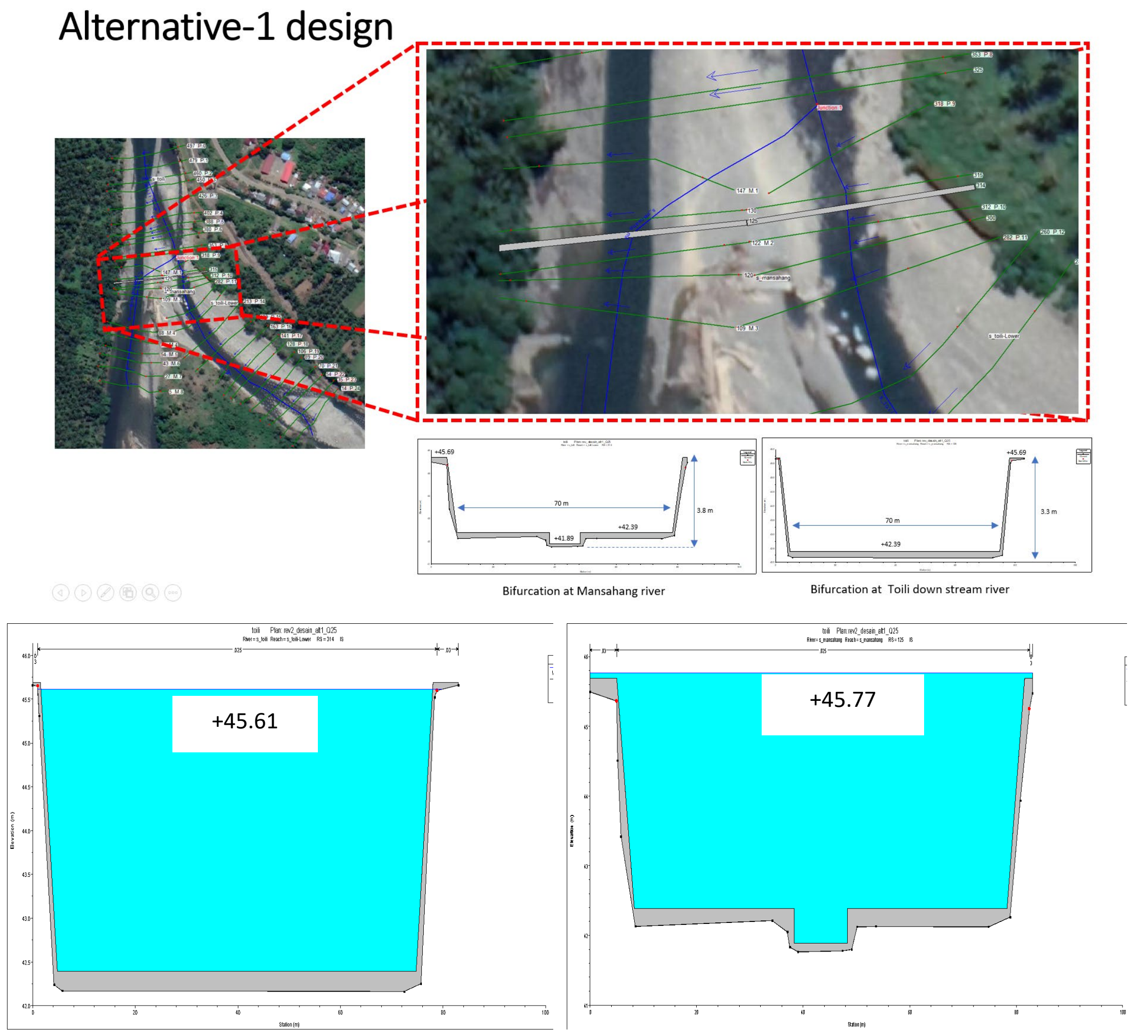
Reach	River Sta		Profile	Q Total (m3/s)	Min Ch El (m)	LOB Elev (m)	W.S. Elev (m)	ROB Elev (m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
s_toili	497	P.0	Max WS	996.81	42.22	50.25	46.42	46.57	2.45	406.8	148.03	0.47
s_toili	479	P.1	Max WS	996.84	42.76	49.92	46.42	46.94	4.94	201.81	100.52	1.11
s_toili	460	P.2	Max WS	996.81	42.1	50.39	45.71	46.42	3.57	279.14	111.28	0.72
s_toili	450	P.3'	Max WS	996.76	40.78	47.49	46.17	45.1	2.49	400.68	97.13	0.39
s_toili	426	P.3	Max WS	996.79	42.37	49.74	46.17	45.14	3.98	251.89	90.55	0.76
s_toili	402	P.4	Max WS	996.8	42.36	49.39	45.52	45.47	4.81	207.17	78.22	0.94
s_toili	388	P.5	Max WS	996.8	42.29	48.86	45.11	46.51	4.91	203.12	85.87	1.02
s_toili	380	P.6	Max WS	996.79	41.86	49.01	44.95	45.14	5.4	184.5	92.33	1.22
s_toili	372	P.7	Max WS	996.79	41.03	47.39	44.77	46.12	5.34	186.82	86.4	1.16
s_toili	353	P.8	Max WS	996.79	41.38	46.95	44.45	45.03	5.29	188.53	116.84	1.33
s_toili-Lower	318	P.9	Max WS	680.56	41.16	47.48	44.24	45.19	2.98	232.64	119.77	0.63
s_toili-Lower	312	P.10	Max WS	680.57	40.15	47.48	44.13	47.77	3.51	202.54	106.31	0.69
s_toili-Lower	282	P.11	Max WS	680.56	39.6	46.95	43.25	45.36	5.55	122.63	80.8	1.44
s_toili-Lower	260	P.12	Max WS	680.56	38.67	43.12	43.09	42.71	3.8	180.34	102.32	0.89
s_toili-Lower	243	P.13	Max WS	680.56	39.21	43.09	43.09	43.12	4.54	151.04	90.84	1.04
s_toili-Lower	213	P.14	Max WS	680.56	40.2	42.58	42.78	43.01	5.6	124.88	86.58	1.37
s_toili-Lower	189	P.15	Max WS	680.56	39.73	42.76	42.04	43.21	5.09	133.82	95.98	1.38
s_toili-Lower	163	P.16	Max WS	680.56	39.86	43.13	41.93	43.98	6.06	112.38	89.66	1.73
s_toili-Lower	141	P.17	Max WS	680.56	38.97	42.82	41.07	42.5	7.41	91.9	106.59	2.55
s_toili-Lower	128	P.18	Max WS	680.56	38.46	40.19	41.24	40.63	2.42	294.51	140.71	0.53
s_toili-Lower	106	P.19	Max WS	680.56	38.53	40.7	41.24	41.47	3.73	183.49	107.46	0.9
s_toili-Lower	89	P.20	Max WS	680.56	38.73	40.68	40.75	41.68	5.18	131.49	120.26	1.57
s_toili-Lower	70	P.21	Max WS	680.56	37.35	39.53	39.75	40.3	4.47	152.5	106.57	1.18
s_toili-Lower	54	P.22	Max WS	680.55	37.15	39.33	40.15	40.1	3.16	217.15	107.8	0.7
s_toili-Lower	35	P.23	Max WS	680.55	37.5	39.67	40.15	40.44	3.81	179.37	107.34	0.93
s_toili-Lower	14	P.24	Max WS	680.56	37.48	39.66	39.8	40.43	4.77	142.67	105.4	1.3

Table 3. The results of running HEC-RAS on the existing condition of the Mansahang River

Reach	River Sta		Profile	Q Total (m3/s)	Min Ch El (m)	LOB Elev (m)	W.S. Elev (m)	ROB Elev (m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
s_mansahang	147	M.1	Max WS	316.22	41.15	44.62	43.84	43.15	3.95	82.83	45.64	0.88
s_mansahang	122	M.2	Max WS	316.21	41.88	45.67	44.05	45.88	3.89	81.5	43.59	0.9
s_mansahang	109	M.3	Max WS	316.21	41.94	45.02	43.87	43.73	1.96	146.14	77.55	0.51
s_mansahang	88	M.4'	Max WS	316.21	41.71	44.73	43.87	44.71	3.56	88.89	62.63	0.95
s_mansahang	74	M.4	Max WS	316.21	40.71	44.25	43.34	44.24	4.37	89.87	71.72	1
s_mansahang	54	M.5	Max WS	316.21	40.78	44.06	43.19	44.09	3.59	88.02	84.65	1.12
s_mansahang	43	M.6	Max WS	316.2	41.3	44.14	43.31	44.52	2.46	128.63	112.19	0.73
s_mansahang	27	M.7	Max WS	316.19	41.44	44.09	43.31	44.42	2.45	129.14	80.57	0.62
s_mansahang	5	M.8	Max WS	316.19	41.4	43.7	43.28	43.57	2.59	122.2	83.4	0.68

In the existing condition, with a discharge load of Q25, the distribution of water discharge flowing from the Toili River to the downstream Toili River/Moilong River is 68.3% and to the Mansahang River is 31.7%. In other words, from the total Q25 discharge (996.81 m3/s), 680.56 m3/s flows into the lower Toili/Moilong River, the remaining 316.22 m3/s flows into the Mansahang River. With almost the same river capacity, between the lower Toili River and the Mansahang River, it is expected that water will flow proportionally (50%) to each river. With this condition, it causes catastrophic flooding in the lower Toili River during the rainy season and causes water shortages in the Mansahang River/Toili weir during the dry season.

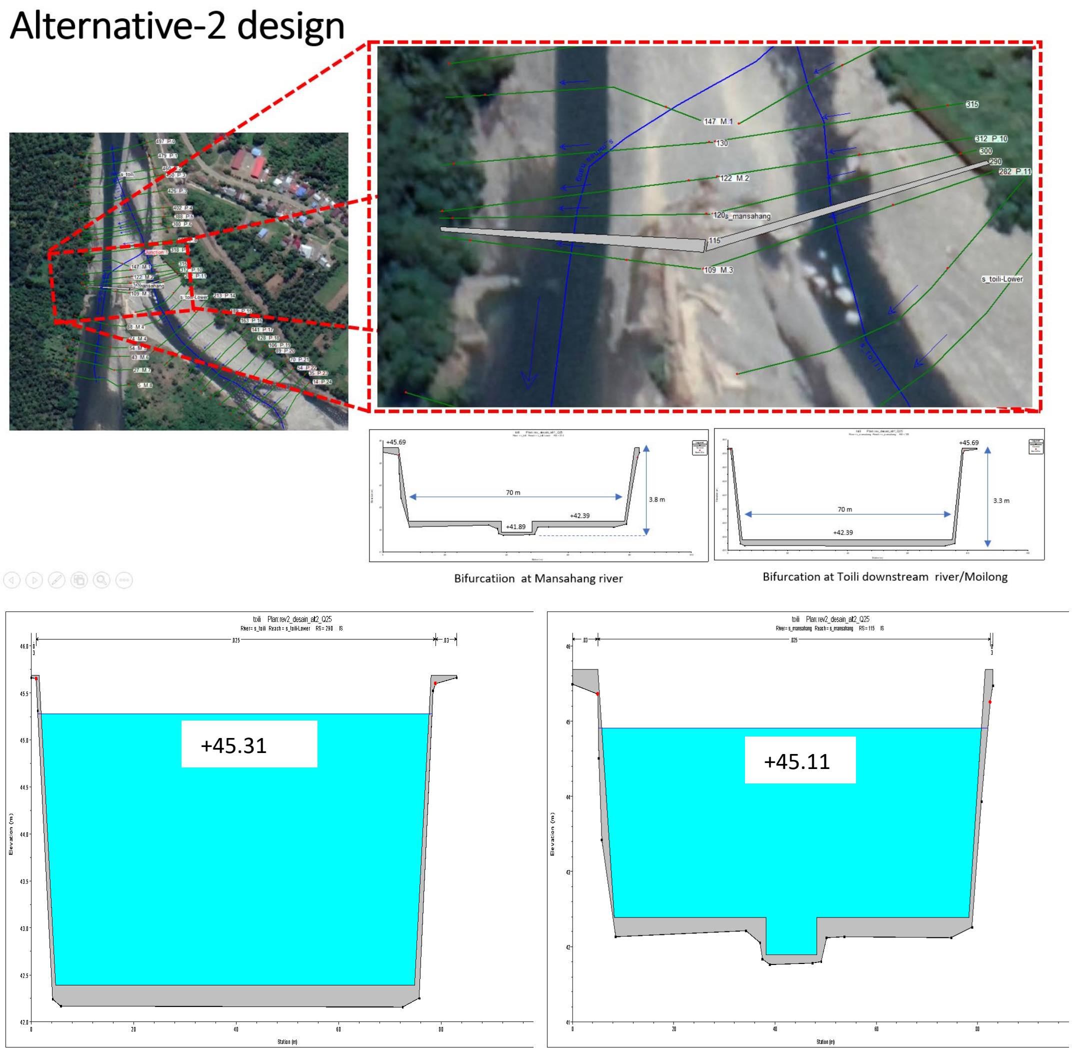
d. Results of running HEC-RAS on existing conditions



Bifurcation at downstream Toili river/Moilong　　Bifurcation at Mansahang river

Figure 13. Alternative-1 bifurcation structure design

In alternative design 1, there is no significant change to the distribution of water discharge and the existing water level. Changes in discharge only ranged from 5 to 8 m3/s. The flood water level is almost level with the embankment and the water almost overflows.



Bifurcation at Toili downstream river/Moilong
Bifurcation at Mansahang river

Figure 14. Alternative-2 Bifurcation structure design

In alternative-2 design, changes in discharge and water level occur quite large, where in the downstream Toili/Moilong River there is a reduction in the discharge value to 112 m^3/s. The value is then allocated to the Mansahang River (the discarge increases). The flood water level elevation in alternative design condition 2 in the downstream Toili/Moilong River is +45.31, while in the Mansahang River the floodwater level is +45.11. In this condition, there is still a guard height.

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Table 4. Results of running HEC-RAS in existing conditions (alternative-1 and 2)

River	Reach	River Sta	Profile	Eksisting		Alt-1		Alt-2		Selisih Eks dan Alt-1		Selisih Eks dan Alt-2	
				Debit	Muka Air	Debit	Muka Air	Debit	Muka Air	Debit	Muka Air	Debit	Muka Air
s_toili	s_toili	497 P.0	Max WS	996.81	46.42	996.81	46.5	996.81	46.45	0.00	0.08	0.00	0.03
s_toili	s_toili	479 P.1	Max WS	996.84	46.42	996.82	46.5	996.82	46.45	-0.02	0.08	-0.02	0.03
s_toili	s_toili	460 P.2	Max WS	996.81	45.71	996.8	45.83	996.8	45.75	-0.01	0.12	-0.01	0.04
s_toili	s_toili	450 P.3'	Max WS	996.76	46.17	996.8	46.23	996.8	46.19	0.04	0.06	0.04	0.02
s_toili	s_toili	426 P.3	Max WS	996.79	46.17	996.79	46.23	996.79	46.19	0.00	0.06	0.00	0.02
s_toili	s_toili	402 P.4	Max WS	996.8	45.52	996.77	45.63	996.78	45.56	-0.03	0.11	-0.02	0.04
s_toili	s_toili	388 P.5	Max WS	996.8	45.11	996.75	45.28	996.78	45.17	-0.05	0.17	-0.02	0.06
s_toili	s_toili	380 P.6	Max WS	996.79	44.95	996.76	45.18	996.77	45.03	-0.03	0.23	-0.02	0.08
s_toili	s_toili	372 P.7	Max WS	996.79	44.77	996.75	45.1	996.77	44.9	-0.04	0.33	-0.02	0.13
s_toili	s_toili	353 P.8	Max WS	996.79	44.45	996.74	45.18	996.77	44.68	-0.05	0.73	-0.02	0.23
s_toili	s_toili	325	Max WS	996.8	44.3	996.46	45.52	996.72	45.1	-0.34	1.22	-0.08	0.80
s_toili	s_toili-Lower	318 P.9	Max WS	680.56	44.24	687.55	45.61	568.5	45.31	6.99	1.37	-112.06	1.07
s_toili	s_toili-Lower	315	Max WS	680.57	44.24	687.43	45.61	568.51	45.31	6.86	1.37	-112.06	1.07
s_toili	s_toili-Lower	312 P.10	Max WS	680.57	44.13	686.31	45.08	568.59	45.28	5.74	0.95	-111.98	1.15
s_toili	s_toili-Lower	300	Max WS	680.56	44.07	686.14	44.39	568.59	45.28	5.58	0.32	-111.97	1.21
s_toili	s_toili-Lower	282 P.11	Max WS	680.56	43.25	686.1	43.38	567.96	44.17	5.54	0.13	-112.60	0.92
s_toili	s_toili-Lower	260 P.12	Max WS	680.56	43.09	686.07	43.14	568.39	43.24	5.51	0.05	-112.17	0.15
s_toili	s_toili-Lower	243 P.13	Max WS	680.56	43.09	686.09	43.14	568.37	43.14	5.53	0.05	-112.19	0.05
s_toili	s_toili-Lower	213 P.14	Max WS	680.56	42.78	686.08	42.8	568.39	42.69	5.52	0.02	-112.17	-0.09
s_toili	s_toili-Lower	189 P.15	Max WS	680.56	42.04	686.07	42.05	568.43	41.93	5.51	0.01	-112.13	-0.11
s_toili	s_toili-Lower	163 P.16	Max WS	680.56	41.93	686.07	41.94	568.47	41.82	5.51	0.01	-112.09	-0.11
s_toili	s_toili-Lower	141 P.17	Max WS	680.56	41.07	686.06	41.08	568.48	40.99	5.50	0.01	-112.08	-0.08
s_toili	s_toili-Lower	128 P.18	Max WS	680.56	41.24	686.03	41.25	568.46	41.02	5.47	0.01	-112.10	-0.22
s_toili	s_toili-Lower	106 P.19	Max WS	680.56	41.24	686.05	41.25	568.47	41.02	5.49	0.01	-112.09	-0.22
s_toili	s_toili-Lower	89 P.20	Max WS	680.56	40.75	686.05	40.76	568.46	40.53	5.49	0.01	-112.10	-0.22
s_toili	s_toili-Lower	70 P.21	Max WS	680.56	39.75	686.04	39.76	568.36	39.74	5.48	0.01	-112.20	-0.01
s_toili	s_toili-Lower	54 P.22	Max WS	680.55	40.15	686.04	40.16	568.47	39.99	5.49	0.01	-112.08	-0.16
s_toili	s_toili-Lower	35 P.23	Max WS	680.55	40.15	686.04	40.16	568.46	39.99	5.49	0.01	-112.09	-0.16
s_toili	s_toili-Lower	14 P.24	Max WS	680.56	39.8	686.04	39.8	568.46	39.66	5.48	0.00	-112.10	-0.14
s_mansah	s_mansahang	147 M.1	Max WS	316.22	43.84	308.32	45.65	428.21	45.1	-7.90	1.81	111.99	1.26
s_mansah	s_mansahang	130	Max WS	316.21	44.05	311.19	45.77	428.2	45.11	-5.02	1.72	111.99	1.06
s_mansah	s_mansahang	122 M.2	Max WS	316.21	44.05	317.56	44.91	428.2	45.11	1.35	0.86	111.99	1.06
s_mansah	s_mansahang	120	Max WS	316.21	43.72	315.44	43.88	428.19	44.91	-0.77	0.16	111.98	1.19
s_mansah	s_mansahang	109 M.3	Max WS	316.21	43.87	313.35	43.86	428.19	44.83	-2.86	-0.01	111.98	0.96
s_mansah	s_mansahang	88 M.4'	Max WS	316.21	43.87	313.09	43.86	428.19	44.32	-3.12	-0.01	111.98	0.45
s_mansah	s_mansahang	74 M.4	Max WS	316.21	43.34	318.59	43.34	428.19	43.71	2.38	0.00	111.98	0.37
s_mansah	s_mansahang	54 M.5	Max WS	316.21	43.19	321.72	43.19	428.18	43.5	5.51	0.00	111.97	0.31
s_mansah	s_mansahang	43 M.6	Max WS	316.2	43.31	309.02	43.29	428.18	43.69	-7.18	-0.02	111.98	0.38
s_mansah	s_mansahang	27 M.7	Max WS	316.19	43.31	320.48	43.29	428.17	43.69	4.29	-0.02	111.98	0.38
s_mansah	s_mansahang	5 M.8	Max WS	316.19	43.28	311.16	43.26	428.17	43.59	-5.03	-0.02	111.98	0.31

By paying attention to the results of the HEC-RAS model simulation, where alternative 2 shows a better hydraulic performance than alternative-1, alternative-2 is used in this planning.

e. HEC-RAS Running Results (alternative 2 and dependable flow)

Table 5. HEC-RAS running results (alternative-2 and dependable flow)

River	Reach	River Sta		Profile	Q Total (m3/s)	Min Ch El (m)	LOB Elev (m)	W.S. Elev (m)	ROB Elev (m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
s_toili	s_toili	497	P.0	Max WS	8.67	42.22	50.25	43.45	46.57	0.14	63.09	70.32	0.05
s_toili	s_toili	479	P.1	Max WS	11.31	42.76	49.92	43.32	46.94	1.41	8	25.45	0.81
s_toili	s_toili	460	P.2	Max WS	23.46	42.1	50.39	43.03	46.42	0.76	30.7	50.21	0.31
s_toili	s_toili	450	P.3'	Max WS	14.13	40.78	47.49	43.01	45.1	0.12	115.32	78.55	0.03
s_toili	s_toili	426	P.3	Max WS	15.06	42.37	49.74	43.01	45.14	1.08	14	41.7	0.59
s_toili	s_toili	402	P.4	Max WS	12.99	42.36	49.39	42.86	45.47	0.78	16.69	57.56	0.46
s_toili	s_toili	388	P.5	Max WS	14.17	42.29	48.86	42.74	46.51	1.66	8.51	37.84	1.12
s_toili	s_toili	380	P.6	Max WS	18.53	41.86	49.01	42.58	45.14	1.04	17.82	38.25	0.49
s_toili	s_toili	372	P.7	Max WS	17.14	41.03	47.39	42.59	46.12	0.51	33.91	55.13	0.21
s_toili	s_toili	353	P.8	Max WS	15.75	41.38	46.95	42.59	45.03	0.63	25.13	49.84	0.28
s_toili	s_toili	325		Max WS	15.65	41.38	46.95	42.56	45.03	0.67	23.5	47.96	0.3
s_toili	s_toili-Lower	318	P.9	Max WS	4.34	41.16	47.48	42.52	45.19	0.07	65.41	82.9	0.02
s_toili	s_toili-Lower	315		Max WS	4.13	42.16	45.65	42.52	45.6	0.17	24.99	71.98	0.09
s_toili	s_toili-Lower	312	P.10	Max WS	4.34	40.15	47.48	42.52	47.77	0.05	88.86	56.61	0.01
s_toili	s_toili-Lower	300		Max WS	4.22	42.16	45.65	42.52	45.6	0.17	24.92	71.98	0.09
s_toili	s_toili-Lower	290		Inl Struct				42.52					
s_toili	s_toili-Lower	282	P.11	Max WS	4.17	39.6	46.95	40.67	45.36	0.4	10.51	19.57	0.17
s_toili	s_toili-Lower	260	P.12	Max WS	4.34	38.67	43.12	40.67	42.71	0.16	26.53	23.4	0.05
s_toili	s_toili-Lower	243	P.13	Max WS	4.34	39.21	43.09	40.67	43.12	0.17	25.86	30.52	0.06
s_toili	s_toili-Lower	213	P.14	Max WS	8.19	40.2	42.58	40.59	43.01	1.17	6.99	26.99	0.73
s_toili	s_toili-Lower	189	P.15	Max WS	7.7	39.73	42.76	40.42	43.21	0.38	20.15	51.12	0.19
s_toili	s_toili-Lower	163	P.16	Max WS	7.17	39.86	43.13	40.16	43.98	2	3.58	21.81	1.58
s_toili	s_toili-Lower	141	P.17	Max WS	11.24	38.97	42.82	39.7	42.5	2.22	5.06	10.86	1.04
s_toili	s_toili-Lower	128	P.18	Max WS	5.07	38.46	40.19	39.31	40.63	0.12	42.28	109.43	0.06
s_toili	s_toili-Lower	106	P.19	Max WS	7.55	38.53	40.7	39.32	41.47	0.33	22.81	45.29	0.15
s_toili	s_toili-Lower	89	P.20	Max WS	4.34	38.73	40.68	39.01	41.68	1.39	3.13	16.29	1.01
s_toili	s_toili-Lower	70	P.21	Max WS	45.86	37.35	39.53	38.35	40.3	1.39	33	51.58	0.55
s_toili	s_toili-Lower		21:55.2	Max WS	20.26	37.15	39.33	38.09	40.1	0.69	29.5	49.78	0.28
s_toili	s_toili-Lower		02:55.2	Max WS	17.11	37.5	39.67	38.08	40.44	1.25	13.66	38.9	0.67
s_toili	s_toili-Lower		41:55.2	Max WS	13.79	37.48	39.66	37.95	40.43	1.56	8.82	34.61	0.99
s_mansah	s_mansahang	147	M.1	Max WS	8.09	41.15	44.62	42.52	43.15	0.28	29.38	35.03	0.1
s_mansah	s_mansahang	130		Max WS	10.07	41.76	45.36	42.52	45.25	0.33	30.69	71.5	0.16
s_mansah	s_mansahang	122	M.2	Max WS	10.2	41.88	45.67	42.52	45.88	0.57	17.9	40.14	0.27
s_mansah	s_mansahang	120		Max WS	10.21	41.76	45.36	42.5	45.25	0.35	29.6	71.45	0.17
s_mansah	s_mansahang	115		Inl Struct				42.5					
s_mansah	s_mansahang	109	M.3	Max WS	4.34	41.94	45.02	42.21	43.73	0.03	34.71	27.46	0.02
s_mansah	s_mansahang	88	M.4'	Max WS	9.96	41.71	44.73	42.14	44.71	1.28	7.8	36.72	0.88
s_mansah	s_mansahang	74	M.4	Max WS	9.54	40.71	44.25	41.94	44.24	0.48	20.27	27.25	0.17
s_mansah	s_mansahang	54	M.5	Max WS	9.52	40.78	44.06	41.94	44.09	1.05	9.09	23.98	0.54
s_mansah	s_mansahang	43	M.6	Max WS	9.41	41.3	44.14	41.85	44.52	1.17	8.05	27.03	0.68
s_mansah	s_mansahang	27	M.7	Max WS	9.23	41.44	44.09	41.77	44.42	0.86	10.73	61.32	0.66
s_mansah	s_mansahang	5	M.8	Max WS	9.04	41.4	43.7	41.72	43.57	0.72	12.63	60.95	0.5

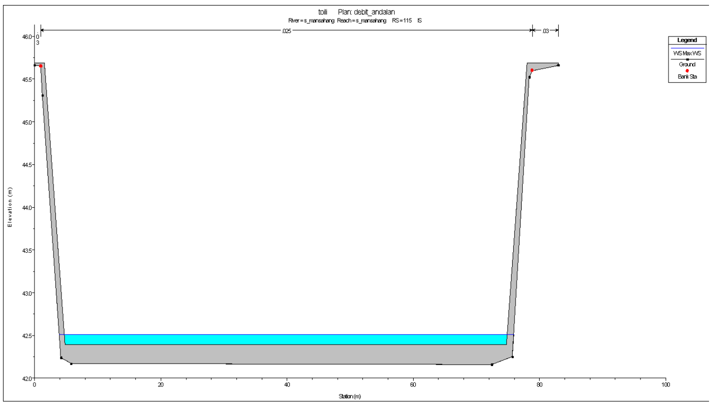

Figure. 15. Cross section of the bifurcation structure on the Toili River (dependable flow conditions)

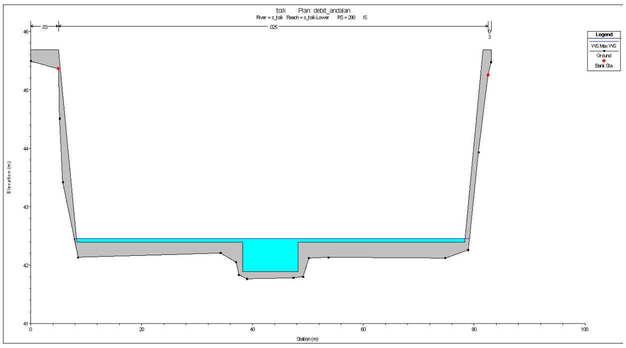

Figure 16. Cross section of the bifurcation structure on the Mansahang river (dependable flow conditions)

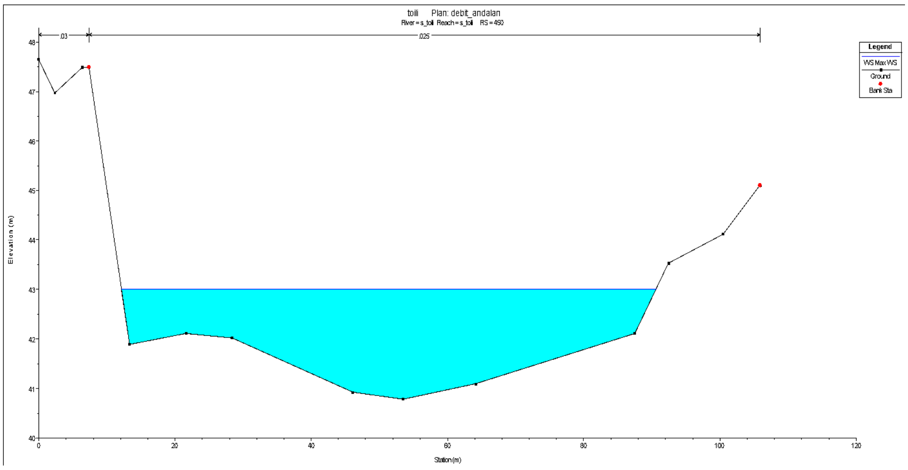

Figure. 17. Cross section of Moilong free intake location (dependable flow condition)

In the HEC-RAS simulation using reliable discharge, the results show that the water level elevation at the Moilong irrigation intake location is +43.01 with a flowrate of 14.13 m3/s. This indicates that the water level is above the Moilong irrigation intake threshold (+41.89) and the required discharge is 2.115 m3/s. Thus, during the dry season, water is still sufficient for the Moilong irrigation area. The Mansahang River/Toili Dam requires a minimum water level in the Bifurcation structure (+42.39) while in this simulation the water level is +42.50. Thus, the water level and the discharge are sufficient during the dry season.

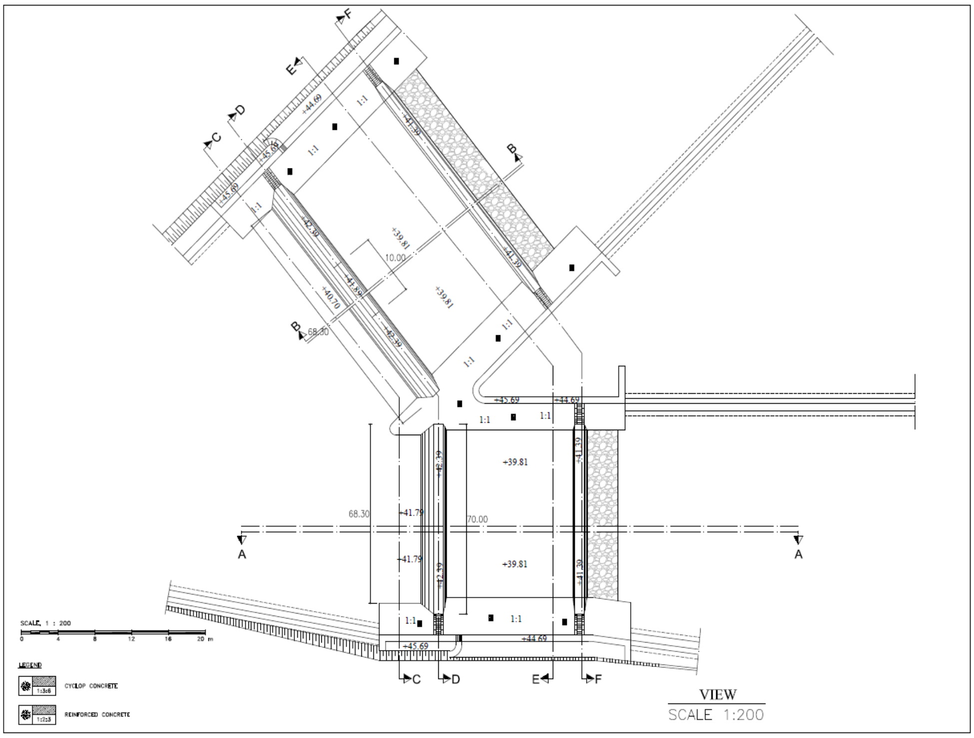

Figure 18. Plan view of bifurcation structure

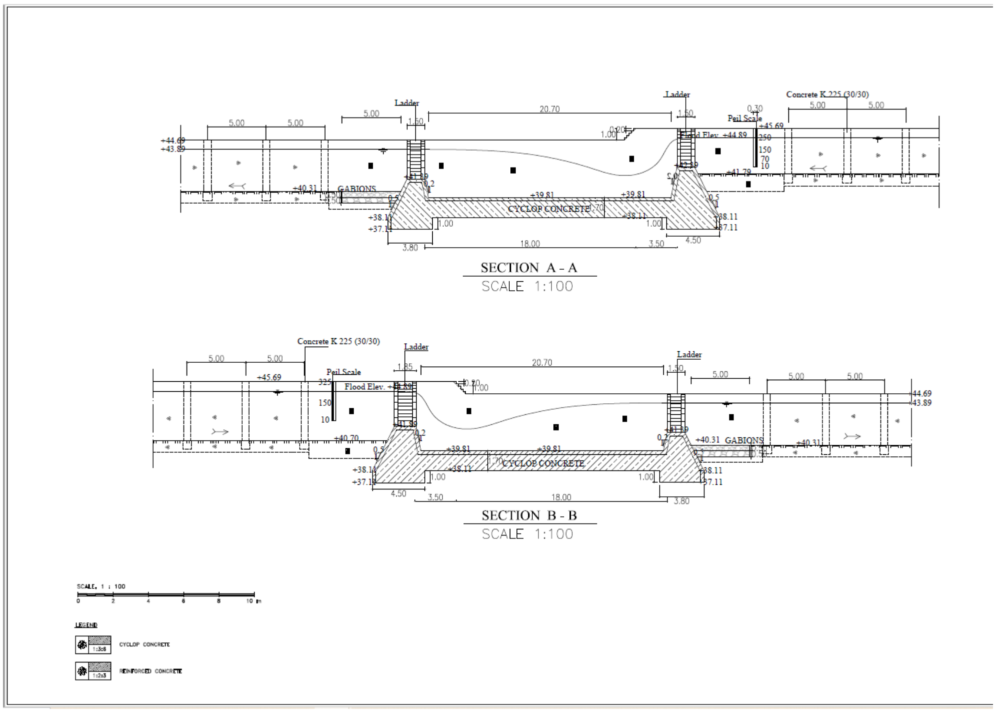

Figure 19. Longitudinal section of the bifurcation structure

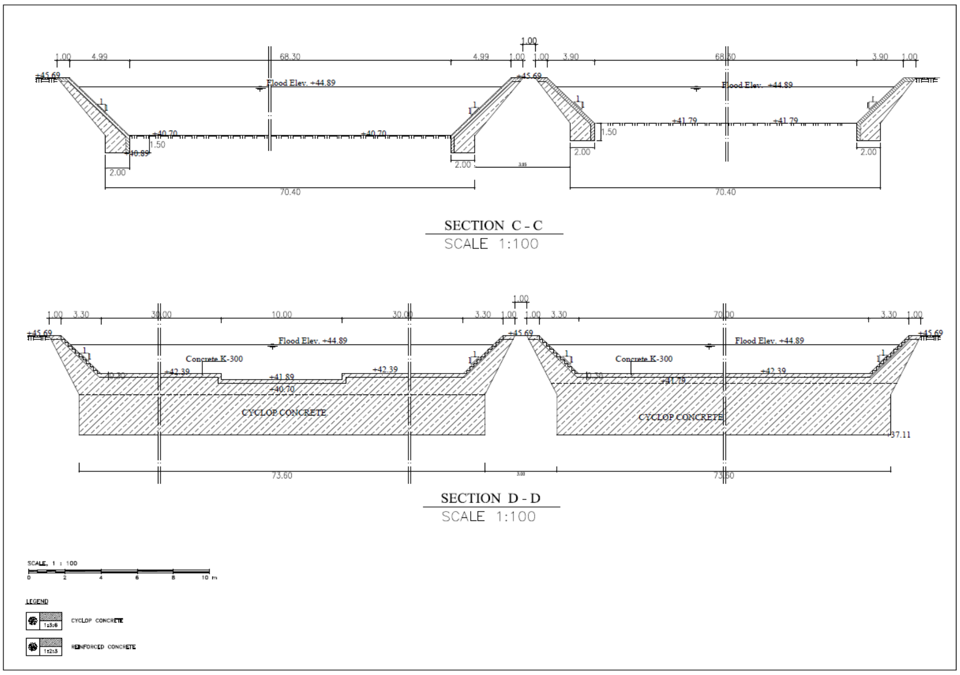

Figure 20. Cross section of the bifurcation structure

5. CONCLUSIONS

Some conclusions that can be drawn from this research include:

1. At the existing condition, with a discharge load of Q25 (996.81 m3/s), the distribution of the water discharge flowing from the Toili River to the downstream Toili River/Moilong River was 68.3% (680.56 m3/s) and 31.7% towards the Mansahang River. (316.22 m3/s). This condition causes catastrophic flooding in the lower Toili River during the rainy season and causes water shortages in the Mansahang River/Toili weir during the dry season.
2. In alternative-1 design, there is no significant change to the distribution of water discharge and the existing water level. Changes in discharge only ranged from 5 to 8 m3/s. The flood water level is almost level with the embankment and even almost overflows. That is, the construction of the bifurcation in alternative-1 does not solve the existing problems.
3. In alternative-2 design, changes in the discharge and water level occur quite significantly, where in the downstream Toili/Moilong River there is a reduction in the discharge value to 112 m3/s. The value is then allocated to the Mansahang River (the debit increases). The flood water level elevation in alternative-2 design conditions in the downstream Toili/Moilong River is +45.31, while on the Mansahang River the floodwater level is +45.11. In this condition, there is still a high guard.
4. By taking into account the results of the HEC-RAS model simulation, where alternative 2 shows a better hydraulic performance than alternative-1, alternative-2 is used in this planning.
5. In the HEC-RAS simulation using reliable discharge, the results show that the water level elevation at the Moilong irrigation intake location is +43.01 with a flowrate of 14.13 m3/s. This indicates that the water level is above the Moilong irrigation intake threshold (+41.89) and the required discharge is 2.115 m3/s.

Thus, during the dry season, water is still sufficient for the Moilong irrigation area. The Mansahang River/Toili Dam requires a minimum water level in the Bifurcation structure (+42.39) while in this simulation the water level is +42.50. Thus, the water level and the discharge are sufficient during the dry season.

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Declaration of competing interest

The authors declare no conflicts of interest.

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