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ARTICLE

FLOOD INUNDATION EVALUATION AND USING THE EPA SWMM 5.2 APPLICATION IN SETRO TENGAH SURABAYA

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Abstract

Flood inundation is a recurring issue in the Setro Tengah area of Surabaya, particularly during the rainy season. This condition is influenced by inadequate drainage capacity, sedimentation, channel narrowing, and high rainfall intensity. This study aims to evaluate the capacity of the existing drainage channels, analyze the causes of inundation, and propose mitigation alternatives using the EPA SWMM 5.2 application. The research method includes rainfall data collection, hydrological analysis, hydraulic analysis, SWMM modeling, and the assessment of planned channel dimensions. The evaluation results indicate that several drainage channels along Setro Tengah Street are unable to accommodate the design discharge due to reduced flow capacity, excessive sediment, and dimensions that do not meet the standards. The SWMM simulation shows that some channels overflow, causing inundation at several points. The proposed solutions include improving channel dimensions, increasing capacity, conducting routine cleaning, and redesigning the drainage network based on the modeling outcomes. This study is expected to serve as a reference for flood inundation mitigation efforts in urban residential areas.

Keywords: Drainage, Flood inundation, EPA SWMM 5.2, Surabaya, Hydrology.

A. INTRODUCTION

Surabaya is the second-largest metropolitan city in Indonesia with rapid population growth and development, particularly in East Surabaya (Setyawati et al., 2022). Population growth and residential development have led to land use changes, from water catchment areas to densely populated residential areas. This has reduced catchment areas and increased the risk of flooding and inundation, particularly in the Setro Tengah area (Putra et al., 2022).

The problems of inundation and flooding in Setro Tengah are caused by several factors, including a suboptimal drainage system, high rainfall, changes in land use, and a lack of maintenance and public awareness of water channel cleanliness. Inadequate drainage channels prevent rainwater from draining properly, resulting in runoff and surface pooling. Furthermore, the accumulation of garbage and sediment in the channels, along with the small dimensions of the channels, exacerbates these conditions (Kartiko et al., 2018).

High rainfall is also a major contributing factor to inundation (Sulaiman et al., 2020). Rainfall is the amount of rainwater collected on the ground surface over a specific period of time and is usually expressed in millimeters (mm) (Latief et al., 2024). If the drainage system is unable to accommodate the volume of water due to high rainfall, inundation and flooding are inevitable (Yunianta et al., 2022).

To address these issues, a comprehensive evaluation of the existing drainage system and appropriate, data-based management planning are required (Aisiyah N, 2016). One software tool that can be used to analyze and design urban drainage systems is EPA SWMM 5.2 (Environmental Protection Agency Storm Water Management Model) (Pakaenoni et al., 2024). This application is capable of simulating rainwater flow, designing pipe networks, controlling flooding, and evaluating the impact of land use changes on drainage systems (Fiani & Pribadi, 2024).

This study aims to evaluate the condition of existing drainage channels, analyze the causes of inundation, and formulate management solutions using EPA SWMM 5.2 in the Setro Tengah area of Surabaya. The research results are expected to provide applicable technical recommendations to improve the performance of drainage systems, reduce the risk of flooding, and support better and more sustainable urban environmental management.

B. LITERATURE REVIEW

Urban Drainage System Theory

Urban drainage system theory explains that drainage is a system designed to drain excess surface water quickly and safely to prevent ponding and flooding (Yunianta & Setiadji, 2022). This system includes a network of channels, control structures, and supporting elements that work in an integrated manner to ensure efficient flow (Santoso et al., 2025). In the context of urban areas, channel capacity must be adjusted to accommodate land-use changes that increase surface runoff (Prasetiani et al., 2023). Dimensional inconsistencies, sedimentation, and channel narrowing are often the main causes of drainage system failure to accommodate runoff (Hegemur M, 2023). Therefore, evaluating hydraulic capacity is a critical component in identifying the channel's inability to optimally channel the design flow. Indicators:

- Adequate channel capacity
- Physical condition of the channel (sedimentation, narrowing, damage)
- Suitability of channel dimensions to the planned discharge
- Connectivity function between channel segments
- Availability of maintenance structures (manholes, inlets, outlets)

Urban Hydrology Theory

Urban hydrology theory studies the relationship between rainfall, catchment area characteristics, and surface runoff in urban environments with low permeability (Suprayogi et al., 2024). In densely built-up areas, changes in land cover from infiltration areas to impermeable surfaces lead to an increase in the runoff coefficient (Abinow A, 2018). This condition significantly increases the volume and peak flood discharge during heavy rainfall events. Basic calculations such as rainfall intensity, time of concentration, and design discharge form the basis for designing drainage capacity (Indriatmoko R, 2019). Thus, hydrology theory provides a comprehensive framework for assessing whether an existing drainage system is capable of accommodating runoff from rainfall with a specific return period (Lufira & Asri, 2021). Indicators:

- Rainfall intensity
- Runoff coefficient (C)
- Time of concentration (Tc)
- Design flood discharge (Q)
- Catchment area size and characteristics

Hydrologic-Hydraulic Modeling Theory (EPA SWMM)

Hydraulic-hydraulic modeling theory explains that computer simulations such as EPA SWMM are used to model the response of stormwater runoff to drainage networks under various rainfall scenarios (Al Amin M, 2020). This model allows for in-depth analysis of flow behavior, surcharge potential, ponding, and flooding points at each node or channel. By incorporating hydrologic and hydraulic parameters, the model can predict existing channel capacity and assess the effectiveness of alternative designs (Nuzul M, 2022). The use of modeling is crucial for visualizing system conditions dynamically, rather than relying solely on static calculations (Fitriyani S, 2025). Therefore, this theory underlies simulation-based drainage network evaluation and redesign methods. Indicators:

• Accuracy of hydrological input (rainfall, runoff coefficient)
• Accuracy of hydraulic input (channel dimensions, slope, Manning's n)
• Identification of problematic nodes and conduits
• Results of surcharge/ponding/flooding simulations
• Effectiveness of alternative designs after modeling

C. RESEARCH METHODOLOGY

Research Location

The research location is on Jalan Setro Tengah, Surabaya City. This location was selected based on the consideration that it has characteristics that align with the research objectives, thus allowing for more in-depth analysis.

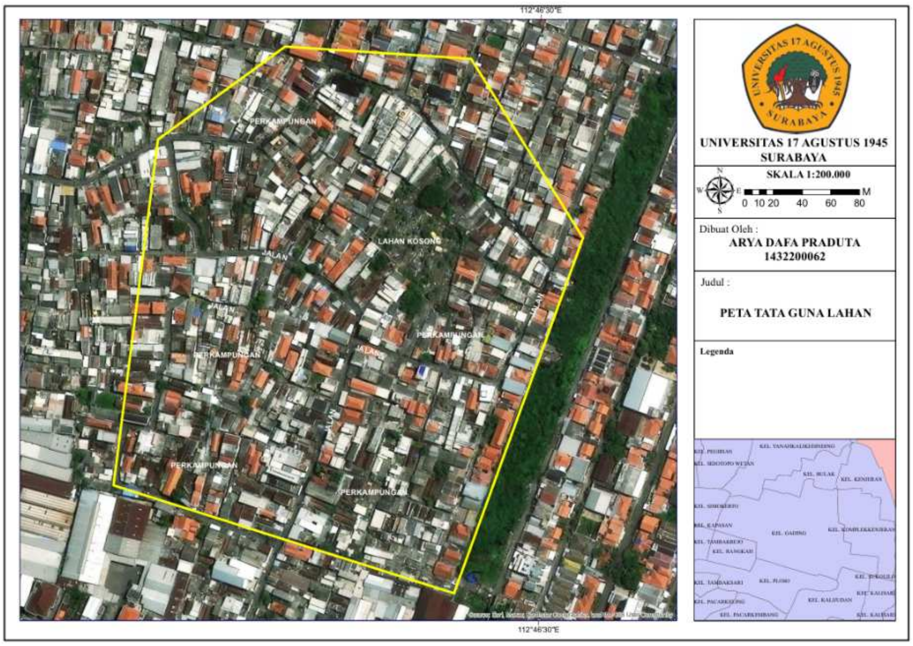

Figure 1. Research Location
Source: (Data processed by researcher, 2025)

Survey and interview results indicate that flooding in Setro Tengah, Surabaya, was caused by high rainfall and non-optimal functioning of existing drainage channels, resulting in stagnant water runoff. Observations also found that water flow remained high even when there was no rain. This study aims to provide an effective solution to prevent flooding and evaluate the condition of the drainage channels. Using EPA SWMM 5.2 software, the drainage system was redesigned to be more optimal, sustainable, and able to improve the community's quality of life. Successful implementation depends heavily on collaboration between the community and relevant parties.

Research Data

The data used in this study are both primary and secondary. The data required include:

Primary Data

Primary data is data obtained directly through observations, measurements, interviews, or field surveys by researchers, which serve as the primary source for analyzing drainage channels. The following is the primary data required by the researcher:

- Channel dimension data
- Drainage channel conditions

Secondary data

Secondary data is data obtained from existing sources, such as government agencies, research institutions, or literature, used to support drainage channel analysis without the need for field observations and measurements. The following is the secondary data required by researchers: Rainfall data 2015 – 2024

- Topographic map
- Catchment area map

Analysis Method

Hydrological Analysis

Regional Average Rainfall

Rainfall analysis uses the arithmetic method. This method is performed by adding the data from the three closest rainfall stations and then dividing by the number of stations. Because this method does not consider geographic location or the area affected by each station, the arithmetic method is most suitable for flat areas and where the distribution of rainfall stations is relatively even.

Frequency Distribution

Probability distribution calculations are performed using previously calculated data, namely average rainfall. The Log Pearson Type III distribution is used in frequency analysis. The selection of the probability distribution can be adjusted based on the previously calculated basic parameter values. This initial stage of statistical parameter calculation is important before determining the distribution used, as each parameter has different characteristics. Therefore, each hydrological data set must be tested for its suitability to its statistical properties to avoid errors in selecting a distribution method.

Data Fit Test

To test the fit between the sample data distribution and the hypothesized theoretical probability distribution function, statistical parameter testing analysis is required. The data is tested using the Smirnov-Kolmogorov method to determine the probability distribution that best fits the observed rainfall data.

Rainfall Intensity

Rainfall intensity is calculated using the Mononobe method. This calculation process aims to determine rainfall intensity. The data used is derived from the planned rainfall values obtained in the previous calculation stage. The results of this calculation then produce a rainfall intensity value in mm/hour.

$$I = \frac{R}{(t+a)n}$$

Where:

- I = rainfall intensity (mm/hour)
- R = planned rainfall (mm)
- t = rainfall duration (hours)
- a and n = constants based on empirical analysis

Design Flood Discharge Calculation

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The design flood discharge calculation is performed using the results of previous calculations, namely rainfall intensity in mm/hour. At this stage, the rational method is used, which produces design flood discharge values for return periods of 2 years, 5 years, and 10 years.

$$Q = 0,278 \cdot C \cdot I \cdot A$$

Where:

- Q = peak discharge (m³/sec)
- C = surface runoff coefficient
- I = rainfall intensity (mm/hour)
- A = catchment area (ha)

Hydraulic Analysis

Hydraulic analysis is the study of water flow behavior in open or closed channels, such as rivers, drainage channels, or irrigation networks, taking into account factors such as discharge, flow velocity, water depth, channel bed slope, and flow energy. The primary objective of this analysis is to design a channel with adequate capacity to optimally channel water without causing ponding or flooding.

Calculating the drainage channel's capacity aims to determine the maximum capacity of the existing channel to convey water discharge. The first step is to determine the wetted cross-sectional area (A) and wetted perimeter (P). The calculation is then performed using the Manning formula, which relates flow velocity (V) to the channel roughness coefficient (n), and includes the hydraulic radius (R) and channel bed slope (S). The resulting capacity calculation will then serve as a benchmark for comparison against the previously calculated design flood discharge (Qhydrologic). If Qhydrologic is less than Qhydrologic, the drainage channel is unable to accommodate the design flood discharge, requiring improvements or normalization of the channel dimensions. To calculate the discharge capacity, the Manning formula is used as follows.

$$V = \frac{1}{2} R^{2/3} Is^{1/2}$$

Description:

- V = flow velocity (m/s)
- n = Manning's roughness coefficient
- R = hydraulic radius = A/P (m)
- i□ = channel bed slope
- A = wetted cross-sectional area (m²)
- P = wetted perimeter (m)

In this study, the channel discharge was calculated using the rational method, which is stated as follows:

Q = V x A

Description:

Q = channel flow discharge (m3/s)

V = average channel velocity (m/s)

A = wetted channel cross-section (m2)

EPA SWMM 5.2 Modeling

Hydrological and hydraulic modeling was performed using EPA SWMM 5.2 software to simulate flow behavior in the drainage system on Jalan Setro Tengah. Modeling began with the creation of subcatchments based on catchment boundaries, area, slope, runoff coefficient, and percentage of impervious surface. Each subcatchment was connected by junctions and conduits representing existing drainage channels. Hydraulic parameters such as channel length, diameter or cross-sectional width, Manning's roughness value, and bed slope were entered based on field survey results. Furthermore, design rainfall data from the hydrological analysis was used as input for the rainfall simulation.

The simulation was conducted to assess channel performance against design discharges, including identifying points experiencing surcharge, ponding, or flooding in the drainage network. The modeling results showed the system's response to specific rainfall levels and highlighted channels that were unable to accommodate runoff. SWMM output, such as hydrographs, flow profiles, and channel capacity reports, identified segments requiring improvement. This information served as the basis for developing technical recommendations for increasing the capacity and improving the drainage network.

In general, the flow of this research can be seen in Figure 2.

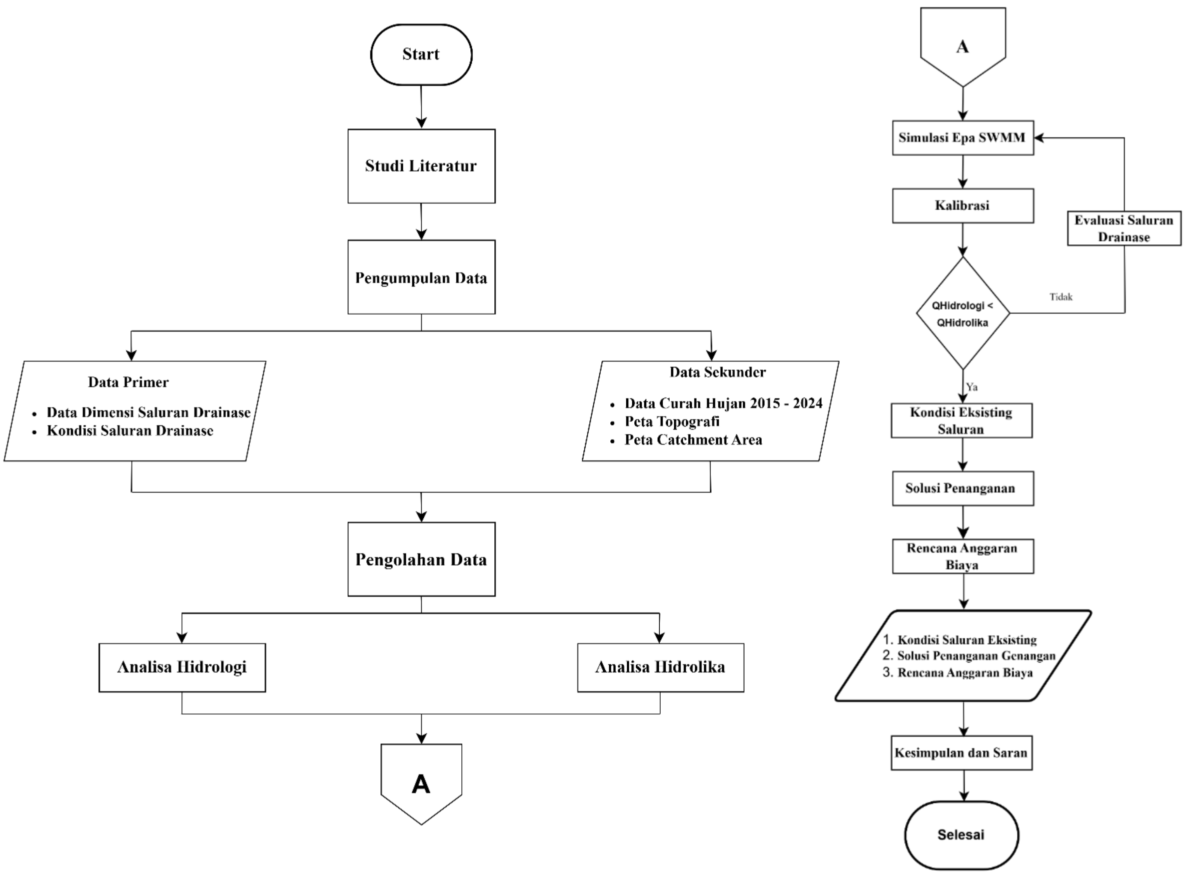

Figure 2. Research Flowchart
Source: (Data processed by researcher, 2025)

D. RESULT AND DISCUSSION

Hydrological Analysis

The hydrological analysis in this study was conducted to determine the magnitude of the planned flood discharge in the study area. The analysis process began with processing rainfall data from Kedung Cowek Station using arithmetic methods to obtain the regional average rainfall. Next, a frequency analysis was performed using the Log Pearson Type III distribution to determine the planned rainfall based on a specific return period. Before use, this distribution was tested for its suitability using the Smirnov–Kolmogorov test to ensure that the observed data matched the theoretical distribution used. The test results showed that the rainfall data conformed to this distribution, thus the calculation results were considered valid. The rainfall values were then used to calculate the time of concentration (Tc), rainfall intensity, and runoff coefficient (C), which reflect the land use characteristics of each subwatershed. Once all parameters were obtained, the planned flood discharge was calculated using the Rational method, which combines rainfall intensity, runoff coefficient, and catchment area. The calculation results for each subwatershed are presented in Table 1, showing the planned flood discharge for various return periods. A summary of these calculation results is shown in Table 3. The combination of the planned flood discharge and wastewater discharge produces the total planned discharge, which serves as the basis for evaluating existing drainage channels. The total discharge value for each sub-watershed is shown in Table 4, illustrating the contribution of runoff from each area to the potential for flooding on Jalan Setro Tengah, Surabaya.

Designed Flood Discharge (Q)

Table 1. Summary of Designed Flood Discharge Calculations

SubDAS	Return period (Year)	Flow	Rainfall Intensity	Area (Km2)	(Design m3/sec)
		(C)	(I)	(A)	
SubDAS 1	2		72,55		0,5074
	5	0,511	85,20	0,02	0,2422
	10		92,21		0,2621
SubDAS 2	2		100,79		0,5288
	5	0,189	118,36	0,1	0,6210
	10		128,10		0,6721
SubDAS 3	2		84,90		0,2872
	5	0,243	99,71	0,05	0,3372
	10		107,91		0,3650
SubDAS 4	2		86,58		0,0208
	5	0,043	101,68	0,02	0,0244
	10		110,05		0,0264
SubDAS 5	2		85,05		0,1298
	5	0,055	99,89	0,1	0,1524
	10		108,10		0,1650
SubDAS 6	2		84,90		0,1332
	5	0,112	99,71	0,05	0,1552
	10		107,91		0,1680
SubDAS 7	2		86,58		0,0745
	5	0,062	101,68	0,05	0,0875
	10		110,05		0,0947
	2		85,05		0,0196
SubDAS 8	5	0,041	99,89	0,02	0,0230
	10		108,10		0,0249

Source: (Data processed by researchers, 2025)

Example calculation for Sub-Watershed 1 with a 2-year return period:

$Q = 0.278 \times C \times I \times A$

$= 0.278 \times 0.511 \times 72.55 \times 0.0144$

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= 0.5074 m3/second

Hydraulic Analysis

Channel capacity calculations were performed for each Sub-Watershed based on existing dimensional data. The calculation results included the wetted cross-sectional area (A), hydraulic radius (R), flow velocity (V), and discharge (Q). These are shown in Table 2 below.

Table 2. Summary of Hydraulic Analysis

No Channels	Channel length	Elv. hulu	Elv, hilir	Channel width	Channel height	Manning coefficient	Channel slope
	(m)			(b)	(h)	(n)	(s)
1	100	31,377	31,34	0,81	0,42	0,014	0,00037
2	100	31,585	31,47	0,60	0,42	0,014	0,00115
3	100	31,6	31,34	0,69	0,16	0,025	0,00260
4	100	31,451	31,12	0,35	0,21	0,014	0,00331
5	100	31, 411	31,101	0,51	0,21	0,025	0,00310
6	87,46	31,446	31,256	1,53	0,73	0,014	0,00217
7	100	31,609	31,172	0,57	0,14	0,025	0,00437
8	100	31,711	31,514	1,53	0,73	0,014	0,00197

Source: (Data processed by researchers, 2025)

Table 3. Summary of Hydraulic Analysis

No. Channels	Channel length	Wet cross-sectional area (m^3)	Wet circumference (m^3)	Hydraulic radius (m^3)	Hydraulic radius (m3)	Flow velocity (m/sec)	existing channel discharge
	(m)	(A)	(P)	(R)	(S)	(V)	(Qs)
1	100	0,34	2,04	0,167	0,00037	0,41627	0,1416
2	100	0,25	1,62	0,156	0,00115	0,70061	0,1766
3	100	0,11	1,54	0,072	0,00260	0,35198	0,0389
4	100	0,07	0,91	0,081	0,00331	0,76786	0,0564
5	100	0,11	1,23	0,087	0,00310	0,43752	0,0469
6	87,46	1,12	3,79	0,295	0,00217	1,47433	1,6467
7	100	0,08	1,28	0,062	0,00437	0,41575	0,0332
8	100	1,12	3,79	0,2952	0,00197	1,40396	1,5681

Source: (Data processed by researchers, 2025)

After obtaining the hydraulic analysis results, the next step is to compare the planned flood discharge (Qhydrology) with the existing channel capacity (Qhydrology) to assess the channel's ability to accommodate runoff. If the channel capacity (Qhydrology) is greater than Qhydrology, the channel is considered inadequate and at risk of flooding. Conversely, if the channel capacity is greater than the planned flood discharge, the channel is considered safe. The results of this comparison are used as a basis for evaluating the drainage system and determining priorities for handling potential flooding. The following is a comparison of Qhydrology and Qhydrology, as seen in Table 3.

Table 4. Summary of Comparison of Qhydrology and Qhydrology

No. Channels		Qhifrologi	Qhidrolika	Information	
	Rephrase	$M^{3/}$Sec	M3/Sec	Qhidrologi	< Qhidrolika
	2	0,5070	0,1416	Flood	
1	5	0,1740		Flood	
	10	0,1890			
	2	0,2070			
2	5	0,2430	0,1766	Flood	
	10	0,2630			
	2	0,0430		Flood	
3	5	0,0510	0,0389	Flood	
	10	0,0550			
	2	0,0950			
4	5	0,1120	0,0564	No Flood	
	10	0,1210			
	2	0,0530		Flood	
5	5	0,0620	0,0469		
	10	0,0670			
	2	0,0410		Flood	
6	5	0,0490	1,6467	Flood	
	10	0,0530			
	2	0,052			
7	5	0,062	0,0332	Flood	
	10	0,069			
	2	0,092		Flood	
8	5	0,10,8	1,5681		

10	0,117

Source: (Data processed by researchers, 2025)

EPA-SWMM 5.2 Modeling

Drainage system modeling was conducted to simulate the response to rainwater runoff in the study area. This model consists of three main components: channel network configuration, hydrological parameters, and hydraulic characteristics. The choice of recurrence period in drainage channel planning is adjusted to the channel's function and the catchment area. Using this hydraulic analysis, EPA-SWMM can calculate and present important information, including the water level elevation at the channel cross-section when a certain discharge flows through it.

Data Input

To run the modeling using EPA-SWMM, researchers first input data from field surveys and previous calculations. The data entered into the EPA-SWMM software includes information such as elevation, channel dimensions, hourly rainfall intensity, channel roughness coefficient, and flow coefficient.

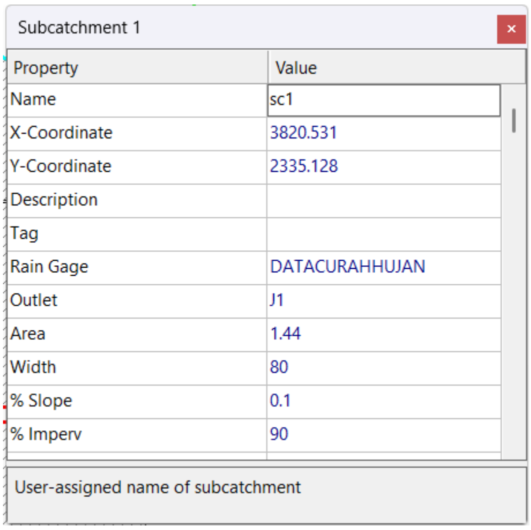

Figure 3. Land Use Flow Coefficient Input
Source: (Data processed by researchers, 2025)

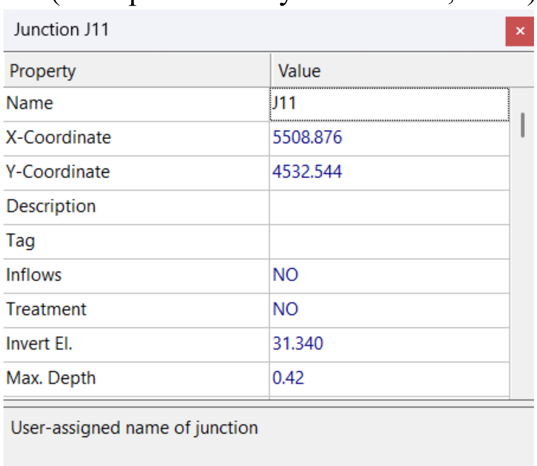

Figure 4. Elevation Data Input at the Junction

Source: (Data processed by researchers, 2025)

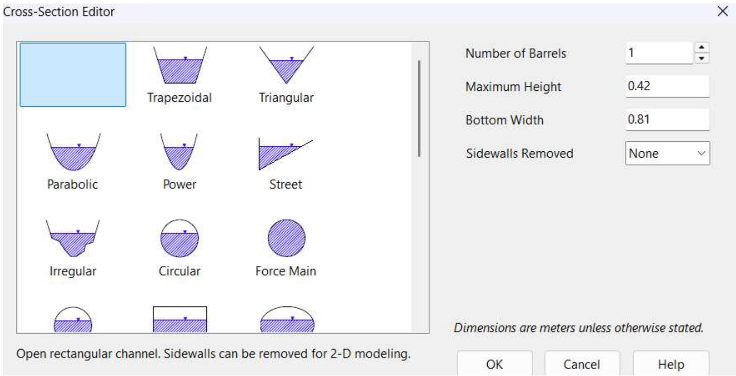

Figure 5. Channel Dimension Data Input
Source: (Data processed by researchers, 2025)

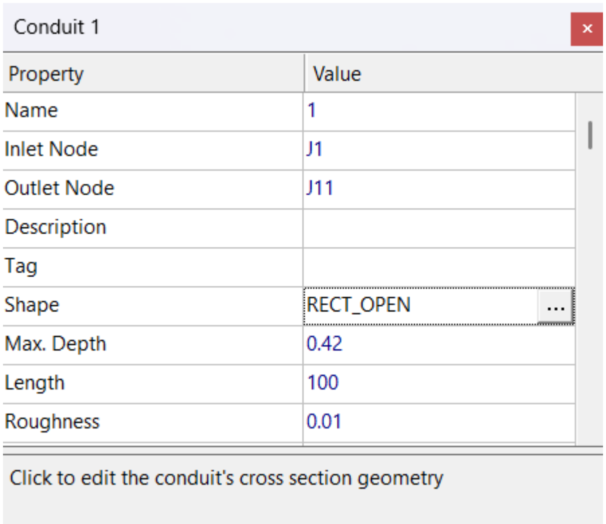

Figure 6. Input Channel Length on Conduit
Source: (Data processed by researchers, 2025)

EPA SWMM 5.2 Running Results

In the EPA-SWMM simulation using existing conditions, it was found that several channel segments with 100-meter intervals were unable to accommodate the resulting rainfall runoff. This simulation used a 10-year return period as the basis for the analysis. Although the model visualizations for each return period appear similar, the resulting runoff volume varies depending on the rainfall intensity during each return period.

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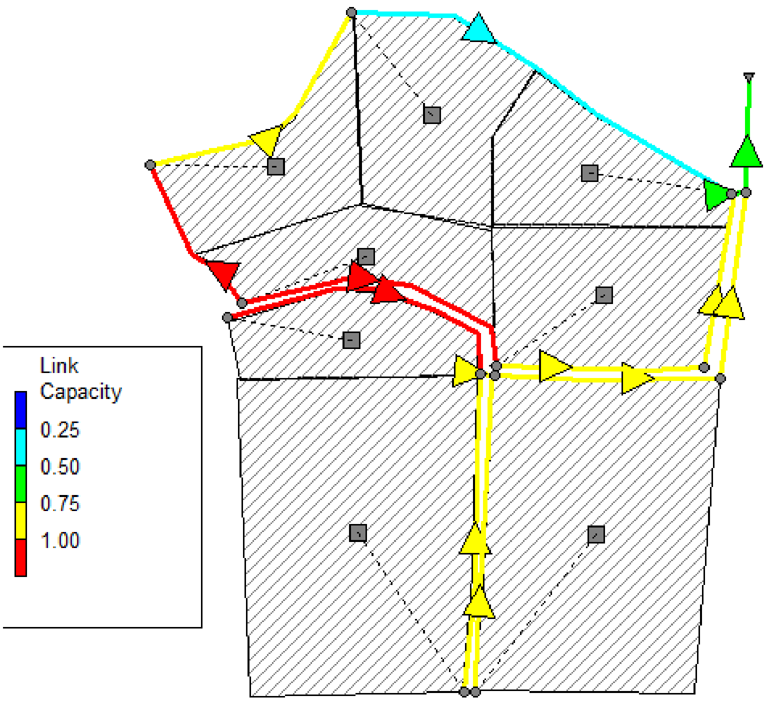

Figure 7. Conduit Running Results
Source: (Data processed by researchers, 2025)

Figure 7 shows that the channel experienced maximum flow in the second hour. In the following hour, runoff discharge began to subside due to decreasing rainfall intensity.

Summary Results

Topic: Node Flooding — Click a column header to sort the column.

Node	Hours Flooded	Maximum Rate LPS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 ltr	Maximum Ponded Depth Meters
J11	4.68	137.36	0	02:00	0.743	0.000
J12	0.01	14.78	0	01:27	0.000	0.000
J14	10.54	236.83	0	02:08	3.393	0.000
J15	0.07	7.26	0	02:01	0.001	0.000
J20	0.01	15.61	0	01:37	0.000	0.000
J21	1.10	21.31	0	02:00	0.025	0.000
J25	0.13	1.56	0	02:00	0.000	0.000

Figure 8. Node Flooding Summary Report Results for 10-Year Return Period
Source: (Data processed by researchers, 2025)

The node flooding summary shows flooding at nodes J11, J12, J14, J15, J21, and J25, while no overflow occurred at other nodes. Therefore, the nodes requiring additional channel depth and width are J11, J12, J14, J15, J21, and J25. The largest flood volume was at node J14 with 3,393 m3, and the smallest volume was at J12 and J20 with 0,000 m3. The flood duration column, in the hours flooded column, showed the longest duration at node J14 at 10.54 hours.

Existing Channel Profile in EPA SWMM 5.2

After running the program, longitudinal channel profile data was obtained, showing all the locations where flooding occurred. To further understand the details, a profile plot was created, resulting in the following image:

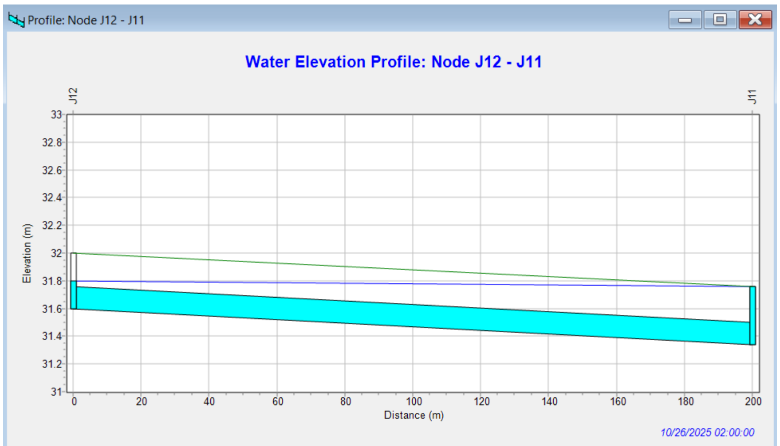

Figure 9. Existing Channel Profile J12–J11
Source: (Data processed by researchers, 2025)

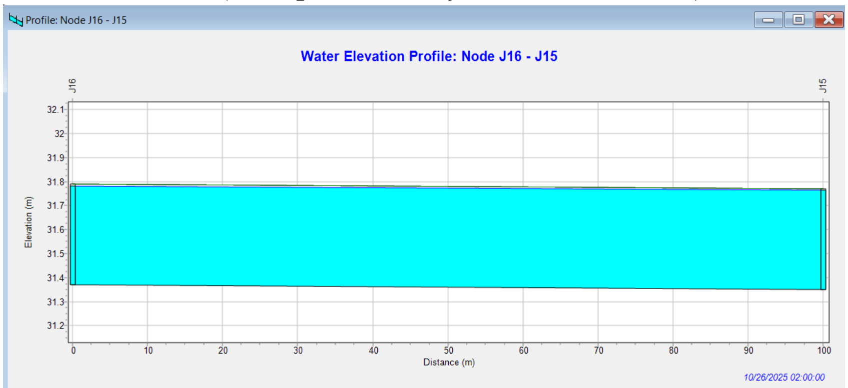

Figure 10. Existing Channel Profile J16–J15
Source: (Data processed by researchers, 2025)

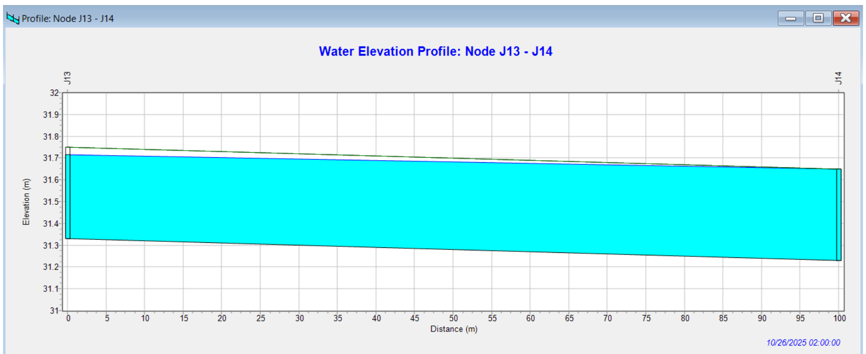

Figure 11. Existing Channel Profile J13–J14
Source: (Data processed by researchers, 2025)

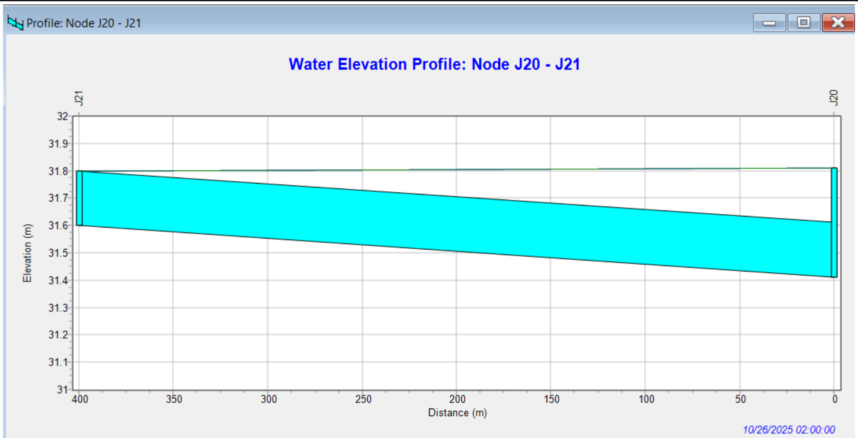

Figure 12. Existing Channel Profile J20–J21
Source: (Data processed by researchers, 2025)

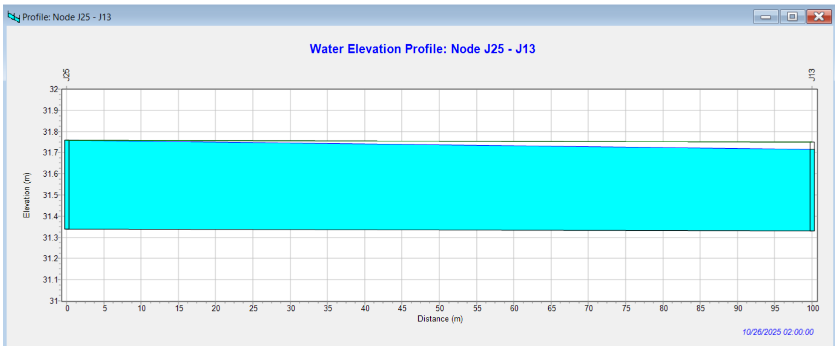

Figure 13. Existing Channel Profile J25–J13
Source: (Data processed by researchers, 2025)

Figures 9-13 show that the existing drainage channel is full, indicating it is unable to accommodate the discharge. This is due to inadequate channel dimensions and sedimentation. This results in the channel being unable to accommodate the discharge, causing water to overflow in the area. The results of the running simulation for the 2-, 5-, and 10-year return periods can be seen in Table 4, Summary of Running Simulation Results.

Table 5. Summary of Running Simulation Results

No. Channels	Channel Type	Birthday period		
		2	5	10
1	Rectanguler	Flood	Flood	Banjir
2	Rectanguler	Flood	Flood	Banjir
3	Rectanguler	Flood	Flood	Banjir
4	Rectanguler	Flood	Flood	Banjir
5	Rectanguler	Flood	Flood	Banjir
6	Rectanguler	No Flood	No Flood	Tidak Banjir
7	Rectanguler	Flood	Flood	Banjir
8	Rectanguler	No Flood	No Flood	Tidak Banjir

Source: (Data processed by researchers, 2025)

E. CONCLUSION

From the existing rectangular channel analysis, six channels were observed to experience flooding at nodes J11, J12, J14, J15, J21, and J25, while no overflows were observed at other nodes. This indicates the need for further management at these points, either through dimension improvement, normalization, or increasing channel capacity. Meanwhile, channels at other nodes have proven effective in channeling runoff discharge, thus minimizing the risk of flooding. By conducting this evaluation, we can identify which channel sections need immediate repair or enlargement to address flooding and prevent flooding.

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