JURNAL ONLINE SKRIPSI
MANAJEMEN REKAYASA KONSTRUKSI POLINEMA

Journal homepage: http://jos-mrk.polinema.ac.id/ **ISSN: 2722-9203 (media online/daring)**

ANALYSIS FLOOD AND HYDRAULICS IN SUB KENDALSARI - KEDAWUNG MALANG CITY

Ilham Nurilfiansyah[1,*], Winda Harsanti[2]
Students of Diploma IV-Construction Engineering Management Program, Department of Civil Engineering Malang State Polytechnic[1],
Lecturer of Diploma IV-Construction Engineering Management Program, Department of Civil Engineering Malang State Polytechnic[2].
Correspondent*, Email: *fiansyahnurililham2801@gmail.com*[1], *winda.harsanti@polinema.ac.id*[2].

ABSTRAK

Analisis banjir dan hidrolika bertujuan untuk menganalisis kondisi hidrolika dan potensi banjir di saluran drainase Kendalsari ke Kedawung di Kota Malang. Daerah ini merupakan wilayah padat penduduk dengan curah hujan tinggi dan pengembangan lahan yang cepat, yang menyebabkan peningkatan volume aliran permukaan. Oleh karena itu, ANALISIS BANJIR DAN HIDROLIK SALURAN DRAINASE KENDALSARI-KEDAWUNG DI KOTA MALANG diperlukan. Metode yang digunakan dalam studi ini meliputi analisis hidrologi dengan Metode Rasional, menghasilkan kapasitas saluran Q = 0,505 m³/detik. Untuk menentukan laju aliran rencana dan simulasi hidrolika menggunakan perangkat lunak EPA SWMM untuk mengevaluasi kapasitas saluran yang ada. Tujuan dari analisis ini adalah untuk menilai kondisi saluran yang ada, dan hasilnya menunjukkan bahwa Saluran K tidak dapat menampung laju aliran puncak, sehingga menimbulkan risiko banjir. Setelah mendesain ulang Saluran K dengan penyesuaian elevasi saluran, volume aliran permukaan dapat dikontrol secara efektif, dan luapan dalam saluran dihilangkan. Untuk perhitungan biaya desain ulang drainase di Titik K, biaya yang dibutuhkan sebesar Rp. 458.283.905.

Kata Kunci: Analisis Banjir, EPA SWMM , Hidrolika Saluran Drainase, Metode Rasional

ABSTRACT

Flood and hydraulic analysis aims to evaluate the hydraulic conditions and flood potential of the Kendalsari–Kedawung drainage channel in Malang City. This area is densely populated, characterized by high rainfall intensity and rapid land development, which increases surface runoff volume. Therefore, a FLOOD AND HYDRAULIC ANALYSIS OF THE KENDALSARI–KEDAWUNG DRAINAGE CHANNEL IN MALANG CITY is required. The methods applied in this study include hydrological analysis using the Rational Method, which produced a channel capacity of Q = 0.505 m³/s. To determine the design discharge and hydraulic simulation using EPA SWMM software to assess the capacity of the existing channel. The objective of this analysis is to evaluate the current channel condition, and the results indicate that Channel K is unable to accommodate the peak discharge, leading to flood risk. After redesigning Channel K by adjusting the channel elevation, the surface runoff volume can be effectively controlled, and channel overflow is eliminated. For the redesign cost calculation of the drainage system at Point K, the required budget is IDR 458,283,905.

***Keywords** : Flood Analysis, EPA SWMM , Drainage Channel Hidraulics, Rational Method*

1. INTRODUCTION

Population growth in Malang area has led to increased demand for residential land, which has resulted in reduced water catchment areas. This leads to a high risk of flooding, especially during the rainy season. According to Antonia et al. (2024), the lack of water catchment area is one of the main causes of inundation. In addition, in Malang City, high rainfall often causes rivers to overflow and flooding in residential areas

Lowokwaru sub-district is one of the flood-prone areas due to the inadequate capacity of the drainage system and reduced soil absorption. Based on previous research, good drainage system planning must be done from the beginning of area development (Winanto, n.d.). Poor drainage is unable to drain runoff effectively, so inundation often occurs, as experienced in the Kedawung area.

This study aims to analyze the hydraulic conditions and flood potential of the Kedawung Road sub-drain, and provide recommendations for effective drainage system improvements. The results of the study are expected to be a reference in water management and flood management in urban areas in a sustainable manner.

2. METHOD

This research was conducted with a quantitative approach through the stages of hydrological and hydraulic analysis to evaluate the capacity of the existing drainage system in the Kendalsari - Kedawung area, Malang City. The methodology used includes several steps as follows.

Rainfall Data

The rainfall data used in these calculations comes from rainfall data from 2015 until 2024 and was collected from three different rainfall stations around the research location, namely the Ciliwung Station, Karangploso Station, and Sukun Station.

Consistency Test

Consistency test aims to determine the correctness of field data. If the results are consistent, there is no change in the environment or measurement method. Conversely, inconsistency indicates change. The consistency testing method is done using the Double Mass Curve method. The Double Mass Curve method compares cumulative rainfall between rainfall stations and base stations. The steps include determining the main rainfall station, calculating the cumulative data, and graphing the bulk curve to determine new and old trends and calculating correction factors to correct the data. The steps that can be taken to apply the Double Mass curve method are as follows:

a. Determining the rain station as the basis for main station
b. Specifying other rain stations as comparison stations
c. Calculating cumulative rainfall data at the main station(dx)
d. Calculating the average rainfall data and its comparison station cumulative (dy)
e. Creating a double mass curve graph with (dx) as the main station and (dy) as the comparison station
f. Defining new trends and old trends. The old trend (m1) is data group that is assumed in a straight line, while the old trend (m2) is data group that is assumed in a non straight line. To calculate the gradient of the new trend and the old trend using the following formula:

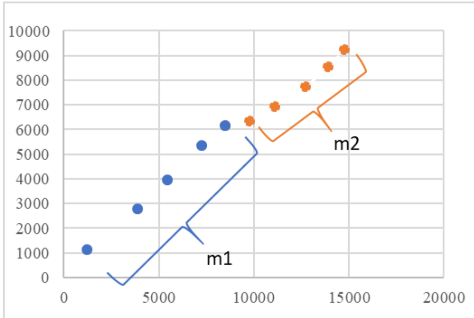
$$m = \frac{n.\sum xi.yi-(\sum xi)(\sum yi)}{n.\sum xi.-(\sum xi)^2} \quad (1)$$

Where:
m = regression coefficient
n = amount of data
Xi = Independent variable value that a certain value
Yi = the value of the predicted dependent variable

g. Calculating the value of the correction factor using the formula:

$$F = \frac{m_1}{m_2} \quad (2)$$

Where:
F = correction factor
m1 = straight line gradient
m2 = non-straight line gradient



h. Correcting data by controlling data that is assumed not to be in a straight line with the correction factor.

Calculation of Regional Rainfall

In regional calculations, the algebraic method is used because it is considered a simple but effective approach to obtaining average values (Triatmodjo, 2008). The Algebraic Average method is calculated by the equation:

$$d = \frac{d_1+d_2+d_3+\ldots d_n}{n} = \quad (3)$$

Where:
d = Average rainfall height (mm)
d1,d2,…, n = The amount of rainfall recorded in each station (mm)
n = Number of rain gauge stations

Rainfall Design Calculation

Rainfall design calculation is data on the largest rainfall in a given period, such as 2, 5, 10, or 20 years. The rainfall analysis method is selected based on appropriate statistical parameters. Determination of planned rainfall is important for calculating flood discharge. The method used is the Log Pearson III distribution.

The Log-Pearson Type III distribution is one of the distributions that is widely applied in resource studies. Its important parameters are the mean, standard deviation, and variance. Steps to calculate rainfall using the Log Pearson Type III method:

$$Cs = \frac{n\sum(logxi-logx_{average})^3}{(n-1)(n-2)s^4} \quad (4)$$

$$S = \sqrt{\frac{n\sum(logxi-logx_{rata-rata})^2}{n-1}} \quad (5)$$

$$LogX_{design} = LogX_{average} + G.S_{Logx} \quad (6)$$

Description:
Cs = coefficient skewness
Xi = rain data

$\bar{X}$ = average value of rainfall data (mm/day)

S = standard deviation

G = reduced variate

Frequncy Distribution Fit Test

To determine whether the data is correct based on the selected theoretical distribution type, further testing is required. To analyze the application test, and the following statistical methods are used:

a. Smirnov-Kolmogorov Test

$\Delta p = \left|P_{(T)} - P_{(E)}\right|$ ……………………………….…(7)

Where:

Δp = The difference between theoretical and empirical probability

P(T) = Theoretical Probability

P(E) = Empirical Probability

b. Chi- Square Test

$X^2 = \sum \frac{(Of-Ef)^2}{Ef}$ …………………………………..(8)

X^2 = Chi-Square

Ef = Frequency (the number of observations expected, according to the class division)

Of = Frequencies read in the same class

Rainfall Intensity

Rains that last for a short duration and cover a not very large area generally occur with high intensity. Meanwhile, rain that covers a large area, can last for a long duration and rarely with high intensity.

Dr Mononobe's formula:

$R_T = \left\{\frac{R_{24}}{t}\right\} \cdot \left\{\frac{t}{T}\right\}^{2/3}$ ……………………..…………………(9)

Where:

R_T = Average Rain Intensity In T Hours (mm/h)

R_{24} = Maximum rainfall 24 hours (mm)

T = Rain Start Time (hour)

t = Concentration time / Tc (hours)

(t for Indonesia = 6 hour)

Rainfall hour to t Formula:

$R_t = (t.R_T) - \{(t-1).(R_T.1)\}$……………..……….…..(10)

R_t = Percentage of Average Rainfall Intensity (in t hours)

Catchment Area

A catchment area is a region that collects rainwater and directs it into drainage channels. The characteristics of the catchment, such as land use and topography, influence the volume and flow of runoff. Therefore, an effective drainage system is essential to convey the collected water efficiently and prevent inundation.

Plan Discharge

A plan discharge is a consideration of the maximum amount of flow that a drainage system can handle, with the main goal of preventing inundation. In the context of urban and highway drainage, this plan discharge is generally determined based on the maximum discharge at the time of flooding with a ten-year return period. This means that there is a possibility that this maximum flood will occur once in a period of ten years, twice in twenty years, or ten times in a hundred years (Suripin, 2004). The determination of the maximum flood discharge for a 10 years period takes into account several factors, including:

a. The risk of inundation due to rain tends to be lower compared to floods caused by river overflows.

b. The area of urban areas is limited if the channel is planned to cope with maximum flood discharge with a return period of more than 10 years.

c. Changes that occur in urban areas over time can affect the condition and capacity of drainage channels.

Channel Capacity

The calculation of the average flow velocity in the channel dimension uses the Manning formula because this formula is simple and its extensive used as a formula in the calculation of uniform flow.

$V = \frac{1}{n}.R^{2/3}.S^{1/2}$

Where:

n = manning's roughness coefficient

R = Hydraulic Radius (m)

S = Channel slope

To get the channel dimensions, it can use the following formula:

$Q = V.A$ ……….…………………………….. (11)

Where:

Q = flow discharge (m³/s)

A = Channel cross-sectional area (m²)

V = velocity (m/s)

Strom Water Management Model (SWMM)

Storm Water Management Model (SWMM) is a hydrological and hydraulics simulation software developed by the US Environmental Protection Agency (EPA). The model is used to analyze stormwater flow, surface runoff, and urban drainage systems. SWMM helps plan and manage drainage systems by simulating catchment response to rainfall, calculating flow rates, and identifying possible flooding. The main components of SWMM include subcatchments, conduits, junctions, storage, and outfalls. Required inputs include rainfall data, land surface characteristics, slope, and channel parameters. Simulation results are displayed in the form of flow, runoff volume, and water level. SWMM is free, flexible, and capable of simulating various stormwater management scenarios.

Cost Budget Plan

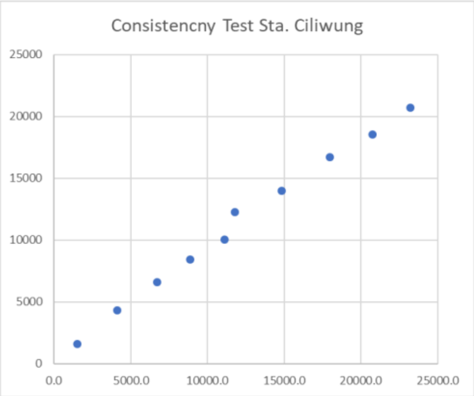
The Cost Budget Plan is a calculation that includes all costs needed for materials, wages, and other expenses related to the implementation of development projects. According to John W. Niron in his book "Practical Guidelines for Budgeting and Wholesale Building Cost Budget Plans" (1992), Cost Budget Plan can be defined as follows:

1) Plan: A set of plans that includes the details and procedures for implementing the construction of a building.
2) Budget: A cost calculation that is compiled based on the best drawings (plan drawings) of a building.
3) Cost: The amount of expenses related to the wholesale listed in the applicable terms.

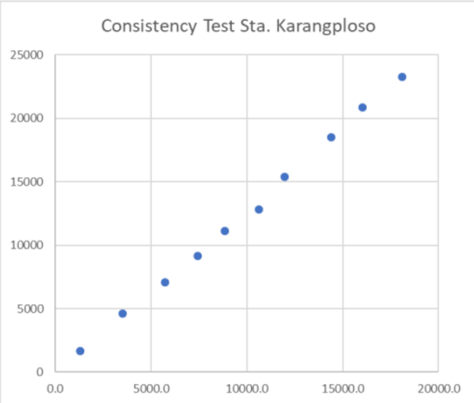
3. RESULT AND DISCUSSION

Consistency Test

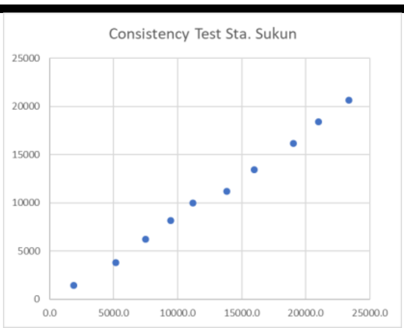
Based on the results of the double mass curve graph, the value of Ciliwung station $R^2 = 0.9936$, Karangploso station $R^2 = 0.998$, Sukun station $R^2 = 0.9966$. Because R^2 is close to 1 so that the data do not need to be corrected.



Picture 1. Double Mass Curve Graph of Ciliwung Station against Karang Ploso Station and Sukun Station



Picture 2. Double Mass Curve Graph of Karang Ploso Station against Karang Ciliwung and Sukun Station



Picture 3. Double Mass Curve Graph of Sukun Station against Ciliwung Station and Karang Ploso Station

Regional Rainfall

The method chosen for the calculation of regional rainfall is the algebraic average method. The result of this calculation is shown on the table below.

Table 1. Average Maximum Rainfall

Year	Mm/hours
2015	62
2016	62
2017	76
2018	54
2019	64
2020	125
2021	75
2022	80
2023	82
2024	94

Design Rainfall

Based on the corrected average maximum rainfall data presented in the table above, the Log-Pearson Type III method was selected for the design rainfall calculation, as it was considered the most appropriate. Using a 10-year return period, the resulting maximum design rainfall is 104.27 mm/day.

Distribution Fit Test

Rainfall distribution testing design using the Smirnov Kolmogorov and Chi Square methods based on maximum average rainfall data and probability of occurrence. In the Smirnov Kolmogorov test, the D max value is 20%. With a confidence degree α of 0.05 and the number of data is 10, the Do value is 41%. Therefore, since the value of D max < Do, it can be concluded that the method is appropriate. In the Chi Square test, the calculated X^2 value is 2.00 with the degree of confidence used 0.05. The data owned is rain data for 10 years, the X^2 value in the reading table is worth 14.067. Because the value of X^2 count < X^2 table, it can be concluded that the method is appropriate.

Rainfall Intensity

Table 2 shows the effective rainfall distribution calculated using the Mononobe formula based on a 10-year return period. The resulting rainfall intensity values are then used as input data in the SWMM software for further hydrological modeling.

For example:

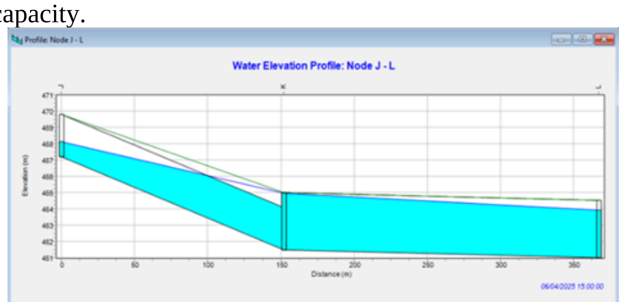
$I = (\frac{1}{6}).(\frac{6}{1})^{2/3} = 0.550$ mm/hours

Table 2. Effective Rainfall Distribution

No	Hour to t	Hour-t Rain Percentage	1-hour net Rainfall (mm/h)					
			1.05 year	2 year	10 year	50 year	100 year	200 year
1	1	55.03%	53.61	72.78	104.43	137.61	153.37	170.25
2	2	14.30%	13.93	18.92	27.14	35.77	39.86	44.25
3	3	10.03%	9.77	13.27	19.04	25.09	27.96	31.04
4	4	7.99%	7.78	10.56	15.16	19.97	22.26	24.71
5	5	6.75%	6.57	8.92	12.80	16.87	18.80	20.87
6	6	5.905	5.74	7.80	11.19	14.74	16.43	18.24
		100.00%						
Net rain (effective rain)		**(mm/day)**	**97.41**	**132.25**	**189.77**	**250.05**	**278.69**	**309.36**

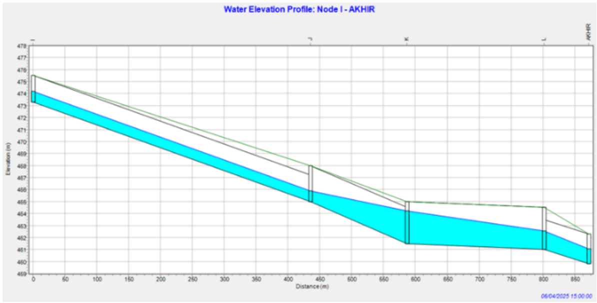
SWMM

The SWMM simulation was conducted to evaluate the capacity of the existing drainage channel using rainfall data with a 10-year return period. The results show that overflow occurs in certain sections, indicating insufficient channel capacity.



Picture 4. Simulation Existing Drainage

This simulation was conducted using SWMM software to analyze the existing conditions of the drainage system. The data entered includes maximum rainfall data from one rainfall station, time series obtained from the Mononobe formula calculation, catchment data (area, slope, runoff coefficient), and dimensions of the existing drainage system. The analysis was conducted to determine the system's capacity to convey runoff flow. The simulation results indicate that at point K-L, there is an overflow condition, indicating the potential for flooding.



Picture 5. Simulation Redesign Drainage

The redesign at point K was carried out by lowering the base elevation of the channel by 1.5 meters with a channel height of 3.5 meters. Lowering the elevation at point J to make the channel steeper by 2.2 meters and lowering the elevation at point L by 0.5 meters with a channel height of 2.5 meters.

Based on the simulation results after the J-L channel redesign, it is known that the channel capacity is sufficient to accommodate the overflow discharge. This is indicated by the absence of overflow in the channel.

Recapitulation of the Cost Estimate

Based on the calculation of the required work volume and the unit price of materials and labor, the budget plan (RAB) for this drainage planning project is estimated to be around IDR 458,283,905 million, which is considered sufficient to cover the implementation of the planned design.

4. CONSCLUSION

Based on the results of the analysis that has been carried out, the following conclusions can be drawn:

1. Log Pearson III analysis shows that the maximum rainfall for a 10-year recurrence period is 104.27 mm, which is used for drainage channel planning.
2. The drainage channels in the Kendalsari–Kedawung sub-watershed are unable to accommodate runoff during heavy rainfall. At point K, overflow occurs, causing flooding to spread to point L. The channel dimensions are inadequate and do not guarantee that this situation will be maintained.
3. The channel redesign is planned to accommodate the design flow rate, as follows:
   Point K : base elevation lowered by 1.5 m, channel height 3.5 m
   Point J : base elevation lowered by 2.2 m
   Point L : base elevation lowered by 0.5 m, channel height 2.5 m
   After the redesign, the channel will be able to drain water without overflow.
4. The total cost required in re-design the drainage at point J,K,L amounted to Rp458,283,905.

REFRENCE

[1] Jawat, W. (2015) 'Metode Pelaksanaan Pekerjaan Pondasi (Studi: Proyek Fave Hotel Kartika Plaza)', PADURAKSA: Jurnal Teknik Sipil Universitas Warmadewa, 4(2), pp. 22–34. Available at: https://www.ejournal.warmadewa.ac.id/index.php/paduraksa/article/view/247.

[2] Niron, John W. 1992. Practical Guidelines for Budgeting and Wholesale Building Cost Budget Plans.

[3] Ramadhani, A., Harsanti, W. and Pudjowati, U.R. (2022) PERENCANAAN ULANG DRAINASE PEMUKIMAN BERWAWASAN LINGKUNGAN KAWASAN JALAN IKAN MAS RAYA KOTA MALANG. Available at: http://jos-mrk.polinema.ac.id/.

[4] Soemarno. 1995. Hidrologi Aplikasi Metode Statistik untuk Analisa Data. Bandung. Penerbit Nova.

[5] Sudjarwadi. 1987. Teknik Sumber Daya Air. Yogyakarta. Penerbit Biro Penerbit KMTS. Fakultas Teknik UGM.

[6] Suripin. 2003. Sistem Drainase Perkotaan yang Berkelanjutan. Semarang. Megister Teknik Sipil Program Pasca Sarjana Universitas Diponegoro.