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The Ant Colony Optimization Model to Determine the Parameters of Hydrograph Unit Snyder

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Abstarct: The relationship of rain flow is needed to get an accurate peak discharge and volume value. This value is require so that the analysis of hydrological problems produces an approach that is closer to reality in the watershed. Calibration and validation have been carried out in the form of statistical steps. The reliability of calibration with statistics in certain sections provides less accurate results. HSS snyder calculation uses the parameters Cp and Ct. These two parameters cannot be determined with certainty. Therefore, the parameters Cp and Ct need to be optimized to get a more reliable value. Calculation of the relationship of rain flow using the Snyder synthetic hydrograph method was chosen because it was able to be used if the watershed characteristics data were limited. Hydrograph calibration is commonly used with standard deviation statistics between the two data. Ant colony optimization was performed so that the calculation results are even better so that it gives a true picture of the hydrological phenomenon in an area. Field data calibration with the optimization of the Snyder hydrograph provides better R and SD values than the HSS Snyder without optimization. The optimization result of the Snyder hydrograph is Q p = 0.44 . A / t p .

Keywords: *ant colony, optimization, hydrograph unit.*

I. INTRODUCTION

River flow discharge information will provide more useful results if presented in the form of hydrograph. However, only few watersheds have discharge+ measurement data, only rivers whose watersheds have been developed provide sufficient discharge measurement data. Therefore, a synthetic unit of hydrograph based on the physical characteristics of a watershed was developed. Information data for each watershed is not necessarily complete; because the availability of measuring devices is not evenly distributed. There are so many methods used to analyze flood hydrographs. The method is useful for calculating flood discharge, both for detailed design of dam components such as spillway, diversion tunnel, flood embankment and other water building component designs.

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In its application, it is important to choose the most appropriate methods to be used in the analysis to result in the analysis which is closer to the truth in the field. Therefore, it is necessary to conduct a study of these methods. Only few rivers have discharge measurement data that can be used as a basis for deriving hydrographic unit, only rivers whose watersheds have been developed have sufficient discharge measurement data. Therefore, a derivation of hydrograph synthetic unit is developed based on the physical characteristics of a watershed. The hydrograph synthetic unit model has been widely developed by experts, including the Snyder Synthetic Unit Hydrograph (HSS) developed based on the characteristics of watersheds in the Appalachian highlands of the United States by FF Snyder in 1938. The Snyder HSS model is not necessarily suitable when applied to a watershed in Indonesia. Because there are differences in characteristics, conditions, and rainfall patterns between watersheds in Indonesia and the regions where this model was developed. The Snyder HSS model has two non-physical parameters: Ct and Cp which are the coefficients that depend on the unit and characteristics of the watershed (Wilson, 1993). Snyder obtained a number of Ct and Cp values from a number of watersheds in the Appalachian highlands of the United States. The coefficients Ct and Cp should be determined empirically, because of the changes from region to another. Therefore, there are difficulties in using the method, especially in rivers in Indonesia. The Snyder HSS model must be adapted to the specific character and local conditions (Siswoyo, 2004).

ACO (Ant colony optimization) has been receiving a lot of attention in water resources and environmental planning lately. Various versions of ACO have proven to be flexible and strong in solving a number of problems that are spatially and temporarily complex. The research seeks to promote the opportunities, advantages and disadvantages of the algorithm as applied to various areas of the problem of water resources. It also intends to identify and present the main contributions of the ant colony algorithm in an organized manner from reservoir operations and surface water management, water distribution systems, urban drainage and sewer systems, groundwater management, environment and watershed management. Current trends and challenges in the ACO algorithm are discussed to get better results. The ant algorithm is proposed and applied to solve various problems in water resources and environmental management [1]. Determination of design floods can provide more useful results if presented in the form of a flood hydrograph.

Much information can be given from the results of the conversion of rain into the runoff hydrograph. Decreasing unit hydrograph from observational flood hydrograph is one method that is considered accurate.

However, the obstacle that is often encountered is the difficulty of obtaining observational flood hydrograph data. Only few rivers have discharge measurement data that can be used as a basis for deriving hydrograph unit, only rivers whose watersheds have been developed have sufficient discharge measurement data. Thus, a derivation of hydrograph synthetic unit based on the physical characteristics of a watershed has been developed.

The choice of the right optimization model will provide more accurate model calibration results making it easier to design flood analysis. Through the synthetic unit hydrograph model which has been optimized the hydrograph pattern will certainly help in the design of watershed management which has limited data. So that watershed management planning can be approached from the hydrological aspect with a synthetic unit hydrograph theory approach.

II. SNYDER METHOD

One of the methods was developed by FF Snyder from the United States in 1938 which utilized riparian zone parameters to obtain synthetic unit hydrographs. A number of watersheds studied by Snyder is located at the Appalachian plateau with a watershed area ranging from 30 to 30,000 km 2 (Chow, et al, 1988). Snyder developed a model with empirical coefficients connecting elements of unit hydrograph with watershed characteristics. It is based on the premise that transforms rain into a flow both on the translational effect and its storage can be explained and influenced by its watershed system. The Snyder method uses four parameters: delay time, peak flow, base time and standard duration of effective rain. The procedures of flood discharge calculation in HSS Snyder plan is regulated in Indonesian National Standard (SNI 2415: 2016).

Determination of peak discharge can be performed by empirical formula or by unit hydrograph. The form of runoff hydrograph is in the form of an increase in runoff to the peak and a decrease until the base flow returns. There are several equations to determine the peak discharge: the rational method, SCS, Nakayasu, Snyder and Izzard. Each method has its own parameters according to when the method was made. Therefore, the parameters taken to calculate runoff in the new watershed must go through an approach based on the method.

This unit hydrograph is related to the physical geometry of the watershed with the following relationship (Triatmodjo 2013).

tp = Ct (L Lc)0,3. ....(2.1)

Qp = Cp A / tp ....(2.2)

T = 3 + tp/8 ....(2.3)

tD = tp/5,5 ....(2.4)

tpR = tp + 0,25 (tr – tD) ....(2.5)

QpR = Qp tp / tpR ....(2.6)

According to the results of the study of the Hoffmeister and Weism in 1977 that the Lc parameters by Snyder is used because the upstream part of a watershed is considered to have no effect on the peak discharge of a hydrograph. Regarding the element of peak discharge, research conducted by Morgan and Johnson in 1962 states that the Snyder equation provides the smallest peak discharge compared to other means such as US SCS, Nakayasu and Gama I. The use of the Snyder method is restricted to the Appalachian highlands of the United States. The use of this method for other areas requires corrections and adjustments (Sri Harto, 1985).

Snyder only created a model to calculate peak discharge and the time required to reach the peak of a hydrograph. Therefore, to obtain the hydrograph curve, it requires time to calculate its parameters.

Ct and Cp are coefficients that depend on the unit and characteristics of the watershed. The coefficients Ct and Cp must be determined empirically, because the amount varies from region to another. In the metric system, the Ct value ranges between 0.75 to 3.00. In addition, Cp value ranges between 0.90 to 1.40 (Soemarto, 1995).

The value of Ct and Cp were obtained by Snyder for a number of watersheds in the highlands of the Appalachian, United States, where if the value Cp is close to its greatest value then the value of Ct will be close to the smallest value, and vice versa (Wilson 1993).

Ct and Cp coefficients should be determined empirically, because their values vary from region to another. These elements are as follows: the drainage area, the length of the main flow, the distance between the center of the drainage area and the outlet area measured along the main flow. The Ct coefficient usually ranges from 1.8 to 2.2, Ct also varies from 0.4 in the mountainous regions to 8.0 along the Gulf of Mexico. Ct coefficient of 1.4 for mountains and Ct 1.7 for the downstream area. In addition, Cp values range from 0.4 to 0.8, where bigger Cp values are associated with smaller Ct values.

Table-I: Table Various Cp and Ct values

No	Ct	Cp	information	Source
1	1.4 - 1.7	0.15 - 0.19	Small CT value for upstream area Big CT value for downstream area	Triatmodjo, 2013
2	0.75 - 3.0	0.9 - 1.4	Small Cp value for downstream area Big CP value for upstream area	Soemarto, 1995
3	0.4 - 8.0	0.4 - 0.8		Score from Mexico Bay

III. HOW THE ANT ALGORITHM WORKS

The ants are able to make their optimal path in their complex environment to find food and then return to their nests by leaving pheromone substance on the paths they pass.

Pheromone is a chemical derived from the endocrine glands and is used by living things to recognize same-sex, other individuals, groups, and to assist the reproductive process. Unlike hormones, pheromone spread outside the body can affect and be recognized by other similar individuals (one species). This pheromone's secretion process is known as stigmergy, a process of modifying the environment that not only aims to remember the way back to the nest, but also allows the ants to communicate with their colonies. Over time, however, the pheromone trail will evaporate and reduce the strength of its attraction. The longer an ant travels through the path, the longer the pheromone evaporates. In order for ants to get the optimal path, several processes are needed:

- At first, the ants randomly walk around, until they find food.
- When they found food they returned to the colony while giving pheromone signs.
- If other ants find the path, they will not travel randomly anymore, but will follow the trail.
- Go back and strengthen it if they find food in the end.
- An ant who accidentally finds the optimal path can travel this path faster than his peers travel, make round-trips more often, and naturally leave more pheromones than the paths that are slower to travel.
- High concentration of pheromone can eventually attract other ants to change lanes, towards the most optimal path, while the other paths are abandoned.
- Eventually, all ants that used different paths can switch to a single path that turns out to be the most optimal from the nest to the food place.

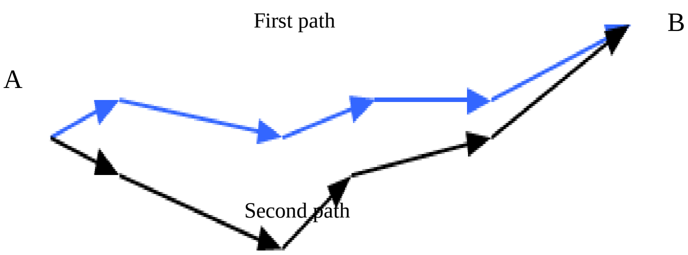


Fig. 1. Ant Initial Path

Where,
A: The starting point of the colony (nest)
B: The purpose of the ant colony (food)
Line 1 (blue): The path taken by 1st ant
Path 2 (black): The path taken by 2nd ant

IV. RESEARCH METHODOLOGY

A. Research Area

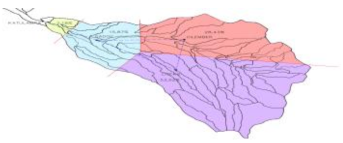


Fig. 2. Research Area

B. Research Data

Research data are the data used to analyze problems in the atershed. The research data are as follows:

- Daily rainfall data for 2008 from Gadog Station, Cilember and Citeko.
- Daily rainfall data for 2009 from Gadog Station, Cilember and Citeko.

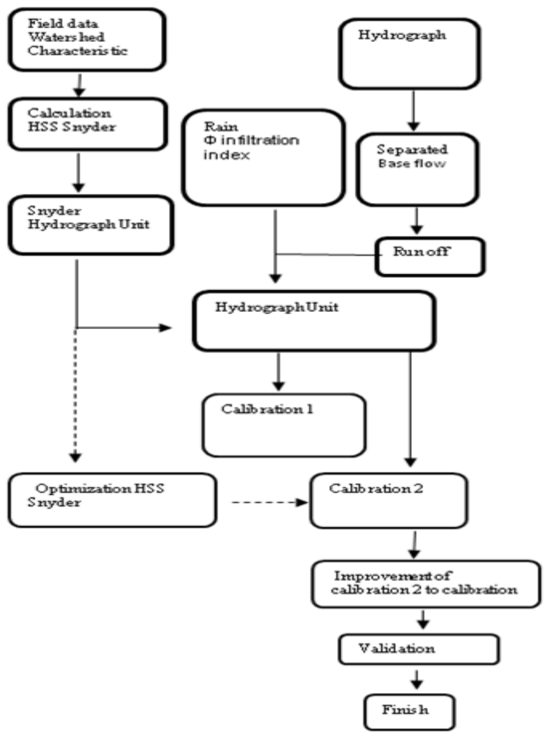
The shape of the Katulampa watershed is elongated with a river in the middle. The characteristics of the Watershed's data are in the form of its physical parameters of the land surface, presented on the table below.

Table-II: Physical Parameters DAS Katulampa

No	Parameter	information
1	Large (km2)	149, 26
2	Topography (%)	9, 00
3	River Gradient (%)	7.00
4	High above sea level (dpl)	500, 00
5	Length of the river (km)	21.80
6	Length of the central river (km)	10, 00
7	Wide of the watershed (km)	5 , 00
8	The length river to the center (km)	12 , 00

Source: Katulampa watersheed , 2005

The research area has certain characteristics. The area is a water catchment area, with varied land uses. Land use in the area includes residential land, rice fields, plantations, forests and other public facilities.



C. Snyder's Hydrograph Unit

The synthetic unit of hydrograph is obtained by entering watershed's parameter data into the Snyder formula. These parameters include:

- Ct which is the slope coefficient of watershed ranges between 1.4 and 1.7. Katulampa watershed is a watershed in the upstream or mountainous regions; Therefore, the Ct value is 1.4.
- Cp which is the characteristic coefficient of watershed or storage coefficient.

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If the watershed has more storage, the value of Cp is smaller. Katulampa watershed is a watershed with a lot of storage then the Cp value was taken at 0.19.

- Katulampa watershed area is 149,2 km2 with the main river length = 21.8 km.

- Calculation with the Snyder method is as follows

$t_p \;= C_t\,(L\,L_c)^{0,3}$

$= 1,4\,(21,8 \times 12)^{0,3}$

$= 7,5$ hours

$Q_p \;= C_p\,A / t_p$

$= 0,19 \times 149,20 / 7,50$

$= 3,7\ m^3$/seconds

$T \;= 3 + t_p/8$

$= 3$ days $+ 7,50/8$

$= 72,9$ hours

$t_D \;= tp/5,5$

$= 7,50/5,5$

$= 1,36$ hours

$t_{pR} \;= t_p + 0,25\,(t_r - t_D)$

$= 7,50 + 0,25\,(2-1,36)$

$= 7,66$ hours

$Q_{pR} \;= Q_p\ t_p / t_{pR}$

$= 3,83 \times 7,50/7,66$

$= 3,8\ m^3$/seconds

D. Optimization of the Snyder's Hydrograph Unit

PHP programs produce this following display, which consists of input and results data. The steps start from data input to fund processing. The order is as follows:

- The characteristics of a watershed are the watershed area (A, km 2), river length (L, km) and length watershed's center of gravity (Lc, km).

A = 149.2 km 2
L = 21 km
Lc = 12 km

- Snyder formula parameters are Ct (slope parameters of the watershed) and Cp (storage parameters, characteristics of the watershed)

Ct = 1.4 (upstream area), using the lowest number
Cp = 0.19 (large reservoir, upstream area), using the highest number

- To create a hydrograph unit, regional rainfall data and direct measurement discharges are required. Direct measurement discharge is reduced by its basic flow so that it becomes a hydrograph unit (can be seen in appendix 1)
- Calibration step

- Snyder hydrograph units are calibrated with field hydrograph units to obtain the calibration values with standard deviations

- The Snyder hydrograph unit is optimized, then the Snyder optimization hydrograph is calibrated with its field hydrograph.

Display of the program is as follows:

- User interface

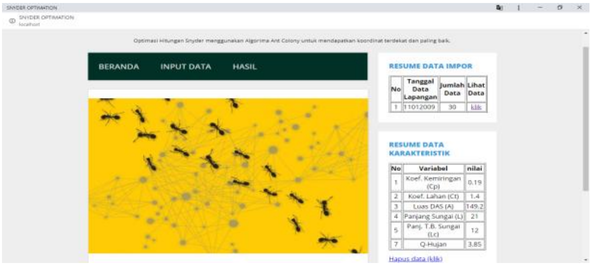

Fig. 3. The user interface and The Data

- The results of data input

SNYDER OPTIMATION
localhost/Snyder-ant-colony/data.php?data=11012009
localhost

Kembali

No	jam ke -	Q (m3/s)	Air Tanah (m3/s)	QLimp
1	1	0	0	0
2	2	0	0	0
3	3	0	0	0
4	4	0	0	0
5	5	0.10941368782378	0	0.10941368782378
6	6	8.0456	0	8.0456
7	7	6.4653	0	6.4653
8	8	5.23245	0	5.23245
9	9	4.3456	0	4.3456
10	10	3.789	0	3.789
11	11	3.0567	0	3.0567
12	12	2.5785	0	2.5785
13	13	1.5716843927815	0	1.5716843927815
14	14	1.2549619762168	0	1.2549619762168
15	15	1.0490971137143	0	1.0490971137143
16	16	0.85161919311334	0	0.85161919311334
17	17	0.66243746032881	0	0.66243746032881
18	18	0.56293499506405	0	0.56293499506405
19	19	0.46547150965613	0	0.46547150965613
20	20	0.44948412374185	0	0.44948412374185
21	21	0.35404761311467	0	0.35404761311467
22	22	0.26062591180221	0	0.26062591180221
23	23	0.24463852588793	0	0.24463852588793
24	24	0.15321930268167	0	0.15321930268167
25	25	0.063790054987872	0	0.063790054987872

Fig. 4. The Display of the Debit Data

The selected results of hydrograph optimization

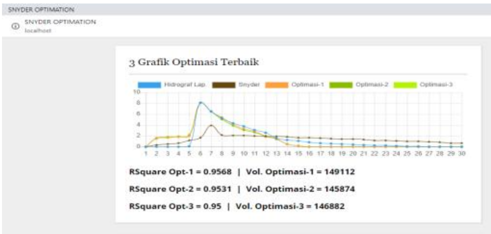

Fig.5. Display of the Graph of Optimization Results

d. Selected graph equation

persaman $y = 1.2\,x + (-1.68)$

Ubah kedalam

$Q_p = 1.2\,t_p + (-1.68)$

$8.05 = 1.2\,t_p + (-1.68)$

$1.2\,t_p = 8.05 + (1.68)$

$t_p = 8.1346077260056$

$t_p = Ct\,(L.Lc)^{0.3}$

$8.1346077260056 = Ct\,(21 \times 12)^{0.3}$

$8.1346077260056 = Ct\,(252)^{0.3}$

$8.1346077260056 = Ct\,(5.2531543578991)$

$C_t = 8.1346077260056 / 5.2531543578991$

$C_t = 1.5485186940631$

Fig.6. Display Ct Optimization Results

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E. Cp and Ct parameter values

The selected calculation shows that the standard deviation has changed after optimization, which is getting smaller. The smaller standard deviation value leads to the better optimization results. Based on the data, the regional watershed values are as follows:

- Ct = 1.55
- Cp = 0.44

$Q p = C p A / t p$

So : $Q p = 0.44 A / t p$

F. Validation of Optimization Results

The results of the calculation after validation are as follows:

$t_p = Ct\ (L.Lc)^{0.3}$

$8.1346077260056 = Ct\ (21.8 \times 12)^{0.3}$

$8.1346077260056 = Ct\ (261.6)^{0.3}$

$8.1346077260056 = Ct\ (5.3124067750725)$

$C_t = 8.1346077260056 / 5.3124067750725$

$C_t = 1.5312471485007$

$Q_p = C_p \times A / t_p$

$8.05 = C_p \times 149.2 / 8.1346077260056$

$8.05 = C_p \times 18.341388426515$

$C_p = 8.05 / 18.341388426515$

$C_p = 0.43889807100767$

Fig.7. The Display of Cp and Ct after validation

V. RESULTS AND DISCUSSION

A. Snyder Hydrograph Unit and its Optimization

The Snyder method is severely limited by unclearly defined values of Cp and Ct. Therefore, the calculation is very influenced by the experience in taking data.

The Snyder' equation is Q = Cp.A / tp , the determination of the values of Ct and Cp requires the experience of various watershed calculations. Of course, if there are no clear parameters, it will be difficult for policy makers in calculating the actual discharge.

The incorrect Ct and Cp values greatly affects the results. The Cp and Ct values which are too general makes it difficult to calculate the peak discharge and base time. The inaccuracy in determining the peak discharge and base time certainly makes the Snyder hydrograph pattern even farther away from the field hydrograph.

The Snyder hydrograph pattern depends on the characteristics of the rain in the form of rainfall intensity and the length of rain. Rain with longer duration makes the runoff time longer. Snyder discharge with a rainfall intensity of 1 mm, valued at 3.85 m 3 / second / mm. The peak time is around 7 hours. While, the basic time is above 72 hours.

The Snyder hydrograph pattern is different from the field hydrograph pattern which can certainly lead to subsequent analysis errors. These errors can pose a risk to humanity and the infrastructure that has been built which can ultimately lead to economic waste and broader disasters.

The use of optimization in making Snyder charts can help provide results that are more accurate. Therefore, it approaches the field hydrograph. This is evident from the results of the smaller standard deviation, between before and after optimization.

The use of ant colony optimization in searching for the hydrograph pattern on the Snyder's hydrograph has major function in providing fish calculation data accurately so that it is close to the field data. The pattern is not the shortest route, but the best pattern, similar to the actual field hydrograph pattern. Pattern selection is performed automatically if the calibration approaches the correlation value 1, the parameter is then selected. The uses of the Snyder equation in its original place and in the Katulampa watershed are as follows:

- The characteristics of the watershed in Katulampa are similar to the American Appalachian plateau which are the plateau and upstream area.
- The area of the watershed of Snyder in America ranging from 30 to 30,000 km2 is similar to the area of Snyder in Katulampa of 149.2 km 2 .
- The characteristics of land use in the Katulampa area are also similar which are mostly forest.
- The characteristics of the selected rainfall data, at that time, the day before, there was no rain so that the process of infiltration and storage went well (C p = 0.19, large storage). So that it is able to accommodate rainwater in sufficient quantities

The Snyder equation is still suitable for certain areas in Indonesia in the form of upstream and land use, which is mostly still forest or open land (not settlement).

The shortcomings of the ant colony optimization are that it cannot certainly be directed towards the required pattern, because the optimization sometimes find the shortest distance. The shortest distance is not necessarily the best hydrograph pattern.

B. Cp and Ct parameters

The Cp and Ct parameter values are in the form of optimized Snyder hydrograph. Cp and Ct parameter changes occur; the data can be displayed as follows:

Table-III: Comparison of Cp and Ct parameter values

No	Parameter	Snyder	Snyder Optimization
1	Cp	.19	0.44
2	Ct	1,4	1.55

Discussion of the small Cp value indicates that vast water reservoirs thereby reducing peak runoff discharge. Therefore, the greater value of Cp leads to the smaller reservoir in the watershed. The increase in Cp from 0.19 to 0.44 is certainly based on the Katulampa watershed. There has been a drastic change in land use due to rapid settlement growth. The increase in settlement can certainly reduce the number of reservoirs. Therefore, the Cp parameter values can increase.

Ct is the value of the gradient parameters of the land and the river. The more inclined slope of the watershed leads to the smaller the value of Ct. Katulampa watershed is located between upstream and middle stream, it makes the value of Ct not in the lower limit but rather slightly increased. Ct value = 1.55 with a little greater than 1.4 indicates that the Katulampa watershed is closer to the Upper than the middle of the watershed.The selection of Cp and Ct is performed if you have obtained the appropriate hydrograph pattern from the optimization process.

The pattern is searched automatically and will stop when the calibration is close to 1. The selection will be made if the standard deviation of the Snyder's optimization is smaller than the Snyder.

C. Data Validation

Synder equation as the result of the optimization can be implemented to the Katulampa watershed or watersheds that have similar characteristics with the Katulampa watershed. From the equation Q p = 0.44 A / t p is then it is validated with rain and field discharge data from other data. The data used for calibration is 2009 data, while the validation data is with 2008 data. By entering the value of Cp = 0.44 and Ct 1.55 into rain data at other time, it turns out that the calibration does not change. Therefore, the results of Cp and Ct remain the same. Then, it can be concluded that the value of equation as the result of the optimization can already be applied to the Katulampa watershed to determine the discharge calculation.

VI. CONCLUSIONS

Conclusions

The research on optimizing Snyder's synthetic hydrograph with the heuristic method can be conclude as follows:

- The calibration of Snyer's Hydrograph unit provides less accurate results with the standard deviation of 2.9.
- Ant colony optimization can find a solution to a better approach to the calculation of the hydrograph using the Snyder model. Being able to produce an approach with a smaller standard deviation = 1.00. It can be conclued that the optimization of the Snyder's hydrograph unit provides better results.
- The results of the Snyder's equation optimization with a calibration value of 0.95 gives the following discharge equation Q p = 0.44 . A / t p.

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