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Original Article

Drainage Analysis of Pondok Jati Housing and Drainage Replanning

Hasan Alif Fathurokman[1*], Esti Wulandari[2], Laksono Djoko Nugroho[3]

[1-3]Departement of Master Civil Engineer, Faculty of Engineer, Universitas 17 Agustus 1945 Surabaya, Surabaya, Indonesia
Email: [1)] hasanalif80@gmail.com, [2)] wulandariesti@untag-sby.ac.id,
[3)] laksononugroho7366@gmail.com

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Abstract

The Pondok Jati housing complex is less able to receive or accommodate rainwater discharge due to changes in channel dimensions, shallowing of channels, and dirt due to waste from people who do not care about the local environment. To anticipate this, it is necessary to repair and build infrastructure that functions as a flood controller according to the characteristics and conditions of the location. Efforts made for this are to redesign drainage at low cost. Hydrology and Hydraulics methods are applied to obtain a 5-year planned discharge and existing channel discharge, to plan channels with a 5-year planned return period. The existing channel discharge for the Pondok Jati housing complex is obtained as much as 0.450 m3/sec, and modeling is carried out in accordance with SNI 02-2406-1991: Procedures for general planning of urban drainage. With the redesign, the planned channel dimensions are obtained measuring 0.50 m x 0.75 m, in the form of a square without a cover.

Keywords: Drainage, Hydrology, Replanning.

1. Introduction

Water stored on the surface generally turns into runoff and much faster than groundwater, given the very low flow rate of the latter. In the rainy season, drainage in the Pondok Jati housing complex is less able to receive or accommodate rainwater discharge due to changes in channel dimensions, shallowing of channels, and dirt due to garbage from people who do not care about the local environment, causing the water to recede in the area for a very long time.

According to Nugroho and Abduh (2023), to anticipate this, it is necessary to repair and build infrastructure that functions as a flood controller according to the characteristics and conditions of the location. Efforts made for this are to redesign drainage at low cost. A well-designed drainage system prevents inundation, flooding, and other negative impacts on the environment and people's lives (Cahyono & Wjaya, 2024). In many areas, especially in rapidly developing urban areas, existing drainage systems are often inadequate to cope with increasing rainfall intensity, changing runoff patterns and the needs of the population. For example, research using the Storm Water Management Model (SWMM) in South Tangerang found that channel dimensions need to be redesigned to accommodate certain maximum discharge rates (Cahyono & Wjaya, 2024).

In addition, urbanization exacerbates the performance of drainage systems, as seen in a study in Macaé, Brazil, where land use change led to increased flood risk and decreased channel capacity (de Souza & Junior, 2023). Evaluation of the existing channels also shows that most of the drainage systems are not able to accommodate the volume of water during heavy rainfall, so that re-planning strategies are needed, such as the implementation of retention ponds and improvement of channel dimensions (Juliastuti et al., 2023). On the other hand, the implementation of Sustainable Urban Drainage Systems (SUDS) is gaining ground in many countries to recycle stormwater, reduce environmental impacts, and improve urban sustainability (Vilariño et al., 2015).

However, drainage planning challenges are growing due to the effects of climate change induced extreme rainfall and uncontrolled urbanization, requiring adaptive and sustainable solutions in the design and re-planning of drainage systems (Zhang et al., 2014). This is relevant in the case of Pondok Jati Housing, where drainage system analysis and re-planning is needed to mitigate flood risk and create a safer and more comfortable environment for the community.

2. Literature Review

2.1. General Planning Procedures for Urban Drainage

Urban drainage planning needs to pay attention to the function of urban drainage as a city infrastructure based on the concept of environmentally conscious development (Yazdanfar & Sharma, 2015). This concept is related to efforts to conserve water resources, which in principle is to control rainwater so that more of it is absorbed into the ground and not wasted as surface flow (Kinkade-Levario, 2007), including by creating artificial infiltration structures, tendon ponds, landscaping and terraces (Indonesia, 1991). The stages of urban drainage planning include:

1) The stages are carried out by making a master plan, feasibility study and detailed planning, with the following explanation:
   - a feasibility study can be made as a continuation of the creation of a master plan;
   - detailed planning needs to be done before urban drainage construction work is carried out;
2) Urban drainage in cities and large towns needs to be planned comprehensively through the master plan stage.;
3) Urban drainage in medium and small cities can be planned through the framework planning stage as a replacement for the master plan.;
4) Urban drainage in medium-sized cities that have rapid physical growth and population growth as well as urban drainage that has complex problems due to local natural conditions, requires comprehensive planning through the master plan stage.;
5) Urban drainage should be planned with various alternatives, and the selection of the best alternative is carried out through a review process that takes into account technical, socio-economic, financial and environmental aspects.;
6) Surveys conducted in the context of urban drainage planning include location, topography, hydrology, geotechnics, land use, socio-economics, institutions or institutions, community participation, population, environment and financing.;
7) Investigations carried out in the context of urban drainage planning are further details of survey work to obtain design parameters.;
8) Urban drainage design should be based on hydrological, hydraulic, structural and cost considerations.;
9) Land preparation for urban drainage construction to be carried out in accordance with applicable laws and regulations;

10) Implementation of urban drainage must be carried out in accordance with commonly used construction regulations and approved by the authorized agency;
11) Operation and maintenance of urban drainage in order to comply with the regulations commonly used and approved by the authorized agencies.

2.2. Drainage System Planning

Some technical aspects in drainage planning include the flow coefficient (C), the shape of the channel cross-section, channel material, channel slope, flow velocity, Manning roughness coefficient and freeboard. The next step to plan the channel dimensions is to find out the planned discharge. The planned discharge is known from the area to be drained/flowed with runoff water (Wibawanto & Suhel, 2023). It needs to be synchronized with city maps and topographic maps to find out the amount of water discharged/flowed based on land use. Then determine the location of the channels (inlet/outlet) from the smallest channel to the main channel. After the discharge for each channel is obtained, calculate the channel dimensions (Saidah et al., 2021).

2.3. Replanning Drainage

Kahuripan Nirwana housing complex and Toll Road, also flowed to Pondok Jati housing complex. As a result, much water accumulates in the drainage of Pondok Jati Housing, so that flooding often occurs in Pondok Jati Housing when the rainy season arrives. In connection with this problem, an evaluation needs to be carried out related to the effectiveness of the channels and drainage needs. For this reason, it is necessary to re-plan the drainage with an environmental perspective which is expected to meet the capacity of the water discharge that will flow and there will be no puddles in the residential area without harming the surrounding environment so as to avoid flooding (Widarmano et al., 2022) .

3. Methods

3.1. Research Flow Chart

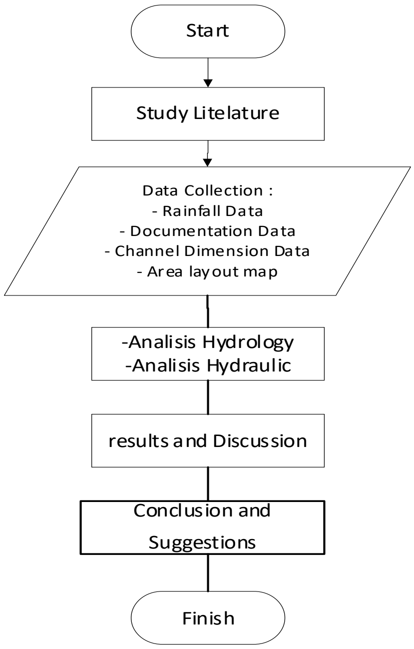

Figure 1.Research Flowchart

3.2. Research Procedure

a. Survey Primer

Searching for data that is not written, or data that has a high level of accuracy. The surveys conducted include the following:

- Filed Observation
- Interview

b. Survey Secondary

It is a data search through literature review, previous research results, required maps, population data, research area conditions obtained from related agencies. The purpose of this survey is to obtain data that will then be processed with proven analysis methods.

c. Hydrological data testing

From the data obtained, rainfall data will be tested to become the average arithmetic method with the formula:

$$\bar{P} = \frac{P_1 + P_2 + P_3 \ldots + P_n}{n}$$

explanation :

$\bar{P}$	= Average rainfall area
P1, P2, ..., Pn	= Rain in station 1, 2, 3, ..., n
n	= Number of rain stations

d. Determining the Recurrence Period

Determine the return period based on city typology, from a watershed area of less than 500 ha using a maximum return period of 5 years.

e. Design Rainfall

The calculation of the planned rainfall is processed based on the amount of planned rainfall, the amount of rainfall intensity to calculate the planned flood discharge in order to be calculated. The calculation of planned rainfall using frequency analysis can be done using; distribution normal distribution, log normal distribution, type III Log Pearson distribution dan Gumbel distribution.

f. Distribution Test

The Frequency suitability test is useful for knowing the results of rainfall analysis on vertical and horizontal data deviations, so that it can be known and accepted or not the distribution method used. The method used is:

- Test Chi-Square
- Test Smirnov-Kolmogorov

g. Rainfall Intensity

If only daily rainfall data is available, then rainfall intensity can be estimated using the formula mononobe (Andung et al., 2019) as follows:

$$I = \frac{R_{24}}{24} \left[\frac{24}{t}\right]^{2/3}$$

h. Planned Flood Discharge

The planned flood discharge is the maximum amount of water that is estimated to flow to a place or river basin during a flood. To calculate the planned flood discharge, the rational method is used with the following formula:

$$Q = 0{,}278 \times C \times I \times A$$

Q : Design flood discharge
C : Surface flow coefficient
I : Rain intensity during concentration time (mm/hour)
A : Water catchment area (km^2)

i. Hydraulic Analysis

Hydraulic analysis is carried out to obtain the channel capacity according to the existing channel conditions. The following is a formula that can be used as follows:

$$Q = V \cdot A$$

j. Flow Velocity Analysis

In the hydraulic analysis formula, the V value is calculated using the Manning method with the following formula:

$$V = (1/n).R^{2/3}.S^{1/2}$$

k. Drainage Design

In the drainage design that will be planned, it must follow SNI regulations, where the shape of the channel will affect the channel discharge.

3.3. Data Analysis Techniques

In a study, data collection is carried out which will be processed into a result of the research objective. The research data used are primary data and secondary data, where primary data is obtained from direct measurements and observations at the research location or field. While secondary data in the study were obtained from various sources where one of the data was obtained from rainfall summarized by the local Sidoarjo service.

4. Results and Discussion

4.1. Average Rainfall Data

This arithmetic method allows for calculating the average rainfall in an area. Measurements taken at several stations at the same time are added together and then divided by the number of stations.

Table 1. Average Area Rainfall

Years	Sidoarjo Station	Sumput Station	Durungbedug Station	Calculation	Average
2014	76.50	75.00	113.00	264.50	88.17
2015	89.94	77.00	100.00	266.94	88.98
2016	170.00	167.00	176.00	513.00	171.00
2017	110.00	175.00	119.00	404.00	134.67
2018	109.00	54.00	102.00	265.00	88.33
2019	97.00	91.00	71.00	259.00	86.33
2020	98.00	95.00	102.00	295.00	98.33
2021	101.00	98.00	93.00	292.00	97.33
2022	101.00	86.00	79.00	266.00	88.67
2023	72.00	65.00	81.00	218.00	72.67

Source: Author's Processed Data, 2024

4.2. Design Rain Results and Intensity

After getting the average value, the calculation of the design rainfall using the Log Pearson method with a 5-year return period that has been tested for frequency and obtained a value of 117.28 mm/day. From the planned return period, the intensity value was obtained with a concentration time of 6 hours, and the intensity value for the 5-year return period was obtained at 12.31 mm/hour.

Table 2. Kala ulang metode Log person type III

Return Period (Tr)	R planning	Explanation	Intensity
2	93.04	not used	9.77
5	117.28	used	12.31
10	137.23	not used	14.41

Source: Author's Processed Data, 2024

4.3. Flood Discharge Plan Analysis

Calculating Q5 years with a catchment area of 38.8 ha. For the surface flow coefficient value of 0.69 and the rainfall intensity of the 5-year return period of 12.31 mm/hour. Then it can be determined by the formula:

$$Q5 = 0{,}278 * 0{,}69 * 12{,}31 * 0{,}388$$
$$Q5 = 0{,}916\ m^3/s$$

4.4. Drainage Channel Redesign

In the field observations, the average channel in the Pondok Jati Sidoarjo housing complex is only able to accommodate 0.450 m^3/s. With a channel cross-section that was initially 0.45 m x 0.60 m, it will be planned to be 0.50 m x 0.75 m (slope 0.0087), with red brick plaster finishing materials.

5. Conclusion

From the results of the analysis of drainage of pondok jati housing complex in Sidoarjo, the planned discharge with a 5-year return period of 117.28 mm/day was obtained and the rainfall intensity was 12.31 mm/hour. In field observations, many drainage channels were found to be unsuitable because of the large amount of sediment deposits at the bottom of the channel. And the size of the pondok jari housing complex in Sidoarjo was found to only be able to accommodate 0.450 m3/s on average. To overcome the overflow that occurred, it was redesigned with a channel size that was initially 0.45 m x 0.60 m to 0.50 m x 0.75 m with a slope of 0.009 or 2%.

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