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RESEARCHARTICLE

IMPACT OF SMART TANK ON RUNOFF COEFFICIENT IMPROVEMENT IN SENTUL CITY FOR PEAK RUNOFF REDUCTION IN BEKASI HULU WATERSHED

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ABSTRACT

Runoff is an important element in the water cycle. The process and the amount of runoff that occurs and the factors that influence it are very necessary as a reference to determine the potential for water availability, water management, land stewardship, and runoff water utilization policies. Smart tanks are facilities that function as rainwater reservoirs for collection and utilization, infiltration, and detention of rainwater. The Sentul City (SC) area is in the Bekasi Hulu watershed, the land area is 2905.33 ha, with planned use for built land 83.62%, green open space 14.37%, and blue open space 2.00% (1). The research objective was to determine the amount of peak runoff, and efforts to reduce it by harvesting rainwater using "smart tanks" in the urban area of Sentul City. Runoff analysis with the rational method. Calculation of parameter runoff uses spatial analysis for land use, drainage boundary, DEM analysis, and rainfall intensity distribution. The dual benefits of implementing smart tanks, apart from being a source of clean water supply and also reducing peak runoff in SC and Bekasi Hulu.

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INTRODUCTION

1. Background

The Sentul City (SC) area has a high annual rainfall which is above 3,000 mm / year so it has a high potential runoff. The prediction of clean water demand in SC is currently 110 liters / second, which is supplied from Local water company (2) by 50 liters / second (3). There is still a shortage of 60 liters / second, and in the future water needs will continue to increase in accordance with the development of regional development and population growth. To meet water needs and reduce dependence on water sources from other regions, it can be done by utilizing potential runoff in the SC area, including rainwater harvesting with the implementation of Smart Tank in buildings and parcels. This rainwater harvesting effort is one of the conservation efforts to maintain adequate water supply in urban areas.

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In addition to having high runoff potential, the SC area is fed by two main rivers, namely the Cikeas river and the Citeureup river and its tributaries. Cikeas river has a water discharge of 84 liters / second and Citeureup river 75 liters / second. The Cikeas and Citeureup rivers are drained throughout the year, while the tributaries are only runny in the rainy season and will dry out in the dry season. Cikeas and Citeureup rivers with a total potential water discharge of 159 liters / second can be used as a source of raw water to meet water needs in SC by exploiting directly from the river (4-6). The current condition of the Bekasi Watershed is very concerning with the increasing frequency of floods and droughts. This is evidenced by the occurrence of flood events in the Bekasi area. One of the causes of flooding is the increasing volume of runoff that occurs. Thereforewe must pay attention to any factors that can increase the volume of runoff. Surface runoff is rainwater that cannot be held by land, vegetation or basin and eventually flows directly into the river or sea. Regional characteristics that influence the magnitude of surface water runoff include topography, soil type, and land use or land cover. The transition of the function of an area that is able to absorb water into a water-resistant area will result in hydrological imbalances and have a negative effect on the condition of the watershed. Changes in vegetation cover in an area will influence the time and volume of surface flow. Seeing these problems, it is necessary to research how much peak runoff occurs in the SC region today, how does the implementation of Smart Tank affect the amount of peak runoff, Smart Tank as low-cost providers of raw water, and regulations / policies used in connection with the implementation of Smart Tank in the planned area will be and have been built.

Research Objective: The research objective was to determine the amount of peak runoff, and efforts to reduce it by harvesting rainwater using "smart tanks" in the urban area of Sentul City and its effect on the peak runoff of the Bekasi Hulu watershed.

Literature Review

2.1. Rainwater Harvesting

Harvesting or rainwater treatment is a series of activities to collect, use and / or absorb rainwater into the soil. Rainwater is one of the directly accessible water sources that can be used for various purposes, including adding other water supply sources in urban areas. Rainwater harvesting is usually easy to implement, has relatively low implementation and maintenance costs, and its operations do not require special training (7).Utilization of rainwater is not something new in human civilization in meeting water needs. In recent decades, as a result of the development of science, many countries have developed rainwater utilization technology. This is done to overcome the increasing pressure on water needs as a result of climatic, environmental, and social change factors (8).In Indonesia, rainwater utilization is regulated by Minister of Environment Regulation No. 12 of 2009, and Rainwater Management in Buildings and Plots is regulated by Minister of Public Works Regulation No. 11 of 2014 concerning (9-10), and the Urban Rainwater Harvesting Policy Handbook issued by the United States Environmental Protection Agency (US-EPA) in 2008. This regulation is a reference for government administrators in Indonesia in the context of conserving water resources and controlling environmental damage.Rainwater utilization is an effort to conserve water resources because it can reduce the rate of exploitation of ground water. Besides rainwater harvesting can also increase the availability of ground water through reabsorption into the soil.This research will explain the method of utilizing rainwater and Rainwater Management in Buildings and Plots (9-10).

2.2. Principles of Management of Rainwater in Buildings and Plots

Rainwater management in buildings and parcels is conceptualized as an effort to support the continuation of the best hydrological cycle, water conservation, fulfillment of water needs, and mitigation of floods through the maximum application of rainwater management engineering techniques that are based on optimizing the use of natural elements and optimization utilization of artificial elements (infrastructure / building facilities).Rainfall that falls on the building plots is calculated as part of the mandatory management status of rainwater which must be sought not to overflow from the parcel of the building. Thus, it is expected that the existence of buildings will not have a detrimental impact on their environment when it rains.
Rainwater management in buildings and parcels in principle is carried out on a priority scale, while still taking into account the requirements and site-specific characteristics / needs of buildings. The priority scale is divided into three, namely maximizing the utilization of rainwater collected in buildings and parcels, maximizing infiltration / absorption of rainwater, and temporarily holding rainwater to reduce water runoff.On the priority scale of maximizing rainwater utilization, the requirements that must be met are the quality of rainwater according to the type of utilization. This priority scale is carried out in areas that have relatively low water availability characteristics. On the priority scale of increasing rainwater infiltration, it must pay attention to the condition of the area or catchment area. In other words, increasing rainwater infiltration is carried out in areas that are permitted for rainwater infiltration. Soil characteristics, groundwater level, distance to buildings, and other variables will be used as factors in determining infiltration or rainwater infiltration areas. While on the priority scale temporarily holding rainwater to reduce water runoff, this is done if priorities 1 and 2 above are not possible.

2.3. Smart Tank

Smart tanks are facilities / infrastructure for rainwater collection which can be in the form of tanks / reservoirs with their supporting devices to collect rainwater that falls on the roof of a house, collected, collected and used as a source of raw water for bathing, washing, latrines or for water drink after going through the drinking water quality standard process.

2.4. Hydrological Cycle

The hydrological cycle is the journey of water from the surface of the sea to the atmosphere then to the surface of the ground and back to the sea which never stops, the water will be temporarily held in rivers, lakes/reservoirs and in the soil so that other living things can be utilized. The hydrological cycle begins with the evaporation of water from the sea. The steam produced is carried by moving air. In possible conditions, the vapor is condensed to form clouds, which in turn can produce precipitation. Precipitation falling to earth spreads in different directions in several ways.

Most of the precipitation is temporarily retained in the soil near where it falls, and finally returned to the atmosphere by evaporation and transpiration. Some water searches its way through the surface and the upper part of the land towards the river, while others penetrate further into the soil to become part of groundwater (groundwater). Under the influence of gravitational force, both surface stream flow and water in the ground move to a lower place that can flow into the sea. However, a large amount of surface and underground water is returned to the atmosphere by evaporation and transpiration before reaching the sea (11). By gravity (naturally) water flows from a high area to a low area, from mountains to mountains, mountains to valleys, then to lower areas, to the coastal areas and eventually will lead to the sea. This water flow is called ground surface flow because it moves above the ground. This flow will usually enter the catchment area or flow area to the river network system, lake system or reservoir (12).

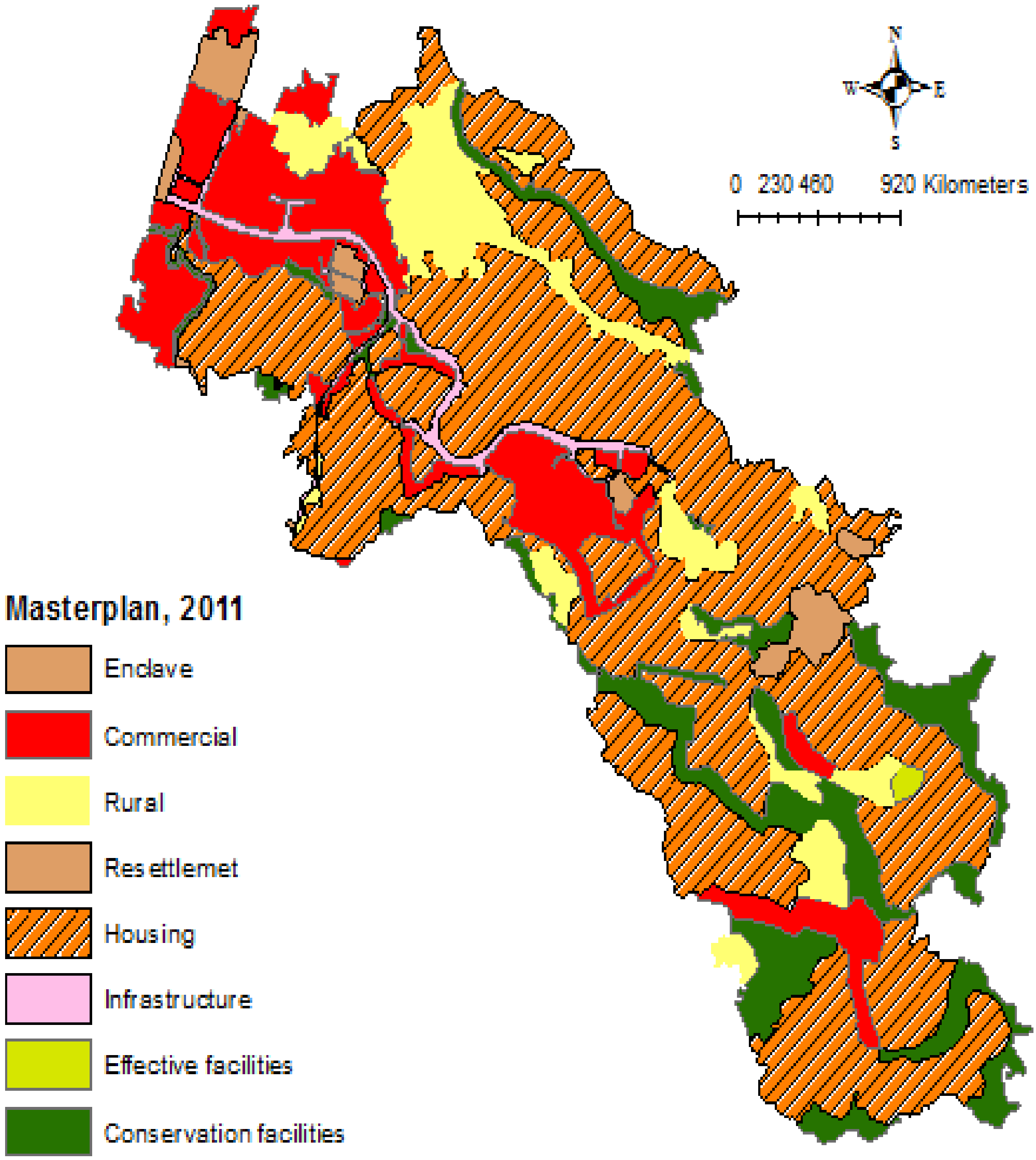

Figure1. Land Use of Master plan, 2011

Tabel 1. Land Use Masterplan (Masterplan, 2011)

No.	Sorts of land use	Area (ha)	CRO value	Cumulative CRO on various smart tanks in housing			
				0%	25%	50%	75%
1	Enclave	63.2	0.75	47.4	47.4	47.4	47.4
2	Commercial	459.35	0.85	390.45	390.45	390.45	390.45
3	Rural	277.37	0.60	166.42	166.42	166.42	166.42
4	Resettlement	23.18	0.75	17.39	17.39	17.39	17.39
5	Housing	1,638.19	0.60	982.91	737.1855	491.457	245.7285
6	Infrastructure	61.4	0.90	55.26	55.26	55.26	55.26
7	Effective facilities	6.56	0.95	6.23	6.23	6.23	6.23
8	Conservation facilities	376.08	0.25	94.02	94.02	94.02	94.02
Total		2,905.33	-	1,760.08	1,514.36	1,268.63	1,022.90
Runoff coefficient				0.61	0.52	0.44	0.35

Table 2. Runoff coefficient for rational methods

No.	Description of land and surface character	Coefficient c
1	Business	
	•urban area	0.70 – 0.95
	•rural area	0.50 – 0.70
2	Housing	
	•single housing	0.30 – 0.50
	•separate multiunit, separate	0.40 – 0.60
	•multiunit incorporated	0.60 – 0.75
	•village	0.25 – 0.40
	•apartment	0.50 – 0.70
3	Industry	
	•light	0.50 – 0.80
	•weight	0.60 – 0.90
4	Pavement	
	•asphalt and concrete	0.70 – 0.95
	•brick and paving	0.50 – 0.70
5	Roof	0.75 – 0.95
6	Home page, sandy land	
	•flat	0.05 – 0.10
	•rather steep	0.10 – 0.15
	•steep	0.15 – 0.20
7	Home page and heavy land	
	•flat	0.13 – 0.17
	•rather steep	0.18 – 0.22
	•steep	0.25 – 0.35
8	Train page	0.10 – 0.35
9	Garden playground	0.20 – 0.35
10	Parks, cemeteries	0.10 – 0.25
11	Forest	
	•flat	0.10 – 0.40
	•bumpy	0.25 – 0.50
	•hilly	0.30 – 0.60

Source: Mc Guen, 1989

Table3. Rainfall data for 2009 to 2018in Sentul City

Year	Month												Average
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
2009	607	541	408	228	389	128	87	15	76	392	331	236	287
2010	417	526	485	84	291	257	139	306	375	445	287	300	326
2011	390	265	226	219	175	140	36	8	58	296	412	268	208
2012	384	348	240	321	152	64	41	12	122	260	366	423	228
2013	851	346	409	349	494	135	279	135	71	355	323	591	361
2014	1,138	624	290	407	244	199	344	250	34	94	549	459	386
2015	285	345	341	207	148	17	9	344	19	52	523	414	225
2016	310	587	574	467	291	213	266	101	431	398	329	181	346
2017	273	689	311	401	239	133	357	49	33.7	375	446	362	306
2018	340	798	444	291	150	152	9	21	162	135	412	232	262
Total	4,994	5,067	3,727	2,973	2,573	1,438	1,566	1,241	1,381	2,803	3,978	3,466	-
Average	499	507	373	297	257	144	157	124	138	280	398	347	293

Source: Meteorology and Geophysics Agency (BMKG)of Citeko -Bogor 2009 – 2018.

Table 4. Average monthly rain intensity (mm/month) and standard deviation

Year	Rain intensity, Xi (mm)	(Xi – X)	(Xi - $\bar{X}$)^2
2009	286.53	-7	47.13
2010	325.95	33	1,060.15
2011	207.69	-86	7,344.20
2012	227.73	-66	4,311.89
2013	361.37	68	4,620.83
2014	385.93	93	8,562.73
2015	225.28	-68	4,638.52
2016	345.65	52	2,731.11
2017	305.70	12	151.54
2018	262.08	-31	980.11
Sum	2,933.90	-	34.448,20
Average	293.39	-	-
Standard deviation	61,87	-	-

Source: The calculation results, 2019

Table 5. Rainwater catchment area with smart tanks, cumulative CROs, and rainwater harvests

Scenario	Proportion (%)	Rainwater catchment area	Cumulative CRO Value	Peak runoff (m^3/year)	Rainwater harvests with smart tanks (m^3/year)
1	25	409.55	0.52	1,977,245,933	342,215,642
2	50	819.10	0.44	1,673,054,251	646,407,324
3	75	1,228.64	0.35	1,330,838,609	988,622,967
4	Without smart tank	1,638.19	0.61	2,319,461,575	-

Source: The calculation results, 2019

2.5. Watershed

The concept of a watershed or often abbreviated as a watershed is the basis of all hydrological planning. In general, Watersheds (DAS) can be defined as an area, which is limited by natural boundaries, such as the ridges of hills or mountains, as well as artificial boundaries such as roads or dikes, where rainwater that falls in the area contributes to flow to the point of release (outlet) (13). Watersheds (DAS) can be seen as part of the surface of the earth where rainwater becomes surface flow and collects into rivers into rivers leading to a point downstream as an expenditure point. Each large watershed which empties into the sea is a combination of several watersheds while the sub-watershed is a combination of small sub-watersheds (14).

2.6. Runoff

Surface runoff is rainwater that cannot be held by land, vegetation or basin and eventually flows directly into the river or sea. The amount of surface flow value greatly determines the level of damage caused by erosion and flooding. The value of surface flow is influenced by rainfall, vegetation (land cover), the existence of water storage buildings and other factors.Rain is the most important input component in the hydrological process of the watershed, because the amount of rain is diversified into runoff through surface runoff, underground flow, and groundwater flow. A rain and flow are interrelated in terms of the relationship between rain volume and flow volume, the distribution of rain per time influences the flow results, and the frequency of rainfall events influences flow (15).

2.6.1. Factors Affecting Runoff

The factors that affect runoff are divided into 2 groups, namely meteorological factors and characteristics of channel catchment areas or watersheds. The factors included in the group of meteorological elements are as follows (13):

1) Rainfall intensity

The effect of rainfall intensity on surface runoff depends on infiltration capacity. If the intensity of rainfall exceeds infiltration capacity, then the amount of runoff will immediately increase in accordance with the increase in rainfall intensity. However, the magnitude of the runoff increase is not proportional to the increase in more rainfall, which is caused by the effects of flooding on the ground. Rainfall intensity affects the discharge and runoff volume.

2) Duration of rain

In each flow area has a rain duration unit or critical rain duration. If the duration of rainfall is less than the duration of critical rain, then the duration of runoff will be the same and does not depend on the intensity of rainfall. If the duration of the rainfall is longer, the length of runoff will also be longer.

3) Distribution of rainfall

If conditions such as topography, land and others throughout the drainage area are the same and for example the amount of rainfall is the same, then the rainfall distribution is evenly distributed which results in a minimum peak discharge. Floods in large drainage areas sometimes occur by heavy rainfall with even distribution, and often occur by ordinary rainfall which covers large areas even though the intensity is small. Conversely, in small drainage areas, maximum peak discharge can occur by heavy rainfall with narrow rain areas.Watershed characteristics that have a large influence on surface flow include the area and shape of the watershed, topography, and land use.

1) Area and shape of the watershed

The rate and volume of surface flow increases with increasing watershed area. However, if the surface flow is not expressed as the total amount of the watershed, but as the rate and volume per unit area, the amount will decrease with increasing watershed area. This is related to the time needed for water to flow from the farthest point to the control point (time of concentration) and also the intensity of the rain. The shape of the watershed has an influence on the flow pattern in the river.

2) Topography

Look at the face of the earth or topography such as the slope of the land, the condition and density of the trenches and / or channels, and other forms of basins have an influence on the rate and volume of surface flow. Watersheds with steep slopes and dense ditches / canals will result in higher flow rates and volumes compared to sloping watersheds with rare trenches and hollows.

3) Land use

The effect of land use on surface flow is expressed in the surface flow coefficient (C), which is a number that shows the ratio between the amount of surface flow and the amount of rainfall.
The runoff coefficient is the percentage of the amount of water that can overflow through the surface of the land from the total rainwater falling in an area. The more impermeable a soil surface is, the higher the value of the drainage coefficient.The surface flow coefficient (C) is the influence of land use in surface flow, namely a number that displays the ratio between the magnitude of surface flow and the amount of rainfall. The value of C ranges from 0 - 1. The value of C = 0 indicates that all rainwater is intercepted and infiltrated into the ground, whereas for values C = 1 indicates that rainwater flows as surface runoff. In a good watershed the price of C is close to zero and the more damaged a watershed the C price is closer to one (12).

2.7. Rational Method

Rational methods are widely used to estimate peak discharge caused by heavy rainfall in small catchments (DAS).

A watershed is called a small watershed if the distribution of rain can be considered uniform in a space and time, and usually the duration of rain exceeds the time of concentration. The rational method can describe the relationship between runoff discharge and the amount of rainfall, practically applicable to the watershed area of less than 300 hectares.Runoff coefficient (C) is a number that shows the ratio between the amount of runoff water to the amount of rainfall (in a catchment):

C = (Di x 86400 x Q) / (P x A) (1)

where:

C = runaway water (mm) / rainfall (mm)
Di = number of days in the 4th month
Q = monthly average debit (m^3/sec) and 86400 = many seconds in 24 hours.
P = average annual rainfall (m/year)
A = watershed area (m^2)

RESEARCH METHODOLOGY

3.1. Literature review

The literature study phase is to collectand study materials related to the problems to be studied. These materials are in the form of material obtained from scientific writings, dictates, journals and books or the internet that are related to the problem under study. Information obtained from library studies can be used as a reference in carrying out this research.

3.2. Data collection

This stage is the stage of data collection that will support the implementation of runoff analysis research in the SC area, the Bekasi Upstream Sub-watershed, Bekasi Watershed. The data needed includes:

- Topographic maps
- Land Map
- Land Use Map
- Daily 10-year rainfall data

3.3. Data analysis

The data that has been obtained from the data collection process, will be processed to obtain modeling-modeling in identifying runoff. The data analysis that will be carried out includes the following:

- Pattern of slope and boundary of SC area through the making of DEM (Digital Elevation Models)
- Calculation of rainfall intensity in SC area
- Analysis of land use classification models through Image Classification
- Analysis of runoff calculations through thematic map overlay techniques.

All the analysis processes are assisted by utilizing the GIS technique using Arc-GIS 10.4 software. The processing of this runoff calculation will use the Rational method.After getting the value of runoff, we can do a field review of the condition of the Upper Bekasi River Basin. To calculate the parameters needed in this study, use the formula as presented below:

3.3.1. Runoff Coefficient

Runoff coefficient (C) is defined as the ratio between peak flow rate and rainfall intensity which is influenced by the rate of soil infiltration, cover crops, and rainfall intensity. The main factors that influence the value of C are the rate of soil infiltration, cover crops and rainfall intensity (14).The runoff coefficient of the study area on various land cover is calculated using the following equation:

$$C_{SC} = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i} \quad (2)$$

where:

C_{SC} = runoff coefficient in the study area (SC)
A_i = land area with land cover type i (ha)
C_i = runoff coefficient type of land cover i
n = number of types of ground cover

3.3.2. Average Monthly Rainfall

The average monthly rainfall (mm / month) for 10 years is calculated using the following equation:

$$\bar{X} = \frac{\sum Xi}{n} \quad (3)$$

where:

$\overline{Xi}$ = maximum rainfall average (mm)
$\sum Xi$ = amount of rainfall each year
n = number of years
n = number of years= 10

3.3.3. Standard Deviation

The monthly rainfall deviation standard is calculated using the following equation:

$$Sx = \sqrt{\sum \frac{(Xi-\bar{x})^2}{n-1}} Sx = \sqrt{\sum \frac{(Xi-\bar{x})^2}{n-1}} \quad (4)$$

where:

Sx = standard deviation
xi = amount of rainfall each year (i – year)
$\bar{x}$ = maximum amount of rainfall (mm)

3.3.4. Maximum Daily Rainfall

The maximum daily rainfall of 24 hours (mm / 24 hours) is calculated using the Gumbel probability distribution equation as follows:

$$R_{24} = \bar{X} + \frac{S_x}{S_y}(y_t - y_n) \quad R_{24} = \bar{X} + \frac{S_x}{S_y}(y_t - y_n) \quad (5)$$

where:

R_{24} = the maximum daily rainfall is 24 hours (mm/hour)
$\bar{X}$ = average rainfall (mm)
S_x = standard deviation

y_n = reduce the mean (Appendix Table)
y_t = reduce variations as return periods (Appendix Tables)
y_t = reduce variations as return periods (Appendix Table
S_n = reduce Standard Deviation (Appendix Table)

3.3.5. Rainfall Intensity

The average rainfall intensity of the 10-year period (mm / hour) is calculated by the formula:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \quad (6)$$

where:
I = rainfall intensity (mm / hour)
R_{24} = daily maximum rainfall for 24 hours (mm)
t = the duration of rain (24 hours)

3.3.6. Peak Runoff

The equation used to calculate the peak flow of surface runoff is as follows (14-15):

$$Qp = 0{,}278 \times C_{SC} C_{SC} \times I \times A \quad (7)$$

Qp = peak runoff (m^3/sec)

C_{SC} = runoff coefficient for various land coverings
I = rainfall intensity (mm/hour)
A = study area (km^2)

That is, if there is rainfall for 1 hour with an intensity of 1 mm/hour in an area of 1 km^2, then the flood discharge is 0.2778 m^3 / sec and overflows for 1 hour (16).

IV. RESULTS AND DISCUSSION

4.1. Overview of the Study Area

SC is an independent city under the auspices of PT. SC Tbk. in which there are residential areas and several other facilities with a total area of 2,465 ha in the area of 3,001.4 ha (17). SC is geographically located at 06º 33 '55 " N, 06º 37' 45" N and 106º 50' 20" E, 106º 57' 10" E. For the boundaries of the SC region itself, the northern part of the area is bordered by Cipambuan Village and Kadumangu Village, in the west it is bordered by Cijayanti Village, Cikeas Village, and Cadasngampar Village. The east is bordered by Hambalang Village and Karang Tengah Village, and in the south it is bordered by Ngarak Village. SC which is flanked by several villages and several regions, namely, Bogor, Jakarta and Jonggol facilitates the achievement of the area. Access from the city of Bogor to SC can be reached through the Bogor Ring Road and Jagorawi Toll Roads which are also accessible from Jakarta, while access from Jonggol city can be reached through Karang Tengah. Housing development in SC is in an area that covers 2 sub-districts, namely Babakan Madang District and Sukaraja District. The SC area is surrounded by Mount Pancar, Mount Paniisan, and Mount Salak.The land cover map in SC in 2016 generally consists of several types of land use. The use of land used is built-up land and non-built land which includes rice fields, gardens, forests, and fields, and rivers. The results obtained in the form of land cover maps in that location. This land cover map was obtained from the Bappeda Bogor Regency (18).The states that what is meant by built-up land is all forms and structures related to human habitation and activities. Meanwhile, what is meant by rice fields and gardens is land cultivated with rice plants and plantation crops.
Forests based on the library mean land covered by forest plants. Fields are defined as vacant or planted but not permanent/irregular land (19).

4.2. Physical Condition of the Bekasi Upstream Watershed Area

4.2.1. Climatology

The average monthly temperature of the SC residential area from January 2009 to December 2009 was 26.0 °C. The highest temperature was 26.6 ° C in September 2009 and the lowest temperature was 25.0 °C in January 2009. The average monthly humidity data from January to December 2009 was 81%. With the highest air humidity of 88% in January to February 2009, the lowest humidity is 75% in August to September 2009 (20). Rainfall data per month from August 2007 to July 2008 was 210.25 mm / month, the highest in March 2008 with 404 mm / month of rainfall and the lowest in July 2008 with 25 mm / month rainfall.Average data Wind speed per month from January 2008 to December 2009 was 2.55 Knots, the highest in February 2009 with a 3.5 Knots wind speed and the lowest in June 2008 with a speed of 2.0 Knots. Based on climate classification according to Mohr, the SC residential area is located in climate type areas with wet months throughout the year, namely climate types which throughout the year rainfall averages more than 100 mm/month or including climate type A based on climate classifications Schmidt and Ferguson.The average annual rainfall in the Bekasi Upper Watershed is based on statistical data in the lowlands + 1,800 mm and for mountainous areas + 3,500 mm. In January and December rainfall in mountainous areas is quite heavy. The highest rainfall occurs in February and most rainy days in December. The temperature of the Bekasi Hulu watershed ranges from 280 - 320, while for the mountain zone 18.9 °C - 25.2 °C.The annual average rainfall of the entire Bekasi Hulu watershed is 3,210 mm with the largest rainfall in Cariu station, which is located in the upper watershed, while the smallest annual average rainfall is at Halim Perdana Kusuma Station of 1,901 mm located in DKI Jakarta.The maximum daily rainfall that has ever occurred is the largest at Cariu station at 345 mm and then at Bekasi station at 250 mm. This rainfall caused flooding that occurred in 2002 in the City of Bekasi.

4.2.2. Land Topography and Slope

SC is above the height of 200 - 750 m mean sea level. The area is generally hilly. Slope ranges from 0 - 45%. The land is hilly as SC's natural topography is maintained. The situation was dealt with by planners with a winding road landscape and houses located on the road (up slope) and under the road (down slope). While the BGH (Green Golf Hill) cluster reaches 300 m above sea level (3).

4.3. Boundary of Sub Watershed

The largest sub-watershed in the Bekasi Hulu watershed is the Cileungsi sub-watershed with an area of 26,525.9 ha or 67.9% of the total Bekasi upstream watershed, while the area of the Cikeas sub-watershed is 11,352.9 ha or 29.1%. This data shows the influence of the Cileungsi Sub-watershed will be more dominant in influencing the floods of Bekasi City when compared to the Cikeas sub-watershed because the area is almost 2.3 times. The smallest watershed is the Cikeruh sub-watershed with an area of 1,790.9 ha or only 3.8% of the total watershed, located in the lower reaches of the Bekasi Upper watershed and is part of the Cileungsi sub-watershed.The largest maximum debit occurred in February at 585.6 m^3/sec and the lowest in September was 47.3 m^3/sec, while the smallest minimum debit occurred in September at 1.3 m^3/sec and the largest in January at 9.7 m^3/sec. The highest average debit occurred in February of 104.3 m^3/sec and the smallest in September was 4.5 m^3/sec. The location of the SC area in the Bekasi Upper Upper Sub-watershed, precisely in the Cikeas Sub-watershed and Citeureup Sub-watershed.

4.4. Land Use Masterplan

According to the master plan that was passed on December 19, 2011, Sentul City has an area of 2,465 ha (1), and based on the results of the digitization, Sentul City's area was 2905.33 ha according to the boundaries of the area in vector form obtained from thepartiescity planner. The Sentul City area is divided into the enclave, commercial, rural, residential, residential, infrastructure, effective facilities, and conservation facilities (1). The largest allotment of the Sentul City area is for housing by 56.38%, while the smallest allotment is for effective facilities 0.23%. The development of Sentul City based on the master plan is carried out in stages, currently, the construction is carried out with plans for 2015-2025 ongoing development including Sentul Garden Apartment, AEON Mixed Use, and other commercial areas.Based on the runoff coefficient in Table 2 and the area of land use can be found the region runoff coefficient values as in Table 1.This coefficient also depends on the nature and condition of the soil. The infiltration rate falls on continuous rain and is also affected by previous water saturation conditions. Other factors that also affect the value of C are groundwater, the degree of soil density, soil porosity and depressed deposits. The following are the C values for various soil types and land uses (13): The proportion of green open room in city area is minimum 30% of city area. Thereof, the settlement of SC has effective the requirements of green open room (21). The land use in the cluster BGH is classified into settlement area, facility, RTH (Green Open Space), and vacant plots. Land Use Masterplan is showed in Figure 1.The cumulative runoff value is 0% of the housing area (without smart tanks), 25%, 50%, 75% is 0.61; 0.52; 0.44; and 0.35. The extent of rain harvest is increasing, so the cumulative runoff value decreases. This will reduce peak runoff so that it can reduce the incidence of flooding in the downstream watershed.

4.5. Rainfall

The closest weather station to the Sentul urban area is the Meteorological, Climatology and Geophysics Climatology Station (BMKG) Citeko, Puncak, Cisarua, Bogor (20). Rainfall data from 2009 to 2018 (Table 3).

Rain Intensity

The rain intensity is calculated by mm (millimeter) unit, which is the height of water accommodated in area 1 m x 1 m or 1 squared meter (m^2). Accordingly, rain intensity 1 mm is the amount of water falling from the sky as much 1 mm x 1m x 1m or 0.001 m^3 or 1 dm^3, identic with 1 liter.

Average monthly rain intensity value

From that data, the average rain intensity value for 10 years, is calculated by equation as follows:

$$\bar{X} = \frac{\sum Xi}{Junlah\ tahun\ (n)} \bar{X} = \frac{\sum Xi}{Junlah\ tahun\ (n)} \quad (7)$$

where:

$\overline{Xi}$ = Average maximum rain intensity (mm)

$\sum Xi$ = Amount of rain intensity per year

n = Number of year (data)

Average rain intensity for 10 years ($\bar{X}$) = 2.934/10 = 293. Average monthly rain intensity (mm/month) showed are showed in Table 3 and standard deviation are showed in Table 4.

Standard Deviation

Standard deviation is calculated by using following equation:

$$Sx = \sqrt{\sum \frac{(Xi-\bar{x})^2}{n-1}} Sx = \sqrt{\sum \frac{(Xi-\bar{x})^2}{n-1}} \quad (8)$$

where:

Sx = Standard deviation

xi = Amount of rain intensity per year (year − i)

$\bar{x}$ = Average maximum rain intensity (mm)

$S_x = 61.87$

Maximum daily rain intensity

Daily rain intensity maximum 24 hours (mm/24 hours) is calculated by using *Gumbel* probability distribution equation as follows:

$$R_{24} = \bar{X} + \frac{S_x}{S_y}\ (y_t - y_n)\quad R_{24} = \bar{X} + \frac{S_x}{S_y}\ (y_t - y_n) \quad (9)$$

where:

R_{24} = Amount of daily rain intensity maximum 24 hours (mm/24 hours)

$\bar{X}$ = Average rain intensity (mm)

S_x = Standard deviation

y_n = Reduce mean (Table)

y_t = Reduce variation as repeat period (Table)

S_n = Reduce Standard deviation (Table)

$$R_{24} = \bar{X} + \frac{S_x}{S_n}(y_t - y_n) = 293 + \frac{61.87}{0.9497}(1.4999 - 0.4952)$$

$$R_{24} = R_{24} = 358.45$$

Rain intensity

Average rain intensity for period 10 years (mm/hour) is calculated by Mononobe equation (22) below:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \quad (10)$$

where:

I = Rain intensity (mm/hour)
R_{24} = Maximum daily rain intensity for 24 hours (mm)
t = Rain duration (24 hours)

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

$$I = \frac{358.45}{24}\left(\frac{24}{24}\right)^{2/3}$$

$I = 14.93$ $I = 14.93$ *mm/hour*

Peak Runoff

Peak runoff in SC area (Qp_SC) is calculated as following equation (Rational Method):

Qp_SC = 0.278 x C_{SC} C_{SC} x I x A …………………….. (11)

where:
Qp_SC = Peak runoff of SC area (m^3/second)
C_{SC} = Runoff coefficient for various land use in SC area
I = Rain intensity (mm/hour)
A = Study area (km^2)

Constant 0.278 is a peak runoff conversion factor to unite in m^3/second. SC masterplan is 29.05 km^2, by peak runoff coefficient (C_{SC}) at value 0.61 with peak runoff value (Qp_SC) at value 73.55 m^3/second. Based on the rational method as in equation (7), the calculation is showed as follows (1): Qp_SC = 0.278 x C x I x A = 0.278 x 0.61 x 14.93 x 29.05 = 73.55 m^3/second or 2,319,461,575 m^3/year. By using the same calculation, the amount of Qp_SC for various CROs can be seen in Table 5.Theamount of rainwater harvested that is accommodated by smart tanks installed in plots of land and buildings, and peak runoff can be seen in Table 5. Rainwater harvesting which is the result of rainwater harvesting by smart tanks, collected rainwater can be used to meet the needs of bathing, washing and latrine water as well as reducing peak runoff, runoff, erosion, and sedimentation.

V. CONCLUSION

After calculating runoff in the SC area, the Bekasi Hulu sub-watershed can be concluded:

- Based on an analysis of land use plans in the 2011 Sentul City master plan, the cumulative runoff coefficient value of 0.61 was obtained with peak runoff of 73.39 m3 / sec. With the implementation of smart tanks by 75%, 50%, and 25% in residential areas can reduce runoff by 31.35; 20.50; and 10.85 m3 / sec.
- The dual benefits of implementing smart tanks, apart from being a source of clean water supply and also reducing peak runoff.
- The wider the water storage area in the smart tank, the more the peak runoff will decrease.

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