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METHODICAL APPROACH FOR THE ESTIMATE OF FLOW WADIS FROM THE NORTH OF ALGERIA

M. Ladjel[1], M. Madani[1], M. Mokhailovna[2], O. Adjissi[3], O. Mimeche[1]

[1]L. R. H. A. E. Université de Bejaia, Algeria

[2]Odessa National Academy of Food Technologies, Department of ecology and Environnmental Technologies

[3]L. R. H. A. E. University Mira A., Bejaia. University Mohamed Boudiaf- Msila, Algeria

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ABSTRACT

The problem of estimating the flow of wadis is of actuality, given the complexity of its genesis, especially on small and medium watersheds. At the level of large basins, river flow, like precipitation and evaporation, is climatic. Local peculiarities, such as pedological, botanical, hydrogeological and morphometric, have a great influence on the flow formation. This makes it possible to differentiate the total flow into two climatic and local components. The spatial variation of the climatic flow follows faithfully that of precipitation and evaporation. Then, it is a question of analyzing and identifying the influence of local factors, indirectly related to the climate, on the local flow, within the framework of horizontal and vertical zonality. The objective of this research is to determine the main factors that affect the local component of the flow and the settlement between it and these factors. This methodical approach allows the estimation of the flow of ungauged watersheds.

Key words: Watershed, Rainfall, Runoff, ETR, Climate.

Author Correspondence, e-mail: ladjel_mahmoud@yahoo.fr

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1. PROBLEM STATE

The rational management of water resources is based on the identification of the main hydrological feature, which is the interannual medium flow (IMF). In the design calculations of several hydrotechnical structures, the value of IMF has an important place, especially in semi-arid climatic conditions, especially for ungauged watersheds. Among the first approaches to estimating the flow of rivers, in the climatic conditions of Southern Europe, where the amplitude of variation of the precipitations P_o was not so wide, we quote those of hydrologists of the time Penk A. and Keller H. [7,22], they proposed formulas in the form of linear relations $E_o = \alpha_o(P_o - P_{\min})$. Later, for large watersheds, Schreiber P. and Oldekop E. M. proposed formulas that take into account main climatic parameters, such as precipitation P_o and actual evapotranspiration ETR_o, or $E_o = f(P_o, ETR_o)$ [21,24]. Other hydrologists have tried to establish the relationship between the flow coefficient and the moisture deficit of the air $\alpha_o(d)$.

The eminent Ukrainian hydrologist, Befani A. N. has genetically formulated the expression of river flow, which takes into account the specific factors of the watershed, considering the subterranean component and the superficial component of the flow.

The underground component of the flow is generated by infiltrated precipitation water. Its value is closely related to the area of the watershed. From this point of view, small rivers do not receive underground supply. And it is only from a given area that the river begins to receive a given underground supply [1-3].

The interannual medium flow (IMF) assessed by the hydro-thermal balance equation $E_o = P_o - ETR_o$, as a function of heat and moisture resource ratios, reflects only the influence of climatic factors, excluding the influence of the underlying factors of area.

For the physico-geographical conditions of Ukraine, Loboda N. S. noticed the inequality of the two types of flow : real E_o and climatic $E_{c\lim}$ and proposed a coefficient of conversion $k = \frac{E_o}{E_{c\lim}}$ of the climatic flow $E_{c\lim}$ in real flow E_o. This coefficient can be less than one and greater than one. Loboda N. S. proposes the following expressions for this coefficient [16]:

- for the lowland landscape, the coefficient depends on the area of the watershed S:

$$k = 1 - \varphi(S) \text{.................................... for } S < S_{cr}$$

$$k = 1 \text{... for } S \geq S_{cr}$$

- for the mountainous landscape, the coefficient depends on the average altitude of the catchment H:

$$k = 1 - \varphi(H) \text{..................................... for } H < H_{cr}$$

$$k = 1 \text{... for } H \geq H_{cr}$$

At present time, the formulas applied do not take into account the factors generating the flow. Their application gives inaccurate results. The issue of estimating IMF is timely and questionable, especially in the new context of inevitable climate change [9-15].

In northern Algeria, liquid rains are the major part of rainfall. They vary greatly over time, during the seasons and in space from North to South [10,22]. The largest quantities fall during the winter season. They are maximum on the littoral and on the high mountains. In general, wadi flow imitates rainfall in a non-linear fashion (Figure 1).

When the amount of rain is minimal, it evaporates entirely. The gradual increase of the rains increases the humidity of the air, from where a part turns into flow. But when the amount of rainfall is high, the air is sufficiently humid, evaporation reaches a stable level corresponding to a climatic value [6,25] and the dependence between flow E_o and rain P_o becomes quasi-linear.

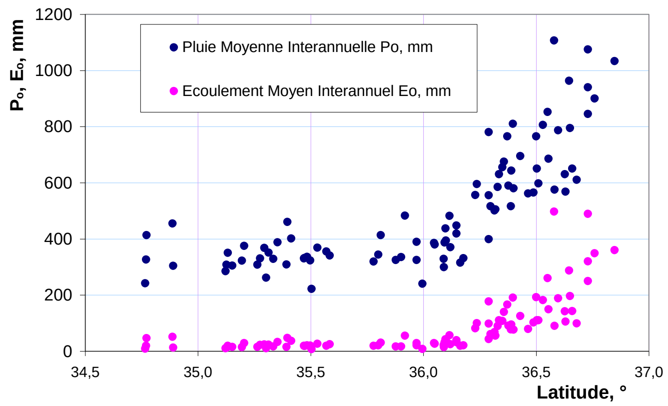

Fig.1. Increased climate flow $E_{c\lim}$ and flow local E_{loc} according to the latitude

In the watersheds of northern Algeria, this dependence $E_o = f(P_o)$ is characterized by a strong correlation $r = 0.98$ (Figure 2), with such a large dispersion of points, which prevents the direct use of this dependence, for the estimation of the interannual medium flow (IMF) of ungauged watersheds.

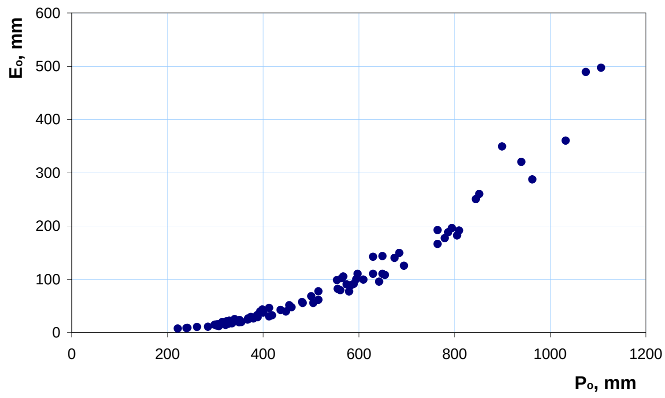

Fig.2. Dependence between E_o and P_o

This dispersion is due to the influence of local factors, at the level of each watershed. The influence of these factors is more important in small and medium watersheds. On the other hand, in large watersheds, it becomes insignificant [15].

2. COLLECTION AND ANALYSIS OF HYDRO-CLIMATIC DATA

The hydrological and climatic data, used in the present research, are collected from the documents of the National Hydric Resources Agency (ANRH) of Algeria and also in other documents. These data belong to 94 watersheds in northern Algeria, ranging in size from 16 km^2 to 4060 km^2. These data are: interannual average flow, medium interannual rainfall, ETP, watershed area, wadi length, average basin elevation and wadi slope. We notice that the average values of climatic and hydrological variables are not always estimated for the same period, including synchronized climate cycles. Often, this data includes many gaps. This has an influence on their homogeneity and on the estimate of the value of averages [10,13].

3. CLIMATE FLOW AND LOCAL FLOW

Considering a region, which receives a constant amount of rain, where the hydrogeological conditions are homogeneous. In small watersheds the amount of rainfall P_o is decomposed into superficial flow $E_{\sup}$, seepage $\inf$ and actual evapotranspiration ETR_o. In average watersheds, the amount of rainfall P_o is broken down into shallow flows $E_{\sup}$, subsurface flow E_{st}, infiltration $\inf$, and sedimentation ETR_o. So, in large watersheds, the amount of rainfall P_o breaks down into river flow (climate) $E_o = E_{\sup} + E_{st}$ and actual evapotranspiration ETR_o (Figure 3).

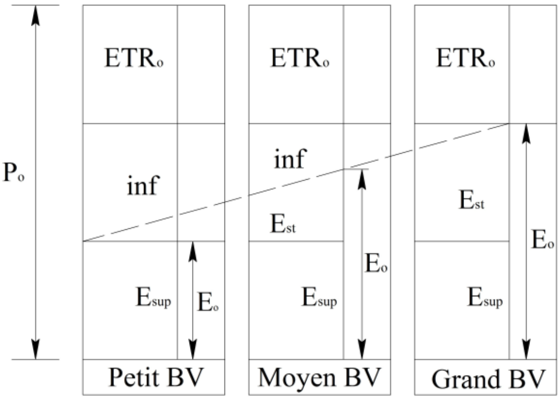

Fig.3. Explanatory diagram of the main elements of the water budget for different sizes of watershed

Thus, one can express the equations of the interannual medium flow (IMF), for different sizes of watersheds:

a- small watershed,

we have $P_o = E_{\sup} + \inf + ETR_o$, with $E_o = E_{\sup}$.

b- medium sized catchment area,

we have $P_o = E_{\sup} + k\,E_{st} + (1-k)\inf + ETR_o$, with $E_o = E_{\sup} + k\,E_{st}$.

c- large watershed, we have $P_o = E_{\sup} + E_{st} + ETR_o$, with $E_o = E_{\sup} + E_{st}$.

For the climatic conditions of Algeria, the average real inter-annual evapoperspiration can be estimated from one of the formulas known in the applied calculations in climatology [4,5,16,17,20,23,24]. We preferred the formula of Odekop, for its simplicity, it is written [20]:

$$ETR_o = ETP\,th\left(P_o / ETP\right) \qquad (1)$$

P_o - average inter-annual rainfall, in mm.

ETR_o - average annual inter-annual evapo- perspiration, in mm.

ETP - average annual inter-annual potential evapo- perspiration, in mm.

4. EQUATION OF THE WATER BUDGET FOR THE DIFFERENT WATERSHEDS

The best expression of the quantitative equilibrium of the hydroclimatic elements is given by the equation of the hydrological balance of a watershed [1,3,11,15,18]. For a large watershed, the water balance equation is written as follows $P_o = E_o + ETR_o$, where the overall river flow is equal to the climatic flow, hence this equation takes shape $P_o = E_{c\lim} + ETR_o$. That is, the amount (value) of rainfall is entirely spent on climatic flow $E_{c\lim}$ and evapotranspiration ETR_o.

The climatic flow $E_{c\lim}$ represents a potential limit, which can generate a quantity of rain P_o in the absence of infiltration loss [15]. The equation of the water balance, for a medium watershed is thus written $P_o = E_o + ETR_o + \inf$, with $E_o < E_{c\lim}$ and some of which rains infiltrate into the subsoil and is added to the losses of the precipitated waters. or small basins, the water balance equation is written $P_o = E_o + ETR_o + \inf$. Rain P_o is turned into flow E_o, evapo- perspiration ETR_o, and seepage $\inf$. In this case, the value E_o represents the superficial part of the flow ($E_{\sup}$), directly during the fall of the rain and the losses of the rainwater $ETR_o + \inf$ reach the maximum value. In semi-arid areas, on the very small basins, small amounts of rain P_o are entirely spent to cover the ETR_o and a small part of the infiltrations [1,7].

5. ANALYSIS OF THE DIFFERENT COMPONENTS OF RIVER FLOW

In general, the flow of wadis E_o is composed of the climatic flow $E_{c\lim}$, conditioned by the main climatic factors, which are rain and evapo-perspiration and a complement of flow, called local flow E_{loc}, determined by the local generating factors. In general, the flow of wadis E_o is composed of climatic flow $E_{c\lim}$ and local flow E_{loc}. The first component depends solely on climatic elements: rain and ETR_o. It is specific to large watersheds, whose drainage capacity is almost complete. In the mentioned conditions, the observations show that the climatic flow $E_{c\lim}$ is always greater than the local flow E_{loc}. As the watershed area increases, it increases its ability to drain groundwater. Hence the value of the total river flow approaches the value of the climatic flow $E_o = E_{c\lim}$. Local flow E_{loc} is related to features, which depend on local factors and terrain characteristics, such as altitude, slope exposure, soil type, and vegetation type. These factors directly affect the quantities of rainfall generating runoff and the losses of rainwater [9-15].

However, increased rainfall P_o with latitude Y causes an increase in the climatic flow $E_{c\lim}$ rate faster than local flow E_{loc} (Figure 4).

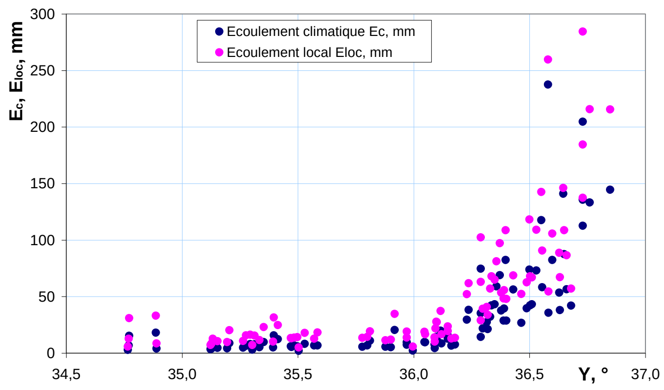

Fig.4. Dependence of the climatic flow $E_{c\lim}$ and local flow E_{loc} with latitude Y

It should be noted that mean rain amounts are subject to spatial reduction, which leads to a reduction in both stream components also with increasing watershed area (Figure 5).

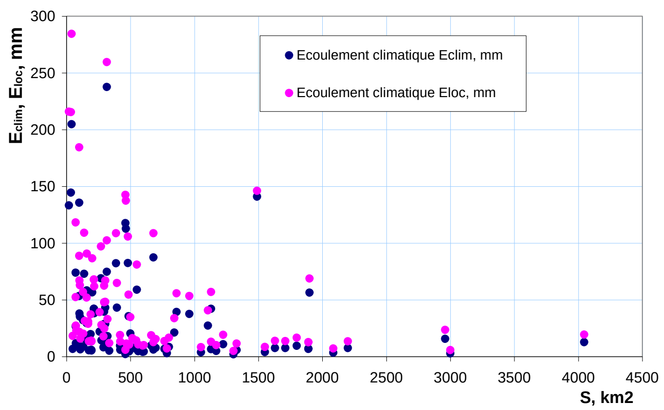

Fig.5. Dependence of climate flow $E_{c\lim}$ and local flow E_{loc} with the area of watersheds

If the climatic flow $E_{c\lim}$ of a watershed is, quite simply, equal to the difference between the rain P_o and the actual evapotranspiration ETR_o, ie $E_{c\lim} = P_o - ETR_o$. So, it remains to determine the local component of the flow E_{loc}. Therefore, it is a question of identifying the main factors that condition the local flow E_{loc}.

Since the two components of the flow are generated by the rains, they increase simultaneously and proportionately. This is checked graphically (figure 6). There is a significant dependence between local flow E_{loc} and climatic flow $E_{c\lim}$.

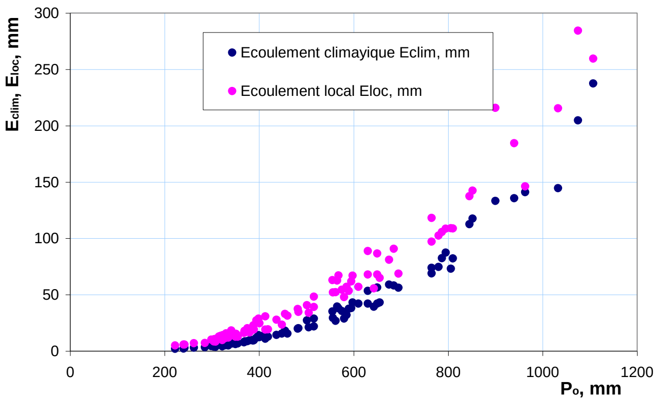

Fig.6. Dependence between the climatic flow $E_{c\lim}$, local flow E_{loc} and average rainfall P_o

The dependence between local flow E_{loc} and climatic flow $E_{c\lim}$ is written as follows $E_{loc} = k\,E_{c\lim}$. At the present stage, we are limited to analyzing the identification of the proportionality coefficient k. For northern Algeria, the factors influencing the formation of fluvial flow are subject to latitudinal and altitudinal climatic zonality. By graphical analysis of the dependencies respectively : $k(ETR_o)$, $k(E_{c\lim})$ and $k(H_o)$, we checked their existence.

The graphical analysis showed the existence of a strong dependence between the coefficient k and the real evapotranspiration ETR_o, which is expressed by the relation $k = const \quad ETR_o^{-1/2}$, deduced from the linear regression (figure 7).

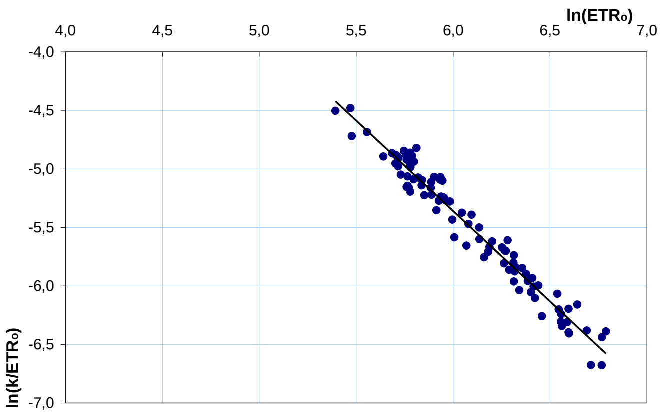

Fig.7. Dependence between the coefficient k and ETR_o

The graphical analysis also showed the existence of a significant dependence between the coefficient k and the climatic flow $E_{c\lim}$, which is expressed by the relation $k = const \quad E_{c\lim}^{-1/5}$, deduced from the linear regression (figure 8).

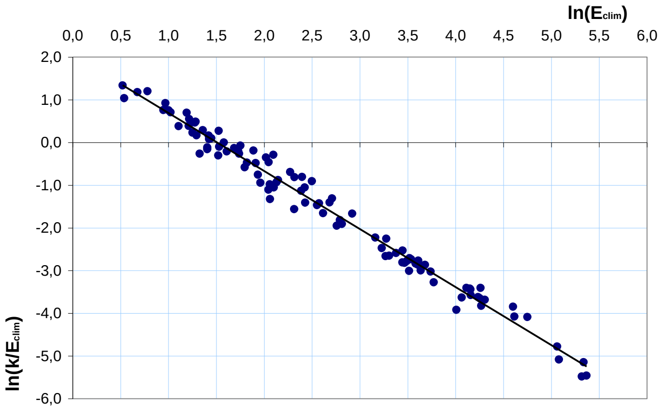

Fig.8. Dependence between the coefficient k and $E_{c\lim}$.

In the same way, we obtain the dependence between the coefficient k and the average altitude of the catchment H_o, in the form of a binomial $k = const\ \ H_o^{1/5}$, deduced from the linear regression (figure 9).

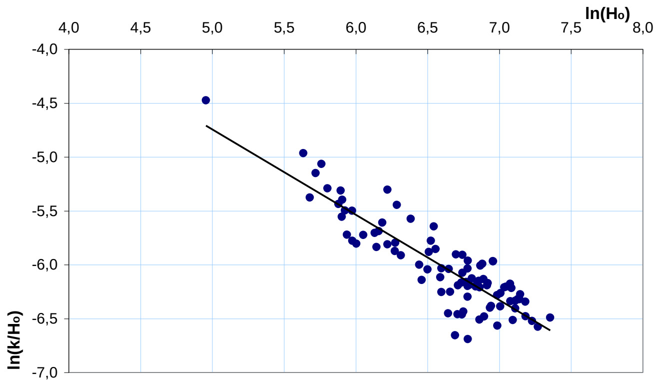

Fig.9. Dependence between coefficient k and mean altitude H_o

Thus, this analysis allowed to express the relation between the coefficient k and the three factors: $k(ETR_o, E_{c\lim}, H_o)$, in the form:

$$k = C_k \frac{1}{\sqrt{ETR_o}} \sqrt[5]{\frac{H_o}{E_{c\lim}}} \qquad (2)$$

or :

ETR_o - average annual inter-annual evapotranspiration, in mm.

H_o - average altitude of the catchment, in m.

$E_{c\,lim}$ - climatic flow, in mm.

C_k - specific climatic coefficient.

The specific climatic coefficient C_k is called this because it reflects the integral influence of the complex of factors, indirectly related to the climate and which are not directly measurable. The graph below (Figure 10) clearly shows the latitudinal climatic dependence of C_k [14,15].

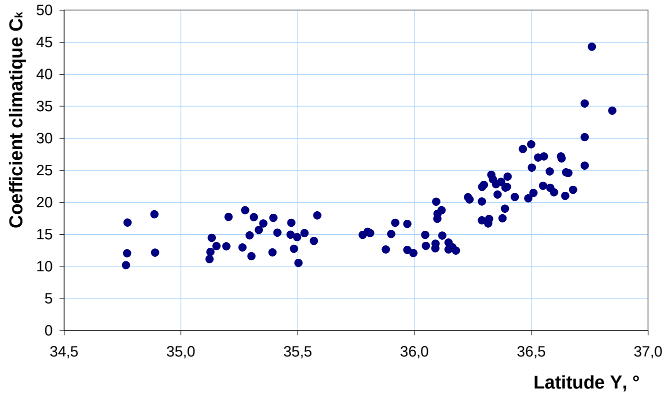

Fig.10. Dependency between C_k and latitude Y

Since the coefficient C_k is subject to latitudinal climatic zonality, it can be mapped as continuous contours (Figure 11). This draft coefficient map C_k shows the trend of increasing local flow from West to East and from South to North.

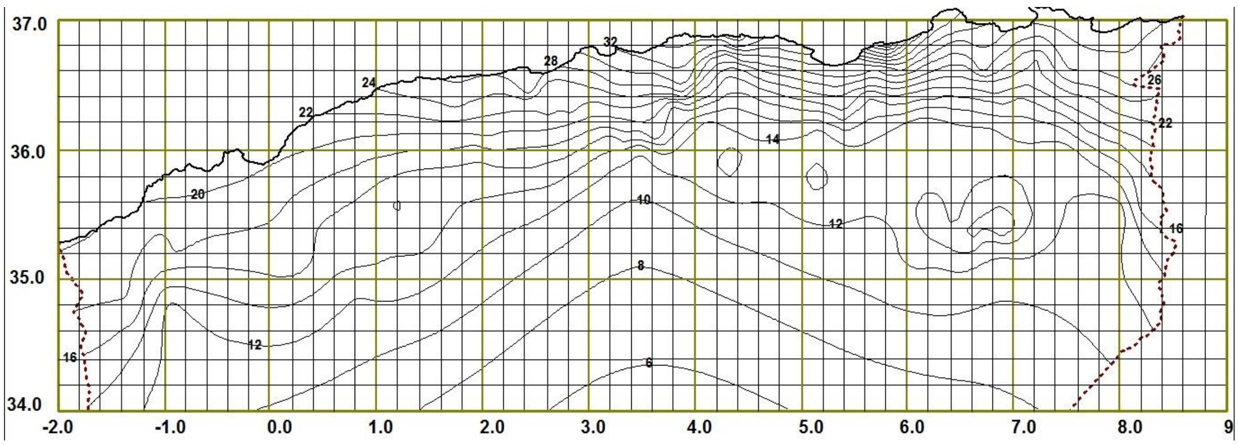

Fig.11. Projet de carte du coefficient C_k

The realization of such a draft map of the coefficient C_k requires support for the analysis of hydrological data, especially in small and medium watersheds. Because some hydrological data (flows) are in contradiction with the dynamics the rainfall data, in the same watershed.

On the other hand, we empirically established the following relation:

$$k = \frac{5.8}{S^{0.1} E_{c\lim}{}^{0.2}} \quad \text{.............................}(3)$$

The average relative error of the coefficient k is of the order of 0.44%. And the average relative error for the estimation of inter-annual mean fluvial flow E_o is of the order of 0.28%.

6. DIGITAL APPLICATION

We want to estimate the average interannual flow of wadi Bousselam to Fertmatou. The necessary data are: average catchment altitude H_o = 1205 m, mean interannual rainfall P_o = 470 mm, ETP= 1224 mm.

1- The actual evapotranspiration is calculated by the Oldékop formula, ETR_o = 448 mm.

2- The climatic flow $E_{c\lim} = P_o - ETR_o$ = 22.0 mm is calculated.

3- The value of the climatic coefficient C_k = 17.5 is taken from the map for the hydrological center.

4- We calculate the value of the coefficient k, by the formula (2), which is equal to 1.84.

5- The value of the local flow $E_{loc} = k\,E_{c\lim}$ = 40.2 mm is calculated.

6- The medium interannual flow is $E_o = E_{c\lim} + E_{loc}$ = 21.8 + 40.2 = 62.0 mm

7- Relative error is of the order of 3.37 %.

7. CONCLUSION

We used ordinary observational data, which are available at hydrological and rainfall stations. The climatic component of the flow varies harmoniously in space. It depends mainly on the rain and the ETR_o. His estimate is no problem. On the other hand, the local component of the flow is very sensitive to the spatial variation of intro-zonal factors. But it is still influenced by rain as the climatic component. Graphoanalytical analysis has made it possible to highlight the relationship between local flow and climatic flow and to establish an empirical relationship with the dominant factors. The specific climatic coefficient C_k is continuously distributed in space, reflecting the continuous variation of rainfall in northern Algeria. A map project of the specific climatic coefficient C_k is realized. It will serve as a support to continue this research project. It can be applied for the estimation of local flow. The method can also be applied for a homogeneous climatic region, to meet an immediate need. he application of the method can be performed with ordinary hydro-climatic data.

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