Environmental Drainage Systems in the Sukun District, Malang Indonesia

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Abstract - Flooding in urban areas is a matter that should be avoided because it will cause disruption to public activity. Early stage to do is an evaluation of the existing drainage channels including supplementary structure. If known drainage channels can not be able to drain the surface runoff during heavy rain, the rest of the flood water must be flowed into the infiltration wells. The water that is in the catchment wells can increase soil water content and can be used during the dry season. Infiltration wells can also serve as a means of soil water conservation with environmental sensitivity. Drainage and infiltration wells into a single entity tII. hat can not be separated. Infiltration wells can be built at people's homes and other public facilities as well as where development should be monitored by the local authorities as well as being a prerequisite for the building permit process.

Keywords - Flooding, drainage, infiltration well, conservation, environmental sensitivity

I. INTRODUCTION

Flooding is one of the natural disasters that frequently occur in many cities in the world. In Malang, especially in the district Sukun occur similar problems, namely the problem of flooding and inundation. It is caused by several factors, one of the main causes is less maximal drainage system. Therefore, it needs evaluation of the existing drainage system. There are 12 blocks drainage area ie A1, A2, A3, A4, B1, B2, B3, C1, C2, C3, C4, Z. If drainage system is insufficient to overflow flooding and inundation, it can be added with the construction of infiltration wells as drainage absorbing well.

II. LITERATURE REVIEW

1.1. Drainage Definition

Drainage has meaning to remove or to divert water. In general defined as a technical measure to reduce the excess water whether from rain, seepage or excess water irrigation from an area or land as a function of undisturbed area. [1]. The subsurface drainage discharge is one of the most important indicators of the impact of the drainage systems on the water management [2]. Surface drainage systems are usually applied in relatively flat lands that have soils with a low or medium infiltration capacity, or in lands with high -intensity rainfalls that exceed the normal infiltration capacity, so that frequen t water logging occurs on the soil surface [3]. The poor drainage systems caused tremendous environmental problems [4]. It is observed that the existing drainage system is inadequate carrying the storm water and it must be improved by lining as well as widening in order to increase the carrying capacity for the area with rapid urbanization [5].

1.2. Flooding Definition

Flooding is an overflow of large volume of water on a normally dry land and may submerge lands causing deluge. It could be naturally induced as in tidal flooding and fluvial flooding or human induced as in pluvial flooding [6]. A flood can be defined or described as the result of run-off from rainfall quantities that are too enormous. Flood can also be defined as the discharge that may be expected from the most severed combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the geographic region involved excluding extremely rare combination [7].

1.3. Hydrological Analysis

Hydrological analysis is useful for calculating discharge rainwater becomes runoff, which is associated with the development objectives of urban drainage to reduce excess water so it does not flood and inundation in the region. Rainfall calculated by the method of E.J Gumbel

XT $= \overline{X} + \frac{S}{Sn}(Y - Yn)$, $\overline{X} = \frac{1}{n}\sum_{i=1}^{n} xi$

For T< 20

Y $= -\ln\left[-\ln\left(\frac{T-1}{T}\right)\right]$

For T ≥20

Y = ln T

S $= \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{n-1}}$

Where :

X_T = rainfall prediction of T years
$\overline{X}$ = average rainfall
Y = Gumbel reduction factor
Sn = reduction of deviation standard
S = deviation standard
T = repeated period

Flow calculated by rational methods

Q = 1/3.6 C I A

Where :

Q = flow capacity (m^3/sec)
1/3,6 = conversion factor
C = runoff coefficient
I = rainfall intensity (mm/h)
A = catchment area (km^2)

Household waste water calculated with formula :

Q_{ww} = (water need x area x people density) x 70 %

Total discharge is $Q_{total} = Q_{flow} + Q_w$

1.4. Hydraulics Analysis

Hydraulics analysis aims to determine the ability of a drainage channel to accommodate the discharge plan. In the design dimensions of the channel of trapezium-shaped must be cultivated to obtain economical To plan the dimensions of the channel, then use the manning formula.

$Q = \frac{1}{n} R^{2/3}\ S^{1/2} .A$

Where :
n = hardness coefficient of wall (Manning)
R = hydraulic radius (m)
S = channel bottom slope
Q = discharge (m3 / sec)
A = sectional area of the channel (m2)

1.5. Environmental Drainage

Environmental drainage is an implementation of a new understanding of the concept of "Green Hydraulic" in the drainage field. Environmental drainage is defined as an attempt to manage the excess water by way of profuse impregnated into the ground through infiltration well.

Capacity of infiltration well :

$V_{well} = \frac{1}{4}.\pi.R^2.H$

Where:

V_{well} = capacity of infiltration well (m^3)
H = depth of infiltration well (m)
R = radius of infiltration well (m)

Inflow to infiltration well : $Q_{well} = \frac{H.F.K}{1 - e^{\left[\frac{F.K.T}{\pi.R^2}\right]}}$

Where :

Q_{well} = Inflow to infiltration well (m^3/sec)
F = Faktor geometrik saluran per satuan panjang (m)
K = coefficient of permeability (m/sec)

H = depth of infiltration well (m)
T = flow time (sec)
R = radius of infiltration well (m)

Flow time of infiltration well : $t_{filling} = \dfrac{V_{well}}{Q_{well}}$

Where :

$T_{filling}$ = flow time of infiltration well (minute)
V_{well} = capacity of infiltration well (m^3)
Q_{well} = discharge of infiltration well (m^3/sec)

The construction of infiltration wells does not mean that flooding will not occur, for there are other issues, such as trash or other objects that can block the infiltration wells. Hence, constructing infiltration wells needs community participation in waste management, namely by being careful in throwing the trash away, so that it will not block the wells. Furthermore, the wells should be maintained in order to keep its functions, especially when there is heavy rainfall that is potential to cause flood. In addition to the wells' maintenance, drainage should be maintained, so that surface runoff will keep flowing and does not become concentrated on lower level lands [8].

III. RESULTS AND DISCUSSION

Design rainfall can be calculated by hydrological analysis and the results can be seen in Table 1.

Table 1. Design Rainfall

No	Repeated period (year)	Xrt	S	Y	Y_n	S_n	Maximum rainfall (X_T)
1	2	46.301	36.067	0.3665	0.4592	0.9496	42.7801
2	5	46.301	36.067	1.4999	0.4592	0.9496	85.8281
3	10	46.301	36.067	2.2502	0.4592	0.9496	114.3254
4	20	46.301	36.067	2.9702	0.4592	0.9496	141.6719
5	50	46.301	36.067	3.9019	0.4592	0.9496	177.0591
6	100	46.301	36.067	4.6050	0.4592	0.9496	203.7637

Design rainfall used is design rainfall of 20 years repeated period is equal 141.6719 mm. From this design rainfall it can be calculated flow discharge of each channel or each drainage area that can be seen in Table 2.

Table 2. Flow discharge in each drainage area

No	Drainage area	C	I (m/sec)	A (m^2)	Q (m^3/sec)
1	A1	0.6392	0.00050	5109.09	0.049
2	A2	0.5739	0.00006	2639.63	0.027
3	A3	0.5545	0.00011	3921.32	0.067
4	A4	0.6276	0.00007	4025.58	0.047
5	B1	0.5826	0.00004	6176.44	0.043
6	B2	0.5829	0.00008	3798.65	0.048
7	B3	0.5325	0.00004	6096.71	0.033
8	C1	0.6154	0.00006	4191.73	0.043
9	C2	0.5213	0.00009	2694.75	0.035
10	C3	0.6183	0.00007	4011.04	0.051
11	C4	0.5641	0.00005	312.68	0.031
12	Z	0.6078	0.00006	183.86	0.002

Before calculate household waste water it must be calculated the projected total population in the planned that can be calculated using the geometric equation :

$P_t = P_o (1 + r)^n$
$16.647 = 16.124 (1 + r)^n$
$r = 0.32\%$

After that it can be calculated estimate of the amount of household waste water up to 2020. With reference to the approximate number of average water needs in the area of Malang, amounting to 150 liters/day/person or equal to

0.001736 liters/s/person, it can be estimated amount of household wastewater that goes into each channel by using the formula : $Q_{RT} = \frac{P_n \times 80\% \times K_{ab}}{A}$

The results of calculation of household waste water discharge and total discharge can be seen in Table 3.

Tabel 3. Calculation of household waste water discharge and total discharge

No	Drainage Area	Area (km^2)	Flow Discharge (m3/sec)	Discharge of Household waste water (m3/sec)	Total discharge (m3/sec)	Compound Total discharge (m3/sec)	
1	A1	0.005109094	0.049	3.31E-06	0.04885331	A1	= 0.04885331
2	A2	0.002639626	0.027	1.71E-06	0.02668370	A1+A2	= 0.07553700
3	A3	0.003921321	0.067	2.54E-06	0.06737272	A1+A2+A3	= 0.14290973
4	A4	0.004025581	0.047	2.60E-06	0.04709255	A4	= 0.04709255
5	B1	0.006176441	0.043	4.00E-06	0.04260761	B1	= 0.04260761
6	B2	0.003798655	0.048	2.46E-06	0.04800000	B2	= 0.04800000
7	B3	0.006096708	0.033	3.94E-06	0.03320834	B3+B1+Z	= 0.07775678
8	C1	0.004191727	0.043	2.71E-06	0.04325989	Z+B+C1+C2	= 0.20408142
9	C2	0.002694750	0.035	1.74E-06	0.03506475	C2	= 0.03506475
10	C3	0.004011040	0.051	2.60E-06	0.05099696	C3	= 0.05099696
11	C4	0.007942790	0.031	5.14E-06	0.03115264	C3+C4	= 0.08214961
12	Z	0.004371460	0.002	2.83E-06	0.00194083	Z	= 0.00194000

It can be seen that the discharge for drainage area of A4, B1, B2, C2, C3, and Z are not flowed from another drainage area so that the flow is permanent.

Hydraulics analysis aims to determine the ability of the existing channel to accommodate the discharge. The results can be seen in Table 4. Capacity calculation can be seen in Table 5.

Table 4. Capacity comparison of existing channel

No.	Drainage area	Area (m^2)	Dimension (m)	Length (m)	Slope (S)	$Q_{existing}$ (m^3/sec)	Q_{flow} (m^3/sec)	Note
1	A1	5109.094	b=0.23 ; h=0.18	176.844	1	0.021186	0.048853	$Q_{flow} > Q_{existing}$
2	A2	2639.626	b=0.23 ; h=0.18	143.026	1	0.023557	0.075537	$Q_{flow} > Q_{existing}$
3	A3	3921.321	b=0.23 ; h=0.18	99.070	3	0.049025	0.142910	$Q_{flow} > Q_{existing}$
4	A4	4025.581	b=0.23 ; h=0.18	167.458	2	0.030789	0.047093	$Q_{flow} > Q_{existing}$
5	B1	6176.441	b=0.44 ; h=0.30	239.607	1	0.086148	0.042608	$Q_{flow} < Q_{exixting}$
6	B2	3798.655	b=0.44 ; h=0.30	109.249	1	0.127582	0.048000	$Q_{flow} < Q_{exixting}$
7	B3	6096.708	b=0.24 ; h=0.18	289.759	1	0.017569	0.077757	$Q_{flow} > Q_{existing}$
8	C1	4191.727	b=0.16 ; h=0.15	152.459	1	0.011345	0.204081	$Q_{flow} > Q_{existing}$
9	C2	2694.753	b=0.16 ; h=0.15	131.168	3	0.021185	0.035065	$Q_{flow} > Q_{existing}$
10	C3	4011.035	b=0.28 ; h=0.32	92.836	0.5	0.051503	0.050997	$Q_{flow} < Q_{exixting}$
11	C4	7942.791	b=0.20 ; h=0.23	312.679	4	0.105728	0.082150	$Q_{flow} < Q_{exixting}$
12	Z	4371.463	b=0.26 ; h=0.30	183.864	2	0.065688	0.001940	$Q_{flow} < Q_{exixting}$

Table 5. Capacity calculation of culvert

No	Culvert location	Slope	Dimension (m)	Length (m)	N	Velocity (m/sec)	$Q_{culvert}$ (m^3/sec)	Q_{inflow} (m^3/sec)	Note
1	Z → B	0.0788276	b=0.26 ; =0.30	5.2858	0.025	2.93106	0.468970	0.00194000	$Q_{inflow} < Q_{culvert}$
2	B → C	0.0724671	b=0.26 ; =0.30	4.3882	0.025	2.81032	0.449652	0.70408142	$Q_{inflow} > Q_{culvert}$

Because there still a culvert that can not accommodate the flow then it must be added with infiltration well as environmental drainage.

Discharge calculation can be done as a function of the characteristics of roof area of the building with a rational formula as follows :

$$Q = C_{roof} \times I \times A_{roof}$$

Where:

Q = inflow discharge (m3/sec)

C_{roof} = roof water flow coefficient

I = rainfall intensity (mm)

A_{roof} = roof area (m2)

Roof area of all of drainage area can be done with Polyline of Auto Cad programme. Changes between the amount of water flowing in the roof with the amount of rainfall that fell on the roof of each drainage area will vary The area of each roof is very influential. For the calculation of the composite roof in each drainage area and roof area can be seen in Table 6.

Tabel 6. Calculation of the composite roof in each drainage area and roof area

No	Drainage area	Area (m^2)	C	% area (A_{roof})	$A_{roof}(m^2)$	$I_{drainage\ area}$ (mm/h)	I_{roof}	Q_{roof} (m^3/sec)
1	A2	2639/626	0.95	64.78 %	1709.950	228.268	0.228268	0.10300
2	A3	3921/321	0.95	60.91 %	2388.477	401.513	0.401513	0.25307
3	A4	4025/581	0.95	73.65 %	2964.840	241.529	0.241510	0.18897
4	B1	6176/441	0.95	61.93 %	3825.070	153.426	0.153426	0.15487
5	B3	6096/708	0.95	56.51 %	3445.249	132.539	0.132539	0.12050
6	C1	4191/727	0.95	70.67 %	2962.293	217.312	0.217312	0.16988
7	C3	4011/035	0.95	73.65 %	2954.127	266.506	0.266506	0.20776
8	C4	7942/791	0.95	62.82 %	4989.661	178.409	0.178409	0.23491
9	Z	4371/463	0.95	66.42 %	2903.526	224.758	0.224758	0.17221

Optimum depth of infiltration wells will be made the same and calculate by using formula as follows :

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

$$= \frac{0,10300}{2.75 \quad 1.5 \times 10^{-4}}\left[1 - e^{\left(-\frac{2,75\,.\,1,5 \times 10^{-4}\,.\,359}{3,14\,.\,(0,5^2)}\right)}\right] = 38.763 \text{ m} = 39 \text{ m}$$

The depth is very high making difficult for implementation so the infiltration wells need to be made in parallel of four infiltration wells and infiltration wells needed for the series system is :

$$n = \frac{38.763}{4} = 9.69 = 10$$

The number of infiltration well for each drainage area is built with same number ie 10 infiltration wells of 4 meters depth and 0.5 meters diameter.

Capacity of one infiltration well :

$$V = ¼.\pi.\ R^2.H$$

$$= ¼\ 3.14\ (0.5)^2.4 = 0.392\ m^3$$

Infiltration discharge :

$$Q = F.K.H$$

$$= 2.75 \quad 1.5 \times 10^{-4} \quad 4 = 0.00165 \text{ m}^3/\text{sec}$$

Infiltration time :

$$t = \frac{v_{well}}{Q_{infiltration}} = \frac{0.392}{0.00165} = 237.57576 \text{ sec}$$

Charging time of infiltration well :

$$t = \frac{v_{well}}{Q_{well}} = \frac{0.392}{0.0428832} = 9.14115 \text{ sec}$$

Total infiltration discharge = 10 x 0.00165 m^3/second = 16.5 liters/sec

Before their infiltration wells, flow rates at the drainage area of A2 is equal to 0.075537 m3 / sec, but after calculating infiltration wells is planned a reduction in the flow rate of 0.0165 m3 / sec. This means that with 10 numbers of infiltration wells in the drainage area of A2 can store groundwater reserves and reduce the discharge flow of 0.0165m3 / sec. or ± 16.5 liters / sec which is capable of reducing the discharge flow of about 21.8%. Reduction of flow due to the construction of infiltration wells can be seen in Table 7.

Table 7. Total discharge after design of infiltration wells

No	Drainage area	Q_{total} before design	$Q_{infiltration\ wells}$	Q_{total} after design	Q_{total} surface runoff	
1	A1	0.04885331	~	0.04885331	A1	= 0.04885331
2	A2	0.02668370	0.00990	0.01678370	A1+A2	= 0.06563700

3	A3	0.06737272	0.00990	0.05747272	A1+A2+A3	= 0.12310973
4	A4	0.04709255	0.00990	0.03719255	A4	= 0.03719255
5	B1	0.04260761	0.00990	0.03270761	B1	= 0.03270761
6	B2	0.04800000	~	0.04800000	B2	= 0.04800000
7	B3	0.03320834	0.00990	0.02330834	B3+B1+Z	= 0.05630678
8	C1	0.04325989	0.00990	0.03335989	Z+B+C1+C2	= 0.17244059
9	C2	0.03506475	~	0.03506475	C2	= 0.03506475
10	C3	0.05099696	0.00990	0.04109696	C3	= 0.04109696
11	C4	0.03115264	0.00990	0.02125264	C3+C4	= 0.06234961
12	Z	0.00194083	0.00165	0.00029083	Z	= 0.00029083

Design of the infiltration wells can decrease surface runoff amounted to 21.8% in each drainage area. Therefore it is necessary to analyse existing discharge using the new surface runoff after design of infiltration wells in order to know whether design of infiltration wells can overcome problems in the Sukun District or not. Existing discharge analysis and surface runoff analysis after design of infiltration wells can be seen in Table 8.

Tabel 8. Existing discharge analysis and surface runoff analysis after design of infiltration wells

No	Drainage area	Area (m^2)	Dimension (m)	Length (m)	Slope (S)	$Q_{existing}$ (m3/sec)	$Q_{surface\ runofft}$ (m^3/sec)	Note
1	A1	5109.094	b=0.23, h=0.18	176.844	1	0.021186	0.048853	$Q_{exist} < Q_{surf.runoff}$
2	A2	2639.626	b=0.23, h=0.18	143.026	1	0.023557	0.059037	$Q_{exist} < Q_{surf.runoff}$
3	A3	3921.321	b=0.23, h=0.18	99.070	3	0.049025	0.109910	$Q_{exist} < Q_{surf.runoff}$
4	A4	4025.581	b=0.23, h=0.18	167.458	2	0.030789	0.030593	$Q_{exist} > Q_{sruf.runoff}$
5	B1	6176.441	b=0.44, h=0.30	239.607	2	0.086148	0.026108	$Q_{exist} > Q_{sruf.runoff}$
6	B2	3798.655	b=0.44, h=0.30	109.249	1	0.127582	0.048000	$Q_{exist} > Q_{sruf.runoff}$
7	B3	6096.708	b=0.24, h=0.18	289.759	1	0.017569	0.043107	$Q_{exist} < Q_{surf.runoff}$
8	C1	4191.727	b=0.16, h=0.15	152.459	1	0.011345	0.152641	$Q_{exist} < Q_{surf.runoff}$
9	C2	2694.753	b=0.16, h=0.15	131.168	3	0.021185	0.035065	$Q_{exist} < Q_{surf.runoff}$
10	C3	4011.035	b=0.28, h=0.32	92.836	0.5	0.051503	0.034500	$Q_{exist} > Q_{sruf.runoff}$
11	C4	7942.791	b=0.20, h=0.23	312.679	4	0.105728	0.049150	$Q_{exist} > Q_{sruf.runoff}$
12	Z	4371.463	b=0.26, h=0.30	183.864	2	0.065688	0.000290	$Q_{exist} > Q_{sruf.runoff}$

From the construction of 10 infiltration wells at 8 drainage area and 1 infiltration well at 1 drainage area which is equal 81 infiltration wells are only able to overcome flooding problems in the drainage area of A4. Therefore, by making 81 infiltration wells have not been able to handle the problems occurred in the Sukun District, so it is required redesign dimensional drainage channels in several blocks that have discharge flow large enough than that at the drainage area of A1,A2,A3,B3, C1 and C2. The calculation of new drainage dimension at each drainage area can be seen in Table 9.

Table 9. Dimension calculation of new drainage

No	Drainage area	Velocity (m/sec)	Dimension (m)	Q_{new}(m3/sec)	$Q_{existing}$(m3/sec)	$Q_{surface\ runofft}$ (m3/sec)	Note	
1	A1	0.63745	b=0.32;h=0.25	0.0509964	0.021185100	0.04885331	$Q_{new} > Q_{surface\ runoff} < Q_{exist}$	proved
2	A2	0.76385	b=0.35;h=0.29	0.0775309	0.023556955	0.05903700	$Q_{new} > Q_{surface\ runoff} < Q_{exist}$	proved
3	A3	1.02253	b=0.35;h=0.32	0.1145237	0.063290782	0.10990973	$Q_{new} > Q_{surface\ runoff} < Q_{exist}$	proved
4	A4	1.52876	b=0.23;h=0.18	0.0632908	0.063290782	0.03059255	$Q_{new} > Q_{surface\ runoff} < Q_{exist}$	proved
5	B1	0.54819	b=0.44;h=0.30	0.0723612	0.127581169	0.02610761	$Q_{new} > Q_{exist} > Q_{surface\ runoff}$	proved
6	B2	0.96652	b=0.44;h=0.30	0.1275812	0.072361208	0.04800000	$Q_{new} > Q_{exist} > Q_{surface\ runoff}$	proved
7	B3	0.48494	b=0.30;h=0.25	0.0363706	0.017569005	0.04310678	$Q_{new} > Q_{exist} > Q_{surface\ runoff}$	proved
8	C1	0.73627	b=0.31;h=0.36	0.0821672	0.027349848	0.15264059	$Q_{new} > Q_{surface\ runoff} > Q_{exist}$	proved
9	C2	1.77494	b=0.31;h=0.36	0.1980829	0.011345050	0.03506475	$Q_{new} > Q_{surface\ runoff} > Q_{exist}$	proved
10	C3	0.61314	b=0.28;h=0.30	0.0515035	0.027349848	0.03449696	$Q_{new} > Q_{surface\ runoff} > Q_{exist}$	proved
11	C4	1.00683	b=0.30;h=0.35	0.1057168	0.011345050	0.04914961	$Q_{new} > Q_{surface\ runoff} > Q_{exist}$	proved
12	Z	0.84217	b=0.26;h=0.30	0.0656891	0.011345050	0.00029083	$Q_{new} > Q_{surface\ runoff} > Q_{exist}$	proved

Planning of infiltration wells can reduce the discharge flow by approximately 22% per block in each second. By doing the re-planning of the existing drainage systems with the addition of widening and depth, now the Sukun has been spared from the problem of flooding and inundation. Added the 81 infiltration wells in the whole drainage area can help improve soil absorbing power so that the supply of ground water continues to grow and does not suffer from drought during the dry season.

IV. CONCLUSION

There are 8 of 12 drainage area that are not able to meet discharge capacity of plan within a period of 20 years (A1, A2, A3, B3, C1, C2, B2, B3).
It takes planning infiltration wells in 9 drainage area, respectively 10 infiltration wells on drainage area A2, A3, A4, B1, B3, C1, C3, C4 and 1 infiltration well on drainage area Z and overall number is 81 infiltration wells.
Infiltration wells planned is able to reduce the discharge flow of 1.3365 m3/sec or equal to ± 133.65 liters/sec. After discharge evaluation has not yet been able to handle the problem of flooding. This means that there needs to plan a new drainage system to do widening and addition of depth of the existing drainage system in several drainage area ie A1, A2, A3, B3, C1 and C2.
With the planning of infiltration wells, widening and addition of depth of the existing drainage system in several drainage area , the problem of flooding and inundation in the Sukun District area is solved.

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