Civil and Environmental Engineering for Resilient, Smart and Sustainable Solutions

Edited by
Tahar Ayadat

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Preface

On behalf of the conference committee, I would like to thank all the contributors and participants in the 1st International Conference on Civil and Environmental Engineering for Resilient, Smart and Sustainable Solutions (CEES2024) which had been held at Prince Mohammad Bin Fahd University (PMU) Khobar, Kingdom of Saudi Arabia on 3-5 November, 2024. I was honored to serve as Chairman of this important event. Firstly, I would like to thank the organizing committee for their unrelenting efforts to organize this congress. In the world community, we were all aware of how important research has been in contributing to the body of knowledge and the development of prospects. The conference aims to exchange scientific information and knowledge in the development of recent and future infrastructures that are resilient, smart, and sustainable. The conference provides an excellent environment for government policy makers, practicing professional engineers, researchers, university professors, students, and general public to extend their interests and expertise in addressing and solving the infrastructure issues faced by societies. The success of CEES2024 reflects a collective commitment to advancing civil and environmental engineering practices. As participants departed Al-Khobar, they carried with them not just new knowledge but also a renewed sense of purpose in shaping a sustainable future. Finally, I thank the keynote speakers, presenters and authors for their contributions.

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Rainfall-discharge modeling in Juana Watershed

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Keywords: Curve Number, Land Use, Rainfall, Juana Watershed, Flood

Abstract. Juana Watershed has various problems, one of which is flooding during the rainy season and drought during the dry season. One of the causes of flooding is changes in land use, which results in an increase in the amount of Juana River runoff. Efforts that can be made to overcome this are by modeling rainfall discharge to approach hydrological values in the field. The purpose of this study was to examine the magnitude of the simulated discharge that occurred in the Juana Watershed. The data used were rainfall, land use maps, soil type maps, and topographic maps. The results of this modeling are a trend of changes in the curve number value (land capacity to absorb water), namely an increase in the CN value in 5 sub-watersheds, a decrease in the CN value in 2 sub-watersheds, and an equivalent CN value (stagnant) in 1 sub-watershed. The largest increase in CN value was in Juana Sub-watershed 2 of 0.93, while the largest decrease was in Gembong Sub-watershed of 0.35.

Introduction

The development of community activities along with the population growth rate has triggered regional growth with various developments in several sectors. This condition results in the formation of land use characteristics in river basins. Changes in land use in river basins (DAS) have a dominant influence on surface runoff and river flood discharge; this affects climate change conditions [1]. Surface runoff conditions significantly in river basins based on peak time and flood volume [2]; this is influenced by the type and area of land cover [3]. One component in seeing the characteristics of river basins is based on land cover change conditions. Floods are the most frequent disasters in Indonesia, with 1531 incidents [4]. Floods trigger infrastructure damage, threaten the lives of living things, and cause economic crises. Floods occur in almost all regions of Indonesia, one of which is in Central Java Province. Juana Watershed is one of the flood retention areas, based on the masterplan planned in 1891, including the construction of a lower embankment on the Serang Lama River (Wulan River), causing floodwaters to overflow into the Juana area and making the Juana area a sedimentation area. Flood disasters that occur in the Juana River basin occur every year, especially during the rainy season, and peak in December to March. There was a 70-cm-high puddle that inundated six sub-districts in 2023 and 2022.

Rainfall is one of the most important climate components that can affect the determination of water availability in a region and also affect human life activities [5]. Climate change can cause a variety of hydrological cycle processes [6], including increased rainfall variations [7] and changes in evaporation rates [9]. Increasing global temperatures will increase the rate of evapotranspiration and accelerate the water cycle [9], which has an impact on the uneven distribution of water vapor in the atmosphere, causing high rainfall in one region and extreme drought in another region [10]. Changes in rainfall patterns in Indonesia with regional development conditions will cause a delay in the start of the rainy season and a tendency for the rainy season to end earlier [1]. This means

that the rainy season occurs in a shorter time but the intensity of rainfall is higher [11]. Rainfall is one of the important climate elements for human activities. Rainfall has characteristics that vary according to space and time, so the availability of adequate data is important to understand the characteristics of rainfall in a region [12]. The hydrological cycle is closely related to elevation [13]. Apart from elevation factors, other additional factors that influence rainfall also need to be considered, including land cover [13].

The phenomenon of rain transformation into surface runoff and flood discharge is a complex natural process, so it is necessary to simplify the actual reality in the form of modeling. Hydrological modeling, namely the Hydrologic Modeling System/HEC - HMS (2000) developed by the US Army Corps Engineers, is a rainfall flow model software that looks at momentary events (events) and continuous events. Flood hydrographs in water catchment areas are influenced by several factors, including rainfall and watershed characteristics. The process of rainwater loss due to evaporation, infiltration, interception, and surface runoff is based on the parameters CN (curve number), % impervious, and initial abstraction so that it affects river and reservoir discharge [14]. In this study, the Juana Watershed, consisting of 8 sub-watersheds, was selected as the training location. Rainfall factors and land use changes that occur in the Juana Watershed affect runoff and flood discharge. It is necessary to study the condition of the curve number against discharge fluctuations in the Juana River.

Material and Method

Material

Geographically, the Juana Watershed is elongated, located between 06°36’46’’ LS and 06°59’27’’ LU and between 110°46’44’’ BT and 111°14’47’’ BT and has an area of 1.282,14 km^2, divided into 8 (eight) sub-DAS, namely JU, JU-1, JU-2, Juana 1, Juana 2, Juana 3, Logung dan Gembong. Juana Watershed is located in 2 districts, namely Kudus Regency and Pati Regency, Central Java Province. Pati Regency dominates the Juana Watershed with 91.71%, while Kudus Regency has 8.29% of the area in the Juana Watershed.

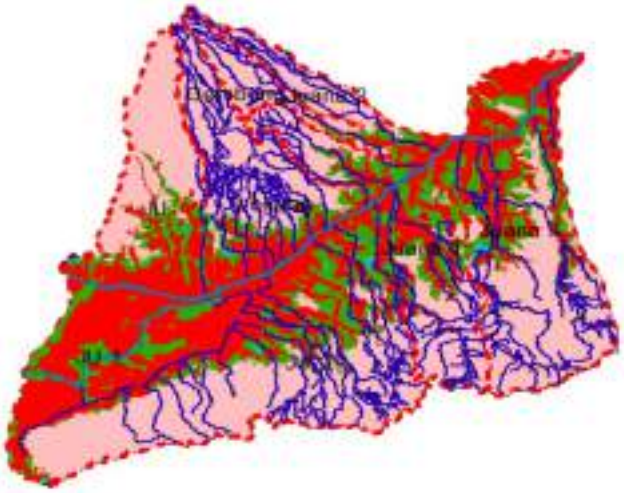

Figure 1. Juana Watershed

The data used in this study are as follows: Topographic map, Juana watershed map, land use map, rainfall data and climatology data. This study compares landuse in 2013 with 2018. Juana watershed have 10 station for rainfall recording, namely Prawoto RW32, 164 SR Kudus , 186 Jan 4 Tanjungrejo, 182 Gembong, 126 SR 17 Wilalung, 194 Kayen, 191 Cabean/ Kedung, 184 Pati and 159 Jan 6Cendono Dawe. Range rainfall data start from 2009 until 2018.

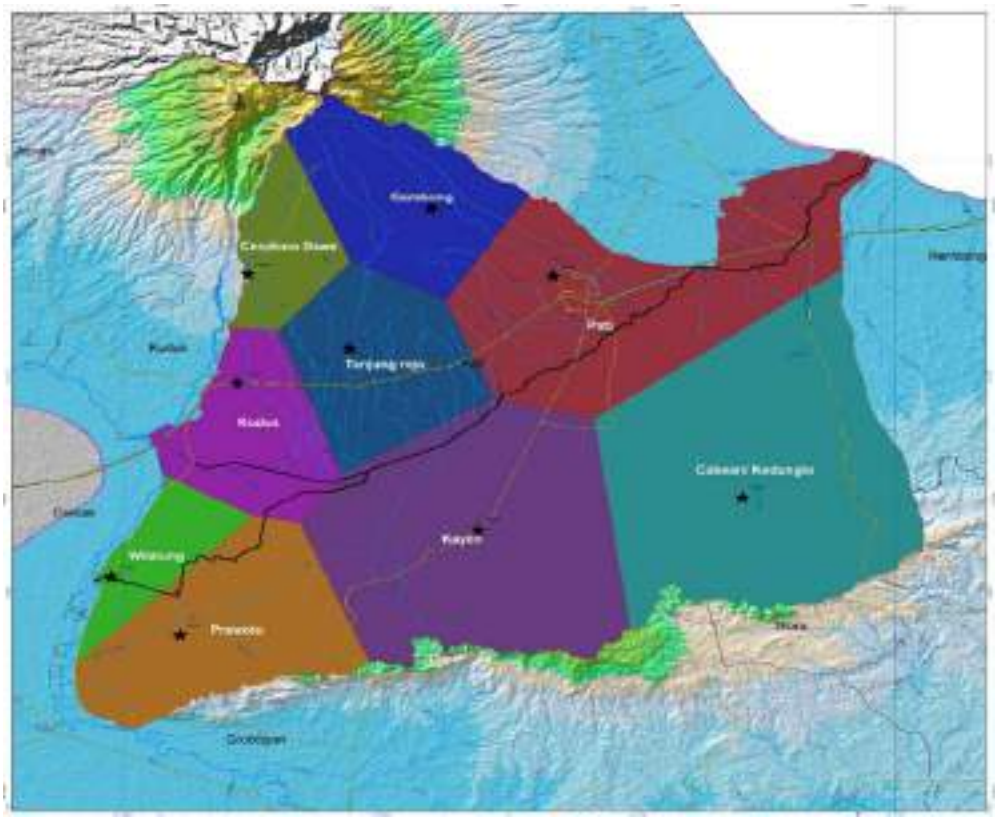

Figure 2. Rainfall station at Juana Watershed

Method

The steps of the research carried out were as follows:

a) Hydrological analysis by collecting rainfall data for 10 years (2009-2018) from 10 rainfall stations in the Juana watershed, as shown in Figure 2.
b) Digitizing watershed parameters by ArcGIS 10.5 software for basin modelling.
c) Digitizing land cover and hydrological soil grouping. Some sources that are often used as references in soil grouping in an analysis are soil data from FAO (Food and Agriculture Organization of United Nations and International Institute for Applied Systems Analysis (IIASA).
d) Analysis of the flood discharge using the Soil Conservation Service Curve Number (SCS-CN) method with the software tools of the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS).
e) Analysis of the design rainfall by return period using normal, gumbel, log normal, and log pearson tipe III method. The result of design rainfall to be used must comply with the requirements of the skewness coefficient (Cs), variation coefficient (Cv), and kurtosis coefficient (Ck). After performing the frequency analysis calculations, the next step involves conducting goodness-of-fit tests using the Chi-square and Smirnov-Kolmogorov tests. These goodness-of-fit tests determine whether the selected distribution type is appropriate for the given data[15].

Result

Hydrology Analysis

The calculation of rainfall distribution in Juana Watershed uses four methods for each station, namely the Normal, Log-Normal, Log-Pearson Type III, and Gumbel distribution methods. The results were obtained using the chi-square and Smirnov Kolmogorov tests. A summary of the design rainfall analysis is in Table 1. The distribution to be used must comply with the

requirements of the skewness coefficient (Cs), variation coefficient (Cv), and kurtosis coefficient (Ck) according to Table 2. From the digitization results, the Juana Watershed area is 1,282.14 km^2 which is divided into 8 Sub-DAS as shown in Figure 2.

Table 1. Recapitulation of Design Rainfall by Return Period in Sub-Watershed

JU 1				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	169.06	217.17	181.92	188.79
50	161.70	199.45	170.91	178.13
25	154.54	181.60	160.82	164.61
10	143.89	157.54	146.91	146.61
5	133.29	138.49	134.25	132.17
2	103.42	109.73	104.17	110.30
JU				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	331.20	474.61	443.53	435.38
50	309.30	421.80	389.32	391.03
25	287.94	368.59	342.87	333.28
10	256.21	296.88	283.88	263.18
5	224.61	240.12	235.21	213.32
2	135.59	154.39	138.49	147.39
JU2				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	165.92	216.26	195.63	163.62
50	158.23	197.72	180.81	157.87
25	150.74	179.05	167.44	149.84
10	139.60	153.87	149.39	139.91
5	128.50	133.95	133.34	128.83
2	97.26	103.86	96.81	106.69
LOGUNG				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	177.62	263.77	406.07	273.96
50	164.46	232.05	326.66	228.20
25	151.64	200.09	264.24	185.19
10	132.57	157.00	192.81	136.33
5	113.59	122.90	140.86	104.12
2	60.11	71.40	58.19	65.19
JUANA 1				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	148.11	191.72	184.99	139.57
50	141.45	175.66	170.04	136.38
25	134.95	159.48	156.64	132.30
10	125.30	137.67	138.65	124.89
5	115.69	120.41	122.78	116.80
2	88.62	94.32	87.19	98.80

GEMBONG				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	303.57	462.64	364.18	553.55
50	279.27	404.06	314.23	406.72
25	255.58	345.04	272.15	298.02
10	220.38	265.49	219.80	196.43
5	185.32	202.53	177.66	142.25
2	86.58	107.43	97.56	90.97
JUANA 2				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	256.55	380.88	322.57	410.10
50	237.56	335.09	280.69	325.64
25	219.05	288.97	245.12	256.66
10	191.54	226.79	200.40	184.27
5	164.14	177.59	163.98	140.50
2	86.97	103.26	93.20	92.54
JUANA 3				
Return period (year)	Normal	Gumbel	Log Normal	Log Pearson Tipe III
100	127.01	221.94	188.21	112.14
50	121.76	335.09	170.10	111.29
25	116.64	288.97	154.12	109.96
10	109.04	226.79	133.11	106.83
5	101.47	177.59	115.02	102.52
2	80.15	103.26	76.24	90.12

Table 2. Parameter Test

JU 1					**JU**				
Chi Square Test					**Chi Square Test**				
	Normal	Gumbel	Log Normal	Log Pearson Tipe III		Normal	Gumbel	Log Normal	Log Pearson Tipe III
$X^{2\ Calculated}$	2.000	2.000	2.000	2.000	$X^{2\ Calculated}$	0.400	4.400	1.200	2.000
$X^{2\ Cr}$	3.841	3.841	3.841	3.841	$X^{2\ Cr}$	3.841	3.841	3.841	3.841
Information	ok	ok	ok	ok	Information	ok	not ok	ok	ok
Smirnov Kolmogorof Test					**Smirnov Kolmogorof Test**				
Δ max	0.162	0.162	0.162	0.082	Δ max	0.164	0.164	0.121	0.165
Δ criticism	0.410	0.410	0.410	0.410	Δ criticism	0.410	0.410	0.410	0.410
Information	ok	ok	ok	ok	Information	ok	ok	ok	ok

JU 2					LOGUNG				
Chi Square Test					**Chi Square Test**				
	Normal	Gumbel	Log Normal	Log Pearson Tipe III		Normal	Gumbel	Log Normal	Log Pearson Tipe III
$X^{2\ Calculated}$	2.000	0.400	2.000	2.000	$X^{2\ Calculated}$	2.000	2.000	3.600	2.000
$X^{2\ Cr}$	3.841	3.841	3.841	3.841	$X^{2\ Cr}$	3.841	3.841	3.841	3.841
Information	ok	ok	ok	ok	Information	ok	ok	ok	ok
Smirnov Kolmogorof Test					**Smirnov Kolmogorof Test**				
Δ max	0.130	0.130	0.083	0.121	Δ max	0.127	0.127	0.032	0.138
Δ criticism	0.410	0.410	0.410	0.410	Δ criticism	0.410	0.410	0.410	0.410
Information	ok	ok	ok	ok	Information	ok	ok	ok	ok

JUANA 1					GEMBONG				
Chi Square Test					**Chi Square Test**				
	Normal	Gumbel	Log Normal	Log Pearson Tipe III		Normal	Gumbel	Log Normal	Log Pearson Tipe III
$X^{2\ Calculated}$	7.600	1.200	1.200	1.200	$X^{2\ Calculated}$	4.400	11.600	2.000	0.400
$X^{2\ Cr}$	3.841	3.841	3.841	3.841	$X^{2\ Cr}$	3.841	3.841	3.841	3.841
Information	Not ok	ok	ok	ok	Information	Not ok	Not ok	ok	ok
Smirnov Kolmogorof Test					**Smirnov Kolmogorof Test**				
Δ max	0.086	0.086	0.097	0.123	Δ max	0.150	0.150	0.303	0.084
Δ criticism	0.410	0.410	0.410	0.410	Δ criticism	0.410	0.410	0.410	0.410
Information	ok	ok	ok	ok	Information	ok	ok	ok	ok

JUANA 2					JUANA 3				
Chi Square Test					**Chi Square Test**				
	Normal	Gumbel	Log Normal	Log Pearson Tipe III		Normal	Gumbel	Log Normal	Log Pearson Tipe III
$X^{2\ Calculated}$	1.200	8.400	2.000	1.200	$X^{2\ Calculated}$	2.000	6.800	3.600	0.400
$X^{2\ Cr}$	3.841	3.841	3.841	3.841	$X^{2\ Cr}$	3.841	3.841	3.841	3.841
Information	ok	Not ok	ok	ok	Information	ok	Not ok	ok	ok
Smirnov Kolmogorof Test					**Smirnov Kolmogorof Test**				
Δ max	0.102	0.102	0.071	0.078	Δ max	0.102	0.111	0.098	0.166
Δ criticism	0.410	0.410	0.410	0.410	Δ criticism	0.410	0.410	0.410	0.410
Information	ok	ok	ok	ok	Information	ok	ok	ok	ok

Note: Ok = Accepted; Not ok= Rejected; Cr= critical

Analysis of Land Cover and Curve Number (CN) Value of the Juana Watershed

The curve number value describes the physical characteristics of the watershed in the form of soil, hydrological conditions and land use. The Juana watershed has 9 types of land cover, namely secondary dry forest, plantation forest, settlements, dryland agriculture, dryland agriculture mixed with shrubs, rice fields, ponds, shrubs, and water bodies. The CN value is determined using the SCS-CN method by combining land use with the Soil Hydrology Group. In addition, the soil hydrology group is divided into A, B, and C based on its texture. External texture determines the hydrology group because it is related to the effective water capacity of the soil and affects

infiltration. The results of the curve number analysis calculation for 8 sub-watersheds are shown in Figure 3. The increase in built-up land cover has the potential to influence the hydrological cycle [16]. The characteristics soil at Juana Watershed based on curve number are loam, sandy loam, and sand

Surface Runoff in the Juana Watershed

Flood hydrograph analysis in this study uses the HEC-HMS model [17], which includes basin and meteorological models, control specifications, time series data, losses, transformed baseflow, and river channels. These parameters are needed to determine the flood discharge value according to the return period in the Juana Watershed. Flood discharge analysis comparing the HEC-HMS model with SCS-CN for various return periods is shown in Table 3. The results in Table 3 are then plotted in Figure 4.

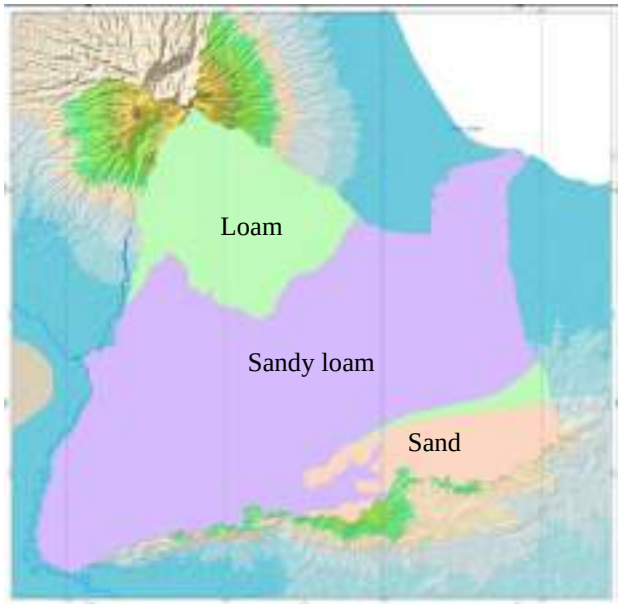

Figure 3. Soil properties in Juana Watershed

There is no Automatic Water Level Recorder measuring device on the Juana River, so a synthetic unit flood hydrograph calculation using the SCS method with a return period of 25 years was carried out on 9 Juana Sub-DAS. The calculation was carried out in 2 observation years (2013 and 2018).

Table 3. Recapitulation SCS-CN Method

No	Sub-watershed	SCS-CN	
		2013	2018
1	JU 1	85.74	85.75
2	JU	1,155.64	1,155.75
3	JU 2	74.53	85.69
4	Logung	636.14	643.64
5	Juana 1	96.37	93.47
6	Gembong	110.88	108.07
7	Juana 2	144.23	153.95
8	Juana 3	130.54	132.62

Hydrograph analysis comparison between HEC HMS model and SCS-CN using the flow ratio tool. Flow ratio calibration is carried out until the RMSE value of the peak discharge or time series (overall hydrograph) is <5%. The same method is carried out on all sub-watersheds with 2 years

of observation (2013 and 2018). The result is a comparison of the peak discharge that occurred during 24 hours in the table 4 and figure 4.

Table 4. Flood Discharge Based on SCS-CN and HEC HMS Models (m^3/s)

NO	SUB	SCS CN		HEC HMS Trial 1		HEC HMS Trial 2		HEC HMS Trial 3	
		2013	2018	2013	2018	2013	2018	2013	2018
1	JU1	85.74	85.75	285.20	285.20	142.60	142.60	85.60	85.60
2	JU	1,155.64	1,155.75	2,652.30	2,652.30	1,326.10	1,326.20	1,193.50	1,193.50
3	JU2	74.53	85.69	616.60	627.80	308.30	313.90	61.70	81.60
4	Logung	636.14	643.64	1,939.40	1,942.60	969.70	971.30	581.80	582.80
5	Juana 1	96.37	93.47	711.70	708.70	355.80	354.30	113.90	106.30
6	Gembong	110.88	108.07	426.10	424.90	213.10	212.40	106.50	106.20
7	Juana 2	144.23	153.95	509.50	514.90	254.70	257.50	152.90	154.50
8	Juana 3	130.54	132.62	1,076.20	1,077.70	538.10	538.90	161.40	161.70

The table above shows the peak discharge that occurs over 24 hours, for example in the JU 1 sub-DAS the peak discharge occurs at hour 10 based on land use in 2013 and 2018. This flood hydrograph can be seen in the image below.

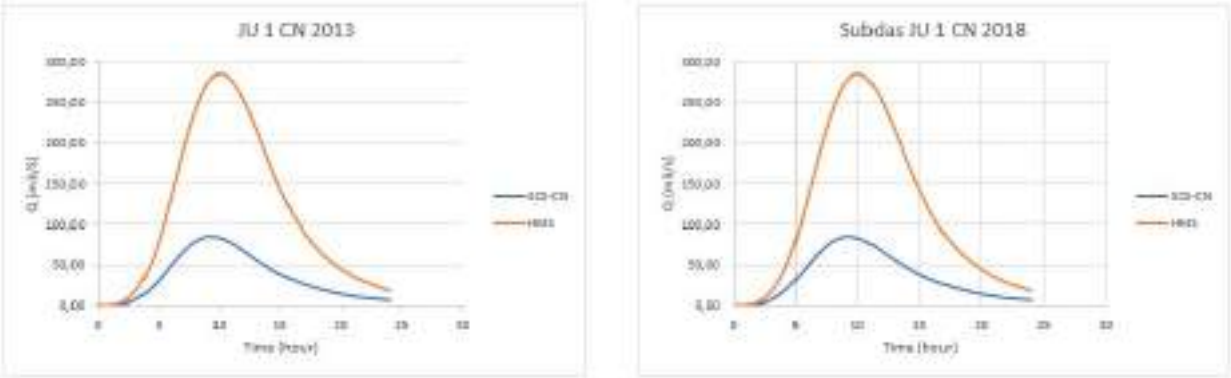

Figure 4. Hydrograph Comparison Chart Between SCS and HMS Models

It was found that out of 8 Sub-watershed, there was an increase in the curve number value in 5 Sub-watershed, a decrease in the curve number value in 2 Sub-watershed, and the same value (constant) in 1 Sub-watershed. Furthermore, hydrological modelling was carried out using the SCS CN method with HEC HMS, which was calibrated with the HSS SCS calculation (SCS-CN), and it was found that 4 Sub-watershed experienced an increase in the peak flood, 2 Sub-watershed experienced a decrease in the peak flood discharge, and 2 other Sub-watershed did not experience a decrease or increase in the peak flood discharge. The increase (4 Sub-watershed) or decrease (2 Sub-watershed) in the peak flood discharge was linear or in line with the increase or decrease in the curve number value. Meanwhile, 1 Sub-watershed that experienced an increase of 0.002, namely JU, did not experience an increase in the peak flood discharge.

Conclusion

Based on the results of the analysis of land use and CN values from 2013 to 2018 in the Juana River Basin, which is divided into 8 sub-basins, there has been a trend of changes in land use that has resulted in changes in the curve number value (land's ability to absorb water). The trend that occurred was an increase in the CN value in 5 sub-basins, a decrease in the CN value in 2 sub-

basins, and an equivalent CN value (stagnant) in 1 sub-basin. From the results of the HEC HMS flood hydrograph model calibrated with HSS SCS statistics, the CN value was obtained to be directly proportional to the curve number value. If there is an increase in the CN value, the resulting flood discharge will increase; conversely, if there is a decrease in the CN value, the flood discharge value (time series hydrograph and flood peak) will decrease, so that the increase in the CN value results in an increase in discharge in a river basin (DAS), namely in the Juana DAS.

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Keyword Index