Sustainable Drainage System Analysis In The Institut Teknologi Sumatera (ITERA)

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Abstract

The Institut Teknologi Sumatera is a new university that still requires planning and infrastructure development, one of the development needed is the construction of a drainage system, namely a sustainable drainage system that adheres to the concept of water conservation. The purpose of this research is to analyze topographic conditions, as well as the performance of the existing drainage system in ITERA and to develop recommendations for a sustainable drainage system. In this study, several stages were carried out, first analyzing the topographical conditions in ITERA. The second is to analyze the existing drainage capacity, which is to compare the existing drainage capacity to the runoff that occurs when it rains. The calculation of runoff discharge is obtained from hydrological analysis of rainfall data using the annual maximum partial series method. Third, synthesizing the connectivity between drainage segments to the reservoirs in ITERA.

The results of several analyzes above show that, firstly, the topography in ITERA is relatively flat with the most dominant elevations being 85 - 100 m and 100 - 105 m. Second, the calculation results show that the existing drainage capacity is still able to accommodate the runoff that occurs. So for now it is still safe against inundation and flooding. Third, the results show that there are several existing drainages that have not been connected to other drainage segments and water does not run off to the designated place as a reservoir, namely the reservoir.

Keyword*: Sustainable drainage, Partial Series Method, Capacity, Connectivity*

I. INTRODUCTION

Insitut Teknologi Sumatera is a new state university in Indonesia. On October 6, 2014, the President of the Republic of Indonesia, Prof. Dr. H. Susilo Bambang Yudhoyono through a Presidential Regulation has inaugurated the Institut Teknologi Sumatera (ITERA) in South Lampung and the Institut Teknologi Kalimantan (ITK) in Balikpapan as State Universities.

ITERA, which is a new State University, will certainly require a lot of adequate planning and infrastructure development, so that teaching and learning activities can run well. One of the developments needed by ITERA is the construction of a drainage system. The development of a good drainage system certainly begins with planning a good drainage system as well

ITERA has drainage problems during the rainy season. There are several points in the area that experience puddles when it rains. One of them is on the road in front of building A and in front of building C (LPPM building) ITERA. The reason is that there is a problem with the drainage of the road. Therefore, with this research, hopefully it can help related agencies to solve these problems.

The basic concept of drainage is to drain water as quickly as possible so that there is no stagnation. But as time goes on, there needs to be a balance between the use and availability of water, so a drainage system is needed that is not only safe against stagnation but also based on water conservation.

Basically the sustainable drainage system must be able to manage water surface runoff, which can then be accommodated or retained in supporting facilities such as ponds to support the concept of water conservation.

ITERA already has at least 6 (six) ponds as water reservoirs or storage. However, the existing drainage does not adhere to the concept of sustainable drainage. Because it is still standing alone and has not been directly connected to the existing reservoirs. So there is a need for a synthesis of a sustainable drainage system.

II. MATERIALS AND METHODS

A. Drainage

The drainage means draining, removing, or diverting water. In general, drainage is defined as a series of waterworks that function to reduce and/or remove excess water from an area or land, so that the land can function optimally. Drainage is also interpreted as an effort to control the quality of groundwater in relation to sanitation (Suripin, 2004).

B. Drainage Cross Section Shape

The shape of the drainage channel is not much different from the irrigation channel in general. In designing the dimensions of the channel, efforts must be made to form an economical dimension. Too large a channel dimension means it is less economical, on the other hand if the dimensions are too small it will cause problems due to inadequate capacity. The forms of drainage channels are generally rectangular, trapezoidal, triangular and circular (Permen PU No 12, 2014).

The rectangular drainage channel does not require much space. As a consequence of this channel shape, the channel must be formed from stone masonry or concrete castings.

In general, the trapesium channels are made of earth, but do not rule out the possibility of stone masonry and concrete castings. This channel requires enough space, functions to accommodate and distribute rainwater runoff, household water and irrigation water with a large debit.

Circular drainage channels are usually used for culverts where the channels are embedded in the ground.

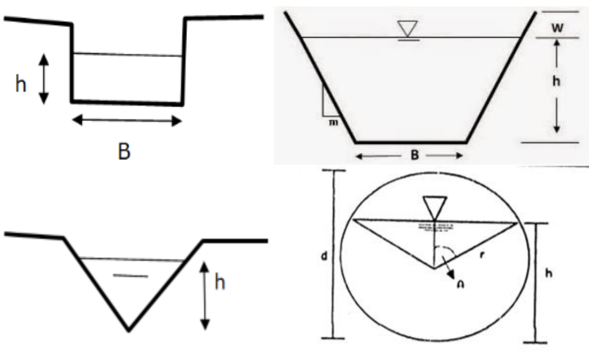

Figure 1. Drainage Cross Section Shape.

Where :
B = channel base width (mm)
h = high water level
w = water free space height
d = diameter
m = wall slope
r = radius

C. Calculation of Rainfall

Calculation of rainfall with the simplest method is the Arithmetic method.

$$\underline{R} = \frac{R_1 + \ldots + R_n}{n}$$

Where :
$\bar{R}$ = watershed average rain in one day (mm)

$R_1 \ldots R_n$ = rain recorded at station 1 to station on the same day (mm)
n = number of rain stations

D. Frequency Analysis

1. Normal Distribution

$$X_T = \underline{X} + K_T S$$

X_T : Estimated value expected to occur with return period
X : The average value of the variate count
S : Standard deviation of the variable value
K_T : Frequency factor, is a function of probability or return period and type of probability distribution mathematical model.

2. Normal Log Distribution

$$Y_T = \mathrm{Y} + K_T S$$

YT : Approximate expected value to occur with a T-annual return period
Y : The average value of the variate count

3. Smirnov Kolmogrov test

The Smirnov Kolmogrov test was carried out to describe the probability of the existing rain data, by comparing the empirical and theoretical distributions in the form of the following equation:

$$\Delta = \max [P(Xm) - P'(Xm)] < \Delta cr$$

Where :
Δ = difference between theoretical and empirical probability

Δcr = critical deviation
P(Xm) = theoretical probability
P'(Xm) = empirical probability

E. Intensity

In this study the authors used the mononobe formula to calculate the amount of rain intensity that occurs.

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

Where:

I = Rainfall intensity (mm/hour)
R_{24} = Highest rainfall in 24 hours (mm)
t = Concentration Time

F. Concentration Time

The concentration time is the time it takes for rain to move to the catchment area. The concentration time aims to determine the length of time it takes for water to move from the catchment at the farthest point to the drainage canal.

$$t_c = t_0 + t_d$$

$$t_0 = [\frac{2}{3} \times 3.28 \times lo \frac{nd}{\sqrt{ls}}]^{0.167}$$

$$t_d = \frac{L}{60V}$$

Information:
t_c = Concentration time (hours)
t_0 = time required for rainwater to move on the surface of the ground from the furthest point (hours)
l_0 = Distance to the farthest point to the drainage (m)
V = Average water velocity in the drainage (m/s)
ls = Longitudinal slope of the channel
nd = drag coefficient
t_d = Time needed for rainwater to move in the channel to the measurement point (hours)
L = channel length (m)

G. Run off Coefficient (C)

This coefficient is the result of a comparison between the amount of rain that falls on the surface and the rain that flows. The magnitude of the runoff coefficient is determined by the average value of the runoff coefficient in areas with different land uses. (Hardjosuprapto, 1998)

$$Cw = \frac{(A_1C_1)+(A_2C_2)+(A_nC_n)}{A_1+A_2+A_n}$$

Information:

A1, A2, An = The area of the flow area is n pieces, with different land uses
Cw = Combined Flow Coefficient
C1, C2, Cn = Flow coefficient (C) of n stream areas, with different land uses.

Table 1. Flow Coefficient Table

Land Description / Surface Character	Runoff Coef
Business	
Urban	0,70 – 0,95
Suburbs	0,50 – 0,70
Housing	
Single house	0,30 – 0,50
Multiunit, separate	0,40 – 0,60
Multiunit, combined	0,60 – 0,75
The village	0,25 – 0,40
Apartment	0,50 – 0,70
Industry	
Light	0,50 – 0,80
Heavy	0,60 – 0,90
Pavement	
Asphalt and concrete	0,70 – 0,95
Bricks, paving	0,50 – 0,70
Roof	0,75 – 0,95
Yard, sandy soil	
Flat, 2%	0,05 – 0,10
Rate rate, 2-7%	0,10 – 0,15
care, 7%	0,15 – 0,20
Yard, heavy soil	
Flat, 2%	0,13 – 0,17
Rate rate, 2-7%	0,18 – 0,22
care, 7%	0,25 – 0,35
Railway yard	0,10 – 0,35
Playground park	0,20 – 0,35
Park, cemetery	0,10 – 0,25
Forest	
Flat, 0-5%	0,10 – 0,40
Corrugated, 5-10%	0,25 – 0,50
Hilly, 10-30%	0,30 – 0,60

H. Sustainable Drainage

The basic concept of developing a sustainable drainage system is increasing the usability of water, minimizing losses, as well as improving and conserving the environment. For this reason, comprehensive and integrative efforts are needed that cover all processes, both structural and non-structural (Suripin, 2004).

The concept of a Sustainable Drainage System is aimed at managing surface runoff by developing supporting facilities to retain rainwater. Based on their function, rainwater retention facilities can be grouped into two types, namely storage type and infiltration type (Suripin, 2004).

Rainwater retention facilities that are available at ITERA are off-site storage types in the form of reservoirs. ITERA already has at least 6 (six) ponds as water reservoirs or storage. The following are photos of the ponds in ITERA.

Figure 5. ITERA reservoir.

III. RESULTS AND DISCUSSION

A. *Zoning Division*

This zoning division is focused on land that has already been built up, namely in the northern part of the ITERA land. From those that have been built, it is further divided into three zones, is zone 1, zone 2 and zone 3.

Figure 6. Research Zoning Map.

B. *Existing Conditions*

In zone 1 the existing drainage conditions are using U-Ditch construction. Drainage using a U-Ditch is located on the ITERA outer ring route which stretches from the west gate roundabout to the front of building C, withWidth 1.0 m, depth 1.0 m and Length 610 m

In zone 2 there is existing drainage using masonry construction. It stretches from the BMKG ITERA station roundabout to the building F roundabout, with a width of 0.9 m, a depth of 0.7 m and a length of 949 m.

In zone 3 there is existing drainage using masonry construction. This drainage is located on the east side of the ITERA outer ring road. It stretches from the side of the student dormitory (TB 2) to the east gate of ITERA, with a width of 0.7 m and a depth of 0.7 m and a length of 590 m.

C. *Topography*

The topography of ITERA is relatively flat, with elevations ranging from 74.5 m to 108 m. The area with the highest topography is on the west side of ITERA and the area has built a Technical Laboratory Building (GLT) 2. The lowest area is 74.5 m, which is in the middle of the ITERA land and that area has built a large pond that reaches 1 km in length , which will later be used for boat rowing. The most dominant topography in ITERA land is between 85-100 m and 100-105 m.

D. *Land Cover*

Based on observations of land use in the ITERA campus area, it consists of Office Land (Buildings), Parking Areas, Reservoir Areas, Pavement Land and Green Land. The area of each land use can be seen in the table below.

Table 2. Land Use

No	Land Use	Area (A) m2
1	Office Land (Building)	37,618.72
2	Parking Land	23,233.71
3	Reservoir area	147,411.00
4	Pavement Land	322,729.41
5	Green Land	2,260,157.60

E. *Hydrological Analysis*

1. Annual Maximum Rainfall

Table 3. Annual Maximum Rainfall

No	R Max ITERA (mm)
1	78.60
2	52.00
3	67.40
4	67.00
5	80.00
6	50.00
7	60.00
8	52.20
9	83.40
10	88.40
11	51.20
12	53.20
13	146.00
14	114.00
15	75.00
16	50.00
17	64.00
18	81.80
19	58.00
20	104.40
21	81.80
22	69.60
23	64.40
Sum	**1692.40**
R Max	**146.00**
Std	**23.35**

2. Normal Dispersion

Table 4. Normal Dispersion

No	missing	Amount
1	R (mm)	1692.4
2	(R-Ri)	0.00
3	$(R-Ri)^{\wedge 2}$	11999.51
4	$(R-Ri)^{\wedge 3}$	406501.70
5	$(R-Ri)^{\wedge 4}$	32722209.33
6	Average	73.5826
7	SD	22.8411
8	Cs	1.5887
9	Ck	6.3232
10	Cv	0.3104

3. Log Normal Dispersion

Table 5. Log Normal Dispersion

No	missing	Amount
1	R (mm)	1692.4
2	Log R	42.5274
3	Log R-Log Ri	0.0000
4	$(Log R-Log Ri)^{\wedge 2}$	0.3315
5	$(Log R-Log Ri)^{\wedge 3}$	0.0302
6	$(Log R-Log Ri)^{\wedge 4}$	0.0151
7	Average	73.5826
8	SD (d)	0.1227
9	Cs	0.8130
10	Ck	3.4917
11	Cv	0.0017

4. Distribution Type Determination

Table 6. Distribution Type Determination

Distribution Type	Requirement	Results	Conclusion
Normal	Cs ≈ 0	1.5887	not
	Ck = 3	6.3232	
Gumbel	Cs ≤ 1,1396	1.5887	not
	Ck ≤ 5,4002	6.3232	
Log Normal	Cs ≈ 3Cv + (Cv)² = 3	1.0276	not
	Ck = 5,383	6.3232	
Log Pearson III	Cs ≠ 0	1.5887	Oke

5. Calculation of design rainfall

Table 7. Calculation of design rainfall

Time Repeat	Log Xr	G	Log Xt	Design Rainfall
2	1.849	1.5887	1.833	68.008
5	1.849	6.3232	1.945	88.021
10	1.849	1.5887	2.013	103.051
25	1.849	6.3232	2.095	124.332
50	1.849	1.0276	2.151	141.524
100	1.849	6.3232	2.205	160.298

6. Calculation of Concentration Time(t_c)

For the calculation of t_c, it begins with the calculation of t_0 and t_d, for the calculation of t_0 and t_d, it can be seen in the following table.

Table 8. Calculation t_0

Zone	S	L (m)	√S	n	t_0 (Min)
Zone 1	0.0230	152	0.1517	0.0130	1.7494
zone 2	0.0263	171	0.1622	0.0130	1.7644
zone 3	0.0262	190.7	0.1619	0.0130	1.7974

Table 9. Calculation t_d

Drainage	R (m)	L (m)	S	n	V	td
Drainage 1	0.33	610	0.019	0.0130	5,19	1.96
Drainage 2	0,27	403	0,016	0.0130	4,13	1.63
Drainage 3	0.23	249	0.018	0.0130	3.92	1.06

Table 10. Calculation t_c

Nama Zone	t_0 (min)	t_d (min)	t_c (min)	tc (hours)
Zone 1	30.6649	1,9601	3.7095	0.0618
zone 2	32.2700	1,6301	3.3945	0.0566
zone 3	36.0539	1,0588	2.8562	0.0476

7. Intensity Rainfall (*I*)

Table 11. Calculation Intensity Rainfall

Time Repeat	*I* (Zone 1) mm/h	*I* (Zone 2) mm/h	*I* (Zone 3) mm/h
2	150.7927	159.9832	179.5002
5	195.1657	207.0606	232.3207
10	228.4930	242.4191	271.9928
25	275.6774	292.4793	328.1600
50	313.7972	332.9224	373.5369
100	355.4237	377.0860	423.0882

8. Calculation Coeffisien Surface Runoff (C)

From the various types of land cover in ITERA, with various areas, the runoff coefficient (C) for each zone is obtained as follows:

Table 12. Calculation Coeffisien Surface Runoff

No	Zone	C
1	Zone 1	0.33
2	zone 2	0.36
3	zone 3	0.31

9. Calculation of Design Debit (Qr) m^3/s

With the existing catchment area, the design discharge calculation uses a 2-year return period.

Table 13. Calculation of design debit (m^3/s)

Zone	Coef C	I (mm/h)	A (m^2)	Qr (m^3/s)
1	0.33	150.7927	83610.30	1.161
2	0.36	159.9832	42903.00	0.693
3	0.31	179.5002	64037.55	0.974

10.Calculation of Channel Debit Qs m^3/s

Table 13. Calculation of channel debit (m^3/s)

Drainage	**Aw (m2)**	**S**	**L (m)**	**n**	**V (m/s)**	**Qs (m^3/s)**
1	1	0,0197	610	0,013	5,19	5,10
2	0.63	0,0161	403	0,013	4,12	2,59
3	0.49	0,0181	249	0,013	3,92	1,92

IV. CONCLUSION

1. The runoff coefficient (C) is an average of 0.3, meaning that only 30% of the rain that falls on the ITERA land becomes a stream, while 70% is infiltrated into the ground. This shows that the land in ITERA is still relatively good, the contributing factor is that there are still many green open areas or there is still a lot of land that has not been developed.
2. The performance of the existing drainage system in the designated zone in terms of its capacity is still safe from flooding, because the reservoir/channel discharge (Qs) is greater than the design discharge (Qr). Puddles that occur on the main road of Building C when it rains are not overflowing from the drainage or inadequate drainage capacity, but rather that water from the shoulder of the road cannot enter the main drainage because the shoulder of the road is higher than the body of the road, and the shoulder of the road which has been overgrown with grass.
3. It is necessary to clean the shoulder of the road regularly, and if the shoulder of the road is higher than the body of the road, then it is necessary to make a drainage line to road drainage.

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