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EVALUATION OF GOLA RIVER ANNUAL DISCHARGE
An Experience of Spring Fed Siwalik Mountain River

by

R.K. Pande*

ABSTRACT

The stream character as such and its discharge behavior are the gross results of a range of events and functions of nature. The word 'stream flow', as used in the present text, is referred to 'catchment yield'. This yield is obviously discharge, q, which has dimensions of volume, L^3, and time, T, expressed here onwards in cumec (one cubic metre per second) which will ultimately be converted into a single voluminous unit litre (1) and hence referred to as Q. As the Gola River is a spring fed river, its discharge behaviour is absolutely dependent on the sub-surface flow of Siwalik Ranges. It has been noticed that the sub-surface flow fluctuates according to the monsoonal and non-monsoonal precipitation intensity. Hence, an interesting seasonal rhythm is noticed in the monsoonal and non-monsoonal discharge with the changing values of stream magnitude and velocity.

INTRODUCTION

The entire watershed of the Gola River (GR) system in the upland lies in the Siwalik hills of U.P. Himalaya and stretches over about 578.35 sq km between the coordinates of 29°12′ to 29°28′ N: 79°24′ to 79°49′ E. The natural vegetation of the region is classified as temperate, though geology and soils rather than elevation and climate make it a complex whole. The forest cover in the basin is Chir 64.64 percent, Banoak 14.71 percent, Sal 5.76 percent and miscellaneous

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* Dr. R.K. Pande is Lecturer in Geography, at the Department of Geography, Kumaun University Campus, Almora 263 601, U.P., India.

species 14.89 percent. The central part of the basin is largely under the pine, while the northern and westernmost portions have *Quercus incana*. Agriculture is restricted to the valleys, while some patches of settlement may be observed in a scattered form away from the valley concentrations.

The climatic conditions are characterized by fog, dew, snow and frost during the retreating monsoon and cold seasons. The lower Gola Valley is very warm during the hot season when high temperatures are experienced up to the height of more than 1500 m above msl. Governed by the monsoonal rhythm, rainfall in the Gola Basin varies from an annual total of about 2500 mm in the nort-west to almost half of it in the north-east and south-west.

OBJECTIVE OF THE STUDY

The ridges which defined its extents stand as water-parting in all directions and its reference point (Pr) has been decided to be near Ranibagh whereafter the mainstream (K) enters the plains via Kathgodam. The importance of the Gola discharge (q) or its volume (Q) lies in its being the only exploitable source of water for porous and therefore dry Bhabar tract of Nainital District and the study as such has its importance multiplied by the execution of the 'Jamrani Dam Project'. Such evaluation as this is also important because the Gola Basin (GB) presents a typical and unique case of rotundity of drainage basin, that is that its basin shape (Sb) is nearly unity, as explained below:

$$Sb = Lb + Wb/2 \cdot d^{-1} \qquad \text{(I)}$$

$$Sb = 29.41045/27.13620 = 1.0838$$

Where : Lb = axial length of the basin, km;
Wb = average width of the basin, km;
d = diameter of the circle with the same area as the basin, km;
Sb = shape of the basin, dimensionless.

The objective of this paper is to obtain such 'q' value (discharge) of the basin at the reference point (Pr) whose reliability may be acceptable to the authorities so that it may be taken as dependable for the future planning or which should not prevasicate much from the arithmatic mean of the 'q' measured for a considerable span of time. Of course, the discharge value (q) of the basin at the Pr can be measured mathematically, but presently it is to be achieved empirically or rationally so that the methodology may be useful for those such basins as may be considered otherwise inaccessible, difficult or impossible for gauging etc.

METHODOLOGY AND ANALYSIS

In the absence of long term data, it is necessary to choose some workable figures and then to work out results from classical empirical formulae, from amongst such works as carried out by Strange, Barlow, Khosla and Lacey (Sally, 1968). Khosla's formula ($Ra = Pa - k\ Ta$) was selected to obtain the weighted average runoff, as it is based on the conception that losses from rainfall depend basically on mean atmospheric temperature for the period under consideration. This conception might be applied to the area without bothering for the geometry of the stream network. Substituting values of weighted average of precipitation ($Pa = 62.47$ inches), weighted average of atmospheric temperature ($Ta = 67.87°F$) and of a constant ($k = 0.5$) generally vary from 0.43 to 0.57 only (Sally, 1968), and weighted average runoff has been estimated ($Ra = 724.86$ mm). This calculated Ra value, however, does not seem to display a satisfactory show in that it spoke of that fraction of precipitation that might runoff but not of the actual value of discharge, q, which increases because of the imported water through channels.

Therefore, to justify the reliable value of discharge for the study basin, Justin's equation was selected ($C = 0.934\ S^{0.155}\ R^2/T$). After substituting the values of average absolute slope of the basin ($S = 0.6885$) with the annual precipitation (square) and mean annual temperature ratio, annual runoff depth ($C = 939.27$ mm) has been estimated.

This calculated value of annual runoff depth, however, could not be much satisfying, too, as along as certain factors exist. The equation seems to have failed to consider the values of annual precipitation and mean annual temperature to be substituted by those of the average of the annual precipitation and mean annual temperature for the Kumaun Siwaliks. Otherwise, the quotient of R^2/T would have increased following the fact that the actual annual precipitation value and actual mean annual temperature value for the Gola Basin should be relatively high and low respectively, and would have thus given a plus value to be added to the present annual runoff depth. Whereas, it appeares to have already exceeded the actual (expected) discharge value at the confluence of the Gola River and the Balia Stream by some one and a half times.

This, the precaricated values of weighted average runoff and annual runoff depth forced to enquire still through some other suitable equation. One popular and yet simple equation was $q = a_c v$ (Linsley *et al.*, 1979), where: a_c = cross sectional area; v = mean velocity and q = rate of discharge. This, of

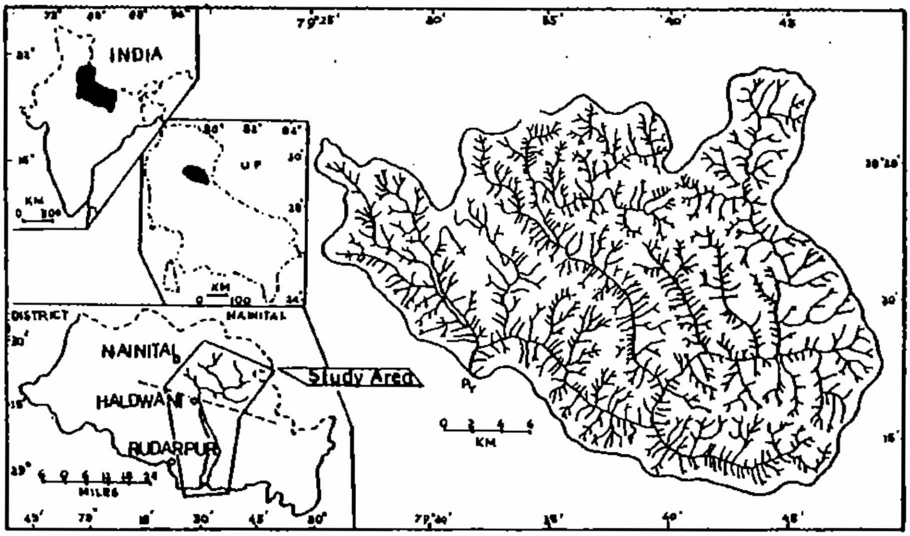

Figure 1. Gola Drainage Basin

course, requires the determination of cross sectional area and mean velocity values at the confluence point (Figure 1). These were accomplished by calculation based on certain measurements of hydraulic mean depth, $\bar{r}$, of the very first stream order magnitude, M, and then applying it to the highest magnitude, M_H, at the confluence point where the ultimate rate of discharge was to be estimated.

Measurements of the hydraulic radius, r, of the exactly twenty first order magnitude streams existing at the Kalsa's (a tributary of Gola River) segments on both the right and left side slopes around Malwa Tal, were taken, during the field work by the investigator, 10 times a week from September 1984 to August 1985. In fact, even each measurement of the hydraulic radius was the mean of three readings. The mean hydraulic depth of these first stream order magnitude, M_1, was 0.034 m which, henceforth, may also be designated as initial hydraulic radius. The total area of the basin is 525.291 sq.km. The highest stream order the first order magnitude is based on the simple fact that each successive inter- first order magnitude is based on the simple fact that each successive inter-bifurcation length gathers water from its sides just as the first order streams do. Hence, each inter-bifurcation length is the product of the total magnitude values supplied by its lower order streams plus one of its own. Therefore, the value of r of the Gola River at confluence point should be 3.3298854 m ($r_1 = r\sqrt{M_H}\,.\,\sqrt{2}$).

This derivation may need some explanation. It is very simple geometrical fact, much utilized in hydraulics, that the hydraulic radius, r, value of a high order channel, which has been supplied with water from its lower order channels, increases at the rate determined by the product of the square root of that higher order value multiplied by the initial r value.

For obtaining velocity value, the equation evolved by Hazen-William (Fair, *et al.*, 1971) was used;

$$\begin{aligned} v &= 1.318\ C\ r^{0.63}\ s^{0.54} \\ &= 1.318\ .\ 4.69\ .\ 10.924793^{0.63}\ .\ 0.0714^{0.54} \\ &= 6.716\ \text{fps}\ .\ 0.3048 \\ &= 2.047\ \text{mps} \end{aligned}$$

where:

C = a coefficient depending on the type and condition of the conduit, dimensionless;

r = hydraulic radius, ft;

s = slope of the hydraulic gradient, ft/ft, and

v = velocity of the flow, mps.

Hazen-William formula actually works appreciably for pressure conduits, hence the value of r_1, as calculated above, is the result of the transformation for pressure conduit, which has been accomplished by multiplying further the product of $\bar{r}\sqrt{M_H}$ (2.354607) by the square root of 2. This may be obtained just by multiplying directly the double value of the initial r by the square root of the M_H, and the product thus obtained being divided by the square root of 2, i.e., 3.3299 m.

Now, the cross-sectional area value ($a_c = \pi(r_1)^2/2$) of the main stream at the confluence point can be obtained easily by first following the simple geometrical relation which will be 17.105971 sq.m. Hence, the Gola River will discharge, at the confluence point, at the rate of 35.016 cum.

To assess the seasonal rhythm in the discharge volume, attempts have been made. Taking the period of monsoon as effective days, as three months of 30 days each, the discharge volume during monsoon is estimated to be $277.238\ .\ 10^6$ cum. Similarly, for non-monsoonal period, for which the value of q, as per following the same procedure as for monsoon, will be $71.28\ .\ 10^6$ cum.

As such, since the total discharge volume of the Gola River, at the confluence point, is the sum of the monsoonal and non-monsoonal discharge, which can be conveniently expressed now as;

$$\begin{aligned} Q_a &= \Sigma Q_{mon} + \Sigma Q_{nom} \\ &= (277.238\ .\ 10^6) + (71.28\ .\ 10^6) \\ &= 348.518\ .\ 10^6\ \text{cum}. \\ &= 348.518\ .\ 10^9\ \text{lit}. \end{aligned}$$

CONCLUSION

On tempering with reality, i.e., the measured average q (q_m) value for the Gola for monsoonal (q_{mon}) (mid June to mid September) period, the basin's calculated q_{mon} (35 cumecs) was less by some 3 percent, hence about 97 percent correct. Even this deviation appeares following difference of about 2.5 km between the gauge for measuring and the Pr for calculating the q. Such high degree of accuracy in the rationally derived result of the Gola's water discharge provided as high degree of reliability of dependence for calculating discharge volume for the non-monsoonal period, too. By what ratio the q_{mon} dropped to become q_{nom} was known from the ratio of M_H for mon, (M_{mon}) to M_H for nom (M_{nom}), hence the ratio of magnitude for mon and nom (RM_{mn}), as the q_{mon} was the product of a_c and v where both were derived from r_1 and from factors including r_1 respectively when r_1 was the product of the r of the M_1 and M_H at the Pr. It was also found that the RM_{mn} (0.078) was significantly correlated with the ratio of q_{mon} to q_{nom} (Rq_{mn}) (0.083).

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