ISSN: 04532198
Volume 62, Issue 08, September, 2020

Analysis of Biopore Drainage System to Control the Floods in the Urban Cluster

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ABSTRACT— The research novelty was to find an effective drainage system for flood hazards in an urban cluster, which is located in a metropolitan city that is experiencing rapid development. The drainage system using biopore infiltration holes (LRB) is an effective system for dealing with flooding. The biopore infiltration hole is a cylindrical hole coated with a plastic pipe that is planted in the ground vertically with a diameter of 10 cm and a depth of 100 cm. The analysis of the LRB is based on daily average maximum rainfall, rainfall intensity, flood discharge, the number of LRB holes. The rainfall intensity analyzed using a diagram of the hyetograph approach. The result of the flood discharge plan was found around 0.98 m^3/second, it obtained by SWMM 5.0 modelling for a period of 100 years. The results demonstrated that 750 holes LRB on the roadside with a span of 750 meters near the primary channel may reduction the drainage load by 33.48 %. The discharge absorbed by the biopore infiltration hole is 0.328125 m3/second. The biopore infiltration hole was successful in reducing flooding in the urban cluster.

KEYWORDS: Drainage system, Biopore Infiltration Hole (LRB), Urban Cluster, SWMM 5.0

1. INTRODUCTION

Drainage is an important infrastructure component to drain excess water. Increased runoff due to days of catchment areas due to development can be overcome by building adequate drainage, so that excess water can be drained. The management quality of a city can be seen from the quality of the existing drainage system. The problem that often arises is that drainage often occurs as a less important job. This causes the drainage that has been made unable to accommodate air as needed so that even though the area already has a drainage network, there are still lots of stagnant air or even flooding [1], [4]. In addition, the existence of this development will affect the lack of rainwater catchment areas which will affect the decrease in the ability of the soil to help infiltrate rainwater [2][3]. Flooding in an area is caused by the drainage system that is unable to accommodate rainwater so that the rainwater spills over to the road. Drainage channels are an important infrastructure component for channeling excess water. Increased runoff due to reduced catchment areas can be mitigated by the construction of adequate drainage channels, which can drain excess water. Currently the existence of the drainage system is one of the most important urban infrastructure assessments [5], [6]. As much as 80% of the rainwater that fell is converted into surface water instead of ground water. This is due to the fact that most of the land surfaces are covered with either concrete or cement, thus making the rainwater unable to be absorbed into the soil. As shown in an urban cluster condition in Figure. 1. This urban cluster in South Tangerang, Indonesia is often experiencing flooding when it rains. Inundated areas usually have low contours and small-dimensional channels. Drains that cannot accommodate wastewater can cause flooding. For this reason, it is necessary to conduct research on the amount of runoff that occurs and its suitability with the available drainage channels. One of the ways to handle floods is by repairing the drainage channel which functions as a place for water to flow. Subsequently, by developed the analysis of rainfall Intensity Duration Frequency (IDF) which is the amount of rainfall expressed by height and volume of rainfall, it one of hydrological method to design extensive drainage systems [9].

Figure 1. Flood Conditions in Urban Cluster

This study is how to determine the discharge plan in the drainage channel and how to determine the magnitude of the effect of biopore infiltration holes (LRB) in reducing flooding. In this research the problem boundaries include the following: (1) The drainage capacity in the housing which is used as research material, (2) Hydrological analysis (3) Modelling using SWMM (4) Biopore infiltration holes planning. This research is expected to provide benefits to the urban community, especially the residents of the Housing. In addition, the study is addresses as initial information or reference material in planning of drainage management, in order to avoid stagnant water or flooding in residential areas.

2. Data Collection

Before calculating the hydrological analysis, it is necessary to know in advance size of the urban cluster watershed. Therefore, the first steps in the methodology is data collection in the urban residential. After that, the hydrological analysis allocated into some steps by determine rain cycle, average height rainfall, periodic rainfall and frequency distribution analysis. Furthermore, the modeling using SWMM which then evaluates the existing capacity of the watershed, if a flood occurs, a biopore infiltration hole is planned, while if there is no flood, the watershed capacity must be re-evaluated. The watershed that is reviewed in the calculation of flood discharge is a catchment area from falling rainwater. The cluster watershed is then divided into sub-watersheds where the boundaries of the sub-watersheds are determined based on the elevation and direction of the same flow in the existing conditions with an area of the area watershed of 0.27 km² which can be seen in Figure 2.

Figure 2. The Residential Watershed (Google Earth, 2020

3. Hydrological Methods

The planned flood discharge is the main guideline for planning water structures. To find out the flood discharge, the hydrological analysis is carried out by the cycle of the rainfall with the following structures:

3.1 The average and height of the daily rainfall

The daily of rainfall is found from the rain gauge stations namely Cisauk Station, South Tangerang Climatology Station, and UPTD Serpong station. It taken from rainfall data in year 2015 to 2019. The following recapitulation of the average daily rainfall can be seen in table 1.

Table 1. The Average of Daily Rainfall

No	Year	Month	Max rainfall.
1	2015	February	79
2	2016	November	84
3	2017	September	69
4	2018	December	60
5	2019	May	66

The analysis height of rainfall is obtained by Average Algebra Method; it is taking by the calculated average value from rain gauge stations

$$R = \frac{R1 + R2 + \square Rn}{n} \qquad (1)$$

3.2 The probability distribution analysis

To determine the rainfall run off planning, it is necessary to analyze the frequency of rainfall using probability distribution theory, which is used as a comparison among others. This research compared between normal Distribution, Log normal Distribution, Log Pearson Type III Distribution and Gumbel Distribution. After obtaining a distribution that meets the requirements, then the frequency distribution conformity test is carried out [9]. After determining the distribution used, the intensity of rainfall is calculated.

3.3 The intensity of rainfall

The intensity of rainfall is the height of rainwater per unit time. The general characteristic of rain is that the shorter of the rainfall, the intensity tends to be higher and the greater of the return period, the intensity would be higher. The relationship between intensity, duration of rain and frequency of rain is usually expressed in terms of the Intensity - Duration – Frequency (IDF) curve. It needs the short-term rainfall data, for example 5 minutes, 10 minutes, 30 minutes, 60 minutes and hours as requirement to form the IDF curve. The intensity of rainfall is formulated as follows:

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

I = The intensity of rainfall (mm / hour)
t = length of rainfall (hours)
R_{24} = maximum rainfall in 24 hours (mm)

4. Modeling with SWMM 5.0

SWMM was first developed in 1971 and has undergone several major developments or improvements since then. SWMM is used widely in the world especially in North America for planning, analysis and design related to rainwater runoff, combined canals, sanitation channels and other drainage systems in urban areas [10]. Runoff analysis can be carried out on a variety of distribution media such as pipe systems, open drain networks, reservoirs or treatment plants, pumps and regulators. SWMM generates the volume and quality of runoff that is transmitted from each sub catchment along with flow velocity, flow depth and water quality in each pipe and channel during the simulation period which consists of various time stages [11], [12]. Moreover, the method is shown as follows:

1) Sub catchment area analysis is the first step in using SWMM 5.0 is the distribution of sub catchments based on the research area. The sub-catchment division is carried out by paying attention to land elevation and movement of runoff that enters the drainage channel.

2) Determination of pervious and impervious areas is done by observing the rainwater catchment area in the study area. After knowing the areas that can absorb rainwater (pervious) and those that cannot absorb rainwater (impervious), then the percentage of each pervious and impervious area will be calculated as input for the sub catchment data.

3) Network model creation is making a network model based on the existing drainage system in the field, so that a network model can be obtained that can represent the actual situation in the field. This network model is made up of a collection of visual and non-visual objects such as rain gauges, sub catchments, junctions, outfalls, conduits, map labels and time series.

4) Making a network model, it must be based on the existing drainage system in the field, so that a network model can be obtained that can represent the actual situation in the field. This network model is made up of a collection of visual and non-visual objects such as rain gauges, sub catchments, junctions, outfalls, conduits, map labels and time series.

5) Model simulation is carried out after the network model is made and all parameters have been entered. The simulation is said to be successful when the continuity error is <10%. Continuity error is a measure or error value that occurs in the modeling process using the SWMM program. In the SWMM simulation, the

amount of flood discharge is calculated by modeling a drainage system. Surface flow occurs when water in the soil reaches its maximum and becomes saturated.

6) The EPA SWMM 5.0 simulation outputs such as the amount of runoff in each sub catchment, water depth at each node & channel, flooded nodes and overflow channels.

7) The suitability of the capacity of the drainage channel, from the results of the analysis using the SWMM model, it can be seen that the suitability of the capacity of the drainage channel with the amount of runoff that occurs. If there are still overflow channels or flooded nodes, it can be concluded that the channel capacity is not in accordance with the amount of runoff. For this reason, it is necessary to change the dimensions of the drainage channel until an appropriate dimension is found so that there are no more abundant channels or flooded nodes

5. Biopore Infiltration Holes (LRB) methods

Biopore infiltration holes are holes that can be cylindrical, or cube shaped. The shape of the biopore infiltration hole depends on the available land. If the land is large enough, we are free to design a biopore infiltration hole according to the wishes of the owner. But if the land is narrow then simply made a cylindrical hole diameter of 10 cm. The depth of the biopore infiltration hole is not more than 100 cm from the soil surface. It should be noted that the depth of LRB should be adjusted to the depth of the groundwater level [7] [8]. The analysis is carried out by determine the value of the geometric factor (F) where the planned infiltration is located on completely porous soil with all the walls of the well permeable and a half-spherical base as follows:

$$F = \frac{2\pi H + \pi^2 R \ln 2}{\ln\{\frac{H+2R}{3R} + \sqrt{\left(\frac{H}{3R}\right)^2} + 1\}} \qquad (3)$$

F = geometric factor (m)
H = depth of each hole (1 m)
R = radius LRB (0.05 m)

Then find the amount of LRB needed to absorb all rainwater discharge with the following formula:

$$Q = F \times K \times H \qquad (4)$$

Q = discharge of water absorbed by LRB (m^3 / sec)
K = soil permeability (0.063 m / h = 1.75 x 〖10〗 ^ (-4) m / sec)
F = geometric factors (2.5 m)

To calculate the reduction in drainage load using the following formula:

% reduction of drainage loads = (LRB discharge / SWMM discharge) x 100 % (5)

Before looking for the depth of the biopore hole, an analysis is first carried out to determine the value of the geometric factor (F) where the planned infiltration is located on completely porous soil with all the walls of the well permeable and a half-spherical base was planned as follows:

1) LRB can be made up to 100 cm high.
2) LRB can be made with a diameter of 10 cm or 4 "the size of the PVC pipe with a distance of 100 cm

between holes.

3) LRB is made by including organic waste in it, which can be leaf waste, vegetable waste, or fruit waste.

4) LRB is made with the construction of pvc pipe, cover the perforated pipe, and provide cement around the outside of the hole mouth.

5) LRB should be made in locations where water collects when it rains, such as drains and close to drains. In addition, LRB can also be made around trees, changes to park contours, park edges, side fences and others while still paying attention to security aspects. Where the illustration of the LRB plan is shown in Figure 3

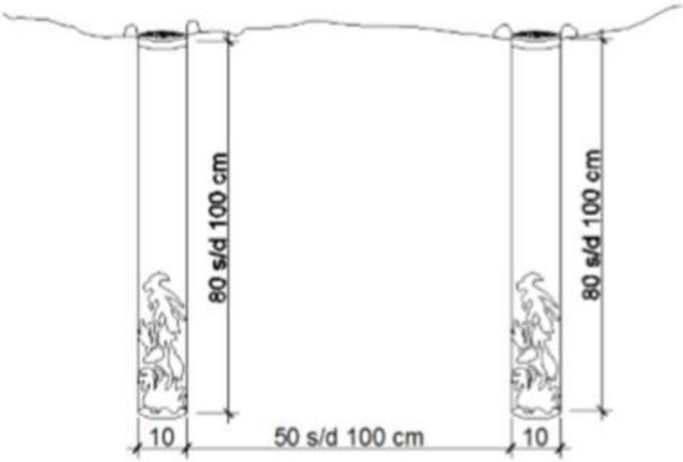

Figure 3. Biopore Infiltration Hole (LRB) Plan

6. Results and discussion

6.1 Hydrological

The rainfall intensity analysis was using Mononabe method. The distribution type used is Log Pearson III. This type of distribution has been tested using the Chi-square and Smirnov-Kolmogorov methods [9]. The following is a table of the results of the calculation of the R24 value and rainfall intensity for the return period of 2 years, 5 years, 10 years, 20 years, 50 years and 100 years:

Table 2. Calculation of Maximum Rainfall in 24 Hours

R_{24} (mm)	
2 tahun	70.446
5 tahun	82.907
10 tahun	91.157
20 tahun	98.967
50 tahun	109.317
100 tahun	116.993

Based on the results of rainfall intensity using. Mononobe then made an approach through the rain plan hyetograph by calculating the concentration time (tc) using the Kirpich formula [9]. The results are shown in Figure 4. While the intensity duration frequency curve results shown in Figure 5.

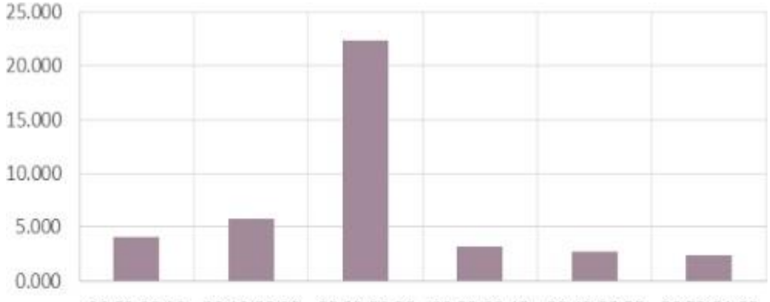

Figure 4. Hyetograph Rainfall

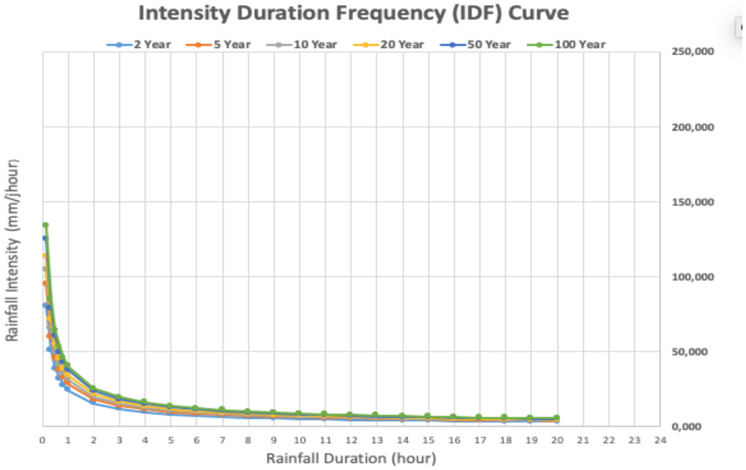

Figure 5. IDF Curve

Flood discharge calculation using EPA SWMM 5.0 modeling is done by making sub catchment, junction, conduit, and outfall. After modeling, 23 sub-catchments, 53 junctions, 49 conduits, and 1 outfall were obtained. The urban cluster is a densely populated housing with different sub catchments. Drainage network modeling can be seen in Figure 6.

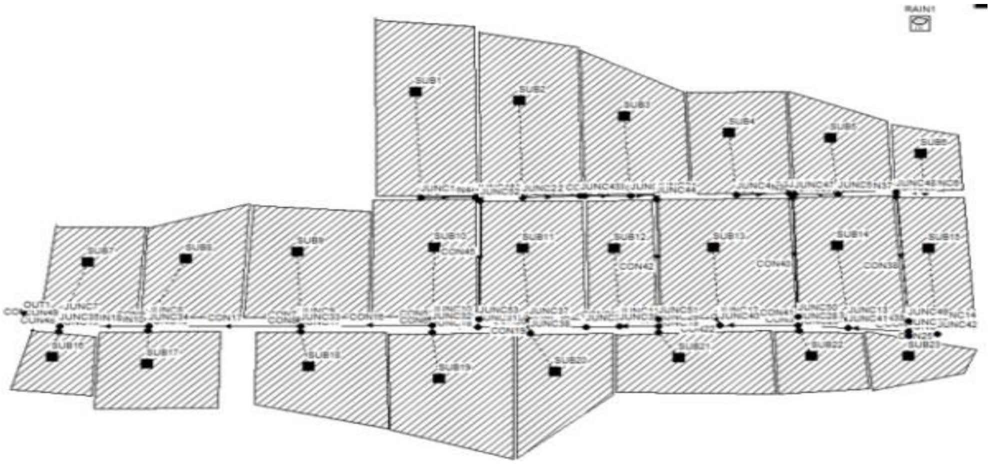

Figure 6. Modeling of Cluster Drainage Network

The research location is a densely populated settlement which has an impervious area of 65%. The sub catchment was built by a house had an impervious value of 65%. The sub catchment area can be seen in the table 3. The size of the sub catchment area varies widely. These various sub catchment areas determine the amount of runoff that occurs and then flows into the junction. The most extensive sub catchment was SUB1 with an area of 1.85 ha and had the potential to contribute the most to runoff. The smallest sub catchment is SUB16 with an area of 0.33 ha.

Table 3. Sub catchment Value

Sub catchment	**Area (ha)**
Sub 1	1.85
Sub 2	1.52
Sub 3	1.24
Sub 4	1.11
Sub 5	0.9
Sub 6	0.45
Sub 7	0.78
Sub 8	1.1
Sub 9	1.33
Sub 10	1.24
Sub 11	1.32
Sub 12	0.86
Sub 13	1.67
Sub 14	1.25
Sub 15	0.93
Sub 16	0.33
Sub 17	0.81
Sub 18	0.97
Sub 19	1.22
Sub 20	0.81
Sub 21	0.99
Sub 22	0.59
Sub 23	0.49

Another component used is the rain gauge stations data which is useful for providing rain plans to the drainage network model that has been made. The simulation flow is performed using rainfall data determined from rainfall analysis. The data is simulated in the team series with the hyetograph calculation of the rainfall data. In the around of 20 to 30 minutes are the highest rainfall values. It can be seen in Figure 7.

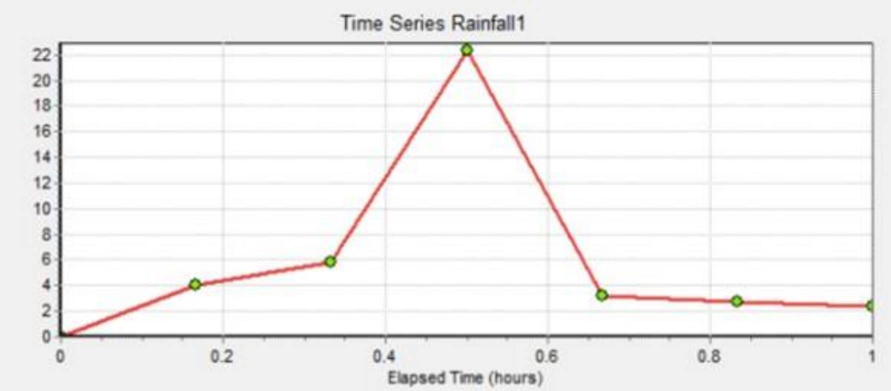

Figure 7. Rainfall Time Series

The next simulation is carried out to see the response of the water flow. The simulation produces a fairly good quality with a continuity error flow routing value of -0.05%. The simulation value is not good if the continuity error value reaches 10%. After the simulation was carried out, it was seen that the main channel had runoff. This means that the water flow in the drain is over capacity. In the 30th minute simulation, there are several channels whose discharge exceeds the capacity it should be because at the 20th to 30th minute the rain intensity peaks. The model simulation at 30 minutes can be seen in Figure 8.

Figure 8. Model Simulation Results

The simulation results show a different color for each component. The blue color shows the safest conditions because the discharge that flows on the channel is smaller than the channel capacity. The channel capacity is still in the actual channel condition according to the flow rate if the channel shows a blue, light blue, green, or yellow color. The red color on the channels CON12, CON14, CON15, CON16, and CON17 shows the results of the simulation, the flow that occurs exceeds the normal capacity. The overflows that occurs in these five channels are the result of the accumulation of the previous channels. The peak discharge on the primary channel at CON47 is 0.98 m³/s. It can be seen in figure 9. While, figure 10 shows water overflowing at JUNC42-JUNC27, JUNC28-JUNC29, and JUNC30-JUNC35.

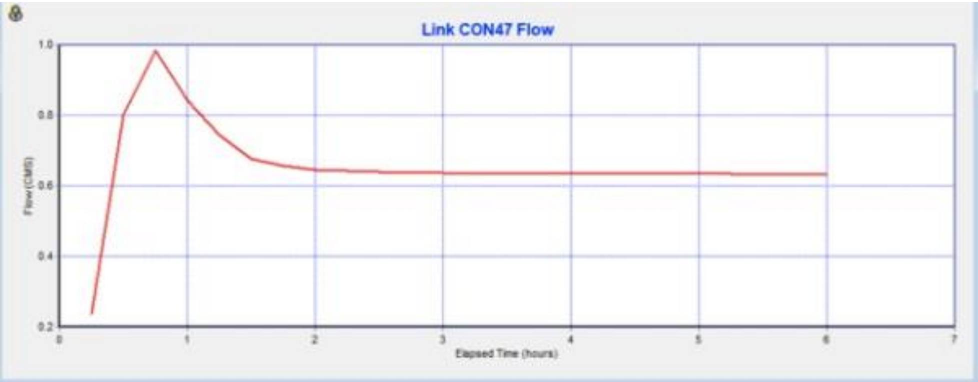

Figure 9. Inflow Curve on SWMM 5.0

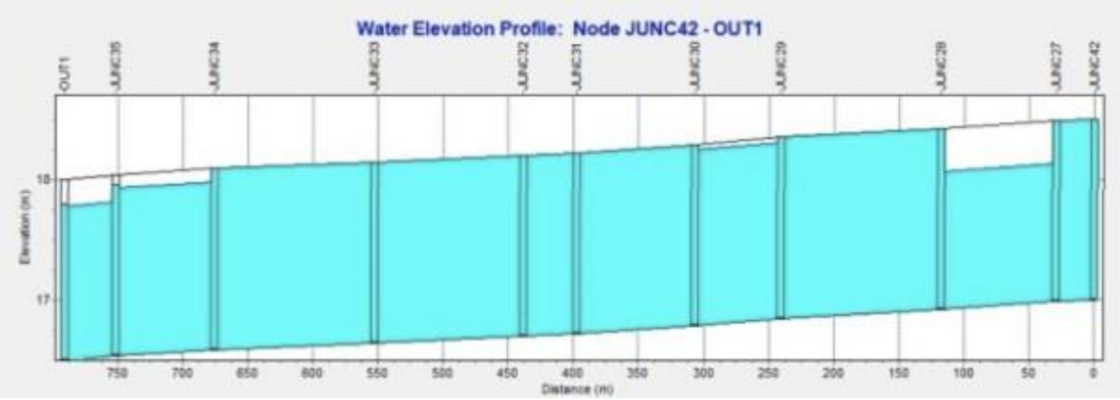

Figure 10. Profile Flow JUNC42-OUT1

6.2 Biopore Infiltration Holes (LRB)

The result value of the geometric factor (F) where the planned infiltration is around 2.5 m, the number of biopore infiltration holes (LRB) required 2240 holes to absorb all the rainwater discharge. However, due to the unavailability of open land for making 2240 biopore infiltration holes, the biopore infiltration holes are planned to be made along the roadside close to the primary channel with a distance of 1 meter between holes with amount 750 holes. Hence, the LRB can absorbed the discharge around 0.328125 m^3 / second. LRB that is implemented can provide many benefits. One of them is the benefit in reducing drainage loads. The reduction in drainage load in question is that with the presence of LRB, rainwater that falls and overflows will enter the LRB first so that it will reduce runoff water into the gutters to runoff leading to the drainage system. Rainwater that enters the LRB will increase the groundwater reserves at the location where the LRB is applied. The discharge that can be reduced with the biopore infiltration hole is 33.48%, so that the flow rate that occurs in the primary channel can be reduced by 33.48%. Therefore, the biopore infiltration hole can be used as an alternative flood prevention for the urban cluster.

7. Conclusion

Based on the simulation result by SWMM 5.0, it can be concluded that flood discharge around 0.98 m^3 / second. The problem of flooding that occurs in the cluster urban in South Tangerang due to overflows from the main channel can be overcome with biopore infiltration holes (LRB). Flood management by building Biopori infiltration holes is may considered as an appropriate solution for urban residents at this time. The biopore infiltration holes were made on the side of the road with a 750-meter span near the primary channel with a 1-meter distance between the biopore infiltration holes with a total of 750 biopore infiltration holes, with an LRB diameter of 10 cm and a depth of 100 cm. The discharge absorbed by the biopore infiltration hole is 0.328125 m^3 / second. The amount of utilization of biopore infiltration holes (LRB) in reducing drainage load around 33.48%. To support the successful implementation of LRB in urban housing, solidarity is needed from the residents so that the LRB implementation runs well. Regular maintenance is carried out on drainage channels such as cleaning up garbage and sediment, as well as in the infiltration building that has been made, and repairs are made if necessary.

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