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Evaluation of Flow Characteristics and Sedimentation in Urban Drainage Post Rehabilitation, Malang City

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ABSTRACT

This study evaluates the flow characteristics and sedimentation potential of the urban drainage system along Soekarno Hatta Street, Malang City, following rehabilitation measures based on hydraulic parameters. Rainfall data spanning from 2015 to 2024 were obtained from BMKG and analyzed using Hydrognomon version 4.0.3, with the Log-Normal distribution yielding the highest design rainfall of 130.268 mm for a 10 year return period. Hydraulic simulations were performed using EPA SWMM under two scenarios, namely existing conditions and post rehabilitation conditions incorporating vegetative swale application and channel dimension improvement to 2 m × 2 m. Simulation results under existing conditions revealed that conduits 41, 42, and 40 recorded maximum flow velocities of 27.25 m/s, 5.52 m/s, and 3.00 m/s respectively, exceeding the safe erosion threshold of 3 m/s, while conduits 19, 23, 25, 17, and 13 recorded velocities below 0.5 m/s, indicating sedimentation risk. Following rehabilitation, flow velocity reductions of 9.0%, 7.4%, and 2.8% were observed in erosion prone conduits, though all remained above the safe threshold. Among sedimentation prone conduits, conduit 19 showed improvement while conduits 23 and 25 experienced further velocity reductions, indicating increased sedimentation risk. The continuity error values of -0.05% and -0.12% confirmed model validity. These findings suggest that while rehabilitation positively influences drainage hydraulics, complementary interventions are necessary to fully address erosion and sedimentation risks.

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1. INTRODUCTION

The rapid development of urban areas is a consequence of population growth and increasing economic activities. Changes in land use, such as the expansion of built-up areas and the reduction of green open spaces, lead to a decrease in the soil's ability to infiltrate rainwater. This condition results in an increase in surface runoff, which directly burdens the urban drainage system (Oktian et al., 2025). Increased runoff is not only influenced by rainfall intensity but also by land use, soil type, and regional characteristics, indicating that urbanization plays a significant role in the hydrological dynamics of a city. The increase in surface runoff places greater pressure on drainage systems. Drainage systems that are supposed to convey excess water often fail to function optimally due to limited capacity, channel narrowing, and inadequate maintenance. In addition, sedimentation and the accumulation of materials within the channels further deteriorate the performance of the drainage system, causing obstructed flow (Hattu et al., 2025). As a result, the functionality of the channels declines, as indicated by disrupted flow and reduced capacity to accommodate water discharge.

The decline in drainage channel performance is one of the main causes of inundation and urban flooding. Various studies indicate that sedimentation, land use changes, and insufficient channel capacity are dominant factors contributing to urban inundation (Sari et al., 2025). In some cases, even when the theoretical capacity of the channel is still adequate, flooding still occurs due to blockages, sedimentation, and poor drainage management (Satriawansyah et al., 2026). This shows that drainage problems are not only related to capacity but also to operational conditions and maintenance. As an effort to address urban drainage problems, various channel rehabilitation programs have been implemented to improve system performance, including channel normalization, dimension enhancement, and network improvements (Rohman et al., 2024). However, such rehabilitation efforts must be followed by comprehensive evaluations of the drainage system, particularly to ensure the compatibility between channel capacity and the actual runoff discharge. The mismatch between channel capacity and actual discharge is one of the main causes of inundation in urban areas, especially when surface runoff increases due to land use changes and urbanization (Amin et al., 2025). In addition, poorly integrated drainage systems and lack of maintenance can worsen flooding conditions, even under relatively low rainfall.

Changes in the physical condition of channels, including sedimentation, inadequate dimensions, and topographic influences, can affect flow characteristics within the drainage system. Sedimentation within channels can reduce the effective cross-sectional area, limiting their ability to accommodate increasing runoff discharge. Moreover, relatively flat and uneven topography can lead to the accumulation of flow at certain points, increasing the risk of inundation (Amin et al., 2025).

Suboptimal drainage system performance can result in various negative impacts, such as flooding, degradation of infrastructure function, and disruption of community activities in urban areas. This condition generally occurs due to the mismatch between channel capacity and the runoff discharge that must be conveyed, preventing the system from functioning effectively in draining rainwater (Amin et al., 2025). In the long term, these issues can increase the potential for urban flooding, influenced by factors such as land use changes, increased surface runoff, and the declining physical condition of drainage channels. Along with technological advancements in water resources engineering, urban drainage system analysis can now be conducted using computer based hydrological hydraulic models, one of which is the Storm Water Management Model (SWMM). This model is a dynamic simulation tool capable of representing rainfall runoff processes and flow within drainage networks in an integrated manner, both for single events and long term simulations (Sihasale et al., 2025). SWMM is widely used in planning, analysis, and design of urban drainage systems due to its ability to model surface runoff, flow in pipes/channels, and interactions between system components in detail (Alam & Rahman, 2024; Wikandhani & Anggraheni, 2025). The model also allows visualization of results in the form of graphs, tables, and flow profiles, facilitating comprehensive system performance evaluation (Arifin & Kilang Permatasari, 2026).

Land use changes contribute to decreased infiltration and increased surface runoff, thereby placing greater pressure on urban drainage systems (Triawati et al., 2024). This condition is further exacerbated by changes in the physical characteristics of drainage channels, including sedimentation, inadequate channel dimensions, and topographic influences, all of which affect flow behavior within the drainage network (Febriana et al., 2025). Sedimentation can reduce the effective cross-sectional area of channels, limiting their capacity to accommodate increasing runoff discharge (Wangsa & Suryatmaja, 2025). In addition, relatively flat and uneven topography may cause flow accumulation at certain locations, increasing the potential for inundation (Effendi et al., 2022). The absence of comprehensive post-rehabilitation evaluation further contributes to the persistence of these issues. Therefore, further research is needed to evaluate flow characteristics and sedimentation in urban drainage channels based on hydraulic parameters, particularly in the study area of Malang City (Rahayu et al., 2025).

2. METHOD

2.1 Research Methodology

This study was conducted along Soekarno Hatta Road in Malang City, an area that frequently experiences flooding during heavy rainfall events. These conditions necessitate a data driven analysis to better understand the contributing factors and patterns of flood occurrence (Sugiyono, 2019). The research employs a quantitative modeling approach, utilizing numerical data and mathematical or statistical models to represent and predict the behavior of the drainage system within the study area (Creswell, 2023).

The overall research framework is illustrated in the proposed research flowchart, as presented in the **Figure 1.**

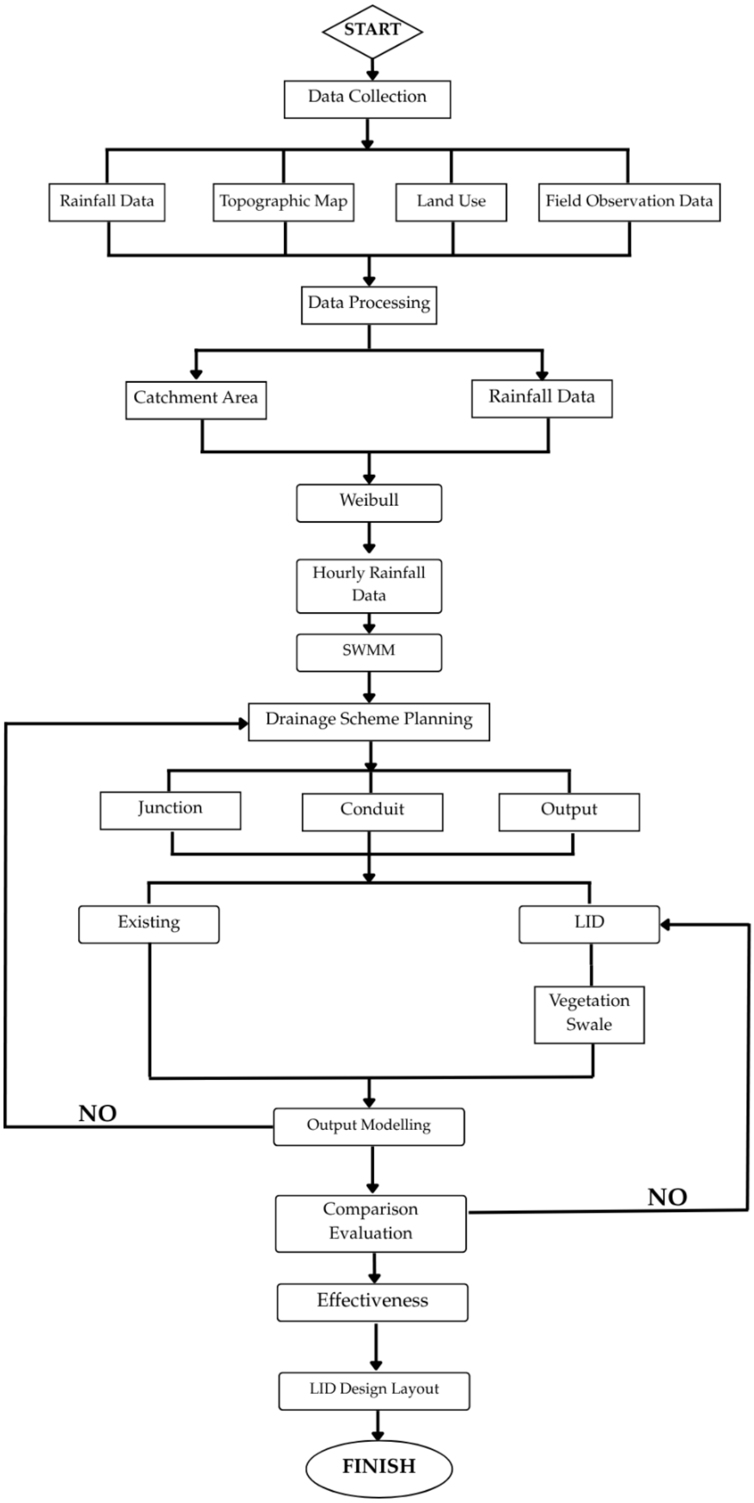


Figure 1. Flow Chart

Figure 1 illustrates the research workflow, starting from data collection and data processing to obtain catchment and rainfall characteristics. Rainfall analysis using the Weibull method produced hourly data for SWMM simulation, followed by drainage modeling under existing and LID conditions. The results were then evaluated through comparative and effectiveness assessments, followed by iterative improvements until the optimal LID design layout was achieved.

2.2 Research Data and Variables

The initial stage of this research involves secondary data collection encompassing three primary aspects. Rainfall data were obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG), East Java Climatology Station, covering a ten year period from 2015 to 2024. Catchment area analysis was conducted to map the distribution of surface runoff and to identify major waterlogging points within the study area. Land use was examined through the interpretation of Google Earth imagery to describe the characteristics of the area and to evaluate the feasibility of implementing the Low Impact Development (LID) concept.

Based on the collected secondary data, the study variables were classified into input, process, and output categories. Input variables consisted of rainfall data, catchment area, runoff coefficient, land use, and slope, which were used to analyze rainfall characteristics, identify contributing areas, and define subcatchments in the SWMM model. Process variables consist of peak runoff discharge, ponding volume, and drainage channel capacity, all of which are derived from SWMM simulations. Output variables include the effectiveness of the existing drainage system and the change in ponding volume following LID implementation, both of which serve as the primary indicators in evaluating the performance of the proposed drainage improvements.

2.3 Analytical Methods

The analysis was conducted quantitatively using Hydrognomon and EPA SWMM software to model the hydrological and hydraulic conditions of the study area. For hydrological analysis, rainfall data spanning from 2015 to 2024 were processed using Hydrognomon version 4.0.3, applying the Gumbel, Log-Pearson Type III, Normal, and Log-Normal distribution methods to estimate future rainfall intensity. Subsequently, hydraulic analysis was performed using SWMM to simulate two scenarios, namely existing drainage conditions and post LID implementation conditions, with particular focus on changes in runoff volume, flow rate, and infiltration performance following the application of vegetated swales (Pramesti et al., 2023). The percentage of velocity reduction between existing and post-rehabilitation conditions was calculated using the formula:

$$\text{Reduction (\%)} = ((\text{Existing} - \text{LID}) / \text{Existing}) \times 100\%.$$

3. RESULT AND DISCUSSION

3.1 Analysis of Planned Discharge Using The Hydrognomon 4 Application

Flood dischoarge analysis in this study was conducted by collecting rainfall data from rain gauges located around the research site. The station used was the Malang Geophysical Station. The rainfall data collected was the highest data for each year. The recapitulation was carried out for a ten-year period starting in 2015 and ending in 2024. The recapitulation can be seen in **Table 1.**

Table 1. Recapitulation of Ten Year Rainfall Period

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2015	68,4	49,5	61	62,8	89,9	3	0	0	0	0	42,4	46
2016	57,3	98	63,3	68	47,8	82,8	29	31,7	31,7	74,5	85,3	76,5
2017	99	61,5	33,3	54,4	10	17,7	43,3	2	2	25	69,5	49,2
2018	44,5	90,5	52,3	45,3	14	107	14,1	0	0	0,5	57	43,3
2019	58	57,8	64	37,5	0,5	1	0	0	0	1	32,5	81
2020	45	94,5	49	51,5	73	13,5	3,6	9,5	9,5	0	39	45,5
2021	52	42	54	40,5	25	35,8	18,3	2,7	2	13,5	93,7	52,5
2022	26,5	57	50,5	49,6	71,7	55,5	5,2	41,4	41,4	130	65	41
2023	58	52,8	69	72	43,2	45,7	86,8	0	0	13,5	25,2	63,3
2024	74,5	54,7	64,2	38,1	9,5	11,5	0	0	0	29,4	145	105

As shown in **Table 1**, the rainfall data represent the maximum daily rainfall recorded anually during the 2015-2024 period. These data were then used to determine the planned discharge according to the selected return period. Maximum rainfall is obtained by calculating the maximum daily rainfall. The data presented will then be used to calculate the planned discharge based on the appropriate return period. This will yield the maximum rainfall for each year, as shown in the **Table 2.**

Table 1. Recapitulation of The Highest Daily Rainfall

Year	Rainfall Maximum (Mm)
2015	89,9
2016	98
2017	99
2018	107
2019	81
2020	73
2021	98
2022	130
2023	72
2024	145

Reffering to **Table 2**, the highest maximum daily rainfall was recordes in 2024, reaching 145 mm. The purpose of modelling the recurrence period using Hydrognomon 4.0.3(.25) software is to determine acceptable and unacceptable distributions that will later influence the selection of distribution tests used in calculating the discharge plan. Thus, the results of the analysis by Hydrognomon 4.0.3(.25), The time series analysis is presented in **Figure 2**.

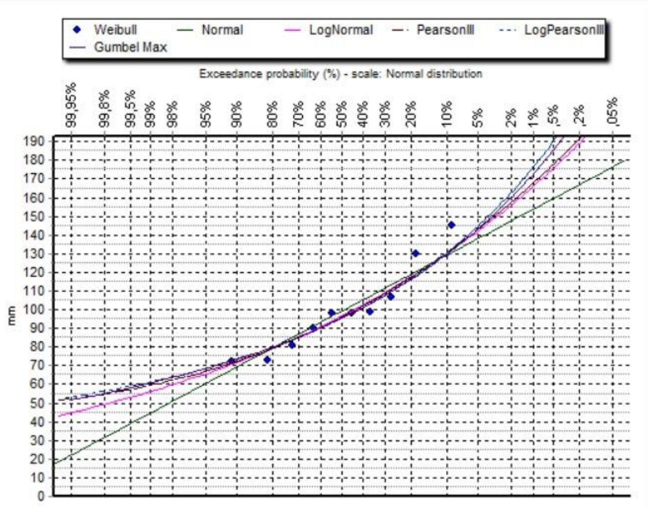


Figure 2. Probability Distribution Graphics (a) normal, (b) Log normal, (Pearson III, (d) log pearson III, (e) gumbell

Based on the results obtained from Hydrognomon, the selected rainfall plan is a Log Normal probability distribution because it has the highest discharge value and is accepted in both suitability tests, namely the Chi-square test and the Kolmogorov-Smirnov test (Triawati et al., 2024). As shown in the graph in **Figure 2**, there is a good fit between the data and the Log Normal distribution. Therefore, it is indicated that this distribution is the most appropriate model for calculating the design flow rate in **Tables 3.** and **4.**

Table 2. Probability Distribution Result

No.	**Repeat Period (years)**	**Probability Distribution**				
		Normal	Log Normal	Pearson III	Log Pearson III	Gumbel
1.	2	99,29	96,626	95,986	95,411	95,434
2.	5	119,036	117,572	117,449	116,685	116,176
3.	10	129,357	130,268	130,679	130,854	129,909
4.	15	134,508	137,108	137,819	138,897	137,657
5.	20	137,881	141,78	142,629	144,561	143,082
6.	25	140,364	145,321	146,381	148,946	147,26
7.	50	147,474	155,958	157,424	162,604	160,133
8.	10	153,87	166,189	167,974	176,443	172,91

Table 3. Chi-Square and Kolmogorov Smirnov Result

No.	**Distribution**	**Chi-square**	**Kolmogrov-Smirnov**
1.	Normal	Accept	Accept
2.	Log Normal	Accept	Accept
3.	Pearson III	-	Accept
4.	Log Pearson III	-	Accept

No.	Distribution	Chi-square	Kolmogrov-Smirnov
5.	Gumbel	Accept	Accept

Based on **Tables 3** and **4**, from the results of the probability distribution, Chi-square and Kolmogorov-Smirnov tests with a 5% percentage, the highest value was obtained in the 10 year recurrence period, namely in the Log Normal distribution, with a value of Reff = 130.268 mm.

3.2 EPA SWMM Analysis of Existing Condition

The rainfall data obtained will be modelled in a time series in SWMM. It is assumed that the amount of rainfall that occurs every hour on that day is equal to the total rainfall recorded on that day. After entering the time series, the data in the rain gauge menu will be adjusted to the time series that has been created(Wang et al., 2023). As shown in **Figure 3,** the Subcatchment, Junction, and Conduit parameters are adjusted to local data.

Figure 2. Digitalization Map in SWMM

Figure 3 illustrates the spacial configuration of the drainage network in SWMM including the connectivity betweet cubcatchments, junctions, and conduits, which form the basic of the hydraulic simulation model. Subsequently, time series calculations were carried out using the maximum effective rainfall (Reff max) obtained from the previous Hydrohnomon analysis. The results of R' are obtained in **Table 5** by using the following equation:

$$R' = Reff\ max. \times Reff\ per\ hour$$

Table 4. Summary Time Series

Reff (Mm)	R' at the Hour of -				
	0-1	1-2	2-3	3-4	4-5
	0,58 Reff	0,15 Reff	0,11 Reff	0,08 Reff	0,07 Reff
130,268 mm	76,18 mm	19,8 mm	13,89 mm	11,06 mm	9,338 mm

As shown in **Table 5**, the effevtive rainfall reaches its peak in the first hour and gradually decreases in the subsequent hours, indicating a diminishing rainfall intensity over time. To provide a clearer representation of the temporal distribution of rainfall, the results are illustrated in the form of a time series grapht as shown in **Figure 4.**

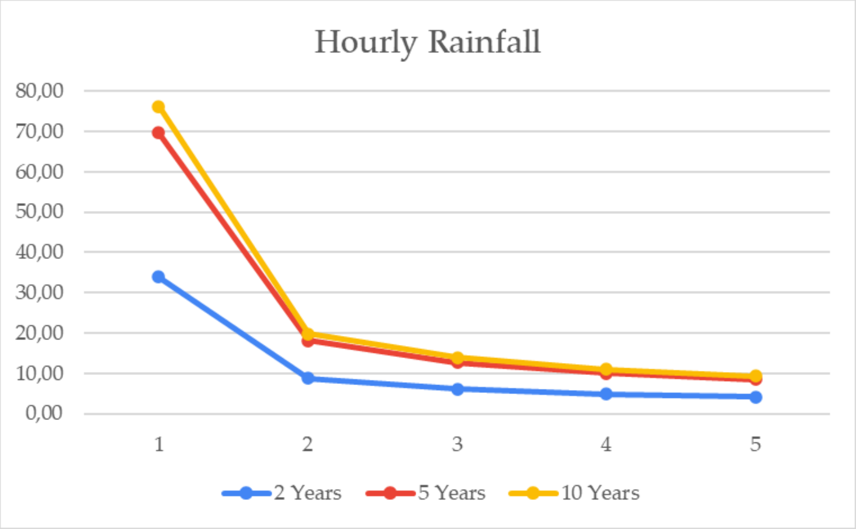


Figure 3. Graphic of Time Series

From the time series calculations, the graph in **Figure 4** was obtained with a 10 year repeat period. There was an increase in the first hour and a significant decrease in the second to fifth hours. These changes in discharge form the basis for determining the required channel capacity at the research site. Therefore, data on the dimensions of the main channel and the small alleyways need to be presented to support further analysis. **Table 6** below shows the dimensional data for the main channel and channels in small alleys around the research site, which are closed and square in shape.

Table 5. Channels Dimension

Conduits	Height (m)	Wide (m)	Conduits	Height (m)	Wide (m)
1	2	2	24	2	2
2	2	2	25	2	2
3	1	0,8	26	2	2
4	1	0,8	27	1	0,8
5	1	0,8	28	1	0,8
6	1	0,8	29	1	0,8
7	1	0,8	30	1	0,8
8	1	0,8	31	1	0,8
9	1	0,8	32	2	2
10	1	0,8	33	2	2
11	1	0,8	34	2	2
12	1	0,8	35	1	0,8
13	1	0,8	36	1	0,8
14	1	0,8	37	2	2
15	1	0,8	38	2	2
16	2	2	39	1	0,8

Conduits	Height (m)	Wide (m)	Conduits	Height (m)	Wide (m)
17	2	2	40	2	2
18	2	2	41	2	2
19	1	0,8	42	2	2
20	1	0,8	43	1	0,8
21	1	0,8	44	1	0,8
22	1	0,8	45	1	0,8
23	1	0,8			

As shown in **Table 6**, the conduits dimensions vary, with larger conduits generally having dimensions of 2x2 m, while smaller alley channels have dimensions of 1x0,8m. This variation reflects the different capacities and functions within the drainage system. After the conduit dimensions were entered into the EPA SWMM model, flow simulations were performed to obtain the maximum link flow conditions, as presented in **Figure 5**.

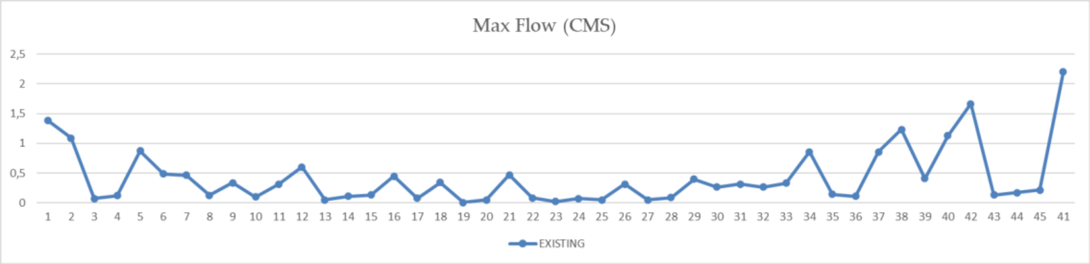


Figure 4. Graphic Flow Maximum

Figure 5 illustrates the maximum flow distribution across all conduits under existing conditions. The simulation results indicate that several conduits experienced relatively high maximum flow values, particularly those exceeding 1 CMS. To further identify the critical conduits, the maximum flow values exceeding 1 CMS are summarized in Table 7.

Table 6. Channels with Link Flow Maximum

Link	Type	Flow Maximum (CMS)
1	CONDUIT	1,383
2	CONDUIT	1,09
38	CONDUIT	1,234
40	CONDUIT	1,126
42	CONDUIT	1,665
41	CONDUIT	2,203

Table 7 shows that six out of the 45 analyzed conduits experienced maximum flow values exceeding 1 CMS, indicating that several channels were unable to adequately accommodate the inflow discharge. Conduit 41 recorded the highest maximum flow value at 2.203 CMS, followed by conduits 42 and 1 with values above 1.3 CMS. These results suggest that the existing drainage capacity is insufficient under the simulated rainfall conditions, thereby increasing the potential for overflow within the drainage network. To further examine the hydraulic performance of the drainage system, a flow discharge simulation was conducted using EPA SWMM under a 10-year return period rainfall scenario. The simulation incorporated 45 conduits adjusted to field measurements, and the resulting water elevation profile is presented in **Figure 6.**

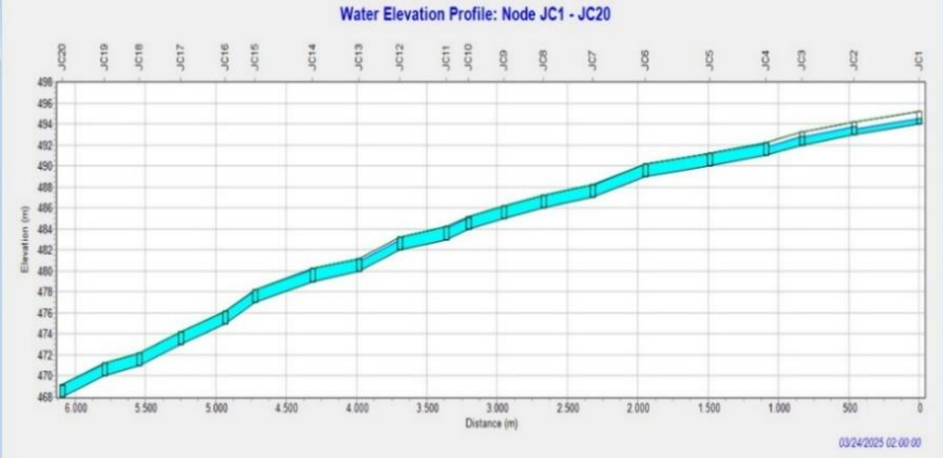
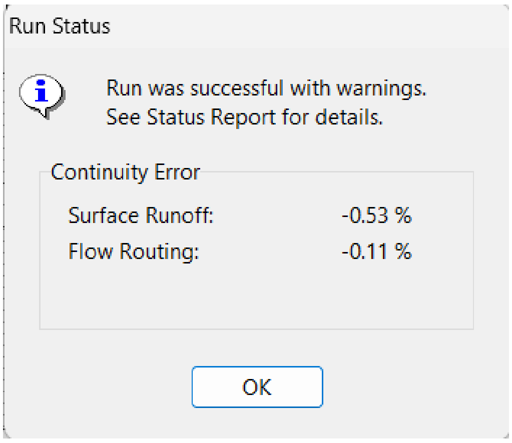


Figure 5. Flow Discharge Simulation

Figure 6 presents the simulated water elevation profile under existing drainage conditions. The continuity error values for surface runoff and flow routing were recorded at -0.53% and -0.11%, respectively, both of which remain within the acceptable error limit of 10% specified in the EPA SWMM Version 5.2 guidelines (Amin et al., 2025). These results indicate that the simulation model produced acceptable hydraulic performance and can therefore be considered valid for further analysis.


Run Status

Run was successful with warnings.
See Status Report for details.

Continuity Error

Surface Runoff: -0.53 %
Flow Routing: -0.11 %

Figure 6. Existing Condition Result from SWMM

In addition, the EPA SWMM run status shown in Figure 7 produced continuity error values of -0.53% for surface runoff and -0.11% for flow routing, both of which remain within the acceptable tolerance limit. These results indicate that the simulation output is sufficiently reliable for hydraulic performance analysis.

To further assess the degree of hydraulic disturbance within the drainage network, maximum flow velocity analysis was performed for each conduit. According to hydraulic criteria, flow velocities exceeding 3 m/s may increase the risk of erosion and structural damage, whereas velocities below 0.5 m/s indicate the potential for sedimentation and blockage within the channel system (Widyantoro, 2023).

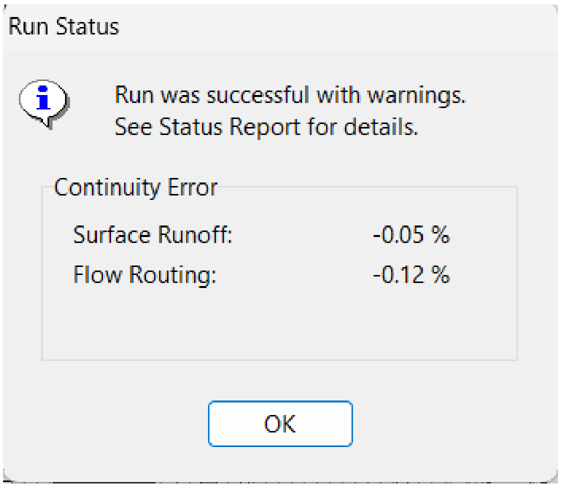
Table 7. Hydraulic Risk Classification Based on Maximum Flow Velocity in Existing Conditions

Link	Type	Maximum Velocity (m/s)	Category	Risk
13	CONDUIT	0,43	Low Velocity	Sedimentation
17	CONDUIT	0,28	Low Velocity	Sedimentation
19	CONDUIT	0,02	Low Velocity	Sedimentation
23	CONDUIT	0,29	Low Velocity	Sedimentation
25	CONDUIT	0,34	Low Velocity	Sedimentation
40	CONDUIT	3	High Velocity	Erosion
41	CONDUIT	5,52	High Velocity	Erosion
42	CONDUIT	27,25	High Velocity	Erosion

As shown in the **Table 8**, Conduit 41 recorded the most critical flow velocity at 27.25 m/s, significantly exceeding the erosion threshold, followed by Conduit 42 at 5.52 m/s and Conduit 40 at 3.00 m/s. These conditions indicate a high risk of structural damage and channel instability. Conversely, Conduit 19, 23, and 25 recorded velocities below 0.5 m/s, suggesting the accumulation of sediment and potential blockage at those points.

3.3 SWMM Simulation Using Vegetative Swale

The LID implementation was simulated by applying a vegetative swale, locally termed as bioswale, positioned along the road median of Soekarno Hatta Street with a width of 5 meters. Prior to LID application, the drainage channel dimensions were rehabilitated to 2 m × 2 m to improve the overall hydraulic capacity of the system. The simulation run status is presented in the **Figure 8**.



Run was successful with warnings.
See Status Report for details.

Continuity Error
Surface Runoff: -0.05 %
Flow Routing: -0.12 %

Figure 8. Running Result Use of Vegetative Swale

As shown in **Figure 8**, the simulation results confirmed the model's validity, with continuity error values of -0.05% for surface runoff and -0.12% for flow routing, both well within the acceptable threshold of 10%. These values also indicate an improvement compared to the existing condition, suggesting that the combination of channel rehabilitation and vegetative swale application positively influenced the overall drainage performance. The changes in link flow across all conduits are illustrated in the following **Figure 9**.

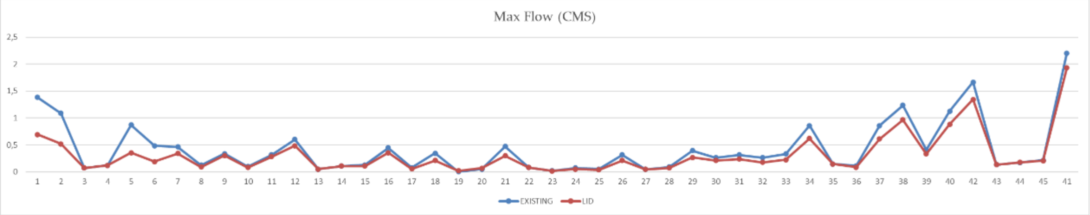


Figure 7. Graphic of Before and After Max Flow Using Vegetative Swale

As illustrated in Figure 9, the implementation of the vegetative swale generally reduced the maximum flow discharge across most conduits in the drainage network. The graph indicates that the post-LID condition consistently produced lower peak flow values compared to the existing condition, particularly at several critical conduits with previously high discharge levels. This reduction demonstrates that the vegetative swale effectively improved stormwater infiltration and delayed surface runoff, thereby decreasing the accumulation of flow within the drainage system. Furthermore, the variation in flow reduction among conduits suggests that the hydraulic response was influenced by the location and runoff contribution of each conduit within the network (Kuok et al., 2024). Overall, these results confirm that the vegetative swale contributed positively to improving drainage performance and reducing the potential risk of hydraulic overload and urban flooding. The comparison of maximum flow discharge at the six critical conduits is presented in the **Table 9**.

Table 8. The Comparison Before and After of Using Vegetation Swale

Link	Type	Flow Maximum (CMS) Before	Flow Maximum (CMS) After
1	CONDUIT	1,383	0,691
2	CONDUIT	1,09	0,518
38	CONDUIT	1,234	0,968
40	CONDUIT	1,126	0,884
42	CONDUIT	1,665	1,343
41	CONDUIT	2,203	1,93

As shown in **Table 10**, the table indicates a consistent decrease in peak discharge across all six critical conduits after LID application. A similar pattern was observed in maximum flow velocity, as presented in the **Table 10**.

Table 9. The Comparison of Using Vegetation Swale

Link	Type	Maximum Velocity (m/s) Before	Maximum Velocity (m/s) After
13	CONDUIT	0,43	0,43
17	CONDUIT	0,28	0,26
19	CONDUIT	0,02	0,17
23	CONDUIT	0,29	0,14
25	CONDUIT	0,34	0,17
40	CONDUIT	3	2,13
41	CONDUIT	5,52	5,11
42	CONDUIT	27,25	26,49

As shown in **Table 10**, the comparison of maximum flow velocity before and after the implementation of vegetative swales provides insight into changes in flow characteristics across the conduits. The velocity comparison confirms that the combined application of vegetative swales and channel rehabilitation effectively reduced flow velocity across critical conduits, thereby minimizing the risk of erosion and structural damage to the drainage system.

3.4 Evaluation of The Effectiveness of LID Implementation With SWMM

The effectiveness of vegetative swale implementation was evaluated based on changes in maximum flow velocity across conduits previously identified as critical. The comparison of flow velocity before and after rehabilitation is presented in the following **Table 11**.

Table 10. Effectiveness of Rehabilitation in Reducing Flow Velocity of Erosion Prone Conduits

Link	Type	Maximum Velocity (m/s) Before	Maximum Velocity (m/s) After	Reduction (%)	Status After LID
40	CONDUIT	3	2,13	9,00%	Still High
41	CONDUIT	5,52	5,11	7,40%	Still High
42	CONDUIT	27,25	26,49	2,85	Still High

As shown in the **Table 11**, conduits 40, 42, and 41 recorded a reduction in flow velocity following LID implementation, with decreases of 9.0%, 7.4%, and 2.8% respectively. However, none of the conduits reached a safe velocity threshold below 3 m/s, indicating that vegetative swales alone are insufficient to mitigate erosion risk in high velocity conduits. This is consistent with the nature of vegetative swales, which primarily function to reduce surface runoff volume rather than directly controlling flow velocity within the primary drainage channel. The comparison of flow velocity in conduits prone to sedimentation is presented in the **Table 12**.

Table 11. Effectiveness of Rehabilitation on Flow Velocity of Sedimentation-Prone Conduits

Link	Type	Maximum Velocity (m/s) Before	Maximum Velocity (m/s) After	Change (%)	Status After LID
13	CONDUIT	0,43	0,43	0,00%	No Change
17	CONDUIT	0,28	0,26	7,10%	Still Low
19	CONDUIT	0,02	0,17	750%	Improved
23	CONDUIT	0,29	0,14	51,70%	More Critical
25	CONDUIT	0,34	0,17	50.0%	More Critical

Reffering to **Table 12**, the results indicate varying responses among conduits with initially low flow velocity. Conduit 19 showed a notable improvement, with velocity increasing from 0.02 m/s to 0.17 m/s, suggesting a more balanced flow distribution following rehabilitation. In contrast, conduits 23 and 25 experienced further velocity reductions of 51.7% and 50.0% respectively, indicating an increased risk of sedimentation at these points. These findings suggest that while vegetative swale implementation contributes to overall runoff reduction, its effects on low velocity conduits require additional interventions such as channel slope adjustment or regular sediment maintenance to prevent long term blockage.

These findings also indicate that the hydraulic performance of vegetative swales is highly dependent on the existing characteristics of the drainage network, particularly conduit slope, channel geometry, and flow accumulation patterns. Although the implementation successfully reduced runoff intensity in several sections, the resulting decrease in velocity in some low-flow conduits may unintentionally increase sediment deposition potential due to the reduced self-cleansing capability of the channels (Devi et al., 2017). Therefore, the effectiveness of vegetative swales should not only be evaluated based on runoff reduction, but also on their influence on overall hydraulic balance within the drainage system. Integrating LID measures with structural improvements and routine maintenance is essential to ensure that both erosion and sedimentation risks can be controlled simultaneously.

4. CONCLUSION

A hydraulic evaluation of the existing drainage system along Soekarno-Hatta Street in Malang City revealed significant imbalances affecting its performance and structural reliability. Based on SWMM simulations using a 10-year return period of 130,268 mm of rainfall, the system is unable to adequately drain runoff, as demonstrated by overflows at several intersections. Critical channels such as 41, 42, and 40 experienced excessive flow velocities of 27.25 m/s, 5.52 m/s, and 3.00 m/s, respectively, exceeding the safety threshold of 3 m/s and posing a high risk of erosion and structural damage. In contrast, channels 19, 23, 25, 17, and 13 exhibited very low velocities below 0.5 m/s, which are susceptible to sediment deposition and long-term blockage. This contrast confirms that the drainage network operates under uneven and complex hydraulic conditions. The implementation of rehabilitation measures, including a 5-meter vegetation ditch and an increase in channel dimensions to 2 m × 2 m, produced measurable but variable effects. Flow velocities in high-risk channels (40, 42, and 41) decreased by 9.0%, 7.4%, and 2.8%, respectively, but remained above safe limits, indicating that the vegetation ditch primarily reduced runoff volume rather than directly controlling channel velocity. For low-velocity channels, channel 19 showed an improvement (from 0.02 m/s to 0.17 m/s), while channels 23 and 25 experienced further decreases of 51.7% and 50.0%, respectively, increasing the risk of sedimentation. Overall, while the combined measures improved some hydraulic conditions, their effectiveness remains limited and site-specific. Therefore, additional interventions such as channel slope adjustment in sediment-prone areas, integration of complementary LID (Low Impact Development) measures (e.g. bioretention and permeable pavements), routine sediment maintenance, and further validation through sensitivity analysis and field calibration are needed to achieve a more balanced and reliable drainage system.

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