DEVELOPMENT OF FLOOD COUNTERMEASURES MODEL IN CAMPUS OF KETINTANG UNESA SURABAYA

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ABSTRACT

Surabaya is capital city of east java province. It is the third biggest city in Indonesia with 374.36 km^2 in width. Southern Surabaya is a lowland 3-6 m above the sea level. There are two campus of Unesa: one stands on the southern Surabaya at Jalan Ketintang district of Gayungan and other stands on the western Surabaya at Jalan Lidah Wetan with the height of 6-10 m above the sea level. In Ketintang, area of the puddle is 89.91 ha with the depth of 10-30 cm and needs 6 hours to shrink. Source of the problem is condition of secondary and tertiary drainage channels which is not able to accommodate debit design. This research aims to analyze capacity of secondary and tertiary drainage channels with the debit design is calculated by using rain analysis design with frequency distribution method of Log Pearson Type III with 10 years rescheduling. Another goal of this research is to make design of extension or revitalization of channels gradually on master plan of campus. Results of the research indicate that 13 of 21 segments of channels on area of research have capacity of channel which is not able to accommodate debit design or Q channel < Q design while other channels only need extra custody height. Other factors exist which may influence the puddle in campus of Ketintang that is extra domestic waste 0.00023936 m^3/s and paddy soil hilling in left of Faculty of Technique and Rectorate that result in function of land changes which previously to accommodate the puddle in the rain season now becomes flat and unable to accommodate the puddle in the rain season. Several tertiary channels should be changed into primary and secondary channels.

Keywords: extension model, flood countermeasures, drainage in campus of Unesa.

INTRODUCTION

1. Background

Surabaya is capital city of east java province with area of 374.36 km^2. Surabaya is center of business, industry and education especially in eastern Indonesia. Southern Surabaya is located in the low land with the height of 3-6 m above sea level including here is campus UNESA Ketintang while in western Surabaya there is campus UNESA Lidah Wetan with the height of 6-10 m above sea level. River Brantas has two branches. One of them is estuary Kali Mas.

Today Surabaya has many problems when rainy season comes. One problem is about flood. This situation happens almost every year but still the problem hasn't been resolved yet even tends to increase both the frequency, the extent, the depth and the duration. This situation, of course, is very harmful and disturbing activities especially in campus UNESA Ketintang such as economy, transportation, education, and many more activities that will be interrupted mainly teaching and learning processes. Data about puddles in Surabaya can be seen in Table 1 and Figure 1-2 show flood/puddle in campus UNESA Ketintang with the depth of 50 cm.

Table 1. Puddle areas in Surabaya

No	Stagnant Region Name	Large (ha)	Long (hours)	Depth (cm)
1.	K. Kedurus	238,22	> 6	30-50
2.	Kp. Petemon	105,77	2-4	30-50
3.	Kp. Kandangan	237,12	> 6	30-50
4.	Jl. Semarang	10,35	2-4	10-30
5.	Ketintang	89,91	> 6	10-30
6.	Jl. Gayungan I, II	29,48	> 6	10-30
7.	Per. Bendul Merisi	31,86	2-4	10-30
8.	Per. Jemur Andayani	31,71	> 6	10-30
9.	Jl. Raya Rungkut/ Industri	122,54	> 6	50-70

10.	Medokan semampir	227,45	> 6	30-50
11.	Jl. Mayjen Sungkono	8,34	> 6	> 70
12.	Gunung Sari	185,17	> 6	50-70

Source: Department of Public Works and Highways drainage Surabaya 2012

The existence of campus Ketintang increases land use change and the high rate of population growth increases the needs of housing and other facilities so that land use for water catchment diminish and result in flood or puddle about 50 cm since 2010 (Figure 1). District Ketintang is one area which yearly has puddle in every rainy season because it has characteristic of low land.

Figure 1.1 The state rectorate inundation area

Figure 1.2 The state of the campus area floodwaters

In district Ketintang, there is paddy lands, housings, and business centers. In addition, there is campus UNESA Ketintang and office of PT. TELKOM with total area is 58.000 m^2. Land elevation of PT. Telkom area is about 80 cm above land elevation of UNESA area (direct measurement) so rain water will flows from PT. Telkom area (high elevation) to UNESA area (lower elevation).

Another factor that influences amount of water debit in campus UNESA Ketintang is water spill from watershed Wonorejo in which the river is located in south of campus. In rainy season, capacity of the river is unable to accommodate amount of water debit so water from the river will spill into area of campus UNESA Ketintang and increase volume of puddle (back water) and increase flow of back water from watershed Wonorejo due to tide. This is confirmed with result of the research on evaluation of channel dimension in river Wonorejo in district Wonorejo Surabaya (Kusnan et all 2011).

2. Problem Formulation

Based on identification of problem above, problem formulation can be obtained as follows:

a. Whether drainage system or tertiary and secondary channels in location of the research able to accommodate the puddle?
b. What factors that can influence puddle in campus UNESA Ketintang?
c. Whether dimension of the existing secondary and tertiary drainages able to accommodate the puddle in the peak of rainy season and whether the addition of primary drainage needed?
d. How to design the master plan of drainage in campus UNESA Ketintang?

3. Goals of this Research

Goals of this research is

a. To contribute ideas on problems of drainage system design which exist in Campus UNESA Ketintang
b. To make plan of drainage extension/revitalization gradually in campus master plan

4. Hydrology analysis

To determine the maximum debit that happens in area of study by analyzing everything to all behavior of hydrology analysis that determines the next planning.

a. Method used in the calculation of maximum daily rain that is arithmetic main method on method of rainfall analysis by arithmetic main method. The average rainfall can be obtained by taking mean scores from the rainfall measurement stations in the observed area (Surpin. 2003. The sustainable urban drainage system. Semarang. Andi Yogyakarta). The formula is

$$R = \sum_{i=1}^{n} \frac{R}{r} \ldots\ldots (1)$$

b. Hydrograph calculation with HSS Nakayasu method is used to determine when (hour) the peak of rainfall happens in the observed research area.

$$Qmax = \frac{1}{3.6} xAx \frac{R_0}{(0.3 \times Tp + T \times 0.3)} \ldots\ldots (2)$$

with
Q_{max} = flood peak debit (m^3/s/mm)
A = area of flow (km^2)
T_p = interval time from start of rain to peak of rain (hour)
Tx0.3 = lowering from peak debit to 30% of peak debit (hour)

c. Frequency distribution method of Log Pearson Type III

This method is used if amount of data is many enough or with the meaning that more data to be analyzed less deviation will be resulted (Suripin. 2003. The sustainable urban drainage system. Semarang: Andi Yogyakarta).

d. Examination of frequency distribution suitability test

The examination of frequency distribution suitability test aims to know the truth of distribution hypothesis from sample of data which has been analyzed so that if the both analysis are compared it will has the same deviation with its theoretical distribution or the occurred deviation is still possible and the truth can be accepted so it needs examination process of suitability test which can be explained as bellows:

1) Suitability between result of the observation and the theoretical distribution model
2) The truth can be accepted or not

There are two ways to obtain the suitability of frequency distribution that generally is used to test the probability that is:

a) Sminov-Kolomogorov Test

Sminov-kolomogorov test is frequently referred to non-parametric suitability test because the test doesn't use specific distribution function as validity test.

b) Chi-Quadrat Test

This test to be aimed to determine whether the chosen distribution equation can represents statistic distribution of the analyzed data sample. The deduction of this test is by using X_2 parameter that can be calculated by the formula:

$$X^2 hit = \sum_{i=1}^{k} \frac{(O_F - E_F)^2}{E_F} \ldots\ldots (3)$$

e. Rainfall debit (Qah)

The method used in calculating debit of rainfall in drainage channels in this research is rational method (Suripin, 2003: 79). This formula is frequently used on ordinary rivers with extensive drainage and also on drainage plan of narrow drainage area. The general equation of rational method is as follows:

$$Q = 0.278 \times C \times I \times A \ldots\ldots (4)$$

with
Q = debit of maximum flood (m^3/s)
C = coefficient of drainage ($0 \leq C \leq 1$)
I = intensity of average rainfall during flood starts (mm/hour)
A = area of drainage (Km^2)
0.278 = factor of conversion

f. Dirty water debit (Q_{ak})

To estimate amount of domestic waste water that will be discarded through drainage channel, it should be known first amount of water requirement for everyone per day that constitutes main indicator to analyze the domestic waste water including percentage of the loss in the process (C.D. Soemarto. 1987. Technique of Hydrology. Surabaya: Usaha Nasional). For the big cities such as city of Surabaya, it is known that amount of waste water per day is 250 litre/person/day, in which percentage of the loss in the process is 20% (Soufyan, Takeo Morimura, 2000).

$$Qak\ total = \frac{P_n \times 80\% \times k_{ab}}{A\ total} 10^{-3} \ldots\ldots (5)$$

g.Calculation of design flood debit

To determine amount of river based on rainfall, we should review first correlation between the existing rainfall debit with topography and land use in the observed area, parameters that influence all hydraulic behavior of water in the determined area reviewed against to several factors that is : coefficient of drainage (C), intensity of rainfall (I), and area of drainage (A).

h.Coefficient of drainage (C)

Coefficient of drainage is ratio between amount of water that flows in an area due the rain is falling to amount of rainfall that fall in the area. The magnitude of drainage coefficient changes from time to time in accordance with effect of land use and river flow. Coefficient of drainage in an area is influenced by important factors (Imam Subarkah, 1978:42) that is:

1. Condition of rain
2. Area and configuration of drainage area
3. Slope of drainage area and slope of river base
4. Infiltration power and percolation of land
5. Wetness of land
6. Air temperature, wind, and evaporation
7. Place of the drainage area to the wind direction
8. Capacity of riverbed and area around

Coefficient of drainage is defined as follows:

$$C = \frac{R_0}{R} \quad \text{...(6)}$$

with
C = coefficient of drainage
Ro = amount of runoff
R = amount of rainfall

i. Coefficient of average drainage (cm)

A place with several kind of land use can be determined too by considering weight of each part in accordance with the represented area. The formula is:

$$Cm = \frac{\sum^{n} A_i . C_i}{\sum^{n} A_i} \quad \text{..................(7)}$$

with
Cm = coefficient of mean drainage
Ai = area of each land use (km^2)
Ci = coefficient of drainage of each land use
n = amount of land use in a drainage area

j. Intensity of rainfall (I)

Intensity of rainfall is the height of rainfall that happens during a specific period in an observed area in which the water get concentrated. To analyze the rainfall in a determined area can uses formula as follows:

$$I = \frac{R_{24}}{24}\left[\frac{24}{t_c}\right]^m \quad \text{.....................................(8)}$$

where
I = intensity of daily rainfall (mm/hour)
R24 = daily rainfall (mm)
t_c = time of the rainfall get concentrated
m = constant (m = 2/3)

k.Time of getting concentrated (tc)

Time of getting concentrated is time that needed by the rainfall to flow from one farthest point to a determined point referred on a drainage area. To determine time of the water flows on land surface, we can use formula as follows:

$$t_c = t_o + t_f \quad \text{.....................................(9)}$$

$$t_f = \frac{L}{V} \quad \text{...(10)}$$

$$t_o = 1{,}44.\left(nd.\frac{L_o}{\sqrt{S}}\right)^{0{,}467} \quad \text{.................................(11)}$$

where
t_c = time of getting concentrated (hour)
t_0 = time of the water takes to go to nearest drainage (hour)
t_f = time of the water takes to flow in drainage (hour)
L_0 = length of the farthest point on land perpendicular to the observed drainage (m)
S = mean slope of rainwater drainage
nd = coefficient of obstacle (Table 2)
L = length of calculated rainwater drainage (m)
V = velocity of drainage (m/s)

Table 2. Coefficient of drainage roughness

Material Channel	Manning (n)
Channels Without Couples	
Soil	0,020 – 0,025
Sand and gravel	0,025 – 0,040
Rock	0,025 – 0,035
Channels with Couples	
Cement mortar	0,015 – 0,017
Concrete	0,011 – 0,015
Masonry mortar wet	0,022 – 0,026
Masonry mortar dry	0,018 – 0,022
Channels Open Channels with stucco	
Asphalt	0,013 – 0,017
Brick couple	0,012 – 0,018
Concrete	0,020 – 0,035
riprap	0,030 – 0,040
channel Excavation	
Land, straight and uniform	0,030 – 0,015
Soil rock	0,050 – 0,140
Natural channel (a small river <3 m)	0,030 – 0,070

Source: Yusro Fahmi M. (2009).

l. Slope of drainage

Slope of drainage is slope of drainage base and slope of drainage wall. Slope of drainage base is slope of drainage in the longitudinal direction which in general is influenced by topography conditions and the necessary height of pressure to obtain specific potential energy thereby the drainage able to flows in accordance to the desired conditions. To determine slope of drainage base, table 3 is provided and to determine slope of land, table 4 is provided.

Table 3. Slope of drainage base in accordance to several material types

Material Channel	The slope of the walls
Stone	Hampir tegak lurus
Peat soils, swamps region	0,25 : 1
Firm clay or concrete-lined ground	(0,5 – 1) : 1
Layered soil or ground stone for large channel	1 : 1
Stiff clay or soil for a small ditch	1,5 : 1
Layered soil loose	2 : 1
Sandy mud or clay concrete	2 : 1

Source: Ven Te Chow, 1989 in Joseph Kristiawan 2008

Table 4. Slope of land based on area of tertiary block

The slope of the land	Tertiary Block Size (ha)
0,0003	< 10
0,0005	10
0,001	20
0,005	40

Source: SDMP 2018

m. Capacity of drainage channel

Basic analysis of drainage dimension design (Kusnan 2010, basic hydrology and urban drainage. Surabaya: UNESA) uses several formulas as follow:

1. Formula of flow rate :
   $V = kR^{2/3}I^{1/2}$....................................... (12)
2. Formula of debit :
   Q = A . V .... (13)
3. Formula of wet cross sectional area :
   A = b . h (Rectangular profile) .... (14)
   A = (b + mh). h (trapezium profile)
   A = 0,5.b.h (triangular profile)
4. Formula of wet periphery :
   Rectangular profile
   P = b + 2h ……......................................(15)
   trapezium profile
   P = b + 2h
   triangular profile
   P = r + r
5. Formula of hydraulic radius:
   $R = \frac{A}{P}$ ....(16)

where
A = wet cross sectional area (m^3)
B = b1 = b2 = width of drainage base (m)
h = height of water surface (m)
r = length of drainage wall slope (m)
P = wet periphery (m)
R = hydraulic radius (m)
V = velocity of mean flow in drainage (m/s)
n = coefficient of roughness of drainage wall
m = slope of drainage wall
S = slope of drainage base
F_b = height of protection
Q = debit of water flow

To determine dimension of drainage, we conduct approach to ratio between the width of drainage base (b) and the depth of flow (h) in relation with capacity of drainage. It can be seen in Table 5.

Table 5. Ratio between the width of drainage base and the depth of water surface

In the discharge (m^3/ s)	Tilt the channel wall	Comparison b/h	Hardness factor (k)
1,50 – 3,00	1,50	1,80 – 2,30	40,00
3,00 – 4,50	1,50	2, 30 – 2,70	40,00
4,50 – 5,00	1,50	2,70 – 2,90	40,00
5,00 – 6,00	1,50	2,90 – 3,10	42,50
6,00 – 7,50	1,50	3,10 – 3,50	42,50
7,50 – 9,00	1,50	3,50 – 3,70	42,50
9,00 – 10,00	1,50	3,70 – 3,90	42,50

Source: Standard irrigation planning, 1986 in Joseph Kristiawan 2008

n.slope of drainage wall

Slope of drainage wall in the design of water drainage should be adjusted to type of construction material used to make body of the drainage. It can be seen in Table 6.

Table 6. Slope of drainage wall to various type of material

Bahan Saluran	Kemiringan Dinding
Batu	Hampir tegak lurus
Tanah gambut atau daerah berawa	0,25 : 1
Lempung teguh atau tanah berlapis beton	(0,5 - 1) : 1
Tanah berlapis batu atau tanah bagi saluran besar	1 : 1
Lempung kaku atau tanah bagi parit kecil	1,5 : 1
Tanah berlapis lepas	2 : 1
Lumpur berpasir atau lempung beton	3 : 1

Source: Ven Te Chow, 1989 dalamYosep Kristiawan 2008

5. Hydraulic Analysis

Hydraulic analysis constitutes further analysis from hydrologic analysis especially as input of determining form of drainage dimension based on designed flood debit.

a. Capacity of drainage

This research of flood prevention model development in campus UNESA Ketintang uses designed flood debit from result of calculation with interval of 2, 5, and 10 years.

b. capacity of channel

Calculation used in calculating capacity of drainage channel is by using formula manning (Suripin, 2003: 144)

$$Q = V \, x \, A \quad \text{.............................} (17)$$

$$V = \frac{1}{n} \, . R^{2/3} \, . S^{1/2} \quad \text{..........................} (18)$$

with

R = hydraulic radius (m)
V = velocity of mean flow (m/s)
N = coefficient of manning roughness
Q = capacity of drainage (m^3/s)
A = cross sectional area (m^2)
S = slope of drainage base

Coefficient of manning roughness (n) from formula manning is determined based on material of drainage body. Coefficient of manning roughness of various material of drainage body and type of drainage can be seen in Table 7.

Table 7. Various type of coefficient of manning roughness

No.	kind	n
A	Channels partially covered with a full flow	
1.	Culverts of concrete straight and free of objects drifting	0,01-0,013
2.	Culverts with a turn and the connection of concrete and there are little things that float.	0,011-0,015
3.	Straight exhaust duct of concrete	0,013-0,017
4.	Masonry coated with cement	0,012-0,017
5.	Couple stone cemented	0,015-0,030
B	**Channel Open**	
1.	Masonry in cement	0,012-0,018
2.	Concrete with plaster	0,013-0,016
3.	Couple stone in cement	0,014-0,035
4.	Rip rap	0,020-0,035

Source: The Chow Ven Open Channel Hydraulics

a. The most economical of drainage form

The most economical of cross section of drainage is the one that can run off the maximum debit for wet cross sectional area, roughness, and slope of determined base. Based on the formula of continuity, it's clear that for the constant cross sectional area, the maximum debit will be reached if the velocity of flow is maximum. From formula manning and Chezy it can be seen that for constant slope of base and roughness, the maximum velocity will be reached if the hydraulic radius R is maximum. Next, for constant cross sectional, the hydraulic radius will be maximum if wet periphery, P, is minimum.

1. Section with rectangular form

Design of drainage with rectangular form section is most efficient by using formulas (Suripin, 2003:147).

$$A = b \, . \, h \quad \text{.......................................} (19)$$

$$P = b + 2 \quad \text{.......................................} (20)$$

$$R = \frac{b \, . \, h}{b + 2h} \quad \text{....................................} (21)$$

with

b = width of drainage base (m)
h = height of drainage that inundated with water (m)
A = cross sectional area of drainage (m^2)
P = wet radius (m)
R = hydraulic radius (m)
m = slope of drainage wall

2. Section with trapezium form

Design of drainage with trapezium form section is most efficient by using formulas (Suripin, 2003:148).

$$A = (b + mh) \quad \text{................................} (22)$$

$$P = b + 2h\sqrt{m^2 + 1} \quad \text{....................} (23)$$

$$R = \frac{(b+mh)h}{b+2h\sqrt{m^2+1}} \quad \text{..............................} (24)$$

METHOD OF RESEARCH

1. Type Of Research

This research of flood prevention model development in campus UNESA Ketintang uses descriptive quantitative research method. Descriptive research is base for all research. Descriptive research can be done quantitatively in order to conduct statistical analysis.

2. Data Of Research

a. Data of condition of observed area consists of
   1) Daily rainfall data in one year
   2) Topography map data of observed area
b. The necessary technical data consists of
   1) Land use map data
   2) Master plan map data of observed area
   3) Profile measurement data and dimension of drainage channel
   4) Drainage network map data
   5) Total population data of observed area
c. The necessary nontechnical data consists of
   1) Direct observation in puddle location
   2) Information about events that relevant with condition of flood puddle from people around

3. Technique Of Data Collection

To obtain reliable data, method of data collection uses:

a. Observation method
b. Documentation method
c. Literature method

4. Roadmap Of Research

Based on wider mandate by UNESA that is in addition to manage educational sciences, UNESA is given authority to open programs of non-educational science. To develop non-educational sciences, technological science based research is developed which have connection to the development master plan (RIP) of UNESA year 2013 specifically the complete design of campus infrastructure in Ketintang that is in relation with campus drainage master plan. Roadmap of the research by the title of "the development of flood prevention model in campus UNESA Ketintang" can be seen in Figure 3.

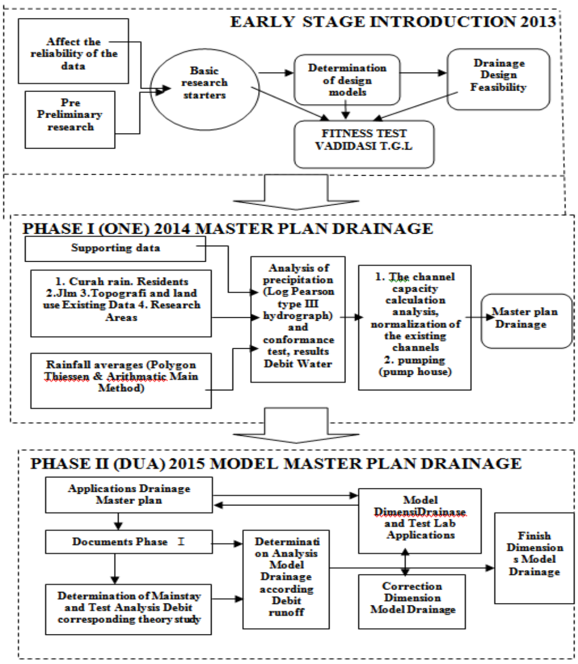

Figure 3. Roadmap of the research

5. Technique Of Data Analysis

Data analysis is conducted by means of mathematic or statistic calculation on the data which obtained from agency, observation and literature.

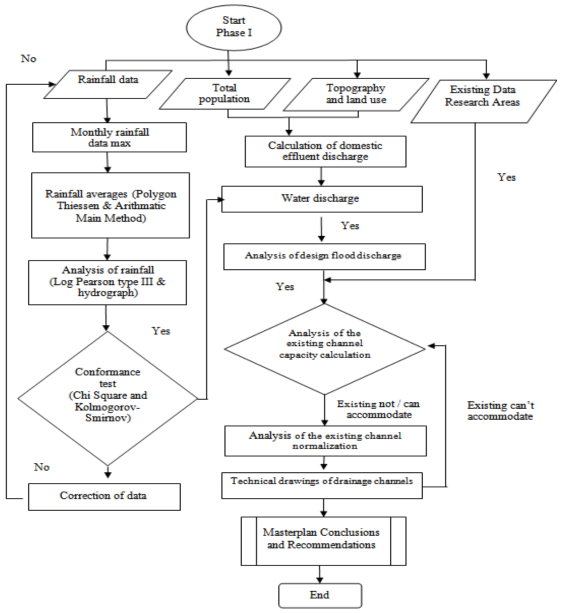

Figure 4. Flowchart of the research

RESULTS AND DISCUSSION

1. Hydrology analysis

Type of rainfall which is needed to make a technical analysis of design of water utilization and flooding prevention is average rainfall for all relevant areas and not rainfall in a certain point on the analyzed area. The determination of average rainfall on an area which has several rainfall measurement stations which is uneven distributed and selection of the rainfall measurement stations which will be used can't be determined directly because different stations have different characteristics. Calculation of average rainfall in area of the research uses arithmetic mean method. Data of rainfall used in this calculation is data from the nearest rainfall measurement stations around Ketintang so station of Kebon Agung, Wonokromo, and Wonorejo will be used.

2. The Drainage System Of Campus Ketintang

The natural channel or river which pass through or become watershed of Wonorejo locates in south of campus Ketintang and serve drainage system of campus Ketintang with the estuary is in south of Kenjeran beach (headwater of Jagir river) is primary channel of Wonorejo river in which the river serves as primary channel or exhaust channel which brings flows in form of rain and sewage from campus Ketintang which derives from downstream of catchment area or local flow of campus Ketintang and housings around. In addition, the channel receives flows from primary, secondary and tertiary drainage channels and direct flow from area around it lead to Wonorejo river and then flow to pump house of Jagir Kalimir and then to Wonorejo I which is accompanied to Jagir river or bozem Wonorejo in east of the beach.

3. Rainfall Analysis By Arithmetic Main Method

On method of analyzing rainfall of the area by using arithmetic main method, average rainfall can be obtained from mean score of each rainfall measurement station in the observed area.

Table 8. Data of maximum rainfall observation for 10 years

No	Year Observation	Rain station Wonorejo	Wonokromo	Kebonagung
1	2003	110	76	75
2	2004	85	92	92
3	2005	90	95	105
4	2006	153	100	98
5	2007	71	107	100
6	2008	68	81	85
7	2009	98	104	76
8	2010	98	110	109
9	2011	94	98	97
10	2012	95	106	114

Source: Department of Irrigation Works in East Java Province

Table 9. Average rainfall by arithmetic method

No.	Year Observation	Average R#1	Order Regression
1	2003	87,00	117,00
2	2004	89,67	105,67
3	2005	96,67	105,00
4	2006	117,00	96,67
5	2007	92,67	96,33
6	2008	78,00	92,67
7	2009	92,67	92,67
8	2010	105,67	89,67
9	2011	96,33	87,00
10	2012	105,00	78,00
		960,67	

Source: Department of Irrigation Works in East Java Province

So average rainfall by arithmetic method is

$$\bar{R} = \frac{960{,}67}{10} = 96{,}067 \text{ mm}$$

4. Calculation Of Channel Capacity

To calculate capacity of drainage channel completely can be seen in Table 10.

Table 10. Calculation of drainage channel capacity of campus Ketintang

Channel	Roving Wet (P) m	Cross-sectional Area (A) m^2	Roughness Coefficient (n)	The Radius of the Hydraulic (R) m	Channel Bottom Slope (*I*)	Speed (Vs) m/det	Channel Capacity (m^3/det
Tertiary channel a1	1,20	0,14	0,022	0,11	0,00156	0,42	0,06
Tertiary channel a2	0,85	0,08	0,022	0,09	0,00052	0,20	0,02
Tertiary channel b1	1,70	0,27	0,022	0,16	0,00138	0,49	0,13
Tertiary channel b2	1,80	0,33	0,022	0,18	0,00069	0,38	0,12
Tertiary channel b3	1,74	0,34	0,022	0,20	0,00075	0,42	0,14
Tertiary channel c	0,70	0,11	0,022	0,16	0,00213	0,62	0,07
Tertiary channel d1	2,83	1,10	0,022	0,39	0,00048	0,53	0,58
Tertiary channel d2	1,40	0,17	0,022	0,12	0,00121	0,38	0,06
Tertiary channel d3	2,00	0,46	0,022	0,23	0,00152	0,66	0,30
Tertiary channel d4	1,40	0,23	0,022	0,16	0,00027	0,22	0,05
Tertiary channel e	1,20	0,18	0,022	0,15	0,00198	0,57	0,10
Tertiary channel f1	1,80	0,33	0,022	0,18	0,00059	0,35	0,11
Tertiary channel f2	2,63	0,50	0,022	0,19	0,00188	0,64	0,32
Tertiary channel f3	1,85	0,29	0,022	0,16	0,00081	0,38	0,11
Tertiary channel g	0,65	0,05	0,022	0,08	0,00032	0,15	0,01
Tertiary channel h	2,63	0,50	0,022	0,19	0,00182	0,63	0,31
Secondary channels i	5,86	0,98	0,022	0,17	0,00015	0,17	0,16
Secondary channels j	5,86	0,98	0,022	0,17	0,00127	0,49	0,48
Tertiary channel k	1,63	0,14	0,022	0,08	0,00138	0,32	0,04
Tertiary channel l	2,25	0,56	0,022	0,25	0,00219	0,84	0,47
Tertiary channel m	2,20	0,53	0,022	0,24	0,00202	0,78	0,41

Source: Calculation results

5. Calculation Of Rainwater Debit (Q_{ah})

To calculate designed debit based on rainwater (Q_{ah}) completely can be seen in Table 11.

Table 11. Calculation of designed debit based on rainwater (Q_{ah})

Channel	L m	Vs m/s	t_f hour	t_c hour	Rainfall (I) mm/hour	Q Rainwater (Q_{ah}) T = 10 year m^3/s
Tertiary channel a1	108	0,42	0,07	0,30	86,32	0,119
Tertiary channel a2	100	0,20	0,14	0,37	75,45	0,059
Tertiary channel b1	266	0,49	0,15	0,42	69,57	0,143
Tertiary channel b2	205	0,38	0,15	0,28	91,90	0,043
Tertiary channel b3	275	0,42	0,18	0,39	73,45	0,103
Tertiary channel c	181	0,62	0,08	0,19	117,30	0,086
Tertiary channel d1	182	0,53	0,10	0,29	88,36	0,239
Tertiary channel d2	114	0,38	0,08	0,20	116,36	0,037
Tertiary channel d3	164	0,66	0,07	0,31	86,26	0,071
Tertiary channel d4	264	0,22	0,33	0,53	59,83	0,065
Tertiary channel e	205	0,57	0,10	0,34	79,84	0,111
Tertiary channel f1	211	0,35	0,17	0,36	77,10	0,065
Tertiary channel f2	189	0,64	0,08	0,25	98,23	0,116
Tertiary channel f3	220	0,38	0,16	0,28	92,22	0,057
Tertiary channel g	156	0,15	0,30	0,50	61,73	0,070
Tertiary channel h	30	0,63	0,01	0,16	134,06	0,007
Secondary channels i	591	0,17	0,97	1,17	34,99	0,114
Secondary channels j	179	0,49	0,10	0,31	85,00	0,064
Tertiary channel k	187	0,32	0,16	0,31	85,99	0,194
Tertiary channel l	509	0,84	0,17	0,44	68,01	0,415
Tertiary channel m	180	0,78	0,06	0,26	97,26	0,117

Source: Calculation results

6. Calculation Of Dirty Water Debit (Q_{ak})

To estimate amount of domestic waste water which will be discharged through drainage channels, we should know first amount of water requirement of each people per day which constitutes main indicator to analyze debit of domestic waste water including percentage of lost in the process (CD Soemarto 1987. Teknik Hidrologi. Surabaya. Usaha Nasional). Calculation of debit of domestic waste water (Qak) completely can be seen in Table 12.

Table 12. Calculation of debit of domestic waste water (dirty water) Q_{ak}

Channel	Discharge calculations	catchment area (A) km^2	total population (Po) Soul	total population (Pn) T = 10 year	$Q_{ak\ total}$ T = 10 year $m^3/s/km^2$	Q_{ak} T = 10 year m^3/s
Tertiary channel a1	a1	0,0137	30347	33633	0,26328830	0,00359415
Tertiary channel a2	a2	0,0077	17044	18890	0,14787425	0,00113375
Tertiary channel b1	a1 + a2 + b1	0,0142	31674	35104	0,27480270	0,00391539
Tertiary channel b2	d	0,0023	5078	5627	0,04405175	0,00010061
Tertiary channel b3	b3	0,0108	23974	26569	0,20799216	0,00224299
Tertiary channel c	b1 + b2 + b3 + c	0,0041	9048	10028	0,07849853	0,00031949
Tertiary channel d1	d1	0,0136	30147	33411	0,26155246	0,00354691
Tertiary channel d2	d2	0,0025	5573	6177	0,04835278	0,00012122
Tertiary channel d3	d1 + d2 + d3	0,0119	26410	29270	0,22913083	0,00272207
Tertiary channel d4	d4	0,0091	20332	22534	0,17639988	0,00161335
Tertiary channel e	d3 + d4 + e + c	0,0126	28002	31034	0,24294040	0,00306008
Tertiary channel f1	f1	0,0078	17407	19291	0,15101805	0,00118247
Tertiary channel f2	f1 + f2	0,0114	25432	28186	0,22064451	0,00252417
Tertiary channel f3	f2 + f3	0,0047	10482	11617	0,09093871	0,00042878
Tertiary channel g	g	0,0076	16873	18700	0,14638914	0,00111109
Tertiary channel h	f3 + g + h + e	0,0011	2419	2681	0,02098437	0,00002283
Secondary channels i	i	0,0305	67710	75042	0,58744671	0,01789245
Secondary channels j	h + I + j	0,0091	20246	22438	0,17564768	0,00159962
Tertiary channel k	k	0,0135	30065	33320	0,26083884	0,00352758
Tertiary channel l	k +l	0,0536	119090	131985	1,03321033	0,05534908
Tertiary channel m	m	0,0102	22620	25069	0,19624632	0,00199681
		0,1881				0,05065902

Source: Calculation results

7. Analysis Of Existing Drainage Capacity

Aim of analyzing existing drainage capacity is to know whether capacity of the existing drainage channel have been able to accommodate debit from rainwater and domestic waste water. From the result of the existing capacity analysis then we can compare with debit of flood from designed existing drainage thereby we can decide whether the existing channel able or not to drain debit of flood which we have analyzed previously.

Existing channel > Q total (safe)

Existing channel < Q total (overflow)

Complete calculation of channel capacity can be seen in Table 13.

Table 13. Analysis of channel capacity with designed debit

Channel	Segment	Q Rainwater (Q_{ah}) T = 10 year m3/s	Q_{ak} T = 10 year m^3/s	Q_{total} $Q_{ah} + Q_{ak}$ m^3/s	Q Burdening Channel m^3/s	Channel Capacity (Q) m3/det	Discharge Overflow / Can be Accommodated	Analysis
Tertiary channel a1	a1	0,119	0,0035941	0,1223	0,1223	0,0561	-0,0663	Overflow
Tertiary channel a2	a2	0,059	0,0011338	0,0606	0,0606	0,0153	-0,0453	Overflow
Tertiary channel b1	a1 + a2 + b1	0,143	0,0039154	0,1467	0,3297	0,1330	-0,1967	Overflow
Tertiary channel b2	d	0,043	0,0001006	0,0433	0,0433	0,1230	0,0797	Secure
Tertiary channel b3	b3	0,103	0,0022430	0,1057	0,1057	0,1438	0,0381	Secure
Tertiary channel c	b1 + b2 + b3 + c	0,086	0,0003195	0,0868	0,5654	0,0693	-0,4961	Overflow
Tertiary channel d1	d1	0,239	0,0035469	0,2430	0,2430	0,5829	0,3399	Secure
Tertiary channel d2	d2	0,037	0,0001212	0,0367	0,0367	0,0622	0,0255	Secure
Tertiary channel d3	d1 + d2 + d3	0,071	0,0027221	0,0738	0,3535	0,2988	-0,0547	Overflow
Tertiary channel d4	d4	0,065	0,0016134	0,0661	0,0661	0,0494	-0,0168	Overflow
Tertiary channel e	d3 + d4 + e + c	0,111	0,0030601	0,1137	1,0987	0,1020	-0,9967	Overflow
Tertiary channel f1	f1	0,065	0,0011825	0,0665	0,0665	0,1141	0,0475	Secure
Tertiary channel f2	f1 + f2	0,116	0,0025242	0,1188	0,1854	0,3188	0,1334	Secure
Tertiary channel f3	f2 + f3	0,057	0,0004288	0,0570	0,2424	0,1099	-0,1324	Overflow
Tertiary channel g	g	0,070	0,0011111	0,0712	0,0712	0,0073	-0,0639	Overflow
Tertiary channel h	f3 + g + h + e	0,007	0,0000228	0,0072	1,4194	0,3136	-1,1058	Overflow
Secondary channels i	i	0,114	0,0178925	0,1317	0,1317	0,1647	0,0330	Secure
Secondary channels j	h + I + j	0,064	0,0015996	0,0651	1,6162	0,4759	-1,1403	Overflow
Tertiary channel k	k	0,194	0,0035276	0,1972	0,1972	0,0442	-0,1531	Overflow
Tertiary channel l	k +l	0,415	0,0553491	0,4707	0,6680	0,4730	-0,1950	Overflow
Tertiary channel m	m	0,117	0,0019968	0,1193	0,1193	0,4106	0,2913	Secure

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8. Analysis Of Normalization Of Existing Channel

From analysis of designed flood debit and existing channel capacity which has been analyzed previously it founds that there is channel section which is unable to drain the existing designed flood debit so it needs normalization of drainage (Kustini, Indiah. 2003. Irigasi. Surabaya. Unesa). Complete calculation and design of channel can be seen in Table 14 and Table 15.

Table 14. Normalization of each channel

Channel	Total Length m	Cross-sectional Shape	Channel Depth (h) m	Depth Count (m) hit	Base Width (b1) m	Width Above (b2) m	m
Tertiary channel a1	108	Rectangular	0,70	0,55	0,50	0,50	0,0000
Tertiary channel a2	100	Rectangular	0,70	0,55	0,60	0,60	0,0000
Tertiary channel b1	266	Trapezium	1,00	0,85	0,80	0,80	0,0000
Tertiary channel b2	205	Rectangular	0,80	0,65	0,60	0,60	0,0000
Tertiary channel b3	275	Trapezium	0,70	0,55	0,45	0,80	0,3182
Tertiary channel c	181	Trapezium	1,10	0,95	0,70	0,80	0,0526
Tertiary channel d1	182	Trapezium	1,20	1,05	1,20	1,20	0,0000
Tertiary channel d2	114	Rectangular	1,20	1,05	1,20	1,20	0,0000
Tertiary channel d3	164	Rectangular	1,20	1,05	1,20	1,20	0,0000
Tertiary channel d4	264	Rectangular	0,90	0,75	0,70	0,70	0,0000
Tertiary channel e	205	Rectangular	1,10	0,95	1,20	1,20	0,0000
Tertiary channel f1	211	Rectangular	0,90	0,75	1,20	1,20	0,0000
Tertiary channel f2	189	Trapezium	0,70	0,55	1,20	1,20	0,0000
Tertiary channel f3	220	Trapezium	0,90	0,75	1,20	1,20	0,0000
Tertiary channel g	156	Rectangular	0,90	0,75	1,20	1,20	0,0000
Tertiary channel h	30	Trapezium	1,20	1,05	1,20	1,40	0,0952
Primary channel i	591	Trapezium	1,20	0,90	2,10	2,10	0,0000
Primary channel j	179	Trapezium	1,20	0,90	2,10	2,10	0,0000
Tertiary channel k	187	Trapezium	0,80	0,65	0,70	0,90	0,1538
Tertiary channel l	509	Persegi	1,20	1,05	0,75	0,75	0,0000
Tertiary channel m	180	Persegi	1,00	0,85	0,70	0,70	0,0000
	4516						

Source: Calculation results

Table 15. Normalization of each channel

Channel	Channel Capacity (Q) m^3/det	Q Burdening channel m^3/s	Discharge Overflow / Can be Accommodated	Analysis
Tertiary channel a1	0,15171	0,12234	0,02937	Secure
Tertiary channel a2	0,11447	0,06063	0,05384	Secure
Tertiary channel b1	0,48004	0,32965	0,15039	Secure
Tertiary channel b2	0,16085	0,04332	0,11753	Secure
Tertiary channel b3	0,15206	0,10565	0,04640	Secure
Tertiary channel c	0,62818	0,56540	0,06278	Secure
Tertiary channel d1	0,65916	0,24297	0,41619	Secure
Tertiary channel d2	1,04382	0,03672	1,00710	Secure
Tertiary channel d3	1,17060	0,35348	0,81711	Secure
Tertiary channel d4	0,15008	0,06612	0,08396	Secure
Tertiary channel e	1,17809	1,09867	0,07943	Secure
Tertiary channel f1	0,47633	0,06652	0,40981	Secure
Tertiary channel f2	0,56330	0,18536	0,37795	Secure
Tertiary channel f3	0,55844	0,24236	0,31607	Secure
Tertiary channel g	0,34858	0,07117	0,27742	Secure
Tertiary channel h	1,46159	1,41940	0,04219	Secure
Primary channel i	0,65337	0,13167	0,52170	Secure
Primary channel j	1,88780	1,61618	0,27161	Secure
Tertiary channel k	0,35371	0,19724	0,15647	Secure
Tertiary channel l	0,70809	0,66797	0,04012	Secure
Tertiary channel m	0,47744	0,11933	0,35812	Secure

Source: Calculation results

9. Topography

In terms of topography condition, campus Ketintang locates on low land ± 3 m above sea level while area outside campus Ketintang has reached height of 3.65-5 m since 2011. This is because of land use change therefore in rainy days rainwater gradually drains to low land that is campus Ketintang. From replenishment of many new buildings in and around campus Ketintang result in less of catchment area or less of water to infiltrate into land.

10. Hydrology

Average rainfall is 117 mm in 2006 in which 90% fall in rain season and 10% fall in dry season (DPU 2010). The highest average rainfall monthly in south Surabaya including Campus Ketintang falls is month of September 2013 and elevation of ground water surface is very low about 3 m and if it is accompanied with tide, then the ground water surface will increase therefore there is a puddle in campus Ketintang it will need long time to dry.

11. Pumping (Pump House)

For drainage area in district Gayungan, water in campus Ketintang due to effect of water seepage from environment around or area of water surface elevation in channels in sub system of campus Ketintang drainage, the need of pumping system or pump house is unavoidable. There are two existing pump houses in campus Ketintang that is PA (C1) (1500 m^3/hour)in east of library center building and PA (C2) (360 m^3/hour) in bozem Unesa. It still needs to build pump house (1500 m^3/hour) near to faculty of technique. Then they are connected to pump houses along watershed of Wonerejo, when water comes to Bendul Merisi in drainage Wonorejo it is divided into two paths, one flows to Jagir kalimir and Prapen. Part of drainage Wonorejo that flows to Jagir Kalimir is pumped to river Jagir with capacity of overall pumps is 2.25 m^3/s, and then part of drainage wonorejo that flows to east when comes to Prapen some will be pumped to river Jagir with capacity of overall pumps is 2.30 m^3/s and other will be continued to east to Wonorejo. When water comes to Wonorejo 1 some will be pumped to river Jagir with capacity of overall pumps is 8.9 m^3/s and other will be continued to Wonorejo 2. When water comes to Wonorejo 2, some will be pumped to river Jagir and other will be continued to bozem Wonorejo. Then after comes to bozem wonorejo, the water will be pumped with capacity of overall pumps is 6.25 m^3/s to sea eastern Surabaya.

CONLUSION AND SUGGESTION

1. Conclusion

Based on discussion above, it can be concluded as follows:

a. 13 of 21 channel segments in area of the research have capacity that unable to accommodate designed debit or Q channel < Q designed while other channels only need extra height of preservation
b. other factors exist that able to influence puddles in campus Ketintang that is extra domestic waste 0.00023936 m^3/s
c. paddy land hilling in east of faculty of technique and rectorate that cause land use change in area of campus Ketintang in which previously it gathers puddles in rainy days now to be flat and unable to contains puddles in rainy days.
d. there are several tertiary channels that should be changed into secondary and primary channels

2. Suggestion

Based on discussion above, there are several suggestions that can be given to design drainage in campus Ketintang for the future as follows:

a. Dimension of drainage channels should be designed by giving strong point on burdens that each channel segments have to bear
b. For the future, tertiary channels should be designed to drain the water smoothly into a greater channel that is channel I (secondary channel Ketintang)
c. For a certain period, conditions of the existing channels should be reevaluated to anticipate the possibility of puddles and flooding due to the channels shallow by sediment and land use change.
d. The tertiary channels a2, b1, b2, f1 and f2 should be changed into secondary channels
e. The tertiary channels d1, d2, d3, i, and j should be changed into primary channels
f. Pump houses should be added in south close to faculty of technique to accelerate the reduction of puddles when flooding comes
g. Extra bozem should be built in district of Jambangan

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