SCIREA Journal of Hydraulic Engineering

http://www.scirea.org/journal/Hydraulic

June 27, 2020

Volume 3, Issue 1, February 2020

HYDROLOGICAL STRUCTURING OF THE BASIN WHERE THE ROCAFUERTE CANTON IS SEATED, WITH ASSESSMENT VIEWS TO ITS WATER RESOURCES, ECUADOR

Mendoza Cedeno Jorge Jhonny[1], Campos Cedeno Antonio Fermin[1], Mendoza Alava Junior Orlando[2]

[1]Faculty of Mathematical, Physical and Chemical Sciences, Universidad Tecnica de Manabi, Portoviejo, Ecuador

[2]Peoples' Friendship University of Russia, RUDN-University, Moscow, Russia

ABSTRACT

The Rocafuerte canton, founded in the year 1852, is a town in the province of Manabí in the central west of its territory. Its main economic activity is carried out in the fields of agriculture, livestock and artisanal production of sweets, which are very well received at the National and international.

One of the main problems in the area that affects the area's normal is the water deficit during the low water periods, which average terms present between the months of June to November of each year.

The present work contains an assessment of the water resource that is generated in the basin where the Rocafuerte canton is located and that constitutes basic information for the control, optimization of works and projects aimed at the management and use of said resource.

For the analysis, statistical and probabilistic methods were used in the management of the monthly rainfall records provided by the National Institute of Meteorology and Hydrology of Ecuador (INAMHI), among which the following stand out: data filling using the orthogonal correlation method, analysis of consistency and variability, estimation of multi-year average precipitation, application of the US Soil Conservation Service (SCS) method to calculate runoff and the multi-year monthly average distribution of precipitation.

The meteorological stations, which cover the study area, were 4, namely: Rocafuerte station (M165), Portoviejo (M005), Rio Chico (M454), Junín (M462).

Keywords: Hydrology, monthly rainfall, assessment of runoff , SCS method , Portoviejo basin

INTRODUCTION

Territorially, the Republic of Ecuador is divided into 24 provinces of which 7 belong to the coastal region and among them is the so-called province of Manabí, which has an extension of approximately 19 thousand km2, which constitutes approximately 6.64% of the entire national territory. In turn, the province of Manabí is made up of 22 cantons.

Of all the provinces in the country, the most deficient in terms of water resources is the province of Manabí, because the watershed divides as a barrier that prevents access to surface water from the melting of the Cordillera de los Andes. This situation has led to the identification and implementation of projects aimed at storing water in the rainy season for its later use in times of drought. One of the projects that has been running since the 1970s is the so-called Chone - Portoviejo integrated project, which addresses the water needs for both irrigation and human consumption in the central area of the province of Manabí.

This research whose main objective is to assess the precipitation and runoff of the basin in which the Rocafuerte parish is located constitutes a contribution to the solution of the problem of the existing water deficit in the area. The tributary rivers to this basin, which the Water Secretariat has coded as the hydrological unit "15142", have as tributaries the El Guanábano, La Papaya and Ojo de Agua estuaries that have their mouth in the Bachillero River and this to its instead it converges with the Portoviejo river near the Pacific Ocean.

This work is proposed as an input to the institutions in charge of national development so that they implement works in order to control and optimize existing water resources.

MATERIALS AND METHODS

The most relevant methodological aspects in this work include: 1) Selection of meteorological stations [1, 2], 2) Collection of monthly rainfall records, 3) Analysis of data consistency[3], 4) Filling of missing data in the series[3], 5) Analysis of variability[4], 6) Estimation of the multi-annual average precipitation 7) Assessment of the volume of water by precipitation, 8) Estimate of the precipitation of the basin[5] ,9) Estimate of runoff in the basin, 10) Monthly distribution of average precipitation.

The basic information carried out for the analysis and development of the research is made up of the monthly rainfall records recorded at the Rocafuerte (M165), Portoviejo (M005), Rio Chico (M454), Junín (M462) meteorological stations. Said information was provided by the National Institute of Meteorology and Hydrology (INAMHI). The total of records per station, corresponding to the monthly precipitation for the analysis period 1963 - 2017, was 660, which led to a total for the 4 stations of 2640 records.

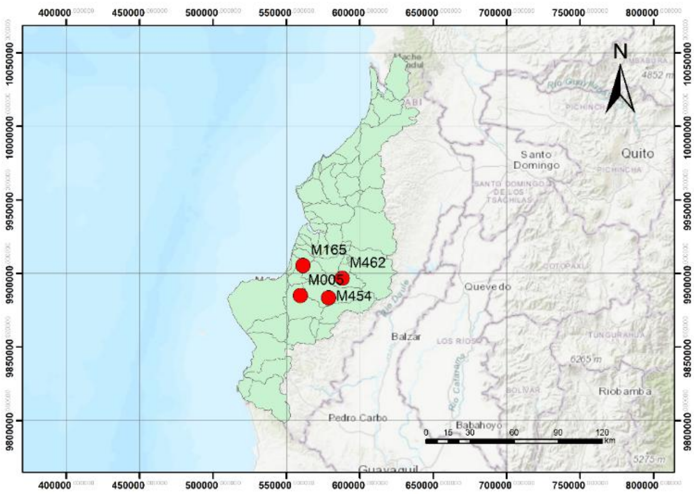

Figure 1. Location of the meteorological stations of the study

The meteorological stations of the study are located in the limits of the hydrological unit of the Manabí River Basin District, coded with the Pfafstetter code "15142"[6, 7]. In Table 1 and

Figure 1, with UTM coordinates WGS84, located in the 17S quadrant, the geographical location of the considered stations is presented.

Table 1. Geographical location of meteorological stations

Station	Code	UTM WGS84 coordinates	
		East	North
Portoviejo-UTM	M005	559523.22	9884982.17
Rocafuerte	M165	561349.93	9905400.22
Rio Chico en Alajuela	M454	578715.81	9883443.13
Junín	M462	588083.86	9896705.80

Prior to the development of the investigation, the records were chosen, analyzed for consistency and variability. Thiessen polygons were used to choose the stations[8]. For the consistency analysis, the mass curves were prepared. Variability analysis was supported by calculating the coefficient of variation with the formula[9]:

$$C_v = \frac{\sigma}{\bar{x}} \qquad (1)$$

Where:

C_v - Coefficient of variation,

σ Standard deviation,

$\bar{x}$- Arithmetic average.

It has been established that if the coefficient of variation is less than 0.30, the uniform series is considered [4]

The multi-year average rainfall of the basin is determined with the following expression:

$$P_{mma} = \frac{\sum_{i=1}^{n} P_i A_i}{\sum_{i=1}^{n} A_i} \qquad (2)$$

Where:

P_{mma} - Multi-year average rainfall of the basin, [mm],

P_i Multi-year average rainfall of each micro-basin, [mm],

A_i Area of each micro basin, [km2],

n Number of micro-basins

The volume of water, as a result of total precipitation, is obtained as the product of the multi-year average precipitation of the basin for its respective area.

Runoff was estimated using the rainfall-runoff hydrological model proposed by the US Soil Conservation Service (SCS) [10, 11], today called the Natural Resources Conservation Service (NRCS). method requires the application of the following formulas:

$$Qe = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{3}$$

Where:

Qe - Effective runoff, [mm]

P - Total rainfall, [mm]

S - Maximum potential difference between P and Q [mm]

$$S = \frac{25400}{CN} \tag{4}$$

Where:

CN - Number of curve, depending on the type of soil, uses and vegetation cover[8].

Due to the fact that the study area is located in the equatorial zone, the available climate is tropical, where there are basically two climatic periods in the year, commonly known as rainy and dry. The rainy period generally begins in December and ends in June, while the dry season predominates in the remaining months (July - November). This situation contributes to the existence of an irregular and disproportionate distribution of rainfall throughout the months of the year. In order to have an overview of the mean behavior of multi-year monthly rainfall, the arithmetic means of each month were determined for the weighted data series.

RESULTS AND DISCUSSION

The meteorological stations chosen for the hydrological analysis are those that correspond to the Thiessen polygons in which the study area is framed. These stations are Rocafuerte

(M165), Portoviejo (M005), Rio Chico in Alajuela (M454) and Junín (M462). The total area of the basin studied amounts to 146.74 km2. This area is made up of 4 parts, of which the majority belongs to the Rocafuerte station with an area of 119.12 km2.

For the selected stations, the monthly precipitation records for the period 1963 - 2017 were obtained from the National Institute of Meteorology and Hydrology (INAMHI). For each station, records were found in the order of 600.

Prior to filling in the missing data, which was done using the orthogonal correlation method[12], the respective consistency analysis was carried out, through which the existence of the correlation of the chosen records was determined. This task was performed by drawing the mass curves[13].

For the variability analysis, the records of each station were subjected to the coefficient of variation calculation, obtaining the values of: 0.62, 0.65, 0.49 and 0.54 for the stations of Portoviejo, Rocafuerte, Rio Chico and Junín, respectively. The fact of having obtained coefficient of variation values greater than 0.30, indicates a non-uniform distribution of the records.

The multi-year average rainfall of the basin was obtained equal to 556.55 mm. Table 2 shows the partial results by micro-basins.

Table 2. Multi-year average rainfall of the basin

Stations	Code	Area [km2]	Rainfall [mm]	P*A
Portoviejo-UTM	M005	0.13	527.79	70.14
Rocafuerte	M165	119.12	454.58	54149.14
Rio Chico en Alajuela	M454	7.72	862.76	6660.48
Junín	M462	19.77	1051.59	20789.88
∑		146.74		81669.64
		Pmma=	556.55	mm

Considering that the total area of the basin is equal to 146.74 km2 and that the multi-year average precipitation has been estimated at 556.55 mm, the multi-year average volume produced by rainfall has been valued at 81.67 hm3.

Based on the soil and vegetation cover maps of Ecuador developed by the Ministry of Agriculture and Livestock (MAG), the Inter-American Institute for Cooperation on Agriculture (IICA) and the Center for Integrated Surveys of Natural Resources by Remote Sensors (CLIRSEN) the map of the curve numbers for the Ecuadorian territory was obtained, a fundamental input for the estimation of runoff in accordance with the US methodology. Soil Conservation Service[8]. The annual runoff layer determined by the SCS method has been estimated at 2631.09 mm. On the other hand, the value of the average curve number, in accordance with the map prepared for the area, turned out to be equal to 81, with which it was obtained that the annual runoff of the basin is in the order of 72.11 hm3, which constitutes 87.8% of the total precipitate.

Table 3 summarizes the partial and total results of runoff from the basin where the canton Rocafuerte is located

Table 3. Basin runoff

Station	Code	Rainfall [mm]	Area [km2]	CN	S	Qe [mm]	Vesc [hm3]
Portoviejo-UTM	M005	527.79	0.13	81.00	59.58	462.46	0.06
Rocafuerte	M165	454.58	119.12	81.00	59.58	390.15	46.47
Rio Chico en Alajuela	M454	862.76	7.72	81.00	59.58	795.16	6.14
Junín	M462	1051.59	19.77	81.00	59.58	983.32	19.44
∑						2631.09	72.11

For each of the stations, the multi-year percentage was determined with respect to the average total, and then, with the help of the respective areas, weighted values were established for the basin in general. Table 4 contains the calculated partial percentages

Table 4. Monthly percentage distribution of precipitation by micro-basins

Code	Area [km2]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
		[Percentage with respect to the total]											
M005	0.13	17.95	25.31	25.07	13.68	6.04	3.25	1.39	0.52	0.68	0.58	1.17	4.36
M165	119.12	17.79	28.69	23.59	13.38	6.15	2.29	1.26	0.74	0.61	0.48	1.05	3.98
M454	7.72	16.65	25.14	22.50	16.32	7.11	3.16	1.25	0.82	0.85	1.01	1.17	4.03
M462	19.77	17.65	26.32	23.79	15.98	5.93	2.00	1.43	0.69	0.38	0.65	1.01	4.16
Weighted Values		17.71	28.18	23.57	13.89	6.17	2.29	1.28	0.74	0.59	0.53	1.05	4.00

From Table 4, based on the weighted values, it follows that the highest concentration of precipitation occurs in the month of February with a percentage equivalent to 28.18%, while the most deficient value of the water resource occurred in the month of October with a value of 0.53%. The analysis also shows that there is a great disproportion in the distribution of precipitation by climatic periods, since 93.52% of the annual total is concentrated in the rainy season (December to June). And the rest, in the dry season (July to November) with a percentage equivalent to 6.48%.

Table 5 and Figure 2 indicate the general values obtained in the analysis of the monthly multi-year mean distribution of rainfall.

Table 5. Monthly distribution of multi-year average precipitation

Month	Rainfall		Season	Total rainfall	
	[%]	[mm]		[mm]	[%]
Dec	4.00	22.28	rainy	520.46	93.52
Jan	17.71	98.58			
Feb	28.18	156.82			
Mar	23.57	131.15			
Apr	13.89	77.30			
May	6.17	34.32			
Jun	2.29	12.77	dry	36.09	6.48
Jul	1.28	7.12			
Aug	0.74	4.11			
Sep	0.59	3.30			
Oct	0.53	2.95			
Nov	1.05	5.84			
∑	100.00	556.55		556.55	100.00

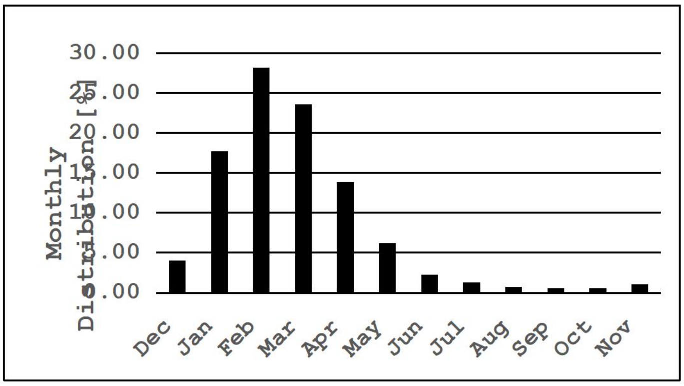

Figure 2. Monthly distribution of mean precipitation

CONCLUSIONS

The surface runoff that occurs in the basin of the hydrological unit "15142" has been estimated to amount to 72.11 hm3 per year, which was obtained by subtracting from the total precipitation the value corresponding to the infiltration according to the type of soil , vegetation cover and use of the territory of the area.

The multi-year average total precipitation obtained from the analysis of the monthly rainfall records for the period 1963 -2017 was estimated at 81.67hm3.

In general terms, it was established that there is great variability in the monthly distribution of rainfall, reaching its maximum value in February and its minimum value in October, corresponding to the values of 28.18 and 0.53%, respectively.

For both the rainy and dry periods, the accumulation rate of precipitation was determined, reaching the conclusion that 93.52% accumulates in the rainy season (December-June), while for the dry season, which occurs between From July to November, the contribution fell considerably to levels estimated at 6.48%.

The population of the Rocafuerte canton estimated in the last population census of 2010, carried out by the National Institute of Statistics and Censuses of Ecuador (INEC) [14], amounted to 33736 inhabitants with a growth rate equivalent to 1.1 %. With the help of these data, a future population was estimated until 2050, and a future population of 52,256 inhabitants was projected for this horizon. On the other hand, taking into consideration the incorporation of 1,500 ha into irrigation, in accordance with the public information released and assigning an average irrigation standard, equivalent to 1.77 l/s/ha, in general, the annual volumes of water were estimated. that are required to cover these vital needs for human consumption and irrigation. The figure reached for this concept amounts to 27.53 hm3.

Confronting the water supply obtained (72.11 hm3) with the demand (27.53 hm3), it is concluded that the annual water resources produced in the "15142" basin turn out to be sufficient for the productive development of the area, and the respective works must be projected and constructed. regulation and storage that allow water to be stored during the rainy period and then used during the dry season.

Acknowledgements

To SENAGUA, INAMHI and IGM of Ecuador for the basic information provided and that served as the main input for the development of the present research.

List of Symbols

Cv	Variation coefficient
σ	Standard deviation
$\bar{x}$	Arithmetic average
Pmma	Multi-year average rainfall
Qe	Effective runoff
P	Total rainfall
S	Maximum potential difference between P and Q
CN	Curve number

REFERENCES

[1] Secretaría de Gestión de Riesgos. Anuarios Meteorológicos. 2014 [cited Secretaría de Gestión de Riesgos 19.11.2014]; Available from: http://186.42.174.231/index.php/clima/anuarios-meteorologicos.

[2] Instituto Nacional de Hidrología y Meteorología, Anuarios Meteorológicos. Vol. 2015. 2015.

[3] Chereque Morán Wendor, Hidrología para estudiantes de ingeniería civil, Wendor Chereque Morán, Editor. 1989: Lima. p. 236.

[4] Valinova, V.S. Coeficiente de variación y coeficiente de determinación. 2016 [cited 2016 15.05.2016]; Available from: http://univer-nn.ru/statistika/koefficient-variacii/.

[5] Chow, V.T., Applied Hydrology, ed. Ven Te Chow. 1988, Urbana-Champaign: University of Illinois.

[6] Pfafstetter, O., Classificação de bacias hidrográficas – Metodologia de codificação. 1989, Departamento Nacional de Obras de Saneamento (DNOS): Rio de Janeiro, RJ. p. 175.

[7] Mello, C.R.d., et al., Abstração inicial da precipitação em microbacia hidrográfica com escoamento efêmero %J Revista Brasileira de Engenharia Agrícola e Ambiental. 2003. 7: p. 494-500.

[8] Campos A.F. and Sinichenko E.K., Características de Sistemas Fluviales Pequeños y Recursos Hídricos de la Demarcación Hidrográfica de Manabí, Perspectivas de Desarrollo. 2017, Moscú: Universidad de la Amistad de los Pueblos de Rusia.

[9] Zheleznikov, G.V., T.A. Negovskaya, and E.E. Ovcharov, Hidrología, Hidrometría y Regulación de la Escorrentía. 1984, Editorial KOLOS: Moscú.

[10] Department of Agriculture United States. USDA Natural Resources Conservation Service Soils. 2015 [cited 2015 03.03]; Available from: http://www.nrcs.usda.gov/.

[11] Campos, A.F., E.K. Sinichenko, and I.I. Gritsuk, Hidráulica e Hidrología para Ingeniería. 2016, Universidad de la Amistad de los Pueblos de Rusia: Moscú. p. 167-174.

[12] Martínez Arnáiz, Orthogonal Regression and Principal Components. Qüestiió, 1994(18(2)): p. 12.
[13] Monsalve Sáenz, G., Hidrología en la ingeniería. 1995: Editoral de la Escuela Colombiana de Ingeniería.
[14] Gobierno del Ecuador. Ecuador en cifras 2020 [cited 2020 19.04.2020]; Available from: https://www.ecuadorencifras.gob.ec/institucional/home/.