STUDY ON REGIONAL FLOOD DISCHARGE REDUCTION USING INFILTRATION WELLS (CASE STUDY OF PERUMAHAN TAMAN ALAMANDA INDAH IN MEDAN)

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Submitted: 17-12-2021	Accepted: 20-12-2021	Published: 19-04-2022

Abstract

Urbanization is one of the factors that cause an increase in the number of residents in urban areas. The increase in population impacts increasing settlements resulting in changes in land use. One of the residential areas in Medan City is Perumahan Taman Alamanda Indah which is located in Tanjung Selamat, Medan Tuntungan District. Around 60.7% of the area of Perumahan Taman Alamanda Indah is a impervious area in the form of houses and roads which causes high surface runoff when heavy rain occurs. The study aims to plan infiltration wells that can function to reduce flood discharge in Perumahan Taman Alamanda Indah area. The planned infiltration well is a communal well that is divided into several zones. It is planned that 50% of the maximum discharge of rain that falls on the roof of the house is absorbed into the infiltration well. From the results of the study, the required number of infiltration wells is 430 units with a diameter of 1 m and a depth of 2 m which is divided into 13 zones. The construction of this infiltration well can reduce the peak discharge in the Perumahan Taman Alamanda Indah by 36.71%.

Key words: *land use, infiltration wells, flood discharge*

INTRODUCTION

According to data from the Central Bureau of Statistics (*Badan Pusat Statistik*/BPS), the population of Medan in 2010 was 2,097,610 people and in 2019 it was 2,279,894 or an increase of 8.69% for 9 years (BPS,2021). The increase in population has implications for the increasing need for housing as a means of residence. Increasing housing development has resulted in changes in land use from open land to closed land.

Changes in land use due to housing development result in an increase in the runoff coefficient in an area. If this condition is not taken seriously, it will result in an increase in flood discharge in the area, especially for areas that do not have a good drainage system. Changes in land use result in changes in the hydrological regime as indicated by an increase in the runoff coefficient and a decrease in baseflow and a tendency to increase the annual maximum discharge and decrease the average annual minimum discharge (Hary et al., 2017). An increase in the average annual runoff, flood discharge, flood frequency, and flood volume are some of the impacts that can be caused by urbanization (Du et al., 2012). Covered soil due to infrastructure development using concrete reduces water infiltration into the soil and increases surface runoff (Pilon et al., 2019).

One of the solutions to reduce flood discharge in housing is to build infiltration wells. Infiltration wells are very effective to implement because they can absorb water and reduce water entering the canal (Ayu et al., 2011). Research conducted by Nurul et al. (2019) concluded that infiltration wells were able to reduce peak discharge by 3-13% from the initial peak discharge in the Katulampa Watershed, Jakarta. The construction of infiltration wells in the Way Kuala Garuntang catchment as many as 15 units in every 4000 m2 with a diameter between 0.8 to 1.4 meters will reduce flood discharge by 7.9% to 12.6% (Kusumastuti et al., 2014). The results of the research by Lussiany et al (2019) stated that the reduction in runoff in Babakan Village, Bogor Regency by using infiltration wells and ditches was 77.02%.

This study aims to plan infiltration wells to reduce flood discharge in *Perumahan Taman Alamanda Indah*. The housing area which has an area of 63951 m2 with 60.7% of the total area is an impervious area.

RESEARCH METHODS

This study was conducted in *Perumahan Taman Alamanda Indah* which is located in *Kelurahan* Tanjung Selamat (Urban Village), Medan Tuntungan District, Medan. The map of Medan Tuntungan District and the study location can be seen in Figure 1 and Figure 2.

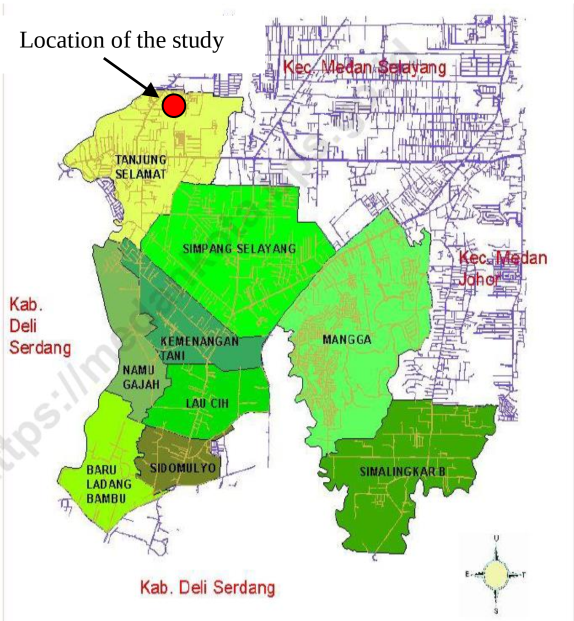

Figure 1. Medan Tuntungan District Map

Figure 2. The Study Location

The rainfall data used in this study is the annual maximum series from 2010 to 2019 obtained from Tuntungan Station. The parameters used to design and calculate the required number of infiltration wells include:

1. Groundwater Table Depth
   The minimum groundwater table depth to construct an infiltration well is 2 m. The groundwater depth can be determined by measuring the depth of the dug wells around the study location as a reference.
2. Permeability Coefficient
   The coefficient of permeability is the rate at which water seeps into the soil.
3. Rainwater Catchment Area
   The catchment area is the total land cover in the study location such as roofs, roads, and vacant land. The land cover area is calculated by digitizing the location using *Google Earth Pro*.
4. Design Rainfall
   The design rainfall used is a 2-year return period design rainfall which is calculated using the frequency analysis method of Normal, Log-Normal, Log Pearson Type III, and Gumbel, then matching the types of probability distributions based on statistical parameter requirements (Badan Standarisasi Nasional, 2017). After that, the probability distribution test was carried out using the Smirnov-Kolmogorov method.
5. Rainfall Intensity
   The rainfall intensity used was obtained from the design rainfall data with a dominant rain duration of 2 hours (Badan Standarisasi Nasional, 2017). The amount of rainfall intensity is calculated using the mononobe formula:

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

   Description:
   I : rainfall intensity (mm/jam)
   R_{24} : maximum daily rainfall for a certain return period (mm)
   t : dominant rain duration (hour)
6. Design Discharge
   Design discharge is calculated using the Rational Formula:

$$Q = C.I.A$$

   Description:
   Q : design discharge (m^3/hour)
   C : runoff coefficient
   I : rainfall intensity (m/hour)
   A : catchment area (m^2)
7. Infiltration Well Depth
   The depth of the infiltration well is calculated by the following equation (Sunjoto, 2016):

$$H = \frac{Q}{F.K}\left\{1 - \exp\left(\frac{-F.K.T}{\pi.R^2}\right)\right\}$$

$$F = 2.\pi.R$$

   Description:
   H : depth of well (m)
   Q : design discharge (m^3/s)
   T : charging time (sec)
   R : radius of well (m)
   K : coefficient of soil permeability (m/s)

RESULTS AND DISCUSSION

1. Hydrological Analysis

The Annual Maximum Series Data at Tungtungan Station is presented in Table 1. The results of the frequency analysis for the design rainfall return periods of 2, 5,10, and 25 years are presented in Table 2.

Table 1. Annual Maximum Series Data at Tuntungan Station

Year	Rainfall (mm)
2010	106
2011	175
2012	104
2013	140
2014	89
2015	169
2016	136
2017	141
2018	123
2019	100

(Source: BMKG of Tuntungan station)

Table 2. Recapitulation of The Calculation of The Design Rainfall

Return period (year)	Design rainfall (mm)			
	Normal	Log Normal	Log Pearson III	Gumbel
2	128	125	125	124
5	153	152	152	159
10	166	168	168	183
25	178	185	187	212

(Source: Research Results, 2021)

By the matching results, the appropriate distribution type is Log Pearson Type III. The results of matching statistical parameters with the conditions for each type of distribution are presented in Table 3.

Table 3. Probability Distribution Type Matching Results

Distribution type	Condition		Calculation Result		Des.
Normal	Cs =	0,14	Cs =	0,36	Not
	Ck =	3,00	Ck =	3,07	Not
Log Normal	Cs =	0,14	Cs =	0,04	Not
	Ck =	3,04	Ck =	2,92	Not
Log Pearson Type III	Cs =	-	Cs =	0,04	OK
	Ck =	-	Ck =	2,92	OK
Gumbel	Cs =	1,14	Cs =	0,36	Not
	Ck =	5,40	Ck =	3,07	Not

(Source: Research Results, 2021)

The test results using the Smirnov-Kolmogorov method show that the probability distribution used is acceptable because the value of the difference between the empirical and theoretical probabilities is smaller than the critical value, ($\Delta P_{maks} = 0{,}12$) < ($\Delta P_{kritis} = 0{,}14$). The results of the probability distribution test using the Smirnov-Kolmogorov method are presented in table 4.

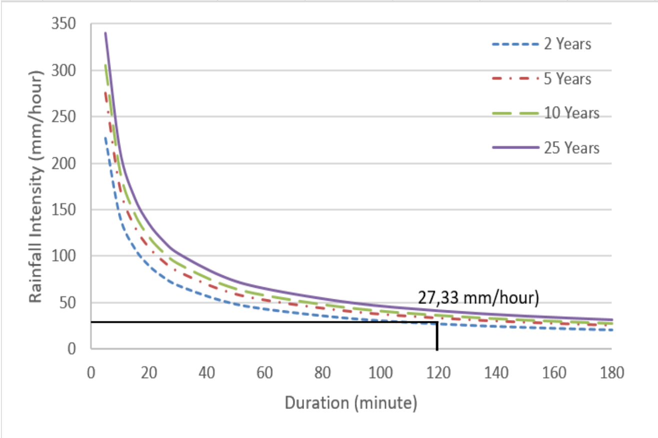

Figure 3. Mononobe IDF Curves

Table 4. Probability Distribution Test Results Using The Smirnov-Kolmogorov Method

i	Log Xi	P (Xi)	f(t)	P'(Xi)	ΔP
1	2,24	0,09	1,47	0,08	-0,01
2	2,23	0,18	1,31	0,10	-0,09
3	2,15	0,27	0,52	0,31	0,04
4	2,15	0,36	0,49	0,32	-0,04
5	2,13	0,45	0,36	0,37	-0,08
6	2,09	0,55	-0,08	0,53	-0,02
7	2,03	0,64	-0,73	0,75	0,12
8	2,02	0,73	-0,82	0,79	0,06
9	2,00	0,82	-1,00	0,85	0,03
10	1,95	0,91	-1,51	1,03	0,12

(Source: Research Results, 2021)

The results of the calculation of rainfall intensity are then presented in the form of an Intensity-Duration-Frequency (IDF) curve. IDF Mononobe curves with return periods of 2, 5, 10, and 25 years are presented in Figure 3. From the IDF Mononobe curves, it can be seen that the rainfall intensity for a 2 year return period for a dominant rainfall duration of 2 hours is 27.33 mm/hour.

2. Land Use

Perumahan Taman Alamanda Indah has a land area of 63,951 m^2. Land use can be categorized into 3 types, namely houses (roofs), paving roads, and vacant land/green space. The type of land use affects the amount of water potential that will run over the surface when it rains. The wider the percentage of land that has a high runoff coefficient value, the greater the flood discharge that will be generated. The area and percentage of land use in the study area are presented in Table 5.

Table 5. Area and percentage of land use

Land use	Area (m^2)	Percentage (%)
Houses (roofs)	30001	46,91
Paving roads	8819	13,79
Vacant land/green space	25131	39,30
Total	63951	100,00

(Source: Research Results, 2021)

For infiltration well planning, land use in the form of houses is grouped into several zoning. The houses that have adjacent roofs are grouped into one zoning. This zoning division aims to find out how many communal infiltration wells are needed for each zoning later. The distribution of communal infiltration well zones and the roof area of each zone is presented in Figure 4.

results is 0.21656 m3/s. In this study, it is planned that the infiltration well to be built absorb 50% of the peak discharge that falls

3. Peak Discharge

Calculation of peak discharge before the construction of infiltration wells at the location is carried out using the Rational Formula. The rain intensity used was obtained from the design rainfall data for a 2-year return period with a dominant rain duration of 2 hours. Based on the calculation using the Rational Formula, the peak discharge is 0.29496 m3/s. The results of the calculation of peak discharge before the construction of infiltration wells are presented in Table 6.

Table 6. The Results of The Calculation of Peak Discharge Before the Construction of Infiltration Wells

Type of land cover	A (m^2)	C	I (mm/ hour)	Q (m3/s)
Houses (roofs)	30.001	0,95	27,33	0,21656
Paving roads	8.819	0,6	27,33	0,04021
Vacant land	25.131	0,2	27,33	0,03819
Total	63.951			0,29496

(Source: Research Results, 2021)

Figure 4. Infiltration Well Zones Division

The calculation of peak discharge to design infiltration wells uses the same formula and rainfall intensity as the calculation of peak discharge before construction of infiltration wells, which is 27.33 mm/hour. The runoff coefficient value used is 0.95, which means that 95% of the rain that falls on the roof of the house will flow into the infiltration well. The peak discharge obtained from the calculation onto the roof of the house, which is 0.10828 m3/s. The results of the calculation of peak discharge using the Rational Formula are presented in Table 7.

Table 7. The Results of Peak Discharge Calculations for Designing Infiltration Wells

Zone	A (m^2)	I (mm/hour)	C	Q (m^3/s)	50%.Q (m^3/s)

1	2.813	27,33	0,95	0,020	0,010
2	734	27,33	0,95	0,005	0,003
3	438	27,33	0,95	0,003	0,002
4	1.518	27,33	0,95	0,011	0,005
5	2.249	27,33	0,95	0,016	0,008
6	1.628	27,33	0,95	0,012	0,006
7	1.524	27,33	0,95	0,011	0,006
8	860	27,33	0,95	0,006	0,003
9	2.566	27,33	0,95	0,019	0,009
10	3.684	27,33	0,95	0,027	0,013
11	3.232	27,33	0,95	0,023	0,012
12	3.523	27,33	0,95	0,025	0,013
13	5.232	27,33	0,95	0,038	0,019
Total	30.001			0,217	0,108

(Source: Research Results, 2021)

4. Infiltration Well Design

The infiltration well is designed with a diameter of 1 m and a depth of 2 m (Badan Standarisasi Nasional, 2017) and is an empty well with porous walls, so that water that enters the well can seep to the side (wall) and the bottom of the well.

The number of infiltration wells required per house zone is calculated by assuming that 50% of the rainwater discharge can be infiltrated into the infiltration wells and the rest is transferred to the drainage canal. This is based on the consideration of land availability and so that the existing drainage can still be utilized. The results of the calculation of the required number of infiltration wells are shown in Table 8.

According to the results, it is found that the number of infiltration wells needed at the study location is 430 units. The infiltration wells are made communally and divided based on predetermined zones. The infiltration wells can be constructed in the yard and using the road in front of the house.

The location of infiltration wells should not be close to septic tanks, dug wells, and building foundations. The minimum distance between the infiltration well and the septic tank is 5 meters. Meanwhile, the minimum distance between infiltration wells and dug wells and building foundations is 3 meters and 1 meter, respectively (Badan Standarisasi Nasional, 2017).

The pipes used as outlet pipes and inlet pipes as well as overflow pipes to drain excess water or puddles and enter the infiltration well are PVC pipes with a diameter of 4 inches.

Infiltration wells that have adjacent constructions require an air exhaust pipe from PVC with a diameter of 0.5 inches to prevent obstruction of the flow of flood discharge into the infiltration well (Badan Standarisasi Nasional, 2017).

5. Change in Peak Discharge

The construction of infiltration wells can have an impact on decreasing peak discharge from the time before and after the construction of infiltration wells. The peak discharge before the construction of the infiltration well is 0.29496 m^3/s and will decrease by 0.10828 or 36.71%.

Table 8. The Results of The Number of Infiltration Wells Needed

Zone	50%. (m^3/s)	R (m)	K (m/s)	T (s)	H_{need} (m)	H_{design} (m)	wells (units)
1	0,01015	0,5	0,00001	7200	80,91	2	40
2	0,00265	0,5	0,00001	7200	21,11	2	11
3	0,00158	0,5	0,00001	7200	12,60	2	6
4	0,00548	0,5	0,00001	7200	43,66	2	22
5	0,00812	0,5	0,00001	7200	64,69	2	32
6	0,00588	0,5	0,00001	7200	46,83	2	23
7	0,00550	0,5	0,00001	7200	43,83	2	22
8	0,00310	0,5	0,00001	7200	24,74	2	12
9	0,00926	0,5	0,00001	7200	73,81	2	37
10	0,01330	0,5	0,00001	7200	105,96	2	53
11	0,01166	0,5	0,00001	7200	92,96	2	46
12	0,01272	0,5	0,00001	7200	101,33	2	51
13	0,01888	0,5	0,00001	7200	150,49	2	75
Total	0,10828				862,92		430

(Source: Research Results, 2021)

Infiltration wells can reduce the peak discharge that was originally drained entirely through conventional drainage because some of the water that falls on the roof of the house is absorbed directly into the ground. The results of the decrease in peak discharge are presented in Table 9.

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CONCLUSION

The construction of infiltration wells can reduce the peak discharge in Perumahan Taman Alamanda Indah by 36.71%. To reduce the peak discharge by 50% in *Perumahan Taman Alamanda Indah* requires 430 units of infiltration wells with a diameter of 1 meter and a depth of 2 meters, which are divided into 13 zones.

Tabel 9 Results of The Decrease in Peak Discharge

	Without Infiltration well		With Infiltration well		Peak Discharge Decrease		
	C	Q (m^3/s)	C	Q (m^3/s)	C	Q (m^3/s)	%
Houses	0,950	0,217	0,475	0,108	0,475	0,11	50,00
Paving roads	0,600	0,040	0,600	0,040	0,000	0,00	0,00
Vacant/green space	0,200	0,038	0,200	0,038	0,000	0,00	0,00
Total Area	0,607	0,295	0,384	0,187	0,223	0,11	36,71

(Source: Research Results, 2021)

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