CS - 23

GEOMORPHOLOGY AND DRAINAGE PATTERN IN NORTH EASTERN GUJARAT (SABARMATI BASIN)

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PREFACE

The quick appraisal of dimension of the physical environment for biological management is the prime necessity. This is more so in semi arid land where the unbalance exist, between the scarce physical environment and bountiful biological needs. Water is the precious commodities in such lands. Keeping in view this phenomena, National Institute of Hydrology has taken up sabarmati basin for hydrological studies.

National Institute of Hydrology is engaged in conducting study and research in the area of hydrology. The Institute has established a Remote Sensing application Division with Major objective to apply remote sensing techniques in hydrological problem areas.

An attempt has been made in this study to map and analyse the Geomorphic units and drainage network, of sabarmati river basin. Landsat imagery of land 4,5, and 7 covering sabarmati basin were interpreted for the texture, shape, size and pattern to study the different geomorphic unit and drainage pattern developed under different climatic environment. The study enables to identify the land form such as hills, ridges, pediment, plain, marine landscape. For morphometric analysis, basin area, stream number, stream length, bifurcation ratio, drainage density etc.have been calculated. The study is carried out by Dr V K Choubey Scientist C and Sri S K Jain, Scientist B of the Institute. The report is an attempt to highlight potential application of remotely sensed data is mapping and analysis of geomorphic units and drainage network. It is proposed to conduct more exhaustive studies in number of river basin.

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CONTENTS

LIST OF FIGURES

Figure	Title	Page

LIST OF TABLES

ABSTRACT

In developing countries like India the quick appraisal of dimension of the physical environment for biological management is the prime necessity. This is more so in the semi arid land where the imbalance exist between the scarce physical endowment and bountiful biological need. Water is the precious commodity in such land. Keeping in view this phenomenon an attempt has been made is this study to map and analysis the drainage network and geomorphic units of the Sabarmati basin.

Landsat imagery of band 1,2,4 covering Sabarmati basin were analysed for the texture, shape, size and pattern to study the different land forms and drainage pattern developed under different climatic environment. The study enabled to identify the land form such as hill,ridges, pediment, plain, marine land scape. The basin area, stream number, stream length, bifurcation ratio, drainage density have been calculated. It can be concluded that a reliable drainage network can be obtained from satellite imagery and aerial photographs in the shortest possible period.

1.0 INTRODUCTION

Importance of Hydrogeomorphology - the bearing of geomorphology on hydrology is very significant and the relationship between the two fairly complex. The relevance of geomorphology for hydrological purposes is being increasingly appreciated. In cases where conventional hydrological data, are limited, non conventional approaches involving climatic, morphometric, geologic, environmental and other data may be used to get some idea of the order of magnitude of hydrologic characteristics.

The geomorphology describes the environment in which the hydrologic processes operate. Therefore, a strong mutual relationship exists between morphologic variables and hydrological characteristics, such relationship can be applied to both surface and groundwater regime. Terrain classification may give an assessment of the environmental situation and surface and ground water resources.

Potential sensors and attributes of Remote sensing techniques : Remote sensing , a recent spin off of man's space exploration is emerging as a powerful method for data acquisition of the earth resources. The various objects on the earth surface can be observed from balloons, rockets, aircraft, space shuttles & space crafts. The sensors used in remote sensing techniques include a variety of systems like :

Photographic camera system
vidicon cameras
Optomechanical line scanners
Push broom scanners
Microwave radiometers
imagery radar
Lasers

The sensors may operate in wavelength ranging from visible to microwave of electromagnetic spectrum.

The most commonly used sensors data have been the following :

Panchromatic black and white photography-Lands at MSS and TM data.ata.

The recently made avalable SPOT-PAN & SPOT-MULTI data and IRS-LISS II data, which provide relatively high resolution, image data,offer greater scope for applications.

The main advantages of remote sensing are :

Synoptic coverage, time and manpower saving, multispectral approach, geometric accuracy, repetitive coverage, feasibility in some cases, multidisciplinary applications, quantification and computer compatibility, repeativity and overall low cost to benefit ratio.

Thus remote sensing technique have a very important role in hydrogeomorphological investigations

Surface water drainage characteristics :

The remote sensing provide excellent information on distribution and types of surface features. Therefore it is evident that it has a great role to play in evaluation of surface water and drainage characteristics specially with regards to the following:

-Type of drainage (whether intermittent or perennial)

-areas of springs and rapids and their genetic types

-areas of water logging and their nature

-morphometric charactéristics of drainage and sub drainage basin including order, shape, size etc to bring out linear, aerial and gradient aspects of drainage basins.

-Drainage density and overland flow

-General idea on the steepness of surface slope and gradient

- type of vegetation and its density areas of the soil cover or bed rock.
- Infiltration into ground water vis-a-vis surface flow
- areas of inundation and flooding
- sediment yield of the catchment and silting estimates
- turbidity and sediment load
- river migration
- different types of fluvial land forms like meander scars, oxbow lakes, abundoned channels, back swamps, natural levees, point bars and their bearing on hydrologic regime.

Groundwater characteristics: for evaluation of Ground water characteristics it is necessary to develop a comprehensive hydromorphologic scheme involving both morphological and lithological parameters. The remote sensing data can provide highly useful information on ground water.

2.0 REVIEW

A number of studies have been conducted in India to map the various river basin characteristics using photographs and satellite imagery.

NRSA has carried out studies covering several watershed parameters using Landsat data. Drainage network maps with morphometric studies have been prepared for several area. geomorphological maps and soil maps upto association of subgroup level on 1:250,000 scale have also been prepared for most parts of India (NRSA,1977).

Space Application Centre (SAC) has under-taken a number of studies on geomorphology using landsat imagery (Sahai ,et al.,1980).

K.Krishnaunni and B.K.Barua (1980) have carried out geomorphological study of multidate imagery for Brahmaputra basin,Assam.In this the objective has been to compare the interpretability of the different image types, viz.air photos with stereo coverage, large scale photo formatted mosaics of MSS imagery for decephering geomorphology and Landuse. The second objective was to review the dynamic changes brought about by the fluvial processes over a period of 90 years as brought out by the available survey data.

Bhattacharjee et al.(1980) carried out a study on geomorphology of Bastar (Jagadalpur distt) through satellite images. An attempt has been made in this study to delineate the macro and micro geomorphic units with visual interpretation of landsat imageries on scale 1:1 million. The studies have revealed that a good landscape analysis map can be prepared from landsat within a short period of time.

A study of geomorphological map of Gujarat from landsat imagery analysis has been done by R S Murthy et al.(1984). In this study Land sat imagery of band 6 and 7 covering Gujarat state were analysed for the texture, shape, size and pattern to study the different Landforms developed under climatic environment. They identified the following landforms (i) Hill (ii) Table land, ridge and dome (iii) pediment (iv) Plain and (v) Mature Landscape alongwith there sub-units.

Niranjan (1988) has reported that satellite imageries could successfully, be used for studying soil erosion. It was found that basin parameters such as drainage basin shape and size could be studied from satellite data.

3.0 STATEMENT OF THE PROBLEM

The various hydrologic variable are requisite to be examined for their emenability and adoptability to remote sensing and subsequent use in hydrologic modelling. Remote sensing can best help in providing relevant information on land surface features and basin characteristics and this can be used to infer the hydrologic features like runoff potential infiltration, etc. A geomorphological and drainage map is of immense use to infer about runoff potential and ground water targetting of drainage basin. The Sabarmati river basin has been chosen for the study.

The objective of this study to extract information about Geomorphic unit and drainage characteristics of the Sabarmati Basin, using remotely sensed data for subsequently hydrologic modelling.

4.0 AVAILABILITY OF DATA

This study is carried out using landsat MSS imagery together with conventional data such as Survey of India toposheets and other reference material on the subject.

4.1 Landsat Imagery

The study area is covered in three frames of landsat imagery (fig.1). The imageries which were used for the study are given below (Table 1)

Table 1 Availability of Landsat data

S.No.	Path and Row No.	Satellite Sensor	Bands	
1.	147 - 044	MSS	4,5,& 7	FCC
2.	147 - 045	MSS	4,5,& 7	FCC
3.	148 - 048	MSS	4,5,& 7	FCC

4.2 Toposheets

The study area is covered in five Survey of India toposheets on 1:250,000 scale. A suitable base map of the study area was prepared from these toposheets.

The following are the toposheets used :

45 D
45 H
46 A
46 B
46 E

Index for these toposheets is shown in Fig.2

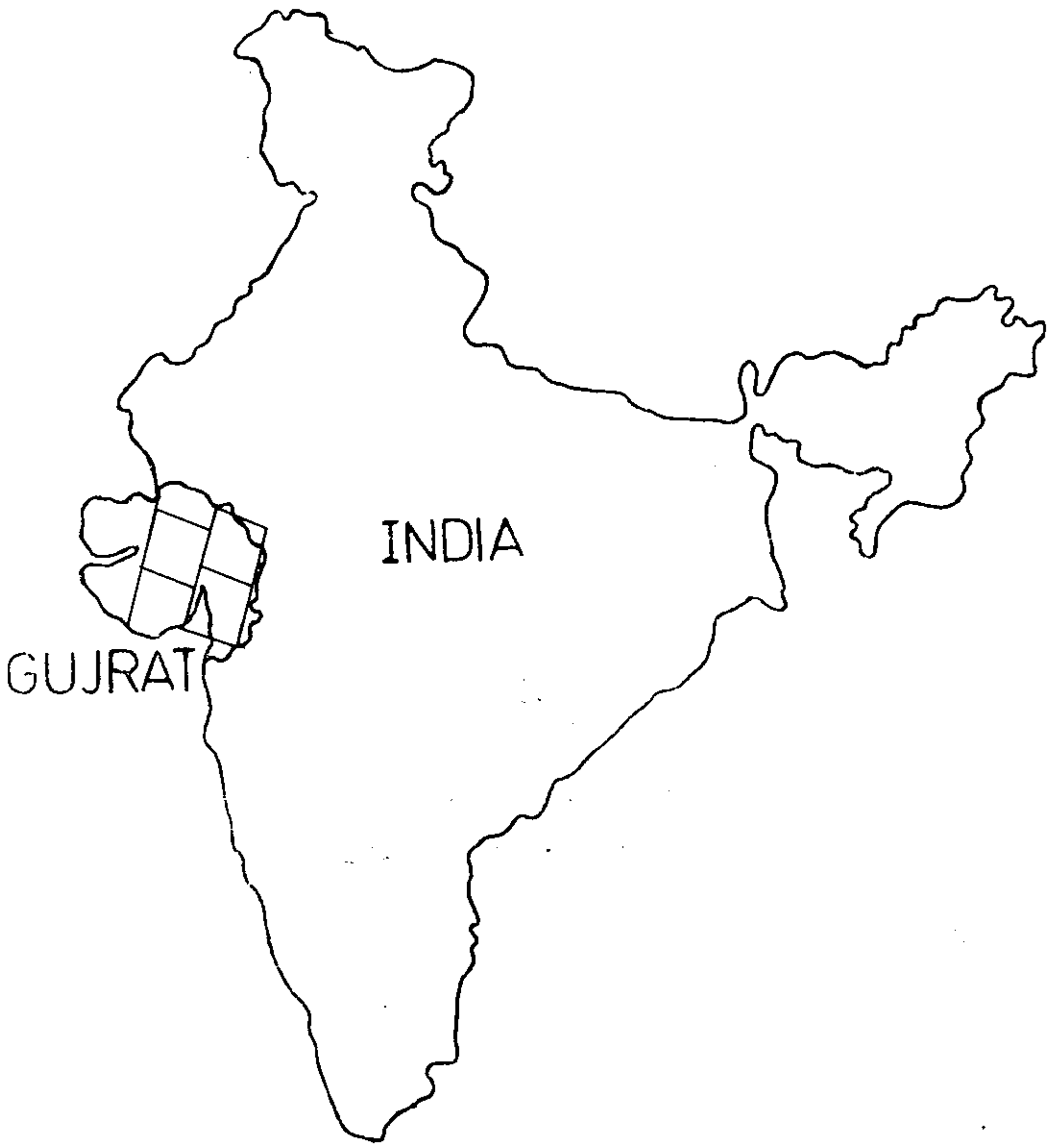


FIG 1 IMAGE INDEX OF LANDSAT 5
OF STUDY AREA

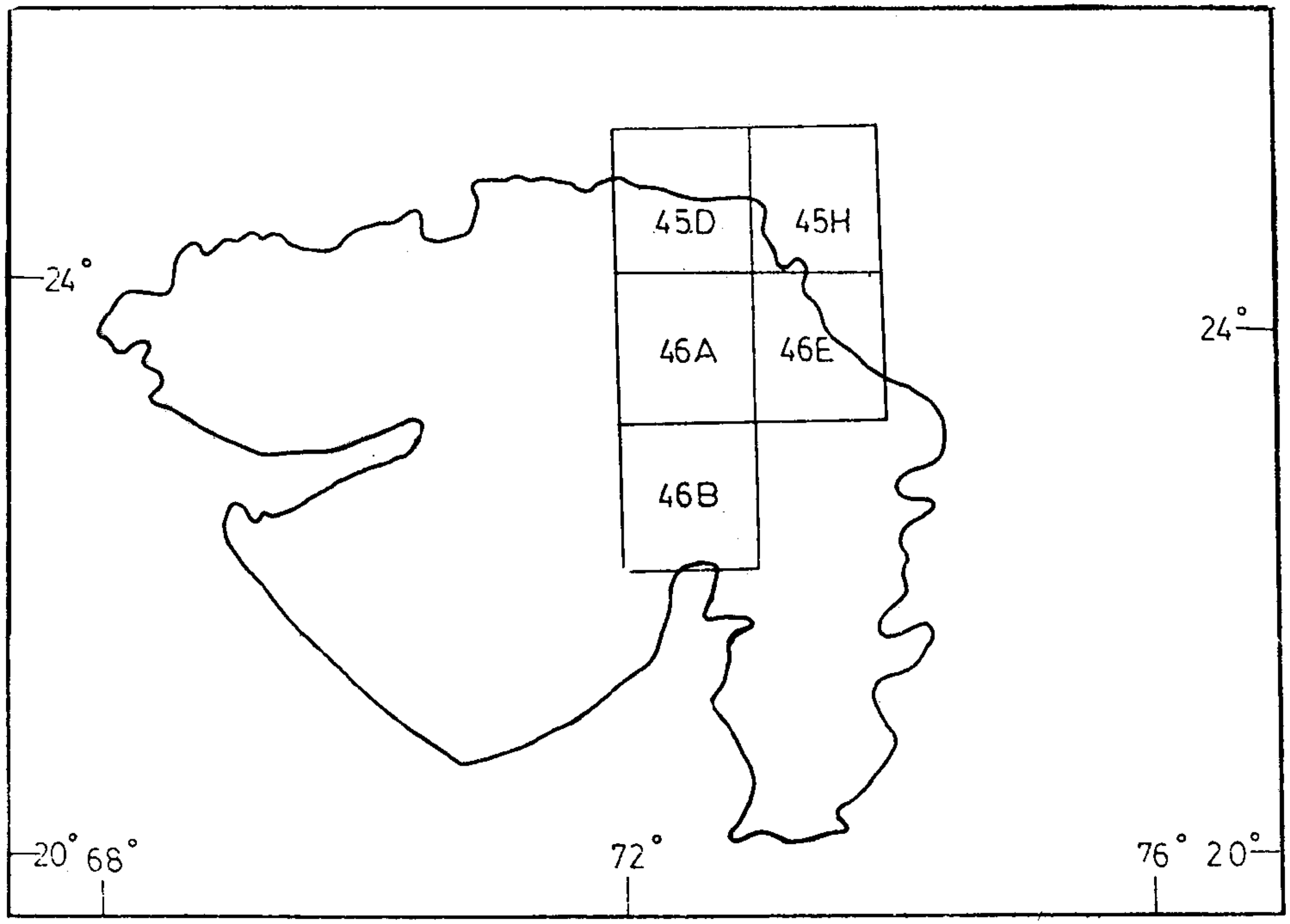


FIG 2 TOPOSHEET INDEX OF STUDY AREA

5.0 DESCRIPTION OF THE STUDY AREA

5.1 Sabarmati Basin :

The area under study is the Sabarmati basin. The basin has an area of 23823.44 Sq.km and lies between longitude $71^{\circ}15'$ to $73^{\circ}30'$ and longitude 22° to $24^{\circ}45'$.

The Sabarmati system consists of five main rivers, Sabarmati, Sei, Wakal, Harnav and Hathmati. It originates from the Aravalli Hills in Rajasthan state, not far off from the popular shrine of Amba Bhavani. It harness a length of 105 miles in south westerly direction dwindling among jungle covered hills,over a bed strewn with shingle and bounders before it enters Dharoi gorge. From here the river comes into the plains of Gujarat and flows south, with a slight westerly trend,till it passes Ahmedabad and ultimately falls into the Gulf of cambay,after having covered about 250 miles from the source.

The major structure located are Dharoi dam near Hadol and Subhash bridge and Wasne Barrage both at u/s and d/s of Ahmedabad. The Dharoi dam is located at a distance of 165 kms u/s of the city of Ahmedabad.

The river Sei and Wakal join the river Sabarmati u/s of Dharoi dam. Each of these tributaries has been claim built on them,Sei river and wakel river.

The river Harnav spills its water directly in the Dharoi reservoir. In the head reaches it has Harnav dam.

The river Hathmati joins the river Sabarmati at a distance of 70 kms d/s of Dharoi dam. In the head reaches it also has Hathmati dam which is ungated dam.

The river Watrak joins the river Sabarmati at a distance of 40 km d/s of Ahmedabad. In the head reaches it has Watrak dam at Bhempoda. It receives the water of Majhan and Mebhwa on the right side and shedi on left bank. Near about the end of river Sabarmati river Omkar joins which receives the water of Bhogva river.

Hadol, Valasan,Vijapur, Sadra, Narora and Ahmedabad are located on the bank of river Sabarmati other important towns which are located in Sabarmati basin are Idar, Himatnagar, Mohanpur, Sanagli, Mehraj, Modasa, Dhanpura, Bayad, Parautil, Dehgam, Kapadvanj, Balasinor, Mahudha, Dakar, Anand,Nadiad, Sojitra, Motar,and Kaira.

5.2 Geology- the Geology of the area as evident from the geological records belongs to the archeans, Marine jurassic,Cretaceous,basalt and recent to sub recent alluvium and marine and aeolian deposts.

Age	Formation group
Quaternary	Alluvium, aeolian sand ,laterite
Upper cretaceous to eocens	Deccan trap
Cretaceous	lime stone and sand stone (Bagh beds) sandstone (Himat nagar)
Precambrian	Granite, gneiss calc-gneiss,schist limestone (Delhi) quartzite and phyllite(Aravallis)

5.3 Climate The climate of the area is tropical,semi arid monsonic type characterised by three well defined seasons viz monsoon, winter and summer. The southwest monsoon comes from third week of June and last upto the end of September. The average annual rainfall is 603.70 mm the intensity of rainfall is high during the months of July and August. The winter season starts from November to February. The summer season starts from March to May. The summer maximum temp 45^{o} in the Month to May, the mean winter temp $12.6^{o}C$.

The humidity is quite high during monsoon period and less during summer months.

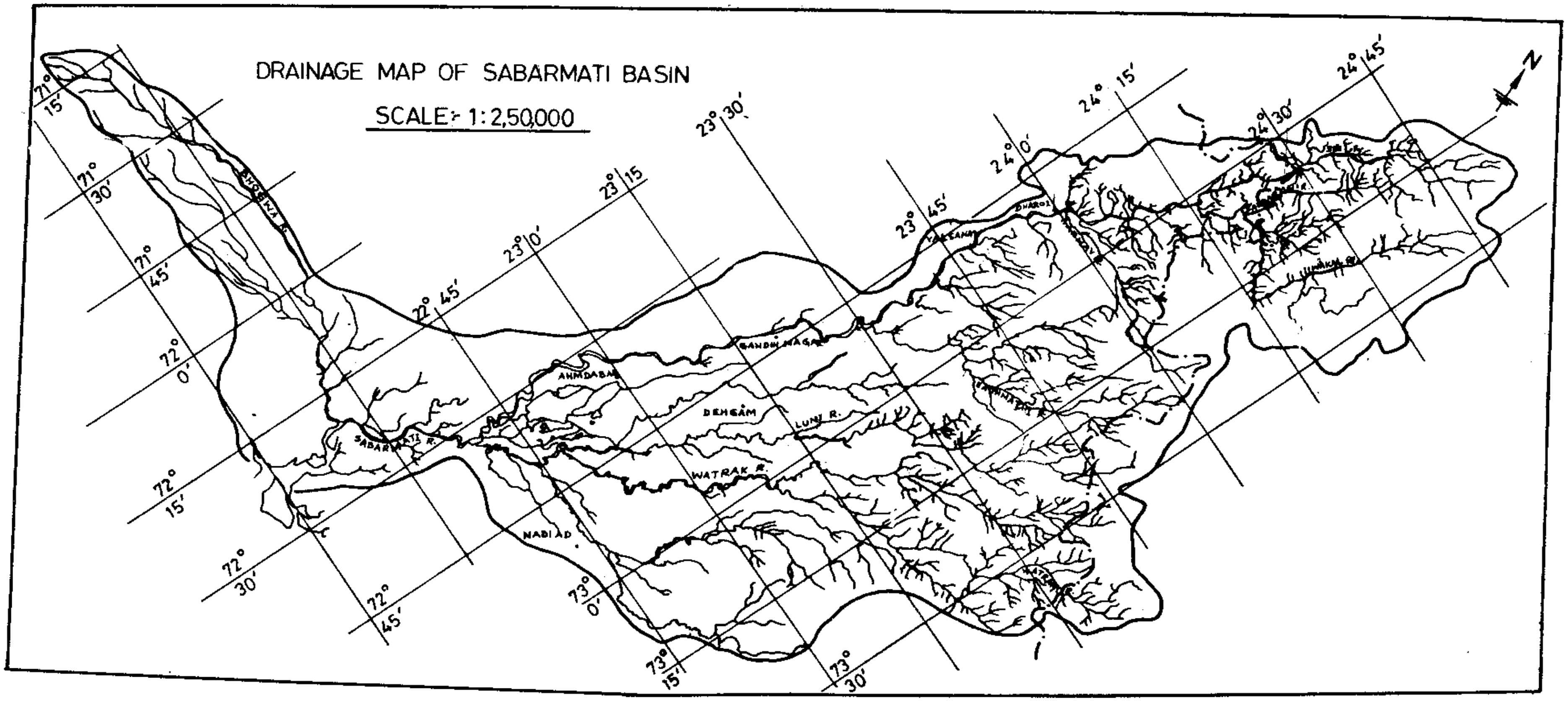
6.0 Methodology: Synoptic view, repetitive coverage and capability to view the scenes in several spectral bands have made remote sensing an effective tool in water resources assessment.

The landsat multispectral imagery (1:1m scale) were visually interpreted using standard photo interpretation techniques. For ground truth existing topographical maps, geological map and field data were consulted. It was observed that features, landscape pattern, vegetation, drainage and erosinal features were clearly visible. B & W imageries were enlarged using large format optical enlarger.

Various cultural features like road, railway line, towns were incorporated in the base map using Survey of India topographical map on 1: 250 000 scale.

The most important information available from aerial photographs and imagery is drainage pattern. Drainage pattern is a long term record of runoff under specific climatic condition that may have prevailed in the catchment. The drainage density and climatic condition will enable to determine the discharge due to surface runoff from drainage basin.

In the study drainage map is prepared using satellite imagery and aerial photographs (Fig.3). The courses of parennial, intermittent and



DRAINAGE MAP OF SABARMATI BASIN
SCALE:- 1:2,50,000
AHMDABAD
GANDHINAGAR
DEHGAM
LUNI R.
WATRAK R.
SABARMATI R.
NABIAD
N

FIG. 3

ephemeral streams of the Sabarmati basin were marked on aerial photograph and imagery.

The element in quantitative analysis of drainage basin stream order, length per unit area drainage density, stream frequency were analysed .

7.0 Analysis and Results

7.1 Geomorphic units: The study of tonal variation, shape and size of features, drainage characteristics, pattern analysis and location individually and in combination helped to separate out the land units on the imagery (Fig.4) which are described below. The image characteristics for different geomorphic units are given in table 2

Hills The tectonic hill, ridges,table land,mesas appears bold on imagery and can be easily separated out due to their distinct structure shape and size. The tonal variation and pattern as well as drainage characteristics are helped in identifying the tectonic features.

Aravalli ridges: Aravalli hill ranges occupy northern part of Sabarmati basin. The ridge and valley appear sharp on the imagery the longitudinal ridges exhibit light grey tones where as valleys are registered in dark tone on the imagery. The Sabarmati river flow through the valley.

Pediments

It is possible to distinguish pediments from other geomorphic features. All the upper reaches of the alluvial plain moderately erode pediment surface is visualised. It can be separated from the adjoining plain by its light tone being the result of the headward erosion process. Location and identification of other features assist in identifying the land unit on the imagery.

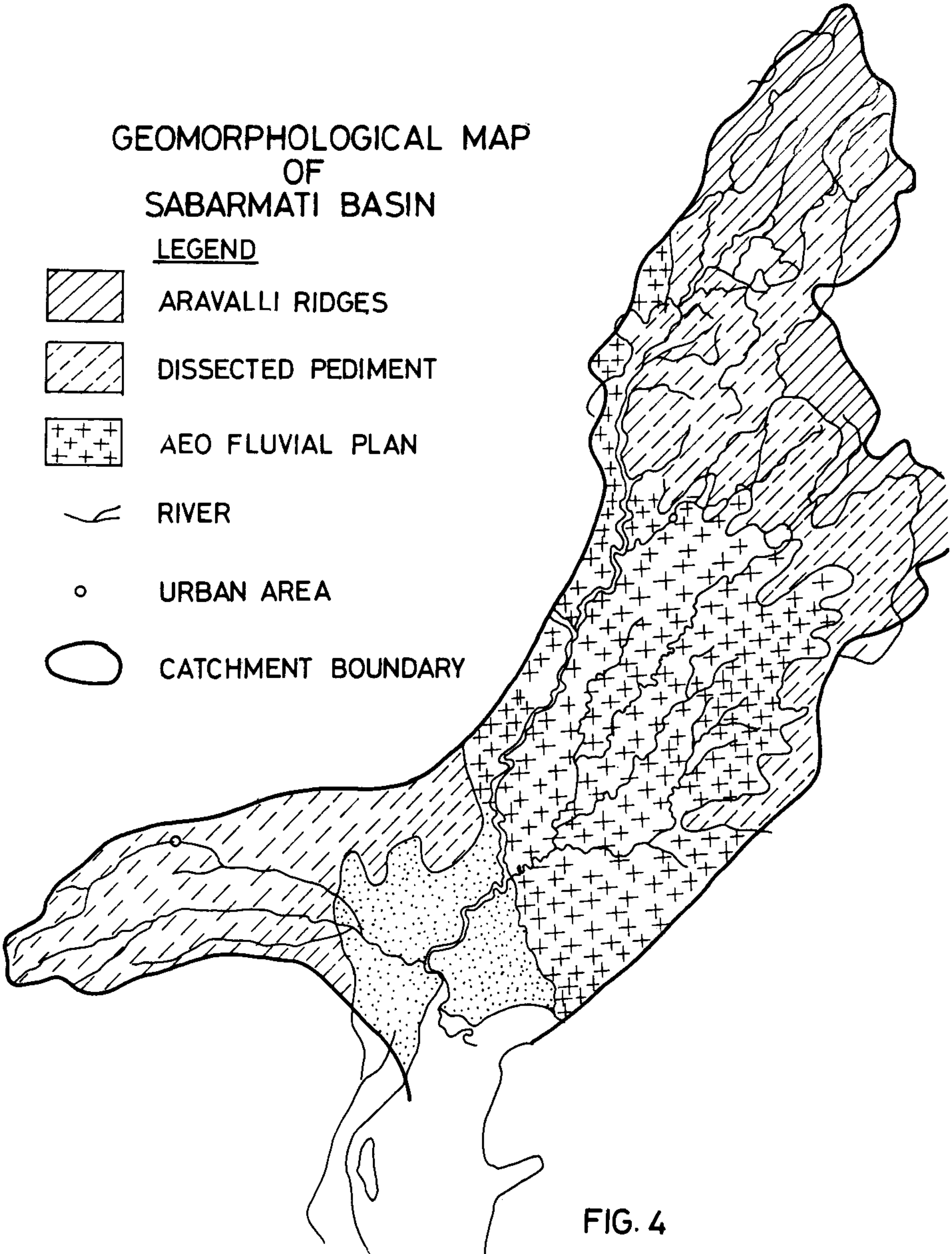

GEOMORPHOLOGICAL MAP
OF
SABARMATI BASIN
LEGEND
ARAVALLI RIDGES
DISSECTED PEDIMENT
AEO FLUVIAL PLAN
RIVER
URBAN AREA
CATCHMENT BOUNDARY

FIG. 4

Table 2

IMAGE CHARACTERISTICS OF DIFFERENT GEOGRAPHIC ZONES

Land Form	Image characteristics
Hilly terain	Black & White : Predominantly dark grey tone, Valley - light grey tone C.P.-Publish blue color
Piedment zone	B/W Greyish white belt
Alluvial plain	B/W grey to dark grey tone coarse to medium texture C.P. Vegetation density Very high - Red High - dark brownish red Moderate - light brown Low - Pink Very low - faint pink Grass land - Yellowish pink
Sandy	B/W flat terain with light grey tone

CP :Color print

B/W :Black & White

Fluvio-aeolian plain: The river Sabarmati and its tributaries originated from Aravalli ranges and folded ridges have developed a huge plain surface in the semi arid to subhumid region of the basin. The plains surfaces can be separated from aeo-fluvial plain because of the visible meandering cources of the Sabarmati river as against braided drainage courses registered on the aeo-fluvial plain. The meandering dry river beds visible on the imagery denote the intermittent characteristics on the river system of Sabarmati as a whole. At places the erosional surface are developed due to severe etching of the surface resulting in the development of fine textured drainaged system.

Tidel inlet:

Tidel marshes and flats are outstanding landforms that occur along the coastal area of the state by glossy white and black tone on the imagery with artery drainage pattern. At the mouth of the river Sabarmati these characteristics are visible on the imagery.

7.2 Drainage Analysis

Drainage basin analysis involves the preparation of a drainage map, designation of stream order, measurement of channel length and catchment area etc. and thereafter computing various parameters like the bifurcation ratio, drainage density, from factor, circularity ratio etc. In the present drainage analysis survey of India toposheets have formed the data base. An accurate base map of the Sabarmati drainage basin, depicting all the channel networks including very small channels was prepared using 1:250 000 toposheets. The basin in covered in the four toposheets at the 1:250,000 scale 45D.45H.46A.46B&C.

7.2.1 Area of drainage basin:

Size or Area of the drainage basins is its most important physical characteristics because it directly affects the size of the hydrograph and magnitude of runoff. In the present analysis area of the drainage basin is determined with the help of dot Grid method. In the dot grid is constructed from a sheet of graph paper printed on tracing paper. The intersection of the grid lines represent 'dots'. The tracing paper grid is laid over the map on which the watershed boundary is out lined for the measurement of area. All dots falling within the watershed are counted. The area on the sheet for each dot is known.The area is obtained by counting all the dots.

7.2.2 Stream orders

The first step in drainage basin analysis is the designation of stream orders which is a measure of the position of a stream in the hierachy of tributaries. In the present study, Strahler (1957) system of stream ordering was used. In this system the first order streams are those which have not tributaries,where as the largest channel in a basin was assigned highest stream order. The second order streams receive both first and second order tributaries. The basin was found to have a sixth order stream.

7.2.3 Stream number

After having assigned the orders to the drainages, the number (Nu) of the streams for each order was determined and calculated (Table 3).The number of streams decreases with increased in stream order.

Table 3: Drainage Parameters of the Basin

Order No.	Number	Length (Km)Lu	Mean length (Km) $I_u = L_u / N_u$	Length Ratio $(R_l = \frac{I_u+1}{I_u})$	Bifurcation ratio $(R_b = \frac{N_u}{N_u+1})$
1	500	2738	4.64	-	-
2	82	873	10.65	2.29	7.195
3.	26	630	24.23	2.275	3.15
4.	9	308	34.22	1.41	2.89
5.	2	285	142.5	4.16	4.50
6.	1	63	62.5	0.44	2.00

Mean length ratio = 2.115
Mean Bifurcation ratio = 3.947

Then the bifurcation ratio were computed by dividing the number of stream segments of a given order by the number of segments of the next higher order. Thus

Bifurcation ratio $R_b = \frac{N_u}{N_u +1}$

The number of stream segments were plotted against stream order on a semi-lograthimic paper (Fig.5).

7.2.4 Stream lengths

Where the number of streams of various orders in a drainage basin are counted, their lengths from mouth to drainage divide are measured and averaged.

The mean length I_u for a given order was obtained by dividing the lengths of segments N_u of that order u,Thus

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

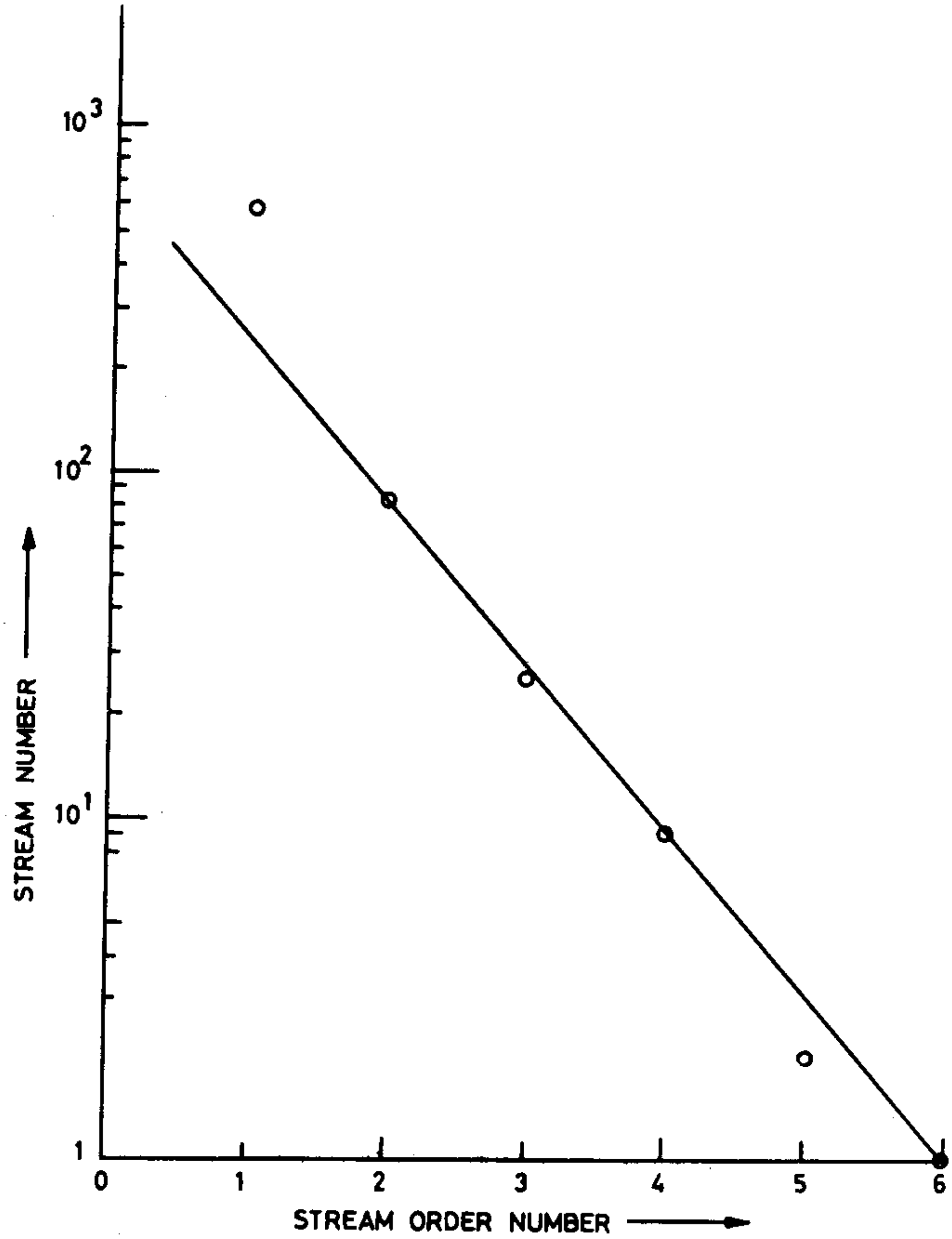


FIG. 5 STREAM ORDER NUMBER Vs STREAM NUMBER

The length ratio (R_c)is the ratio of mean length I_u of segments of order u to mean length of segments of the next order.

$$R_e = \frac{I_u}{I_{u \pm 1}}$$

A plot of stream length against stream order is shown in Fig.6.

The plot of total length and stream number shows a linear relation by Log Log scale (Fig.7).

7.2.5 Drainage density

The drainage density D is simply the ratio of total channel segment length comulated for all orders within a basin to the basin area Drainage Density $= \frac{EI_u}{A_u}$

The basin is found to have a drainage density of 0.205 (Table 4).

7.2.6 Stream frequency

Horton (1945) introduced stream frequency as the number of stream segments per 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 as .0297.

Table 4: Stream density and Stream Frequency

No.of channels Nu	Total length of channel(Lu)	Area of basin (Sq.Km)	Stream frequency $F=\frac{Nu}{Au}$	Stream density $D=\frac{Lu}{Au}$
709	4895.5	23823.438	.0297	.205

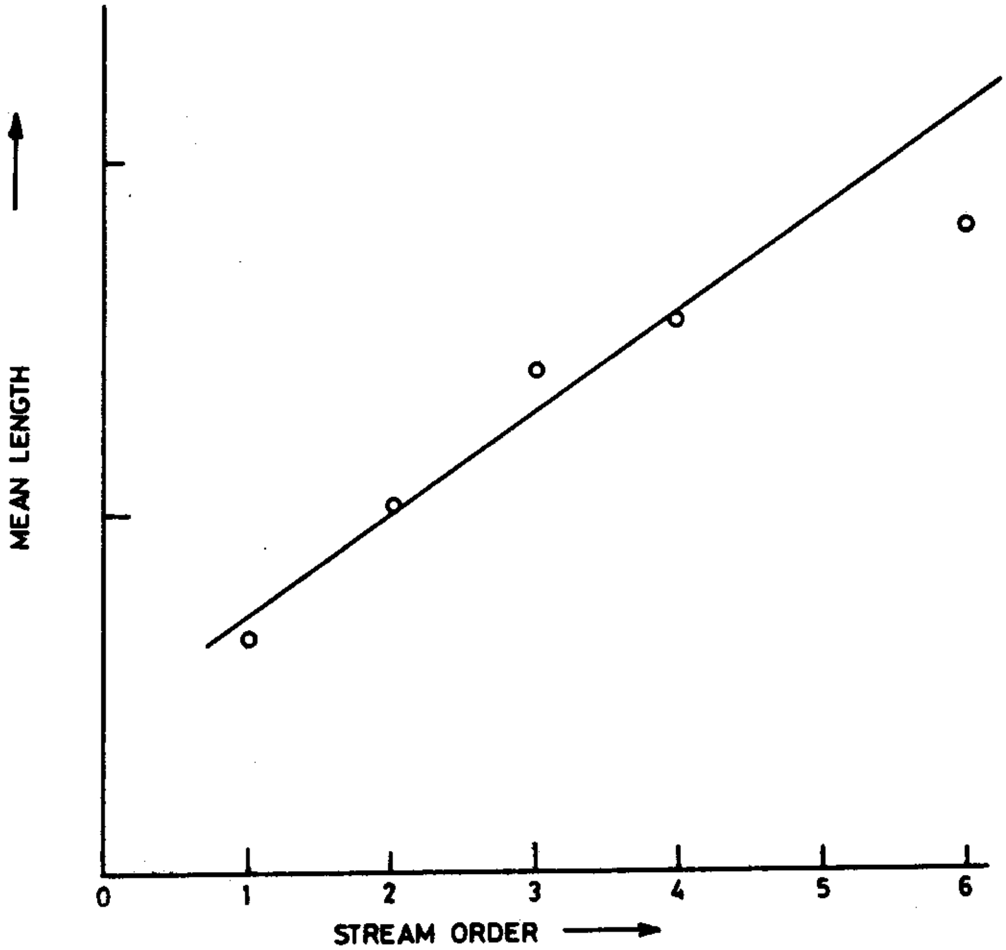


FIG. 6 - STREAM ORDER Vs MEAN STREAM LENGTH

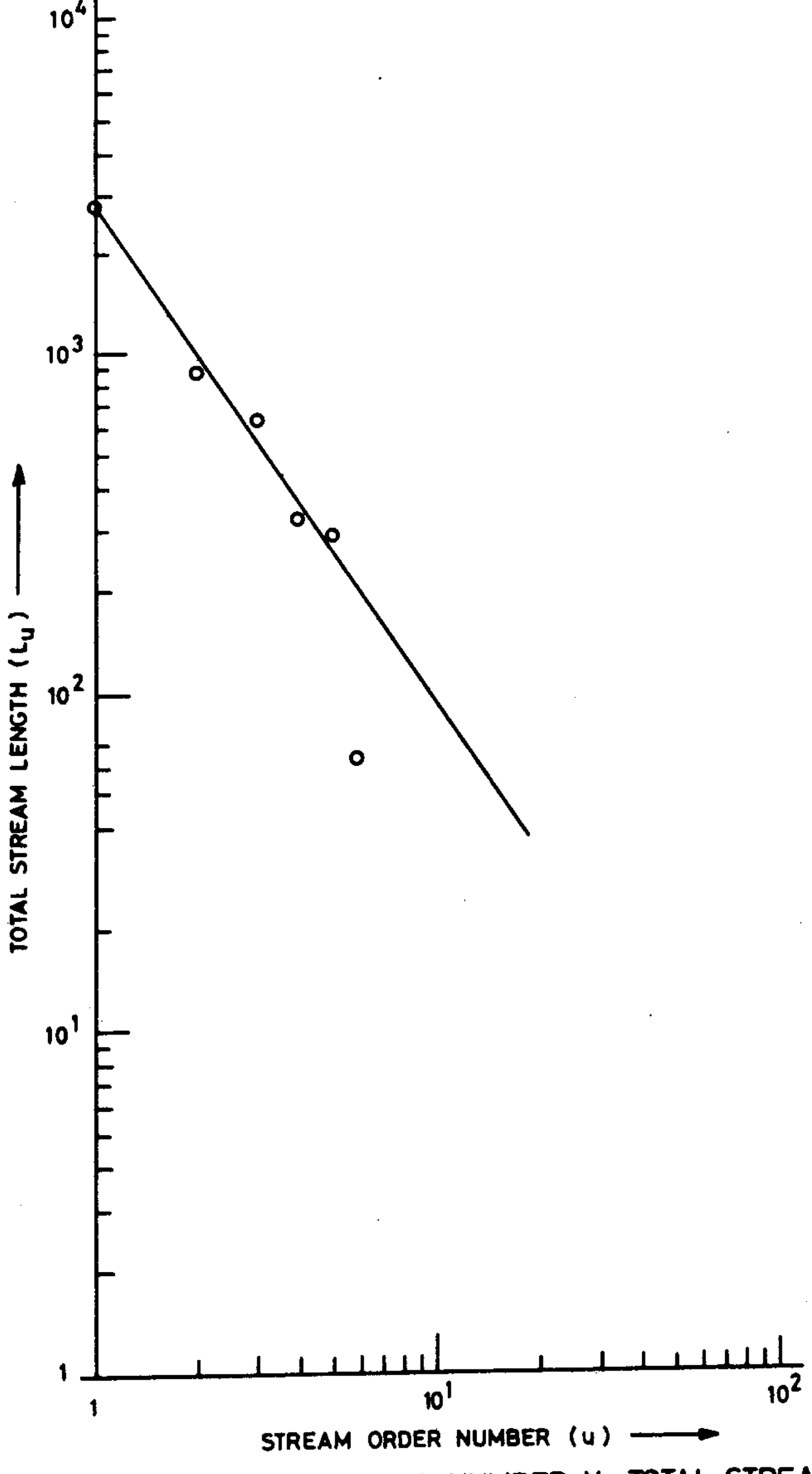


FIG. 7 STREAM ORDER NUMBER Vs TOTAL STREAM LENGTH

7.2.7 Length of overland flow

Length of overland flow is one of the most important variables affecting both the hydrologic and physiographic development of drainage basins. Horton (1945) defined length of overland flow to be roughly equal to half the drainage density. The length of overland flow calculated thus for the basin works out to be 2.44 Kms.

7.2.8 Constant of channel maintenance

It is defined as the inverse drainage density. The basin has a constant of channel maintenance equal to 40.8 sq.km./km.

7.2.9 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_c

7.2.10 Form Factor

It is defined as the ratio of the basin area A_u to the square of basin length L_b.

$$R_f = \frac{A_u}{L_b^{2b}}$$

This comes out to be 0.31 (Table 5)

Table 5: Basin Configuration Characteristics

Area of basin	Perimeter (Km)	Max.Basin length(Km) (L_b)	Main channel length(Km) L	Average width	Form Factor R_f
23823.438	1030	280	327.5	85.08	0.31
			Circulatory ratio 0.282	Elongation ratio 0.622	

7.2.11 Circulatory ratio

Miller has defined circulatory ratio as ratio of the basin area A_u to the area of a circle Ac having the same perimeter as the basin. The basin under has a circularity ration 0.282.

7.2.12 Elongation ratio

It is the ratio of diameter of circle of same area as the of the drainage basin to the maximum basin length. In the present case elongation ratio comes out to be 0.622.

8.0 CONCLUSION

An successful attempt has been made in the study to identify and demarcate the boundaries of various land units involved in the various morphogenetic environment and tectonic activities by visual interpretation of landsat imageries.It can be concluded that a detailed geomorphological map indicating major geomorphic unit can be prepared from the satellite imagery within a short period. The map may provide the planners a useful analytical fool for general evaluation of basin characteristics for planning.

REFERENCES

1. Chorley,R.J.(1969) the drainage basin as the fundamental geomorphic unit,Introduction to fluvial process II 30-51(chorley R.J.Ed)Methnen & Co.Ltd.

2. Harton,RE(1945) Erosional development of stream and their drainage basins hydrophysical approach to quantitative analysis Bull of Goel.Soc. of America Vol.56 pp 275-370.

3. Murthy R.S. et.al.(1984) Geomorphological map of Gujarat from landsat imagery analysis photo irvachak Vol.12 No.1 p.29-35.

4. Niranjan S.,,M.Y.Gajbi and M.L.Manchandra (1985) Physiographic Analysis for Small Scale Soil and Landuse Mapping of Mewat area, Haryana,using Satellite imagery, Photonirwachak,Vol13,No.1pp.49-53.

5. NRSA (1977) (1977) Satellite remote sensing survey of natural resource: Nagaland; NRSA: TR-023.

6. Strahler, A.N., (1957) Quantitative analysis of watershed geomorphology. Trans. American Geography Union, Vol.38, pp.913-922. Hand book of Hydrology, V.T. Chow.

7. Strahler AN (1964)quantitative Geology of drainage basin and channel net work (chow.V.T.,Ed)Handbook of Applied Hydrology-4 pp,39-76 Mc Grawhill Book Co.

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