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Design of Infiltration Well to Reduce Inundation in Rawa Makmur Village, Bengkulu City

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ABSTRACT

Rawa Makmur Village, especially Merpati I, has an area of 3.6 hectares, has experienced land use changes of 30% in the last 3 years. The purpose of this study is to design infiltration wells to reduce inundation that often occurs in this region. The data used are primary data (soil sampling and laboratory testing) and secondary data (rainfall data, land use data and other supporting data) that are processed using hydrological analysis and hydraulic analysis. Based on the results of data processing obtained the intensity of rainfall with a 20-year return period is 2.56 mm/hour and the flood discharge plan is 0.01229 m^3/s. The household debit is 0.212 m^3/s, the roof discharge is 0.00000037 m^3/s, so the total debit that must be reduced is 0.222 m^3/s. The soil sample at the study location is taken and tested in the laboratory. The test results show the soil permeability coefficient is 2.630 x 10-4 m^3/s. Infiltration discharge into the soil is 0.000152 m^3/s, then the reduced discharge is 0.2218 m^3/s. Based on the analysis results obtained the design of infiltration wells with a diameter of 1 meter and a depth of 2.2 meters. One well was effectively used for 2 houses with a reduction of 0.2218 m^3/s with a reduction time of 1,297 minutes.

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INTRODUCTION

Rawa Makmur Village is one of the villages in Muara Bangkahulu Sub-district which is located on the edge of Bengkulu City with an area of 150 Ha and a population of 1,468 people [1]. This village has experienced a high population growth in the last 3 years. This caused the conversion of land from swamps to dry land.

Land use changes of 30% in the last 3 years have resulted in inundation every rainy season with high intensity and low intensity. Inundation height ranges from 5 - 50 cm on the highway and reaches 100 cm in the population area, especially those adjacent to the river. Based on the results of topographic measurements that have been carried out and analyzed, it can be seen that the topographic conditions in this village are wavy [2].

Land use in this region consists of 44.66% houses, 2.62% offices, 13.12% swamps, 32.25% shops, vacant land 7.35%. This area is a swamp area that acts as a reservoir for rainwater before finally flowing into the river. The absorption function will be returned as a means to reduce inundation that often occurs in this area during the rainy season with an environment-based infiltration well method.

The inundation that occurred is caused by changes in land use, namely from the swamp

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ecosystem to a built area. The purpose of this research is to reduce the inundation that occurs, one of them is by making infiltration wells.

Related to this research, research has been carried out with the title "Flood Control Study in Kepanjen District with Infiltration Wells" [3]. The study analyzed that to overcome the problem of inundation, several alternatives were used with environmentally sound drainage methods in the study area and also carried out improvements to the drainage channel by changing the dimensions of the drainage channel and planning a drainage system that could accommodate rainwater discharge.

Therefore, in the planning of drainage systems based on water conservation that is by using the design of artificial recharge on the infrastructure of the dainage network system can be infiltration wells in each residential area. From the calculation, the plan for infiltration wells with a diameter of 1 m and a depth of 3 m is 619 units. Planning of infiltration wells is placed in locations of residential areas that are prone to flooding in accordance with the calculation of channel capacity evaluation. The results of the budget plan obtained for planning the infiltration wells do not require a greater cost than the rehabilitation of the channel, so that at this location it is recommended to use rehabilitation in the form of infiltration wells.

Flooding is one of natural phenomena that can cause great harm to humans. Flooding can occur due to overflowing rivers, reservoirs, lakes, seas, or other water bodies that flood the lowlands and basins that were not initially flooded. Besides that, flooding can also occur if rainwater is trapped in a basin and becomes an inundation [4].

Flooding can be interpreted as the overflow of rainwater with a large discharge held in a lower area with a water level of 30 to more than 200 cm [5]. Flood control efforts that are carried out are generally still conventional, namely enlarging and improving the existing drainage channels so that rainwater can be channeled immediately. The concept of conventional drainage has the disadvantage of not providing an opportunity for water to seep into the soil [4].

The concept of environmental conservation is the area must be free from stagnant water immediately, by pulling it into the water purification network system and flowing it into the river then to the sea [6]. Infiltration well is building that is made in such a way that resembles the shape of a dug well with a certain depth that serves as a place to collect rainwater that falls on the roof of a house or animpermeable area and absorbs it into the soil [7].

Infiltration well is defined as circles or rectangles dug wells with a certain depth. Infiltration well function to accommodate and absorb rainwater that falls on the surface of the soil through the roof of building, road and courtyard.Infiltration well serves to: (a) reduce the surface of flow so as to prevent or reduce the occurrence of floods and stagnant water; (b) maintain and increase the groundwater level; (c) reduce of erosion and sedimentation; (d) prevent the land subsidence; (e) reduce the concentration of groundwater pollution [3].

Determination of planned flood discharge (design flood) needs to obtain the intensity of rainfall value, especially if the rational method is used. The intensity obtained from the results of frequency analysis of rainfall data is based on the statistical properties of past event data to obtain the probability of the amount of rain in the future. In statistics there are several parameters related to data analysis which include average, standard deviation, coefficient of variation and skewness coefficient.

Frequency analysis that is often used for hydrology field are normal distribution, normal log distribution, Log Pearson III distribution, and Gumbel distribution. Parameter testing is needed to test the suitability of the data sample frequency distribution to the probability distribution function that is estimated to be able to describe or represent the frequency distribution. Testing parameters that are often used are the chi-square test and Smirnov-Kolmogorov [8].

Rainfall equation using the Gumbel distribution is:

$$\bar{X}=\mathrm{X}+\mathrm{sK} \quad (1)$$

$\bar{X}$ = average sample

s = standard deviation

$$s = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}} \quad (2)$$

$$K = \frac{YTr-Yn}{Sn} \quad (3)$$

Y_n = *reduced mean*which depends on the number of samples

S_n = *reduced standard deviation*which depends on the number of samples

Y_{Tr} = *reduced variate*

Based on the calculation results above, the amount of rainfall is calculated using the Mononobe Method.

$$I_T = \frac{R24}{24}\left[\frac{24}{t}\right]^{2/3} \quad (4)$$

with:

I_T = Rain intensity (mm/hour).

t = duration (hour).

R_{24} = Maximum rainfall in 24 hours (mm).

Because of the Rational formula cannot be distributed from time to time from the discharge reaching the peak and back down, it is necessary to calculate the time of concentration (tc) is the length of time needed to reach the observation point by the rain falling in the furthest place from the observation point. The time of concentration is divided into two: the time needed to drain water through the soil surface to the nearest channel (tof: time overland flow) and the time to flow in the channel to the measured place (tdf: time detention flow) [9]. The time of concentration equation is:

$$tc = \left[\frac{0{,}87\ xL^2}{1000\ xS}\right]^{0{,}385} \quad (5)$$

with:

tc = time of concentration (hour).

L = Main channel length from upstream to downstream (m).

S = The average slope of the main channel

The mathematical equation of the Rational method is expressed in form:

$$Q_p = 0{,}002778\ C.I.A \quad (6)$$

Where Qp is the peak surface flow rate (debit) in m^3/sec, C is the coefficient of surface flow ($0, \leq C \leq 1$), I is the intensity of rain in mm / hour, and A is the watershed in hectares. The rational method was developed based on assumptions and evenly distributed throughout the watershed for at least equal to the concentration time (tc) of the watershed.

The effect of land use on surface flow is stated in the surface flow coefficient (C), which is a number that shows a comparison between the amount of surface flow and the amount of rainfall [9]. This surface flow coefficient is one indicator to determine the physical condition of a watershed. The value of C ranges from 0 to 1. The value of C = 0 indicates that all rainwater is intercepted and infiltrated into the ground, whereas for the value of C = 1 indicates that all rainwater flows as surface runoff.

The ability of a fluid to flow through a porous medium is a technical trait called permeability. Permeability can also be defined as the properties of a material that allows the flow of seepage of liquid to flow through the pore cavity [10]. The permeability unit is m^2. Generally in geothermal reservoirs, vertical permeability ranges from 10-14 m^2, with horizontal permeability can reach 10 times greater than its vertical permeability (about 10-13 m^2).

Theoretically, the volume and efficiency of infiltration wells can be calculated based on the balance of water entering the well and the water that seeps into the soil and can be written as follows [11]:

$$H = \frac{Q}{F.K}\left[1 - e^{\frac{F.K.T}{\pi R^2}}\right] (7)$$

Where: H = Water level in the well (m), F = Geometric Factor (m), Q = Incoming water debit (m^3/s), T = Flow time (sec), k = soil permeability coefficient (m/s) , R = well radius (m).

Calculation of rainwater infiltration wells in accordance with SNI No. 03-2453-2002 [12], divided into:

(1) The volume of flood shares will be transferred to rainwater infiltration wells. The formula used:

$V_{ab} = 0{,}855.C_{cistern}.A_{cistern}.R$ (7)

note:

V_{ab} = The volume of floods that will be absorbed by infiltration wells (m^3)

$A_{cistern}$ = land area (m^2)

$C_{cistern}$ = Runoff coefficient from the field of cistern (without units)
R = Average daily rain height

(2) The volume of rainwater that permeates the formula:

$V_{recharge} = \frac{Te}{24} . A_{total} . K$ (8)

note:
V_{rsp} = The volume of rainwater that permeated
T_e= Effective rain duration (hours) $= 0.9.\frac{R^{0,092}}{60}$(hours)
A_{total}= Well wall area + Area of well base (m^2)
K = Soil permeability coefficient

EXPERIMENTAL METHOD

The study was conducted in the Rawa Makmur Village, Bengkulu City. Data collection methods consist of primary data are soil sampling (soil testing in laboratories and topographic surveys) and secondary data consisting of annual rainfall data, land use data, and other supporting data. The data were analyzed by using hydrological analysis, hydraulic analysis and descriptive analysis.

RESULTS AND DISCUSSION

The location of the study was chosen the areas that were most severely flooded, namely Merpati 1 RT 21 Rawa Makmur Village which had an area of 3.6 Ha. Land use in this area consists of residential areas, rice fields and oil palm plantations with an area of 18.33% is community housing, 20.56% is rice fields and 61.11% is oil palm plantations.

Rainfall data obtained from BMKG station in Bengkulu City is processed and analyzed by using statistical distribution.

Table 1. Statistical distribution test results

Type of Distribution	Terms	Calculation	Information
Normal	$C_s \approx 0$	0.156	Qualify
	$C_k \approx 3$	0,307	Not Eligible
Log Normal	C_s=3Cv +Cv^2=0.152	-0.092	Not Eligible
	$C_v \approx 0{,}06$	0.0409	Not Eligible
Gumbel	$C_s \approx$ 1.1396	0,156	Not Eligible
	$C_k \approx$ 5.4002		Not Eligible
Log Pearson III	$C_s \neq 0$	-0.092	Not Eligible
	$C_v \approx 0{,}3$	0.0409	Not Eligible

Source: (Results of Analysis, 2018)

From the calculations that have been done with the above conditions, then a normal distribution is selected to ensure the selection of the distribution needs to be compared with the results of statistical calculations with Chi Square and Smirnov-Kolmogrov alignment tests.

Table2.Calculation of Chi Square Test

No	Probability (%)	O_f	E_f	E_f-O_f	$\frac{(E_f-O_f)^2}{E_f}$
1	165,225<X< 209.575	1	2	1	0
2	209.575<X<253.925	3	2	-1	0,5
3	253.925<X<298.275	2	2	0	0,5
4	298.275<X<342.625	2	2	0	-2
5	342.625<X<386.975	2	2	0	0
		10	$(\lambda h)^2$		0,5

Source : Results of Analysis(2018)

From the calculation above, the Chi Square value (λh) 2 = 0.5. The critical limit of Chi Square values for dk = 7 with α = 5% (0.05) is (λh) 2cr = 14.067. Value (λh) 2 = 0.5 <(λh) 2cr = 14.067. Then the distribution calculation using the Normal method is acceptable.

Soil permeability coefficient data is obtained from the results of laboratory tests based on soil samples taken using a handbor. Based on the results of testing at the Civil Engineering laboratory of Universitas Prof. DR. Hazairin, SH Bengkulu, it is known that the soil type is categorized as silty soil with a soil coefficient value of 2 m depth is 2,630cm / second.

Table 3. Soil Testing Results

Depth (meter)	Hand Drill Soil Samples
Piknometer Number	1
Piknometer Weight + sample W_2	81,500
Piknometer Weight W_1	30,500
Soil sample weight $W_T = W_2 - W_1$	49,700
Temperatrur (Celcius degrees)	25 C^0
Piknometer Weigth + Water + Soil	92,400
Weight + Piknometer + Water	80,500
$W_5 = W_2 – W_1 + W_4$	111,300
Land content W_5 - W_3	18,900
Soil Specific Gravity $\frac{WT}{W5-W3}$	2,630
Rata-rata	2,630 m^3/detik

Source : test results in the laboratory(2018)

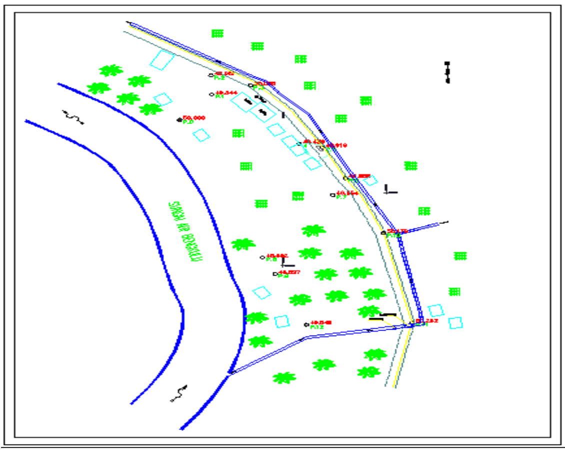

Fig.1. Layout of Research Sites

Based on topographic measurement data, it is known that point P0 (Air Bengkulu river bank) has an elevation of +50,169 higher than the point P5 elevation (primary channel). This condition indicates that the river mouth elevation is lower than the primary channel point. The Muara Bangkahulu River will experienced high rainfall and cause backflow to the primary channel, causing inundation in the neighborhood. One alternative problem solving is to make infiltration wells to minimize the puddle.

From land use data obtained runoff coefficient value of 0.48. The width of the Muarabangkahulu River is 40 meters and a length of 17297 meters with a research area of 3.6 Ha. The elevation (H) of the upstream point is 50,057 m/dpl and the elevation of the downstream elevation is 49,916 m/dpl so the slope of the river bed is 0,0538. The time needed to drain water from the furthest point to the outlet (Tc) is 374,512 hours, so that the annual rainfall intensity of 2,560 mm/hour is obtained and the flood discharge of the 20-year plan is 0,01229 m^3/s.

The measurement of flow velocity in the channel obtained a number of 0.282 m/s with a wet cross-sectional area of 280 m^2, then the channel discharge was calculated as 78.96 m^3/s so that the flood runoff was 78.948 m^3/s.

The discharge to be flowed into the infiltration well is the total housing area including the yard and roof area, household discharge discharge and planned flood discharge. Based on the calculation, it is obtained that the roof discharge is 0.00000037m^3/s, the discharge discharge of household waste is 0.212 m^3/s, and the total discharge (Q_m) is 0.222 m^3/s.

The depth of infiltration wells including the reinforcement walls of infiltration wells (concrete buis) with concrete wall height is R = 1.00 H meters = 0.5 m so the depth of the infiltration wells is 2.2 meters. Infiltration discharge is 0,000152 m^3/s and reduced discharge is 0,221848 m^3/s. The capacity of infiltration wells was 1,727 m^3 with the time to fill the well for 0.1297 minutes.

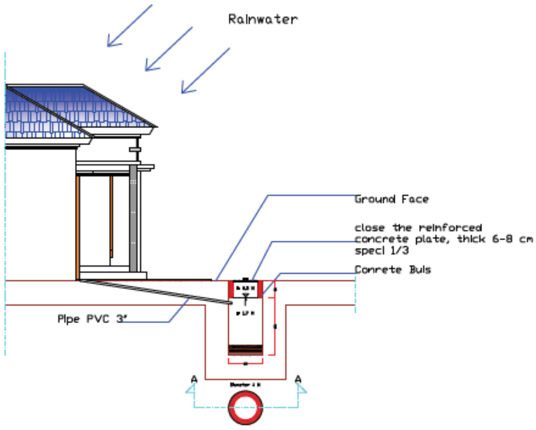

Fig. 2. Infiltration Well Design

CONCLUSION

Topographic survey results shown the elevation P_0 (downstream of the river) + 50,169 meters higher than the elevation point P_5 (upstream of the river) + 49,882 meters, so infiltration wells are needed using buis concrete with a diameter of 1,00 m and a depth of 2,2 m to reduce inundation.

The absorption capacity of the infiltration pond is 1,727 m^3, then runoff delay is 0.1297 minutes before the water enters the ground. Flood discharge before the infiltration well is 0.00678 m^3/s, significantly reduced by the application of infiltration wells of 0.000526 m^3/s.

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