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Analysis of Flood Discharge and Water Level of the Babon River in Semarang

M. Fakhrurrozi[1], Esti Wulandari[2], Laksono Djoko Nugroho[3]
Universitas 17 Agustus 1945 Surabaya, Indonesia
*Email: rozi.statham@gmail.com[1], wulandariesti@untag-sby.ac.id[2], laksonodjoko@untag-sby.ac.id[3]

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ABSTRACT

This study aims to determine the toll rates desired by the people of Gresik Regency based on the value of Ability to Pay (ATP) and Willingness to Pay (WTP) on the Krian – Legundi – Bunder (KLB) Toll Road. Through traffic count surveys and Road Side Interviews (RSI) at toll gates and arterial roads, data on vehicle population, payment ability, and user preferences for existing toll rates were obtained. The analysis employed a Logit model to evaluate the relationship between the ATP and WTP values and their correlation with the current toll rates. The results revealed that both the WTP and ATP of the community were lower than the existing toll tariff. Specifically, the study found that the optimal toll rate for users would be Rp. 1,100/km, which is 26.96% lower than the current rate of Rp. 1,506/km. This adjustment not only aligns better with the financial capacities of the users but also presents an opportunity for revenue optimization. By lowering the toll rate, it is predicted that increased traffic volume could compensate for the reduced fee, ultimately benefiting both the toll operator and the community. In conclusion, establishing a toll rate that reflects user preferences is crucial for enhancing accessibility and ensuring sustainable revenue generation for infrastructure development.

INTRODUCTION

Flooding is a significant challenge faced by many urban areas, particularly in developing countries where rapid urbanization outpaces infrastructure development. Semarang, a coastal city in Indonesia, is particularly vulnerable to flooding due to its geographical location, low elevation, and inadequate drainage systems (Wahyudi et al., 2014). The Babon River, which flows through this region, often experiences increased discharge during the rainy season, leading to overflow and flooding in surrounding areas. Understanding the hydrological dynamics of this river is crucial for effective flood management and urban planning (Kodoatie & Sjarief, 2017).

In recent years, various studies have highlighted the need for integrated water resource management to address urban flooding effectively. For instance, (Nurdiansyah et al., 2020) emphasized the importance of understanding local hydrological conditions and implementing appropriate drainage solutions to mitigate flood risks. (Yulianto et al., 2018) investigated the effectiveness of retention ponds in managing stormwater runoff, advocating for their incorporation into urban planning frameworks. These findings underline the necessity of conducting localized research that focuses on specific waterways, such as the Babon River, to develop tailored solutions that enhance flood resilience in Semarang.

Infrastructure development is currently encouraged by the Government in programs that support development in all fields. The Ministry of Public Works and Public Housing as the spearhead of infrastructure development. One field is in the field of Water Resources. This field of natural resources as mandated in the Law is in the control of water damage in potential floods which is manifested in river normalization, utilization of natural resources in irrigation and irrigation, raw groundwater and water resources conservation.

Water Resources (SDA) is the control of water damage both in a watershed system and in the Urban Drainage System. Drainage systems in general can be described as a way of draining water by making channels (tertiary) to accommodate rainwater that flows above the ground level. Then it is channeled to larger systems (secondary and primary) and then to rivers and seas (Kodoatie & Sjarief, 2017). In addition, it can also be defined as a water building system that functions to reduce excess water from a land so that the function of the land after drying can be used optimally. Other functions can also be for soil quality control related to sanitation (Triadi & Indra, 2009).

In the rainy season, the area where the Semarang - Demak Package 1C Toll Road works, namely the Trimulyo Village, Genuk District, Semarang City, is feared to experience a rise in the water level in the rivers, resulting in flooding, especially the overflow of water from the Babon River which is exactly passing through and emptying at the Semarang Demak Toll Road Construction site. This can have an impact on several things, namely flood-prone locations that are unsafe for workers and also the location of pump houses that are feared to be flooded by water from the overflow of the Babon River. Therefore, it is necessary to conduct a study related to the overflow of water from the Babon River, especially during the rainy season period that will occur. Related to the construction of a retention pond that is integrated with the sea embankment of the Semarang Demak Toll Road, river-integrated activities, especially in the Semarang Babon River as a place for the outlet channel of the Terboyo Retention Pond. In addition to permanent buildings related to the handling of flows at the mouth of the Babon River, the use of culverts as a support for temporary connecting bridge buildings that function as temporary access roads to facilitate traffic. The planning stage continues the implementation of activities at the river mouth accompanied by Engineering Implementation Technology Construction Implementation is focused on development engineering related to hydrology/hydraulics, geotechnical engineering development, Technology development related to construction buildings are usually located in the river channel area where relevance is needed between the Maximum Discharge during the implementation of the work in Q2 and Q5 which is calculated to occur which is related to wide conditions and The area of the river cross-sectional hydraulic starts from the upstream which widens downstream. The calculation of the highest elevation that will later be recorded in a water reservoir in the morphology of the river which affects the structure of the temporary building to be built. Retention ponds are one of the urban drainage systems where this can be added again in a system. The main function of retention ponds is as a medium to replace catchment land that has undergone changes such as housing. Offices, and industrial areas with minimal infiltration. In addition, retention ponds have other functions, namely being used for flood control, water distribution, waste management by considering the required volume that is accommodated in the retention pond (Wahyudi & Adi, 2014). In this case, the system taken is the Polder system. A polder drainage system is a collection of lowlands that form an artificial hydrological unity surrounded by an embankment (*dijk*/*dike*) (Alfiyana, 2014).

Numerous studies have investigated flood control and hydrological dynamics in urban areas, emphasizing the importance of effective drainage systems. For instance, research by (Abdurohim, 2022) highlighted the correlation between urbanization and increased flood risks, emphasizing the need for enhanced drainage infrastructure in flood-prone areas. Similarly, (Nurcahyanie & Yulianto, 2024) conducted a study on the effectiveness of retention ponds in managing stormwater runoff in Semarang, demonstrating that properly designed retention systems can significantly mitigate flood impacts. These studies underscore the critical role of integrated water resource management in urban planning.

Additionally, (Kodoatie & Sjarief, 2017) explored the integrated management of water resources, emphasizing the significance of understanding catchment characteristics in flood risk assessments. They posited that utilizing hydrological models can improve predictive capabilities regarding flood events. In a related study, (Kusumajaya et al., 2020) examined the implications of land use changes on flood susceptibility, suggesting that urban expansion often exacerbates flooding issues, especially in low-lying areas. These findings collectively point to the necessity for tailored hydrological studies to address specific regional challenges.

Despite the wealth of existing literature on flood management, there remains a significant gap concerning localized studies that focus on the Babon River in Semarang. While previous research has provided broad insights into urban flood dynamics and management strategies, specific analyses of the Babon River's hydrological characteristics are limited. The existing studies often overlook the unique geological and hydrological conditions of this region, which can lead to inadequate flood management solutions tailored to local needs (Khan et al., 2022).

Moreover, most studies have concentrated on theoretical models and simulations without practical assessments of ongoing infrastructure projects. This research aims to fill this gap by providing empirical data and insights into the flood discharge and water level of the Babon River, particularly during the rainy season. By integrating field observations with hydrological modeling, this study seeks to offer a more comprehensive understanding of the factors influencing flood risks in this area (Nugroho et al., n.d.).

The novelty of this research lies in its comprehensive approach, combining hydrological analysis with practical engineering solutions tailored to the Babon River's specific context. Unlike previous studies that primarily focused on theoretical frameworks, this research employs real-time data collection and hydrological modeling to assess flood risks and water levels accurately. By integrating empirical observations with established hydrological methods, this study provides actionable insights for local infrastructure development (Dharmawan et al., 2024).

Furthermore, this research emphasizes the importance of adaptive management strategies in urban flood control, particularly in response to climate change and urbanization pressures. The findings will not only contribute to the academic discourse on flood management but also offer practical recommendations for policymakers and engineers involved in infrastructure projects in flood-prone areas (Wahyudi & Adi, 2014)

Drainage is a basic facility that is planned as a system to meet needs and is an important component in planning a city infrastructure system. In addition, drainage can be in the form of curves of waterways on the surface or underground, where they can be formed naturally or man-made. In the context of the field, it can be in the form of trenches on the surface or culverts under the surface; where both function to prevent floods as well as the supply of irrigation and raw water (Kusumajaya et al., 2020). Regarding a system that rainwater that falls to the land needs to be drained by making a channel. For those at ground level, they are channeled to larger channels, while smaller ones, such as household channels, are combined with other infrastructure systems. And developed for liquid waste through treatment system (Kodoatie & Sjarief, 2017).

In a building structure, including the river reinforcement structure, the behavior of the subsoil and geological classification play an important role. Especially in the river estuary area which is dominated by clay (*silt*) mixed with sand and shell fragments at a depth of up to 12 meters. Meanwhile, hard soil is obtained at a depth of 100 meters. The structural analysis with the above geotechnical conditions is concluded by the implementation of excavation and the base soil where the temporary building is placed.

The Geographical Position of Semarang City has two positions where there is a city position that has a higher elevation position (Upper City) and a lower elevation (Lower City). In accordance with natural laws related to water flow, the lower city often experiences flood disasters. This condition is exacerbated by the decline of the ground level in the lower city which results in the occurrence of Rob from the sea. One of the steps of activities in the lower area is the Normalization of the Bacon River in the east of Semarang City.

This research takes one of the objects in the Semarang Demak Toll Road Development Project which is integrated with sea embankments and toll roads where there is a retention pond structure. Related to simulation and evaluation to assess the structure of temporary buildings to support work affected by hydrology and soil behavior of the ground. The importance of this research is related to the evaluation of construction in its function. The results of this research can be a suggestion for implementation for typical in other locations so that it is better and can run smoothly from the implementation in the Semarang Babon River.

The purpose of this study is to determine the flood discharge and water level of the Babon River, find effective temporary construction technical solutions to drain water without causing flooding at the project site and its surroundings, and identify alternative solutions with the most cost-effective solutions. The benefits of this research include increasing the insight of students or researchers about project implementation methods and efficient solutions in dealing with field obstacles, providing effective and efficient technical solutions for contractors in handling the flow of the Babon River during the construction of the Semarang – Demak 1C Toll Road, as well as being a reference for institutions related to flood management at the mouth of the river during the rainy season.

This research contributes significantly to the understanding of flood management in urban environments, particularly in the context of climate change and rapid urbanization. By providing detailed analyses of flood discharge and water levels in the Babon River, the study offers actionable insights that can enhance infrastructure planning and design. These findings can assist local authorities in implementing more resilient drainage systems, ultimately reducing flood risks and improving public safety. Additionally, the research aids in raising awareness about the importance of effective water resource management among stakeholders, facilitating better collaboration among government agencies, urban planners, and the community (Rusdiyanto et al., 2022)

METHOD

This research method uses a scientific approach to obtain data through primary and secondary data documentation, observation, and collection methods. Documentation involves the use of written materials and documentary films from previous studies for simulations and evaluations related to hydrology, hydraulics, sedimentation, and structural stability. Observations are carried out directly in the field with geospatial surveys of river systems, river structures, and building conditions, while secondary data is obtained from related agencies such as the River Region Center, including rainfall data, watershed area, and situation plots. This study evaluates external factors (rainfall, flood discharge, sedimentation, and river hydraulics) as well as internal factors (geology, soil mechanics, topography, excavation methods, and building foundations) on construction stability. Data analysis is carried out through literature studies, field surveys, primary and secondary data collection, and data processing with hydrological and hydraulic methods which include the stages of editing, coding, and tabulation to obtain valid conclusions (Sugiono et al., 2020).

RESULTS AND DISCUSSION

Results of Hydrology Analysis

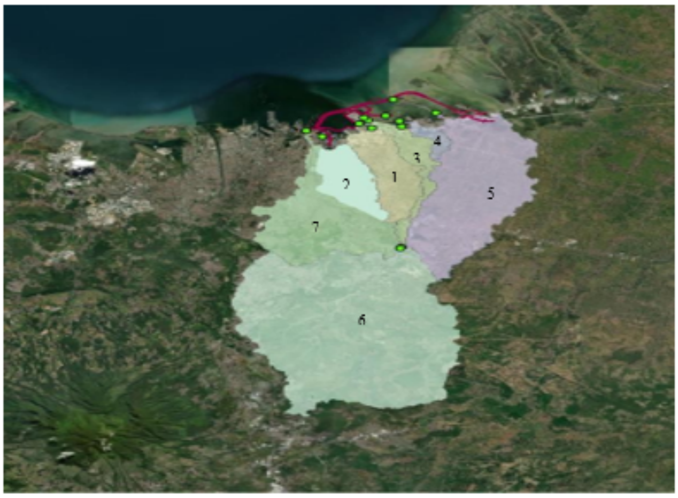

Figure 1 Watershed Degradation in ArcGIS
Source: Researcher Processing, 2024

Based on the characteristics of the watershed image above, the area of the Babon River watershed is 9.14 km2, the length of the main river is 17.80 km and the slope of the river is 0.0001.

The rainfall data obtained has been tested in various ways, by using frequency analysis, planned rainfall with various re-periods is obtained in the table below.

Figure 2. Recapitulation of draft rainfall with various re-periods

No.	Return Period (Year)	Design Rain (mm) Gumbel	Normal	Log Normal	Pearson III	Log Pearson III
1	1.25	60.38	60.06	60.63	60.04	60.46
2	2	70.52	73.06	71.65	70.24	70.09
3	5	84.17	86.06	84.68	84.43	83.82
4	10	93.21	92.86	92.41	93.67	93.30
5	20	101.88	98.48	99.33	102.33	102.67
6	25	104.63	100.12	101.44	105.03	105.71
7	50	113.10	104.80	107.73	113.24	115.30
8	100	121.51	109.01	113.72	121.25	125.20
9	200	129.88	112.87	119.49	129.11	135.50
10	500	140.94	117.54	126.88	139.35	149.82
11	1000	149.29	120.81	132.34	147.00	161.27
SMIRNOV - KOLMOGOROF TEST						
D Maximum, D Max		0.091	0.060	0.061	0.068	0.070
Degree of Significance		0.050	0.050	0.050	0.050	0.050
D Critical		0.290	0.290	0.290	0.290	0.290
HYPOTHESIS		Accepted	Accepted	Accepted	Accepted	Accepted
CHI SQUARE TEST						
Chi-Square calculation		5.37	3.57	3.57	3.57	4.77
Chi-Square is critical		7.82	7.82	7.82	7.82	7.82
Degrees of Freedom		3.00	3.00	3.00	3.00	3.00
Degree of Significance		0.05	0.05	0.05	0.05	0.05
HYPOTHESIS		Accepted	Accepted	Accepted	Accepted	Accepted

Source: Researcher Processing, 2024

Land use conditions from the results use GIS as software whose results will be developed into runoff for planned flood discharge analysis.

Figure 3. Land use results in the Baboon watershed

Legend	Area (km2)	C.N	Impervious (%)
Shrubs	13.37	83.00	5.00
Plantation/Gardening	49.06	86.00	5.00
Moorland/Field	34.68	89.00	5.00
Ricefield	6.52	81.00	5.00
Lake/Situ	0.11	100.00	100.00
Meadow	3.57	89.00	5.00
Settlement	23.69	87.00	30.00

Source: Researcher Processing, 2024

The distribution of hourly rain uses the PSA 007 method with 6 hours of rain distribution. The results of the distribution of the hours are as follows.

Figure 4. Rainfall distribution in the Babon watershed

DISTRIBUTION RAIN		62,445	74,682	83.122	94,184	102,729	111,549	120,719	143,684
KUM	O'CLOCK	2	5	10	25	50	100	200	1000
0	0.000	0.000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
0.05	0.050	3.122	3,734	4,156	4,709	5.136	5,577	6,036	7,184
0.15	0.100	6,245	7,468	8,312	9,418	10,273	11.155	12,072	14,368
0.75	0.600	37,467	44,809	49,873	56.511	61,637	66,929	72,431	86,211
0.91	0.160	9,991	11,949	13,300	15.069	16,437	17,848	19,315	22,989
0.97	0.060	3,747	4,481	4,987	5,651	6,164	6,693	7,243	8,621
1	0.030	1.873	2,240	2,494	2,826	3,082	3,346	3,622	4,311

Source: Researcher Processing, 2024

Analysis of the calculation of planned flood discharge using the SCS synthetic unit hydrograph method, so that the results obtained are as follows.

Figure 5. Flood discharge of Babon River plan

FLOOD LEVEL OF BABON RIVER PLAN (m3/second)						
Q2	Q5	Q10	Q25	Q50	Q100	Q1000
0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.24	7.21	8.14	9.65	11.05	12.70	22.55
29.31	34.23	38.44	44.84	50.50	57.00	89.74
123.07	143.55	161.32	188.42	212.54	240.32	387.34
260.62	307.36	343.53	395.00	438.10	485.52	680.79
262.75	314.38	348.94	393.05	426.00	458.78	550.65
210.95	253.70	281.00	314.40	338.15	360.66	417.01
177.55	214.12	236.98	264.39	283.44	301.34	347.34
156.04	188.19	208.39	232.77	250.28	267.30	316.89
144.99	174.44	193.48	217.08	234.28	251.11	306.30
136.63	164.03	182.17	205.15	222.26	239.35	298.10
128.62	154.26	171.38	193.47	210.17	227.06	286.37
117.15	140.47	156.04	176.39	191.90	207.69	263.18
102.06	123.10	135.88	153.85	167.66	181.86	233.01
87.04	104.37	115.87	131.25	143.11	155.33	199.67
71.95	86.16	95.78	108.52	118.35	128.49	165.37
59.47	71.17	79.16	89.69	97.83	106.23	136.83
49.27	58.92	65.58	74.31	81.05	88.01	113.36
40.71	48.68	54.19	61.40	66.97	72.72	93.67
33.60	40.18	44.72	50.67	55.27	60.02	77.30
27.70	33.13	36.88	41.79	45.58	49.49	63.75
22.66	27.10	30.16	34.17	37.28	40.48	52.14
18.36	21.96	24.44	27.69	30.20	32.80	42.24
15.04	17.99	20.02	22.68	24.74	26.87	34.60
12.39	14.82	16.49	18.68	20.38	22.13	28.50
10.30	12.31	13.70	15.53	16.94	18.39	23.69
8.68	10.38	11.55	13.09	14.28	15.50	19.97

Source: Researcher Processing, 2024

Based on Figure 5, a hydrograph of the flood can be made as shown in the image below.

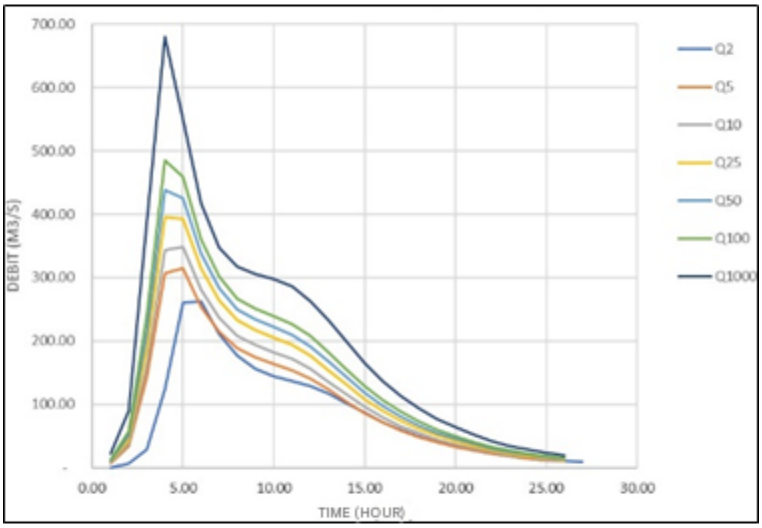

Figure 6. Babon River flood hydrograph graph
Source: Researcher Processing, 2024

Results of Hydraulic Analysis

This hydraulic analysis aims to determine the height of the river water level profile in accordance with the planned discharge. After knowing the conditions that occur, the height of the water level (Flood Water Level Elevation) and the flow speed (V) will be known. By using the HEC-RAS program, the profile of the water surface can be known. HEC-RAS will display the model from the Babon River in Semarang City according to the data input provided. Here's a hydraulic model of the Baboon River elongated cut.

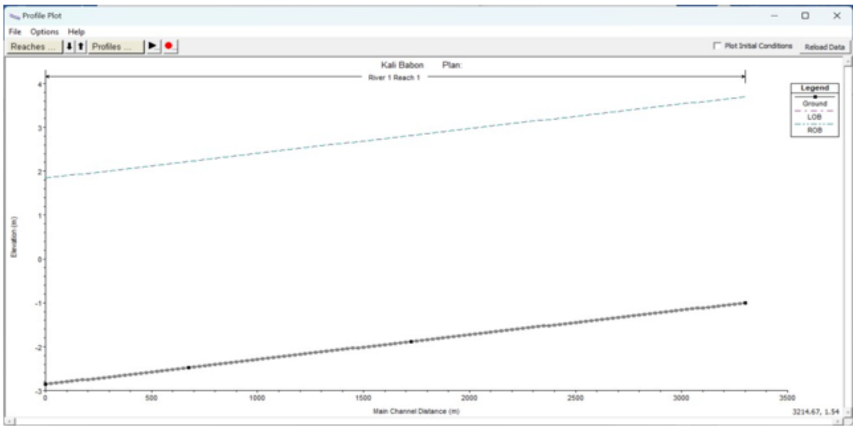

Figure 7 Hydraulic Model of Baboon River Elongated Cut
Source: Researcher Processing, 2024

After incorporating the 2-year planned flood discharge, the hydraulic model on several sections of the Baboon River as seen in the figure below.

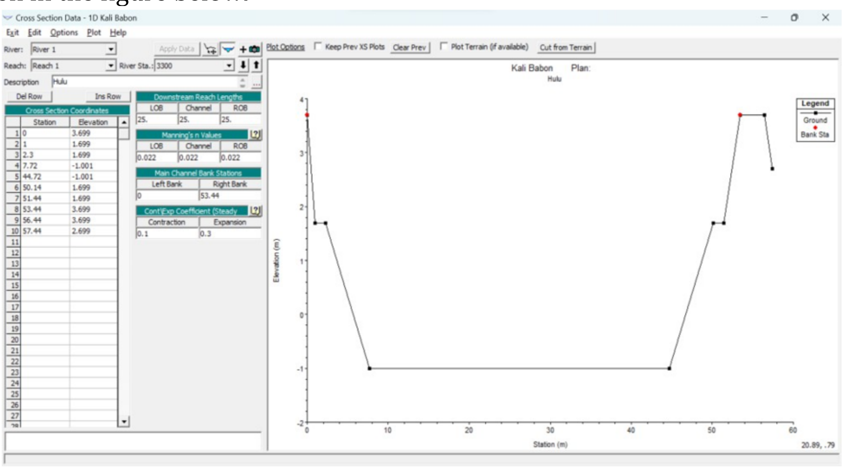

Figure 8 Hydraulic Model of Baboon River Cross Section HM 8+250
Source: Researcher Processing, 2024

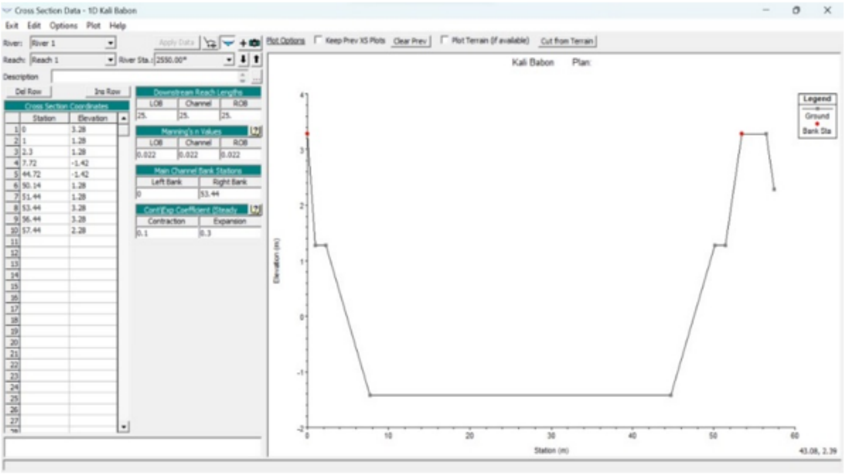

Figure 9 Hydraulic Model of Baboon River Cross Section HM 16+000
Source: Researcher Processing, 2024

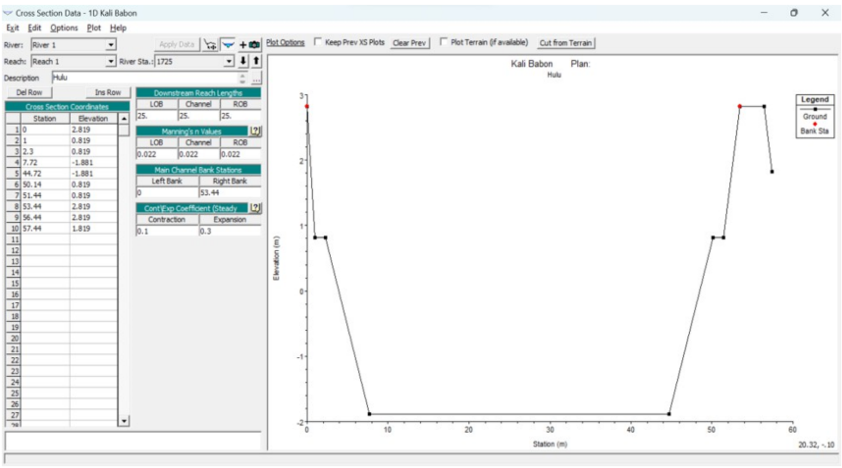

Figure 10 Hydraulic Model of Babon River Cross Section HM 24+000
Source: Researcher Processing, 2024

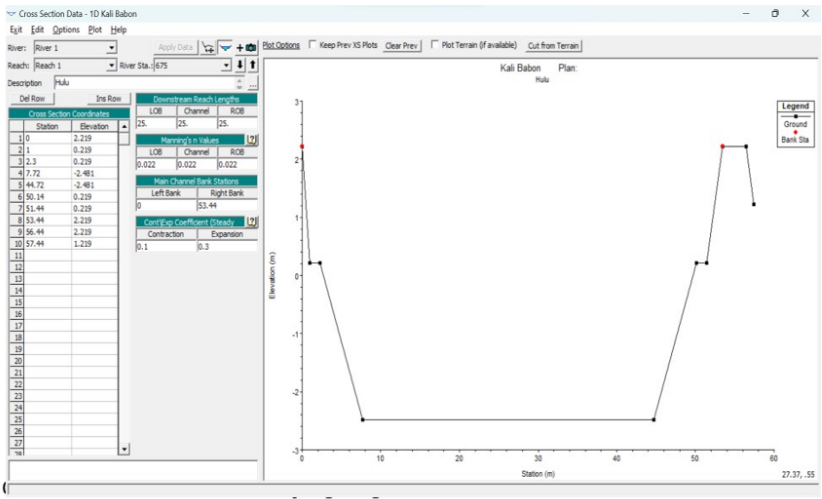

Figure 11 Hydraulic Model of Baboon River Cross Section HM 34+500
Source: Researcher Processing, 2024

Based on the above hydraulic analysis, the results of the modeling are obtained:

- Water Suface (WS) : Elv. +1.500
- Ground/ Riverbed : Elv. -2.860
- Bank Height : Elv. +1.850

From these results, the height of MAB is below the banks of the Babon River. Bank Height as for the downstream of the Babon River, there is a tidal elevation of the water with the following data used:

- MSL = Elv. +0.583
- LLWL = Elv. +0.320
- HHWL = Elv. +1.100

CONCLUSION

This study concluded that the peak discharge in the rainy season of 262.75 m^3/s (Q2 years) was chosen for the construction period of 2 years by considering non-permanent needs. From the hydraulica modeling, the elevation of the water level with the height of Elv was obtained. +1,500, Elv. -2,860, and the height of the Elv. +1,850, as well as the MSL Elv. +0.583, LLWL Elv. +0.320, and HHWL Elv. +1.100.

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