Prediction of Snyder Synthetic Unit Hydrograph Coefficient for Cidurian Watershed

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ABSTRACT

Watershed management is starting with knowing and recording the problems that exist in the watershed. Condition of the watershed that continues to deteriorate can trigger natural disasters such as flash floods that occurred in the Cidurian Watershed. Hydrological design, especially for short-term phenomena runs generates the synthetic unit hydrograph. Snyder synthetic unit hydrograph is the common synthetic hydrograph that widely used on hydrological analysis. Generally, on the snyder synthetic unit hydrograph, the coefficient value (peak coefficient, time coefficient, CW75 and CW50) is only based on estimates or previous research so that the calculation of discharge is less accurate and needs further research. This study discusses the prediction of the value of the Peak Coefficient (Cp), Time Coefficient (Ct), CW75 and CW50 in the Cidurian Watershed using the Snyder Synthetic Unit Hydrograph (HSS) and get a calculation graph between the Polynomial and Collins Unit Hydrographs against the Snyder Synthetic Unit Hydrograph (HSS) in the Cidurian Watershed with rainfall data processing using the Thiessen Polygon, Mononobe, and Alternating Block Method (ABM). The results showed that the value of Peak Coefficient (Cp) = 0.59, Coefficient of Time (Ct) = 0.09, CW75 = 1.22, CW50 = 2.14, with Peak Discharge (Qp) Collins Measured Unit Hydrograph 19th hour = 1.589 m^3/s, and Peak Discharge (Qp) Snyder Synthetic Unit Hydrograph 11th hour, 1 = 1.59 m^3/s.

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1. INTRODUCTION

Watershed (DAS) can be interpreted as a unit of space consisting of abiotic elements (soil, water, air), biotic (vegetation, animals and other living organisms) and human activities that interact and depend on each other, so that it is a unified ecosystem, this means that if the linkage has been implemented, the management of forests, soil, water, society and others must pay attention to the role of these ecosystem components [1].

Watershed management can be designed starting from knowing and recording the problems that exist within the watershed. This is because the problems between one watershed with other watersheds are different. The condition of the Cidurian Watershed that continues to deteriorate can trigger natural disasters. Disasters that have occurred in the Cidurian Watershed include flash floods that have occurred two years in a row. Based on the problems that have occurred at the research location, the value of the Peak Coefficient (Cp), Time Coefficient (Ct), CW75, and CW50 at this time is often only based on estimates so that the calculation of discharge is less accurate and needs to be investigated the value of the Peak Coefficient (Cp), Time Coefficient (Ct), 75% Hydrograph Width Coefficient (CW75), and 50% Hydrograph Width Coefficient (CW50).

This study aims to obtain the magnitude of the Peak Coefficient (Cp), Time Coefficient (Ct), Width Coefficient of the 75% Discharge Hydrograph (CW75), and Width Coefficient of the 50% Discharge Hydrograph (CW50) on the Snyder Synthetic Unit Hydrograph (HSS) for the Cidurian Watershed as the object of research.

2. METHODS

2.1 Watershed

Watershed is an area bounded by mountain ridges where rainwater that falls on each area will accommodate, store, and drain the rainwater towards the main river and gather at the station under review. Watershed is composed of a unit of land and river area, including its tributaries, so that the watershed can be composed of several sub-watersheds. The unity of the watershed area is described in a unit called the watershed boundary. Determination of watershed boundaries has several purposes such as knowing the shape of the flow hydrograph to predict peak discharge, can also be used in flood analysis, and water resources management planning and others [8][10].

2.2 Rainfall

Rainfall is the amount of water that falls on the ground surface during a certain period measured in millimeters above the surface. The calculation of the average rainfall area using the Thiessen Polygon method takes into account the weight of each station that represents the surrounding area. In an area within a watershed, it is assumed that the rainfall is the same as that occurring at the nearest station, so that the rainfall recorded at a station represents the area [9][10].

2.3 Hourly Rainfall Distribution Pattern with Empirical Method

a. Manonobe Approach

Manonobe is one form of rain distribution pattern used to calculate the hourly rain distribution pattern. To calculate the hourly rainfall from daily rainfall, the following equation can be used :

$$I = \frac{\mathrm{R}}{24} + \left(\frac{24}{t}\right)^{2/3} \tag{1}$$

b. Alternating Block Method (ABM)

The Alternating Block Method (ABM) is a simple way to create a plan hyetograph where the design rainfall is distributed into hourly rainfall from an IDF curve. The difference between successive rainfall thickness values is the rainfall increment in the time interval Δt. The rainfall increments (blocks), are sorted back into a time series with the maximum intensity at the center of the rainfall duration Td and the remaining blocks are arranged in alternating descending order to the right and left of the center block.

2.4 Measured Unit Hydrograph

The measured unit hydrograph is the unit hydrograph resulting from the reduction of rain and discharge data. Rain data is obtained from stations on rain recording devices, such as Automatic Rainfall Recorder (ARR). While discharge data is obtained from discharge recording devices, such as Automatic Water Level Recorder (AWLR). If rainfall and discharge data are not sufficiently available, then the reduction of the unit hydrograph is done by synthetic means, the result is a Synthetic Unit Hydrograph. To reduce the measured unit hydrograph, a widely used method is the completion of the Polynomial Method and the Collins Method [2][13].

a. Polynomial Method

The Polynomial Method is the simplest way to derive the measured unit hydrograph, to derive the unit hydrograph, the hydrograph data and rainfall data are required.

b. Collins Method

The unit hydrograph calculated from a flood case is not yet a hydrograph that represents the watershed concerned. Therefore, a unit hydrograph derived from a flood case is required, then averaged. In complex rainfall (not single rainfall), the derivation should be done by the Collins method to avoid successive errors [2].

2.5 Synthetic Unit Hydrograph

Synthetic unit hydrographs can be used in areas where hydrological data are not available to derive unit hydrographs, so synthetic unit hydrographs are made that are based on the physical characteristics of the watershed. One method commonly used is the Snyder Synthetic Unit Hydrograph. The Snyder Synthetic Unit Hydrograph involves 4 parameters namely lag time, peak flow, base time, and standard duration of effective rainfall for the unit hydrograph associated with the physical geometry of the watershed [3].

3. RESULTS AND DISCUSSION

3.1 Short-term Rainfall Recording

Short-term rainfall phenomena quantification conducts simple analysis to obtain the value of 5 (five) minutes rainfall rate. In this research, short-term rainfall phenomena data starts from 23 until 25 November 2021.

3.2 Determining the Basic Flow Separator

Estimates of base flow during the dry season are needed to manage water availability in the Cidurian watershed. The base flow used in this study is from November 23, 2021 at 10:00 to November 25, 2021 at 15:00 [15].

Table 1. Base Flow Time and Discharge

t	Q
1	121,59
54	124,04

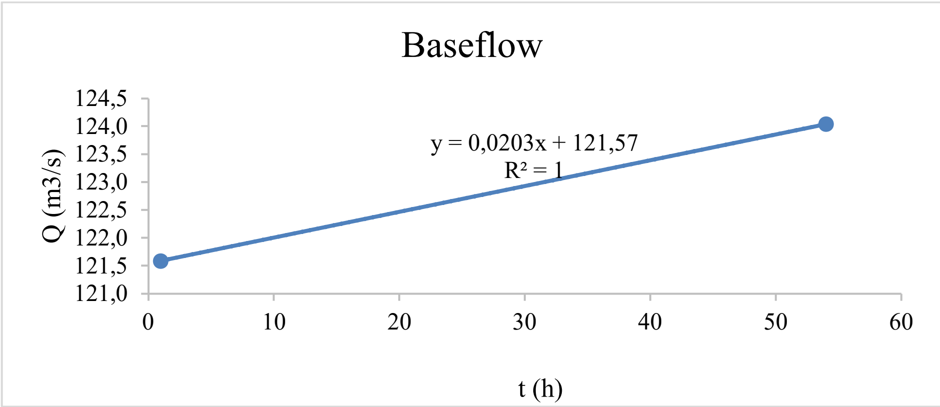

Figure 1. Base Flow Graph Between Discharge and Time

The resulting equation from the base flow graph is used to calculate the base flow value in the Cidurian watershed, after the base flow value is obtained. To calculate the water discharge that will be used in reducing the Measured Unit Hydrograph, namely:

$$Q_{run-off} = Q_{total} - Q_{base\ flow} \tag{2}$$

3.3 Rainfall

The rainfall area used in this study is 4 stations closest to the research location in the Cidurian Watershed, namely Cicinta, Toge, Cisalak Baru, and Cikasungka stations. By using the Thiessen Polygon method, the area of each area at each influential station was obtained [11].

Table 2. Thiessen Polygon Average

Station	***Area* (m²)**	***Area* (km²)**
Cicinta	224531422.743	224.531
Toge	185376308.459	185.376
Cisalak Baru	126702087.201	126.702
Cikasungka	132363003.815	132.363

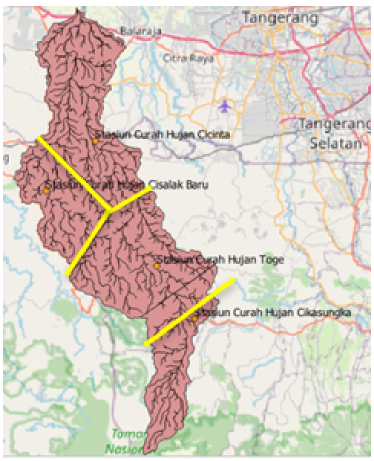

Figure 2. Thiessen Polygon Station Area

Based on the known area, rainfall calculation can be done with Thiessen Polygon, the average 24-hour rainfall with Thiessen Polygon is 33 mm. With this rainfall, the calculation of hourly rainfall can be done using the empirical method.

3.4 Pattern of Hourly Distribution of Empirical Methods

Analysis of hourly rainfall distribution patterns with empirical methods in this study using Manonobe and Alternating Block Method (ABM).

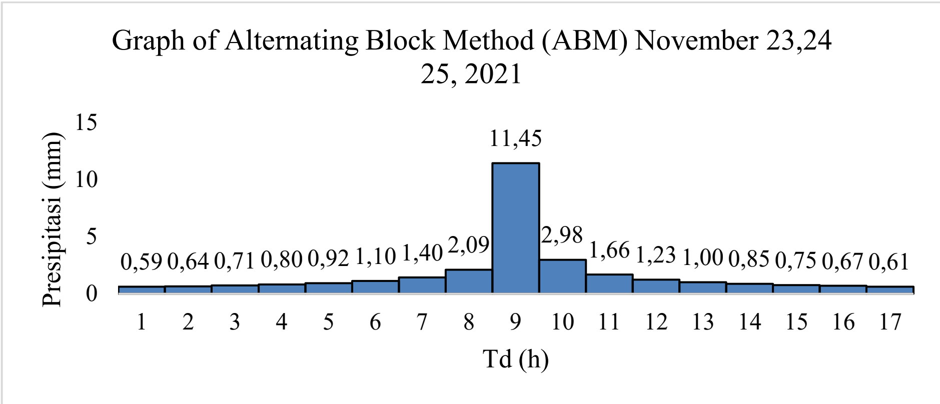

Figure 3. Graph of Alternating Block Method (ABM)

Hourly rainfall using the empirical method can produce the highest rainfall of 11.45 mm**.**

3.5 Decrease in Measured Unit Hydrograph

The calculation of the decrease in the Measured Unit Hydrograph in this research uses 2 methods, namely [4][7]:

a. Polynomial Method

Table 3. Recapitulation of Ux in Polynomial Method

U1	0.00	$m^3/s/mm$	**U20**	-731.92	$m^3/s/mm$
U2	1.02	$m^3/s/mm$	**U21**	-1196.64	$m^3/s/mm$
U3	4.02	$m^3/s/mm$	**U22**	-1639.31	$m^3/s/mm$
U4	5.73	$m^3/s/mm$	**U23**	1752.60	$m^3/s/mm$
U5	5.07	$m^3/s/mm$	**U24**	-607.41	$m^3/s/mm$
U6	-0.91	$m^3/s/mm$	**U25**	-722.11	$m^3/s/mm$
U7	0.61	$m^3/s/mm$	**U26**	-2705.04	$m^3/s/mm$
U8	-1.60	$m^3/s/mm$	**U27**	-33.30	$m^3/s/mm$
U9	-5.90	$m^3/s/mm$	**U28**	20817.39	$m^3/s/mm$
U10	-23.55	$m^3/s/mm$	**U29**	9588.52	$m^3/s/mm$
U11	-54.30	$m^3/s/mm$	**U30**	3562.48	$m^3/s/mm$
U12	-19.69	$m^3/s/mm$	**U31**	-56834.62	$m^3/s/mm$
U13	34.79	$m^3/s/mm$	**U32**	31511.59	$m^3/s/mm$
U14	127.88	$m^3/s/mm$	**U33**	2892.24	$m^3/s/mm$
U15	12.53	$m^3/s/mm$	**U34**	21835.59	$m^3/s/mm$
U16	63.43	$m^3/s/mm$	**U35**	-65700.10	$m^3/s/mm$

U17	109.12	$m^3/s/mm$	**U36**	-336890.19	$m^3/s/mm$
U18	309.55	$m^3/s/mm$	**U37**	193535.83	$m^3/s/mm$
U19	428.64	$m^3/s/mm$	**U38**	200044.78	$m^3/s/mm$

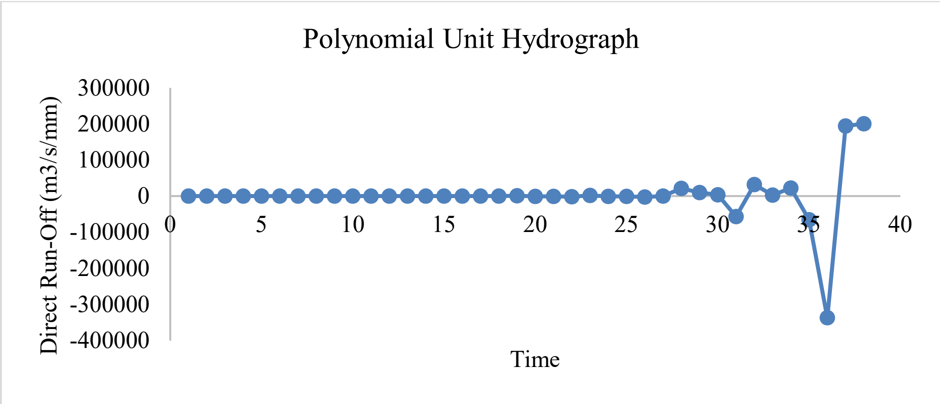

Figure 4. Polynomial Hydrograph Graph

Based on the graph of the Polynomial calculation, the results are very biased and do not converge, so the Polynomial Unit Hydrograph cannot be used.

b. Collins Method

The beginning of this calculation is to make the measured hydrograph a percentage hydrograph, then determine the initial estimated unit hydrograph of 10 $m^3/s/mm$. After that, recalculate the initial estimated hydrograph Wgh [4].

Table 4. Preliminary Hydrograph Wgh

Notation	*Estimate*		*Weight*	*Notation*	*Estimate*		*Weight*
U1	0.02	$m^3/s/mm$	0.00	U20	1.587	$m^3/s/mm$	0,04
U2	0.10	$m^3/s/mm$	0.00	U21	1.58	$m^3/s/mm$	0,04
U3	0.23	$m^3/s/mm$	0.00	U22	1.56	$m^3/s/mm$	0,04
U4	0.35	$m^3/s/mm$	0.01	U23	1.51	$m^3/s/mm$	0,04
U5	0.37	$m^3/s/mm$	0.01	U24	1.47	$m^3/s/mm$	0,04
U6	0.43	$m^3/s/mm$	0.01	U25	1.40	$m^3/s/mm$	0,04
U7	0.48	$m^3/s/mm$	0.01	U26	1.31	$m^3/s/mm$	0,03
U8	0.48	$m^3/s/mm$	0.01	U27	1.26	$m^3/s/mm$	0,03
U9	0.49	$m^3/s/mm$	0.01	U28	1.20	$m^3/s/mm$	0,03
U10	0.52	$m^3/s/mm$	0.01	U29	1.05	$m^3/s/mm$	0,03
U11	0.68	$m^3/s/mm$	0.01	U30	1.05	$m^3/s/mm$	0,03
U12	0.87	$m^3/s/mm$	0.02	U31	0.96	$m^3/s/mm$	0,03
U13	1.08	$m^3/s/mm$	0.02	U32	0.90	$m^3/s/mm$	0,02
U14	1.23	$m^3/s/mm$	0.03	U33	0.86	$m^3/s/mm$	0,02
U15	1.34	$m^3/s/mm$	0.03	U34	0.77	$m^3/s/mm$	0,02
U16	1.44	$m^3/s/mm$	0.03	U35	0.77	$m^3/s/mm$	0,02
U17	1.51	$m^3/s/mm$	0.03	U36	0.75	$m^3/s/mm$	0,02
U18	1.548	$m^3/s/mm$	0.04	U37	0.67	$m^3/s/mm$	0,02

U19	1.589	m^3/s/mm	0.04	U38	0.64	m^3/s/mm	0,02

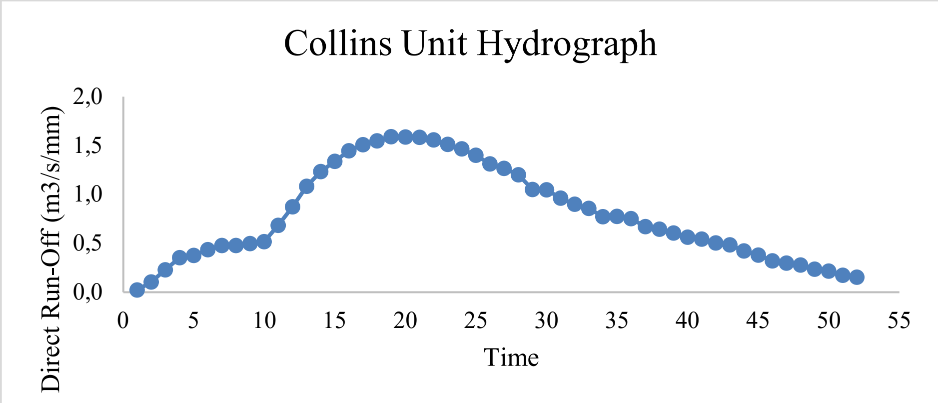

Figure 5. Collins Method Hydrograph Graph

From the calculation graph of the Collins Method Unit Hydrograph, it is obtained that the peak (Qp) at the 19th hour is 1.895 m^3/s.

3.6 Snyder Synthetic Unit Hydrograph

Synthetic Unit Hydrograph is a method used to predict flood discharge that occurs in a river basin based on watershed characteristics data [12].

By knowing the characteristics of the Cidurian Watershed, it can calculate the Snyder Synthetic Unit Hydrograph [5][6]:

Watershed Area (A) = 668.97 km^2
Length of Main River (L) = 125.49 km
Watershed Weight Point (Lc) = 62.75 km

a. Snyder Synthetic Unit Hydrograph before calibration

Snyder Synthetic Unit Hydrograph Calculation Data

Peak Coefficient (Cp)	= 0.5	(Assumption)
Time Coefficient (Ct)	= 1.7	(Assumption)
tR	= 6 hours	(Indonesian Standard Rainfall)
C1	= 0.75	(SI units)
C2	= 2.75	(SI units)
C3	= 5.56	(SI units)
CW75	= 1.22	
CW50	= 2.14	

Step 1: Standard Hydrograph Analysis
In the standard hydrograph analysis, we can know the value of tp = 18,81 hours, qp = 0.073 $m^3/s.km^2$.cm, tr = 3.42 hours, and tpR = 19.45 hours [4].

Step 2: Snyder Hydrograph Analysis
After analyzing the standard hydrograph, analyze the Snyder hydrograph to determine the value of qpR = 0.071 $m^3/s.km^2$.cm, tb = 75.235 hours, W75 = 21.34 hours, and W50 = 37.43 hours [4].

To make the Snyder Synthetic Unit Hydrograph graph, it is necessary to make several points 0, a, b, peak, c, d, and Tb.

Table 5. HSS Snyder Calculation Results Before Calibration

No	*Time* (h)	qpR (m^3/s.mm)	*Description*
1	0	0	*Beginning*
2	8.69	2.364	*50%peak*
3	14.05	3.546	*75%peak*
4	21.16	4.728	*peak*
5	35.39	3.546	*75%peak*
6	46.11	2.364	*50%peak*
7	75.23	0	*tb*

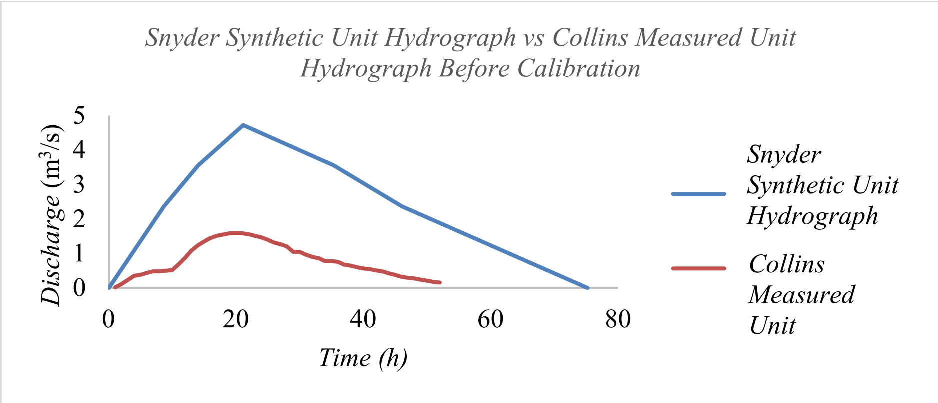

Figure 6. Coordinate Graph of Snyder Synthetic Unit Hydrograph vs Collins Measured Unit Hydrograph Before Calibration

Based on the graphic image of the Snyder Synthetic Unit Hydrograph before calibration, it can be seen that the hydrograph shape between the Collins Measured Unit Hydrograph and the Snyder Synthetic Unit Hydrograph has a much different graphic shape. Peak Discharge (Qp) Snyder Unit Hydrograph at 21.16 hours = 4.728 m^3/s.mm, while the Collins Unit Hydrograph at 19 hours = 1.589 m^3/s.mm. So based on this, the Snyder Unit Hydrograph with a Peak Coefficient (Cp) = 0,5, Time Coefficient (Ct) = 1,7 and shape coefficient (CW75 = 1.22 and CW50 = 2.14) is not in accordance with the characteristics of the Cidurian Watershed [14].

b. Snyder Synthetic Unit Hydrograph after calibration

Snyder Synthetic Unit Hydrograph Calculation Data:

tR	= 17 hours	(Manonobe and ABM calculations)
tpeak	= 19 hours	
C!	= 0,75	(SI units)
C2	= 2,75	(SI units)
C3	= 5,56	(SI units)
CW75	= 0,25	
CW50	= 0,45	

In calculating the Snyder Synthetic Unit Hydrograph after calibration, we can first calculate qpR from the peak of Collins = 1.59 m^2/s/mm = 0.024 m^2/s.km2.cm, with the Coefficient of Time (Ct) and Coefficient of Peak (Cp) calculated by equations, namely 0.59 and 0.09, respectively, tp = 46.47 hours, qp = 0.038 m^3/s.km2.cm, tr = 1.19 hours, tpR = 10.5 hours, tp = 6.55 hours, tb = 233.93 hours, W75% = 14.19 hours, and W50% = 25.54 hours [4].

To make a graph of the Snyder Synthetic Unit Hydrograph, it is necessary to make several points 0, a, b, peak, c, d, and Tb.

Table 6. HSS Snyder Calculation Results Before Calibration

No	*Time (h)*	qpR (m^3/s.mm)	*Descriptions*
1	0	0	*beginning*
2	2.58	0.795	50% *peak*
3	6.37	1.193	75% *peak*
4	11.10	1.590	*peak*
5	20.55	1.193	75% *peak*
6	28.12	0.795	50% *peak*
7	52	0	tb

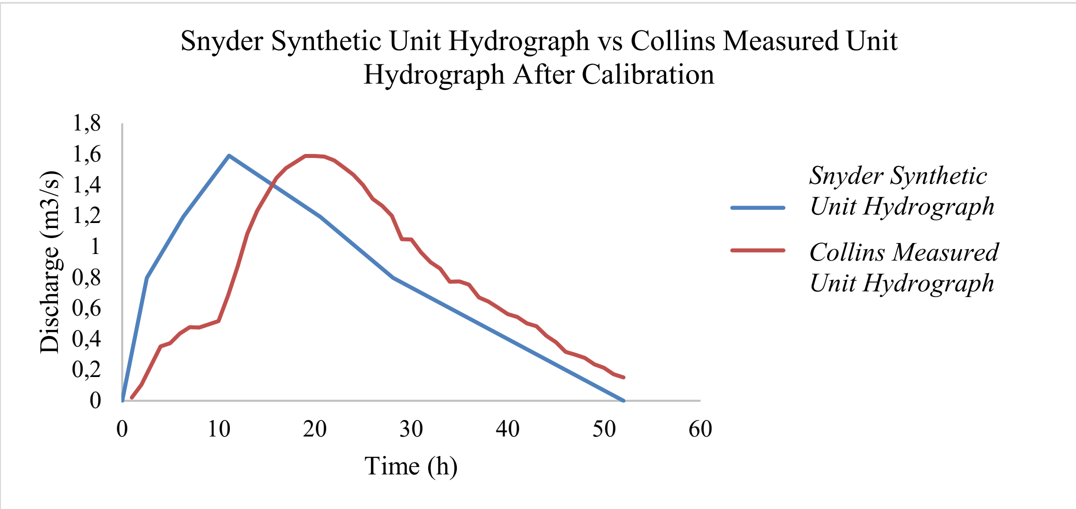

Figure 7. Coordinate Graph of Snyder Synthetic Unit Hydrograph vs Collins Measured Unit Hydrograph After Calibration

Based on the graphic image of the Snyder Synthetic Unit Hydrograph (HSS) before calibration, it can be seen that the hydrograph shape between the Collins Measured Unit Hydrograph and the Snyder Synthetic Unit Hydrograph has almost the same graphic shape. Peak Discharge (Qp) Snyder Unit Hydrograph in the 11th hour, 1 = 1.59 m^3/s.mm while the Collins Unit Hydrograph in the 19th hour = 1.589 m^2/s.mm. So based on this, the Snyder Unit Hydrograph with a Peak Coefficient (Cp) = 0.5, Time Coefficient (Ct) = 1.7 and shape coefficient (CW75 = 0.25 and CW50 = 0.45) is in accordance with the characteristics of the Cidurian Watershed [14].

3.7 *Commissioning at Different Times*

1. *Commissioning on November* 7 - 8, 2021

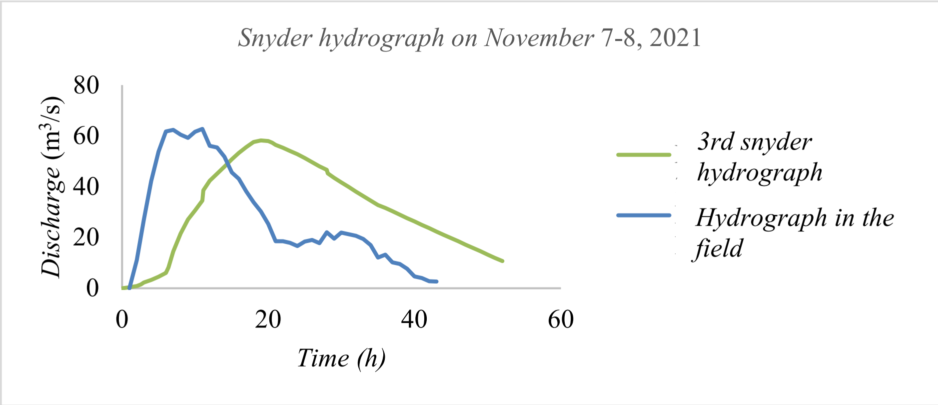

Figure 8. Snyder hydrograph on November 7-8, 2021

The graphical results of the commissioning on November 7 - 8, 2021 show that the Snyder Synthetic Unit Hydrograph Qp at the 11th hour = 62.8 m3/d and also the field hydrograph Qp at the 23rd hour = 58.23 m3d. With the graph of the Snyder Synthetic Unit Hydrograph on November 7 - 8, 2021 resembling the field hydrograph, it proves that the Peak Coefficient (Cp), Time Coefficient (Ct), and shape coefficient (CW75 and CW50) are accurate in the time span of November 7 - 8, 2021.

2. Commissioning on December 29 - 31, 2021

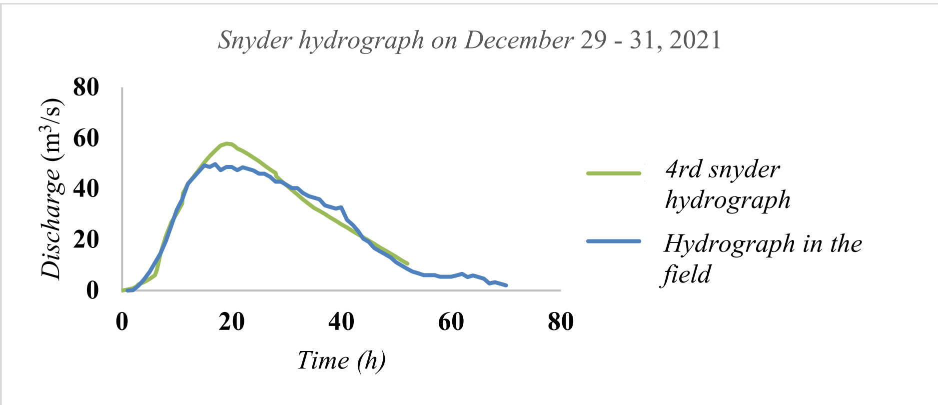

Figure 9. Snyder hydrograph on December 29 - 31, 2021

The graphical results of the commissioning on November 7 - 8, 2021 show that the Snyder Synthetic Unit Hydrograph Qp at the 11th hour = 62.8 m3/d and also the field hydrograph Qp at the 23rd hour = 58.23 m3d. With the graph of the Snyder Synthetic Unit Hydrograph on November 29 - 31, 2021 resembling the field hydrograph, it proves that the Peak Coefficient (Cp), Time Coefficient (Ct), and shape coefficient (CW75 and CW50) are accurate in the time span of November 29 - 31, 2021.

4. CONCLUSION

The conclusions that have been generated in the research entitled "Prediction of The Cidurian Watershed Coefficient With Snyder Synthetic Unit Hydrograf" are as follows :

1. The Peak Coefficient (Cp) and Time Coefficient (Ct) values of the Cidurian watershed that have been obtained from the analysis of the Synthetic Unit Hydrograph (HSS) of the Snyder method against the analysis of the Polynomial and Collins Measured Unit Hydrographs are Peak

Coefficient (Cp) = 0.59, Time Coefficient (Ct) = 0.09, and shape coefficients such as CW75 and CW50 respectively obtained results 0.25 and 0.45.

2. The shape of the calculation graph between the Polynomial and Collins Measured Unit Hydrograph against the Snyder Synthetic Unit Hydrograph (HSS) in the Cidurian watershed illustrates the comparison of the results of the calculation of the peak discharge of the Unit Hydrograph (HS) Collins Method and the Snyder Synthetic Unit Hydrograph (HSS). From the results of the calculation of peak discharge (Qp) Unit Hydrograph (HS) Collins Method at the 19th hour obtained Qp = 1.589 m^3/s, while for the Synthetic Unit Hydrograph (HSS) Snyder Method obtained peak discharge (Qp) at the 11th hour, 1 = 1.59 m^3/s.

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