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DRAINAGE SYSTEM TRANSFORMATION TOWARDS EFFECTIVE FLOOD CONTROL WITH EPA SWMM

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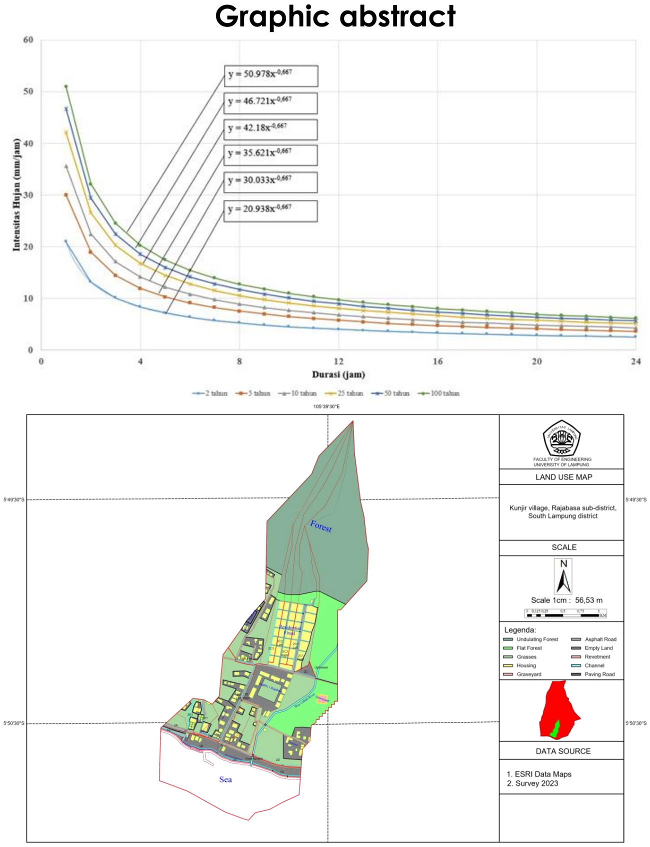
Graphic abstract



Abstract

The village of Kunjir often experiences floods caused by suboptimal drainage systems, land use changes, and revetment construction. The utilization of EPA SWMM proves to be an interesting solution to address flood issues. The research aims to analyze the drainage channel capacity using the EPA SWMM program, assess the tidal influence on the channels, and provide solutions to the existing problems. The method involves hydrological and hydraulic analysis using Microsoft Excel and the EPA SWMM program. Rainfall and topographic data are utilized to determine flood discharge, while existing channel data are used to calculate channel capacity. HWL values are used to analyze the tidal influence on the channels. The modeling process involves creating a network scheme and inputting data into the existing channels. The program is executed, and evaluations are conducted on problematic channels. Redesign planning is implemented by altering channel dimensions and re-running the simulations. The conclusion indicates that channels 2B, 2B1, 2B1 Left, 2C, and 2D cannot accommodate the flow discharge, tidal influence affects channel 1C, Box Culvert, and Downstream River, and solutions include enlarging channels, adding bottom slope to channels, regular maintenance, and installing floodgates to mitigate tidal effects.

Keywords: *Revetment, Hydrology, Hydraulics, Tides, Channel Capacity*

1.0 INTRODUCTION

Kunjir Village, South Lampung is an area that is vulnerable to flooding. Flooding can be caused by inadequate existing drainage capacity [1], [2], [3]. The problem of flooding is a serious concern because it impacts people's daily lives, damages infrastructure and has the potential for significant economic losses

[4], [5], [6]. So optimizing the drainage system and flood prevention efforts is very important to increase the resilience and quality of life of local communities.

Floods can occur due to high rainfall, insufficient drainage capacity, and poor flood control system designs [7], [8], [9]. This is exacerbated by changes in land use and the construction of revetments along the coastline. Measures to reduce flood and inundation risks include repairing existing channels or constructing new drainage channels [10], [11]. The EPA Storm Water Management Model (EPA SWMM) simulation is the key to understanding hydrological and hydraulic dynamics and designing effective solutions to increase drainage system capacity and reduce flood risks.

Flood control is not easy, so analyzing flood causes and drainage capacity is important [12], [13]. Utilizing EPA SWMM is an attractive solution to address existing issues [14], [15], [16]. This program is a sophisticated modeling tool for simulating surface water flow, drainage, and rainwater management systems in both urban and rural environments [17], [18], [19]. With this program, in-depth analysis of the performance of existing drainage systems can be conducted, vulnerable flood points can be identified, and effective mitigation strategies can be developed.

While there may be numerous studies on drainage analysis, analysis in the village has not yet been conducted. Therefore, by simulating using EPA SWMM, it is hoped that concrete recommendations related to optimizing drainage systems, increasing drainage channel capacities, identifying potential locations for flood control infrastructure development, and sustainable rainwater management strategies can be generated. This approach will also provide new insights into addressing challenges in other areas experiencing similar issues. The research aims to analyze drainage channel capacities using the EPA SWMM program, assess the influence of tides on the channels, and provide solutions to address existing issues.

2.0 METHODOLOGY

2.1. Research Location Map

This research was located in Kunjir Village, Rajabasa District, South Lampung Regency, Lampung. The coordinates are 5°49'30''S - 5°50'30''S and 105°38'30''E - 105°39'30''E. See Figure 1.

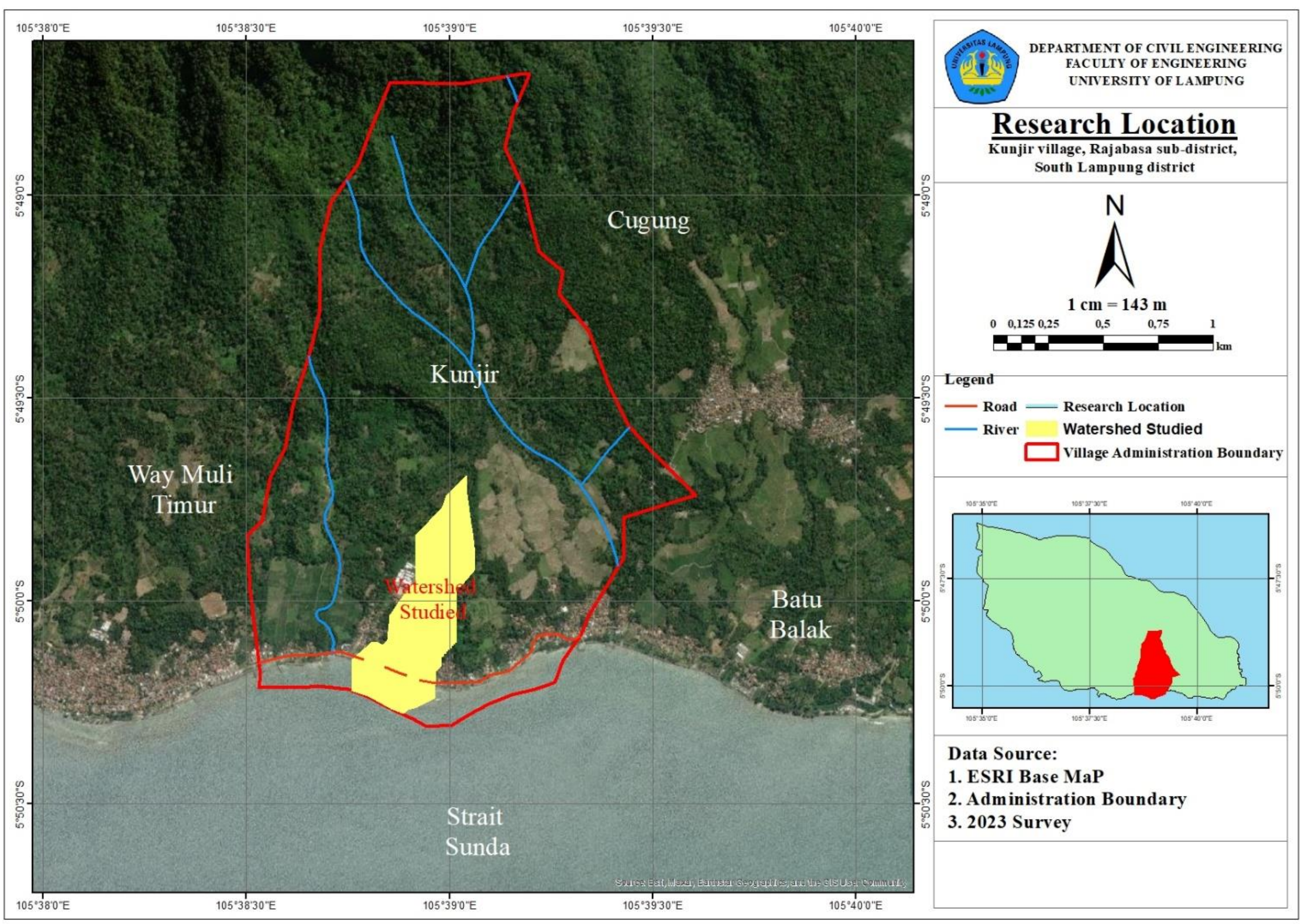


Figure 1 Research Location Map

2.2. Research Data

The data used in this study are as follows:

1. Existing channel data from field measurements (see Table 1 for measurement results).
2. Documentation photos.
3. Rainfall data.
4. Area and population data.
5. Tidal data.
6. Topographic data.

Table 1 Existing channel data

No.	Channel Section	Shape	Size			Elevation		Length (m)
			Top Width (m)	Bottom Width (m)	Height (m)	Upstream (m)	Downstreaam (m)	
1	Channel 1A	Rectangle	0.5	0.5	0.6	1.13	1.04	84.38
2	Channel 1B	Rectangle	0.5	0.5	0.6	1.24	1.04	127.53
3	Channel 1C	Rectangle	0.8	0.8	0.8	1.24	0.37	118.38
4	Channel 1D	Rectangle	0.5	0.5	0.6	1.40	1.22	173.30
5	Channel B	Rectangle	1.2	1.2	0.6	2.45	1.24	42.86
6	Channel 2C3	Rectangle	0.35	0.35	0.6	17.90	7.30	222.57
7	Channel 2C2 Left	Rectangle	0.35	0.35	0.6	16.70	7.24	224.82
8	Channel 2C2 Right	Rectangle	0.35	0.35	0.6	16.63	7.23	225.57
9	Channel 2C1 Left	Rectangle	0.35	0.35	0.6	17.80	7.17	283.47
10	Channel 2C1 Right	Rectangle	0.35	0.35	0.6	17.85	7.16	279.71
11	Channel 2C	Rectangle	0.6	0.6	0.6	7.30	7.10	170.89
12	*Box Culvert*	Rectangle	3.8	3.8	1.3	1.76	0.00	45.11
13	Channel 2A	Trapezoid	0.46	0.4	0.4	2.12	2.00	74.15
14	Channel 2A1	Trapezoid	0.82	0.55	0.63	3.75	2.00	112.03
15	Channel 2B	Trapezoid	0.45	0.4	0.48	2.48	2.30	115.00
16	Channel 2B1	Trapezoid	0.52	0.45	0.55	4.20	2.43	121.52
17	Channel 2B Left	Trapezoid	0.54	0.45	0.5	7.25	2.35	290.24
18	Channel 2B Right	Trapezoid	0.48	0.35	0.54	5.65	2.32	252.64
19	Channel 2B1 Left	Trapezoid	0.54	0.45	0.5	7.62	7.30	63.16
20	Channel 2D	Trapezoid	0.44	0.4	0.4	1.90	1.70	168.21
21	Upper River	Trapezoid	4.5	3.5	2.2	13.20	7.10	135.34
22	Downstream River	Trapezoid	10.5	7.9	3	7.10	0.00	403.03

2.3. Hydrological Analysis

a. Frequency and Probability Analysis

Frequency analysis is a method used to evaluate the relationship between the level of extreme events and the frequency of the possible occurrence of such events [2]. The utilization of the statistical properties of available data was used to predict the probability of rainfall magnitudes in the future [24].

In evaluating the suitability of data distribution types, various variables such as mean, standard deviation, skewness, kurtosis, and variation are used and incorporated into equations 1-5. To estimate hydrological frequency, various distribution types can be considered, including the log Pearson III distribution applied in Equation 6 [20].

1. Average Value

$$\bar{X} = \frac{\sum_{i-1}^{n} X_i}{n} \quad \text{.......(1)}$$

2. Standard Deviation

$$S_d = \sqrt{\frac{\sum_{i-1}^{n} (X_i - \bar{X})^2}{n-1}} \quad \text{.......(2)}$$

3. Skewness Coefficient

$$C_s = \sqrt{\frac{\frac{1}{n}\sum_{i-1}^{n} (X_i - \bar{X})^3}{(n-1)(n-2)Sd^3}} \quad \text{.......(3)}$$

4. Kurtosis Coefficient

$$C_k = \sqrt{\frac{\frac{1}{n}\sum_{i-1}^{n}(X_i - \overline{X})^4}{Sd^4}} \quad \text{...(4)}$$

5. Coefficient of Variation

$$C_v = \frac{S_d}{\overline{X}} \quad \text{...(5)}$$

Where:
$\overline{X}$ = Variant average value (mm)
S_d = Standard deviation
C_s = Skewness coefficient
C_k = Kurtosis coefficient
C_v = Variation coefficient
X_i = Annual maximum rainfall data to i
n = Total data

$$\text{Log } X_T = \text{Log } \overline{X}_T + (K_T \times Sd) \quad \text{.. (6)}$$

Where:
X_T = Design rainfall (mm)
$\overline{X}_T$ = Average rainfall (mm)
K_T = Variable subtraction
S_d = Standard deviation

b. Concentration Time

Concentration time is the duration needed for rainwater to flow from the farthest location to reach the control point [21]. Concentration time is calculated based on equation 7 [22].

$$t_c = \left[\frac{0.87\, L^2}{1000\, S}\right]^{0.385} \quad \text{.. (7)}$$

Where:
t_c = Concentration time (hour)
L = Channel length (km)
S = Slope of the channel area

c. Rainfall Intensity
d.
The general characteristics of rain are a shorter duration, a tendency towards higher intensity, and vice versa [23]. Rain intensity can be determined through rainfall data analysis, either statistically or empirically. Rain intensity is calculated using the Mononobe formula in equation 8 [18].

$$I = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{\frac{2}{3}} \quad \text{... (8)}$$

Where:
I = Rainfall intensity (mm/hour)
R_{24} = Maximum 24-hour rainfall (mm)
t_c = Concentration time (hour)

e. Design Flood Discharge

The design flood discharge is calculated by summing the rainfall runoff with the wastewater discharge [19].

1. Rainwater Discharge

Rainfall runoff is the amount of water within a certain period that is not absorbed by the soil and becomes surface runoff [23]. The rational method in Equation 9 is used to calculate the magnitude of rainfall runoff [18].

$$Q_{ah} = 0.278.C.I.A \quad \text{... (9)}$$

Where:
0.278 = Plan flood discharge conversion factor to units of (m^3/s)
Q_{ah} = Rainwater discharge (m^3/s)
C = Surface flow coefficient
I = Rainfall intensity (mm/hour)
A = Catchment Area (km^2)

2. Dirty Water Discharge

Before determining the amount of wastewater to flow into the drainage channel, it is important to know the average water demand and population in the planned area [19]. It is estimated that about 70% of the clean water demand will enter the collector channel as waste. The discharge of wastewater per square kilometer can be calculated using Equation 10 [19]

$$Q = \frac{(P_n \times Q_{keb} \times 70\%)}{A} \quad \text{... (10)}$$

Where:
Q = Dirty water discharge (liter/second/km^2)
P_n = Population in year n
Q_{keb} = Clean water demand (liter/day/person)
A = Catchment Area (km^2)

The flow rate of wastewater for each channel is determined by multiplying the flow rate of water per km^2 by the area of the residential area. The calculation is based on Equation 11 [19].

$$Q_{ak} = Q \times \text{residential area} \quad \text{.. (11)}$$

Where:
Q = Dirty Water Discharge (liter/s/km^2)
Q_{ak} = Dirty Water Discharge (m^3/s)

2.5. Channel Capacity

The capacity of drainage channels refers to the ability of the channel to accommodate water [22].

2.6. SWMM Program

The EPA Storm Water Management Model (SWMM) simulation software is used to model rainfall and water runoff [18]. EPA SWMM can be used to perform the following tasks: 1) drainage system planning to control floods; 2) mapping flood inundation; 3) pond planning for flood control and water quality protection; 4) designing control strategies to minimize sewer overflow; and 5) evaluating the impacts of inflow and infiltration flow.

2.7. Data Analysis

a. Analysis Using Microsoft Excel

1. Average rainfall using arithmetic method.
2. Calculation of frequency analysis and design rainfall using Pearson III log distribution.
3. Determining the limits of sub-watersheds.
4. Finding the concentration time using the Kirpich formula.
5. Calculating rainfall intensity using the Mononobe method.
6. Calculating the coefficient of surface runoff (c).
7. Calculating rainfall runoff using the rational method, as well as dirty water flow and design flow.
8. Calculating channel capacity.
9. Channel flow simulation.
10. Illustration of the influence of tides on the channel.

b. Analysis Using SWMM Program

Flowchart analysis using SWMM, see Figure 2.

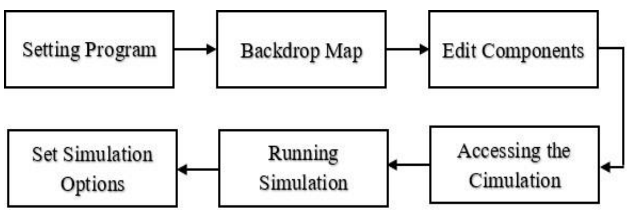


Figure 2 Flowchart of SWMM Program Analysis

3.0 RESULTS AND DISCUSSION

3.1 Rainfall Data

The rainfall data used were from the PH.030 Penengahan and R.021 Penengahan stations, which are averaged using the arithmetic mean method, and the maximum rainfall is determined. See Figure 3. From the figure, it can be seen that the highest rainfall occurred in 2017 with a magnitude of 110.5 mm and the lowest rainfall occurred in 2014 with a magnitude of 27 mm.

3.2 Hydrological Analysis

Equations 1, 2, 3, 4, 5, and 6 were used to calculate the design rainfall. Then, the concentration time was computed using Equation 7. Rainfall intensity was calculated using the Mononobe formula in Equation 8 (see calculation results in Figure 4). From the figure, it can be observed that the graph exhibits a similar pattern for each return period, and the intensity of rainfall increases with larger return periods. Furthermore, the design rainfall was computed by calculating the rainfall discharge based on Equation 9, which employs land use data from Figure 5, sub-catchment area with polluted water discharge based on Equations 10 and 11, as well as data on the population and service area in Kunjir Village. Figure 5 is a land use map created based on data from Google Earth and direct field observations. The map indicates that the majority of the area comprises forests, fields, settlements, and vacant land. Detailed design discharge can be seen in Table 2. From the table, it can be concluded that the highest rainfall intensity occurs in the first hour of rainfall descent with varying magnitudes depending on the existing sub-catchment area and flow concentration time.

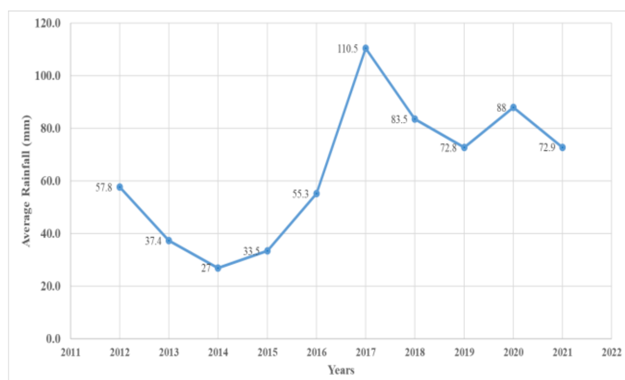


Figure 3 Average Rainfall Graph of Penengahan Station

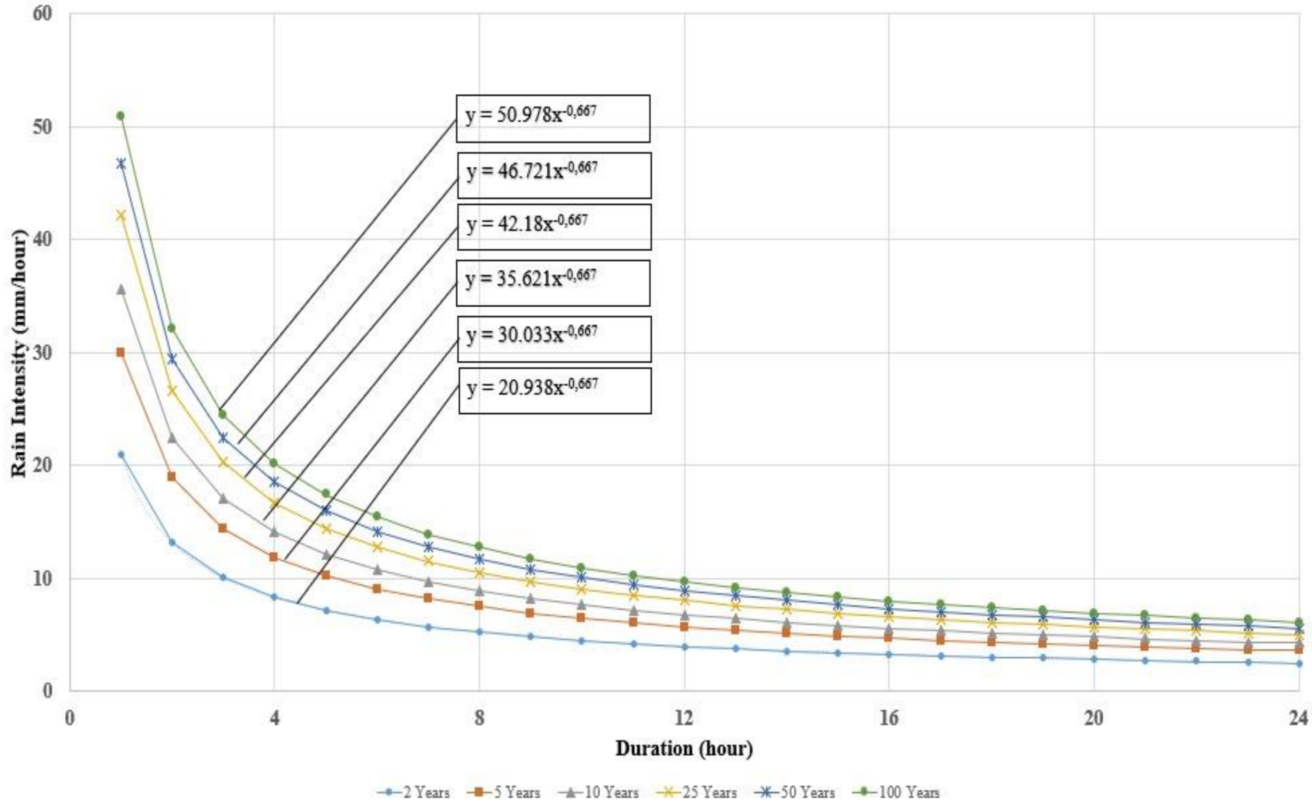


Figure 4 Mononobe Method Hourly Rainfall

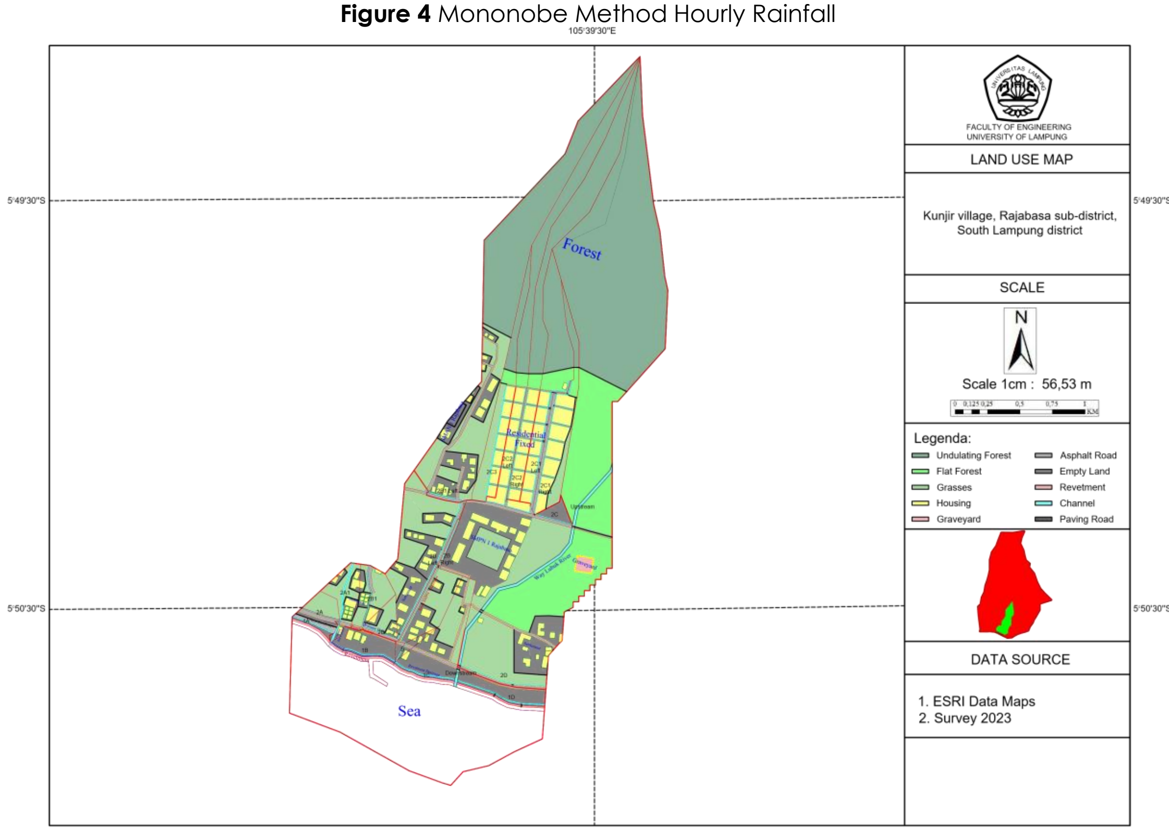


Figure 5 Land Use Map

Table 2 Discharge discharge in Kunjir village

Channel Section	Design Discharge (m^3/s			
	Before Rainfall	First Hour Rain	Second Hour Rain	Third Hour Rain
Channel 1A	0.0E+00	0.0476	0.0300	0.0229
Channel 1B	1.4E-06	0.0362	0.0228	0.0174
Channel 1C	2.3E-06	0.0595	0.0375	0.0286
Channel 1D	0.0E+00	0.1231	0.0775	0.0592
Channel B	6.4E-07	0.0139	0.0087	0.0067
Channel 2C3	8.4E-06	0.0979	0.0617	0.0471
Channel 2C2 Left	8.9E-06	0.1100	0.0693	0.0529
Channel 2C2 Right	1.1E-05	0.1419	0.0894	0.0682
Channel 2C1 Left	1.1E-05	0.1701	0.1071	0.0818
Channel 2C1 Right	1.5E-05	0.1714	0.1080	0.0824
Channel 2C	2.5E-06	0.0486	0.0306	0.0233
Box Culvert	3.2E-07	0.0122	0.0077	0.0059
Channel 2A	0.0E+00	0.0361	0.0227	0.0173
Channel 2A1	3.0E-06	0.0565	0.0356	0.0272
Channel 2B	1.1E-06	0.0288	0.0181	0.0138
Channel 2B1	2.2E-06	0.0435	0.0274	0.0209
Channel 2B Left	6.6E-06	0.0930	0.0586	0.0447
Channel 2B Right	3.1E-06	0.0545	0.0343	0.0262
Channel 2B1 Left	4.3E-06	0.2225	0.1402	0.1070
Channel 2D	2.9E-06	0.0884	0.0557	0.0425
Upper River	0.0E+00	0.4059	0.2557	0.1952
Downstream River	1.1E-05	0.2718	0.0300	0.1307

3.3 Hydraulics Analysis

Hydraulic analysis was conducted by calculating the channel capacity based on the existing data in Table 1 and topographic data. The calculations were performed by determining the cross-sectional area of the channel (A), wetted perimeter of the channel (P), and hydraulic radius of the channel (R) based on the type of the channel using equations 12, 13, 14, 15, 16, and 17. Then, the flow velocity (v), channel slope (S), and channel capacity can be determined using Equations 18, 19, and 20. The channel capacity in Kunjir Village can be found in Table 3.

Table 3 Channel storage capacity

Channel Section	A (m^2)	P (m)	R (m)	n	S	V (m/s)	Q_{sal} (m^3/s)
Channel 1A	0.3000	1.7000	0.1765	0.0170	0.0010	0.8905	0.2672
Channel 1B	0.3000	1.7000	0.1765	0.0170	0.0016	1.1163	0.3349
Channel 1C	0.6400	2.4000	0.2667	0.0170	0.0074	3.1182	1.9957
Channel 1D	0.3000	1.7000	0.1765	0.0170	0.0011	0.9010	0.2703
Channel B	0.7200	2.4000	0.3000	0.0170	0.0246	6.1654	4.4391
Channel 2C3	0.2100	1.5500	0.1355	0.0300	0.0476	2.8592	0.6004
Channel 2C2 Left	0.2100	1.5500	0.1355	0.0300	0.0421	2.6875	0.5644
Channel 2C2 Right	0.2100	1.5500	0.1355	0.0300	0.0417	2.6745	0.5616
Channel 2C1 Left	0.2100	1.5500	0.1355	0.0300	0.0375	2.5371	0.5328
Channel 2C1 Right	0.2100	1.5500	0.1355	0.0300	0.0382	2.5613	0.5379
Channel 2C	0.3600	1.8000	0.2000	0.0300	0.0012	0.5811	0.2092
Box Culvert	2.6600	5.2000	0.5115	0.0170	0.0390	11.0664	29.4366
Channel 2A	0.1720	1.2089	0.1423	0.0300	0.0016	0.5445	0.0937
Channel 2A1	0.4316	1.9208	0.2247	0.0300	0.0156	2.2940	0.9900
Channel 2B	0.2040	1.3652	0.1494	0.0300	0.0016	0.5533	0.1129
Channel 2B1	0.2668	1.5589	0.1711	0.0300	0.0142	1.8212	0.4858
Channel 2B Left	0.2475	1.4661	0.1688	0.0300	0.0169	1.9712	0.4879
Channel 2B Right	0.2241	1.4609	0.1534	0.0300	0.0132	1.6340	0.3662
Channel 2B1 Left	0.2475	1.4661	0.1688	0.0300	0.0059	1.1612	0.2874
Channel 2D	0.1680	1.2040	0.1395	0.0300	0.0012	0.4607	0.0774
Upper River	8.8000	8.3332	1.0560	0.4500	0.0451	0.7290	6.4148
Downstream River	27.6000	15.8398	1.7424	0.4500	0.0176	0.6364	17.5638

The result shows that the capacity of the channel is quite significant in the Box Culvert channel at 29.4366 m^3/s and Downstream River at 17.5638 m^3/s. This is because these channels have much larger existing cross-sections than other channels, and both channels are the final discharge points of the drainage system under review.

3.4 Flow Distribution

The distribution of flow occurs because not all existing discharge flows directly into the river or sea; instead, some of the discharge remains in the sub-watershed, and some are left in the channels, even forming inundation there. Simulations were conducted based on the concentration time data in the sub-watershed and drainage channels, as well as based on the existing drainage network. Thus, the magnitude of the discharge flowing in the channels is obtained when there is no rain, during the first hour of rain, the second hour of rain, and the third hour of rain. See Table 4.

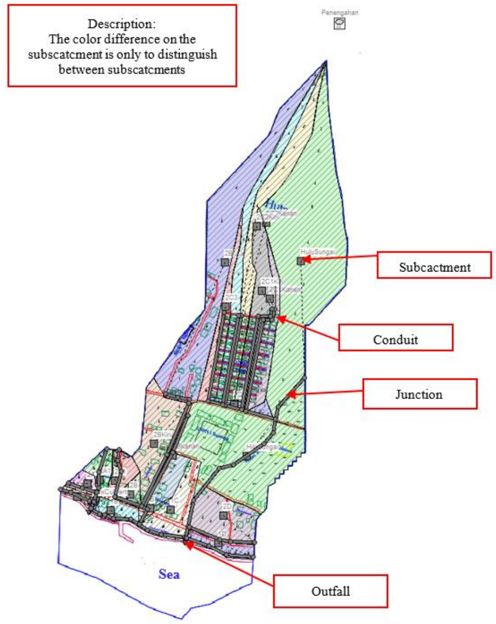
Table 4 Discharge flowing in the channel

Channel Section	Discharge flowing in the channel (m^3/s)			
	Before Rainfall	First Hour Rain	Second Hour Rain	Third Hour Rain
Channel 1A	0	0.0403	0.0327	0.0240
Channel 1B	1.7E-05	0.2576	0.3176	0.2547
Channel 1C	1.8E-05	0.2977	0.3353	0.2612
Channel 1D	0	0.0920	0.0890	0.0638
Channel B	3.2E-05	0.5474	0.5902	0.4496
Channel 2C3	8.4E-06	0.0840	0.0668	0.0492
Channel 2C2 Left	8.9E-06	0.0873	0.0777	0.0563
Channel 2C2 Right	1.1E-05	0.1130	0.1001	0.0725
Channel 2C1 Left	1.1E-05	0.1430	0.1172	0.0858
Channel 2C1 Right	1.5E-05	0.1469	0.1170	0.0860
Channel 2C	5.6E-05	0.4790	0.5358	0.4045
Channel Box Culvert	3.3E-06	0.1314	0.1034	0.0765
Channel 2A	0	0.0311	0.0246	0.0181
Channel 2A1	3.0E-06	0.0509	0.0376	0.0280
Channel 2B	1.7E-05	0.2814	0.3166	0.2437
Channel 2B1	2.2E-06	0.0378	0.0295	0.0218
Channel 2B Left	1.1E-05	0.2227	0.2271	0.1677
Channel 2B Right	3.1E-06	0.0437	0.0383	0.0278
Channel 2B1 Left	4.3E-06	0.1737	0.1582	0.1143
Channel 2D	2.9E-06	0.0619	0.0655	0.0464
Upper River	5.6E-05	0.7729	0.8220	0.6192
Downstream River	8.9E-05	1.2335	1.4960	1.1822

The results indicate that the flow rate during the first to the third hour of rainfall at the downstream of the river was significantly larger compared to other channels, with values of 1.2335 m^3/s, 1.4960 m^3/s, and 1.1822 m^3/s. This is because the channel accommodates almost the entire sub-watershed and serves as the ultimate discharge point before reaching the sea.

3.5 SWMM Program Analysis

The analysis stage in this SWMM program was carried out based on Figure 2 by creating a network scheme of the existing drainage and inputting all available data, including 24-hour rainfall data. Figure 6 illustrates the drainage network scheme in Kunjir Village, where the sizes of existing channels vary considerably, with the largest flow channel being the Way Lubuk river. Figure 7 shows the rainfall data inputted into the program, known as a rain gauge. This rain gauge data originated from previously calculated hourly rainfall data in Figure 4, combined with the magnitude of wastewater flow converted into rainfall and assumed to flow continuously for 24 hours. The rain gauge magnitudes exhibit the same pattern for each recurrence. After that, run the program and the results can be displayed for evaluation.



6 Schematic of The Drainage Network in Kunjir Village

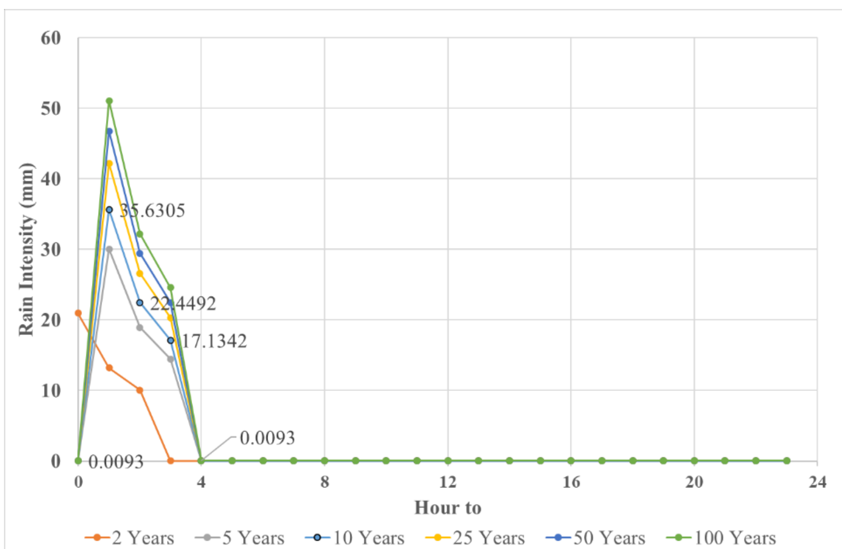
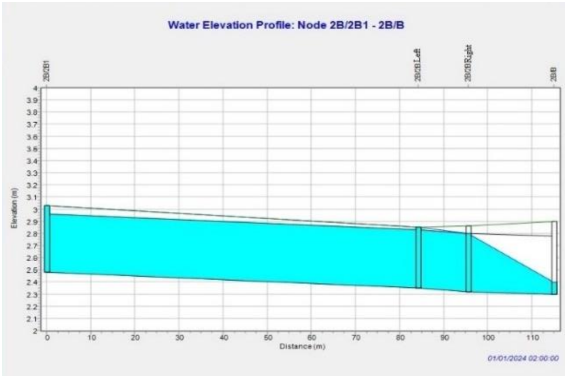
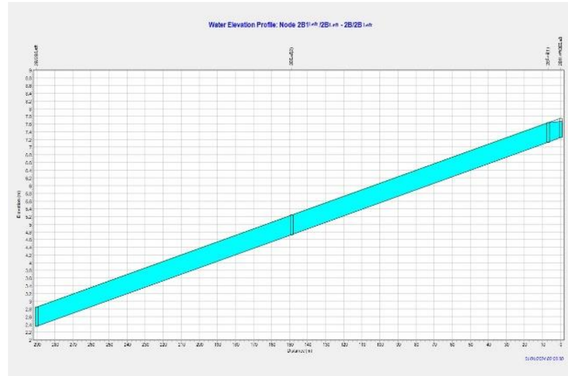


Figure 7 24-Hour Rain Data

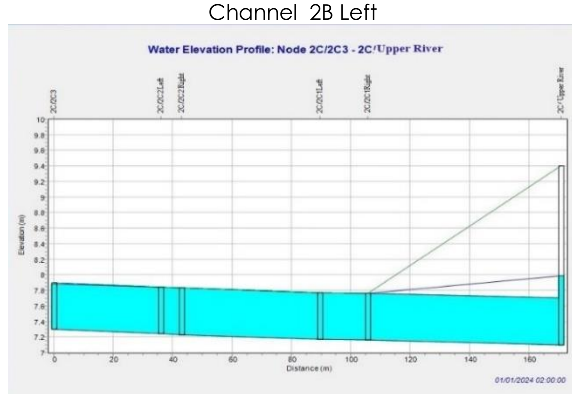
Based on the results of the program run, it was found that several channels experienced flooding, namely channels 2B, 2B Left, 2B1 Left, 2C, and 2D. Figure 8 displays the points where node flooding occurred. This flooding is caused by the existing channels being unable to contain large water discharge, resulting in channel overflow. These findings are used to evaluate the existing channels and assess relevant steps to address the flooding issues in the channels.



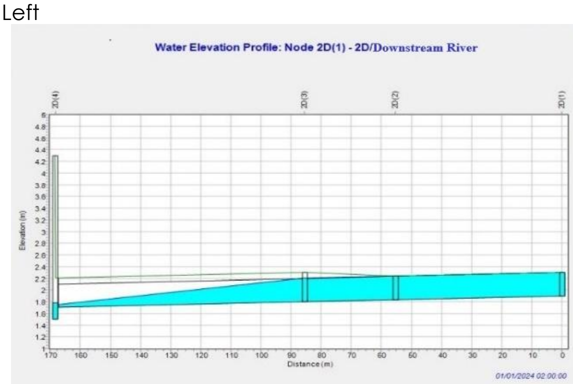
Channel 2B


Channel 2B Left

Channel 2B1 Left



Channel 2C

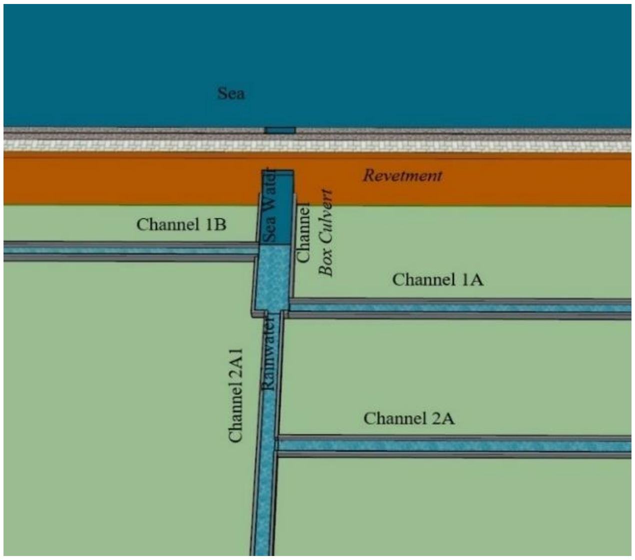


Channel 2D

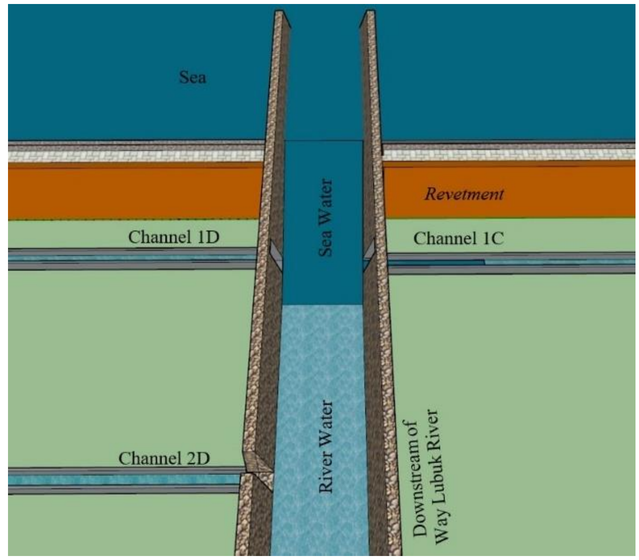
Figure 8 Node Flooding in Kunjir Village

3.6 Tidal Influence on The Channel

The ebb and flow of the tide are the periodic rising and falling of the sea surface over a certain period of time [21]. In Figure 9, the effect of tides on the channel is shown. The magnitude of this tidal influence must be considered and analyzed to determine whether the tide is one of the causes of flooding in Kunjir Village. The Highest Water Level (HWL) in Kunjir Village is 0.6 meters. Based on observations, the channels affected by the tide were channel 1C, Box Culvert channel, and the downstream of the Way Lubuk River. The existing tide was simulated into the program to obtain the graph of the tidal influence in Figure 10, which can be seen that the channels inundate and cause the water level in the three channels to rise higher. However, the existing channels can still accommodate the flowing water discharge, and it can be concluded that the existing tide is not the cause of the flooding in the village.

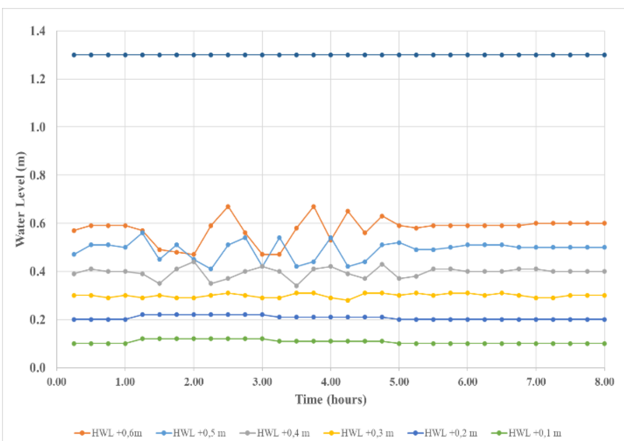


(a)

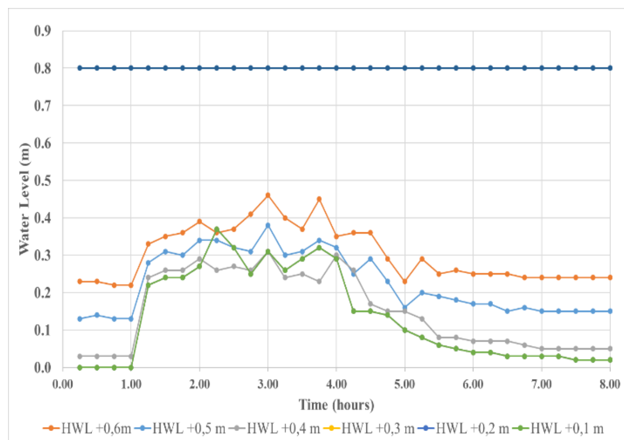


(b)

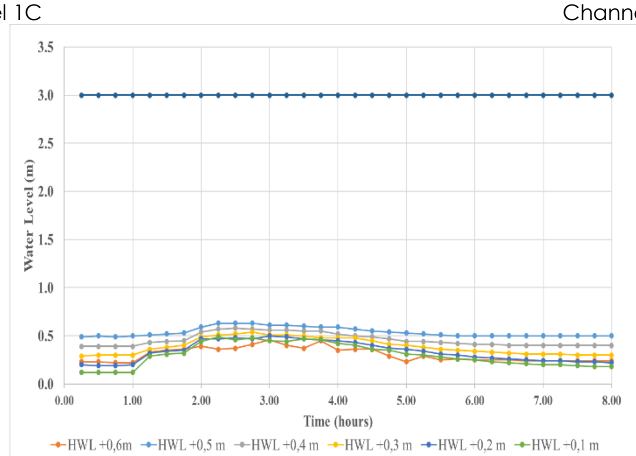
Figure 9 Tidal Influence on the Channel



Channel 1C



Channel Box Culvert



Downstream River

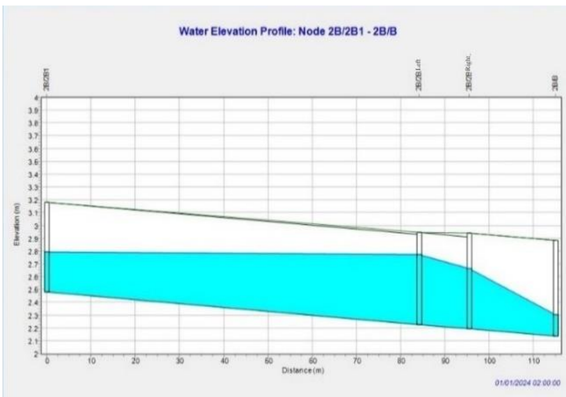
Figure 10 Tidal Influence on the Channel

3.7 Completion Solution

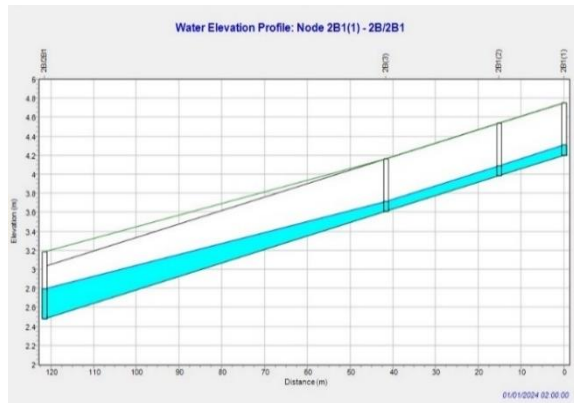
Based on the analysis results of the total 22 channels available, 4 channels experienced overflow, resulting in a channel performance percentage of 81.81%. Based on the channel condition assessment criteria in Fauziah's study [19], the channel damage and the amount of sedimentation in the village are considered to be in a good condition.

According to Fransiska's study [24], several solutions recommended to address the flooding issues in the Jati Kota Padang area including dimension enlargement, flow diversion, and the construction of infiltration wells. From this research, the proposed solution to address the existing flooding issues in Kunjir Village are periodic maintenance and redesigning of channels by increasing their dimensions and elevation differences. See Table 5. From the table, it is evident that the largest dimension increase is in channel 2C, with an increase in downstream channel height of 0.4127 m and a width increase of 0.4 m. The new dimensions of the channel were then re-inputted into the SWMM program, and after running, the program output results are presented in Figure 11. From the rerunning results, it can be concluded that with the new dimensions, the channels experiencing problems have been resolved.

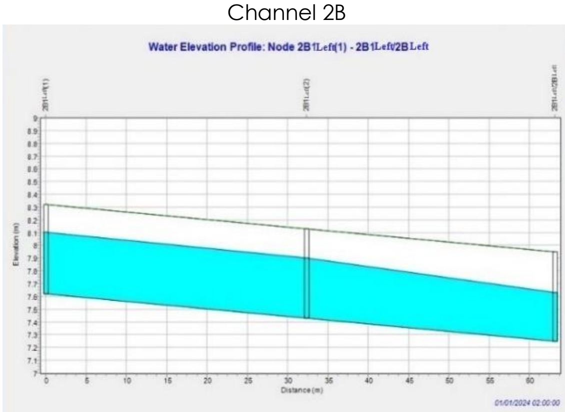
As for addressing the channels affected by tidal influences, channel 1C needs to be equipped with an automatic water gate at the downstream section to prevent seawater from entering the channel. The operation of this device involves the gate opening when the water level downstream (channel water level) is lower than the water level upstream (river water level), and vice versa, the gate will close when the upstream water level is higher than the downstream water level. It is hoped that with the use of these water gates, the impact of tidal influences on the existing channels can be reduced, making the channels more durable.



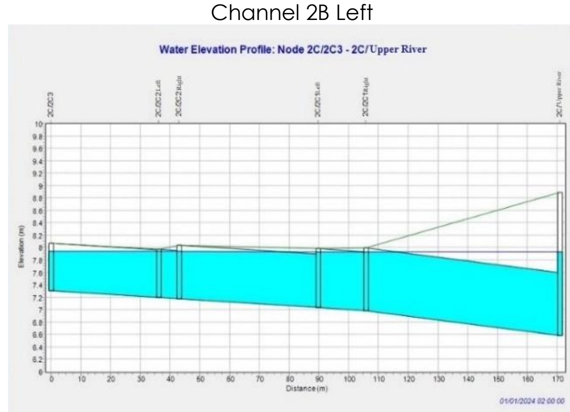
Channel 2B



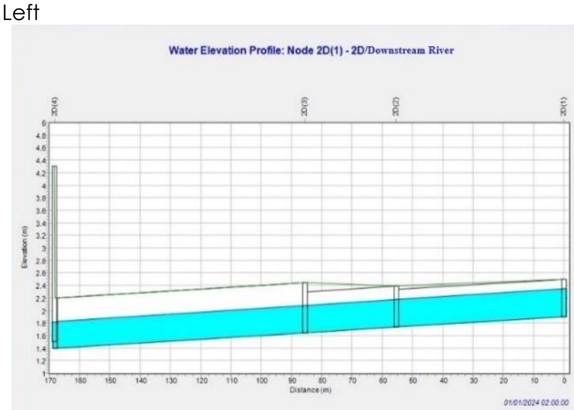
Channel 2B Left



Channel 2B1 Left



Channel 2C



Channel 2D

Figure 11 Node Flooding After Re-planning

Table 5 Annel enlargement

Channel Section	Upstream Section		Downstream Section		Direction of Channel Width Increase
	Height (m)	Width (m)	Height (m)	Width (m)	
Channel 1A	0	0	0.1651	0	-
Channel 1B	0	0	0.1736	0	-
Channel 1D	0	0	0.3349	0	-
Channel 2C	0.1	0	0.4127	0.4	Above
Channel 2A	0	0	0.1024	0	-
Channel 2A1	0	0	0.1024	0	-
Channel 2B	0.1	0	0.4650	0	-
Channel 2B Left	0.15	0.1	0.15	0.1	Left
Channel 2B1 Left	0.15	0.1	0.15	0.1	Above
Channel 2D	0.1	0	0.4046	0	-

4.0 CONCLUSION

The conclusion is that channel 2B, 2B1, 2B1 Left, 2C, and 2D cannot accommodate the flowing discharge; tidal fluctuations affect channel 1C, Box Culvert, and downstream rivers; the solutions that can be implemented include channel enlargement, addition of channel bottom slope, periodic maintenance, and installation of water gates to mitigate the effects of tidal fluctuations. By implementing these measures, it is hoped that the impact of tidal fluctuations can be reduced and the channel capacity can be increased to cope with high water discharge.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

References

[1] Putra, M. A. R., Andawayanti, U. & Lufira, D. R. 2022. Studi Evaluasi dan Penanganan Genangan Menggunakan Aplikasi SWMM 5.1 pada Sistem Drainase Darmo Kali Kota Surabaya. *Jurnal Teknologi dan Rekayasa Sumber Daya Air*. 2(2): 128-141. Doi: https://repository.ub.ac.id/id/eprint/190736/.

[2] Mugume, S. N., Gomez, D. E., Fu, G., Farmani, R., & Butler, D. 2015. A Global Analysis Approach for Investigating Structural Resilience in Urban Drainage Systems. *Water Research*. 81: 15-26. Doi: https://doi.org/10.1016/j.watres.2015.05.030.

[3] Sangsefidi, Y., Bagheri, K., Davani, H., & Merrifield, M. 2023. Data Analysis and Integrated Modeling of Compound Flooding Impacts on Coastal Drainage Infrastructure under a Changing Climate. *Journal of Hydrology*. 616: 1-13. Doi: https://doi.org/10.1016/j.jhydrol.2022.128823.

[4] Damilola, A. E. 2016. The Osun Drainage Basin in the Western Lithoral Hydrological Zone of Nigeria: A Morphometric Study. *Malaysian Journal of Society and Space*. 12(8): 71-88. Doi: https://doi.org/10.17576/geo-2021-1701-01.

[5] Rosyidie, A. 2013. Banjir: Fakta dan Dampaknya, Serta Pengaruh dari Perubahan Guna Lahan. *Jurnal Perencanaan Wilayah Dan Kota*. 24(3): 241-249. Doi: https://doi.org/10.5614/jpwk.2013.24.3.1.

[6] Qodriyatun, S. N. 2020. Bencana Banjir: Pengawasan dan Pengendalian Pemanfaatan Ruang Berdasarkan UU Penataan Ruang dan RUU Cipta Kerja. *Aspirasi: Jurnal Masalah-Masalah Sosial*. 11(1): 29-42. Doi: 10.22212/aspirasi.v11i1.1590.

[7] Berggren, K., Olofsson, M., Viklander, M., Svensson, G., & Gustafsson, A. M. 2012. Hydraulic Impacts on Urban Drainage Systems Due to Changes in Rainfall Caused by Climatic Change. *Journal of Hydrologic Engineering*. 17(1): 92-98. Doi: https://doi.org/10.1061/(asce)he.1943-5584.0000406.

[8] Wit, J. A. de, Huijgevoort, M. H. J. van, Dam, J. C. van, Eertwegh, G. A. P. H. van den, Deijl, D. van, Ritsema, C. J., & Bartholomeus, R. P. 2024. Hydrological Consequences of Controlled Drainage with Subirrigation. *Journal of Hydrology*. 628: 1-14. Doi: https://doi.org/10.1016/j.jhydrol.2023.130432.

[9] Chandraseana, D. C. N., Yusof, K. W., Mustafa, M. R. U., Mustaffa, Z. & Umar, S. I. 2016. A Theoretical Discussion and Case Study on The Development of Smart Storm Drainage Unit for Compact Cities. *Jurnal Teknologi*. 78(5-3): 85-90. Doi: https://doi.org/10.11113/jt.v78.8517.

[10] Bibi, T. S. 2022. Modeling Urban Stormwater Management in The Town of Dodola Based on Landuse and Climate Change Using SWMM 5.1. *Journal of Hydrology: Regional Studies.* 44: 1-20. Doi: https://doi.org/10.1016/j.ejrh. 2022.101267.

[11] Katimon, A. 2018. Steady State Open Drainage System for Minimizing Fire Hazard on Peat Areas. *Malaysian Journal of Civil Engineering*. 10(2): 12-19. Doi: https://doi.org/10.11113/mjce.v10.15583.

[12] Kartiko, L., Santoso, R. & Waspodo, B. 2018. Analisis Kapasitas Saluran Drainase Menggunakan Program SWMM 5.1 di Perumahan Tasmania Bogor, Jawa Barat. *Jurnal Teknik Sipil Dan Lingkungan*. 03(03): 133-148. Doi: https://doi.org/10.29244/jsil.3.3.133-148.

[13] Istianah, Kuncoro, A. H. B., & Budiningrum, D. S. 2023. Analisis Kapasitas Saluran Drainase Perumahan Jagansari Residence Kabupaten Grobogan. *Jurnal Teknik Sipil ITP*. 10(1). Doi: https://doi.org/10.21063/JTS.2023.V1001.052-63.

[14] Piadeh, F., Behzadian, K., Chen, A. S., Kapelan, Z., Rizzuto, J. P., & Campos, L. C. 2023. Enhancing Urban Flood Forecasting in Drainage Systems using Dynamic Ensemble-Based Data Mining. *Water Research*. 247: 1-17. https://doi.org/10.1016/j.watres.2023.120791.

[15] Wijaya, N. 2016. Coastal Community's Responses to Water Infrastructure Under Climate-Related Disaster in Semarang City, Indonesia. *ASEAN Engineering Journal*. 5(1): 14-33. Doi: https://doi.org/10.11113/aej.v5.15469.

[16] Yunusa, G. H. & Kassim, A. 2016. Optimizing Irrigation and Drainage Rates in Sri Paddy Fields. *Jurnal Teknologi*. 78(6-12): 23-29. Doi: https://doi.org/10.11113/jt.v76.5966.

[17] Faizal, R., Prsetya, N. A., Alstony, Z. & Rahman, A. 2019. Evaluasi Sistem Drainase Menggunakan Storm Water Management Model (SWMM) dalam Mencegah Genangan Air di Kota Tarakan. *Borneo Engineering: Jurnal Teknik Sipil*. 3(2): 1-12. Doi: https://doi.org/10.35334/be.v3i2.1177.

[18] Pratama, A., Sumiharni & Febrina, R. 2023. Evaluasi Sistem Drainase Menggunakan Program EPA SWMM 5.2 (Studi Kasus : Jalan Pramuka Kecamatan Rajabasa Kota Bandar Lampung). *Journal of Sustainable Civil Engineering (JOSCE)*. 05(01): 63-69. Doi: 10.47080/josce.v5i01.2522.

[19] Fauziah, S. 2021. Evaluasi Kapasitas Saluran Drainase dengan Menggunakan Software Hec-Ras 4.10 dan EPA SWMM 5.*1* Thesis, Universitas Islam Sultan Agung Semarang. Doi: http://repository.unissula.ac.id/25701/.

[20] Resmani, E., Andawayanti, U., & Nur Cahya, E. 2017. Analisa Kapasitas Tampung Saluran Drainase Akibat Pengaruh Limpasan Permukaan Kecamatan Kota Sumenep. *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*. 8(2): 214-221. Doi: https://doi.org/10.21776/ub.pengairan.2017.008.02.7.

[21] Efrizal, E., Hidayati, N. & Saputro, Y. A. 2022. Implementasi Software Hec-Ras 4.1.0 dan Epa Storm Water Management Model (SWMM) 5.1.0 pada Efektivitas Analisis Saluran Drainase (Studi Kasus Desa Kelet Kecamatan Keling Kabupaten Jepara). *Jurnal Civil Engineering Study*. 02(1): 7-16. Doi: https://journal.unisnu.ac.id/CES.

[22] Kirpich, T. P. 1940. *Time of Concentration of Small Agricultural Watersheed*. Civil Engineering (6 ed., Vol. 10). 362 hlm.

[23] Suadnya, D. P., Sumarauw, J. S. F. & Mananoma, T. 2017. Analisis Debit Banjir dan Tinggi Muka Air Banjir Sungai Sario di Titik Kawasan Citraland. *Jurnal Sipil Statik*. 5(3): 143-150. Doi: https://ejournal.unsrat.ac.id/v3/index.php/tekno.

[24] Fransiska, Y., Junaidi & Istijono, B. 2020. Simulasi dengan Program EPA SWMM Versi 5.1 untuk Mengendalikan Banjir pada Jaringan Drainase Kawasan Jati. *Jurnal Civronlit Unbari*. 5(1): 38-48. Doi: 10.33087/civronlit.v5i1.5.