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Research Article

Depelopment of Hydraulic Design Criteria for Runoff on Residential Area in Bekasi, Indonesia

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Abstract: The incompatibilities of urban or residential area's drainage channel construction with design criteria were often found caused by the difficulties in designing drainage channel. This research aims to determine drainage coefficient and develop drainage channel's hydraulic design criteria in residential area. The hydraulic design criteria of residential drainage system was able to be developed into nomogram. The width and height of channel can be determined using the nomogram according with the runoff. The residential drainage coefficient value was 0.28 m^3/s.ha at 0-2 % slope and 162.9 mm design rainfall condition.
Keywords: drainage coefficient, hydraulics design criteria, nomogram, residential drainage system, run off.

BACKGROUND

The incompatibilities of urban or residential area's drainage channel construction with design criteria were often found. The design criteria of drainage channel for many channel type has been developed. However, the incompatibilities in its application was often occurred. This was caused by the difference and interrelated of drainage channel design criteria and the value range differences in each criteria. Therefore, the study to test the appropriate drainage channels design criteria was necessary to ease its application in the field.

Studies on drainage systems associated with its hydraulic design in urban areas have been conducted. Many hydraulics design studies have been conducted such as the study of drainage channel on the main roads in urban areawhich was conducted byLubis and Terunajaya [1], and the study of environmentally friendly drainage system by Supriyani *et al.* [2]. Hydraulics design analysis for raw water in flat to steep topography residential areas (2-8% slope) was conducted by Wijaya [3] who developed the hydraulics design criteriainnomogram. The results of these studies showed thatthe further development of drainage system hydraulic design in flat residential area (0-5% slope) was required. Residential area's drainage channel hydraulics design development was preceded by runoff analysis and drainage system coefficient determination. The results of drainage channel hydraulics design is expected to be applied easily in designing drainage systemin another relatively flat residential areas.

METHOD

Location and Time

The study was conducted on Cluster Sanur in Pondok Ungu, Bekasi in August 2014 - June 2015.

Data Collection and Analysis

Data Collection

Data collection methods consisted of data collection relating to drainage channels planning, field observations, measurements, interviews, and secondary data collection. The required data is the 10 years maximum daily rainfall data from BMKG; rainfall data by direct measurement in rain events, the drainage channel hydraulics design factors : flow velocity, slope, roughness, flow depth, and the cross section size of drainage channel that obtained through primary data collection or through field measurements and observations; flow rate: obtained through field measurements using weir in measured drainage channel when rain occurred; drainage network which obtained by field mapping and secondary data from the drainage network map, topography and residential land use.

The analysis in this research consisted of:

1. Drainage system analysis. The initial stage of the study was conducted field observation and channel tracing in the study location to determine the drainage network pattern and

measure the drainage channel dimensions (length, width, depth, slope, and embankment). From these data, the mapping of drainage network based on field measurement data (length, depth, width and the slope of channel), topographic maps and residential site plan was conducted usingSketch Up 8 program and ArcView.

2. Collector channel hydrograph analysis
   From the results of channel tracing, the water level measurement location using weir in drainage channel was determined to obtain channel discharge. The measurement location was determined based on the lowest point of the collector channel or channels outlet slope. From the results of discharge measurement then data tabulation was conducted by comparing rainfall and discharge to discover the relationship between rainfall and measured flow to be made into hydrograph.
3. Before the runoff analysis conducted, the runoff coefficient (C) was determined according to the type and extent of land use based on the site plan and field observations. Time of concentration (Tc) analysis using Kirpich method was based on the channel length and slope. The calculation of rain intensity value (mm / hr) using Mononobe method was based on time of concentration (Tc) and total maximum daily rainfall in channel discharge measurement. Then, runoff discharge (QL) was obtained using rational equation method with the area and thenthe drainage coefficient can be calculated.

a) Analysis of hydraulics design criteria; this analysis was related to drainage channel dimensions with consideration to runoff, channel characteristics, allowed flow velocity, channel's slope and roughness. The flowing runoff will be analyzed based on design rainfall with an appropriate return period for specific research area which was based on maximum daily rainfall data. Channel base width (B) and depth (h) was calculated using trial and error method based on the channel geometric elements method and relationships of discharge value's range to B / h ratio, where if Q> 0.5m^3 / s then B / h = 1, if 0.5 m^3 / s < Q <1.1 m^3 / s then B / h = 2, if 1.1 m^3 / s <Q <3.5 m^3 / s then B / h = 3 (DPU, 1989).

The analysis results will be used as developed design criteria for drainage channel that can be used as decision-makers in residential drainage network development and as design standard of surface drainage channels.

RESULTS AND DISCUSSION

Sanur Cluster is one residential cluster located in PondokUnguPermai Residential in Central Kaliabang, North Bekasi District. PondokUnguPermai Residential geographically located in 6˚10'21,96 " until 6˚10'29,47" south latitude and 107˚1'18,54 " until 107˚1'25,37 " east longitude. Cluster Size Sanur was consisted of 3.39 ha of rainwater catchment area. 499 housing units in this cluster will be built by PT. Duta Graha Jaya Putra, where at this point the completed house that already being built was 235 units. The research location is located at 5-9 m above sea level and 0-2% slope.From the results of tracing with the help of the site plan specified research sites are being used as discharge measurements which can be seen in Figure 1.

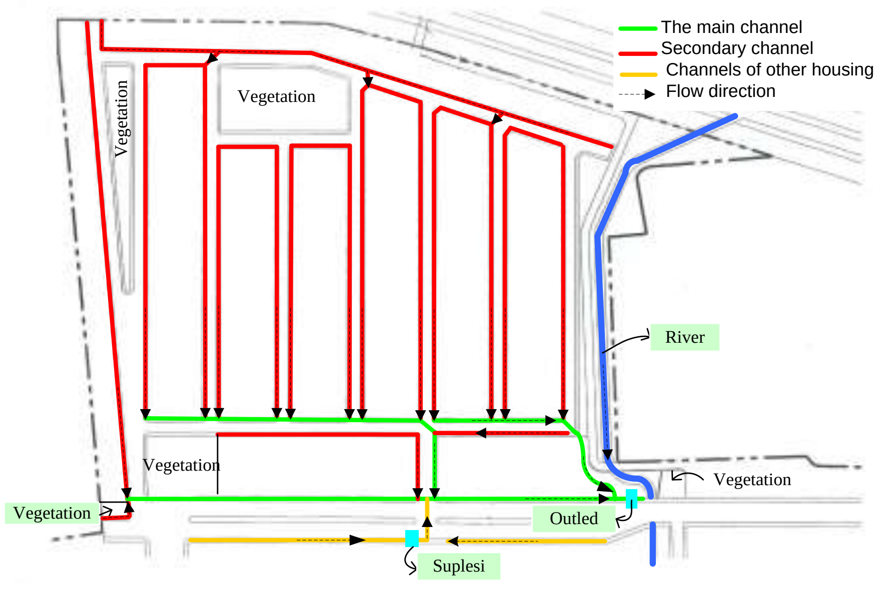

Fig-1: Drainage channel trace and flow direction

Table-1: Land use typein study location

Land use	Area	
	m^2	%
Building	11261.66	33.13
Undeveloped	11508.58	41.23
Vegetation	2508.21	
Road	8714.86	25.64
Total	33993.31	100.00

Land use in the study site can be seen in Table 1 .Sanur Cluster drainage channels was made of smooth surface concrete with Manning coefficient of 0.014. Based on main channel analysis results, the concentration time for 175 meters channel with slope of 0:17% was 13.3 minutes. According to TxDOT [4], the amount of concentration time will be relatively same if it occurs in relatively similiar channel length and slope. Concrete trapezoidal channel characteristic can see in Table 2.

Table-2: Concrete trapezoidal channel characteristic

Characteristic	Value
Channel length, P (m)	175.000
Channel base width, B (m)	0.740
Channel top width, b (m)	0.945
Channel depth, h (m)	1.020
Freeboard, w (m)	0.200
Channel slope, S	0.170
Channel embankment, m_1	0.078
Channel embankment, m_2	0.118
Concentration time, T_c(mnt)	13.000

Surface Runoff

This residential area was almost consisted of 58.74% of paved and house surfaces that cannot pass water into the ground, with the rest of area is the park / open land (yard and garden) that can pass water which can be factors that determine the runoff coefficient (C) and furthermore determine the amount of runoff using rational method(Table 3). Runoff coefficient was determinedbased on water catchment area's land cover. According Verrina *et al*. [5], topography, land use and soil type will affect the amount of runoff that occured in the area. The land cover in Sanur Cluster consisted of multiunit houses / buildings, parks and roads.

Table-3: Land use classification and runoff coefficient for rational method

No.	Land use	Runoff coefficient (C)
1.	Multiunit, combined	0.60 – 0.75
2.	Concrete/ asphalt paving	0.70 – 0.95
3.	Pavement	0.50 – 0.70
4.	Play parks	0.20 – 0.35
5.	Garden or graveyard	0.10 – 0.25

According to Froehlich [6], the runoff discharge value was determined by the rain intensity that occurred in region during the time of concentration, runoff area and runoff coefficients. Drainage channel's runoff discharge at the study location with 3.39 ha area, C value of 0.65, and 10-48 mm of rainfall were ranged 0.078-0.299 m^3 / s with 6 times performed measurements. Discharge value and drainage coefficient on several rain events (2015) were shown in Table 4.

Table-4: Discharge and drainage coefficient value in several rain events

Date	C	R (mm)	I	Q_L	q_L	Q_s	q_s
			(mm/hr)	(m^3/s)	(m^3/s.ha)	(m^3/s)	(m^3/s.ha)
01 Feb	0.65	48.0	46.13	0.282	0.083	0.222	0.065
08 Feb		45.0	43.25	0.264	0.078	0.175	0.052
10 Feb		10.0	9.61	0.059	0.017	0.076	0.022
12 Feb		22.5	21.62	0.132	0.039	0.133	0.039
28 Feb		12.5	12.01	0.073	0.022	0.076	0.022
01Mar		16.0	15.38	0.094	0.028	0.098	0.029

R: Rainfall, I: Rain intensity, Q_L :Runoff discharge q_L: Runoff Coefficient, Q_s : Channel discharge, q_s: Channel drainage coefficient

Dhakal *et al*. [7] stated that the amount of designed discharge was depended to any changes in land cover which defined as C value. In this study, no change of land use so that the C value was fixed. Based on the analysis and measurement of runoff discharge and drainage coefficient during rainfall events, the obtained runoff coefficient values in drainage channels and drainage runoff coefficient value were 0.076-0.022 m^3/s.ha and 0.017-0.083 m^3/s.ha. According to Wijaya [3], any difference in the rainfall and land use type in each location gives the different drainage coefficient value.

According to Ahmadi [8], the selection and using of appropriate drainage coefficient has always been problem in the designing drainage system. The lower value will reduce the effectiveness of the drainage system while the higher value will increase the cost. Figure 3 shows that the drainage coefficient values in Sanur Cluster were determined by the runoff discharge that occurred in specific area. This is due to land and topography condition at the study site.

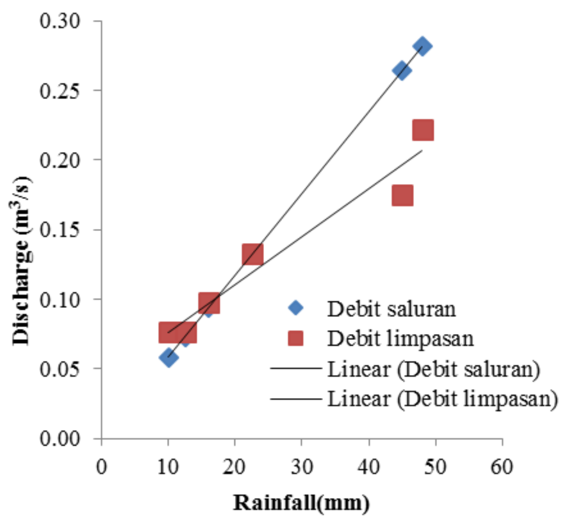

Fig-2(a)

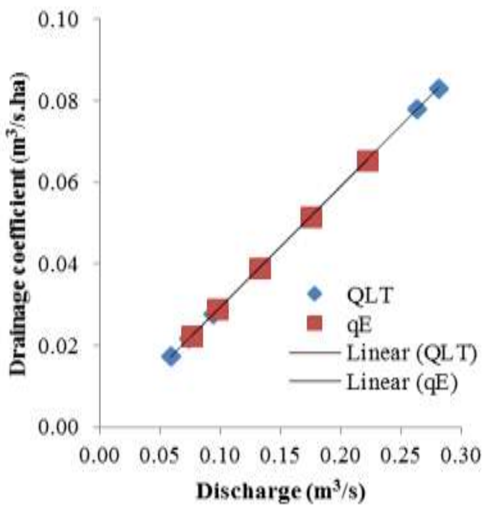

Fig-2(b)

Fig-2: a. Discharge and rainfall relation curve. b.Discharge and drainage coefficient relation curve

Figure 2 a shows the relation curve of discharge and rainfall. Formed linear lines illustrate that each discharge will be proportional with rainfall. This was caused by the differences in area, topography and surface hydrology. In addition, runoff discharge (QL) and channel discharge (QS) (Table 3) which plotted in Figure 6 shows the discharge differences in same rainfall event. This differences can be explained by rainfall that occurred among the sites respond differently to discharge value.

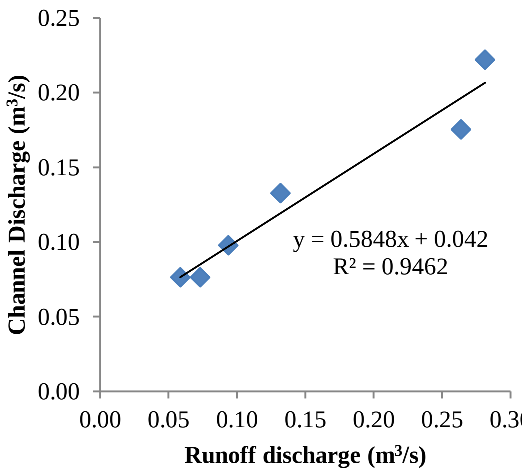

Fig-3: Runoff discharge and channel discharge

R^2 value in the graph explains that 94.6 % is the diversity of peak discharge measurement channel that can be explained theoretically. Any change in the rainfall intensity will give different drainage channels discharge in each rainfall event.

Collector channel hydrograph

Table 4 shows the discharge channel analysis and the measurement results at some rainfall events in the study location. Based on field measurements during rain, the difference of measured channel's discharge was obtained, when the rainfall greater rainfall then the channel discharge will be great too. According to Oktarina [9], due to an increase in rainfall intensity and land slope, there will be also an increase in peak discharge and shorter peak time.

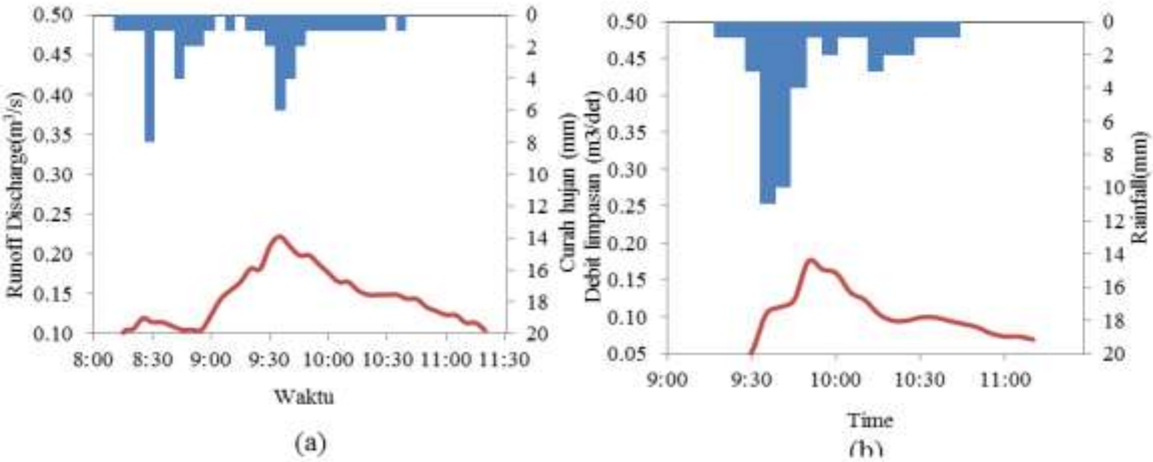

Fig-4: Flow hydrograph in Cluster Sanur channel (a)1st February 2015(b) 8th February 2015.

Table-5: Channel discharge analysis and measurement in several rain events

Date	R (mm)	T_{CH} (minute)	H (m)	Q_s (m^3/s)
01 February 2015	48	204	0.28	0.222
08 February 2015	45	96	0.24	0.175

R : Rainfall, T_{CH}: Rain duration, h:water depth in channel, Q_s: Channel discharge

Table 5 shows based on the field measurement results, measured channel discharge reached 0.222 m^3/s at rainfall of 48 mm and 0.175 m^3/s at rainfall of 45 mm. On February 1 2015, the rainfall was 48 mm and the surface flow was 0.222 m^3/s with a rain duration of 204 minutes. On February 8 2015, the rainfall was 45 mm and the surface flow was 0.175 m^3/s with a rain duration of 96 minutes. According to Kennedy and Watt (1976) in Harto [10], the rain characteristics which greatly affects the hydrograph shape are rain intensity, rain duration and rain direction.

Hydraulic design criteria analysis

In the channel dimensions planning, hydraulic profile calculations were very important. The continuity equation method can be used to determine the channel design [11]. Drainage must be planned well and optimal. Because the too small drainage will not capable to accommodate runoff, and the too large channel will be cost too much [12]. Design discharge analysis result and drainage coefficient in Table 6

Table-6: Design discharge analysis result and drainage coefficient

Parameter	Researcher
Catchment area (ha)	3.39
Channel slope, S (%)	0.17
Runoff coefficient, C	0.65
Concentration time,t_C (minute)	13.00
Design rainfall, CH (mm)	162.90
Rainfall intensity (mm/hr)	156.6
Design discharge (m^3/s)	0.95
Drainage coefficient, q	0.28

According Situmorang *et al*. [13], if the drainage channel capacity is greater than the design runoff then the channel is still decent and there will be no overflow. In the residential area, rectangular channel is commonly be used and made of concrete. For the drainage channel planning, a nomogram for discharge ranged from<1 m^3/s and 0.2 m freeboard was created in accordance with the DPU [11].

The result of the calculation of the draft discharge (Q) Table 7 on a plan of land area (ha) based on the value of the coefficient of drainage, it can then be determined defined width of the base line (B) and a channel depth (h). Value discharge surface runoff (Q) calculation results become the basis for determining the value of B and H with reference to the value of ratio B / h (Table 4) (DPU 1986) trial error.

Table-7: Concrete channel hydraulic design criteria analysis results in study location

Parameter	Shape		
	Rectangular	Trapezoid m=1	Trapezoid m=0.5
Manning roughness coefficient, n	0.014	0.014	0.014
Jari-jarihidrolik, R (m)	0.170	0.163	0.206
Wetted perimeter,P (m)	1.230	1.980	1.562
Section Area, A(m^2)	0.107	0.322	0.322
Channel base width, B (m)	0.210	0.400	0.265
Channel depth (m)	0.710	0.990	0.780
Flow velocity,v(m/s)	3.000	3.000	3.000
freeboard, W (m)	0.200	0.200	0.200
Channel slope, S (m/m)	0.170	0.170	0.170
Discharge,Q (m^3/det)	0.967	0.967	0.966

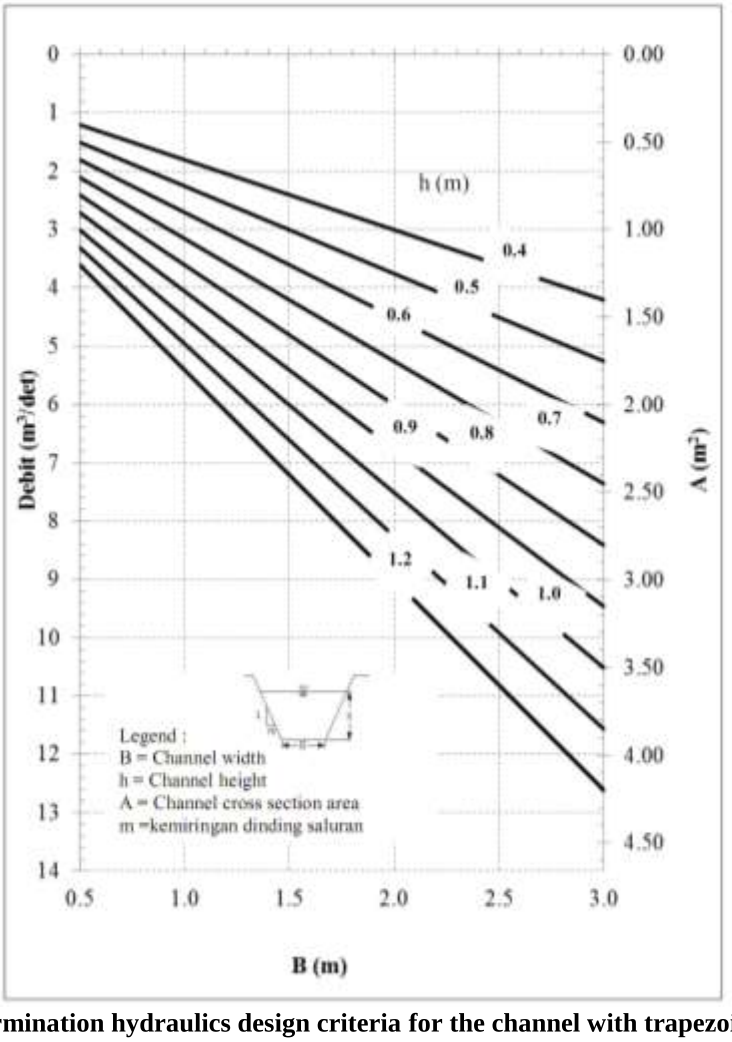

Fig-5: Nomogram determination hydraulics design criteria for the channel with trapezoidal cross-section (slope talud 0.5) and a pair of concrete

The research was developed of hydraulics design criteria has been done based on the characteristics of channel, water velocity on channel that was permitted, discharge, channel slope, and channel roughness. The base width (B) and depth (h) of channel were determined by trial and error method, based on Ministry of Public Work regulation [11] about b/h value ratio for channel design. Drainage coefficient determination was developed on nomogram, according to rainfall and runoff coefficient on each location. From the results was developed nomogram. Figure 5 nis Nomogram determination hydraulics design criteria for the channel with trapezoidal cross-section (slope talud 0.5) and a pair of concrete.

CONCLUSION

Drainage coefficient value for residential area is 0.28 m^3/s.ha on 0-2% slope and 162.9 mm design rainfall. Hydraulics design criteria for residential drainage systems have been developed in the form of nomogram. Using the nomogram, the width and height of channel can be determined according to runoff.

REFERENCES

1. Lubis A, Terunajaya; Analisis Intensitas Curah Hujan Maksimum Terhadap Kemampuan Drainase Perkotaan (Studi Kasus Drainase Jalan Sisingamangaraja Kota Sibolga). Jurnal Teknik Sipil USU. 2013; 2 (1).
2. Supriyani E, Bisridan M, Dermawa V; Studi Pengembangan Sistem Drainase Perkotaan Berwawasan Lingkungan StudiKaSus Sub Sistem Drainase Magersari Kota Mojokerto). Jurnal Teknik Pengairan, 2012; 3(2): 112–121.
3. Wijaya HK; Pengembangan Kriteria Rancangan Hidrolikapada Pemanfaatan Air Limpasanuntuk Air Baku di Kawasan Perumahan. [tesis]. Bogor (ID): Institut Pertanian Bogor. 2014.
4. [TxDOT] Texas Department of Transportation. 2002. Hydraulic Design Manual. Austin, Texas (US): The Bridge Division of the Texas Department of Transportation.
5. Verrina GP, Anugrah DD, Sarino; Analisarunoff pada Sub DAS Lematanghulu. Jurnal Teknik Sipildan Lingkungan , 2013;1(1).
6. Froehlich DC; Short-Duration Rainfall Intensity Equations for Urban Drainage Design. Journal of Irrigation and Drainage Engineering, 2010;136(8):519–526.
7. Dhakal N, Fang X, Cleveland TG, Thompson DB, Asquith HW, Marzen LJ; Estimation of Volumetric Runoff Coefficients for Texas Watersheds Using Land-Use and Rainfall-Runoff Data. Journal of Irrigation and Drainage Engineering, 2012; 138(1).
8. Ahmadi MZ; A Field Approach To Estimation Of Humid Area Drainage coeffIcients. Elsevier Science.Agricultural water management, 1955; 29:101-109.
9. Oktarina NR; Analisishidrograflimpasanaki batvariasiintensitashujandan kemiringanlahan (kajianlaboratoriumdengan simulator hujan).Jurnal Teknik Sipildan Lingkungan. 2015; 3(1).
10. Harto BR; Analisis Hidrologi. Jakarta(ID): Gramedia Pustaka Utama. 1993.
11. [DPU]Departemen Pekerjaan Umum; Standarperancangan Irigasi KP-03 Kriteria Perancangan Bagian Saluran. Jakarta(ID): Departemen PU. 1989.
12. Kawer DCW, Hartoyo A, Djajadi R; Studi optimasi dan perencanaan drainase bandara Frans Kaisiepo Biak Papua. Jurnal Dimensi Pratama Teknik Sipil. 2012; 1(1).
13. Situmorang MJ, Azwa N, Kartini; Evaluasi Kapasitas Tampungdan Perencanaan Sistem Drainase di Kawasan Desadalam Kaum Kec. Sambas Kab. Sambas, 2012.