International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2022.8.4.11

Volume 8, Issue 4
April - 2022

Study of the use of Infiltration Wells in the Drainage System in the Town Square Area:A Case Study of Town SquareArea, Jember Regency, Indonesia

Noor Salim

Civil Engineering Study Program, Faculty of Engineering,

Muhammadiyah University of Jember

Indonesia

ABSTRACT

The town square in Jember Regency is one of the attractions located on the National Road of Jember Regency, East Java, Indonesia, the condition of the land surface is relatively flat, so an environmentally friendly drainage design is needed without burdening the surrounding area. Therefore, to overcome this, one of the steps that need to be taken is to examine the use of infiltration wells to prevent waterlogging in the city square area. From the results of this study, it can be concluded that the flood discharge that occurred in the town square area in Jember Regency was 0.056 m³/sec. Infiltration wells with a diameter of 1 m and a depth of 5 m were used as many as 32 pieces. The drainage channel used is a rectangular shape measuring 30 x 30 cm. It is recommended that garbage cleaning be carried out in the Jember Regency town square area, both in general and especially in the canal so that the garbage does not clog the flow of water in each channel. Further research is needed to apply other types of drainage to cope with flooding in the area and other important areas.

Keywords: *Drainage, Flood Discharge, Infiltration Well.*

I. INTRODUCTION

The town square in Jember Regency is one of the attractions located on the National Road of Jember Regency, East Java, Indonesia. Similar to the city square in other districts, the city square in Jember district is also an open and strategic space, located in the city center which is located in the middle of Jember district. The results showed that visitors' activities on weekdays were dominated by sports and leisure activities. [1]. As an open space for the public, the town square must be easily accessible and comfortable to visit. The resulting factors are three factors, namely related to accessibility, comfort and security as well as the ability to attract users.[2]. Public open space is usually a meeting place for various social communities as a place to interact. According to Carr, public open space is a communication node and means of social binding to create interactions between community groups [3]. And the planning of public open space must include matters relating to social interaction. There are several variables that are used to measure and compile the "Good Public Space Index", including: Intensity of use, social activities, duration and variety of activities and diversity of use. [4]. The point is that in general planning, open space for the public is very multifunctional. As a place for various types of activities, public open space provides several benefits for the quality of life, such as psychological and physical health, recreational benefits and fulfilling the need for a pleasant urban environment [5].

For the problem of physical planning is also very important in making public open spaces. This was done by Irfandi and his friends regarding the physical elements, namely aspects related to the physical design and facilities of urban public open spaces. [6]. With regard to the physical development of public open spaces, it must not cause new problems, namely environmental problems. For example, land cover in the process of developing public spaces causes flooding in the area. Changes in land use have an effect on increasing the value of the drainage coefficient due to the increase in land cover area [7]. So there is a need for integration in the planning of public open spaces between interdisciplinary sciences. To minimize this problem, it is necessary to have a synergistic planning between spatial planning and drainage system arrangement in an urban area [8]. Likewise, for the problems that occur in the town square in Jember Regency, it is necessary to arrange arrangements so that there will be no puddles during heavy rains, so it is necessary to arrange with this drainage network problem. This also happens in other areas. In a study conducted by Eka Mutia1 and Wan Alamsyah, it was said that the drainage development had not yet functioned optimally with the existing drainage network with the existing spatial arrangement.[9] This is reinforced by Suripin's statement in his book which says that the drainage system is a very important part of urban infrastructure, so that a good drainage system can free the city from puddles of rainwater, so it should not be neglected in a plan. [10]

On another issue, the town square in Jember Regency is a flat area so it needs special attention. The current drainage system that is generally used is a conventional drainage system that drains runoff into rivers. Environmentally friendly drainage is needed as a control of runoff which directly absorbs into the ground which is able to be a water conservation so that it can maintain ground water quality.[11]. Meanwhile, according to Sunjoto, 1987, the concept of rainwater drainage design based on groundwater conservation is essentially the design of a drainage system in which rainwater falls on the roof / pavement, is accommodated in a water infiltration system, while only water from the yard is not the required pavement. accommodated by the drainage network system. [12] So seeing this, in the study of the drainage system at the city square in Jember Regency, it was designed using an infiltration type, namely infiltration wells.

2. METHODOLOGY

2.1 Research Site

The location of this drainage system study is located in the town square of Jember Regency. Geographically, Jember Regency is located at a position of 7059'6" to 8033'56" south latitude and 113016'28" to 114003'42" east longitude. The area of Jember Regency covers an area of 3,293.34 Km^2, with a topographic character of fertile canyon plains in the middle and south and surrounded by mountains that extend the west and east boundaries. The research location data is presented in Figure 1 below.

Figure 1 :Research Location

2.1 Data Collection

The data collection is divided into 2, namely: primary data collection and secondary data collection.

1. Primary data collection, namely field survey data, field mapping, elevation measurements, observations of river flows, existing drainage channels and observations of wells or groundwater around the location of the town square of Jember Regency.
2. Collecting secondary data, namely data sourced from related agencies. Rainfall data is processed into maximum daily rainfall data which is then used to calculate the design flood discharge. Rainfall data adjacent to the location of the town square of Jember Regency.

2.3 Data analysis

After the data is complete for the Jember Square drainage study, the next steps that must be carried out in this study are:

1. Hydrological Studies
   - Analysis of regional average rainfall
   - Frequency analysis
   - Frequency match test (distribution type)
   - Estimating the runoff rate (flood discharge)
2. Hydraulics Study
   - Calculation of maximum Q at the outlet
   - Calculation of cross-sectional capacity at the outlet
   - Calculation of Infiltration Wells

DOI: 10.31695/IJASRE.2022.8.4.11

3.RESULTS AND DISCUSSION

3.1 Topographic maps

Rainfall data is processed into maximum daily rainfall data which is then used to calculate the design flood discharge. Rainfall data close to the location of the Jember Town Square, namely Semanggi Station, Wirolegi Station, Jember Station and Bintoro Station. The recorded data that has been obtained is calculated for 10 years starting from 2009 to 2018. So for the purpose of obtaining regional average rainfall data, it is calculated using a Thiessen polygon. based on a topographic map, the Jember Regency Town Square is located at an elevation of + 150 m with a lower elevation to the west, so that the movement of water flow will go towards the outlet.

3.2 Land Use

Land use is a land use and land arrangement carried out in accordance with the existing natural conditions. The land use of the surrounding area is in the form of office buildings and other public services. The land area in the town square area of Jember Regency is 0.6390 Ha. So for the purposes of a drainage study, it is necessary to compare the impact of the initial conditions before the town square and public service areas were built, and after the construction of the town square area as a public service area.

3.3 Channel Network Plan and Infiltration Well Position

The channel network plan and the position of infiltration wells in the town square of Jember Regency are presented in Figure 2. as follows

.Figure 2 : Channel Network Plan and Infiltration Well Position

3.3 Annual Maximum Rainfall

After all data is collected and inputted into the rainfall calculation data, the next step is to look for maximum rainfall data. This is done by taking the highest rainfall data which is presented in Table 1 below.

Table 1. Annual Maximum Rainfall

RAINFALL STATION (mm)						
No	Year	Dam Semanggir	Wirolegi	Jember	Bintoro	Amount
		R1	R2	R3	R4	
1	2008	2,852.0	616.0	2,717.0	2,798.0	8,983.0
2	2009	2,386.0	2,484.0	2,253.0	2,509.0	9,632.0
3	2010	2,342.0	2,486.0	2,172.0	3,161.0	10,161.0
4	2011	2,191.0	1,923.0	2,046.0	2,460.0	8,620.0
5	2012	2,116.0	1,777.0	1,669.0	2,226.0	7,788.0
6	2013	1,938.60	1,506.0	1,064.0	2,818.0	7,326.6
7	2014	2,024.0	1,874.0	1,601.0	1,952.0	7,451.0
8	2015	1,651.0	1,843.0	1,651.0	1,880.0	7,025.0
9	2016	1,716.0	1,153.0	650.0	1,167.0	4,686.0
10	2017	1,218.0	907.0	661.0	1,121.0	3,907.0
Average		2,043.5	1,656.9	1,648.4	2,209.2	7,558.0

Source: calculation results

DOI: 10.31695/IJASRE.2022.8.4.11

From the data above, it can be seen that the rain stations used are Semanggi Dam Rain Station, Wirolegi Rain Station, Jember Rain Station, and Bintoro Rain Station. The total area of the watershed is 2.094 km² and the coefficient for the Semanggi Dam station is 0.29, the Wirolegi rain station is 0.21 the Jember rain station is 0.22, and the Bintoro rain station is 0.28 which is presented in Table 2 below.

Table 2. Regional Average Rainfall

Station CH	Region	Area (km²)	Coefficient
Dam Semanggir	Kaliwates	616	0.2941738
Wirolegi	Sumbersari	431	0.2058262
Jember	Sumbersari	468	0.2234957
Bintoro	Patrang	579	0.2765043
Total Region Area		2,094	1,0000000

Source: calculation results

3.4 Maximum Daily Rainfall

After all data is collected and inputted into the rainfall calculation data, the next step is to look for maximum daily rainfall data. This is done by taking the highest daily rainfall data which is presented in Table 3 below.

Table 3. Maximum Daily Rainfall

RAINFALL STATUS (mm)						
No	**Year**	**Dam Semanggir**	**Wirolegi**	**Jember**	**Bintoro**	**Amount**
		R1	R2	R3	R4	
		0,29	0,21	0,22	0,28	
1	2008	97	130	95	97	103.440
2	2009	82	110	80	81	87.120
3	2010	89	120	87	89	95.040
4	2011	160	215	156	159	170.540
5	2012	99	133	97	99	105.720
6	2013	60	80	58	59	63.640
7	2014	106	142	104	105	112.980
8	2015	104	140	102	104	111.430
9	2016	94	127	92	94	100.780
10	2017	90	122	88	90	96.420
Average		980	1320	960	977	1046,22

Source: calculation results

3.5 Rain Data Frequency Distribution

The next step is to calculate the selection of the rain data method. This calculation aims to find out what method is suitable for use in subsequent calculations before further calculations are carried out. In statistics, there are several types of distribution, some of which are often used in hydrology, namely:

1. Gumbel Distribution
2. Normal Log Distribution
3. Pearson Type III Log Distribution
4. Normal Distribution

The following is a comparison of the distribution conditions and the results of the calculation of the rainfall frequency analysis which are presented in Table 4 below.

DOI: 10.31695/IJASRE.2022.8.4.11

Table 4 omparison of Distribution Terms and Calculation Results

NO	Distribution Kind	Conditon	Calculation Result	Remark
1	Normal Log	Cs > 0 Ck > 0	Cs = 1	Don't fulfill
2	Log Person Type III	0 < Cs < 0,9	Cs = 1	Fulfill
3	Gumbel	Cs ≤ 1,1396 Ck ≤ 5,4002	Cs = 1 Ck = 5,2	Don't fulfill
4	Normal	Cs ≈0 Ck = 0	Cs = 1 Ck = 5,2	Don't fulfill

Based on the calculations that have been done, it can be seen that the Cs value is 0.840. The value of Ck is -0.541. For the value of Cv obtained by 0.225. Based on the criteria that have been registered, the suitability of the data obtained with these criteria is to use the Log Person Type III method. For the discussion of log person type III, it is presented in Table 5 as follows.

Table 5. . Rain Data Frequency Distribution Selection Method

No.	Year	Ri	P	(Ri - R)	$(Ri - R)^2$	$(Ri - R)^3$	$(Ri - R)^4$
1	2008	103.440	9.091	-1.271	1.615	-2.053	2.610
2	2009	87.120	18.182	-17.591	309.443	-5443.417	95755.144
3	2010	95.040	27.273	-9.671	93.528	-904.512	8747.532
4	2011	170.540	36.364	65.829	4333.457	285267.157	18778851.660
5	2012	105.720	45.455	1.009	1.018	1.027	1.036
6	2013	63.640	54.545	-41.071	1686.827	-69279.673	2845385.466
7	2014	112.980	63.636	8.269	68.376	565.404	4675.327
8	2015	111.430	72.727	6.719	45.145	303.329	2038.068
9	2016	100.780	81.818	-3.931	15.453	-60.745	238.788
10	2017	96.420	90.909	-8.291	68.741	-569.929	4725.281
	Average	104.711			6623.604	209876.588	21740420.911

Source: calculation results

3.6 Calculation of Planned Rainfall

Based on the calculations that have been done using the Log Person Type III method. The results are presented in Table 6. as follows.

Table 6. Log-Person Type III method

Method of Log Pearson III								
No	Year	Ri (mm)	Log R	Log R - Log Rr	(Log R - Log	(Log R - Log	Calculation Result	
1	2008	103.440	2.015	0.007	0.000	0.000	Log Rr =	2.008
2	2009	87.120	1.940	-0.068	0.005	0.000	Sy / Ds =	0.017
3	2010	95.040	1.978	-0.030	0.001	0.000	cs =	0.000
4	2011	170.540	2.232	0.224	0.050	0.011	G (2) =	0.000
5	2012	105.720	2.024	0.016	0.000	0.000	G (5) =	0.842
6	2013	63.640	1.804	-0.204	0.042	-0.009	G (10) =	1.282
7	2014	112.980	2.053	0.045	0.002	0.000	G (25) =	1.751
8	2015	111.430	2.047	0.039	0.002	0.000	G (50) =	2.054
9	2016	100.780	2.003	-0.005	0.000	0.000	G (100) =	2.326
10	2017	96.420	1.984	-0.024	0.001	0.000		
n =	10							
Amount		1047.110	20.080	0.000	0.102	0.002		
Average	Log Rr =	104.711	2.008	0.000	0.010	0.000		
X	2.00							
Sy / Ds	0.017							
Cs =	0.000							

Source: calculation results

DOI: 10.31695/IJASRE.2022.8.4.11

Because the method is already known, namely using the log person type III method, for further calculations using the log person type III method. For the results of the calculation of log person type III using data from the Jember Square, the planned rainfall is presented in Table 7 below.

Table 7.. Rainfall Plan

Tr (Year)	Pr (%	K	K.Sy	Log Rt	Rt Designed rainfall (mm)
2	50	0	0.000	2.008	101.86
5	20	0.842	0.014	2.022	105.20
10	10	1.282	0.021	2.029	106.99
25	4	1.751	0.029	2.037	108.93
50	2	2.054	0.034	2.042	110.20
100	1	2.326	0.039	2.047	111.35

Surce: calculation results

3.7 Concentration Time

Next is to find Tc (Time Concentration). Time Concentration is the time it takes to flow from the end of channel I to the end of channel II. Or the time it takes for rainwater to reach the drain.

Concentration time (tc) is the time required by the point of rain that falls furthest on the soil surface in the Catchment Area to the nearest channel (to) and added time to flow to a point in the drainage channel under consideration (td). The following is an example of calculating Tc on channel A1. Calculations according to (Imam Subarkah; 1978; 48).[13]

$Tc = 0{,}0195 \times L / S^{0,5} \times 0{,}77$

$= 0{,}0195 \times 36{,}00 / 0{,}056^{0,5} \times 0{,}77$

$= 2{,}293$

Tc in hours

$Tc = 2{,}293 / 60 = 0{,}038$

The maximum Tc value that we got after doing the calculations was 0.733 hours or about 44 minutes.

Table 8. Calculation of Concentration Time

No	Channel Name	L (m)	AH (m)	S	tc (minute)	tc (hr)
1	A	193.00	2	0.010	28.467	0.474
2	B	163.00	2	0.012	22.095	0.368
3	C	105.00	2	0.019	11.423	0.190
4	D	147.00	2	0.014	18.923	0.315
5	E	100.00	2	0.020	10.617	0.177
6	F	160.00	2	0.013	21.488	0.358

Surce: calculation results

3.8 Rain Intensity

Next is the calculation of the intensity of rainfall. This calculation aims to determine the thickness of the rainwater when it rains. In this calculation, the data required is tc and the maximum rainfall value.

Rainfall intensity is the amount of rain that falls expressed in high rainfall or rainfall volume per unit time. The amount of rain intensity varies, depending on the duration of rainfall and the frequency of occurrence. The following is an example of calculating the intensity of rain at PUH 2. The calculation uses the formula (Loebis ; 1992).[14]

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

$I = (101{,}86 / 24) \times (24 / 0{,}733)^{2/3} = 43{,}95$

Where:

I : rain intensity (mm/hour)

DOI: 10.31695/IJASRE.2022.8.4.11

R24 : daily maximum rainfall in 24 hours (mm/hour)
t : duration of rain (hours)

Table 9. . Calculation of Rain Intensity

No	Return Period (Year) (tahun)	Designed Rain (mm)	tc (hr)	I (mm/hr)
1	2	101.86	0,733	43,95
2	5	105.20	0,733	45,39
3	10	106.99	0,733	46,16
4	25	108.93	0,733	47,00
5	50	110.20	0,733	47,54
6	100	111.35	0,733	48,04

Surce: calculation results

3.8 Peak Discharge

From the calculation analysis, it was found that the flood discharge that occurred in the City Square area of Jember Regency for the 25 year anniversary period was 0.056 m³/sec. The complete results are presented in Table 10 below.

Table 10. Calculation of Peak Discharge

No	Return period (Year)	C	I (mm/hr)	A (km^2)	Q (m^3/s)
1	2	0,71	43,95	0,006	0,052
2	5	0,71	45,39	0,006	0,053
3	10	0,71	46,16	0,006	0,055
4	25	0,71	47,00	0,006	0,056
5	50	0,71	47,54	0,006	0,056
6	100	0,71	48,04	0,006	0,057

Surce: calculation results

3.9 Infiltration wells

$$H = \frac{Q}{F \ x \ K}\left(1 - e^{-\frac{FKT}{\pi R^2}}\right)$$

where:
H = Water level in the well (m)
F = Geometric factor (m)
Q = Inlet water discharge (m3/second)
T = Stream time (seconds)
K = Soil permeability coefficient (m/sec)
R = radius of well (m)

a) Infiltration wells as many as 400 pieces

R = 121,6110872 mm
t = 1 hours
C = 0,71

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

= 47,00 mm/hours
A = 200 m^2
= 0,02 Ha
Q masuk = C x I x A
= 0,00185 m^3/sec

b) **Design of Infiltration wells**
T = 3600
D = 1 m

DOI: 10.31695/IJASRE.2022.8.4.11

R = 0,5 m
k = 0,00000065 cm/sec
F = $2\ \pi\ x\ R$
= 3,14 m

c) Depth of Infiltration wells

$$H = \frac{Q}{F\ x\ K}\left(1 - e^{-\frac{FKT}{\pi R^2}}\right)$$

= 8,50 m,
Planned = 5,00 m

d) Rainwater Infiltration Discharge

R = 1 m
π = 3,14
k = 0,0000006 cm/s
H = 5,00 m
F = $2\ x\ \pi\ x\ R$
= 3,14 m
Q Resapan = $F\ x\ k\ x\ H$
= 0,001 m^3/sec
Rencana total sumur reszapan = 32 x 0,001 = 0,032 m^3/sec

e) Capacity of Infiltration wells

R = 0,5 m
H = 5,00 m
π = 3,14
V = $\pi\ x\ R^2 x\ H$
= 3,925 m^3

Amount of Runoff Discharge that Can Be Absorbed By Infiltration Wells
Q total = 0.056 m3/sec
Q entering the infiltration well = 0.032 m3/sec
Q inlet to Channel = 0.024 m3/sec
Total absorbed discharge = 0.032 / 0.056 = 59,26 %
So the amount of runoff that can be absorbed by infiltration wells is 59.26 %. And the remaining 40,74 % goes into the drainage channel.

3.10 Drainage Channel

The channel cross section needs to be planned to get an ideal and efficient cross section in land use. Efficient land use means taking into account the availability of existing land. This needs to be considered because in dense residential areas the land that can be used is very limited. The ideal channel cross-section is strongly influenced by the cross-sectional form factor. With the existing design flood Q, the cross-sectional capacity will remain even if the cross-sectional shape is changed, so it is necessary to pay attention to the stable cross-sectional shape of the channel. The single rectangular cross-section shown in Figure 7 below

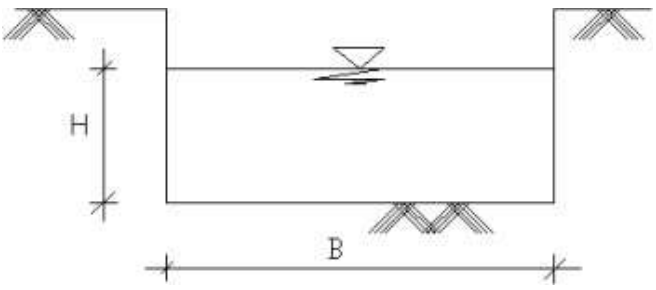

Figure 3 Design of a Single Rectangular Cross

DOI: 10.31695/IJASRE.2022.8.4.11

$$Q = A * V$$

$$R = \frac{A}{P}$$

$$V = \left(\frac{1}{n}\right) \times R^{2/3} \times I^{1/2} \text{ m/dtk}$$

$$A = B \times H$$

$$P = 2.H + B$$

Where :
Q = Flow (m^3/sec)
V = Flow speed (m/sec)
m = Cross Slope
n = Coefficient of Manning Hardness
P = Wet cross section (m)
A = Wet cross-sectional area (m^2)
R = Radius of hydraulic(m)
I = Slope os Channel

With calculations using the above formula, and the calculated flowrate, the design of the channel is in the form of a single rectangular cross-section which is suitable for draining drainage flows of the same size, which is 30 cm x 30 cm.

So the calculation (taking the shortest one) is as follows.

B = 0.30 ; H = 0.30 ; A = 0.09 m2 ; P = 2.32 m ; R = 0.039 m ; n channel = 0.035 (river stone) ; S channel = 0.01 ; L – 83 m ; V = 0.327 m/sec ; Q = 0.029 m3/sec

Meanwhile, Q due to rainwater is 0.024/8 = 0.003 m3/sec, so the existing channel is very sufficient.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusion

Based on the results and discussion, the conclusions are as follows.

1. The flood discharge that occurred in the City Square area of Jember Regency for the 25 th anniversary period was 0.056 m^3/sec.
2. Infiltration wells with a diameter of 1 m and a depth of 5 m are used as many as 32 pieces
3. The drainage channel used is a rectangular shape measuring 30 x 30 cm

4.2 Suggestion

1. It is necessary to clean up the garbage in the Jember Regency city square, both in general, especially in the canal so that the garbage does not clog the flow of water in each channel.
2. Further research is needed to apply other types of drainage to cope with flooding in the area and other important areas.

REFERENCES

[1] A. Fatony, and A. M. Sukmawati,(2021) "Faktor-Faktor yang Menentukan Pemanfaatan Alun-alun Sebagai Ruang Terbuka Publik di Kabupaten Ngawi," Jurnal Ruang, vol. 7, no. 1, pp. 34-45, Jun. 2021. https://doi.org/10.14710/ruang.7.1.34-45

[2] Dini Faza Illiyin, Hertiari Idajati (2015). Faktor-faktor yang mempengaruhi masyarakat dalam penggunaan ruang terbuka publik sebagai fungsi sosial di gor delta sidoarjo berdasarkan prefernsi masyarakat. Jurnal Teknik ITS, vol 4 no. 2, 2015

[3] Carr, Stephen, dkk. 1992. Public Space, Combridge University Press. USA.

[4] Mehta, V., 2007, A Toolkit For Performance Measures of Public Space, 43rd ISOCARP Congress

[5] Maller, C., et al. (2009). Healthy Parks, Healthy People:The Health Benefits of Contact with ature in a Park Context: GeorgeWright Forum Volume 26 Number 2

[6\] Irfandi1, Mirza2, Irzaidi3, Khairul Huda 2017. Pengaruh Kualitas Fisik Ruang Terbuka Publik ktif Perkotaan Terhadap Kualitas Hidup Masyarakat Prosiding Temu Ilmiah Ikatan Peneliti ingkungan Binaan Indonesia (IPLBI) 6, 2017.

] Rahmat Irawan, 2017. The study of urban drainage system based on spatial structure plan. Thesis – Re142551. Program Magister bidang keahlian Teknik Sanitasi Lingkungan jurusan Teknik Lingkungan FTSP, ITS Surabaya, 2017

[8] Kusumadewi, DA. Djakfar, l. Bisri, M,. 2012. Arahan Spasial Teknologi Drainase Untuk Mereduksi Genangan Di Sub DAS Watu Bagian Hilir. Malang: Jurnal Teknik Pengairan Universitas Brawijaya Malang

DOI: 10.31695/IJASRE.2022.8.4.11

[9] Eka Mutia1dan Wan Alamsyah, 2015. Penataan Jaringan Drainase Berdasarkan Tata Ruang Kota Langsa. Jurnal Ilmiah Jurutera. Volume 2 Nomer 1, 2015

[10] Suripin.2004.Sistem Drainase Perkotaan yangBerkelanjutan. ANDI Offset:Yogyakarta

[11] Sarbidi (2013) 'Aplikasi Sistem Drainase Berwawasan Lingkungan Zero Run Off Pada Kawasan Permukiman Application Of The Zero Run Off Sustainable Drainage System For The Human Settlement', Jurnal Teknik Sipil, Pp. 128–135.

[12] Sunjoto, 1998. Sistem Drainase Air Hujan Yang Berwawasan Lingkungan.Majalah Konstruksi. 1998

[13] Imam Subarkah, 1978. Hidrologi untuk Perencanaan Bangunan Air. Penerbit, Idea Dharma Bandung. Tahun Terbit, 1978.

[14] [Loebis, J., 1992, Banjir Rencana Untuk Bangunan Air, Penerbit Pekerjaan Umum, Jakarta

DOI: 10.31695/IJASRE.2022.8.4.11