ANALYSIS OF THE EFFECT OF SEDIMENTATION ON THE CAPACITY AND PERFORMANCE OF DRAINAGE CHANNELS ON THE KAPTEN M. JAMIL LUBIS–PERINGGAN MEDAN ROAD SECTION

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Abstract
Urban drainage systems play a crucial role in controlling stormwater runoff and preventing flooding. However, drainage channel performance often declines due to sedimentation and increased flow loads. This study aims to analyze the effect of sedimentation on the capacity and performance of drainage channels on the Jalan Kapten M. Jamil Lubis to Jalan Peringgan section in Medan City. The methods used included hydrological analysis to determine runoff discharge based on rainfall return periods (2, 5, 10, 25, and 100 years), measuring the dimensions of existing channels, and calculating sedimentation volume and channel capacity. The results showed that the total sedimentation volume reached approximately 1,359.63 m^3, with an average decrease in channel capacity of 17.49%. Runoff discharge increased with increasing rainfall return periods, from 0.171 m^3/s at a 2-year return period to 0.246 m^3/s at a 100-year return period. This indicates that the existing channel capacity is beginning to suboptimally accommodate the design discharge, especially at medium to high return periods. Furthermore, population growth has increased the burden of domestic waste entering drainage channels. Based on the analysis, mitigation efforts are needed, including routine maintenance through sediment dredging, increasing channel capacity, and implementing a sustainable drainage system to reduce runoff. With proper management, it is hoped that drainage system performance can be improved and the risk of flooding can be minimized.

Keywords: Urban drainage; sedimentation; channel capacity; runoff discharge; Medan City

INTRODUCTION

Sediment is solid material such as sand, soil, mud, and organic particles carried by water flow and then deposited when the flow velocity decreases. This deposition process, known as sedimentation, frequently occurs in various water systems, both natural and man-made, including urban drainage systems. In drainage systems, sediment generally originates from soil erosion, road runoff, construction activities, and organic material carried by rainwater flow. Continuous sediment accumulation can cause silting of the channel bed, reducing the effective dimensions of the channel and disrupting drainage system performance (Butler & Davies, 2018; Liu et al., 2020).

Urban drainage systems play a crucial role in channeling rainwater runoff from roads and residential areas to receiving water bodies. A well-functioning drainage system can help prevent flooding and puddles in urban areas. Furthermore, drainage systems play a role in maintaining environmental stability and supporting the smooth functioning of social and economic activities. However, rapid urban development often leads to increased surface runoff that is not matched by adequate drainage system capacity (Marsalek et al., 2019; Nguyen et al., 2021).

One common problem in urban drainage systems is sediment accumulation at the bottom of the canal. Sedimentation can narrow the channel dimensions, reducing the water flow capacity of the canal. The reduction in drainage capacity due to sedimentation has the potential to cause various negative impacts, such as waterlogging, disruption to transportation activities, and a decline in environmental quality in urban areas. Therefore, the management and maintenance of drainage channels are crucial for maintaining drainage system performance (Ashley et al., 2018; Zhang et al., 2022).

Several previous studies have examined the problem of sedimentation in urban drainage systems and its impact on channel hydraulic performance. Research by Liu et al. (2020) shows that Sediment accumulation in drainage channels can significantly reduce flow capacity. Another study by Nguyen et al. (2021) also stated that sedimentation in urban drainage systems can increase the potential for flooding if regular channel maintenance is not carried out. Furthermore, Zhang et al. (2022) suggested that sedimentation can affect the efficiency of drainage systems in diverting rainwater runoff and potentially reduce channel hydraulic performance.

In Indonesia, sedimentation problems in drainage channels are also common in various large cities. Sedimentation in urban drainage channels is generally influenced by land use conditions, soil erosion levels, the presence of waste, and a lack of channel maintenance. These conditions cause channel silting, reducing their capacity to drain water (Pratama & Nugroho, 2020; Suryadi, 2019).

Medan, as one of the major cities in Indonesia, also faces various problems related to urban drainage system management. Rapid population growth, along with the development of residential areas and transportation, has led to an increase in surface runoff that must be channeled through the drainage system. Based on data from the Medan City Central Statistics Agency, the population in the study area has increased from approximately 18,226 in 2015 to 21,254 in 2025. This population increase has the potential to increase residential activity, transportation, and infrastructure development, which ultimately can increase surface runoff and solid material carried by rainwater into drainage channels.

This increase in surface runoff can accelerate the sedimentation process in drainage channels. Solid materials such as sand, soil, and organic particles carried by rainwater will settle at the bottom of the channel, causing silting. This condition can reduce the effective dimensions of the channel and reduce the drainage flow's capacity to drain rainwater. If sedimentation occurs continuously without adequate maintenance, the performance of the drainage system can decline and potentially cause waterlogging in urban areas.

One location showing signs of this problem is the section from Jalan Kapten M. Jamil Lubis to Jalan Peringgan in Medan City. This road section is an area with high transportation and residential activity, potentially generating surface runoff that carries solid material into the drainage channel. The accumulation of sediment in the channel bed can cause the channel to become shallow and reduce the channel's water flow capacity.

Several previous studies have discussed sedimentation in urban drainage systems and its impact on the channel's hydraulic performance. However, most of this research has focused on hydrological analysis or general evaluation of drainage systems. Research specifically analyzing the relationship between sediment volume and drainage channel capacity based on direct field measurements is still relatively limited, especially at the channel segment scale in urban areas. Furthermore, research integrating channel dimension measurements, sediment thickness, and quantitative analysis of channel capacity reduction across several channel segments with systematic observation intervals is also rare, particularly in Medan City.

Therefore, the purpose of this study is to address this gap by analyzing sedimentation volume and its impact on drainage channel capacity based on direct measurements of several drainage channel segments spread along Jalan Kapten M. Jamil Lubis to Jalan Peringgan in Medan City. Through this approach, the study is expected to provide a clearer picture of the sedimentation conditions in drainage channels and its impact on the channel's capacity to drain rainwater.

The results of this study are expected to provide both academic and practical benefits. Academically, this research can add to the scientific literature on sedimentation analysis in urban drainage systems and its relationship to drainage channel capacity. Practically, the results of this study are expected to serve as a reference for local governments and related agencies in managing and maintaining drainage channels, thereby maintaining the performance of urban drainage systems and minimizing the risk of waterlogging.

RESEARCH METHODS

Research Location

This research was conducted on the drainage channels along Jalan Kapten M. Jamil Lubis to Jalan Peringgan in Medan City. This area is characterized by high transportation and residential activity, thus potentially generating significant surface runoff during rainfall events.

The research was conducted in February, with the main activities being field observations, drainage channel dimension measurements, sediment thickness measurements, and secondary data collection, including rainfall and population data

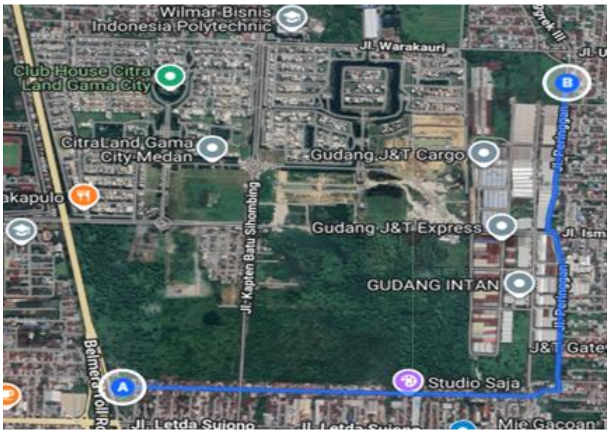

Figure 1. Peta Lokasi Penelitian

Research Segments

The drainage channels at the research site were divided into seven observation segments, each spaced 463 meters apart. This segmentation was designed to obtain a representative picture of the drainage channel conditions throughout the study area.

Tabel 1.Segmen Penelitian

Segmen	Jarak Antar Segmen (m)	Koordinat Latitude	Koordinat Longitude
Segmen 1	463	3.598824	98.728775
Segmen 2	463	3.598646	98.732951
Segmen 3	463	3.598488	98.737121
Segmen 4	463	3.601190	98.738884
Segmen 5	463	3.605340	98.738733
Segmen 6	463	3.609382	98.738934
Segmen 7	463	3.613049	98.738503

In each segment, the following measurements were taken:

1. Channel width
2. Channel depth
3. Sediment thickness
4. Physical condition of the drainage channel

Research Flowchart

The research stages are carried out systematically, starting from problem identification to data analysis. The research flowchart is shown below:

Figure 2. Diagram Alir Penelitian

Population Projection Analysis and Domestic Liquid Waste

Population projections are conducted to determine future population growth in the research area.

Arithmetic method:

P_t=P_0+(r×t)……………………………………(1)

Where:
P_t= population in year t
P_0= population in base year
r= average population increase per year
t= projection period (years)

Domestic liquid waste production is calculated based on the population and clean water consumption per person per day. This calculation is performed to determine the amount of domestic waste flowing into the drainage system. Domestic liquid waste production is calculated using the equation:

Q=P×q×f……………………………………(3)

Where:
P = population
q = water demand per capita
f = domestic waste conversion factor

Rainfall Analysis

Rainfall analysis is conducted to determine the design rainfall used in calculating runoff discharge in the drainage system. Rainfall analysis is conducted using data from the nearest climatology station. The design rainfall is analyzed using probability distribution methods such as:

1. **Gumbel Distribution**

The Gumbel distribution is used to analyze extreme event data such as maximum rainfall.

$X_T = \bar{X} + K_T \times S$……………………………(4)

Description:
X_T = Design rainfall/discharge for the annual period.
$\bar{X}$ = Average daily rainfall/maximum discharge.
K_T = calculated based on the rainfall return period.
S = Standard deviation of the maximum rainfall data.
with the i $K_T$value calculated based on the rainfall return period.

2. **Log Pearson III**

The Log Pearson Type III distribution is a method widely used in hydrological analysis because it can better describe the characteristics of rainfall data.

$\log X_T = \overline{\log} X + K_T \times S_{\log}$………………(5)

Description:
$\log X_T$ = Logarithm of the planned rainfall/discharge value for the return period.
$S_{\log}$ = : Standard deviation (standard deviation) of the logarithmic value of the rainfall/discharge data.

K_T = Frequency factor that depends on the return period (T) and the skewness coefficient (C_S) of the data.

Runoff Analysis
Runoff discharge is calculated using the rational method:
Q=C×I×A……………………………………(7)

where:
Q = runoff discharge
C = runoff coefficient
I = rainfall intensity
A = catchment area

Sediment Volume Analysis
Sediment in drainage channels can originate from soil erosion, sand, debris, and mud. Sediment volume is calculated based on the sediment thickness measured in each channel segment.

$V_s = L \times B \times T_s$……………………………………(8)

where:
Vs = sediment volume
L = channel length
B = channel width
Ts = sediment thickness

Drainage Channel Capacity Analysis
The volume of the drainage channel is calculated using the equation:
V = L × B × H……………………………………(9)
The effective capacity of the channel is calculated by taking into account the sediment volume:
V_effective = V_channel - V_sediment………………(10)
This analysis is used to determine the reduction in channel capacity due to sedimentation.

Evapotranspiration Analysis
Evapotranspiration is the process of water loss from the land surface to the atmosphere, occurring through two mechanisms: evaporation from the soil surface and transpiration from plants. The amount of evapotranspiration is influenced by several climatic factors such as air temperature, solar radiation, air humidity, and the condition of vegetation in an area. Evapotranspiration is calculated using the Thornthwaite method.

$ET_0 = 16\left(\frac{10T}{I}\right)^a$……………………………………(11)

Note:
ET_0= potential evapotranspiration (mm/month)
T= average monthly temperature (°C)
I= annual heat index
a= empirical constant

Evapotranspiration values are used to understand the components of water loss in the hydrological system that can influence the amount of runoff in the study area.

RESULTS AND DISCUSSION

General Conditions of the Observation Location and Segments

The research location was a drainage canal along Jalan Kapten M. Jamil Lubis to Jalan Peringgan, Medan City. Based on the segmentation methodology, the canal was divided into seven observation segments with a relatively equal distance between segments, approximately 463 m. This division was intended to allow representative observations of the canal conditions along the entire study section. Channel width, depth, and sediment thickness were measured for each segment.

Observations showed that channel dimensions varied between segments. Segments 1 to 3 had smaller channel widths than segments 4 to 7. Sediment thickness was also found throughout all segments, indicating that sedimentation occurred diffusely along the canal. This indicates that the reduction in channel capacity is influenced not only by the initial geometric dimensions but also by the amount of sediment deposited on the canal bed.

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Tabel 2 . Dimensi saluran dan ketebalan sedimen tiap segmen

Segmen	Lokasi	Panjang (m)	Lebar, B (m)	Kedalaman, D (m)	Ketebalan sedimen, Ds (m)
1	Jl. Kapten M. Jamil Lubis	462	1,20	0,97	0,22
2	Jl. Kapten M. Jamil Lubis	462	1,13	0,90	0,25
3	Jl. Kapten M. Jamil Lubis	462	1,40	0,85	0,12
4	Jl. Peringgan	462	2,16	1,04	0,24
5	Jl. Peringgan	462	2,20	1,14	0,20
6	Jl. Peringgan	462	2,60	1,77	0,20
7	Jl. Peringgan	462	2,50	1,64	0,30

Population Projections and Their Implications for Domestic Wastewater Discharge

Tabel 3 . Data Penduduk

Tahun	Penduduk
2015	18.226
2016	18.241
2017	18.249
2018	18.396
2019	18.465
2020	19.171
2021	21.142
2022	21.022
2023	21.105
2024	21.254
2025	21.254

Source : Badan Pusat Statistik Kota Medan

Based on secondary data from 2015–2025, population projections were made using three methods: arithmetic, geometric, and exponential. The results are summarized in the following table:

Tabel 4.Proyeksi Jumlah Penduduk

Tahun	Aritmatika (jiwa)	Geometrik (jiwa)	Eksponensial (jiwa)
2027	21.860	21.917	21.918
2030	22.769	22.952	22.951
2035	24.284	24.788	24.784
2050	28.829	31.222	31.206
2125	51.554	98.959	98.807

The results show that the three methods yield relatively similar values in the short term (2–10 years), but differ significantly in the long term (25–100 years).

The arithmetic method produces linear growth, resulting in lower population growth. This is because it assumes constant annual population growth. According to research by Prasetyo et al. (2021), the arithmetic method is suitable for areas with stable growth and not experiencing high urbanization.

Conversely, the geometric and exponential methods show faster growth because they take into account compound growth factors. By 2125, the population using the geometric method nearly doubled compared to the arithmetic method. This aligns with a study by Sari & Nugroho (2022), which states that the geometric method is more representative of urban areas experiencing dynamic growth.

The exponential method produces nearly identical values to the geometric method. This shows that the population growth pattern at the research location tends to follow an exponential pattern, where growth is continuously influenced by birth, death, and migration factors (Rahman et al., 2023).

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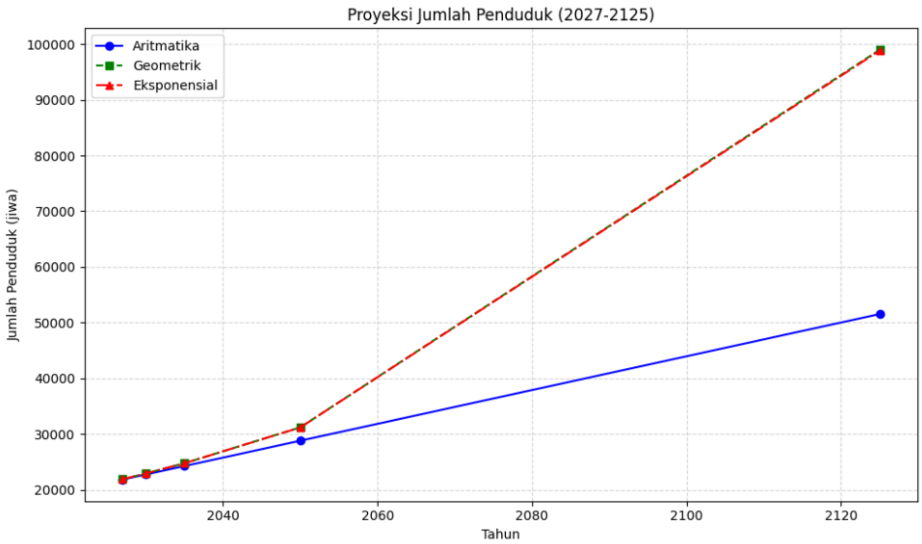

Figure 3. Grafik Proyeksi Jumlah Penduduk

Based on calculations of domestic wastewater discharge using the population projection method, a clean water requirement of 120 liters/person/day, and a waste factor of 0.8, domestic wastewater discharge increases significantly with population growth.

In 2027, with a population of 21,918, the domestic wastewater discharge will be 2,104,128 liters/day, equivalent to 2,104.128 m³/day. Furthermore, in 2030, the population will increase to 22,951, with a wastewater discharge of 2,203,296 liters/day, or 2,203,296 m³/day.

In 2035, the population will reach 24,784, producing a wastewater discharge of 2,379,264 liters/day, or 2,379,264 m³/day. Meanwhile, in 2050, the population will increase to 31,206, with a wastewater discharge of 2,995,776 liters/day, or 2,995.776 m³/day.

In the long-term projection for 2125, the population is estimated to reach 98,807, with a domestic wastewater discharge of 9,485,472 liters/day, or the equivalent of 9,485.472 m³/day.

These results indicate that domestic wastewater discharge is increasing consistently in line with population growth.

Tabel 5. Debit Limbah Cair Domestik

Tahun	Penduduk (jiwa)	Debit (L/hari)	Debit (m³/hari)
2027	21.918	2.104.128	2.104,128
2030	22.951	2.203.296	2.203,296
2035	24.784	2.379.264	2.379,264
2050	31.206	2.995.776	2.995,776
2125	98.807	9.485.472	9.485,472

The increase in domestic wastewater discharge in the study area demonstrates a strong relationship between population growth and the burden on the drainage system. A larger population means an increased need for clean water, which directly results in a larger volume of domestic wastewater.

This increasing wastewater discharge has the potential to put pressure on the capacity of the existing drainage system. Furthermore, based on field conditions, drainage channels have experienced significant sedimentation, reducing their effective capacity. If the increase in wastewater discharge is not matched by an increase in channel capacity, the risk of inundation and flooding will increase.

According to Rahman et al. (2023), increasing domestic wastewater discharge in urban areas without an adequate management system can lead to overloading of the drainage system, ultimately reducing the channel's hydraulic performance. Furthermore, research by Sari et al. (2021) states that discharging domestic waste directly into drainage channels accelerates sedimentation and blockages, reducing the channel's capacity.

Furthermore, Pratama and Wibowo (2022) explain that in areas with high population growth, drainage systems often double as wastewater channels, leading to a significant increase in flow load. This results in the channel being unable to accommodate the planned discharge, especially during heavy rainfall.

In addition to impacting drainage capacity, increased domestic waste also has the potential to cause environmental problems, such as water pollution and decreased sanitation quality. This is supported by research by Kurniawan et al. (2024), which states that increased untreated domestic wastewater can degrade residential environmental quality and increase the risk of public health problems.

Based on these results, integrated management efforts are needed to reduce the waste load on the drainage system, including through the construction of wastewater treatment systems (IPAL), separation of drainage systems and domestic waste, and regular channel maintenance to reduce sedimentation.

Rainfall Analysis

Tabel 6. Data curah hujan tahunan wilayah penelitian tahun 2013–2023

Tahun	Curah hujan (mm)	Banyaknya hari hujan
2013	2.799	225
2014	2.148	200
2015	2.803	189
2016	2.830	201
2017	3.190	243
2018	3.181	217
2019	3.301	227
2020	3.729	233
2021	3.205	196
2022	3.495	230
2023	3.424	241

Source: Stasiun Klimatologi Deli Serdang

Rainfall analysis was conducted using annual maximum rainfall data from 2013–2023 obtained from the nearest climatology station. The data was then analyzed using several probability distribution methods, namely the Gumbel method, Log Normal, and Log Pearson Type III, to determine the design rainfall for various return periods.

Based on the calculation results, the design rainfall values are as follows:

Tabel 7. Curah hujan rencana berdasarkan metode distribusi probabilitas

Periode Ulang (Tahun)	Gumbel (mm)	Log Normal (mm)	Log Pearson III (mm)
2	3.224	3.070	3.168
5	3.608	3.486	3.484
10	3.861	3.725	3.605
25	3.966	3.868	3.821
100	4.656	4.360	3.784

The analysis results show differences in the design rainfall values produced by each distribution method. The Gumbel method tends to produce higher values than the Log-Normal and Log-Pearson Type III methods, especially for long return periods. This is because the Gumbel distribution is designed to analyze extreme events, making it more sensitive to maximum values in the data.

Conversely, the Log-Normal and Log-Pearson Type III methods produce more moderate results because they take into account the asymmetrical data distribution and skewness. In many hydrological studies, the Log-Pearson Type III distribution is often considered more representative because it better describes the statistical characteristics of rainfall data.

According to Hidayat et al. (2021), the Gumbel method is very effective in analyzing extreme events such as maximum rainfall, but it tends to produce higher estimates, so it needs to be combined with other methods to obtain more realistic results. Furthermore, research by Saputra and Nugraha (2022) states that the Log-Pearson Type III distribution is the most commonly used method in hydrological planning because it can accommodate non-normal data variations.

In relation to drainage systems, high planned rainfall values will directly impact the amount of runoff that must be accommodated by the channel. If rainfall values are used using the Gumbel method, the planned discharge will be higher, thus requiring larger drainage channel dimensions.

This aligns with research by Prasetyo et al. (2023), which states that the choice of rainfall distribution method significantly influences drainage planning results, where higher rainfall values will increase the planned discharge and

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channel capacity requirements. Furthermore, Wicaksono et al. (2024) explain that errors in selecting rainfall distribution can lead to underdesign or overdesign of the drainage system.

Based on the analysis, the Log Pearson Type III method was deemed more appropriate for use in this study because it provides more stable results and takes into account the statistical characteristics of the data. However, the Gumbel method was still used as a comparison to assess potential extreme conditions.

Therefore, the obtained planned rainfall values must be used carefully in drainage capacity planning to ensure they can accommodate the maximum runoff discharge without causing flooding.

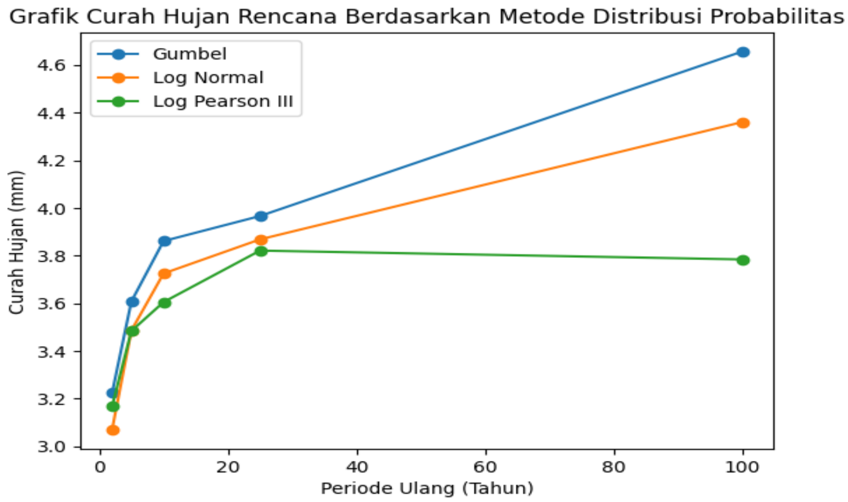

Figure 4. Grafik Curah Hujan Rencana terhadap Kala Ulang

Runoff Analysis

Based on the results of runoff discharge calculations using the rational method, the runoff discharge values for various rainfall return periods are as follows:

Tabel 8. Analisis Runoff

Kala Ulang (tahun)	Hujan Rencana Gumbel (mm)	Intensitas Hujan (mm/jam)	Debit Runoff (m³/det)
2	3224	134,33	0,171
5	3608	150,33	0,191
10	3861	160,88	0,204
25	3966	165,25	0,210
100	4656	194,00	0,246

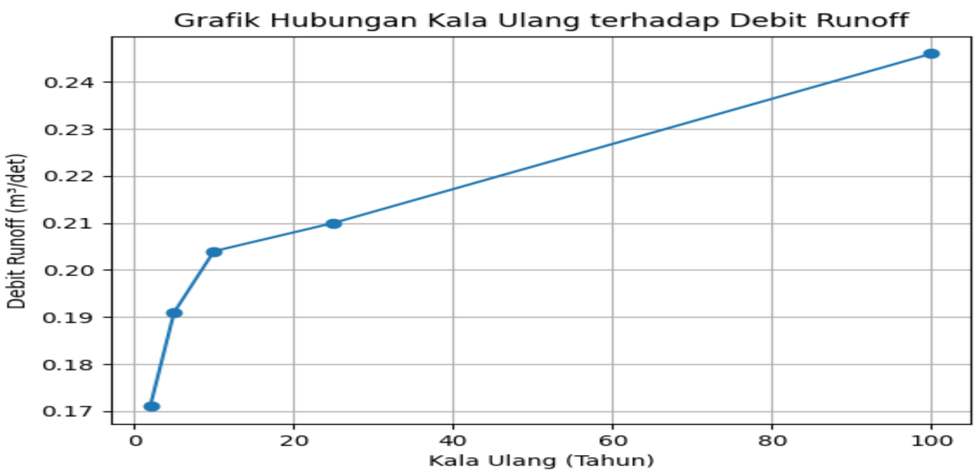

Figure 5. Grafik Debit Limpasan

The analysis results show that runoff discharge is significantly influenced by rainfall intensity and catchment area characteristics. The increase in runoff discharge from 0.171 m³/s (T = 2 years) to 0.246 m³/s (T = 100 years) represents a significant increase of approximately 43.8%, reflecting an increased potential for surface runoff during extreme rainfall conditions.

A runoff coefficient of 0.75 indicates that the study area has a high level of impermeability, allowing most rainwater to directly flow into surface water. This condition generally occurs in residential areas or urban areas dominated by hard surfaces such as roads and buildings.

According to Saputra et al. (2021), a high runoff coefficient value due to land-use changes will significantly increase runoff discharge and reduce water infiltration into the soil. This places a greater burden on the drainage system.

Furthermore, increased rainfall intensity with a longer return period also directly contributes to increased runoff discharge. This is consistent with research by Wibowo et al. (2023) stated that rainfall intensity is the most dominant parameter in the rational method, so increasing intensity will increase discharge linearly.

When associated with existing drainage conditions, this increase in runoff discharge is a critical factor in evaluating channel capacity. Based on field data, drainage channels experience significant sedimentation, resulting in a decrease in their effective capacity. This condition reduces the channel's ability to accommodate runoff discharge.

According to Kurniawan et al. (2024), the combination of high surface runoff and reduced channel capacity due to sedimentation is the primary cause of flooding in urban areas. Furthermore, Hidayat and Prakoso (2022) stated that drainage systems that are not adjusted to the design discharge are prone to failure during high-intensity rainfall events.

Thus, the results of the runoff analysis indicate that the drainage system in the study area needs to be increased in capacity to accommodate runoff discharge up to a certain return period (e.g., 10 or 25 years), thereby reducing the risk of flooding and inundation.

Sediment Volume Analysis

Based on field measurements of each drainage channel segment, sediment volume was calculated using the equation $V_S = L \times B \times T_S$. The parameters used included channel length, channel width, and sediment thickness in each segment.

The calculations showed sediment accumulation in all observed channel segments. Sediment volume varied depending on channel dimensions and the thickness of the sediment formed.

Tabel 9. Volume Sedimen

Segmen	Lokasi	Panjang (m)	Lebar (m)	Ketebalan Sedimen (m)	Volume Sedimen (m³)
1	Jl. Kapten M. Jamil Lubis	462	1.20	0.22	121.97
2	Jl. Kapten M. Jamil Lubis	462	1.13	0.25	130.52
3	Jl. Kapten M. Jamil Lubis	462	1.40	0.12	77.62
4	Jl. Peringgan	462	2.16	0.24	239.50
5	Jl. Peringgan	462	2.20	0.20	203.28
6	Jl. Peringgan	462	2.60	0.20	240.24
7	Jl. Peringgan	462	2.50	0.30	346.50
	Total				**1,359.63**

The results yielded a total sediment volume of approximately 693.00 m³. This value indicates significant sediment accumulation in the drainage channel.

The analysis revealed that sediment accumulation in the drainage channel was significant and distributed throughout each segment. The varying sediment thickness indicates a material deposition process influenced by flow velocity, channel conditions, and activity around the catchment area.

This sediment accumulation directly affects the channel's hydraulic capacity. The greater the volume of sediment deposited, the greater the channel's wet cross-sectional area, thereby reducing the channel's capacity to accommodate the flow rate. This condition can lead to overflows when the incoming flow exceeds the channel's capacity.

According to Kurniawan et al. (2022), sedimentation in urban drainage channels is a major factor contributing to reduced flow capacity and increasing the risk of flooding. Furthermore, research by Saputra and Hidayat (2021) suggests that sedimentation occurs due to low flow velocity and high solids content carried by surface runoff.

When compared to the results of previous runoff analyses, the increased runoff discharge that occurs during large return periods will increase the potential for sediment transport into the channel. However, when flow velocity decreases, the sediment will settle and cause channel silting.

This aligns with research by Prasetyo et al. (2023), which states that the combination of high surface runoff and sedimentation can accelerate the decline in drainage system performance. Furthermore, Wibowo et al. (2024) explain that without routine maintenance, sedimentation can reduce channel capacity by more than 30%.

Therefore, the condition of the drainage channels in the study area indicates the need for serious management, including:

• channel normalization (sediment dredging)
• routine maintenance
• controlling sediment sources from the catchment area
• increasing channel capacity
• These efforts are necessary to maintain drainage system performance so that it can accommodate the ever-increasing flow of runoff and domestic waste.

Drainage Channel Capacity Analysis

Channel capacity calculations were performed based on the existing channel dimensions using the channel volume equation $V = L \times B \times H$, as well as the effective capacity, taking into account sediment volume.

Based on field data, each channel segment is 462 m long, with a width of 1.2 m–2.50 m, and a channel height of 0.85 m–1.77 m.

Tabel 10. Kapasitas Saluran Drainase

Segmen	Volume Saluran (m^3)	Volume Sedimen (m^3)	Kapasitas Efektif (m^3)	Penurunan Kapasitas (%)
I	537.77	121.97	415.80	22.68
II	469.85	130.52	339.33	27.78
III	549.78	77.62	472.16	14.12
IV	1037.84	239.50	798.34	23.08
V	1158.70	203.28	955.42	17.54
VI	2126.12	240.24	1885.88	11.30
VII	1894.20	346.50	1547.70	18.29
	7774.26	**1359.63**	**6414.63**	**17.49 (rata-rata)**

The analysis results show that the drainage channel capacity has decreased significantly due to sedimentation. Based on calculations, the total channel volume of 7,774.26 m³ decreased to 6,414.63 m³, resulting in an average capacity decrease of 17.49%. This decrease indicates that sedimentation has a direct impact on the channel's effectiveness in conveying water flow.

Theoretically, drainage channel capacity is strongly influenced by geometric conditions and the presence of sediment within the channel. Accumulated sediment reduces the wetted cross-sectional area, thereby reducing the flow's ability to accommodate runoff (Putra et al., 2021). This is in line with the results of this study, which found that the greater the sediment volume, the greater the reduction in channel capacity.

Per segment, the largest capacity reduction occurred in Segment II (27.78%), followed by Segment IV (23.08%), and Segment I (22.68%). This indicates that segments with relatively small dimensions tend to be more susceptible to sedimentation. According to research by Siregar and Lubis (2022), channels with limited width and depth are highly sensitive to cross-sectional changes due to sedimentation, resulting in a more rapid reduction in capacity.

Conversely, segments with larger dimensions, such as Segment VI, showed a smaller capacity reduction of 11.30%. This indicates that channels with a large geometric capacity can still accommodate flow despite the presence of sediment. This finding is supported by research by Pratama et al. (2023), which states that channels with large dimensions have a smaller capacity reduction ratio due to the lower sediment volume relative to total capacity.

In addition to dimensional factors, high sedimentation is also influenced by environmental conditions around the canal. Based on the research locations on Jl. Kapten M. Jamil Lubis and Jl. Peringgan, the likely source of sediment is surface runoff carrying soil, garbage, and other solid particles. This aligns with research by Ramadhan et al. (2020), which states that urban areas with high activity levels tend to have higher sedimentation rates due to the contribution of domestic waste and surface erosion.

Furthermore, untreated sedimentation can cause a decrease in flow velocity and increase the potential for ponding. According to Hidayat et al. (2021), if the effective capacity of a canal is reduced by more than 15%, the risk of local flooding will increase significantly, especially during heavy rainfall. This condition is relevant to the research findings, which showed an average capacity reduction of 17.49%, indicating that some canal segments are already in suboptimal condition.

From an infrastructure management perspective, these results demonstrate the importance of routine canal maintenance activities, such as sediment dredging (normalization). Kurniawan et al. (2022) stated that regular maintenance can restore channel capacity to near its initial condition and reduce the risk of drainage system failure.

Thus, it can be concluded that sedimentation is the dominant factor causing the decline in drainage channel capacity at the study site. Without proper management, this condition has the potential to degrade the overall performance of the drainage system and increase the risk of flooding in the area.

Evapotranspiration Analysis

Tabel 11. Suhu Rata-Rata Bulanan Kota Medan

No.	Bulan	Suhu Rata-Rata (°C)
1	Januari	26,5
2	Februari	26,5
3	Maret	27,0
4	April	27,6
5	Mei	27,8
6	Juni	27,8
7	Juli	27,7
8	Agustus	27,8
9	September	27,7
10	Oktober	27,3
11	November	26,9
12	Desember	26,8

Source: Badan Pusat Statistik Kota Medan, *Rata-rata Suhu dan Kelembaban Udara Menurut Bulan di Kota Medan, 2015.*

Potential evapotranspiration (ET_0) was calculated using the Thornthwaite method based on average monthly temperature data for Medan City. The temperature data used ranged from 26.5°C to 27.8°C, indicating a tropical climate with relatively high temperatures throughout the year.

Based on the calculation of the annual heat index (I) and the empirical constant (a), the monthly evapotranspiration values are as follows:

Tabel 12. Evapotranspirasi Potensial (ET_0)

No	Bulan	Suhu (°C)	ET_0 (mm/bulan)
1	Januari	26,5	142,3
2	Februari	26,5	142,3
3	Maret	27,0	147,8
4	April	27,6	154,6
5	Mei	27,8	156,9
6	Juni	27,8	156,9
7	Juli	27,7	155,8
8	Agustus	27,8	156,9
9	September	27,7	155,8
10	Oktober	27,6	154,6
11	November	27,0	147,8
12	Desember	26,7	144,5

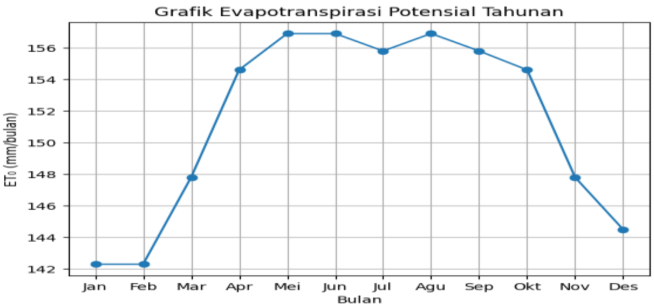

Figure 6. Grafik Evapotranspirasi Potensial Tahunan

The analysis results show that potential evapotranspiration in the study area is high and relatively stable throughout the year. This is due to the tropical climate, with temperatures that do not fluctuate significantly.

Evapotranspiration is a crucial component of the hydrological cycle because it plays a role in water loss from the soil surface and vegetation. A high ET_0 value indicates that some of the rainfall returns to the atmosphere, thereby reducing the amount of water that becomes surface runoff.

According to Hidayat et al. (2021), evapotranspiration has a direct impact on the water balance, where the higher the evapotranspiration value, the lower the potential runoff. This indicates that evapotranspiration can function as a factor in reducing runoff discharge.

However, in urban areas or areas with a high level of impermeability, the effect of evapotranspiration on reducing runoff is relatively small. This is due to the reduction in vegetation, which plays a role in the evapotranspiration process. Saputra and Nugroho (2022) stated that land use changes from vegetation to impermeable surfaces can reduce the contribution of evapotranspiration to the hydrological cycle.

In relation to the results of previous runoff analyses, despite relatively high evapotranspiration, the high runoff coefficient ($C = 0.75$) indicates that most of the rainwater remains as surface flow. This indicates that the effect of evapotranspiration on reducing runoff discharge in the study area is not significant.

Furthermore, Kurniawan et al. (2023) explain that in urban areas, the dominant factors influencing runoff discharge are rainfall intensity and land surface conditions, while evapotranspiration plays a secondary role.

Thus, although evapotranspiration contributes to reducing water volume in the hydrological system, its impact on the drainage system in the study area is relatively small compared to factors such as rainfall, runoff, and channel capacity.

CONCLUSION AND SUGGESTIONS

Hydrological analysis shows that runoff discharge increases with increasing rainfall return periods, from 0.171 m^3/s at a 2-year return period to 0.246 m^3/s at a 100-year return period. This increase indicates that the drainage channels will have to accommodate a greater load, especially during extreme rainfall events. Conversely, the sedimentation of the channels reduces their capacity, increasing the potential for flooding.

Furthermore, population growth projections indicate a significant long-term increase in population, which will lead to increased domestic wastewater discharge. This further increases the burden on the drainage system, especially since the channels also serve as a means of disposing of domestic waste.

Overall, it can be concluded that the combination of sedimentation, increased runoff discharge, and growing domestic waste load has led to a decline in drainage system performance. If not properly addressed, this condition has the potential to increase the risk of inundation and even flooding in the study area, especially during periods of medium to high rainfall.

Based on the research findings, integrated management efforts are needed to improve the performance of the drainage system at the study site. Routine drainage channel maintenance through normalization or sediment dredging is essential to restore channel capacity to its original condition. Furthermore, regular waste removal is crucial to prevent blockages that could exacerbate the decline in channel capacity.

In the medium term, an evaluation of the dimensions of existing drainage channels is necessary, especially in segments experiencing the greatest decline in capacity. If the channel capacity is no longer sufficient to accommodate the planned discharge, efforts to increase capacity by widening or deepening the channel are necessary.

In the long term, more comprehensive drainage system planning is needed, taking into account the increase in runoff due to land use changes and population growth. Implementing sustainable drainage systems, such as the construction of infiltration wells, retention ponds, and green open spaces, can be a solution to reduce surface runoff.

Furthermore, separation of the drainage system and the domestic waste disposal system is necessary to reduce channel load and prevent accelerated sedimentation. The construction of a wastewater treatment plant (WWTP) is also a crucial step in reducing pollution and maintaining drainage system performance.

With integrated maintenance, capacity building, and management efforts, it is hoped that the drainage system at the research location can function optimally in the short and long term, so that the risk of inundation and flooding can be minimized.

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