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Flood Control Analysis in the Jakarta Garden City Area, Cakung, East Jakarta

Rosadi[1]

[1] Universitas Sangga Buana YPKP, Indonesia
* Correspondence e-mail; rosadi@usbypkp.ac.id

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Abstract

Land use changes in urban areas due to population growth and urbanization have reduced water catchment areas and increased surface runoff, resulting in inundation and flooding, including in the Jakarta Garden City area of Cakung, East Jakarta. This study aims to evaluate the performance of the existing drainage system and formulate more effective flood control measures. The analytical techniques used are hydrological and hydraulic analysis. The results of the analysis indicate that the capacity of the existing drainage system is not yet able to accommodate the planned flood discharge, resulting in inundation with a water level of approximately 0.4 m. The pump system is able to control the flood but requires a relatively long operating time to restore normal conditions, so flood control still relies on post-rain drainage. Therefore, it is necessary to increase channel capacity, optimize pump operation, and integrate with regional flood control systems such as the East Flood Canal to reduce inundation and accelerate receding times. This study shows that the effectiveness of the polder system is not only determined by pump capacity, but by the balance between inlet discharge, storage volume, and drainage operation time.

Keywords Flood Control, Flood Hydrograph, Polder System, Pump Operation, Urban Drainage

INTRODUCTION

Rivers and urban drainage systems are a crucial part of water resource management, supporting community activities across social, economic, and environmental dimensions. However, rapid population growth and high rates of urbanization in urban areas, particularly Jakarta, have led to significant changes in land use. These changes are characterized by a reduction in open land as water catchment areas and an increase in built-up areas such as residential areas, industry, and infrastructure, resulting in increased surface runoff that can potentially cause inundation and flooding.

Flooding problems in urban areas require comprehensive planning based on scientific analysis to provide effective and sustainable solutions. One approach is hydrological and hydraulic analysis to determine flow characteristics, drainage system capacity, and the potential for inundation, allowing for the formulation of an optimal flood control system.

The Marunda Sub-Polder, located in the Jakarta Garden City area of East Cakung Village, Cakung District, East Jakarta, is a low-lying residential area equipped with a polder system. This area has several reservoirs, namely Reservoir A, Reservoir B, and Reservoir C, which function to store rainwater and serve as a drainage system. However, despite this infrastructure, the area still experiences flooding, especially during heavy rainfall. This condition indicates that the existing flood control system is not functioning optimally.

This research is scientifically important to conduct at the present time due to the increasing frequency of extreme rainfall events associated with climate change and ongoing urban expansion in Jakarta. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), urban areas in tropical coastal regions are projected to experience more intense rainfall events, which will significantly increase urban flood risks if existing infrastructure systems are not upgraded. In Jakarta, the urgency of improving urban flood resilience is further heightened by continuing land subsidence and the expansion of built-up areas in eastern districts. The Jakarta Garden City area represents a strategic case study because it reflects the broader challenges faced by many urban residential developments in Indonesia that rely on polder systems for flood protection. By evaluating the performance of the existing drainage infrastructure and proposing more effective flood control alternatives, this research contributes not only to local flood management planning but also to the broader development of adaptive urban drainage strategies in rapidly growing cities. The findings are expected to support evidence-based policymaking for urban water management and provide practical recommendations for improving polder operation efficiency in flood-prone urban environments.

Based on these conditions, comprehensive flood control planning is required through evaluation of drainage system capacity, determination of planned flood discharge based on accurate hydrological analysis, and planning of a flow system integrated with regional flood control infrastructure. One alternative solution that can be implemented is to direct surface runoff to the East Flood Canal (BKT) as the main drainage channel, thus expected to reduce the risk of inundation and improve the performance of the flood control system in the Jakarta Garden City area.

METHODS

Flood modeling requires identifying flooded areas using the HEC-RAS program and collecting data to aid modeling. The graph below shows the methods used in the flood modeling analysis for each of the review watersheds.

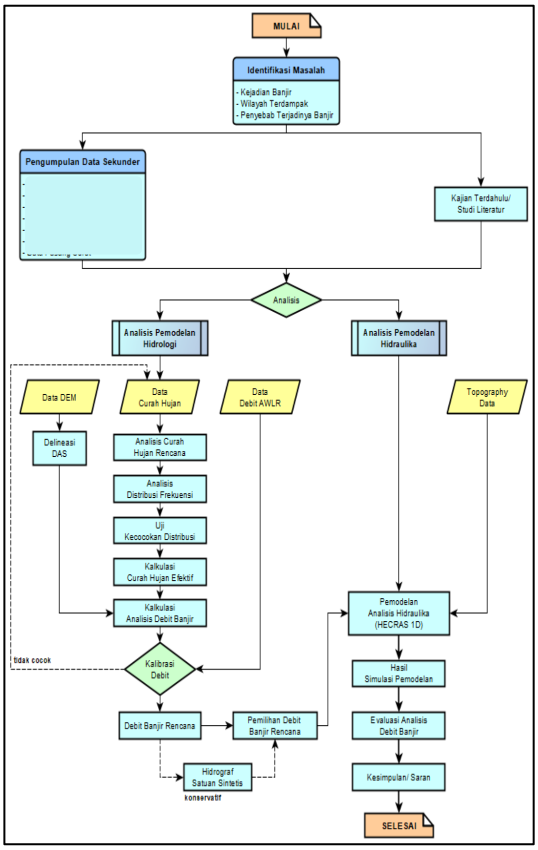

Figure 1. Framework of Thought

Primary and secondary data are required for any planning (Soedibyo, Dam Engineering, 1993).

1. Primary data

Collected from actual information about the current situation, as well as from interested parties. Data obtained from topographic measurements are the main source of this research.

2. Secondary data

This includes archival data that influences planning and is obtained from relevant agencies. The data required for flood modeling based on watersheds and polder systems include:

a. Rainfall data around the study area obtained from BMKG/SDA Bintek (STA Cawang)
b. DEM data obtained from DEMNAS/SRTM.
c. Land Cover Data

The polder system is a flood control method widely used in low-lying areas. This system controls water levels, discharge, and volume within an area bounded by embankments, preventing outside water from entering the system. Rainwater falling within the area is collected through a drainage network and channeled to reservoirs before being pumped out to receiving water bodies.

The primary function of a polder system is to control water levels to prevent ponding or flooding within the area. This control is achieved by temporarily storing water in retention ponds or reservoirs and then releasing it using pumps according to the system's capacity.

A polder system consists of several main components: a drainage network to collect runoff, a holding pond for temporary storage, a dike to demarcate the area, and a pump to control outflow. The performance of a polder system is greatly influenced by the balance between incoming water flow, storage capacity, and the pump's ability to drain water from the system.

The research location is in the Jakarta Garden City area, Cakung District, East Jakarta Administrative City, DKI Jakarta Province. Geographically, this location is in the Universal Transverse Mercator (UTM) coordinate system zone 48S with the WGS84 ellipsoid reference. The coordinate points of the research location are at X = 717833.00 m and Y = 9318832.00 m, or geographically located at 0°6'17.2067" South Latitude and 114°53'23.3966" East Longitude.

The topography of the study area is relatively flat with low elevations, potentially causing flooding during heavy rainfall. Topographic measurements were conducted using the JK 11 benchmark point located near the study site. Topographic data is used as the basis for hydrological and hydraulic analyses, as well as for modeling drainage systems and flood control.

Hydrological analysis is conducted to determine the characteristics of rainfall and planned flood discharge as a basis for planning a flood control system. The analysis stages include determining the watershed (DAS), processing rainfall data, analyzing the planned rainfall, and calculating flood discharge. Watershed delimitation was conducted to determine the boundaries of the water catchment area that affected the study location. Next, rainfall data was analyzed through a process of checking, filling in missing data, and consistency testing. Regional rainfall was calculated using the algebraic average method and Thiessen polygons to obtain representative values.

The design rainfall analysis was conducted using several probability distributions, namely the Gumbel method, Log Pearson Type III, and Log Normal. The best distribution was selected through a goodness-of-fit test using the Chi-Square and Smirnov-Kolmogorov methods. Next, the planned flood discharge was calculated using the Snyder synthetic unit hydrograph method. These results were then used in hydrological simulations using HEC-HMS software to obtain peak flood discharges with various return periods.

Hydraulic analysis was conducted to determine the channel's capacity to carry flood discharge and evaluate the potential for runoff. This analysis used HEC-RAS software, which can simulate one-dimensional flow under both steady and unsteady flow conditions. The data used in the modeling includes channel geometry, cross-sectional and longitudinal measurements, Manning's roughness coefficient, and the planned flood discharge derived from hydrological analysis. Furthermore, boundary conditions are determined based on the flow characteristics upstream and downstream of the system. Hydraulic calculations are based on the Saint-Venant equations, which include the continuity and momentum equations. Simulation results are used to determine water level profiles, channel capacity, and potential inundation. Thus, this analysis forms the basis for designing an effective and integrated flood control system.

FINDINGS AND DISCUSSION

Hydrological Analysis

Hydrological analysis was conducted to determine the characteristics of rainfall in the study area as a basis for flood control planning. The data used consisted of maximum daily rainfall, which was then analyzed using several probability distribution methods, including Log Pearson Type III, Gumbel, Normal, and Log Normal.

Calculations using these various methods aim to obtain design rainfall values for several return periods, allowing comparisons and the most appropriate method to be selected. The results of the design rainfall calculations using each method are presented in the table below.

Table 1. Results of Planned Rainfall Calculations

No.	Periode Ulang	Log Pearson III	Gumbel	Normal	Log Normal
		mm	mm	mm	mm
1	2	118,713	114,506	120,05	113,066
2	5	156,63	163,454	154,493	155,664
3	15	186,445	211,406	179,914	197,096
4	25	198,975	236,811	190,097	216,635
5	50	209,481	267,188	204,106	246,723
Rata-rata		174,049	198,673	169,732	185,837
Jumlah		870,243	993,365	848,66	929,184
Sd		36,729	60,488	33,168	52,413

Source: 2026 Calculation Results

Table 1 shows that the design rainfall value increases with increasing return period. Each distribution method produces different results, with the Gumbel method tending to produce higher values than the others, while the Normal method produces relatively lower values. These differences are due to the characteristics of each method in accommodating extreme data. Therefore, a distribution fit test is necessary to determine which method best represents the rainfall data used.

Suitability Test Analysis

Determining planned rainfall requires a distribution method that matches the data characteristics. Therefore, a goodness-of-fit test was conducted using the Smirnov-Kolmogorov and Chi-Square methods, while considering the standard deviation values of each distribution.

Tests were conducted on several distribution methods, namely Log Pearson III, Gumbel, Normal, and Log Normal. The results of the goodness-of-fit tests were used to determine the distribution method that best represented the rainfall data.

The results of the suitability test calculations are presented in the following table.

Table 2. Smirnov-Kolmogorov Goodness-of-Fit and Chi-Square Tests

Metode	Metode Smirnov	Metode Chi Kuadrat	Standar Deviasi	Analisis Frekuensi
Normal	OK	OK	33,168	Tidak Memenuhi
Log Normal	OK	OK	52,413	Tidak memenuhi
Gumbel	OK	OK	60,488	Memenuhi
Log Pearson III	OK	NO	36,729	Memenuhi

Source: 2026 Calculation Results

Based on the suitability test results, the Gumbel method met the Smirnov-Kolmogorov and Chi-Square test criteria and had the smallest standard deviation. Therefore, the Gumbel method was selected as the basis for calculating the planned rainfall in this study.

Rain Intensity Analysis

Rainfall intensity calculations were performed assuming a 5-hour rainfall duration using the Mononobe method, based on maximum daily rainfall data. This method is used to distribute rainfall into hourly rainfall to obtain an effective rainfall pattern.

The results of the analysis of rainfall intensity distribution for a 2-year return period are presented in Table 3, which shows the variation in rainfall intensity at each hour and the percentage distribution.

Table 3. Analysis of Rain Intensity for 2-Year Return Period

t (jam)	Rt (mm)	I (mm/jam)	Bobot	I (mm/jam)	Persentase (%)
1	114,506	39,697	0,120	13,576	12,002%
2	114,506	25,008	0,221	25,008	22,107%
3	114,506	19,084	0,351	39,697	35,093%
4	114,506	15,754	0,169	19,084	16,871%
5	114,506	13,576	0,139	15,754	13,927%
Total		113,119	1,000	113,119	100%

Source of 2026 Calculation Results

Table 3 shows that the highest rainfall intensity occurred in the third hour, indicating that the peak rainfall occurred midway through the rainfall duration. This pattern indicates uneven rainfall distribution and a tendency for it to be concentrated at certain times.

The results of the analysis for various return periods are then summarized in Table 4 which shows the distribution of rainfall intensity for return periods of 2, 5, 15, 25, and 50 years.

Table 4. Summary of Rainfall Distribution Analysis Results

t (jam)	Rt (mm)	I (mm/jam)	Bobot	I (mm/jam)	Persentase (%)
1	236,811	23,591	0,120	23,591	12,002%
2	236,811	43,455	0,221	43,455	22,107%
3	236,811	68,981	0,351	68,981	35,093%
4	236,811	33,163	0,169	33,163	16,871%
5	236,811	27,375	0,139	27,375	13,927%
Total		196,565	1,0000	196,565	100%

Source: 2026 Calculation Results

Based on Table 4, it can be seen that the longer the return period, the higher the resulting rainfall intensity. Furthermore, the rainfall distribution pattern shows that maximum intensity generally occurs in the third hour, making this period a critical condition in flood discharge analysis.

The results of this rainfall intensity analysis form the basis for determining the planned flood discharge used in hydraulic analysis.

Hydraulic Analysis

Hydraulic analysis was performed using HEC-RAS software to model channel flow, taking into account geometric conditions, channel roughness, and design flood discharge. This modeling aims to determine flow characteristics and the channel's capacity to accommodate flood discharge.

In HEC-RAS modeling, the data used include channel geometry, topographic data, Manning's roughness coefficient, and the design flood discharge obtained from previous analyses. Calculations are based on a one-dimensional energy equation, taking into account energy losses due to friction and changes in cross-section.

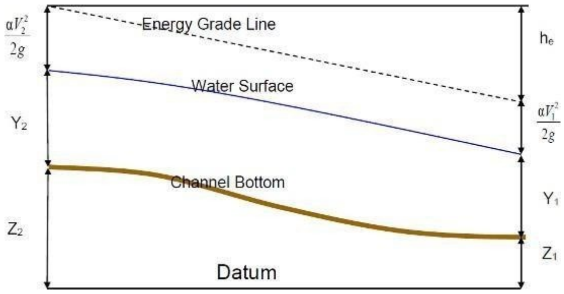

Figure 2. Energy Equation Scheme

Source: HEC-RAS User Manual, Brunner, 2020

Based on this scheme, the water surface profile is calculated using the standard step method, which calculates the energy change from one cross-section to the next. Furthermore, the calculation also takes into account the distribution of flow between the main channel and the overbank to obtain accurate conveyance values.

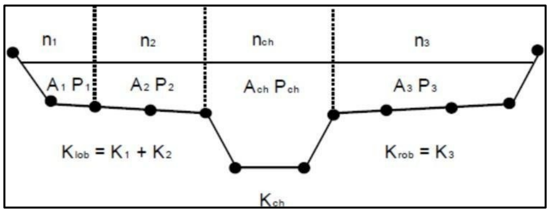

Figure 3. Schematic for Default Conveyance Subdivision Method

Source: HEC-RAS User Manual, Brunner 2020

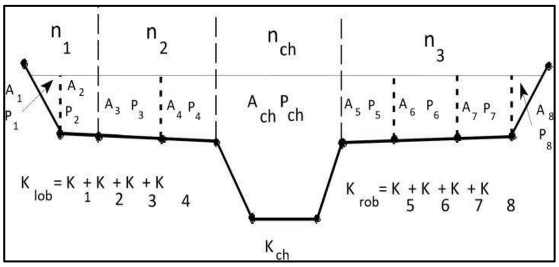

Figure 4. Schematic for Alternative Conveyance Subdivision Method

Source: HEC-RAS User Manual, Brunner, 2020

Both methods are used to describe the distribution of flow within the channel cross-section, both in the main channel and in the left and right overbank sections. Furthermore, the results of the hydraulic modeling using HEC-RAS are displayed in the form of longitudinal profiles and cross-sections of the flow.

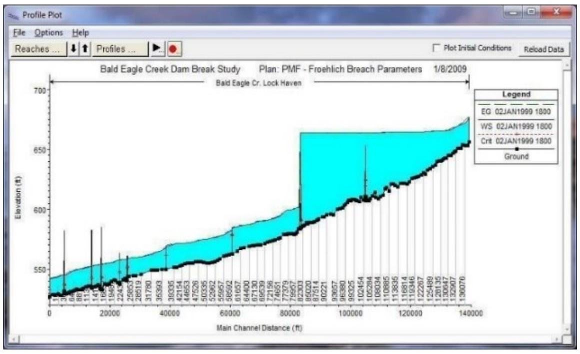

Figure 5. Example of Longitudinal Cross-Section and HEC-RAS Model Output

Source: HEC-RAS User Manual, Brunner, 2020

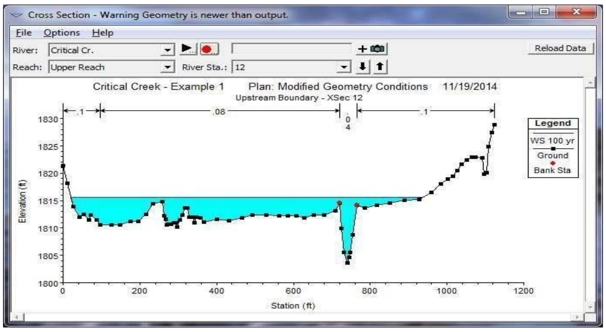

Figure 6. Example of Cross Section and HEC-RAS Model Output

Source: HEC-RAS User Manual, Brunner, 2020

Simulation results show that the water surface profile is influenced by channel geometry, roughness, and the magnitude of the flood discharge. This analysis is used to evaluate channel capacity and the potential for overtopping under specific discharge conditions.

Alternative Flood Control Planning

To improve the effectiveness of the flood control system in the Jakarta Garden City area and its surroundings, an evaluation of the capacity configuration and number of pump units in the Marunda Sub-Polder system (Reservoir C) and the Adhiyaksa Pump House was conducted. This evaluation aimed to achieve a more hydraulically optimized and operationally efficient system.

Based on the Jakarta Planning Criteria (KPJ), the pump capacity of Reservoir C was planned at 5.5 m^3/s, with an initial configuration of five pumps, each with a capacity of 1.1 m^3/s. However, based on the results of hydrological analysis and hydraulic modeling using HEC-RAS, alternative pump configurations were implemented to improve system efficiency.

The proposed alternative configuration consists of 2 pump units with a capacity of 2 m^3/second each and 1 pump unit with a capacity of 1.5 m^3/second, so that the total capacity still meets the planned flood discharge requirements.

A comparison of the initial and alternative configurations shows that using fewer pump units with higher capacity can improve operational efficiency and simplify system management. Furthermore, this alternative offers mechanical and electrical benefits, such as reduced maintenance requirements and optimized energy use.

CONCLUSION

Based on the results of hydrological and hydraulic analysis, as well as evaluation of the polder system in the Jakarta Garden City area, the following conclusions can be drawn: 1) The results of the hydrological analysis with a planned rainfall of 15 years return period show that the flood discharge that occurred exceeded the capacity of the existing drainage system, causing flooding in several areas. 2) Hydraulic modeling using HEC-RAS shows the presence of inundation with a water level reaching ±0.4 m, which indicates that the capacity of the polder channels and reservoirs is not yet able to optimally accommodate the planned flood discharge. 3) The existing pumping system is capable of controlling flooding, but requires a relatively long operating time to lower the water level, so the system's performance is still not efficient in responding to flood events. 4) The flooding problem that occurred was included in the category of local drainage flooding which was influenced by regional rain runoff and the performance of the polder system. 5) The planning alternative is to change the pump configuration to a smaller number of units with a larger capacity, which is still able to meet the planned discharge requirements and increase the operational efficiency of the system.

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