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Flood Analysis: Case Study of Terusan Pemuda Road

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A B S T R A C T

This study analyzes flood characteristics on Jalan Terusan Pemuda, Kesambi District, Cirebon City, driven by climate change and urbanization. Methods include rainfall analysis using the Thiessen Polygon method, rainfall frequency analysis with the Gumbel method, and drainage capacity evaluation using the Manning equation. Maximum daily rainfall data from 2015–2024 shows that the Penggung station contributed the most rainfall despite its smaller coverage area. The design rainfall for 2-, 5-, and 10-year return periods is 95.58 mm, 130.62 mm, and 153.83 mm, respectively. Drainage evaluation revealed that channels P5 and P9 are overloaded, while P1 and P10 are non-functional due to sedimentation and waste. Recommendations include channel normalization, construction of interceptor systems, implementation of Low Impact Development (LID) concepts, public education, and improved inter-agency coordination.

INTRODUCTION

Floods are one of the most frequent natural disasters in Indonesia and cause significant losses both economically and socially. According to data from the National Disaster Management Agency (BNPB), floods are the third most frequent disaster in Indonesia after fires and fallen trees throughout 2020. The problem of flooding is increasingly complex in urban areas due to uncontrolled population growth, poor land use planning, and lack of public and government understanding of the risks of flood disasters.(NASA, 2020)(BNPB, 2020)

Cirebon City as one of the coastal cities in West Java Province is not spared from the threat of flooding. Based on the Flood Disaster Risk Map issued by BNPB, several areas in Cirebon City are included in the high to very high risk category for flooding. Kesambi District is one of the areas that often experience waterlogging during the rainy season, especially along Jalan Terusan Pemuda.Jalan Terusan Pemuda has a strategic role as one of the main accesses that connects the Kesambi area with the center of Cirebon City. The inundation that occurs on this road not only disrupts transportation activities but also has an impact on the economic and social activities of the surrounding community. The flood problem in this location is suspected to be caused by several factors, including: (1) inadequate drainage system capacity, (2) land use changes that increase runoff coefficients, (3) sedimentation and waste that reduce the effective capacity of channels.

Various previous studies have examined the problem of urban flooding in Indonesia. conducting a comparative study of hydrological and hydraulic modeling in predicting floods. mapping flood-prone areas using Geographic Information Systems. Meanwhile, research by shows that the approach to flood management in Indonesia is still dominated by a top-down approach without involving optimal community participation. In a global context, climate change has increased the intensity and frequency of flood events. Indonesia as an archipelagic country in the tropics is very vulnerable to the impact of climate change. High-intensity rains that can reach more than 200 mm per day, coupled with massive construction along riverbanks, have exacerbated flooding conditions especially in urban areas (Siregar & Indrawan, 2017) (Authority Et Al.,2022) (Damayanti, 2020)(Siregar & Indrawan, 2017)

The use of flood modeling technology has grown rapidly in the last decade. The HEC-RAS (Hydrologic Engineering Center's River Analysis System) software developed by the US Army Corps of Engineers has been widely used for flood analysis in various countries including Indonesia. The integration of HEC-RAS with the Geographic Information System (GIS) allows for better visualization of the flood-affected areas. (*HEC-RAS_6.0_UsersManual*, n.d.)

This research is important considering that there is no comprehensive study of the characteristics of flooding on Jalan Terusan Pemuda, Kesambi District. The results of the study are expected to provide technical recommendations for more effective and sustainable flood management. The approaches used include hydrological analysis to determine the amount of planned flood discharge and hydraulic analysis to evaluate the capacity of existing drainage systems.

LITERATURE REVIEW

1. (Authority Et Al.,2022):This study maps flood-prone areas in Ambon City using the Geographic Information System (GIS). The results of the study show that several areas in Ambon, including have a high risk of flooding due to factors such as changes in land use and inadequate drainage systems. This study emphasizes the importance of risk mapping for better spatial planning.
2. (Damayanti, 2020): This study explores flood management approaches in Indonesia, with a focus on community involvement in the planning process. The results show that the dominant top-down approach often ignores community participation, which can reduce the effectiveness of flood management. This study recommends the need for a more inclusive approach to improve community resilience to flooding.
3. (Siregar & Indrawan, 2017) : This study analyzes the impact of climate change on the frequency and intensity of floods in Indonesia's urban areas. Using rainfall data and hydrological models, the study found that an increase in extreme rainfall intensity contributes significantly to an increase in flood risk, especially in areas experiencing rapid urbanization. This research provides recommendations for the development of infrastructure that is more adaptive to climate change.

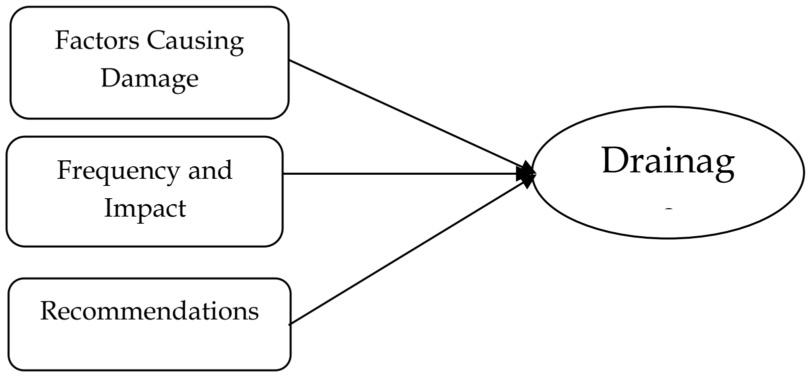

Figure 1. Frame of Mind

METHODOLOGY

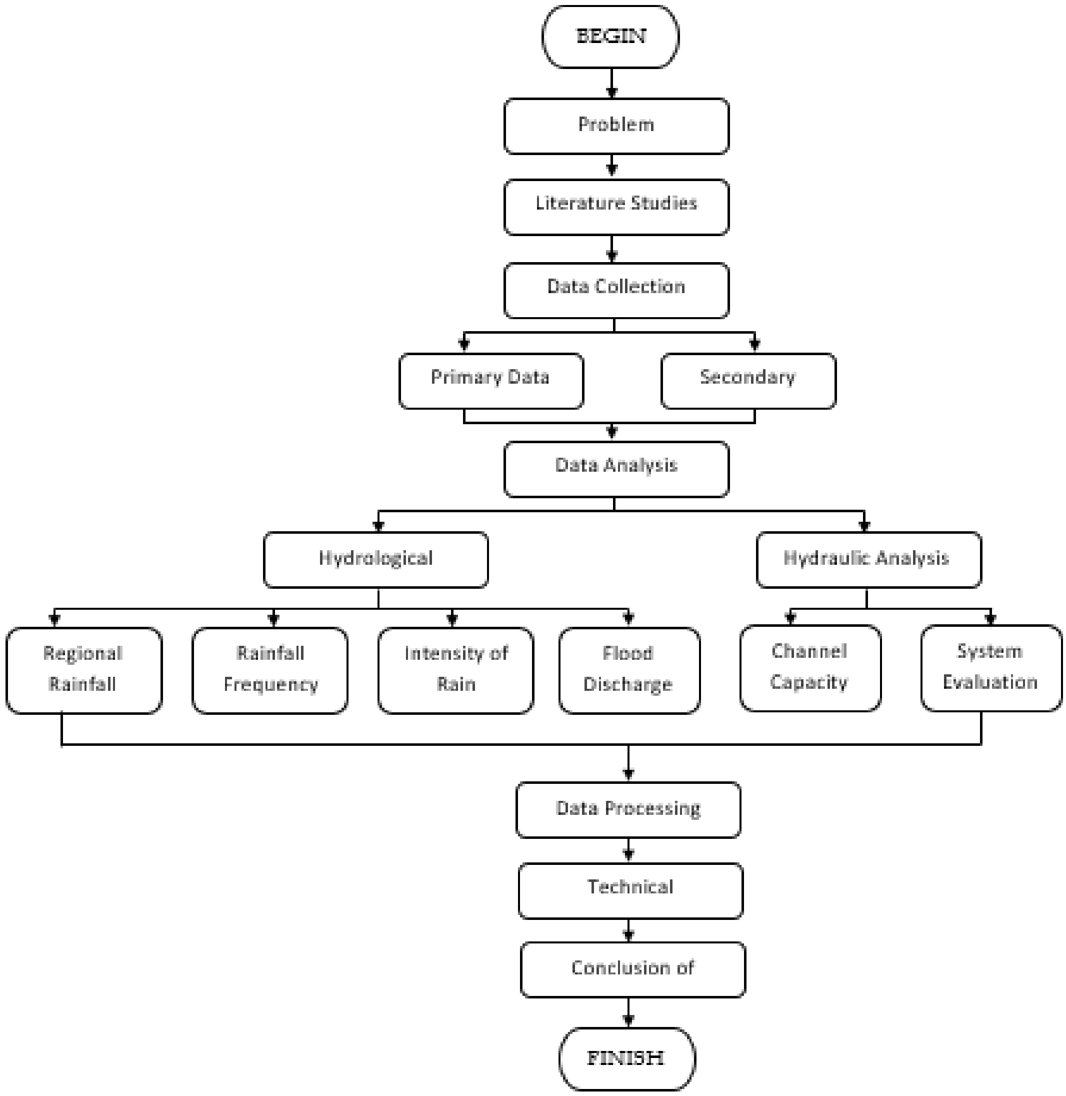

Figure 2. Research Flowchart

This study uses quantitative methods to analyze the influence of rainfall characteristics, calculate the planned rainfall intensity, evaluate the condition and capacity of drainage systems, identify factors that cause flooding and provide technical recommendations. This research was conducted on Jalan Terusan Pemuda, Kesambi District, Cirebon City, West Java Province. Geographically, Cirebon City is located at the coordinates of 6°41'0" - 6°46'0" South Latitude and 108°33'0" - 108°36'0" East Longitude using secondary data in the form of Rainfall Data obtained from POS BMKG and NASA, Map Data from Ina-Geoportal, Cirebon City drainage Masterplan from Cirebon City PUPR, Flood Incident Report, and Demographic Data of Kesambi District. Using binary logistics analysis with the help of SPSS software. The research method used the Thiessen Polygon from three observation posts (Harjamukti, Penggung, and BBWS Sunyaragi), rainfall frequency analysis using the Gumbel method, and evaluation of the capacity of existing drainage systems using the Manning equation

RESEARCH RESULTS

To analyze the drainage system, it is necessary to calculate the characteristics of rainfall, the condition of the existing drainage system, the capacity of the channel and the effectiveness of the drainage so that technical recommendations for the drainage channel will be obtained

1. Rainfall Characteristics

Table 1. Annual Maximum Daily Rainfall Data

Year	Item 1: Harjamukti	Item 2: Publisher	Post 3: BBWS(Sunyaragi)	Average
2015	138	47	107.17	97.39
2016	86	68	89.00	81.00
2017	111.5	69	117.50	99.33
2018	127	83	109.67	106.55
2019	71	74	71.17	72.05
2020	141.5	187	175.17	167.89
2021	139.5	61	98.68	99.72
2022	148.5	60	130.50	113.00
2023	135.5	70	97.33	100.94
2024	21.54	65	86.52	57.68

Figure 3. Distribution Map of Rainfall Observation Posts

a. Calculation of Regional Rainfall using the Thiessen Polygon method

$\bar{P} = \Sigma(Ai \times P_i) / \Sigma A_i$

Example calculation for 2024:

$\bar{P} = (21.71\times112 + 5.18\times125 + 10.10\times97) / 37.00$

$\bar{P} = (2431.52 + 647.50 + 979.70) / 37.00$

$\bar{W} = 109.86$ mm

In the analysis of the area of influence, there are three main posts that have different areas and percentages. The Harjamukti Post, with an area of 21.71 km², covers 58.68% of the total catchment area which reaches 37.00 km². In addition, Pos Penggung and Pos BBWS Sunyaragi have an area of 5.18 km² (14.01%) and 10.10 km² (27.31%), respectively. After that, when looking at the contribution of rainfall from 2015 to 2024, the Harjamukti Post produced 21,863.30 mm which contributed 34.69%. Meanwhile, Pos Penggung recorded the highest number with a total of 24,588.90 mm (39.02%) and Pos BBWS Sunyaragi contributed 16,568.04 mm (26.29%).

b. Calculation of Rain Intensity Frequency Analysis Using the Gumbel Method

Table 2. Results of Rainfall Calculation of Gumbel Method Plan

Birthday Period (year)	YT	K	XT (mm)
2	0.3665	-0.13553075	95.57877251
5	1.4999	1.058024431	130.6248816
10	2.2502	1.848357203	153.8312561
25	3.1985	2.846777591	183.1476634
50	3.9019	3.587510531	204.8976486
100	4.6001	4.322767481	226.4868434

Chi-Square Test:

- X^2count = 2.45
- X^2table (α=5%, dk=2) = 5.991
- X^2count < X^2table → Distribution accepted

Smirnov-Kolmogorov Test:

- Δmax = 0.182
- Δcritical (n=10, α=5%) = 0.410
- Δmax < Δcritical → Distribution accepted

Table 3. Rain Intensity Plan Using the Mononobe Formula

Duration (hours)	I_2 (mm/h)	I_5 (mm/h)	I_{10} (mm/h)
0.25	47.77	66.13	78.30
0.50	30.11	41.68	49.35
1.00	18.98	26.27	31.11
2.00	11.96	16.56	19.61
3.00	8.94	12.38	14.66

2. Existing Drainage System Conditions

Table 4. Existing Drainage Channel Data

Yes	**Channel Name**	**Type**	**Width (m)**	**Height (m)**	**Length (m)**	**Slope (%)**	**Manning (n)**	**Watershed Area (Ha)**	**Koef. C**
1	P1	U-Ditch	0.55	0.55	90	0.15	0.012	0.009	0.75
2	P2	U-Ditch	0.55	0.55	200	0.18	0.012	0.02	0.75
3	P3	U-Ditch	0.55	0.55	200	0.2	0.012	0.02	0.7
4	P4	U-Ditch	1.5	1.1	145	0.22	0.012	0.0145	0.7

5	P5	Culvert	3	1.3	24	0.25	0.015	0.0024	0.65
6	P6	U-Ditch	1.95	1.05	170	0.28	0.012	0.017	0.65
7	P7	Culvert	1.1	1	17	0.3	0.015	0.0017	0.65
8	P8	U-Ditch	1.25	1.35	500	0.25	0.012	0.05	0.65
9	P9	U-Ditch	1.85	2.2	440	0.35	0.012	0.044	0.6
10	P10	U-Ditch	0.55	0.55	185	0.38	0.012	0.0185	0.6
11	P11	U-Ditch	1.9	1.4	485	0.12	0.012	0.0485	0.7
12	P12	U-Ditch	0.55	0.55	75	0.15	0.012	0.0075	0.7
13	P13	Kali Stone Couple	1.7	1.8	30	0.25	0.02	0.003	0.65
14	P14	U-Ditch	0.35	0.45	260	0.2	0.012	0.026	0.7
15	P15	U-Ditch	0.65	0.6	440	0.2	0.012	0.044	0.2
16	P16	U-Ditch	0.55	0.62	415	0.2	0.012	0.0415	0.2
17	P17	U-Ditch	0.47	0.5	675	0.2	0.012	0.0675	0.2
18	P18	U-Ditch	0.63	0.9	675	0.2	0.012	0.0675	0.2

Figure 4. Channel Location Points

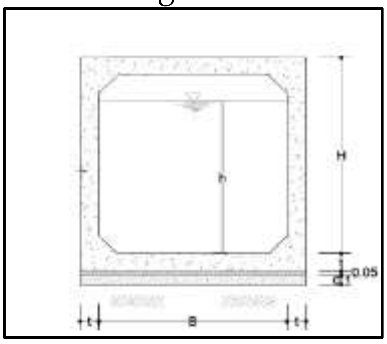

Figure 5. Stuttgart

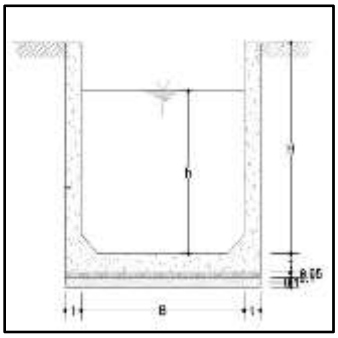

Figure 7. U-Ditch

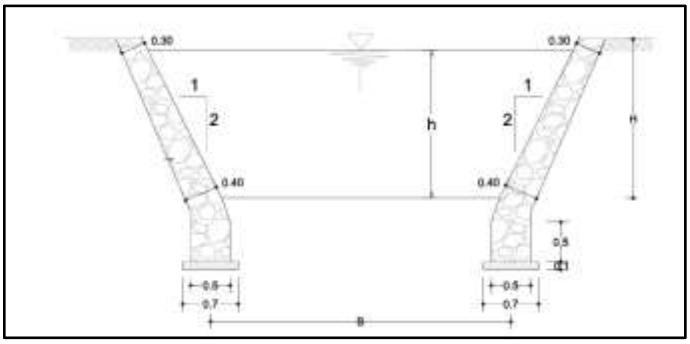

Figure 6. Trapezoidal stone pairs

The survey results show various problems that exist in the drainage system in the area studied. First, channels P1 and P10 are in a dead state, which is characterized by being fully filled with sediment and garbage, so it does not function as drainage channels and requires complete rehabilitation. Furthermore, channels P2 and P3 are in a dry state, and are only filled when it rains, so they experience sedimentation reaching 30-40% of the height of the channel and there is a lot of domestic waste in them. Not only that, but channels P5 and P9 are in critical condition, as they receive flows from the outside area and often overflow during moderate rainfall. In addition, other channels also experience problems with an average sedimentation of 20-30%, where waste reduces the effective capacity of the channel and some points suffer structural damage.

3. Channel Capacity
   Using the Manning equation:
   Example calculation for Channel P6:
   - $b = 1.95$ m, $h = 1.05$ m
   - $A = b \times h = 1.95 \times 1.05 = 2.0475$ m²
   - $P = b + 2h = 1.95 + 2(1.05) = 4.05$ m
   - $R = A/P = 2.048/4.05 = 0.5055$ m
   - $S = 0.0028$, $n = 0.015$
   - $Q = (1/0.015) \times 2.0475 \times \times ()(0.5055^{\frac{2}{3}})0.0028^{0.5}$
   - $Q = 4.583$ m³/s

Table 5.Existing Channel Capacity

Yes	Channels	b (m)	h (m)	A (m²)	P (m)	R (m)	S	n	Q hood (m³/s)	V (m/s)
1	P1	0.55	0.55	0.3025	1.65	0.183333333	0.0015	0.012	0.315077496	1.0415785
2	P2	0.55	0.55	0.3025	1.65	0.183333333	0.0018	0.012	0.345150104	1.14099208
3	P3	0.55	0.55	0.3025	1.65	0.183333333	0.002	0.012	0.363820155	0.003712451
4	P4	1.5	1.1	1.65	3.7	0.445945946	0.0022	0.012	3.764455653	2.281488275
5	P5	3	1.3	3.9	5.6	0.696428571	0.0025	0.015	10.21396595	2.618965628
6	P6	1.95	1.05	2.0475	4.05	0.505555556	0.0028	0.012	5.729731506	2.798403666
7	P7	1.1	1	1.1	3.1	0.35483871	0.003	0.015	2.013180497	1.830164088
8	P8	1.25	1.35	1.6875	3.95	0.42721519	0.0025	0.012	3.988384291	2.363486987
9	P9	1.85	2.2	4.07	6.25	0.6512	0.0035	0.012	15.07498123	3.703926591
10	P10	0.55	0.55	0.3025	1.65	0.183333333	0.0038	0.012	0.501491475	1.657823057
11	P11	1.9	1.4	2.66	4.7	0.565957447	0.0012	0.012	5.253880608	1.975143086
12	P12	0.55	0.55	0.3025	1.65	0.183333333	0.0015	0.012	0.315077496	1.0415785
13	P13	1.7	1.8	3.06	5.3	0.577358491	0.0025	0.02	5.304264103	1.733419641
14	P14	0.35	0.45	0.1575	1.25	0.126	0.002	0.012	0.147523545	0.936657429
15	P15	0.65	0.6	0.39	1.85	0.210810811	0.002	0.012	0.51482577	1.320066077
16	P16	0.55	0.62	0.341	1.79	0.190502793	0.002	0.012	0.420748293	1.233865962
17	P17	0.47	0.5	0.235	1.47	0.159863946	0.002	0.012	0.257969661	1.097743237
18	P18	0.63	0.9	0.567	2.43	0.233333333	0.002	0.012	0.800881019	1.412488569

Although hydraulically the drainage system has adequate capacity, its actual effectiveness is very low due to a combination of poor maintenance factors, uncontrolled external loads, and physical degradation of the channel. This indicates that the flood problem at the study site is more caused by operational and maintenance aspects than design aspects.

4. Drainage System Effectiveness

Table 6.Discharge Plans for Multiple Re-Periods

Yes	Channels	C	A (Ha)	A (km²)	I_2 (mm/h)	I_5 (mm/h)	I_{10} (mm/h)	Q_2 (m³/s)	Q_5 (m³/s)	Q_{10} (m³/s)
1	P1	0.75	0.009	0.00009	33.135309	45.285117	53.330317	0.000621784	0.000849775	0.001000743
2	P2	0.75	0.02	0.0002	33.135309	45.285117	53.330317	0.001381742	0.001888389	0.002223874
3	P3	0.7	0.02	0.0002	33.135309	45.285117	53.330317	0.001289626	0.001762497	0.002075616
4	P4	0.7	0.0145	0.000145	33.135309	45.285117	53.330317	0.000934979	0.00127781	0.001504822
5	P5	0.65	0.0024	0.000024	33.135309	45.285117	53.330317	0.000143701	0.000196392	0.000231283
6	P6	0.65	0.017	0.00017	33.135309	45.285117	53.330317	0.001017884	0.001391114	0.001638254
7	P7	0.65	0.0017	0.000017	33.135309	45.285117	53.330317	0.000101788	0.000139111	0.000163825
8	P8	0.65	0.05	0.0005	33.135309	45.285117	53.330317	0.002993775	0.00409151	0.004818394
9	P9	0.6	0.044	0.00044	33.135309	45.285117	53.330317	0.002431867	0.003323565	0.003914019
10	P10	0.6	0.0185	0.000185	33.135309	45.285117	53.330317	0.001022489	0.001397408	0.001645667
11	P11	0.7	0.0485	0.000485	33.135309	45.285117	53.330317	0.003127344	0.004274055	0.005033369
12	P12	0.7	0.0075	0.000075	33.135309	45.285117	53.330317	0.00048361	0.000660936	0.000778356
13	P13	0.65	0.003	0.00003	33.135309	45.285117	53.330317	0.000179627	0.000245491	0.000289104
14	P14	0.7	0.026	0.00026	33.135309	45.285117	53.330317	0.001676514	0.002291246	0.002698301
15	P15	0.2	0.044	0.00044	33.135309	45.285117	53.330317	0.000810622	0.001107855	0.001304673
16	P16	0.2	0.0415	0.000415	33.135309	45.285117	53.330317	0.000764564	0.001044909	0.001230544
17	P17	0.2	0.0675	0.000675	33.135309	45.285117	53.330317	0.001243568	0.00169955	0.002001487
18	P18	0.2	0.0675	0.000675	33.135309	45.285117	53.330317	0.001243568	0.00169955	0.002001487

Table 7. Channel Capacity Evaluation

Yes	Channels	C	A (Ha)	A (km²)	I_2 (mm/h)	I_5 (mm/h)	I_{10} (mm/h)	Q_2 (m³/s)	Q_5 (m³/s)	Q_{10} (m³/s)
1	P1	0.75	0.009	0.00009	33.135309	45.285117	53.330317	0.000621784	0.0008497	0.001000743
2	P2	0.75	0.02	0.0002	33.135309	45.285117	53.330317	0.001381742	0.0018883	0.002223874
3	P3	0.7	0.02	0.0002	33.135309	45.285117	53.330317	0.001289626	0.0017624	0.002075616
4	P4	0.7	0.0145	0.000145	33.135309	45.285117	53.330317	0.000934979	0.001277	0.001504822
5	P5	0.65	0.0024	0.000024	33.135309	45.285117	53.330317	0.000143701	0.0001963	0.000231283
6	P6	0.65	0.017	0.00017	33.135309	45.285117	53.330317	0.001017884	0.0013911	0.001638254
7	P7	0.65	0.0017	0.000017	33.135309	45.285117	53.330317	0.000101788	0.0001391	0.000163825
8	P8	0.65	0.05	0.0005	33.135309	45.285117	53.330317	0.002993775	0.004091	0.004818394
9	P9	0.6	0.044	0.00044	33.135309	45.285117	53.330317	0.002431867	0.0033235	0.003914019
10	P10	0.6	0.0185	0.000185	33.135309	45.285117	53.330317	0.001022489	0.0013974	0.001645667
11	P11	0.7	0.0485	0.000485	33.135309	45.285117	53.330317	0.003127344	0.0042740	0.005033369
12	P12	0.7	0.0075	0.000075	33.135309	45.285117	53.330317	0.00048361	0.0006609	0.000778356
13	P13	0.65	0.003	0.00003	33.135309	45.285117	53.330317	0.000179627	0.0002454	0.000289104
14	P14	0.7	0.026	0.00026	33.135309	45.285117	53.330317	0.001676514	0.0022912	0.002698301
15	P15	0.2	0.044	0.00044	33.135309	45.285117	53.330317	0.000810622	0.0011078	0.001304673

16	P16	0.2	0.0415	0.000415	33.135309	45.285117	53.330317	0.000764564	0.00104490	0.001230544
17	P17	0.2	0.0675	0.000675	33.135309	45.285117	53.330317	0.001243568	0.001699	0.002001487
18	P18	0.2	0.0675	0.000675	33.135309	45.285117	53.330317	0.001243568	0.001699	0.002001487

Table 8. Channel Conditions

Yes	Channel Code	Status	Condition	Information
1	P1	Die	Not Working	Closed/completely damaged channel
2	P2	Dry	No Water	No inflow
3	P3	Dry	No Water	No inflow
4	P4	Active	Flow	Jump to P5
5	P5	Critical	Clogged	Sedimentation + Waste
6	P6	Active	Flow	Jump to P5
7	P7	Active	Flow	To P5 & P9
8	P8	Active	Flow	To P5 & P9
9	P9	Critical	Overflow	Overload capacity
10	P10	Die	Not Working	Closed/damaged lines
11	P11	Active	Flow	To P5 & P9
12	P12	Active	Flow	To P5 & P9
13	P13	Active	Flow	To P5 & P9
14	P14	Active	Flow	To P5 & P9
15	P15	Critical	Clogged	To P5 & P9
16	P16	Critical	Clogged	To P5 & P9
17	P17	Critical	Clogged	To P5
18	P18	Active	Flow	To P5

Theoretical drainage systems should be able to accommodate Q_{10} without a capacity deficit, but actual conditions suggest that some channels, such as P1 and P10, are not functioning at all. In addition, the P5 and P9 channels are overloaded due to external flows, while sedimentation has reduced capacity by 30-40%. Garbage buildup also causes flow blockages, exacerbating inundation problems. The causative factors include poor maintenance, uncontrolled additional flow, and damage to the channel structure. Technical issues faced include dead lines as well as overload at some point. On the other hand, non-technical problems such as low public awareness and lack of coordination between agencies also affect these conditions.

DISCUSSION

Based on the results of the research analysis, the Harjamukti Post has an area of 21.71 km², accounting for 58.68% of the total catchment area of 37.00 km², while the Penggung Post and the Sunyaragi BBWS Post cover an area of 5.18 km² (14.01%) and 10.10 km² (27.31%), respectively. From the analysis of rainfall between 2015 and 2024, Pos Penggung was recorded to make the highest contribution with 24,588.90 mm (39.02%), followed by Pos Harjamukti with 21,863.30 mm (34.69%), and Pos BBWS Sunyaragi with 16,568.04 mm (26.29%). The survey indicated that channels P1 and P10 were not functioning because they were covered with sediment and garbage, while channels P2 and P3 were only active when it rained. Channels P5 and P9 are in critical condition, often overflowing due to flows from the outside area. Although the duct capacity is hydraulically sufficient, its effectiveness is hampered by poor maintenance and physical degradation. The problem of flooding in the location is more caused by operational factors than design. Technical and non-technical, such as low public awareness and lack of coordination between agencies, also affect drainage conditions.

The findings of this study show consistency with some previous studies but also reveal site-specific characteristics:

Comparison with Rakuasa et al. (2022):

Rakuasa research in Ambon City identified the main factors for flooding are changes in land use and inadequate drainage systems. The results of this study reinforce these findings, but with different characteristics: in the Youth Canal Road, the hydraulic capacity is theoretically sufficient (Q_kapasitas > Q_rencana for all channels), but the operational effectiveness is very low. This indicates that in areas with existing drainage infrastructure, the main problem is not in the design aspect but in maintenance and operational management. Rakuasa emphasized the need for risk mapping for spatial planning, while the findings of this study show that even with good planning, implementation and maintenance are critical factors.

Comparison with Siregar & Indrawan (2017):

Siregar analyzed the impact of climate change on extreme rainfall intensity in urban Indonesia. This study uses daily maximum rainfall data of 200 mm/day as an indicator of extreme rainfall. The findings of the study show that the rainfall planned for the 10-year re-period reached 153.83 mm, still below the extreme threshold of Siregar. However, inundation persists due to non-climatic factors: 40% of the capacity of the channel is reduced due to sedimentation and 11% of the channels (P1, P10) are completely non-functional. This confirms Siregar's hypothesis that rapid urbanization exacerbates flood conditions, but by a different mechanism – not just due to increased rainfall intensity, but rather to the degradation of existing infrastructure.

Research Contribution to the Body of Knowledge:

This study fills the gap between the findings of Rakuasa (risk mapping focus) and Siregar (climate focus) by providing empirical evidence that urban flooding problems in Indonesia are not always caused by inadequate design capacity, but often by poor operational management. The finding that Pos Penggung had the highest rainfall contribution (39.02%) despite the smallest area (14.01%) also confirmed the high spatial variability of rainfall in Indonesia's tropics, supporting Siregar's recommendation for adaptive infrastructure development.

CONCLUSIONS AND RECOMMENDATIONS

Thiessen's analysis shows that the BMKG Penggung Post has the highest rainfall contribution (39.02%) despite the smallest area of influence (14.01%), indicating a higher rainfall intensity in the southern region. The results of the frequency analysis of the Gumbel method for rainfall planned for the 2, 5, and 10 consecutive periods are 95.58 mm, 130.62 mm, and 153.83 mm, which have met the Chi-Square and Smirnov-Kolmogorov tests. Although all channels are theoretically capable of accommodating the planned discharge of the 10-year re-period, field conditions indicate that channels P5 and P9 are overloaded, while P1 and P10 are filled with sediment and waste, requiring complete rehabilitation.

Technical recommendations for handling drainage problems are divided into short, medium, and long-term. In the short term, normalization of priority channels such as P1, P2, P3, and P10 needs to be carried out by cleaning up sediment and debris to restore at least 80% capacity, as well as building interceptor channels for critical channels P5 and P9. In the medium term, structural rehabilitation of damaged channels and the construction of supporting infrastructure such as trash racks and sediment traps are urgently needed, with a total estimated cost of Rp 4.3 billion. Meanwhile, in the long term, the implementation of the Low Impact Development (LID) concept and the development of IoT-based monitoring systems will increase the effectiveness of drainage systems. In addition, non-technical recommendations include the establishment of a Drainage Technical Implementation Unit (UPT) at the sub-district level and strengthening coordination between related agencies. Public education programs on waste management and drainage are also important to increase public awareness.

ADVANCED RESEARCH

Further research on the analysis of urban drainage systems is essential to address the challenges faced by modern cities. With technological advancements, such as the use of sensors and geographic information systems (GIS), we can monitor and analyze water flow in real-time. In addition, the application of environmentally friendly technology in drainage design can reduce the impact of flooding and improve water quality. The development of the times also encourages the integration of drainage systems with other urban infrastructure, such as transportation and green open spaces. This not only improves the efficiency of the drainage system, but also creates a more sustainable urban environment. Therefore, this research is expected to provide relevant recommendations for future drainage system planning and management.

Based on the findings of this study, some of the recommended future research areas include:

1. Economic Cost-Benefit Analysis Study
    - Cost-benefit analysis evaluation of normalization of priority channels (P1, P2, P3, P10)

- Analysis of economic losses due to inundation vs investment for drainage system rehabilitation
- Financial feasibility study of the implementation of Low Impact Development (LID) in urban areas

2. Integration of Drainage Systems with Green Open Space Planning
   - Research on the effectiveness of green infrastructure as a complementary solution to conventional drainage systems
   - Analysis of the correlation between changes in green land cover and runoff coefficient (C) in catchment areas
   - Study on the implementation of bioretention areas and constructed wetlands to reduce the load of P5 and P9 channels
3. Study of Community Perception and Participation
   - Survey of the perception of Jalan Terusan Pemuda users on the impact of inundation on economic and transportation activities
   - Analysis of the community's willingness to pay for sustainable drainage maintenance programs
   - Study on the effectiveness of community education programs in reducing waste disposal into drainage channels
4. Development of Monitoring Technology
   - Implementation of IoT-based early warning systems for critical channels (P5, P9)
   - Development of real-time flood prediction models using machine learning
   - Integration of NASA satellite rainfall data with local observation posts to improve prediction accuracy
5. Calculating the effectiveness of flood control supporting infrastructure:
   - Calculating the effectiveness of retention ponds on reducing flood discharge on Taman Pemuda road.
   - Calculating the effectiveness of the addition of the construction *of an interceptor sewer channel* from Campus 3 (in front of RRI) directly to the river on flood management on Jalan Taman Pemuda.
   - Calculating the effectiveness of adding culverts on flood control on Jalan Taman Pemuda.

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