

URBAN DRAINAGE CAPACITY ON JLN. EAST PERJUANGAN, MEDAN PERJUANGAN DISTRICT.

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Abstract

This research was motivated by the problem of inundation and flooding on Jalan Perjuangan, Medan Perjuangan District, which was caused by the drainage system capacity not being optimal. The aim of this research is to evaluate the capacity and performance of drainage channels based on existing dimensions and assess the channel's ability to accommodate the planned discharge at various return periods. The methods used include hydrological and hydraulic analysis. Hydrological analysis is carried out through rainfall distribution tests, Chi-Square tests, and determining planned rainfall with various return periods. Rain intensity is calculated using the Mononobe method. Next, hydraulic analysis is carried out using the Manning formula to determine the flow capacity of the drainage channel. The data used in this research consists of primary data from field surveys and secondary data from related agencies. The research results show that the most suitable rainfall distribution is Log Pearson Type III. The existing channel dimensions of 4 m × 3 m have proven capable of accommodating the planned discharge up to a return period of 100 years with a discharge of 54 m³/sec, so that technically it still meets the currently required capacity. However, factors such as increasing population, sediment accumulation and domestic waste disposal have the potential to reduce channel performance in the future. Therefore, routine maintenance efforts and sustainable drainage management planning are needed to ensure the system continues to function optimally and is able to anticipate increases in flow loads in the future.

Keywords: Urban Drainage, Capacity Evaluation, Hydrological Analysis, Channel Hydraulics, Design Discharge

INTRODUCTION

Urban drainage is an important infrastructure in the water management system in urban areas. The drainage system functions to channel rainwater and surface runoff so that it does not cause puddles or floods which can disrupt community activities. Along with increasing development and population growth in urban areas, the ability of the drainage system to accommodate and channel water becomes increasingly important to pay attention to. Many cities in Indonesia experience waterlogging problems due to the capacity of drainage channels being unable to accommodate the incoming water discharge, either due to inadequate channel dimensions or due to sedimentation and channel narrowing (Ardiansyah, 2024; Notanubun, 2023). Drainage capacity problems are often related to physical conditions or channel geometry that is not in accordance with flow discharge requirements. Channel dimensions such as length, width, height and depth of the water body greatly influence the channel's ability to drain water optimally. If the channel dimensions are inadequate, the water will overflow and cause puddles on the surface of roads and residential areas. This condition shows that evaluating the dimensions of drainage channels is an important aspect in efforts to improve the performance of urban drainage systems (Saragi, 2023; Rahmawati, 2021).

The importance of evaluating the dimensions of drainage channels has encouraged a lot of research on drainage capacity analysis in various regions in Indonesia. Several previous studies emphasized the analysis of rainfall, runoff discharge, and hydrological projections in determining drainage channel capacity. Research by Singal (2023) and Fitriyadi (2023) focuses

more on analyzing planned flood discharge using probability distribution methods such as Log Pearson III or Gumbel to determine the required drainage channel capacity. However, only a small number of studies specifically examine the geometric conditions of channels in detail, especially regarding channel dimensions such as length, width, channel height, and depth of water bodies in the field. In fact, the geometric condition of the channel is an important factor that directly influences the flow capacity in the drainage system (Lindawati, 2021; Indriyani, 2022).

Medan Perjuangan District area, especially along Jl. Struggle, facing serious challenges regarding an effective drainage system. Floods and standing water often occur, especially on main routes such as Jl. William Iskandar, who indicated that there were fundamental problems with drainage infrastructure. This condition not only causes damage to roads and buildings, but also has the potential to threaten public health due to the spread of water-borne diseases, as well as having a negative impact on environmental sustainability. One indication of this problem is the variation in dimensions of the drainage channels on Jl. Struggle. This difference shows that there is no comprehensive and integrated drainage planning. This shows that research is still needed that specifically evaluates drainage capacity based on the physical dimensions of the channel and water depth conditions in the field (Kinanthi, 2023; Tifani, 2024).

This research is novel in the analytical approach used. This research not only considers hydrological aspects, but also focuses on directly evaluating the geometry of drainage channels through measuring channel dimensions such as length, width, channel height and depth of the water body. By using these parameters, it is hoped that this research can provide a more real picture of the capacity and performance of existing drainage systems in the field. This approach is important because the physical condition of channels often experiences changes due to sedimentation, channel narrowing, or infrastructure damage which is not always reflected in hydrological analysis alone (Leonard, 2023; Sulistyani, 2025).

Based on these conditions, the aim of this research is to evaluate the capacity and performance of the drainage system based on channel dimensions which include length, width, channel height and depth of the water body. Apart from that, this research also aims to find out whether the dimensions of the existing drainage channels are still able to accommodate water flow optimally or not. Thus, it is hoped that the results of this research will provide an overview of the actual condition of the drainage system as well as potential problems that could occur if the channel capacity is inadequate. This research is expected to provide significant benefits in various aspects related to urban drainage management. Practically, the results of evaluating the capacity and performance of the drainage system based on channel dimensions will provide accurate and comprehensive information regarding the actual conditions of drainage in the research area. This information is very useful for local governments, property developers and other related parties in planning, designing and maintaining more effective and efficient drainage systems. Apart from that, this research can also be a basis for identifying potential drainage problems that may arise due to inadequate channel capacity, so that appropriate preventive measures can be taken. Academically, this research offers an innovative analytical approach by combining hydrological aspects and direct channel geometry evaluation.

RESEARCH METHODOLOGY

1. Research Location

This research case study took place In the Jalan Perjuangan Drainage Channel, Medan Perjuangan District. Has a drainage channel on the side of Jalan Perjuangan 3.33 km long.



Figure 1. Research Location

2. Flowchar

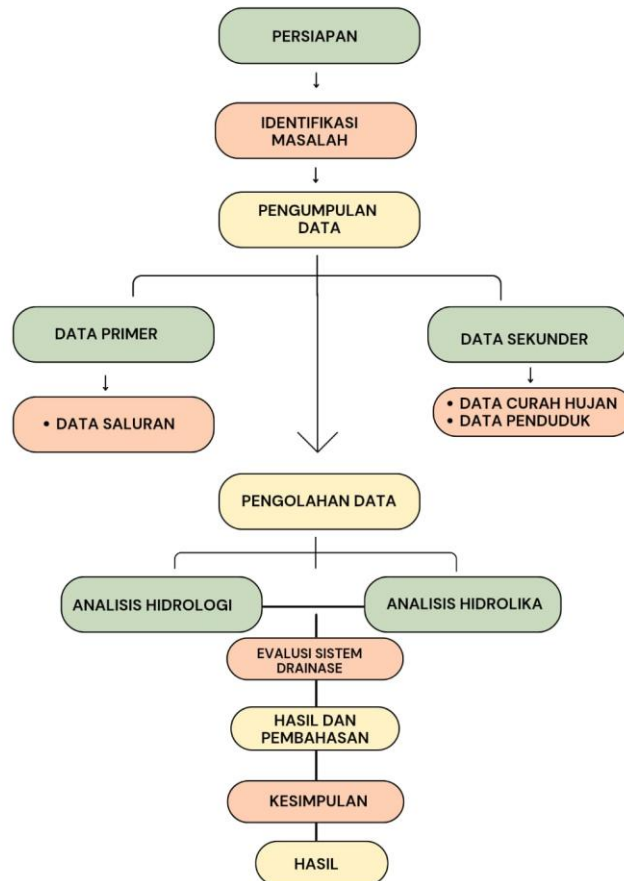


Figure 2. Flowchart

3. Data Collection

In this study, two types of data were used. Primary data is data collected through direct measurements and observations in the field, namely data on documentation of channel conditions, channel height, and drainage channel width. Meanwhile, secondary data is supporting data in a study obtained from maximum rainfall data (2014-2023) Medan Tembung District.

4. Data Processing

After all the data is collected, the data will be processed and analyzed. The steps in this analysis method include:

1. Carry out hydrological analysis for maximum daily rainfall data.
2. Carry out a suitability test for rainfall distribution .

Namely with 2 stages;

a) Test the statistical descriptor of rainfall, using the statistical parameter descriptor value formula.

- **Coefficient of Variation (CV):** measures the variation of data

$$CV = \frac{s}{\bar{x}}$$

- **Skewness Coefficient (Vs):** measures the skewness of the data distribution

$$Cs = \frac{n \sum (Xi - \bar{X})^3}{(n-1)(n-2)S^3}$$

- **Kurtosis Coefficient (CK):** Measures the skewness of the distribution

$$CK = \frac{n^2 \sum (Xi - \bar{X})^4}{(n-1)(n-2)(n-3) \cdot S^4}$$

b) Chi Square Test The Chi square test is used to determine the probability distribution method that can represent the statistical distribution being analyzed. Test Chi Square can be calculated with the formula:

$$Xh^2 = \sum G = \frac{1(Oi - Ei)^2}{Ei}$$

Xh² = Calculated chi-square parameter

G = number of subgroups

O_i = number of observation values

E_i = Total theoretical value

The Chi Square test can also use the Gumbel, Log Person III, Long Normal and Normal distribution methods. This test determines which distribution is most suitable for sample data by comparing theoretical and observational frequencies. This probability distribution method is commonly used to analyze daily maximum rainfall or planned flood discharge.

3. Look for rain return periods, 2, 5, 10, 25, and 100 years based on one of the methods that have been determined from the analysis using the Gumbel method, Log Person III, and Log Normal.
4. Rain intensity is searched using the mononobe method for rain conditions with a relatively short rain duration. The Mononobe Method formula is:

$$I = \frac{R24 \cdot 24^{2/5}}{(24/t)^{2/5}}$$

Where: I = Rain intensity for the duration corresponding to a certain return period

R24 = maximum daily rainfall (mm) corresponding to the return period

T = duration of rain (hours)

5. Drainage hydraulics analysis is carried out to evaluate and plan the dimensions of the channel so that it is able to accommodate and channel the planned flood discharge, in order to prevent inundation and flooding in an area. This analysis models the water surface profile, flow velocity, and carrying capacity of existing or newly planned channels. Calculate hydraulic analysis using Maning's formula, namely:
 Cross-sectional area (A)

- Square: $A = b \times h$ (Width \times water level height)
 - Wet Perimeter (P): Calculates the length of the channel wall that is submerged in water. A
 - Hydraulic radius (R): $R = P$
 - Kecepatan Aliran (V): $v = \times R n$
 - Debit Eksisting (Qeks): $Qeks = A \times V$
6. Analyze population projections to plan the capacity of drainage channels so that they remain effective in collecting water runoff in the future.
 7. Analysis of Sediment Generation and Volume Projections to plan, manage and maintain drainage channel capacity in a sustainable manner, to prevent flooding and infrastructure damage due to silting.
 8. Analysis of Domestic Liquid Waste Production Projections in the drainage system aims to plan, manage and evaluate sewer infrastructure so that it can accommodate current and future waste loads without polluting the environment.

RESULTS AND DISCUSSION

1. Maximum Daily Rainfall Analysis

Data from 2015-2023

Table 1. Maximum Rainfall

Year	Xi(mm)
2015	2803
2016	2830
2017	3190
2018	3181
2019	3301
2020	3729
2021	3205
2022	3495
2023	3424

2. Distribution Fit Test

Table 2. Results of the Fit Test for the Statistical Distribution of Rainfall

Parameter	Value
Amount of data	9
Raw Track (n)	3239.78
Standard deviation (S)	297.50

Coefficient of Variation (CV)	0.092
Skewness Coefficient (Cs)	-0,08
Koefisien Kurtosis (Ck)	2.6

This rainfall data tends to follow the Normal distribution, but still needs to be confirmed with the Chi-Quadratic follow-up test.

3. Chi Square Test

Table 3. (a). Normal Distribution

Classes	oi	Ei	(Oi-Ei) ² /Ei
1	2	1.8	0.022
2	2	2.2	0.018
3	2	2.4	0.067
4	3	2.6	0.062
χ^2		0.169	

Table 4. (b). Gumbel Distribution

Kelas	Oi	Ei	(Oi-Ei) ² /Ei
1	2	1.5	0.167
2	2	2.0	0.000
3	2	2.5	0.100
4	3	3.0	0.000
X^2		0.167	

Table 5. (c). Distribution of Type III Log Persons

Kelas	Oi	Ei	(Oi-Ei) ² /Ei
1	2	1.7	0.053
2	2	2.1	0.005
3	2	2.3	0.039
4	3	2.9	0.003
X^2		0.100	

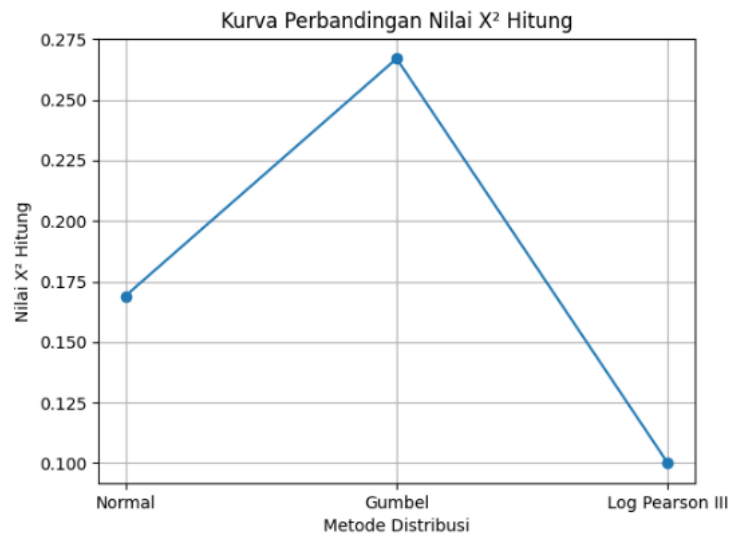


Figure 3. Comparison of Results

From the table of results Chi Square, it shows that the smallest value of X^2 is the Type III Person log where the best distribution is the Type III Log Person.

4. Rains Anniversary Period 2,5,10,25 and 100 Years

Table 6. Rainfall Results of the Re-Period

Periode ulang (tahun)	Normal (mm)	Gumbel (mm)	Log Person Tipe III (mm)
2	3239.78	3192.18	3235
5	3489.68	3453.98	3495
10	3620.58	3626.53	3635
25	3728.67	3795.11	3780
100	3933.95	3989.58	4005

From the results of the calculation of the rainfall period in the table shows that from the previous test, the best distribution is Log Person Type III, so the planned rain used is Log Person Type III.

5. Rain Intensity Using the Mononobe Method

Rain duration (t) = 1 hour

Rain Plan Best Log Person Type III.

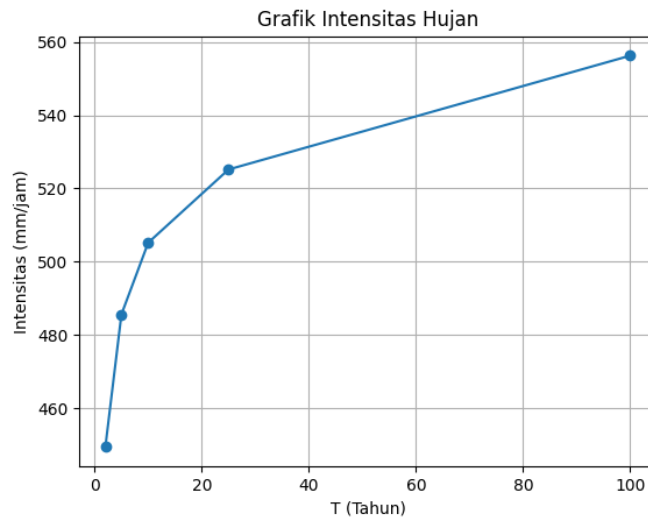


Figure 4. Rain Intensity Results

6. Hydraulic Analysis Using Maning Formulas

Table 7. Hydraulic Analysis Results

No	Parameter	Simbol	Value	Units
1	Channel Width	b	4	m
2	Water Height	h	3	m
3	Cross-sectional area	A	12	m ²
4	Wet Circumference	P	10	m
5	Hydraulic radius	R	1.2	m
6	Slope	S	0.001	-
7	Coefficients Squirt	n	0.015	-
8	Speed Flow	V	4.5	m/det
9	Debit	Q	54	m ³ /det

From the results of the hydraulic analysis, the dimensions of the 4m × 3m channel are able to accommodate the discharge. The flow is quite fast at approximately 4.5 m/sec. The line on the road is safe for the Q100 plan discharge.

7. Population Projections

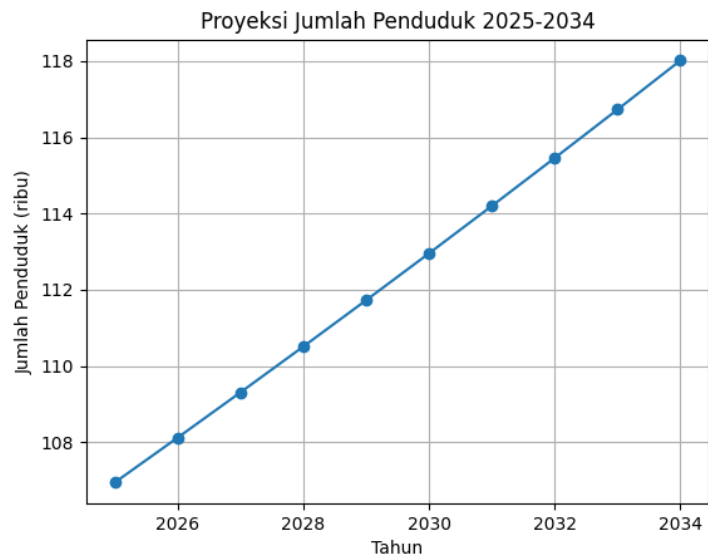


Figure 5. Population Projection

There is an increase of approximately 12,000 people in 10 years, the impact that can occur on drainage can increase water runoff (watertight surface increases) and drainage discharge will increase.

Table 8. Implications for Planning

Parameter	Conditions Now	Planning
Population	105.778	118.015
Rise	-	+11.6%
Impact Runoff	Medium	Higher
Capacity Channels	Enough	The Need for Anticipation

Based on the results of the implications for Population Growth Planning of approximately 1.1% per year, in the next 10 years it will increase significantly. The duct should be designed larger or add capacity reserves to make it more secure for the future.

8. Analysis of Sediment Generation and Volume Projections.

Table 9. Sediment Generation Projection Analysis

Year	Volume Sedimen (m³)	Rise (%)	Volume Kumulatif (m³)	Impact on Drainage
2024	4.67	-	4.67	Initial condition
2025	4.90	5%	9.57	Starting the Siltation
2026	5.15	5%	14.72	Reduced capacity

2027	5.40	5%	20.12	Slowed down flow
2028	5.67	5%	25.79	Risk of inundation
2029	5.95	5%	31.74	Potential for minor flooding
2030	6.25	5%	37.99	Flooding increases
2031	6.56	5%	44.55	Channel is not optimal
2032	6.89	5%	51.44	Need a large dredging
2033	7.23	5%	58.67	High risk
2034	7.59	5%	66.26	Very critical

Table 10. Sediment Volume Calculation Results

Segmen	Height (m)	Width (m)	Depth (m)	Volume (m)
I	1.70	1.80	0.50	1.53
II	0.80	1.25	0.80	0.08
III	0.90	2.00	0.05	0.09
IV	1.10	1.84	0.07	0.14
V	1.30	2.00	0.31	0.81
VI	1.22	1.60	0.17	0.33
VII	1.28	1.50	0.39	0.75
VIII	1.80	2.60	0.20	0.94

To maintain optimal drainage, normalization or dredging is carried out at least once every 1-2 years.

9. Analysis of Domestic Liquid Waste Production Projections

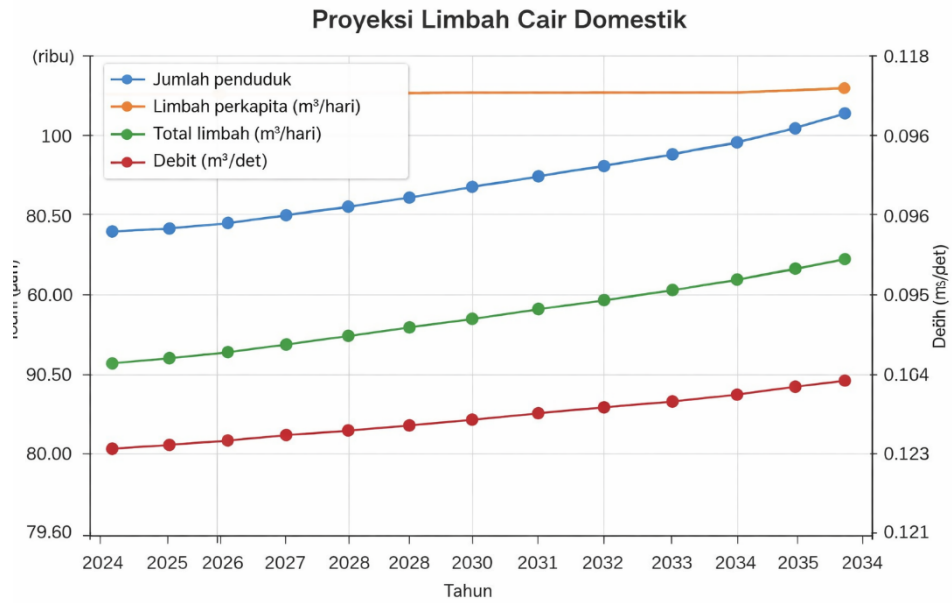


Figure 6. Domestic Liquid Waste Projection
 Gravik tabel 14

From the results of the analysis in the table above, liquid waste increased from 10,155 to 11,329 m³/day. The increase in wastewater for the next 10 years is approximately 11.6%. This condition is not dominant during heavy rain but significant during dry conditions. Domestic waste must still be taken into account.

CONCLUSION

Based on hydrological analysis and distribution fit test, the maximum rainfall data at the research location is most suitable using the Log Pearson Type III method, with the smallest Chi-Square value ($X^2 = 0.100$). Therefore, this method is used in determining the design rainfall. The results of the return period rainfall calculation show that the design rainfall increases as the return period increases, where for a 100-year return period it is obtained at 4005 mm, with a rainfall intensity reaching 556.3 mm/hour (1 hour duration, Mononobe method).

Based on hydraulic analysis using Manning's formula, the existing channel dimensions of 4 m × 3 m are able to accommodate a flow rate of 54 m³/sec, so that the current capacity of the drainage channel is still safe for the planned discharge (Q100). Population projections show an increase of around 11.6% in 10 years, which has the potential to increase surface runoff and drainage loads. This indicates that future channel capacity needs to be anticipated with greater planning or additional capacity reserves.

Sediment projection analysis shows a gradual increase in sediment volume to critical conditions within 10 years, which can cause silting and decrease channel capacity. Therefore, regular normalization or dredging activities are required (once every 1–2 years). Domestic liquid waste projections have increased from 10,155 m³/day to 11,329 m³/day within 10 years. Although not dominant during heavy rain, this waste still makes a significant contribution to baseflow and needs to be taken into account in drainage planning. Overall, the drainage capacity at the current research location is still sufficient, but in the long term, sustainable management is needed, including increasing capacity, sediment control, and domestic waste management to maintain optimal drainage system performance.

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REFERENCES

- Akan, A. O. (1993). *Urban stormwater hydrology*. Lancaster, PA: Technomic Publishing.
- Arsyad, S. (2010). *Konservasi tanah dan air*. Bogor: IPB Press.
- Asdak, C. (2018). *Hidrologi dan pengelolaan daerah aliran sungai* (Edisi revisi). Yogyakarta: Gadjah Mada University Press.
- Badan Standardisasi Nasional. (2016). *SNI 2415: Tata cara perencanaan drainase perkotaan*. Jakarta: BSN.
- Chow, V. T. (1959). *Open-channel hydraulics*. New York, NY: McGraw-Hill.
- Direktorat Jenderal Sumber Daya Air. (2014). *Pedoman perencanaan drainase perkotaan*. Jakarta: Kementerian PUPR.
- Gupta, R. S. (2017). *Hydrology and hydraulic systems* (4th ed.). Long Grove, IL: Waveland Press.
- Harto, S. (2000). *Analisis hidrologi*. Jakarta: Gramedia.
- Kodoatie, R. J. (2012). *Pengelolaan sumber daya air*. Yogyakarta: Andi.
- Maidment, D. R. (1993). *Handbook of hydrology*. New York, NY: McGraw-Hill.
- Soemarto, C. D. (1999). *Hidrologi teknik*. Jakarta: Erlangga.
- Soewarno. (1995). *Hidrologi: Aplikasi metode statistik untuk analisa data*. Bandung: Nova.
- Subramanya, K. (2013). *Engineering hydrology* (4th ed.). New Delhi: Tata McGraw-Hill.
- Suripin. (2004). *Sistem drainase perkotaan yang berkelanjutan*. Yogyakarta: Andi.
- Triatmodjo, B. (2008). *Hidraulika II*. Yogyakarta: Beta Offset.
- Viessman, W., & Lewis, G. L. (2003). *Introduction to hydrology* (5th ed.). New York, NY: Pearson.
- Wanielista, M., Kersten, R., & Eaglin, R. (1997). *Hydrology: Water quantity and quality control* (2nd ed.). New York, NY: Wiley.