JICE Journal Innovation of Civil Engineering

Vol. 4, No.2, p.116-128, 2023
Send: 22-07-2023 |
Received: 03-08-2023 |
Publish: 27-09-2023 |

INFILTRATION WELLS ECO-DRAINAGE PLANNING AS A FLOOD PREVENTION EFFORT IN BINANGUN SUB-DISTRICT, BLITAR REGENCY

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ABSTRACT

The existence of land use change and loss of water catchment areas causes environmental ecosystems to be disrupted. Previously, green land has changed its function to become a development area which causes an increase in the volume of surface water when it rains because the water is not reabsorbed by the soil. In October 2022, there was a flood in the Binangun sub-district which was caused by the overflow of the drainage canals and rivers due to the large volume of surface water that entered. As an effort to deal with the flooding problem that occurs, planning infiltration wells is an effective solution to reduce the volume of surface water in the Binangun sub-district. Infiltration well planning was carried out with hydrological analysis and design discharge with a rational calculation method. From the analysis, it was found that the planned debit value was 284.61m3/s. The soil permeability value was obtained from the Falling Head soil sample test. The permeability test results of the falling head method obtained soil permeability values in 3 regions namely, North = 0.003094m/s, Middle = 0.002827m/s, South = 0.001525m/s. The planning results showed that the dimensions of the infiltration wells for the Southern region are R=0.5m, L=1.5m, H=6m with the assumption that the number of design wells is 333 which can reduce the planned discharge in the Binangun sub-district area by 35%.

Keywords: *Infiltration Wells; Floods; Drainage Planning.*

1. Introduction

Climate change that is happening in Indonesia has caused an increase in hydrometeorological disasters. Such as floods, droughts, landslides, tornadoes, and forest fires[1]. One of the problems that we often encounter around us is flooding. Flood conditions are the inability of the canal to accommodate water or obstruction of the flow of water in the canal[2]. Floods that occur are not only caused by natural factors, but environmental changes and uncontrolled land use have resulted in the loss of water catchment areas being one of the major factors[3]. Land use changes that occur, such as logging forests that are used as residential areas or facilities and infrastructure, can affect the environmental ecosystem, which is disrupted, where when rain occurs, surface water can seep back into the ground, but changes in land use that occur result in a volume of water runoff. surface level rises and flooding occurs.

Binangun Sub-district is an area in the southeastern part of Blitar Regency, right to the south of the Brantas river[4]. It was previously rich in water catchment areas. However, development and changes in land use have recently become a frequent occurrence. With this, the water catchment area is reduced. In October 2022, a flood disaster occurred in Binangun Sub-district due to high rain intensity. Floods occur due to overflow of river water and primary drainage channels caused by an increase in the volume of rainwater that enters the canal or river. From the observations and analysis

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carried out, the main cause of flooding is the loss of water catchment areas in the area due to land use changes.

Eco-drainage is an environment-based water management system. In contrast to the conventional drainage system, where water is collected and channeled as quickly as possible to the final disposal/river, one of the eco-drainage systems is an infiltration well where the water that is on the surface is collected again and absorbed back into the soil before the water is released into the river. With that, the eco-drainage planning of infiltration wells is an effective solution as an effort to prevent flooding in Binangun Sub-district.

2. Materials and methods

Binangun sub-district is administratively located in the East Java Province, which is precisely in Blitar Regency with a geographical point of 8°12'22.662” South Latitude - 112°20'7.264” East Longitude.

2.1. Data collection

In this study, the data needed consists of primary data and secondary data, it can be seen as follows:

1. The primary data used is the soil permeability data which was obtained from the results of the Falling Head soil test[5] and was carried out independently by taking 9 samples of soil as a test material.
2. Secondary data is supporting data which needed as a reference for the analysis that carried out such as rain intensity data in the Binangun sub-district for the last 10 years. It was obtained from the Public Works and Spatial Planning Office of Blitar Regency, topological maps in Binangun sub-district, River Basin Maps (DAS), hydrology maps , soil movement maps, and several planning references in the book on sustainable urban drainage systems (Suripin), and calculation references on [6] Concerning the technical planning procedures for rainwater infiltration wells for yards.

2.2. Methodology

The stages of analysis carried out in the study are:

1. Average Rainfall

   The average rainfall data analyzed is in a certain period of time. Determination of the value of rainfall is taken according to the rain observation station (SPH) in the region. The rain observation stations taken according to (planning) have at least 3 comparison stations for data consistency and homogeneity. This method is used to calculate the average rainfall by taking into account the area of influence of each station [7].

   There are several ways to determine the average rainfall value in the region, there are 2 methods that can be used, namely [8]: Polygon Thiessen method, and Iso-hyet method. In accordance with regional conditions and the distribution of rain observation stations in Binangun sub-district, the Polygon Thiisen method of average rainfall is used. The formula for determining average rainfall is the Thiessen Polygon Method as follows[8]:

$$Ri = \frac{Ra\ x\ Aa + Rb\ x\ Ab + Rc\ x\ Ac}{Aa + Ab + Ac} \tag{1}$$

   Information :
   Ri : Average rainfall
   Ra : High average rainfallta area at Station A
   A A: Area at Station A

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2. Maximum Daily Rain
   There are two calculations to determine the maximum daily rain, they are Gumbel Method and Log Person III with the following equation [8]:
   Gumble:

$$XT = \bar{x} + sK \tag{2}$$

   Log Person III :

$$XT\ \log s = \log s\bar{x} + K \tag{3}$$

   Information :
   XT = Planned rainfall for the period of the year
   $\bar{x}$ = average sample price
   S = standard deviation (standard deviation) of the sample

3. Probability Distribution Testing
   The probability distribution test is carried out to determine which probability distribution equation can be used to show the statistical distribution of the sample data being analyzed [9]. Testing the suitability of rain data can be determined by means of Chi-square and Kolmogorov Smirnov [10].

4. Rain Intensity
   Rain intensity analysis is determined by three methods, namely: Bell, Van Breen, and Hasper Weduwen

5. Land Use
   This understanding shows that land is a landscape where all living things live and survive by making use of it [11].

6. Flow Coefficient
   The value of the flow coefficient is used to determine the design debris in the testing area [12]. For determining the flow coefficient with the following equation:

$$C = \frac{C1.A1 + C2.A2 + C3.A3 + \cdots Cn.An}{A1 + A2 + A3 + \cdots An} \tag{4}$$

   Information :
   C = flow coefficient
   A = catchment area (m^2)

7. Planning Debt
   In drainage planning, in general, the discharge calculation used is the rational method. Basically the calculation of the design discharge is used to determine the value of the peak flood plan discharge in an area. The formula for calculating the planned flood discharge using the rational method is as follows[8].

$$Q = 0.0027785\ CIA \tag{5}$$

   Q = Planning debt (m3 /sec)
   C = Surface flow coefficient
   I = Rainfall intensity (mm/hour)
   A = Watershed area (ha)

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8. Permeability Coefficient

Permeability is defined as a property of a material that allows seepage flow from a liquid in the form of water or oil to flow through the pore cavity [13]. The permeability value was obtained from the results of the soil sample test using the Falling Head method. The equation for determining the permeability value of the soil is used as follows[5]:

$$k = 2{,}303\,\frac{aL}{At}\log\frac{h2}{h1} \tag{6}$$

Q = Obtained water output debt (cm3)
K = Laboratory permeability value (cm/s)
a = Measuring burret pipe area (standpipe), Cm2
A = Cross-sectional area of the soil sample (m² or cm²)
L = Soil sample length (m or cm)
r = The fluid travel time L (s/second)
h1 = Initial height (m/cm)
h2 = Final height (m/cm)

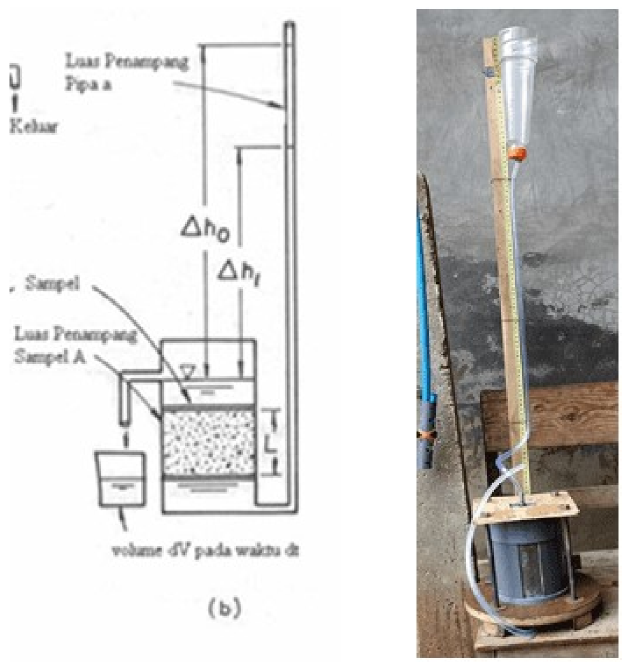

Figure 1. Falling Head Permeability Test Equipment
Source: Documentation, 2023

9. Infiltration Well Planning

According to the reference [8] The general requirements that must be fulfilled before planning an infiltration well are as follows:

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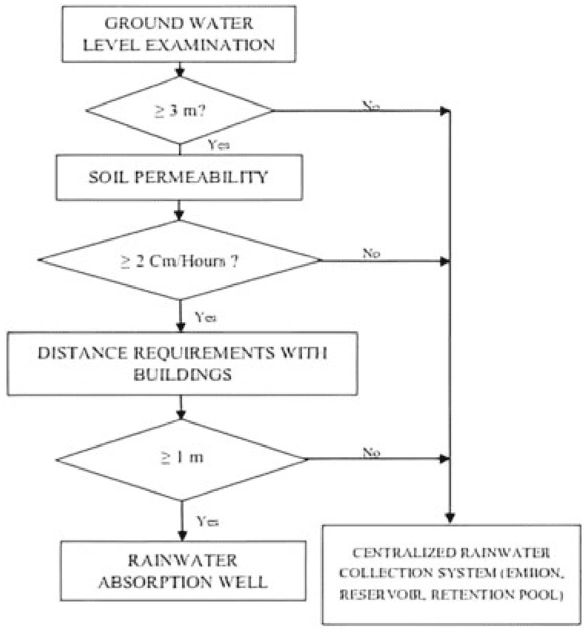


Figure 2. General Requirements for Infiltration Wells Planning
Source: Suripin, 2004

Infiltration well planning can be determined by the dimensions of the infiltration well according to the planned model. The types of infiltration wells are:

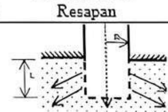
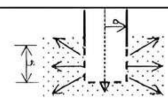
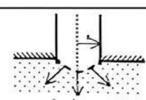
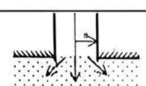
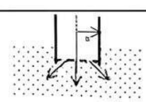
Sumur Resapan	Bentuk Sumur Resapan	Debit Resapan (Q_0)	Keterangan
SRB1		$Q_0 = \frac{2.\pi.L.K.H}{\ln\left(\frac{L}{R}+\sqrt{1+\left(\frac{L}{R}\right)^2}\right)}$	L = H dan permukaan tanah kedap air
SRB2		$Q_0 = \frac{2.\pi.L.K.H}{\ln\left(\frac{L}{2R}+\sqrt{1+\left(\frac{L}{2R}\right)^2}\right)}$	L = H dan permukaan tanah tidak kedap air
SRB3		$Q_0 = 2.\pi.R.K.H$	L=0, dasar sumur resapan berbentuk cembung, dan permukaan tanah kedap air
SRB4		$Q_0 = 4.R.K.H$	L=0, dasar sumur resapan berbentuk datar, dan permukaan tanah kedap air
SRB5		$Q_0 = 5{,}5.R.K.H$	L=0, dasar sumur resapan berbentuk datar, dan permukaan tanah tidak kedap air

Figure 3. Types of infiltration wells
Source: Sunjoto, 1988; in Suripin, 2004

In selecting the type of infiltration well, there are several provisions that must be considered, they are: land use conditions, soil vulnerability, and surface water flow and ground water flow. There is the formula example to determine the capacity of an infiltration well:

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$$H = \frac{Q}{FK}\left[1 - e^{-}\left(\frac{FKT}{\pi R^2}\right)\right] \tag{7}$$

Information :
H : water level in the well (m),
Q : inlet water debit (m3/sec),
F : geometric factor (m),
K : soil permeability coefficient (m/s),
Q : streaming time (seconds),
R : radius of the well (m).
The formula for determining the effectiveness of reduction is as follows:

$$\text{Qef} = \frac{Q\ tot}{Q\ renc} x\ 100\% \tag{8}$$

Qef : Effectiveness of reduced debit
QTot : Planned whole well debit (m3/sec),
Qrenc : Planned debit (m3/sec),

3. Results and Discussion

3.1. Hydrological Analysis

The hydrological cycle is an event that lasts continuously and does not know when it will end [14]. Rainfall data is annual data for the last 10 years in Blitar Regency taken from 3 Rain Monitoring Stations, they are: Kademangan Station, Wlingi Station, and Sumber-Ringin Station. From the rain data obtained are as follows:

Table 1. Rainfall Data for the Last 10 Years

No	YEAR	ST. KADEMANGAN	ST. WLINGI	ST. SUMBER-RINGIN
1	2022	126,4	267.5	272.25
2	2021	105,3	244.0	220,3
3	2020	79.0	233.6	241,1
4	2019	73.5	171.6	117,2
5	2018	113.8	115,3	130.8
6	2017	116.9	246.4	229.5
7	2016	193.0	322.9	311,2
8	2015	129.8	183.9	161.7
9	2014	119.5	177.6	162.3
10	2013	165,1	193.3	182.2
	AVERAGE	122	216	203
	Total	1096	1889	1756

1. Homogeneity Test
   Analysis carried out by rain data from 3 stations taken in the Binangun sub-district area was declared as homogeneous.

2. Rain Distribution Test
   The distribution test result showed that the data was acceptable and can represent the frequency distribution using the Chi Square and Kolmogorof Smirnof methods. The analysis result showed that the data is acceptable.

3. Maximum Daily Rainfall
   For the calculation of the HHM analysis plan discharge with the Gumbel method and Log Person type III. It can be seen from Table 2, the highest HHM value was selected by the calculation results.

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Table 2. Maximum Daily Rainfall (HHM)

PUH	HHM	
	Gumbel	log person III
2	196,1	173.9
5	274.3	216,1
10	329,1	243.3
25	399,1	277,1
50	451.3	302.0
100	503,2	326.7

Source: Analysis, 2023

4. Rain Intensity Analysis
For design safety, the intensity of rainfall chosen based on the calculation results tends to be higher. Figure 1 shows a comparison of the calculated rainfall intensity. As can be seen from Figure 1, the Van Breen method was used to calculate rain intensity.

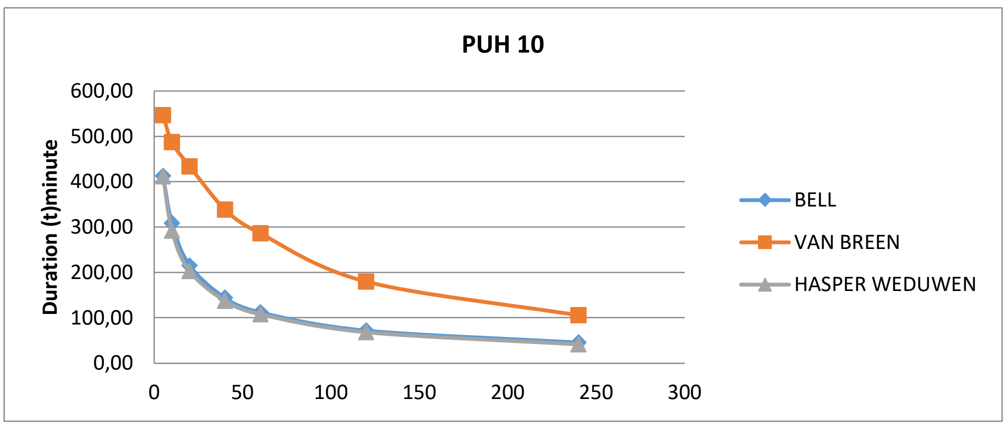

Figure 4. Intensity and Frequency Curves
Source: Analysis, 2023

5. Rain Intensity Formula Selection
In this study, 10-year Rain Return Period (PUH) was used, adjusted to the planning carried out. The calculation results showed that the selected formula for rain intensity is the Van Breen method formula as follows;

$$I = \frac{1302{,}81}{t^{0{,}413}}$$

3.2. Infiltration Well Planning

1. Planned Debit Analysis
The calculation of the planned discharge analysis was determined by the rational method. To determine the planned debit, firstly, the runoff coefficient value was determined [15] (C), the value of the planned rain intensity (I), and the area of the catchment area (A). From the calculations performed, the planned debit value was obtained, below:

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Table 3. Planned Debit Calculation

NO	LOCATION	C	I (mm/H)	A (Ha)	Q(m3/s)
1	KEC. BINANGUN	0.50	183.75	1105.70	284.61

Source: Analysis, 2023

Information:

$$Q = 0{,}0027785.C.I.A$$
$$= 0{,}0027785x\ 0{,}50\ x\ 183{,}75\ x\ 1105{,}70$$
$$= \mathbf{284{,}62\ m3/s}$$

From the calculation above, it was obtained that the planned debit (QRen) = 284.62 m3/

2. Soil Permeability Test
   For determining the soil permeability value in Binangun sub-district, Blitar Regency. The researcher conducted a soil sampling test independently with reference to previous research techniques and the Indonesian National Standard (SNI). Fixed permeability tests are suitable for granular soils such as sand, gravel, or a mixture of silt and sand. Falling Head permeability experiments are suitable for measuring the permeability of fine-grained soils[16].

Figure 5. Sampling Process at Sample Point 1 in Birowo Village
Source: Documentation, 2023

Soil samples were taken directly in the Binangun sub-district area. With the area studied for sampling, there were 9 samples taken from 9 different locations and spread across the region. The points taken based on the planned map are as follows:

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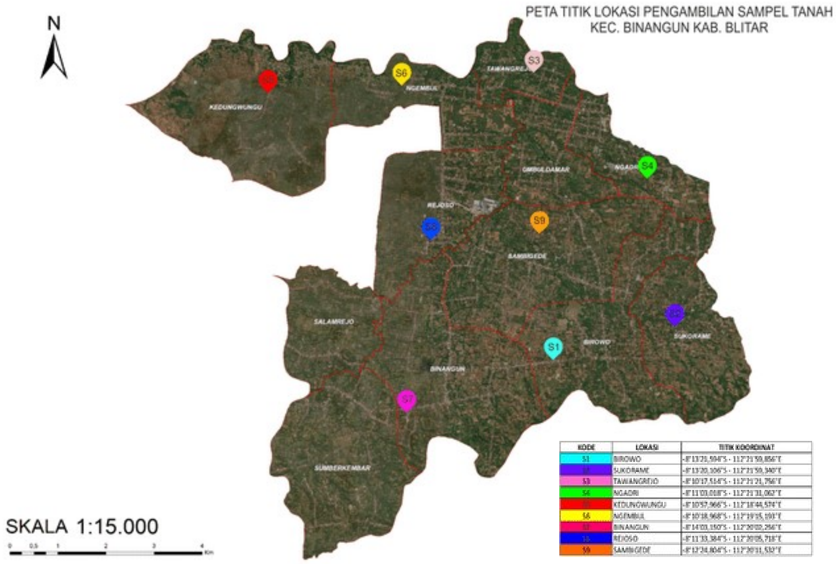

Figure 6. Sampling Points Map

Binangun sub-district is an area with slightly loamy fine-grained soil characteristics. Therefore, the Falling Head soil sampling test method was chosen as method to determine the permeability value (k) because the Falling Head method was suitable for fine grained soil characteristics.

Table 4. Soil Sample Test Result Data

	LOCATION	**: BIROWO**	
	NO. SAMPLE	: S1	
NO. TEST	1	2	3
Area of burette/pipe, a (cm^2)	0.2826	0.2826	0.2826
Sample Diameter, D (cm)	11	11	11
Sample Height, L (cm)	10	10	10
Sample Area, A (cm^3)	94,985	94,985	94,985
Initial Water Level, h1 (cm)	80	70	60
Final water level, h2 (cm)	70	55	45
Test Duration, t(s)	9.97	11.78	10,26
Volume of Water Obtained, Vw (cm^3)	20	26	13
K (permeability value)	0.0396163	0.084537548	0.08783256
Average Permeability (k) (Cm/s) 0.070662			

Source: Analysis, 2023

From the table above, the permeability values are taken 3 averages from the Binangun sub-district area, they are the North, Central and South Regions. The permeability values obtained are as follows:

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Table 5. Average Permeability Value

Region	Average K value (m/s)
North	0.003094
Middle	0.002827
South	0.001525

Source: Analysis, 2023

3. Infiltration Well Planning
   The planning of wells must consider the conditions and surface conditions that exist around, they are land use, vulnerability to ground movement, as well as groundwater flow and surface water flow.[16]. Therefore, the infiltration well design was obtained as follows:

   - Infiltration wells with high, local and moderate productive aquifer conditions with medium soil movement susceptibility (southern part of Binangun sub-district).

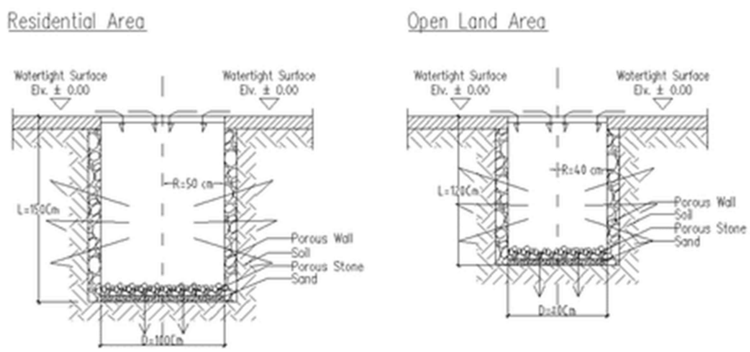

Figure 7. Infiltration Well Design for Southern Region
Source: Analysis, 2023

   - Infiltration wells with small productive aquifer conditions with very low soil movement vulnerability (the northern part of Binangun sub-district).

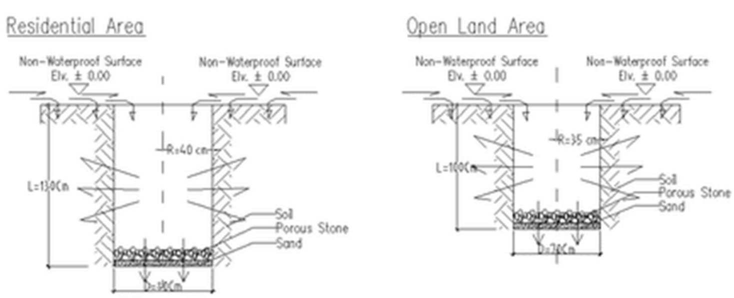

Figure 8. Infiltration Well Design for North Region
Source: Analysis, 2023

   - Infiltration wells with small aquifers with small soil movement susceptibility (central area of Binangun sub-district).

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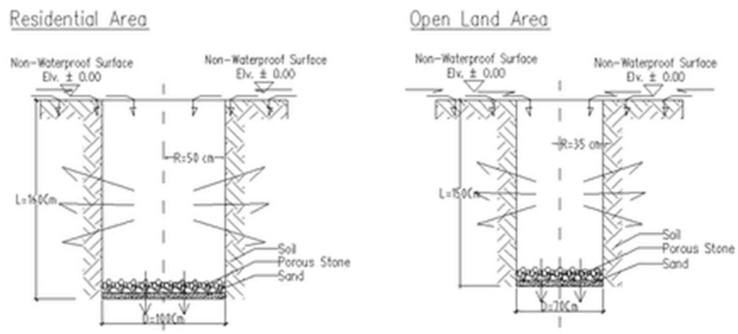

Figure 9. Infiltration Well Design for Central Region
Source: Analysis, 2023

From the planned dimensions, the number of infiltration wells is adjusted to the number of RTs, namely 333 wells. In Binangun District. It is assumed that there is 1 infiltration well in each RT.

Table 6. Total of Infiltration Wells

Location	Number of Wells
Southern Region of Binangun District	30
	40
North Region of Binangun District	64
	79
Central Region of Binangun District	58
	62
Amount	333

Source: Analysis, 2023

4. Infiltration Wells Effectiveness
   From the results of the infiltration wells planning, it can be determined the effectiveness of the infiltration wells values in reducing the planned flood debit as follows:

Table 7. Effectiveness of Infiltration Wells

Model	Location	Capacity	Amount	Qtot	Reduction percentage
Southern Region of Binangun District	Settlement	0.04741	30	14.223	0.50%
	Open field	0.03161	40	12.642	0.44%
North Region of Binangun District	Settlement	0.29467	64	188.591	6.63%
	Open field	0.33477	79	264.469	9.29%
Central Region of Binangun District	Settlement	0.32774	58	190.091	6.68%
	Open field	0.51298	62	318.049	11.17%
Amount		154.918	333	988.064	**35%**

Source: Analysis, 2023

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For the effectiveness of the entire area in Binangun sub-district with a total number of planned infiltration wells of 333 it can reduce the planned debit by 35%. From the planning above and referring to previous studies, Eco-Drainage of infiltration wells has considered effective in reducing water runoff discharge as an effort to deal with floods in Binangun sub-district.

4. Conclusion

From the results of the infiltration well drainage planning as a flood prevention in Binangun sub-district, the planned debit value (Q ren) in the study area was 284.62 m3/s. Infiltration well planning was divided into 3 parts of the area with 3 models based on the land use conditions, the vulnerability of soil movement and groundwater flow in the Binangun sub-district area. The permeability test results of the falling head method obtained soil permeability values in 3 regions they are North = 0.003094 m/s, Middle = 0.002827 m/s, South = 0.001525 m/s. From the planning results, the dimensions of the infiltration wells for the South region were obtained: for residential areas the radius of the well was R=0.5m, the depth of the planned well was L=1.5m, the depth of the groundwater table was H=6 m, for open residential areas the radius of the well was R= 0.4m, the depth of the planned well was L=1.2m, the depth of the groundwater table was H=5m with the assumption that the number of wells planned was 1 well in each RT according to land use in Binangun sub-district, it was 333 infiltration wells,

As a suggestion for further research, it is necessary to know that infiltration wells can be planned in all areas, but there were several things that must be considered, such as soil permeability values > 2 m/hour, groundwater levels > 3m, land use, vulnerability to soil movement and groundwater flow and planning. Infiltration wells were not grounded with a steep slope.

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Received: 03-08-2023 |
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