TR-51

WATERSHED CHARACTERISTICS OF ONG SUB-BASIN

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CONTENTS

LIST OF TABLES

LIST OF FIGURE

ABSTRACT

Watershed characterisation is a foremost task in any water resources development project. The conventional methods of watershed characterisation through ground based survey and aerial photographs are time consuming and costly. Remote Sensing which is in an advance stage of development, is becoming a versatile tool for such studies because of the accelerated speed, better accuracy, repeated measurements and synoptic coverage and finally an integrated data base. The present study was taken up for mapping and analysis of various watershed characteristics of Ong sub basin using Landsat imagery. The parameters which were included in the study are; drainage, basin configuration, relief, land cover and soil erosion. Drainage, basin configuration and relief were studied from the available toposheets. Information about land cover and soil erosion and supplementary information on drainage was obtained from satellite imagery.

1.0 INTRODUCTION

Water is one of the vital natural resources to mankind. Its scientific management and judicious use is important for maximising agricultural production. Before taking up any water resources development project, the probable quantity of water available from a watershed and its quality are needed to be known. Both quality and quantity of run-off available from a watershed are dependent on the watershed characteristics. These watershed characteristics include land use, soil type, geology, geomorphic and morphometric parameters.

The land use parameters of a watershed are drainage area, impervious area, bare land, cultivated land, grass land, shrubs, thin and dense forests, water bodies and the snow cover. The geomorphic parameters include land forms, slope disposition and processes going on over them. The morphometric parameters are stream order, stream length, basin area and shape, drainage density, drainage frequency and stream sinuousity.

Land use parameters are helpful in estimation of various losses such as infiltration, evapotranspiration and interception. Quality of runoff is greatly affected by the land use characteristics of a watershed. Thus by expressing hydrologic parameters as a function of land use it is possible to predict the impact which any change in land use pattern will have on the quality and quantity of run-off from a watershed. Geology and soil characteristics influence seepage, soil erosion and chemical properties of runoff. Morphometric parameters are important from the point of view of studying flow characteristics of out-flow from the watershed. Occurrance of peak flow and shape are dependent on morphometric parameters together with stream characteristics. Thus, study of watershed characteristics is the foremost task in water resources development programme.

Conventional methods of watershed characterisation through ground based survey are tedious, slow and very expensive. Also, it is difficult to get recent information from such surveys. Spatial variations of watershed parameters generate uncertainties about the point data collected by conventional method. The synoptic view provided by satellite imagery gives information for the identification of broad geomorphic features, land use and water spread area. Since the data is repetitive it is possible to update the existing data base and base maps for use in various hydrologic purposes. Also, it is possible to study the integrated effects of various aspects of ecosystem and it is often possible to correlate the cause and effect of changes which are being monitored. These information could be suitably used as input to various hydrologic studies such as stream flow estimation and peak flow estimation. Two types of models are available for the purpose, (i) multiple regression models using significant basin characteristics and (ii) run-off coefficient models using informations on land cover, watershade slope, shape and drainage area. WMO (1983) has listed out observational requirements for these parameters and the possible use of remote sensing to estimate these parameters. Some of the observational requirements of these parameters have been modified by Working Group of Water Resources set up by Planning Commission.

TABLE 1 : OBSERVATIONAL REQUIREMENTS FOR WATERSHED CHARACTERISTICS

Parameter and its definition	REQUIREMENTS				AVAILABLE FROM SATELLITES	
	Scale	Resolution	frequency	Accuracy	Expected 1980s	Remarks
Drainage area:whole area having a common outlet for its surface runoff	A,B,C C	30 m 100 m	Every 10 years	(±10% of watershed area)	Possible	
Channel dimensions & patterns; length, number order and pattern of stream channel networks must be outlined, even into the head-water reaches, to define the channel pattern. Channel order or number values can then be assigned to channel branches according to a variety of geomorphic quantification techniques	A,B C	30 m 100 m	Every 5 years or after major flood event)	(±5% of length	Possible	
Overland flow length: Average horizontal distance that water must flow over the ground before it enters a definite channel	A,B,C	30 m 100 m	Every 5 years	(±5% of length	Possible	
Surface slope: the average slope between a divide and the stream channel over which water must run to reach the stream channel	A,B,C,	30 m 100 m	Every 5 years	(±horz. (±5 cm vert.	Not possible	
Land cover type: natural vegetation or soil or artificial surface, expressed as a percentage of watershed area	A,B,C	100 m	Every year	(±1% of watershed	Possible	Can be met on a limited area basen at present. Requires large-scale digital proce-sssing.

Note: Scale A = Less than 100 Km^2; Scale B = between 100 and 1000 Km^2;Scale C = more than 1000 Km^2

2.0 REVIEW OF LITERATURE

A number of studies have been conducted in India to map the various watershed characteristics such as land use, soil types and land forms using aerial photographs and satellite imagery. Most of the studies have been concentrated towards mapping of land use in Himalayan catchments.

Indian Photo Interpretation Institute, Dehradun (now I.I.R.S.) started such studies in 1975 in parts of Karnataka, Maharashtra, Andhra Pradesh for soil mapping (Mirajkar et al., 1975). Utpal Miri (1975) demonstrated utility of B & W panchromatic aerial photographs for hydrologic investigations. Similar study was taken up by Jain (1976)for Tons basin. His work was mainly based on visual interpretation for land cover mapping. Further in 1977, Ashok Kumar studied Ramganga basin characteristics such as drainage, land use, basin configuration, relief etc. from aerial photographs. Dubey (1978) and Acharya (1979) were next to carry out photo interpretation studies in Upper Yamuna catchment for land cover mapping. They found that results from satellite imagery interpretation in agreement with aerial photo-interpretation.

NRSA has carried out studies covering several of watershed parameters using Landsat data. Drainage network maps with morphometric studies have been prepared for several areas. Geomorphological maps and soil maps upto association of sub-group level on 1:250000 on scale have also been prepared for most parts of India (NSRA, 1977).

Space Applications Centre (SAC) has undertaken a number of studies on land-use, geology, geomorphology and soils using Landsat imagery (Sahai, et al, 1980). Further investigations have been done to use such information for watershed management, Soil erosion and flow prediction studies. Niranjan (1986) has reported that satellite imageries could successfully be used for studying soil erosion. It was found that basin parameters such as drainage, land cover, basin shape and size could be studied from satellite data. Further, an integrated approach help in dentifying erosion prone and quantifying amount of sediment load in the river. Pandit (1985) studies Ramganga basin characteristics such as landuse, geology using aerial photos and satellite imagery from the view point of land capability analysis.

Mapping of soil erosion boundaries was attempted by Singh and Manchanda (1982) using visual interpretation methods. Delineation of eroded areas was based on association of rock types, vegetal cover with erosion patterns. In Nagarjun Sagar catchment digital image processing was attempted to identify erosion prone areas. it was found that at many places coarse sandy loam was misclassified as eroded areas.

3.0 STATEMENT OF THE PROBLEM

Watershed characteristics such as shape and size, land use/ land cover, topography, drainage, soil and their characteristics, geology etc. have a significant influence on the quantity and quality of runoff available from it. The traditional methods of collecting these data based on ground surveys, are time consuming and often lack accuracy. These days, remote sensing is being used more and more in studying these parameters rapidly in a cost effective manner. The main objective of this study is to assess the suitability of remote sensing in the study of watershed characteristics of a small watershed. The watershed characteristics which have been studied include watershed configuration, drainage, relief, land use/land cover and soil erosion.

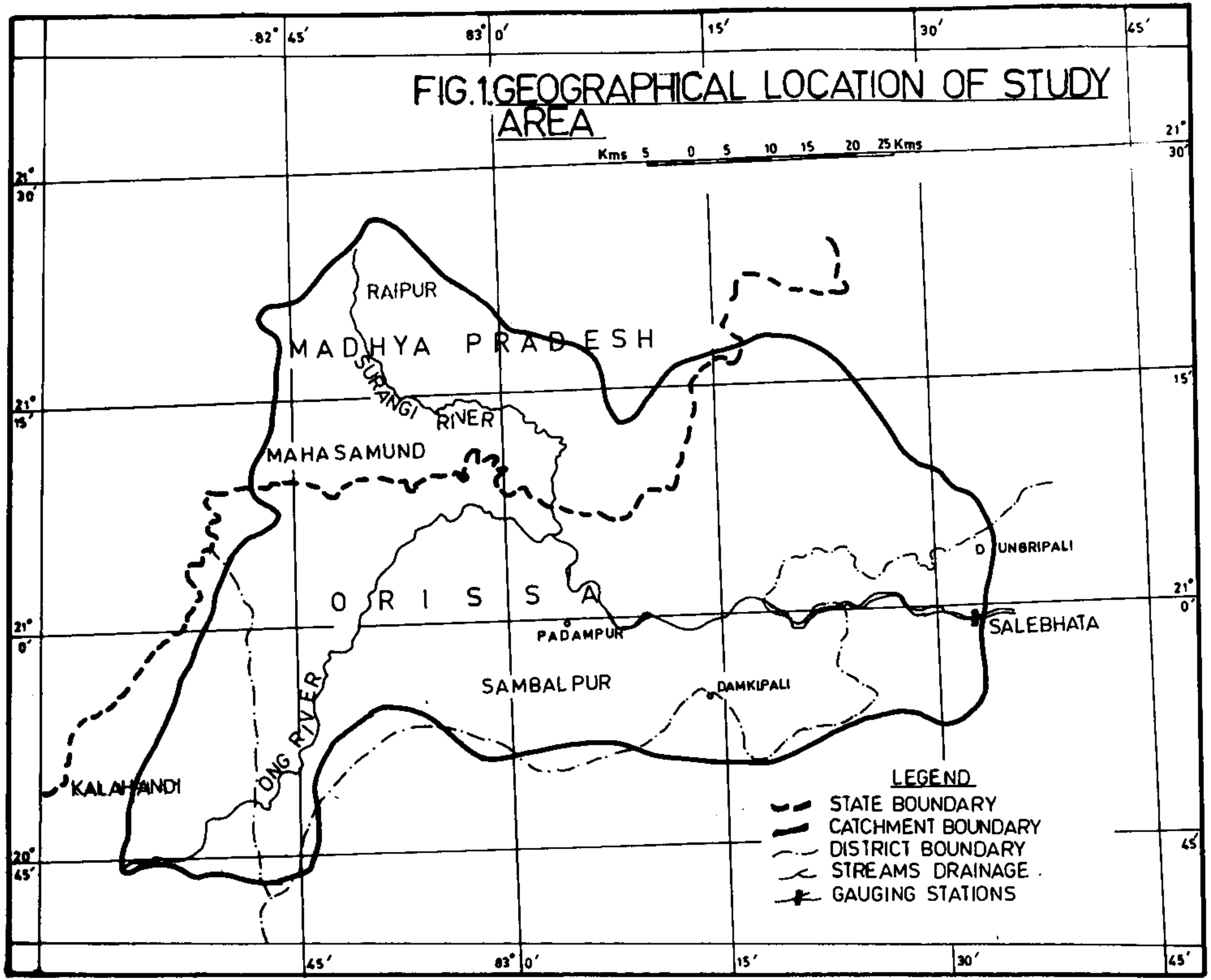


FIG.1 GEOGRAPHICAL LOCATION OF STUDY AREA

4.0 DESCRIPTION OF STUDY AREA

Ong is one of the important tributaries of the river Mahanadi. It originates at an elevation of 457 m and hill on the northern outskirts of the south-north running range of mountains situated to the right of the Jonk river. The Ong flows for a total length of about 204 km to join the Mahanadi on its right about 11 km above Sonepu . The Ong drains an area of 4855 sq. km lying in the interior of the main sub-basin.

4.1 Geographic Location of the Sub-Basin

The catchment of Ong river upto Salebhata covers an area of about 4855 sq. km and lies between 20° 42' to 21° 30' north latitudes and 82° 30' to 83° 45' east longitudes. The catchment is spread over the district Raipur of Madhya Pradesh and districts Sambalpur and Kalahandi of Orissa state (Fig.1).

4.2 Climate:

The climate of the basin is mainly dry sub-humid. There are four distinct seasons in the year, (i) the cold weather (ii) the hot weather (iii) the south-west monsoon and (iv) the post monsoon.

The mean minimum temp. ranges between 1° and 13.7°C. The maximum temperature ranges from 38°C over the hills to 43°C. In the plains south west monsson is the principal rainy season. During this period the basin receives over 90 percent of its total annual rainfall.

4.3 Soils and Geology

Systematic soil information about the basin is not available. The general information about the soils of India indicate the presence of mainly red and yellow soils. Mixed red and black soils occur in parts of Sambalpur district of Orrissa.

The general geologic sequences responsible for the present topography of the high land area are from the Archoean era to the Pleistocene age. The unclassified crystallines which include granite, geneisses and other magmatic rocks are found in Sambalpur district of the region. Rock of Gondwana system consisting of shales, sand stones and gret are found in a narrow and elongated form.

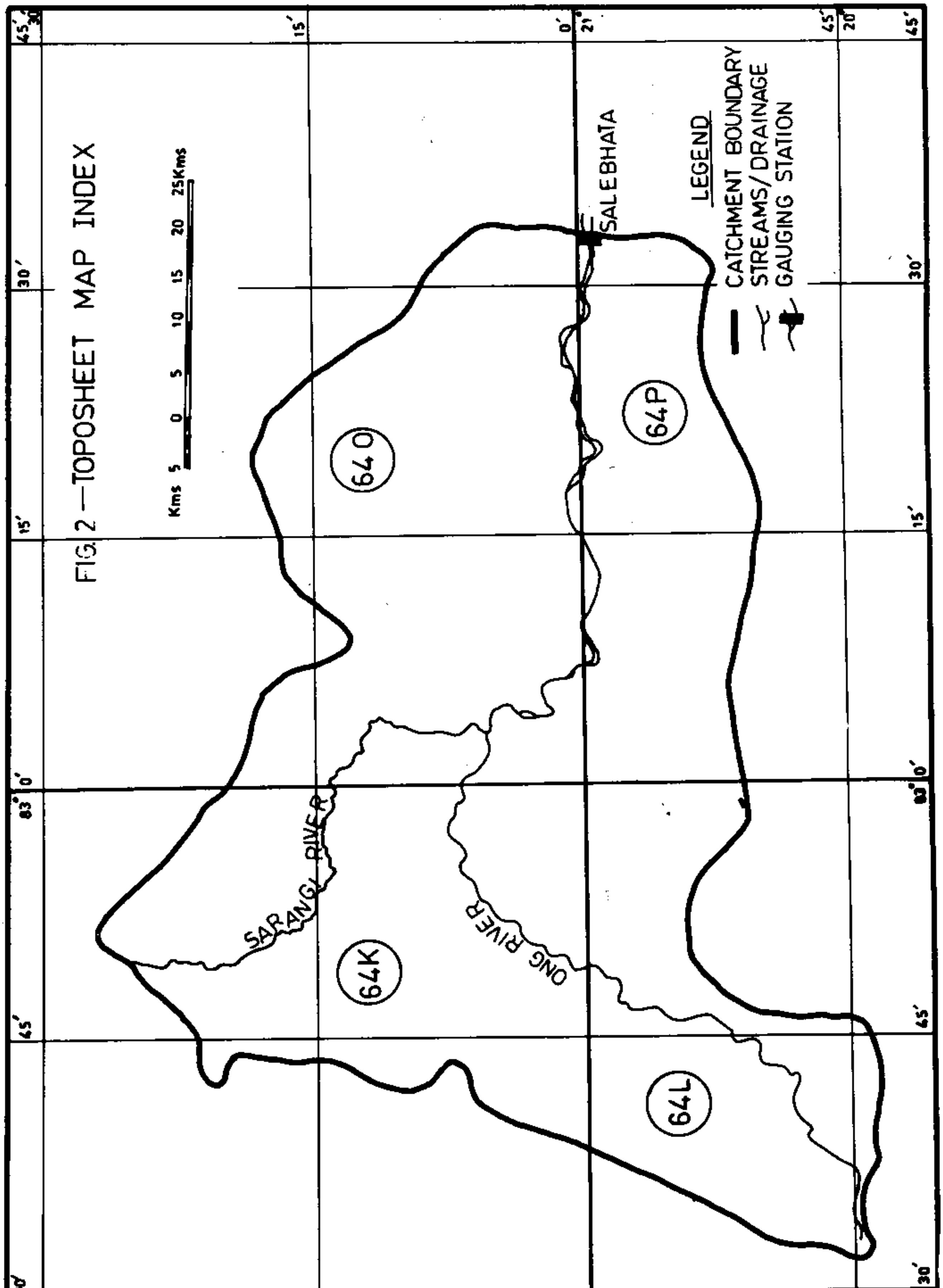


FIG 2 — TOPOSHEET MAP INDEX

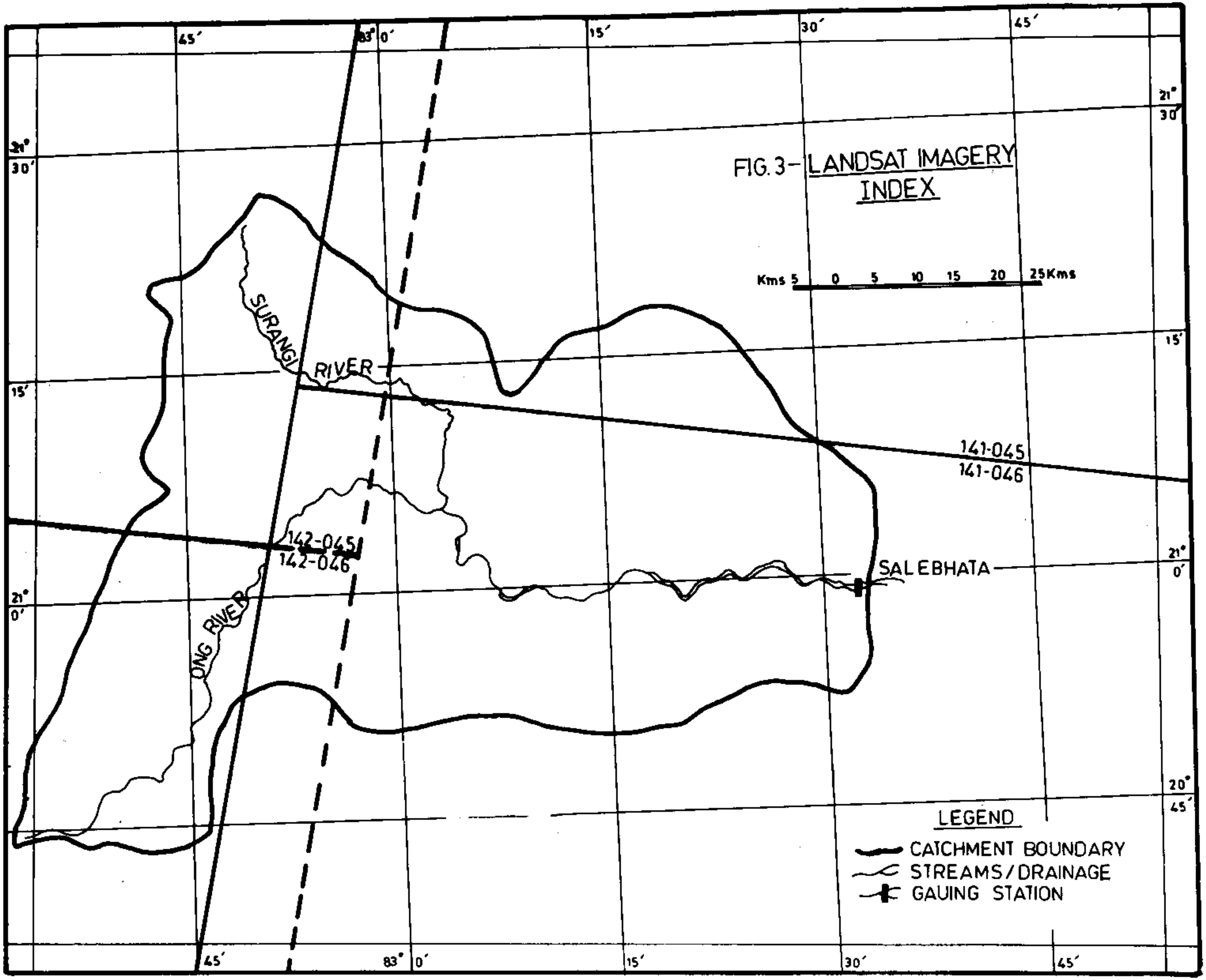


FIG. 3- LANDSAT IMAGERY INDEX

5.0 DATA USED

The study was carried out using Landsat MSS imagery and survey of India topographic maps at 1:250,000 scale. The area is covered in four toposheets; 64 K,64 L, 64 O and 64 P. The index of toposheets and Landsat imagery is given in figure 2 and 3, brief description of Landsat imagery is given in table 2. The other related information

TABLE 2 : DESCRIPTION OF LANDSAT IMAGERY

Sr.No.	Path and Row	Date	Satellite	Season	Data type
1.	141-045	28.10.85	L4	MSS	2,4
2.	141-046	29.11.85	L4	MSS	2,4
3.	142-045	20.11.85	L5	MSS	2,4
4.	142-046	20.11.85	L5	MSS	2,4

such as agriculture and natural vegetation, soils and geology of the areas was collected from Agricultural Atlas of India. Climatologic data was obtained from report of Irrigation Commission.

6.0 METHODOLOGY

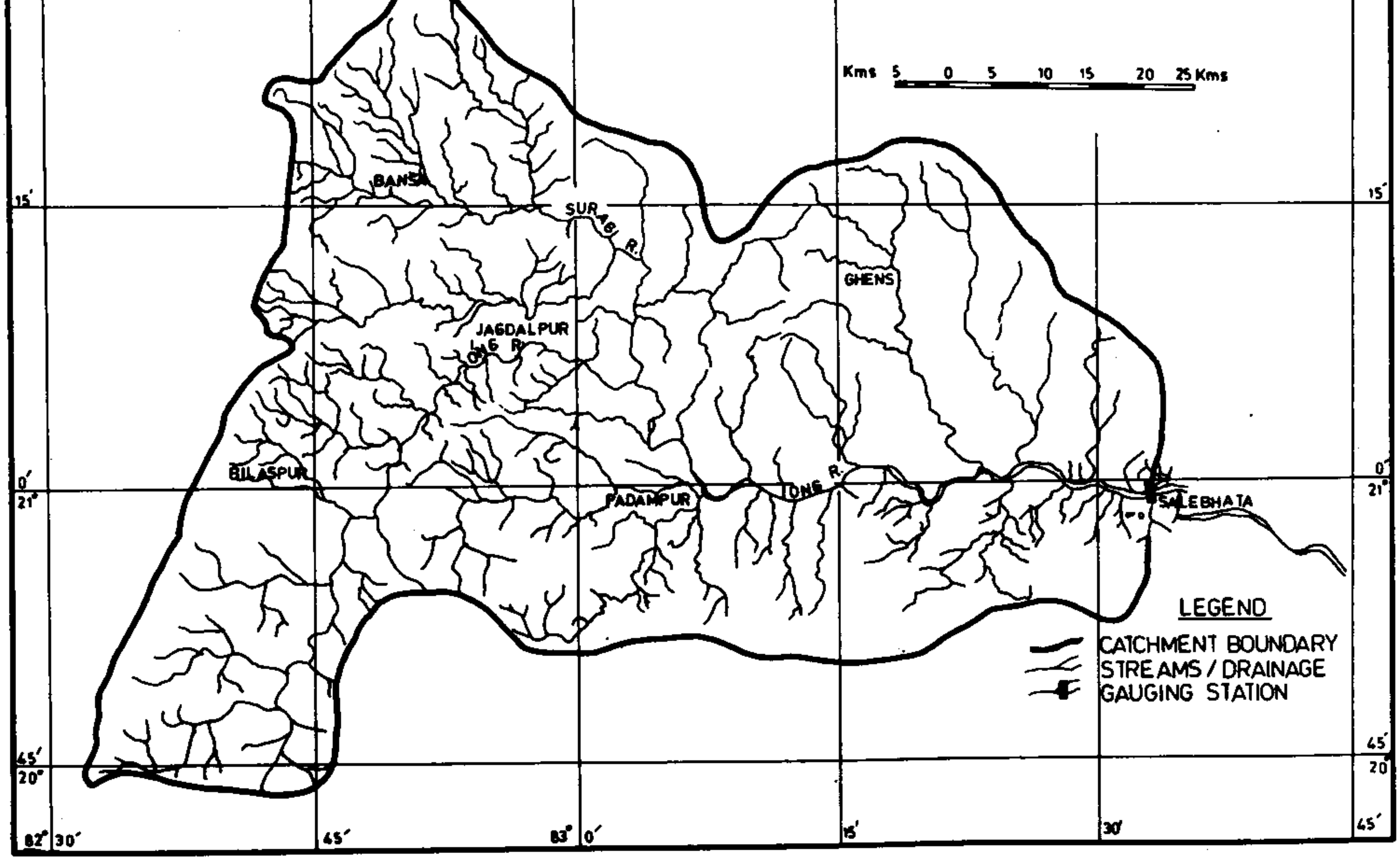
This study was done using Landsat imagery and Survey of India Toposheets. Drainage map of the area was prepared from 1:250,000 scale toposheets. Landsat imagery were used to supplement the drainage map. The basin boundary was initially delineated from River Basin Atlas. On the basis of drainage map drainage basin boundary was plotted. A relief map of the basin was prepared from toposheets.

Land use/land cover map of the basin was prepared by visually interpreting Landsat MSS 2 imagery at 1:250,000 scale. This map was superimposed on base map of the area so that geometric distortions of the imagery are removed. The land use/vegetal classification scheme adopted in the study is given in Table 3. Areas subjected to soil erosion were identified as barren patches within forested hilly regions.

TABLE 3: LAND USE/LAND COVER CLASSIFICATION SCHEME

Sl.No.	Level I	Level II
1.	Forest Land	Thin Forest Desnse forest
2.	Agricultural Land	-
3.	Water	-
4.	Barren Land	Sand and gravel Exposed soil

FIG.4 - DRAINAGE MAP OF ONG SUB BASIN UPTO SALEBHATA



7.0 ANALYSIS AND RESULTS

7.1 Drainage Analysis

Survey of India toposheets have formed the data base for the study. An accurate base map of the Ong drainage basin, depicting all the channel networks including very small channels was prepared using 1:250,000 toposheets (figure 4). The basin is covered in the four sheets at 1:250,000 scale; 64 K, 64 L, 64 O, 64 P. The drainage network for the part of basin covered in the toposheet 64 L was prepared from Landsat MSS 4 imagery due to non-availability of toposheet No. 64 L. Using the drainage map, morphometric analysis of the entire basin was made and the parameters such as basin perimeter, area of the drainage basin, bifurcation ratio, drainage density, stream frequency, elongation ratio, circulaity ratio, form factor, ruggedness number length of overland flow, constant of channel maintenance etc. were computed for the basin as a whole.

7.1.1 Stream Orders

The first step in drainage basin analysis is designation of stream orders. In this study, Horton's system of stream ordering was used. In this system smallest unbranched stream is designated as the first order stream. The channel formed by merging of two second order channel is a third order stream. This basin was found to have a fifth order stream.

7.1.2 Stream Numbers

After having assigned the orders to the drainages, the number (N_u) of the streams for each order was determined and tabulated (Tab.4) The number of stream decreases with an increase in stream order.

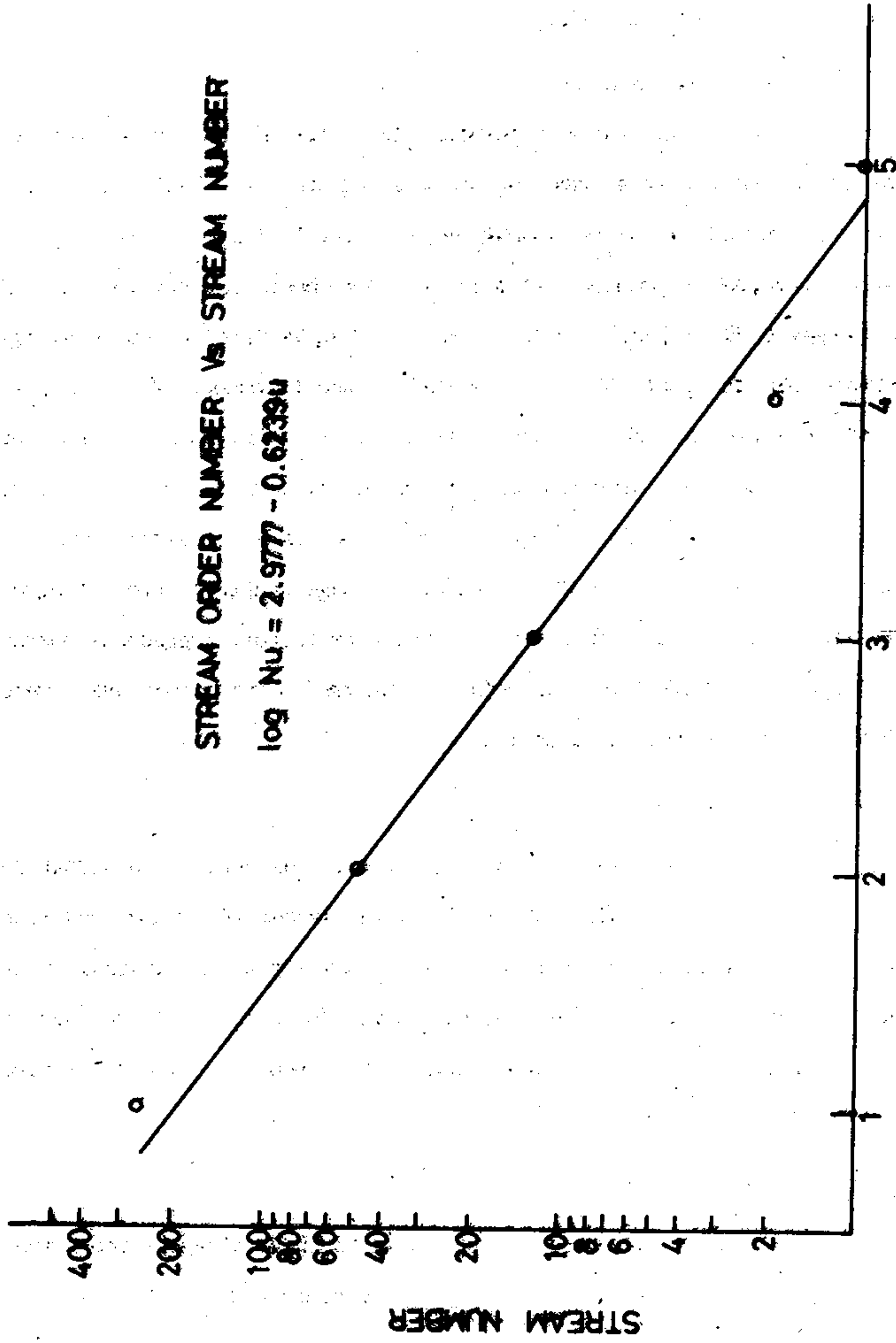


FIG.5 — STREAM ORDER NUMBER

TABLE 4 : DRAINAGE PARAMETERS OF THE BASIN

(u)	Number (N_u)	Length (km) (L_u)	Mean length (km) ($I_u = \frac{L_u}{N_u}$)	Length Ratio ($R_e = \frac{I_{u+1}}{I_u}$)	Bifurcation ($R_b = \frac{Nu}{Nu+1}$)
1	266	920	3.4575	-	-
2	49	350	7.14525	2.066	5.428
3	13	170	13.0775	1.831	3.769
4	2	95	47.5	3.632	6.5
5	1	72.5	72.5	1.526	2.0

Mean length ratio = 2.264

Mean bifurcation ratio = 4.424

Then, the bufurcation ratios were computed by dividing the number of stream segments of a given order by the number of stream segments of the next higher order. Thus,

$$\text{bifurcation ratio } R_b = \frac{N_u}{N_{u+1}}$$

The number of stream segments were plotted against stream order on a semi-logarithmic paper (figure 5). The regression coefficient b of the plot is 0.6239.

7.1.3 Stream lengths

Stream lengths for each order were measured using a thread. The mean length I for a given order was obtained by dividing the total length by the total number of segments Nu of the order u.

$$I_u = \frac{L_u}{N_u}$$

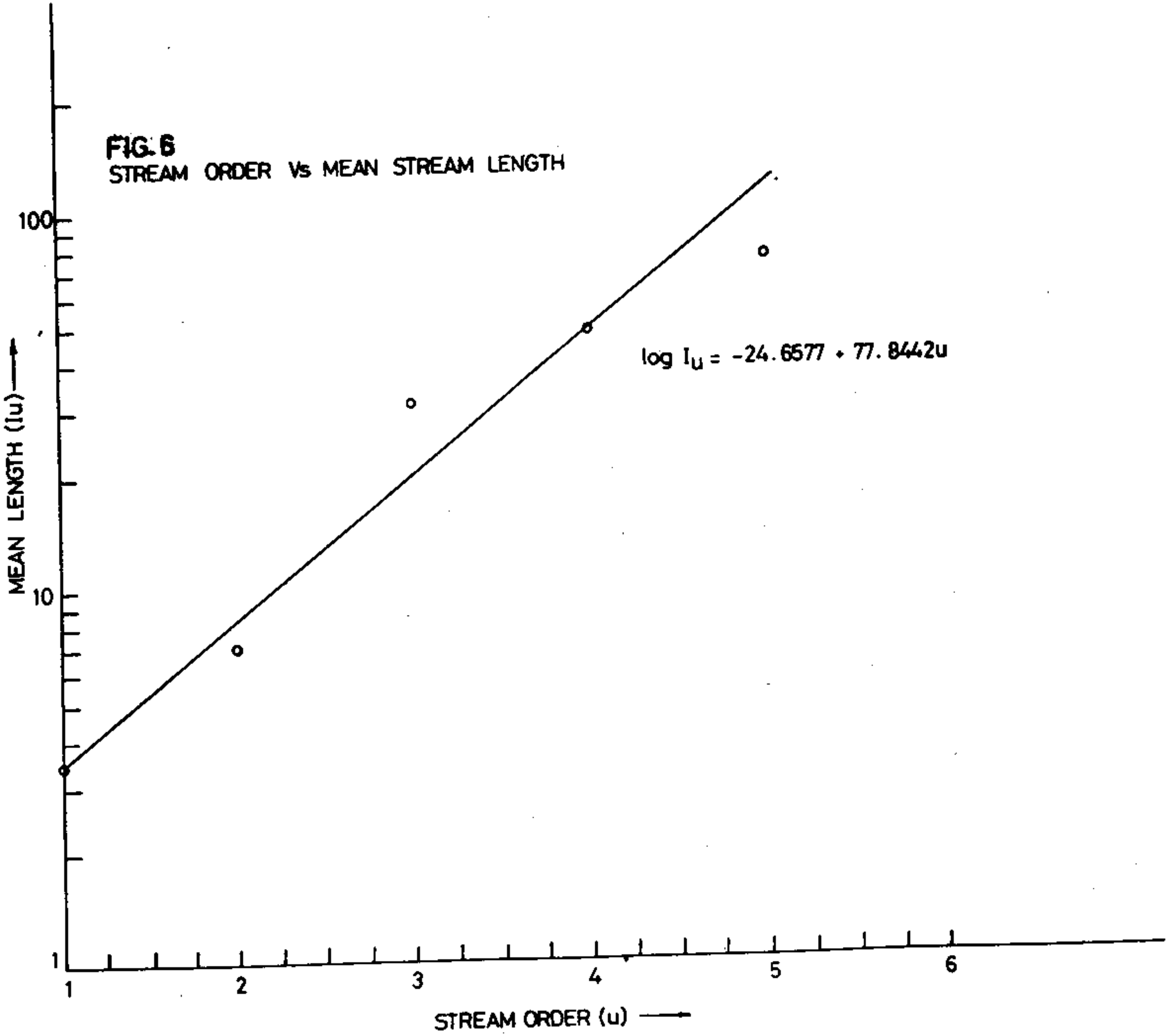
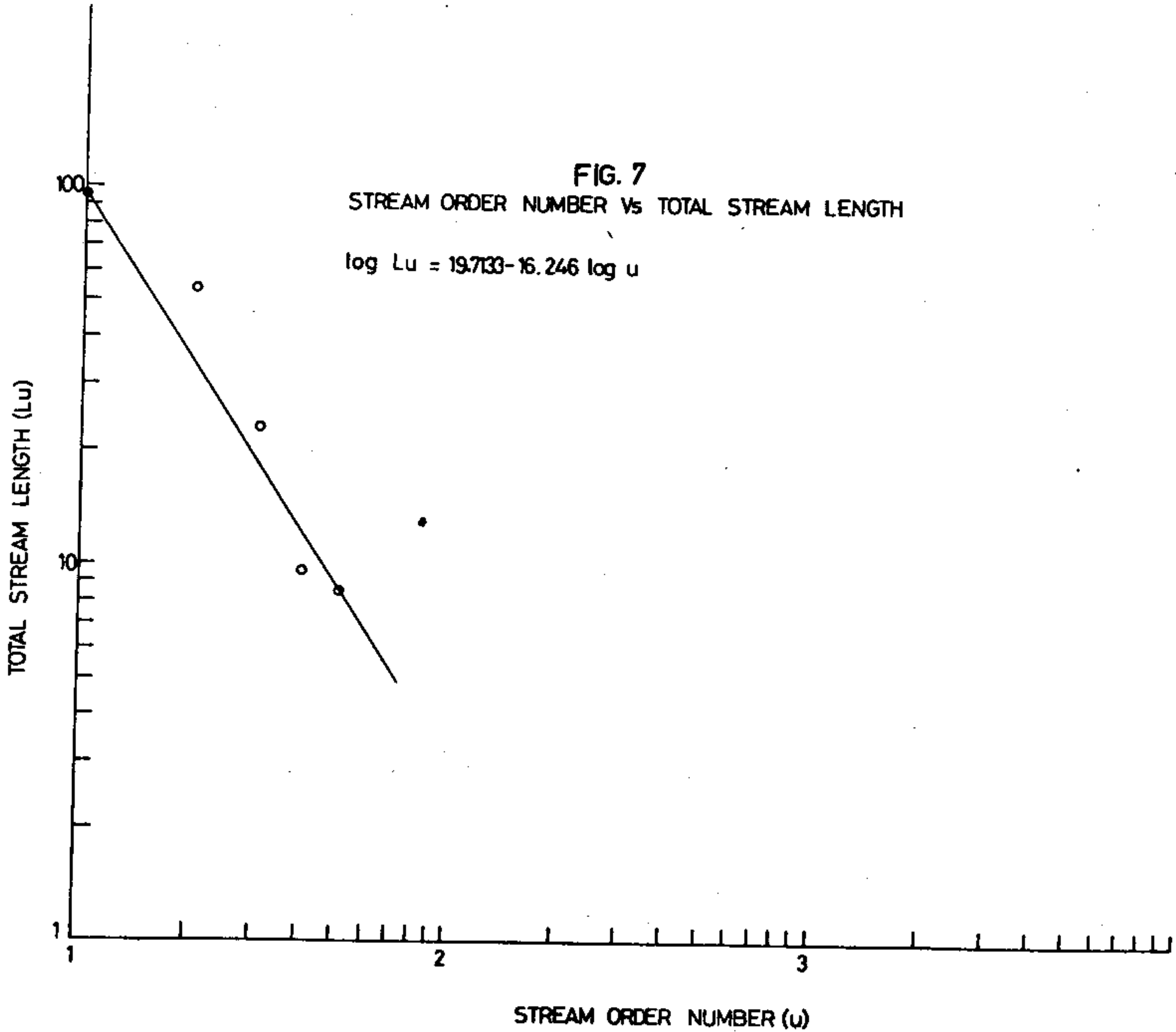


FIG. 6
STREAM ORDER Vs MEAN STREAM LENGTH

FIG. 7

STREAM ORDER NUMBER Vs TOTAL STREAM LENGTH

$\log Lu = 19.7133 - 16.246 \log u$



The length ratio R_u was calculated as:

$$R_u = \frac{I_u}{I_u+1}$$

The total lengths, mean lengths, the length ratios and computed mean length ratio are given in table 2.

A linear relationship is observed from the plot of mean stream length against stream order (fig. 6). The coefficient regression is found to be -1.6296. The plot of total stream length and stream area number show a linear relation by log scale (fig. 7).

7.1.4 Drainage density

It is the ratio of total channel segment lengths to the basin are A_u

$$\text{Drainage density} = \frac{L_u}{A_u}$$

The basin is found to have a drainage density of 0.381 (Table 4).

7.1.5 Stream frequency

Horton (1945) introduced stream frequency F as the number of stream segments for unit area. It is obtained by dividing the total number of stream segments by the total drainage basin area. The basin has a stream frequency of 0.06818.

TABLE 5 : STREAM DENSITY AND STREAM FREQUENCY

No. of Channcels (N_u)	Total length of channel(km) (L_u)	Area of basin (sq.km) (A_u)	Stream frequency (km/sq.km) ($F=\frac{N_u}{A_u}$)	Stream density (km/km²) ($D=\frac{L_u}{A_u}$)	Length of leverland flow (km) ($\frac{1}{2D}$)	Constant of channel maintenance (sq.km/km) (1/D)
331	1607.5	4854.7	0.06818	0.331	1.51	33.02

7.1.6 Length of Overland Flow

This term is used to refer to the length of the run of the rain water on the ground surface before it gets into the channels. Since, this length of overland flow, on an average is about half the distance between the stream channels. Horton (1945) defined it to be roughly equal to half the reciprocal of the drainage density. The length of overland flow calculated thus far the basin works out to 1.51 Km.

7.1.7 Constant of channel maintenance

It is defined as the inverse of drainage density. The basin has a constant of channel maintenance C equal to 33.02 sq.km/km.

7.2 Basin Configuration

The shape of the basin is quantitatively defined by the following dimensionless ratios:

i) Form factor R_f

ii) Circulatory ratio R_c

iii) Elongation ratio R_e

7.2.1 Form Factor

The form factor is defined as the ratio of the basin area A_u to the square of the basin length L_b

$$R_f = A_u / L_b^2$$

The form factor for the basin was found to be 0.42.

7.2.2 Elongatio ratio

It is the ratio of diameter of a circle of same area as that of the drainage basin to the maximum basin length. The Ong river has a elongation ratio of 0.731. The computations for various basin configura-

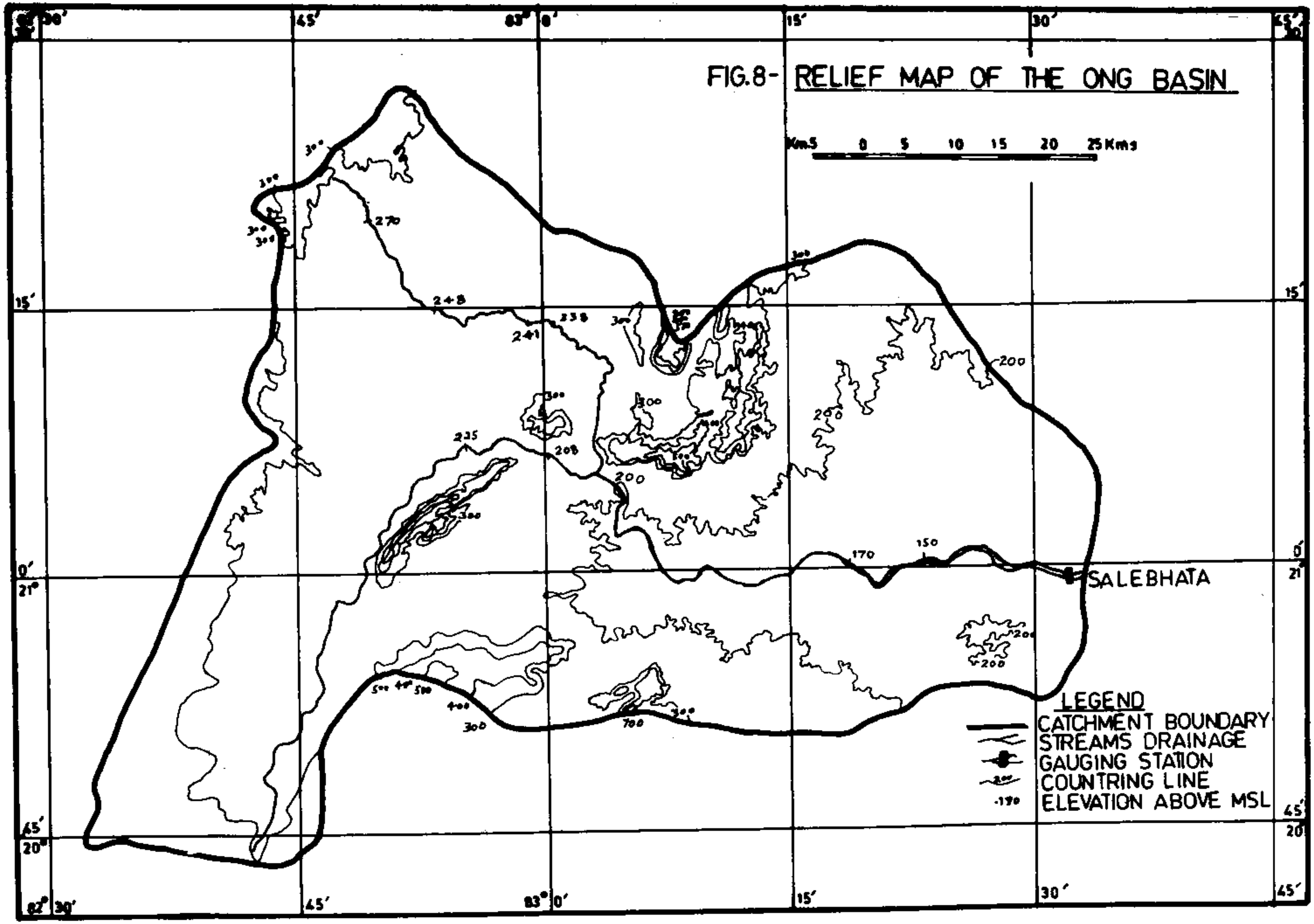


FIG.8- RELIEF MAP OF THE ONG BASIN

tion parameters are presented in table 6.

TABLE 6: BASIN CONFIGURATION CHARACTERISTICS OF ONG SUB-BASIN

Area of basin (Sq.km)	Perimeter (km)	Maximum Basin length (km)	Main channel length (km)	Average width (km)	Form factor	Circulatory Ratio	Elongation Ratio
4854.7	347.5	107.5	135	45.16	0.42	0.731	0.505

7.3 Relief Aspects

A contour map of the basin prepared from toposheets. Spot levels at certain points were also taken from the toposheet (figure 8). Following parameters were studies to define relief characteristics:

a. Channel Gradient

b. Maximum basin relief

c. Ruggedness number

7.3.1 Channel Gradient

The stream elevation was estimated from the contour crossing and spot levels given in the toposheets. The longitudinal profile of the river Ong is given in figure 9.

TABLE 7: DISTRIBUTION OF BASIN AREA BETWEEN CONTOUR RANGES

Contour range (m)	Area covered (sq.km)	Percentage of total area
700	36.63	0.75
700-500	74.30	1.53
300-400	554.62	11.42
200-300	2947.59	60.72
200	1241.70	25.58

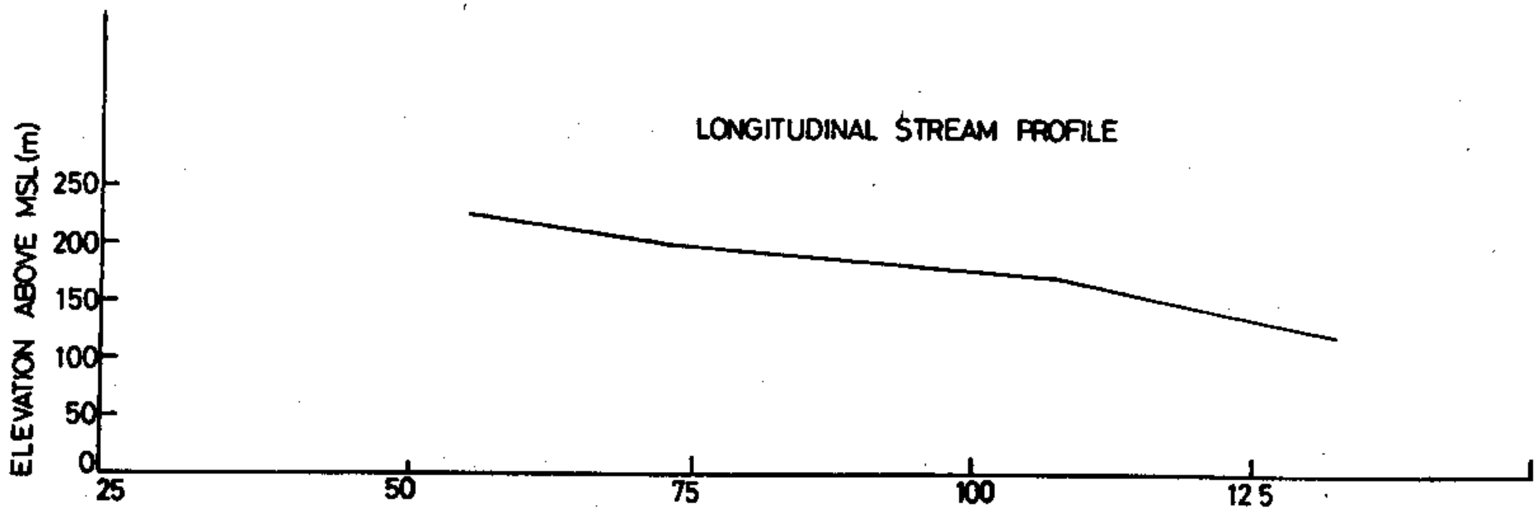


FIG. 9 – MAIN STREAM LENGTH (KMS)

7.3 Max basin relief

The maximum basin relief was obtained for the basin from the highest point on the basin perimeter to the mouth of the basin. The maximum elevation on the perimeter of the basin was 778 m, and the elevation on the mouth of the basin was 120 m. Thus, the max. basin relief (H) works out to be 658. The relief ratio (R_h) was computed by dividing the relief by the maximum length of the drainage basin. The relief ratio for the basin was computed as 0.0062 (table 7).

7.3.3 Ruggedness Number

Ruggedness number (HD) is the product of basin relief and the drainage density. It describes the quality of the slope steepness with the length (Table 7) on the basis of ruggedness Number the basin is classified as 0.0021.

TABLE 8 : RELIEF CHARACTERISTICS OF THE BASIN

Maximum elevation on the perimeter (m) (E1)	elevation of the mouth (m) (E_2)	maximum basin relief (m) ($H=E_1-E_2$)	max. basin length (L_b)	relief ratio ($R_h=\frac{H}{L_b}$)	Ruggedness number (H_D=HxD)
778	120	658	107.5	0.0062	.0021

7.4 Land Use/Vegetal Cover

The land use/vegetal cover map of the basin is given in figure 10. Areal extent of various types of land covers are shown in table 9. Also, the distribution is pictorially represented in figure 9. The following conclusions may be drawn from the land use/vegetal cover map of the basin.

1. About 18.58 percent of the basin is covered with forests, out of which 13.37 percent area is densly forested.

2. Cultivation is predominant in catchment with 79.12 percent of the area under cultivation.

3. Barren/eroded areas amounts to be 1.71 percent of total basin area.

4. Only a very small portion i.e. 0.28 percent area is occupied by reservoirs, streams etc.

TABLE 9 : AREAL EXTENT OF LAND USE/VEGETAL COVER

Sl.No.	Level I	Level II	Areal Extent (Sq.km)	Areal Extent (%)
1.	Forest land	Thin Forest	243.2	5.01
		Dense Forest	648.9	13.37
2.	Agricultural land	-	3849.0	79.12
3.	Water	-	13.6	0.28
4.	Barren land	Sand and gravel	24.60	0.51
		Expored soil	83.2	1.71

8.0 CONCLUSION

On the basis of the analysis of various physical parameters of the basin it is concluded that;

1. The Horton's first low of stream numbers is applicable to the sub-basin. The average bifurcation ratio is 4.424 which lies between 3.0 and 5.0. It indicates that geologic structures have not distorted the drainage pattern of the basin. Higher values of bifurcation ratio (R_b) indicate on extended peak flow whereas the lower value of R_b indicate a short peak. The present basin would yield flood hydrograph somewhere between these two extremes.
2. The semilog plot of mean length Vs stream order is straight line which indicates that Horton's second low of stream lengths is applicable to the basin.
3. The drainage of the basin is defined as coarse.
4. The constant of channel maintenance is 3.02. It means that on an average, 0.391 sq.km. of surface area is needed to support each linear kilometer of channel.
5. Longitudinal profile of the main channel indicates gentle terrain along the main channel.
6. The elongation ratio of the basin is found to be 0.731 and the circularity ratio is found to be 0.505. The elongation ratio values between 0.6 to 0.8 are generally associated with strong relief and steep ground slopes.
7. Agriculture is the predominent land cover of the basin.
8. The forested area amounts to be less the 19% of the basin area.

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