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Evaluation of an Urban Drainage System in a Big City

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ABSTRACT

Population growth has led to increased runoff and wastewater flowing into drainage channels. This study, therefore, aims to evaluate the drainage capacity of selected channels in Medan City and whether they can still serve the community in the next 10, 20 and 30 years. The observed channel starts from Taduan Street No. 1 to Taduan Street No. 153, with a length of 1,000 m. This evaluation considers population growth, the volume of domestic wastewater, the volume of runoff, the generation of sediment in channels, and evapotranspiration as part of the water cycle. Monthly maximum rainfall data from 2012-2021 from the BMKG Sampali Medan and population data along Taduan are used in the review in this article. Based on the investigation, it is known that the volume of drainage on Taduan Street is no longer able to serve the community even for 2032. It is necessary to review and redesign the dimensions to ensure that wastewater from household activities and runoff does not have a negative impact, especially during the rainy season. With as many as 48 injection wells and the Watershed expansion, it is expected to reduce inundation.

1. INTRODUCTION

With a total land area of 265 km^2, Medan City is the third-largest metropolitan region in Indonesia (Khair *et al*., 2019). It has a population of 2.4 million. Transmigration and urbanization have caused the city to expand quickly in the previous ten years (Pasaribu *et al*., 2022). According to data from 2010, Medan City's population expanded by almost 340 thousand individuals, or roughly 15-20 thousand more people each year (BPS, 2022). According to population forecasts, the preceding number will likely increase through the year 2030. Compared to Indonesia's average population density of only 161 persons per

km^2, the population density of $9{,}000/km^2$ is unusually high. Out of the twenty-one districts in Medan City, Medan Tembung has the sixth highest population in terms of area, with more than 146 thousand residents in 2020. The success rate of regional management in Medan City is influenced by its location in the city center. Contrarily, these facts create brand-new issues that haven't yet been fully resolved. A shift in the natural hydrological cycle brought on by the large reduction in catchment areas brought on by the growth of domestic land has disrupted the settlement drainage system (Carstensen *et al*., 2020; Giambastiani *et al*., 2020).

In an era of increasingly pervasive environmental concerns and destruction, drainage channels are fundamentally built as an effort to respond to environmental problems (Rubinato *et al*., 2019). Urban infrastructure must have a sufficient and integrated drainage system, which must also be managed carefully. Most Indonesian cities, including Medan City, have drainage systems that are only intended to direct rainfall (runoff) as soon as possible to the nearest water body, like a river (Saraswat *et al*., 2016; Akhter *et al*., 2020). Urban drainage fills up faster because of the massive amount of water gathered at one location. In contrast, due to erosion and sedimentation, the drainage capacity is extremely constrained and tends to keep declining. Every time it rains, Taduan Street in Medan Tembung, Medan City, frequently floods. Every year, because of the accumulation of household garbage in the drainage channels, floods of up to 20 to 80 cm occur (Prayogo *et al*., 2023). Eventually, the waterway was unable to dispose of runoff water effectively. According to records from 2022, the flood disaster in Medan City flooded 56 sub-districts, affecting 4,306 houses (Dara, 2022). The biggest floods not only caused enormous financial losses totaling Rp. 26 billion but also the deaths of dozens of cattle and three residents (Wismabrata, 2020). This amount does not include damage to structure and public infrastructure.

This study highlights the importance of evaluating the drainage channels on Taduan Street for the next 30 years to determine whether the existing drainage volume can accommodate runoff and domestic wastewater. In this study, researchers used four commonly used methods to calculate projected population growth to identify evapotranspiration factors that affect the water volume reduction in the channels. Several similar studies on the evaluation of urban drainage systems have been conducted by (Suryaman, 2013), (Fairizi, 2015), and (Wulandari *et al*., 2022) but are limited to only considering runoff which causes inundation in residential areas in Palembang City; (Dwijaya, 2018) and (Budiman *et al*., 2021) only predict flood discharge with a return period of no more than 10 years; (Dewi et al., 2014)] studied the discharge of runoff entering urban drainage channels in the Purwokerto area but not for predicting specific return events. The methods used by previous researchers were felt to be less comprehensive, while others used a flood modeling system (Rabori & Ghazavi, 2018; Remesan *et al*., 2021). To the best of the author's knowledge, there still needs to be more articles discussing comprehensive urban drainage evaluations that consider runoff and domestic wastewater with projections up to the next 30 years. For completely, Table 1 shows the conditions of previous studies regarding evaluating drainage channels in various regions in Indonesia and shows the differences of location, area, analysis (rainwater/wastewater), total data, method, projection, result, compare with this study.

Table 1. Previous research of urban drainage evaluation in Indonesia

No	Study Location	Area (km)	Consideration		Data (year)	Method	Projection (year)	Drainage status	Reference
			Rainwater	Wastewater					
1	Ponorogo District	2.055	✓	X	10	Rational	25	X	(Suryaman, 2013)
2	Solo Sragen Street	-	✓	X	8	Rational	Same year	X	(Dewi *et al.*, 2014)
3	Talang Kelapa Residence	$4,2 \times 10^{-4}$	✓	X	10	Rational	Same year	X	(Fairizi, 2015)
4	Soekarno Hatta Residence	3.5×10^{-4}	✓	X	10	Rational	5	X	(Widodo & Ningrum, 2015)
5	Sariharjo Village	-	✓	X	10	Rational	5	X	(Sulistiono & Ardiyanto, 2016)
6	Nanga Bulik	6,4	✓	X	11	Rational	5	X	(Dwijaya, 2018)
7	Sukomanunggal	-	✓	X	-	Rational	10	X	(Budiman *et al.*, 2021)
8	Lowokwaru	22.6	✓	X	10	Rational	5	X	(Wulandari *et al.*, 2022)
9	Tuamang Road	1	✓	✓	10	Rational	10, 20, 30	X	(Pasaribu *et al.*, 2022)
10	Tanjungpura University	2.4×10^{-5}	✓	X	10	Rational	5	X	(Januardi *et al.*, 2022)
11	Lueng Street	8.4×10^{-2}	✓	X	10	Rational	10, 20, 30	X	(Safriani *et al.*, 2022)
12	Taud Street	1	✓	✓	10	Rational	10, 25, 50	X	(Pasaribu, 2023)

Note: X = not working

2. MATERIALS AND METHODS

2.1. Data Collection Technique

Following the collection of population and rainfall data for the previous ten years, drainage dimension measurement, population projection, hydrological analysis accounting for wastewater discharge from domestic activities, ten return period runoff, 10, 20, and 30 years, as well as the impact of evapotranspiration and infiltration, and drainage channel evaluation were all performed on the chosen channels (Figure 1). The amount of effluent that may be accommodated is determined using the current drainage dimensions. Based on the discrepancy between the projected drainage volume and the sediment volume, the dimensions of the existing drainage are established.

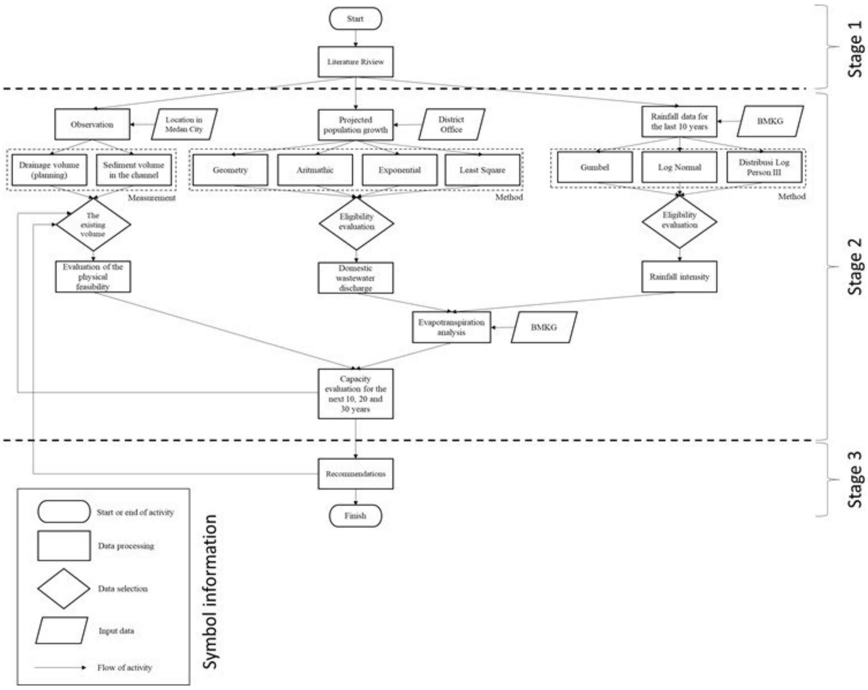

Figure 1. General description of the research procedure

Based on measurements taken at ten separate locations that were each 100 m apart, this study calculated the design drainage dimensions and sediment volume. Secondary data from the Medan Tembung Office and BMKG Class I Climatological

Station-Deli Serdang were used to compile the population and rainfall. In this study, researchers did not project the channel's increase/decrease in sediment. Sediments are considered the same in every possible increment of time due to normalization efforts by residents. Sediments are measured at ten different points to get values representatively.

An in-depth study of each section uses literature, mostly Indonesian studies from local journals. Studies that previous researchers regarding drainage evaluation have carried out are like what we did very limited, especially those who published their research results in reputable journals. Even though most of the references that we use are not from reputable journals, but by using research that has been conducted in Indonesia with site characteristics that are almost like what we did, it is hoped that this can help us in analyzing more deeply.

2.2. Overview of Research Locations

The study site (Figure 2) is a drainage channel on Taduan Street in Medan City, North Sumatra, with a total observed channel length of 1,000 m, extending from Taduan Street No. 1 (3° 36' 22.1688'' N 98° 41' 43.008'' E) to Taduan Street No. 153 (3° 36' 20.2572'' N 98° 42' 23.7816'' E). Almost the whole area of this heavily populated neighborhood is made up of pavement and built-up land. This region is strategically located since it is close to a higher education complex that includes Universitas Negeri Medan, Universitas Islam Negeri Sumatera Utara, and Universitas Medan Area. It is on the border of Medan City and Deli Serdang Regency. According to estimates, many students will reside in boarding houses, apartment buildings, and a variety of commercial settings, including cafes and places of worship. The lack of public awareness to manage their waste and unavailable facilities causes the waste to flow directly into the drainage without being treated.

Figure 2. Site map: Taduan street, Medan City

2.3. Data Analysis Technique

2.3.1. Population Projection

When calculating the potential amount of wastewater production that could enter the drainage system, the population size is considered. Based on the number of people in the current year multiplied by the projected wastewater output per person per day, the total amount of domestic wastewater is determined. After comparing each approach, population estimates are used to obtain projections that are most accurate for the features of the area being examined. The geometric (equation (1)), arithmetic (equation (2)), exponential (equation (3)), and least square (equation (4)) have been selected to project population growth. Here, n is the number of intervals with the base year, P_n is the projected population for the nth year, P_0 is the population data for the base year, r is the population growth rate, and e is the exponential number 2.7182812. With the use of calculated a and b constants, the least square approach employs the Y_n variable to describe the population in the projected year. The population in the n^{th} year will always fluctuate, hence an equation must be developed to calculate the value of r, which represents the population growth rate of each technique over a certain period. The population growth rate equation using the geometric is given the equation (5), the arithmetic is given by the equation (6), the exponential method is given by the equation (7), and the least square method is given by the equation (8) for a calculation and (9) for b calculation. The difference (value) between the base year and the desired n-year is described by the t variable in this equation. The base year serial number and the nth year population are represented by the X and Y variable, respectively.

$$P_n = P_0(1 + r)^n \quad (1)$$

$$P_n = P_0(1 + r_n) \quad (2)$$

$$P_n = P_0.(e^{rn}) \quad (3)$$

$$Y_n = a + b(x) \quad (4)$$

$$r = \frac{(\frac{P_n}{P_0})^{\frac{1}{t}}}{t} - 1 \quad (5)$$

$$r = \frac{(\frac{P_n}{P_0}) - 1}{t} \quad (6)$$

$$r = \frac{\{\ln\left(\frac{P_n}{P_0}\right)\}}{t} \quad (7)$$

$$a = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{n(\Sigma X^2) - (\Sigma X)^2} \quad (8)$$

$$b = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{n(\Sigma X^2) - (\Sigma X)^2} \quad (9)$$

2.3.2. Hydrological Analysis

To determine the total volume of water flowing and filling the drainage canal space. The analysis starts from the frequency of rainfall, determining the value of rainfall intensity, to distinguish between runoff on drainage and calculation of domestic wastewater. The frequency of rainfall is determined by comparing three methods, namely Gumbel, normal log, and Pearson type III log. Calculating rainfall in the t-year anniversary period (X_t) with the Gumbel method is determined using the equation (10). Or is the average value of maximum rainfall, K is the frequency factor, and S_x is the standard deviation. S_x is determined using the equation (11). Where X_i is the average rainfall value, X_r is the average maximum rainfall value, and *n* is the amount of data. The value of *K* is determined using the equation (12). Y_t is the reduced variate, Y_n is the average reduced variate price, and S_n is the reduced standard deviation. To be selected as the appropriate distribution method in calculating the planned rainfall with the t-year anniversary period, the value of $C_s \leq 1.1396$ and $C_k \leq 5.4002$. The normal log distribution is the result of a transformation from the normal distribution, namely by changing the value of the *X* variable to the logarithmic value of the *X* variable. Calculation of rainfall (R_t) using the Normal Log method is determined using the equation (13) Where X_r is the rainfall value is the mean, K_t is the variable standard for the birthday period, and S_x is for the standard deviation. To be selected as an appropriate distribution method for calculating planned rainfall with a *t*-year return period, the value of $C_s \approx 3$, $C_v + C_{v2} = 3$, and $C_k \approx 5.383$. Pearson log type III will be a normal log distribution if the slope coefficient $C_s = 0.00$. Calculation of rainfall using the Pearson log type III method is determined using the equation (14). To be selected as the appropriate distribution method for calculating planned rainfall with a return period of t years, the value of $C_s \neq C_v$.

The method used in analyzing the amount of rainfall intensity is the Mononobe method (equation (15)). Where *I* is the rainfall intensity (mm/h), *R* is the design rainfall (mm), and *t* is the duration of rain (h). The planned rainfall discharge is determined using the rational method because this method follows the conditions of the drainage area, which is a manageable size, and the rainfall is considered uniform. The rational method has an equation (16). Where 0.0278 is the correction factor, *C* is the runoff coefficient ($0 \leq C \leq 1$), I is the rain intensity (mm/h), and *A* is the channel area (m^2). Domestic wastewater discharge is the waste from household activities channeled into drainage channels. The amount is determined by the number of people living in the area. SNI 6728.1:2015 stipulates that the estimated daily consumption of clean water for metropolitan areas with a population of more than 1,000,000 is 150-200 L/person. At the same time, the wastewater produced is around 80% clean water.

$$X_t = X_r + (K.S_x) \tag{10}$$

$$S_x = \frac{\sqrt{(X_i - X_r)^2}}{n-1} \tag{11}$$

$$K = \frac{Y_t - Y_n}{S_n} \tag{12}$$

$$R_t = X_r + (K_t.S_x) \tag{13}$$

$$\log R_t = \log X + G_t.S \log X \tag{14}$$

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \tag{15}$$

$$Q_{ch} = 0.278\ C.I.A \tag{16}$$

3. RESULTS AND DISCUSSIONS

3.1 Existing Drainage Volume

With an average air temperature of 27 °C, a humidity of 83%, an average wind speed of 0.96 m/s, and an average monthly total evaporation rate of 115.85 mm, Medan City has a tropical climate. The city area is 2.5–37.5 m above sea level and faces north.

Medan City is extremely vulnerable to flooding during the rainy season due to its location in the lowlands and the numerous basins in the nearby areas, especially if the drainage system is not working effectively. The region chosen for this study is Taduan Street, one of the areas of the city that is urbanizing the fastest. The findings of viewing the drainage channel's location on Taduan Street yielded information on the size of the existing drainage, which is shown in Table 2. It is known that the 1,000 m long channel, which serves as the observation location, has an average width of 1.11 m and a depth of 1.07 m. It is possible to determine the drainage volume used in the city's initial planning, which is 1,188 m^3. Table 2 shows the characteristics of the location and condition of the channel upstream and downstream at this study which were generally closed by residents to reduce odors and the spread of mosquitoes. The road that became the study location is an area that often experiences inundation compared to other locations in Medan City. Even though it is a small street because of its short size, the population is very dense.

Residents' homes are connected to the drainage channel on Taduan Street by a tertiary channel that is 0.20-0.30 m wide and 0.15-0.25 m deep. This bigger dimension collects all runoff and wastewater in the region and transports it. Every day of the year, residents in practically every home create little channels to drain wastewater from bathing, washing, cooking, and various other comparable activities. Taduan Street frequently has puddles of 30–50 cm due to the relatively level (0–8%) and steep (8–15%) slopes in Medan City during periods of intense rain lasting 2-4 hours.

Table 2. Drainage dimensions at upstream and downstream points

Location	Channel Wide l (m)	Channel Depth D (m)	Sediment Depth D_s (m)	Visualization
Upper Point: Taduan Street No. 1 (3° 36' 22.1688'' N 98° 41' 43.008'' E)	1.15	1.20	0.19	 
Downstream Point: Taduan Street No. 153 (3° 36' 20.2572'' N 98° 42' 23.7816'' E)	1.18	1.20	0.24	 

The channel used for this investigation is a secondary type of channel, whose capacity is unquestionably higher than that of a tertiary channel. According to field research, Taduan Street's planned drainage volume ($Q_{planning}$) is 1,188 m^3. (Suryaman, 2013) investigated channels in Ponorogo and obtained channel data in community settlements with an average volume of 1,150 m^3, (Kencana *et al*., 2021) obtained $Q_{planning}$ of secondary channels in Singosari-Malang with a volume of 959 m^3, (Fairizi, 2015) obtained the highest data on channels in the Talang Kelapa-Palembang resident area with a volume of 1,320 m^3, and The drainage channel on Taduan Street has a size that is not significantly different when compared to other Indonesian cities with features similar to Medan City. However, the total number of individuals served at the earlier research sites did not exceed 277. The community's economic level, which in this location is the intermediate economic level, may be considered while planning drainage systems. It is predicted that individuals in this category won't produce more than 150 L of sewage/day. While circumstances in Indonesia are typically favorable, sedimentation causes the drainage volume to gradually diminish (Figure 3).

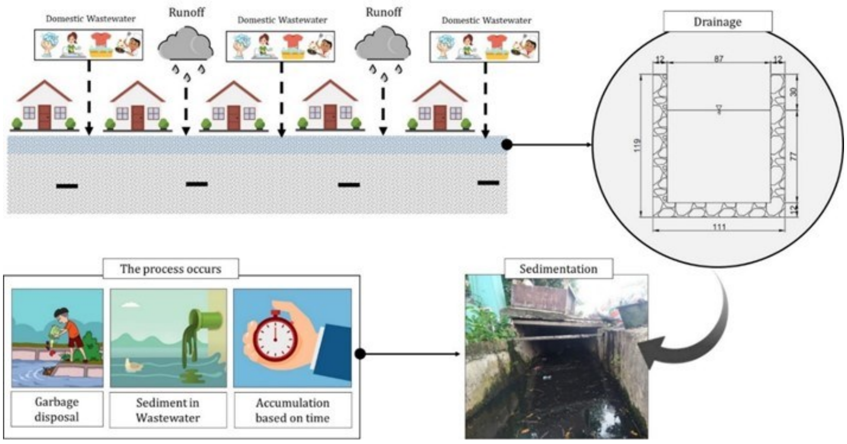

Figure 3. Site condition

Following an assessment of the study's chosen waterway, sediment was discovered there with various thicknesses. Sedimentary material particles typically resemble rock in both their chemical and physical makeup. The sizes and forms of these particles range from very large (boulders) to very microscopic (colloids). Typically, measurements of sediment are only dependent on the type of silt and other contaminants that assemble at the channel bottom. The drainage system in this study has 595.95 m^3 of sediment, according to measurements taken at 10 random locations while taking the amount of silt into account. When compared to the findings of the study by (Wijaya *et al*., 2022), who collected 425 m^3 of sediment from 500 m of drainage ditches on the Tano-Sumbawa Cross Road, this volume is substantial. Other sites, as on Jalan Srikoyo in Jember, measured sediment generation at 746 m^3 at a channel length three times that of this study (Romadhoni, 2016). The materials used by the community for domestic wastewater disposal, the type of soil at the study site, the rate of runoff flow, and the length of time the formation process took all point to numerous potential causes for the substantial amount of sediment that settles at the bottom of the drainage channel (Prayogo *et al*., 2020; 2022). Although this study does not specifically address this issue, it is projected that water flow velocity, particularly during the rainy season, causes silt transfer to be dispersed uniformly along the channel.

When compared to waterways in other regions, the average findings of measuring sediment volume are higher because of this. No area of the channel was affected, according to observations of the drainage conditions. Based on Table 1, with channel length of 1000 m, the current drainage volume is 592.05 m^3 based on the findings of the average data measurement of the actual drainage volume and sediment volume.

3.2 Population Growth

Data from the Sidorejo Village Office indicates that there are 50 dwellings on Taduan Street's left side, with an assumed population of 4-6 people. Even though the research location is in a city, it is on the edge of another district, therefore it is also significantly impacted by other adjacent places. When compared to other cities, particularly those on the Java Island like Jakarta, Malang, and Bogor, where only 3–4 people live in each house. Medan is significantly different, particularly influenced by regional conditions and culture. It is anticipated that there will be 277 people living in 2021. Table 3 provides an illustration of method validation for projections' viability. Figure 4 displays the outcomes of population forecasts for the upcoming 10, 20, and 30 years using geometric, exponential, arithmetic, and least square. The viability of the procedure is assessed using standard values. The correlation value is near to 1.00, while the deviation is almost equal to 0.00.

Table 3. Determination of the method for population growth projection

No.	Year	Population	Growth Rate								
			Arithmetic		Geometry		Exponential		Least Square		
			r	P	r	P	r	P	a	b	Y
1	2012	253	1.05%	253	1.01%	253	1.01 %	253	250	-1.10	175
2	2013	255		256		256		256			176
3	2014	258		258		258		258			177
4	2015	261		261		261		261			178
5	2016	264		264		263		263			179
6	2017	266		266		266		266			180
7	2018	269		269		269		269			181
8	2019	272		272		271		271			182
9	2020	274		274		274		274			183
10	2021	277		277		277		277			184
Deviation Standard				8.0737		8.0736		8.0736			3.3001
Correlation				0.9993		0.9991		0.9991			0.9993

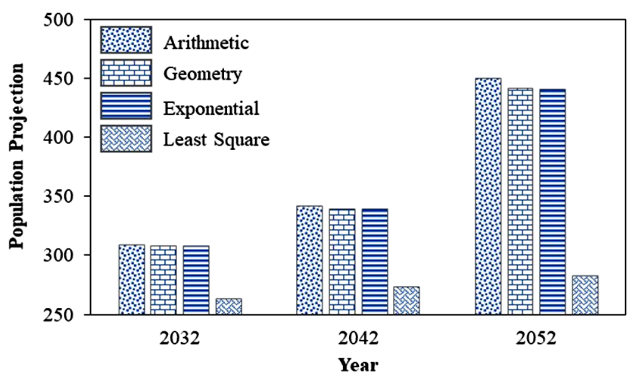

Figure 4. Population in 10, 20, and 30 years in the future

3.3. Domestic Wastewater

Residents' homes were classified as medium-type residences with type I based on observations made at the study site. The amount of drinking water utilized for this sort of construction was based on the table of clean water demands, which (Sutjahjo *et al.*, 2011) determined to be 150 L/person/day. Domestic wastewater finally turns into 80% of the total amount of clean water needed to be consumed, after which it is sent into drainage channels. Along with the population, the economic status (income) of people and the kinds of daily activities that demand clean water have a significant impact on the volume of water discharge. From bathing, washing, cooking, and other comparable activities, a person with a high income typically produces more wastewater than a person with a low income. The expected discharge of domestic wastewater for those living on Taduan Street in the ensuing 10, 20, and 30 years is shown in Table 4. The peak factor (f_{Peak}=2.4) is considered by (Pratiwi & Purwanti, 2015) when computing the total wastewater discharge (Q_{Total}). In this study shows 182.40 x 10-2 L/person/s for 2032, 201.88 x 10-2 L/person/s for 2042, and 265.63 x 10-2 L/person/s for 2052 are the total wastewater discharges from residential, like wastewater bath, wash and kitchen. For the base year, the estimated discharge is 163.51 x 10-2 L/person/s.

Table 4. Production of domestic wastewater in 10, 20, and 30 years in the future

Period (Year)	Year	Population (person)	$Q_{WaterNeeds}$ (L/person/day)	$Q_{Wastewater}$ (L/s)	Q_{peak} (L/s)	Q_{Total} (L/s)
0	2021	277	150	48.09 x 10^{-2}	115.42 x 10^{-2}	163.51 x 10^{-2}
10	2032	309		53.65 x 10^{-2}	128.75 x 10^{-2}	182.40 x 10^{-2}
20	2042	342		59.38 x 10^{-2}	142.50 x 10^{-2}	201.88 x 10^{-2}
30	2052	450		78.13 x 10^{-2}	187.50 x 10^{-2}	x 10^{-2}

3.4. Rainfall Intensity

The Sampali Climatology Station-Medan City provided the rainfall data for the most recent ten years, from 2012 to 2021. The research site is the nearest station to this one. Based on rainfall statistics, the maximum measurement was 165 mm, which was obtained in December 2014. Using the Mononobe method (equation 15), computations are made to determine the intensity of the rain. The greatest rain intensity is 3.73 mm/min according to the data and formulae presented. The Pearson log type III test was used as the design rainfall chi-square test for the return period (Table 5). According to the calculation, the average rainfall statistical characteristics for the years 2032, 2042, and 2052 are 64.91 mm/hour, 66.72 mm/hour, and 72.46 mm/hour, respectively, with a coefficient of skewness (C_s) of -7.11 and a coefficient of variation (C_k) of 0.05. Due to the values of $C_s < C_v$ dan C_v = 0.3, this approach satisfies the criteria to be chosen as a distribution method for estimating anticipated rainfall.

The difficulty with the technique selection is that the population data is too sparse; as a result, Table 2's projection results from one way to another are comparable. The standard deviation values and finite correlations in 10^{-6} must be identified, aside from the somewhat altered *r* values. The Least Square does not appear to be utilized to match the estimated data from growth fluctuations with a small number of values. This might apply to data sets containing a lot of information, like those from bigger study sites or denser populations. The projection results on the primary data do not demonstrate accuracy, even though the standard deviation is the lowest compared to the other three methods and the correlation shows a value close to 1.00. As a result, this case study employs Arithmetic, which has the most data of the four methods. The largest population predictions are 309, 342, 450 persons according to Table 3 population projections for the next 10, 20 and 30 years. This quantity serves as the benchmark for calculating the volume of domestic wastewater generated by bathing, washing, and cooking activities that is subsequently piped into the Taduan Street drainage channel. Figure 5 shows the highest rainfall intensity obtained from data for the next 10, 20, 30 years in Taduan Street.

Table 5. Planned flood debit against drainage capacity

Period	R_t (mm)					
	Gumbel		Normal Log		Log Pearson Type III	
10	86,80	C_s = -7,11	80.19	C_s = -7,11	84.14	C_s = -7,11
20	91,89	C_k = 340,79	87.26	C_v = 0,05	85.18	C_v = 0,05
30	93,74		91.53		85.50	
Result	Does not meet standards		Does not meet standards		Meet the standards	

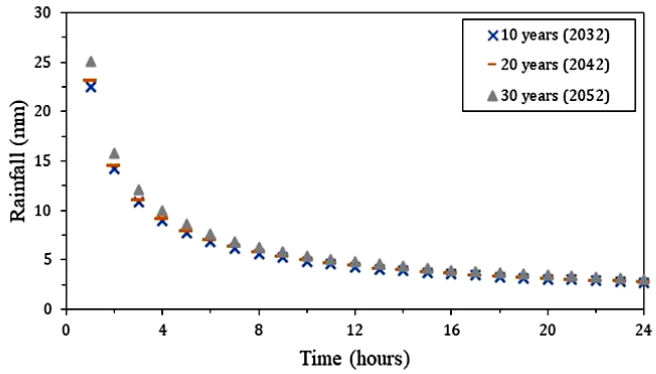

Figure 5. Rainfall for the next 10, 20 and 30 year

The Mononobe can gather data quickly (within 1-2 hours); the results are shown in Table 2. Figure 3 displays the highest rainfall intensity during the following ten years, with values from 5.87 mm/h in 2032 to 6.04 mm/h in 2042 to 6.56 mm/h in 2052. Numerous academics have looked at rainfall intensity due to the regular occurrence of rain-related issues in Medan City. (Aqsha & Harahap, 2022) obtained a result of 415.91 mm/h in 2020; (Andrian & Ningsih, 2014) obtained a rainfall intensity of 249.4 mm/h in 2017, and (Sibagariang & Saputra, 2021) obtained figures of 44.62 mm/h in 2024 and 44.79 mm/h in 2039. These results can be compared to the results in this article. Numerous studies have produced various anticipated rainfall intensity findings for Medan City. Depending on the study's precise location, it may impact the observation station and the rainfall data used to do the computation. Since each method's sensitivity to another varies, the projection method may produce varied computation results when employed with other methods. Table 6 compares the forecasts of rain intensity from several earlier researchers who chose Medan City as their study area to know about the environmental disaster related with rainfall or domestic wastewater in urban areas.

3.5. Evapotranspiration and Infiltration

To calculate water balance, evapotranspiration is highly helpful. The phrase "evapotranspiration" is created by combining the terms "evaporation" and "transpiration," which describe how water is lost from plants and the soil, respectively. To calculate evapotranspiration (*ET*), the Thornthwaite equation was used:

$$ET_0\ ((Tm < 26.5\ °C) = 1.6(10t/I)^a \quad (17)$$

Table 6. Rainfall intensity values for Medan City

Location	Method	Rainfall Intensity (mm/h)		Reference
		Average	Maximum	
Medan Tembung (2015)	Log pearson type III	561.90	712.20	(Andrian & Ningsih, 2014)
Medan Helvetia (2016)	Mononobe	-	13,80	(Sinaga & Harahap, 2016)
Medan City (2017)	Backpropagation	170.02	255.70	(Zevri, 2017)
Deli River Basin (2019)	Gumbel	-	118.23	(Lukman, 2018)
Medan Tembung (2020)	Mononobe	113.33	415.91	(Zevri, 2019)
Sei Sikambing River (2021)	Log pearson type III	-	89.28	(Sibagariang & Saputra, 2021)
Medan Tembung (2021)	Mononobe	124.40	124.00	(Pasaribu *et al.*, 2022)
Medan Baru (2023)	Mononobe	-	14.2	(Safriani *et al.*, 2022)
Medan Tembung (2032)	Mononobe	-	64.91	(Pasaribu, 2023)

where Tm is the average temperature for the m^{th} month, ET is the monthly potential evapotranspiration, I is the annual heat index, and a is a constant. The drainage conditions, including the building material, significantly impact the process of water infiltration in the drainage system. This study used concrete to construct the drainage system, including the base and channel walls. As a result, water infiltration into the soil is thought to be nonexistent. Drainage to lower locations causes more water loss. The National Oceanic and Atmospheric Administration (NOAA) provided the data on Medan City's monthly average temperature (Table 7).

Table 7. Evapotranspiration analysis

Period (2022)	T_m (°C)	I (mm/h)	ET (cm)	T_m (°C)	I (mm/h)	ET (cm)	T_m (°C)
Jan	31	12.56	18.44	Jul	32	11.99	20.01
Feb	32	12.92	19.08	Agt	32	12.06	19.94
Mar	32	12.7	19.3	Sep	31	12.35	18.65
Apr	32	13.07	18.93	Oct	31	12.63	18.37
May	33	12.78	20.22	Nov	31	12.42	18.58
Jun	33	12.35	20.65	Dec	30	12.28	17.72

3.6. Evaluation of the Capacity of Drainage Channels

The examination of the Taduan Street drainage channels revealed that, in the next ten years, the drainage system would not even be able to handle wastewater from a combination of runoff and domestic wastewater (Table 8). This situation is exacerbated by the results of testing the water velocity on the channel which is only close to 0 m/s, making the flow almost stationary, while at peak hours such as morning and evening the addition of domestic wastewater always occurs. Table 8 contains a comparison for the three periods between the dimensions of the existing drainage channel and the total water that must be accommodated. In the next 10 years, rainfall will be about 5.87 mm/hour in 2032, 6.04 mm/hour in 2042, and 6.56 mm/hour in 2052. Total wastewater discharge from domestic activities will be 182.40 x 10^{-2} L/person/s in 2032, 201.88 x 10^{-2} L/person/s in 2042, and 265.63 × 10^{-2} L/person/s in 2052. The current drainage volume is 1,188 m^3, with an observed channel length of 1,000 m. The channel's existing capacity prevents simultaneous entry of runoff and wastewater, particularly during peak hours when wastewater production is 2.4 times more than at other times. It is crucial to regularly normalize the canal because the drainage circumstances are open and located next to a public street, making it possible for natural materials to enter and obstruct the drainage's ability to function. According to the concrete's age, the concrete structure might age. Environmental elements can also contribute to this aging process. At coordinate locations, including 3° 36' 20.6532" N 98° 42' 16.0056" E, 3° 36' 21.0024" N 98° 42' 6.7752" E, 3° 36' 21.618" N 98° 41' 51.3636" E, and 3° 36' 21.9636'' N 98° 41' 47.0004'' E. Drainage on Taduan Street was investigated for possible damage to the canal walls. Renovation and reinforcement of the materials are required, including the use of reinforcing beams and the removal of vegetation. This effort can help stop wastewater from contaminating groundwater by leaking through drainage channel wall fractures.

Table 8. Drainage capacity evaluation

Period (Year)	Year	$Q_{Planning}$ (m³/s)	$Q_{drainase}$ (m³/s)	Remark
10	2032	1.8256	0.33	Not meet standards
20	2042	2.0204		Not meet standards
30	2052	2.6581		Not meet standards

The issue of flooding and overflow, which frequently affects Indonesia's major cities, must be resolved immediately and correctly, especially when the rainy season begins. Stagnant water can harm infrastructure such as roads and public buildings, which results in losses for the financial and public health sectors. Several options are available, but other technical factors such as time, financial, human resource availability, community social dynamics, and others must also be considered. A green technology known locally as Lubang Resapan Biopori (LRB) was developed in 1976 and is useful for lowering the amount of runoff that will be directed into drainage channels. Due to a reduction in water catchment areas, residential areas in metropolitan regions converted to pavement are to blame for the excessive runoff volume. Many studies have examined the efficiency of LRB in redirecting runoff water (Juliandari *et al*., 2013). They investigated a hole dug for 28 days on clay and silt with a water content of 38.42-40.52% and measured the water infiltration rate at 0.3-6.40 mm/min. For a dwelling area of 120 m^2, at least 5 holes with a depth range from 0.50-1.00 m and a diameter of 0.20 m are made with an anticipated catchment water volume by the LRB of 180 L/hour. (Karuniastuti, 2014) estimates that it costs Rp. 220,000 to produce one LRB, with the money going toward one LRB drill, one meter of porous PVC pipe, and a worker's wage of 60 min for each hole. Additionally, ongoing outreach to locals regarding channel border areas is required. This endeavor tries to stop locals from erecting structures that can obstruct drainage because they are situated close to the border. Consideration must also be given to community empowerment initiatives through training, the formation and strengthening of institutions, assistance, and socialization regarding the ban on putting trash into channels. The usual depth range for groundwater potential in Medan City is 10 to 30 m, with resistivity values between 100 and 500 m. The fact that the depth of groundwater is high in Medan City, thus provides an opportunity for the success of reducing floods/inundation with LRB. These holes will be a place for rainwater to flow into the ground while maintaining soil absorption.

4. CONCLUSIONS

The drainage channel on the current Taduan Street cannot hold a combination of runoff and domestic wastewater even for the next 10 years, from Taduan Street No. 1 to Taduan Street No. 153. With 277 more people served, the amount of wastewater produced by daily activities like bathing, cleaning, and cooking increases, making the capacity insufficient to handle peak discharge during the rainy season. Creating an LRB to increase the catchment area can help reduce inundation that may occur. However, it must be balanced with several supporting programs such as community empowerment to help accelerate community understanding of the construction, maintenance, and benefits of water management facilities. In the future, the drainage needs to be redesign with adequate dimensions and the right system. Open channel drainage is generally made to collect and drain runoff. But, in Indonesia it is used to drain domestic wastewater into larger water bodies. Basically, the network for drainage and domestic wastewater should have different channels. This is because the functions of the two channels are different. It is also necessary to pay attention to making inlets for planning closed drainage channels in Medan City, especially on Taduan Street.

REFERENCES

Akhter, F., Hewa, G. A., Ahammed, F., Myers, B., & Argue, J. R. (2020). Performance evaluation of stormwater management systems and its impact on development costing. *Water*, ***12***(2), 375. https://doi.org/10.3390/w12020375

Andrian, Y., & Ningsih, E. (2014). Prediksi curah hujan di kota medan menggunakan metode backpropagation neural network. *Prosiding Seminar Nasional Informatika*, ***1***(1), 184-189.

Aqsha, S., & Harahap, D.S. (2022). Evaluasi sistem drainase di kawasan pemukiman penduduk di Jalan Air Bersih, Kelurahan Sudirejo I, Kecamatan Medan Kota. *Jurnal Teknik Sipil (JTSIP),* ***1***(1), 73-77.

BPS (Badan Pusat Statistik). (2022, December 1). *Penduduk, Laju Pertumbuhan Penduduk, Distribusi Persentase Penduduk, Kepadatan Penduduk, Rasio Jenis Kelamin Penduduk Menurut Kabupaten/Kota*. Badan Pusat Statistik Sumatera Utara, Medan.

Budiman, B., Suprapto, B., & Rachmawati, A. (2021). Studi evaluasi sistem drainase di Kecamatan Sukomanunggal Kota Surabaya. *Jurnal Rekayasa Sipil*, ***10***(3), 80-90

Carstensen, M. V., Hashemi, F., Hoffmann, C. C., Zak, D., Audet, J., & Kronvang, B. (2020). Efficiency of mitigation measures targeting nutrient losses from agricultural drainage systems: A review. *Ambio*, ***49***(11), 1820–1837. https://doi.org/10.1007/s13280-020-01345-5

Dara, D. (2022). *56 Kelurahan Dari 14 Kecamatan Terdampak Banjir Medan, BPBD Evakuasi 415 Warga.* https://Pemkomedan.Go.Id/Album-5735-56-Kelurahan-Dari-14-Kecamatan-Terdampak-Banjir-Medan-Bpbd-Evakuasi-415-Warga.Html.

Dewi, A.K., Setiawan, A., & Saido, A.P. (2014). Evaluasi sistem saluran drainase di ruas jalan Solo Sragen Kabupaten Karanganyar. *Jurnal Matriks Teknik Sipil*, ***2***(1), 170-176.

Dwijaya, A. (2018). Evaluasi drainase perkotaan dengan metode Hecras di Kota Nanga Bulik, Lamandau Propinsi Kalimantan Tengah. *Jurnal Rekayasa Sipil*, ***2***(2), 104–115.

Fairizi, D. (2015). Analisis dan evaluasi saluran drainase pada kawasan Perumnas Talang Kelapa di Subdas Lambidaro Kota Palembang. *Jurnal Teknik Sipil dan Lingkungan*, ***3*** (1), 755–765.

Rabori, A.M., & Ghazavi, R. (2018). Urban Flood Estimation and Evaluation of the Performance of an Urban Drainage System in a Semi-Arid Urban Area Using SWMM. *Water Environment Research*, ***90***(12), 2075-2082. https://doi.org/10.2175/106143017x15131012188213

Giambastiani, B.M.S., Macciocca, V. R., Molducci, M., & Antonellini, M. (2020). Factors affectingwater drainage long-time series in the salinized low-lying coastal area of Ravenna (Italy). *Water*, ***12***(1), 256. https://doi.org/10.3390/w12010256

Januardi, H., Gunarto, D., & Erwan, K. (2022). Evaluasi kondisi existing sistem drainase di lingkungan Universitas Tanjungpura Pontianak. *JeLAST: Jurnal Teknik Kelautan, PWK, SIpil dan Tambang*, ***9***(3).

Juliandari, M., Nirmala, A., & Yuniarti, E. (2013). Efektivitas Lubang Resapan Biopori Terhadap Laju Resapan (Infiltrasi). *Jurnal Teknologi Lingkungan Lahan Basah*, ***1***(1), 1-10. https://dx.doi.org/10.26418/jtllb.v1i1.3441

Karuniastuti, N. (2014). Teknologi biopori untuk mengurangi banjir dan tumpukan sampah organik. *Swara Patra: Majalah Ilmiah PPSDM Migas*, ***4***(2), 60–68.

Kencana, A., Noerhayati, E., & Rokhmawati, A. (2021). Studi Evaluasi Drainase di Kecamatan Singosari Kabupaten Malang. *Jurnal Rekayasa Sipil*, ***9***(4), 312–321.

Khair, H., Rachman, I., & Matsumoto, T. (2019). Analyzing household waste generation and its composition to expand the solid waste bank program in Indonesia: A case study of Medan City. *Journal of Material Cycles and Waste Management*, ***21***(4), 1027–1037. https://doi.org/10.1007/s10163-019-00840-6

Lukman, A. (2018). Evaluasi sistem drainase di Kecamatan Helvetia Kota Medan. *Buletin Utama Teknik*, ***13***(2), 163-174.

Pasaribu, H. (2023). Comprehensive evaluation of drainage channels along selected roads in Medan City, North Sumatra. *JST (Jurnal Sains dan Teknologi)*, ***12***(1). https://doi.org/10.23887/jstundiksha.v12i1.52487

Pasaribu, H.S.V, Marbun, H.S., Sakinah, N., Panjaitan, N., Arifianingsih, N.N., & Prayogo, W. (2022). Evaluation of an urban drainage channel system on Tuamang Road, Medan. *International Journal of Architecture and Urbanism*, ***6***(2), 221–232. https://doi.org/10.32734/ijau.v6i2.9693

Pratiwi, R. S., & Purwanti, I. F. (2015). Perencanaan sistem penyaluran air limbah domestik di Kelurahan Keputih Surabaya. *Jurnal Teknik ITS*, ***4***(1), D40–D44.

Prayogo, W., Chairani, R., Telaumbanua, D.R., Fitria, N., Alam, F.C., Ikhwali, M.F., Azizah, R.N., & Zamani, S. (2022). The effects of community characteristics on solid -waste generation and management in the village (A case study: Kurandak, North Sumatra). *Jurnal Presipitasi*. ***19***(2), 303–315. https://doi.org/10.14710/presipitasi.v19i2.303-3015

Prayogo, W., Siregar, J.P., Soewondo, P., Nasution, Z., Hanami, Z.A., Ikhwali, M.F., Estim, A., & Suryawan, I.W.K. (2023). The investigation on mineral wool performance as a potential filter to remove TSS in Cikapayang River, East Jawa, Indonesia. *Environment and Natural Resources Journal*, ***21***(1), 9–18. https://doi.org/10.32526/ennrj/21/202200118

Prayogo, W., Soewondo, P., Zakiyya, N.M., & Muntalif, B.S. (2020). The removal of organic materials and nutrients with addition of artificial supporting materials in the water body (a case study of Cikapayang River, Bandung City Hall). *IOP Conf. Ser.: Earth Environ. Sci.*, ***409***, 012007. https://doi.org/10.1088/1755-1315/409/1/012007

Remesan, R., Prabhakaran, A., Sangma, M.N., Janardhanan, S., Mainuddin, M., Sarangi, S.K., Mandal, U. K., Burman, D., Sarkar, S., & Mahanta, K.K. (2021). Modeling and management option analysis for saline groundwater drainage in a deltaic island. *Sustainability*, ***13***(12), 6784. https://doi.org/10.3390/su13126784

Romadhoni, A.Z. (2016). Analisis Sedimentasi Pada Saluran Drainase Jalan Srikoyo Kecamatan Patrang Kabupaten Jember. [*Undergraduate Thesis*]. Jurusan Teknik Sipil, Fakultas Teknik, Universitas Jember.

Rubinato, M., Nichols, A., Peng, Y., Zhang, J., Lashford, C., Cai, Y., Lin, P., & Tait, S. (2019). Urban and river flooding: Comparison of flood risk management approaches in the UK and China and an assessment of future knowledge needs. *Water Science and Engineering*, ***12***(4), 274–283. https://doi.org/10.1016/j.wse.2019.12.004

Safriani, M., Suciatina, C.S., & Fachruddin, F. (2022). Evaluasi tampang drainase Desa Kuta Padang Kabupaten Aceh Barat. *Jurnal Teknik Sipil dan Teknologi Konstruksi*, *8* (2), 110-120. https://doi.org/10.35308/jts-utu.v8i2.5954

Saraswat, C., Kumar, P., & Mishra, B. K. (2016). Assessment of stormwater runoff management practices and governance under climate change and urbanization: An analysis of Bangkok, Hanoi and Tokyo. *Environmental Science & Policy*, ***64***, 101 –117. https://doi.org/10.1016/j.envsci.2016.06.018

Sibagariang, Y., & Saputra, P. A. E. (2021). Analisis drainase di daerah rawan banjir dan dampaknya di Kecamatan Medan Baru Kota Medan. *JUITECH: Jurnal Ilmiah Fakultas Teknik Universitas Quality*, ***5***(1), 66–80.

Sinaga, R.M., & Harahap, R. (2016). Analisis sistem saluran drainase pada Jalan Perjuangan Medan. *Jurnal Education Building*, ***2***(2), 41-49. https://doi.org/10.24114/eb.v2i2.4494

Sulistiono, B., & Ardiyanto, A.F. (2016). Evaluasi kapasitas saluran drainase Desa Sariharjo Ngaglik Sleman Yogyakarta. *Jurnal Teknik Sipil*, ***14***(1), 47-52. https://doi.org/10.24002/jts.v14i1.1016.

Suryaman, H. (2013). Evaluasi sistem drainase Kecamatan Ponorogo kabupaten Ponorogo. *Jurnal Kajian Pendidikan Teknik Bangunan*, ***2***(1), 1–8.

Sutjahjo, N., Anggraini, F., & Pamekas, R. (2011). Konsumsi dan pelanggan air minum di kota besar dan metropolitan. *Jurnal Permukiman*, ***6***(3), 138–146. https://doi.org/10.31815/jp.2011.6.138-146

Widodo, I., & Ningrum, D. (2015). Evaluasi sistem jaringan drainase permukiman soekarno hatta Kota Malang dan penanganannya. *Sistem: Jurnal Ilmu Ilmu Teknik*, *11*(3), 1-9.

Wijaya, I., Arabia, T., & Basri, H. (2022). Pengaruh pengelolaan drainase terhadap beberapa sifat kimia tanah histosol di Rawa Gambut Tripa Kabupaten Aceh Barat Daya. *Jurnal Ilmiah Mahasiswa Pertanian*, ***7***(3), 381-392.

Wismabrata, M.H. (2020). *Banjir Bandang di Medan, 3 Orang Tewas Hingga Imbauan Gubernur Edy.* . Https://Regional.Kompas.Com/Read/2020/12/04/12140061/Banjir-Bandang-Di-Medan-3-Orangtewas-Hingga-Imbauan-Gubernur-Edy-?Page=all.

Wulandari, E., Suprapto, B., & Rokhmawati, A. (2022). Evaluasi Saluran Drainase Perkotaan Pada Kecamatan Lowokwaru Kota Malang. *Jurnal Rekayasa Sipil*, ***12***(2), 80-89.

Zevri, A. (2017). Analisis volume tampungan kolam retensi DAS Deli sebagai salah satu upaya pengendalian banjir Kota Medan. *Jurnal Rekayasa Sipil*, ***13***(2), 113-122. https://doi.org/10.25077/jrs.13.2.113-122.2017

Zevri, A. (2019). Studi pemetaan daerah genangan banjir DAS Sei Kambing dengan sistem informasi geografis. *Teras Jurnal: Jurnal Teknik Sipil*, ***9***(2), 165-178. https://doi.org/10.29103/tj.v9i2.233