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Study of Drainage Pattern Through Aerial Data in Naugarh Area of Varanasi District, U.P.

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ABSTRACT

Drainage pattern of Naugarh Block of district Varanasi has been mapped. The basin characteristics have been analysed in terms of basin morphology and related parameters. The drainage system of the region is composed of 3 perennial rivers with 7 sub-basins. A total of 1223 streams of 1st to 6th order exist, out of which 761 are of 1st order and 350 of 2nd order which hold sufficient amount of water during the peak monsoon period. Surface water resources could be enhanced in the region by constructing check dams and creating artificial recharge through effective planning and management.

Introduction

The surface drainage pattern characteristics of various basins and sub-basins have been studied using conventional methods in earlier studies (Horton, 1945; Strahler, 1969; Srivastava, 1997). Such studies lack time effectiveness of data for a large drainage network over a whole river basin. Remote Sensing data in the form of aerial photos and satellite images provide a unique data set for studying the drainage pattern, drainage density etc. The information about drainage characteristics is essential for the determination of linear and aerial aspects of the drainage. Therefore, using aerial photographs, the drainage map of drought affected Block Naugarh, Distt. Varanasi, U.P. has been prepared. Quantitative evaluation of morphometric parameters as outlined by Strahler (1969) and Horton (1945) has been undertaken.

Location of the Area

Geographically the block Naugarh covering an area of 806 km^2 lies between latitudes 24°42'30' to 25°01' E and longitudes 82°57' to 83°20' N falling in Survey of India toposheet Nos. 63O/4, 63P/1, 63P/2, 63P/5 and 63P/6 on 1:50,000 scale. Major portion of the area lies in the interfluve of the Chandraprabha and Karamnasha river.

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General Geology, Geomorphology & Physiography

The area forms a part of Vindhyan range comprising rocks of Protereozoic age. The Kaimur group of rocks exposed are represented by horizontal low dipping quartzitic sandstone. The area is well represented by denudational structural hills, pediment glacis, burried pediment and valley fill deposits. Topographically the area is irregular with eroded rocky hills. The height varies from 196 to 376 M above mean sea level (M.S.L.). The area enjoys subtropical type of climate with a long dry hot summer. The average annual rainfall is about 1220 mm.

Data Used and Methodology

Panchromatic aerial photographs of the year 1975-76 on 1:60,000 scale were used for mapping of drainage pattern of the area. Base map of the area on 1:50,000 scale was prepared using Survey of India toposheets. Standard photointerpretation technique was adopted for identifying and mapping drainage pattern.

The entire study area has been divided into 3 major basins i.e. Karmnasha, Chandraprabha and Garai which has further been subdivided into 7 sub-basins namely K-1, K-2, K-3, K-4 (under Karmnasha), C-1, C-2 (under Chandra Prabha) and G-1 (under Garai) respectively.

The map, showing drainage pattern in each sub-basin was prepared after ground truth verification on major rivers viz. Karmnasha, Chandraprabha and Garai (Fig. 1). Various morphometric parameters such as stream length, frequency, bifurcation ratio and aerial extent of identified sub-basins were calculated with the help of PLACOM-Digital Planimeter.

The sub-basin wise drainage characteristics of block Naugarh has been determined under the following two heads :

Linear Aspects: Stream order (W), stream length (LW) and bifurcation ratio (RB) were found out (Tables 1 & 2).

Areal Aspects: Drainage area and density, shape parameters viz. elongation ratio, form factor, circularity ratio etc. alongwith stream frequency, infiltration number were calculated.

Results and Discussion

The drainage characteristics of the seven sub-basins were determined and are summarised in Tables 3 & 4.

In the six sub-basins (K1, K2, K3, C1, C2, G1), the trunk stream is of Vth order and in K-4 sub-basin, the trunk stream is of VIth order.

The values of mean bifurcation ratio (RB) shows only a small variation between the sub-basins. The bifurcation ratio for the sub-basins fall in the range of 2.638 to 4.07 indicating that the geological structure did not distort the drainage pattern in all these water sheds. (CGWB 1982).

In general, low drainage density is favoured in regions of highly resistant or highly permeable sub-soil materials, under dense vegetative cover and where relief is low. High drainage density is favoured in regions of impermeable sub surface materials, sparse vegetation and mountainous relief.

The low values of drainage density (Dd), stream frequency (Fs) and infiltration number (If) for K-2 sub-basin suggests that it is covered mostly with colluvium (major portion of this sub-basin falls in adjoining block Chatra of district Sonbhadra) as compared to the higher values of drainage density, stream frequency and infiltration under for the six sub-basins with hard rock area, clearly indicate the possibility of higher infiltration and low run off in K-2 sub-basin. The values of Drainage density (Dd), Stream frequency (Fs) and Infiltration number (If) for C-1, K-1 and K-3 are also low, indicating the possibility of higher infiltration and low run off, as the rocks in these sub-basins are more jointed and weathered. Field traverses corroborate this inference showing that geology/lithology plays an important role in the development of drainage density, and stream frequency (Agarwal *et al.*, 1993, 1997).

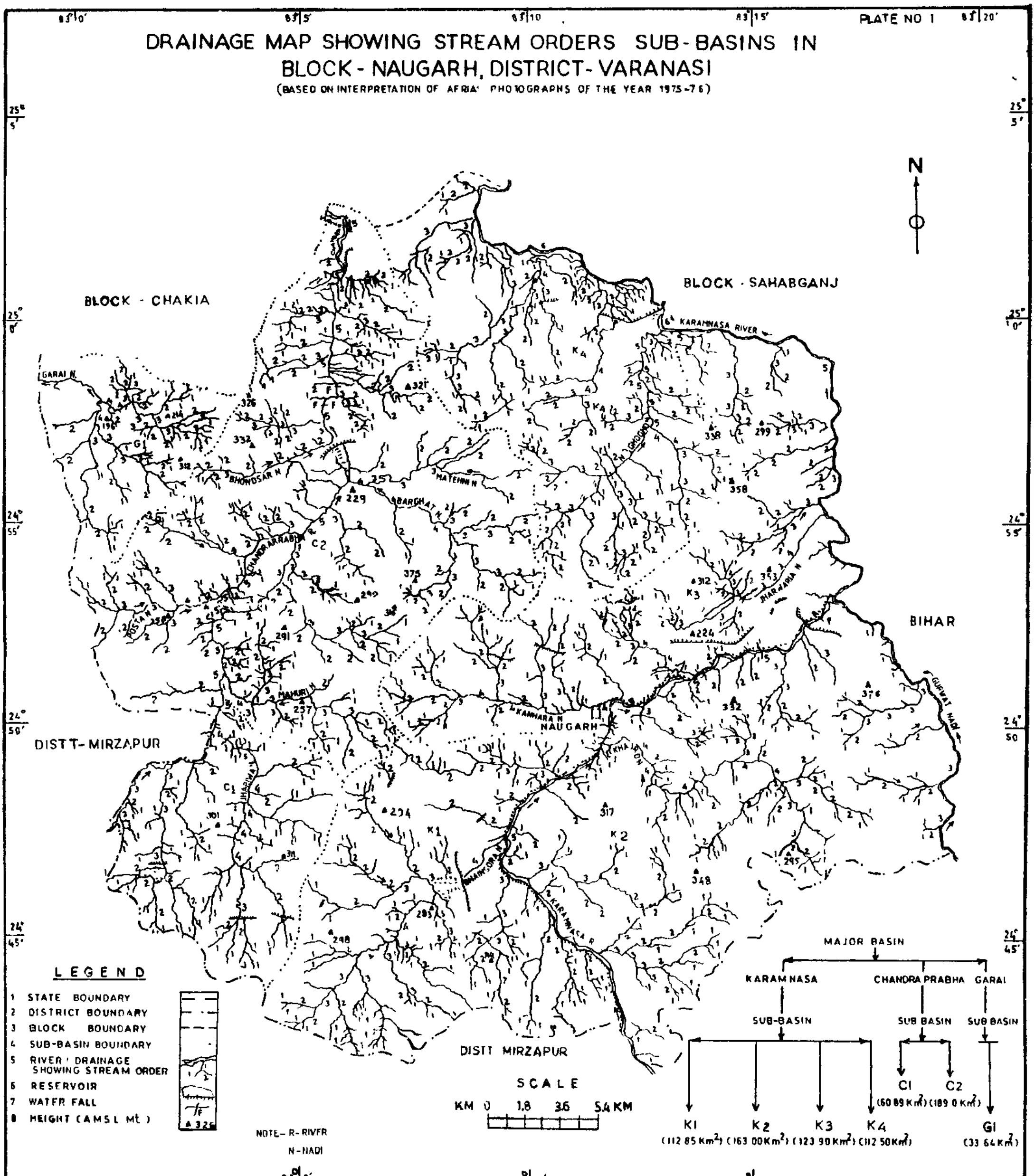
PLATE NO 1
DRAINAGE MAP SHOWING STREAM ORDERS SUB-BASINS IN
BLOCK - NAUGARH, DISTRICT- VARANASI
BLOCK - CHAKIA
BLOCK - SAHABGANJ
KARAMNASA RIVER
BIHAR
DISTT- MIRZAPUR
NAUGARH
DISTT MIRZAPUR
LEGEND
1 STATE BOUNDARY
2 DISTRICT BOUNDARY
3 BLOCK BOUNDARY
4 SUB-BASIN BOUNDARY
5 RIVER / DRAINAGE SHOWING STREAM ORDER
6 RESERVOIR
7 WATER FALL
8 HEIGHT (AMSL Mt)
NOTE- R- RIVER
N-NADI
SCALE
KM 0 1.8 3.6 5.4 KM
MAJOR BASIN
KARAMNASA
CHANDRA PRABHA
GARAI
SUB-BASIN
SUB BASIN
SUB BASIN
K1
K2
K3
K4
C1
C2
G1

Table 1. Order, Number & Lengths of streams in different sub-basin.

Sl. No	*Sub-basin*	*Stream Order (W)*	*No of Streams (NW)*	*Total length of Streams (LW) (in km)*	*Log NW*	*Log LW*
1	*2*	*3*	*4*	*5*	*6*	*7*
1.	C-1	1	74	47.5	1.8662	1.6767
		2	21	29.37	1.3222	1.4679
		3	4	11.25	0.6021	1.0511
		4	2	10.00	0.3010	1.00
		5	1	1.25	0.00	0.960
2.	K-1	1	120	91.87	2.0792	1.9631
		2	31	50.62	1.4914	1.7044
		3	9	16.87	0.9542	1 2271
		4	2	16.25	0.3010	1.2081
		5	1	6.87	0.00	0.8370
3.	K-2	1	137	95.62	2.1367	1 9806
		2	48	72.5	1.6812	1.8603
		3	13	28.12	1.1139	1.4642
		4	3	25.62	0.4771	1.4085
		5	1	18.12	0.00	1.2582
4.	K-3	1	90	46.37	1.9542	1.8087
		2	56	70.00	1.7482	1.8451
		3	13	26.87	1.1139	1.4292
		4	2	10.00	0.3010	1.00
		5	1	30.62	0.00	1.4860
5.	K-4	1	104	68.12	0.0170	1.8326
		2	57	100.62	1.7559	2.0025
		3	16	50.62	1.2041	1.7044
		4	4	11.87	0.6021	1.0745
		5	2	5.62	0.3010	0.7497
		6	1	11.87	0 00	1.0745
6.	C-2	1	174	121.87	2.2405	2.0859
		2	119	219.37	2.0755	2.3412
		3	26	76.25	1.4150	1.8823
		4	5	21.25	0.6990	1.3273
		5	1	25.62	0.00	1.4085
7.	G-1	1	37	22.5	1.5682	1.3522
		2	18	23.75	1.2553	2.3756
		3	4	8.12	0.6021	0.9096
		4	2	2.12	0.3010	0.4942
		5	1	3.75	0.00	0.5740

Table 2. Bifurcation ratio in different sub-basins.

Sl. No	*Name of Sub-Basin*	*Bifurcation Ratio (Rb)*					*Mean*
		W (Streams Orders) 1, 2	*W = 2, 3*	*W = 3, 4*	*W = 4, 5*	*W = 5, 6*	
1.	C-1	3.523	5.250	2.00	2.00	–	3.193
2	K-1	3.870	3.444	4.50	2.00	–	3.452
3.	K-2	2.854	3.692	4.33	3.00	–	3.469
4.	K-3	1.607	4.307	6.50	2.00	–	3.603
5.	K-4	1.824	3.562	4.00	2.00	2.0	2.677
6.	C-2	1.504	4.576	5.20	5.00	–	4.07
7.	G-1	2.055	4.500	2.00	2.00	–	2.638

Table 3. Morphometric analysis of different sub-basins.

Sl. No.	*Sub-basin*	*Area (A) (sq km)*	*Total no. of streams (NW)*	*Total length of streams (in kms) (LW)*	*Stream Frequency* $FS = \frac{NW}{A}$	*Drainage Density* $Dd = \frac{LW}{A}$	*Bifurcation ratio*		*Infiltration number*
							Mathematical	*Graphical*	*IF = DdxFs*
1.	C-1	60.89	102	99.37	1.675	1.631	3.193	3.255	2.733
2.	K-1	112.85	163	182.48	1.444	1.617	3.452	3.548	2.344
3.	K-2	163.00	202	239.98	1.239	1.472	3.469	3.890	1.823
4.	K-3	123.90	162	201.86	1.307	1.629	3.603	3.981	2.129
5.	K-4	122.50	184	248.72	1.502	2.030	2.677	2.606	3.049
6.	C-2	189.09	330	464.36	1.745	2.455	4.070	4.732	4.283
7.	G-1	33.64	62	61.24	1.843	1.820	2.638	2.667	3.355

The process of run off is quite complex and cannot be directly related to all the drainage characteristics. However, it was observed that drainage density, maximum basin relief, mean basin slope and ruggedness number have considerable influence on run off.

Normally, if the bifurcation ratio (Rb) is low, the basin produces a sharp peak of discharge, and if Rb is high, the basin yields a low but extended peak flow.

An analysis of the aerial photographs shows that only dendritic type of drainage is prevailing in the area having 1st to 6th order stream, the trunk stream being obviously 5th or 6th order. In the area 761 Ist order streams, 350 IInd order streams, 85 IIIrd order streams, 20 IVth order streams, 6 Vth order streams and one VIth order stream have been identified.

From the above results, it can be clearly stated that the area is composed of sedimentary sandstone formations as the drainage density is quite low ranging from 1.472 to 2.455. The low values of drainage on the other hand suggest that region is composed of highly resistant sub soil materials and are under dense forest cover. (Srivastava; 1997). In the present case the low values of drainage density indicate high permeability of the area. Moreover, the streams in the area are mostly of first order and second order, indicating more permeable formations.

The bifurcation ratio for river basins in which the geological structures do not distort the drainage pattern normally ranges between 3 and 5. Higher bifurcation ratio indicates some sort of geological control. In the present case, the bifurcation ratio ranges between 2.638 and 4.07 (Mathematical) and 2.606 to 4.732 (Graphical), which indicate lack of geological control on the drainage pattern. Further, it also indicates sharp peak of flood discharge. (C.G.W.B. 1992)

The values of all the 3 shape factors i.e. elongation ratio (Re), form factor (Rf) and circularity ratio (Re) for K-3 sub-basin indicate that this sub-basin is more elongated as compared to the other six sub-basin which are relatively more circular.

Table 4. Shape parameters of different sub-basins.

Sl. No.	*Sub-basins*	*Drainage area* (km^2)	*Basin Perimeter* (*km*) *P*	*Maximum basin length* (*km*) *Lb*	*Width of the basin* (*km*)	*Elongation Ratio* $Re = \frac{2\sqrt{Au/\pi}}{Lb(Max)}$	*Form factor* $Rf = \frac{Au}{Lb^2}$	*Circularity ratio* $Re = \frac{4\pi Au}{P^2}$
1.	C-1	60.89	33.12	11.25	9.06	0.782	0.48	0.670
2.	K-1	112.85	55.00	17.50	13.75	0.685	0.37	0.468
3.	K-2	163.00	81.25	19.37	14.37	0.743	0.43	0.310
4.	K-3	123.90	65.62	20.00	13.12	0.628	0.31	0.361
5.	K-4	122.50	52.50	17.50	9.06	0.713	0.40	0.558
6.	C-2	189.09	69.37	22.50	18.12	0.689	0.37	0.493
7.	G-1	33.64	26.87	8.12	7.81	0.806	0.51	0.585

The value of infiltration number (If) is lowest for K-2 sub-basin and highest for C-2 sub-basin. The values of (If) for K-1 and K-3 sub-basins are more nearer to that of K-2 sub-basin. The values of (If) for the remaining (C-1, K-4 & G-1) sub-basins are more close to the value of C-2 sub-basin. These (If) values indicate that there is possibility of more infiltration in K-1, K-2 and K-3 sub-basins, and consequently less run off. Whereas it is vice-versa in case of C-1, C-2, K-4 and G-1 sub-basins.

The detailed morphometric analysis finally concludes that sub-basin K-1, K-2 and K-3 of Karamnasha basin are having better scope for artificial recharge scheme and deep ground water exploration, as the infiltration is more with less run off. The water table in the area vary from 1.70 to 16.40 M. (bgl) with number of springs, which can be utilised for artificial recharge scheme.

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