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Srivastava Santosh Kumar
Associate Professor,
Department of Irrigation and Drainage Engineering, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India

Imtiyaz M
Ex. Head, Department of Irrigation and Drainage Engineering, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India

Denis DM
Ex. Head, Department of Irrigation and Drainage Engineering, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India

Srivastava Himanshu
Department of Geography, D.A.V, Post Graduate College, Dehradun, Uttarakhand, India

Mukesh Kumar
Centre for Geospatial Technologies, SHUATS, Prayagraj, Uttar Pradesh, India

Corresponding Author
Srivastava Santosh Kumar
Associate Professor,
Department of Irrigation and Drainage Engineering, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India

Flow dynamics of river Tapti at the distance between 650-700 km

Srivastava Santosh Kumar, Imtiyaz M, Denis DM, Srivastava Himanshu and Mukesh Kumar

Abstract
The spatial dynamics of the river for the period of 37 years has been analyzed by using GIS and RS tool. The entrenchment ratio is a major to understand the flow dynamics of the river where the observations are the ratio of flood prone width and bankfull width. The MSS 1975 data revealed that the river fall under the category of sinuous at a downstream length from 650 to 700 km and the TM 1989 imaginary also reveals that the river is sinuous and the ETM 2009 imaginary reveals that again the river is moving towards sinuous. At each observation point, there is a decrease in the flood prone width and bankfull width is identified due to sedimentation process of the river. Our study indicates that remotely sense data can be used successfully to define basic characteristics of the river.

Keywords: Meandering, sinuosity, entrenchment ratio, soil erosion, rural development

1. Introduction

As early as 4000 B.C. people built dams across rivers to store water, dug canals for navigation purposes and also for irrigation purpose. These earlier civilization were confronted with problems of flood control therefore, Chinese had been developed dikes for the protection of inhabited areas against flood. Thus, the drawn of civilization, mankind has faced problems associated with rivers, and solved them to the best of their ability. Major rivers in world flows through different type of terrain and they represent similar geological functions. Tectonic process results in the uplift and formation of major mountain chain, while the world's major rivers systems help erode those mountains Jacobs *et al*. (1994) [10]. The Indus river and its river basin represent one of the world's highly developed and regulated river systems, with a history of massive inundation canals dating back four millennia (Jacobs, 2003) [9].

Traditionally, the channel pattern of a river has been classified into straight, meandering and braiding types (Leopold and Wolman, 1957) [12]. The channel pattern of a river depends on its plain form geometry and the processes operating within its reach Rachna *et al*. (2004) [15]. Someone, geomorphologist is interested in fluvial morphology principally should explained as a tool in explaining the origin of the present form of the surface of the earth. (Davies and Lee, 1984) [5] reported, cycle erosion in the primary action is the formation of the earth by the movement of water in the geographical or geomorphological cycle. It starts with nearly flat land surface, which is generally warped by the movement of the earth crust. This gives a rise to the increased erosive and transporting power of water flow from land, the water begins to carve the landscape into various forms. The development of remote sensing (RS) and geographic information system (GIS) have assisted to understand and assess the ease with which the data from different sources can be combined to the river morphology Yang *et al*. (1999) [22]. For an effective management of flood water in low lying flood prone areas, GIS and remote sensing technology are proving to be a useful and efficient instrument (Wagner, 1989; Wu and Xia, 1990; Rahman, 1992) [20, 21, 16].

Remote Sensing is the science and the art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lilesand and Kiefer, 1994) [13].

The data set of the required geological surface can be visually and numerically displayed for exploring relationships with geological and spatial data sets, identify locations which meet to specific criteria, making land use, should assess how to propose projects for area development. The information system consisting of spatial and non-spatial data can be modelled to obtain information, which can be directly used to implement for decision support scenario.

Others maintain that GIS and modelling are largely separate traditions in computer assisted geographical research that can be integrated Birkin *et al*. (1987) [2]. GIS is established method as a common feature for both in management and research in such diverse areas i.e. planning for urbanization, at regional and national level, natural resource inventory, morphological and geological analysis, and natural hazard evaluation. GIS may be the most important technology that resource managers have acquired in recent past.

Thus, the activities normally carried out by GIS include the measurement of natural and human made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems, elements, attributes, and relationships. These features can be of three types, points, lines, or areas (polygons). The data collected or discovered by numerical manipulation and modelling of different pieces of data, can be depicted through some type of maps, graphs or statistics.

The Geospatial analysis and integration of RS and GIS is a crucial tool for the resources manager to face the new challenges. It helps resource managers to develop, analyze, and display spatially explicit to deal with larger spatial scales such as regional landscapes. At its most fundamental level, RS provides a mean by which data can be produced and analyzed for an area and then incorporated in decision making or procedures (Colwell, 1983) [4].

Practically, a characteristic of water flow of river in a definite pattern tends to meander or not to flow in straight line because it is affected by many natural factors, which make the river to deviate from the straight-line path. The river of the Deccan Plateau region of central India are totally dependent on the monsoon and these rivers dry up in summer and almost all of them are non-perennial rivers.

Tapti, also known as river 'Tapi', is one of the major river in central India with a length of 724 km (Indianetzone, 2010) [8]. The geography of Tapti river represent land soil formation all along its course. The geology of Tapti river represents more or less similar pattern to the geology in Indian peninsula. The geology of Tapti river can be said as old and geologically stable region with an average elevation between 300 and 1,800 meters (Indianetzone, 2010) [8]. The basin of Tapti river has fertile patch of agriculture land in central India.

The information regarding the flow dynamics of Tapti river should be the main source of irrigation in the Madhya Pradesh, Maharashtra and Gujarat are lacking. Therefore the objectives of the present study are as follows:

1. To study the flow dynamics of the river Tapti.
2. To study the entrenchment ratio of the river Tapti.
3. To study the sinuosity index of the river Tapti.

2. Materials and Methods

2.1 Study area

The Tapti River is a river of central India. It is one of only three rivers in peninsular India that runs from east to west, the others being the Narmada and the Mahi River. The river rises in the eastern Satpura range of southern Madhya Pradesh and flows westward, draining in Madhya Pradesh's Nimar region, Maharashtra's Kandesh and east Vidarbha regions in the northwest region of the Deccan Plateau and South Gujarat, before emptying into the Gulf of Cambay of the Arabian Sea, at Surat. The river, along with the northern parallel Narmada River forms the boundaries between North and South India.

The Tapti river basin encompasses an area of 65, 145 Sq. km, which is nearly two percent of the total area of India. We studied the Tapti river at the length from 650 km to 700 km. The basin of the river Tapti is shown in Fig 1 (Plate).

2.2 Materials

The Survey of India, Dehradun, Uttarakhand, India topographical sheets of the river Tapti of year 1972 has been used for the study. The data of Landsat mobile satellite services (MSS), remotely sensed data set of 1975, data of Landsat Thematic Mapper (TM), remotely sensed data set of 1989, and data of Landsat Enhanced Thematic Mapper (ETM), remotely sensed data set of 2009.

The toposheets were mosiaced and georeferenced. The mosaiced toposheet covers the complete study length of the Tapti River. Georeferenced toposheets provide the informations about the features prevailing in the area and details of latitude /longitude for the study length of Tapti river.

2.3 Methodology

2.3.1 Georeferencing

The topographical sheets is geo-referenced by using the software program Arc GIS 9.3, using at one degree (1^0) polynomial geo-referencing operation. The satellite data were then subsetted with boundary of the study area and delineated from the toposheet to get the satellite imagery of the study area.

2.3.2 Digitization of bank full and central stream line

The 1975, 1989 and 2009 years Landsat satellite imageries were mosaic and geo referenced. The Satellite imagery of 1975 has been taken as reference map for change detection during the period of 1975 – 2009. The centre line of river flow is digitized through satellite imageries, this digitized bankfull and centre line measurement has been taken along latitude and longitude with the help of grid. A grid each of 500 meters square dimension is created for the study length of digitized Tapti river. Finally the Grids were superimposed on the digitized vector file of river Tapti and the measurement has been taken from the stream central line to left and right site.

2.3.3 Determination of Sinuosity Index

Sinuosity index (SI) is used to separate straight from sinuous and meander channels, (Brice, 1964; Ahmed and Fawzi, 2009) [3, 1]. The sinuosity index (SI) can be calculated as follow:

$$\text{Sinuosity Index} = \frac{\text{Length of Channel}}{\text{Length of meander belt axis}}$$

According to sinuosity index channel can be classified into three classes

Sinuosity Index <1.05 straight

Sinousity Index 1.05 – 1.50 sinuous

Sinousity Index > 1.5 meandering

Vector files of central stream of the river flow for the three mentioned years were digitized from satellite data by using the measurement tool Arc GIS 9.0, and the central stream width, bankfull width and flood prone area. The bank width dimension from the central stream line has been measured. The sinuosity Index is the distance measured between two points only stream divided by straight line distance between two points.

2.3.4 Determination of Entrenchment ratio

The Entrenchment ratio has been determined by dividing the width of the flood prone area by the bankfull width. The flood prone area is defined by measuring the width of the channel bank and bankfull width for different years on screen visual interpretation by using different years of satellite data. (Rosgen, 1994) [2] used the entrenchment ratio of the flood prone width to the bankfull width can be calculated as follows: Flood-prone width

$$\text{Entrenchment ratio} = \frac{\text{Flood-prone width}}{\text{Bankfull width}}$$

3. Results

The study length of river is studied technically by using different years of satellite data. The sinuosity of the river has been measured and presented in the form of sinuosity index (SI). Based upon the sinuous behaviour of the river, erodible and non erodible banks have been identified by the efficient role of RS and GIS tool.

3.1 Flow dynamics of the river

The flow dynamics of river is in the form of flood prone width and bankfull width. The centre line of the river Tapti has been determined by using topographical sheet. The flood prone width and bankfull width has been obtained through MSS, TM and ETM$^+$ along with the centre line of river, the MSS 1975 data revealed that the mean flood prone width of the river is minimum 400.94 m at 697 km and the maximum 8038.03 m at the distance from 661 km from the origin. Whereas TM 1989 data revealed that the minimum is 845.74 m at 681 km and the maximum mean flood prone width is 8126.50 m at 661 km downstream, as per ETM$^+$ 2009 data the width is minimum at 265.62 m at the distance of 678 km whereas the maximum width is 1153.02 m at 688 km downstream Fig 2. The mean bankfull width of the river according to MSS 1975 is minimum at 97.40 m at 697 km and the maximum at 5772.37 m at the distance of 661 km from the origin. As per TM 1989 the minimum mean bankfull width has been observed minimum 212.29 m at the downstream of 659 km from origin and the maximum is 5435.14 m at 661 km downstream. As per ETM$^+$ 2009 the minimum mean bankfull width has been observed 61.44 m at the distance 689 km from origin and the maximum has been observed 773.49 m at a distance of 695 km downstream as shown in Fig 3.

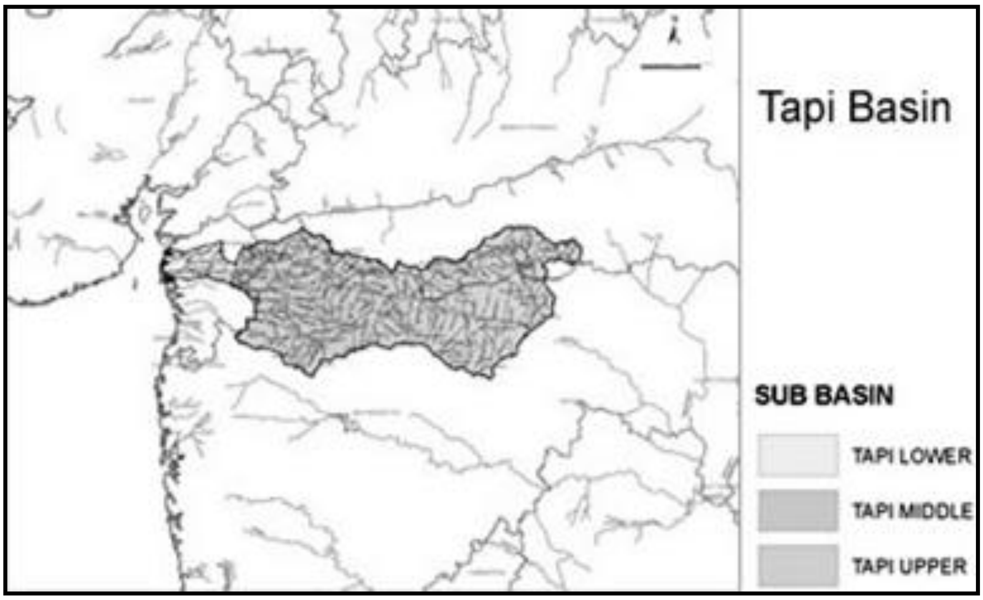

Fig 1: Basin of River Tapti.

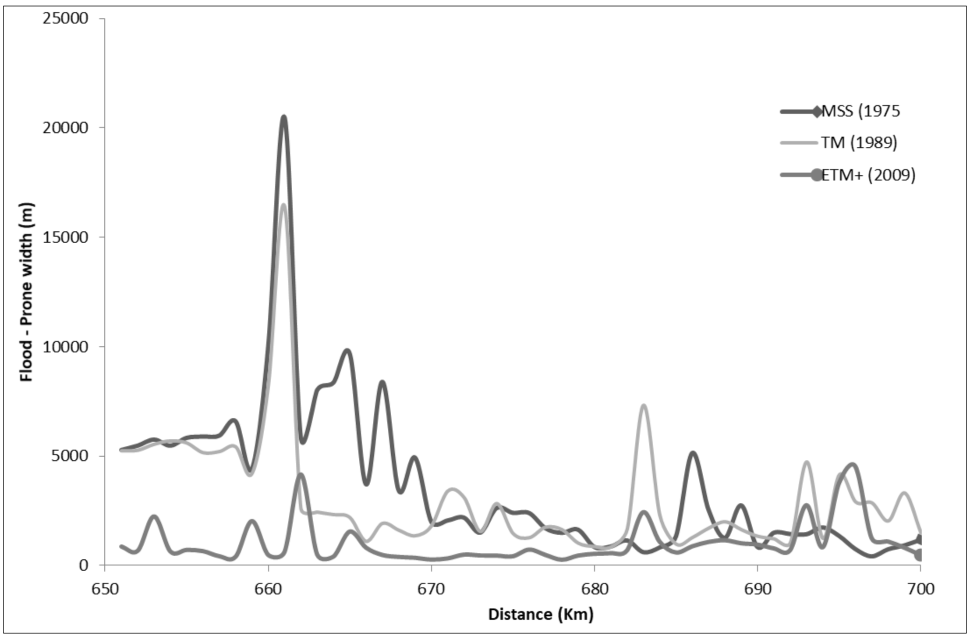

Fig 2: Mean Flood Prone width of the river from 650 to 700 km downstream

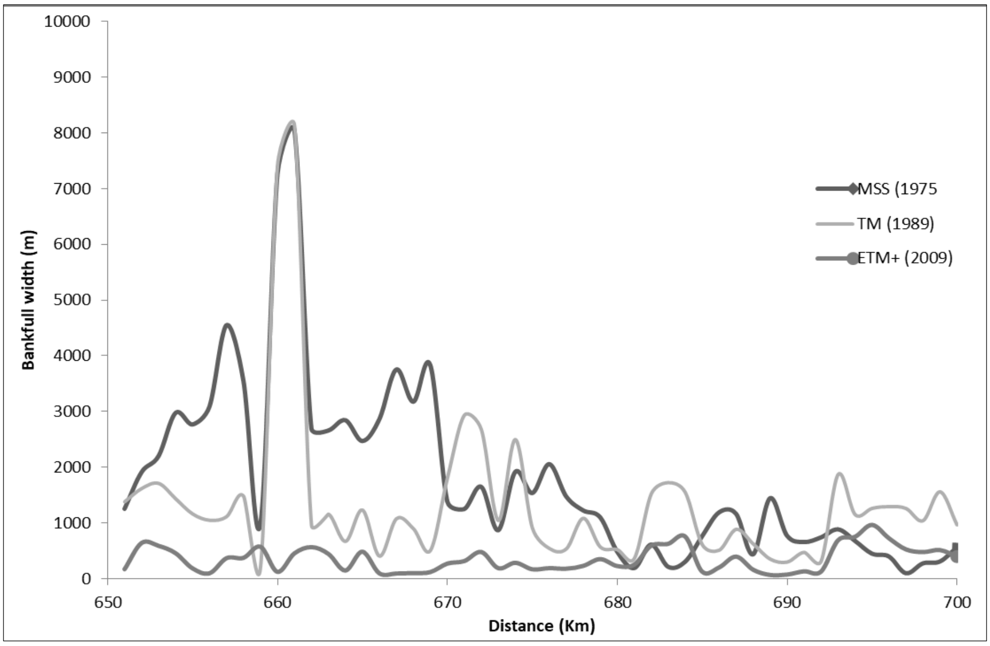

Fig 3: Mean Bankfull width of the river from 650 to 700 km downstream

3.2 Entrenchment ratio of the river

Migration of river course is due to the water currents at the river bends has been detected from satellite imagery of 1975, 1989 and 2009. Meandering river shifts their courses across the valley bottom by the deposition of sediments inside of bends which simultaneously eroding on the concave side of the meander. A channel is considered moderately entrenched when its ratio of flood prone width to bank full width is 1.4 to 2.2. It is slightly entrenched when the ratio was greater than 2.2 (Rosgen, 1996) [19].

The mean entrenchment ratio of the river from 650 to 700 km downstream according to MSS 1975 is minimum 1.23 at 686 km and the maximum is 4.49 at the distance from 659 km from the origin. As per TM 1989 the minimum mean entrenchment ratio has been observed 1.00 at the downstream of 670 km from origin and the maximum is 19.78 at 659 km downstream. As per ETM^{+} 2009 the minimum mean entrenchment ratio has been observed 1.01 at 670 km from origin and the maximum is 16.55 at the distance of 689 km downstream as shown in Fig 4. The peaks in Fig 4. Explain with respect to time the change in the mean entrenchment ratio of the river. We observed at each observation point there is a change in the entrenchment ratio because of the erosion and sedimentation process of the river Tapti.

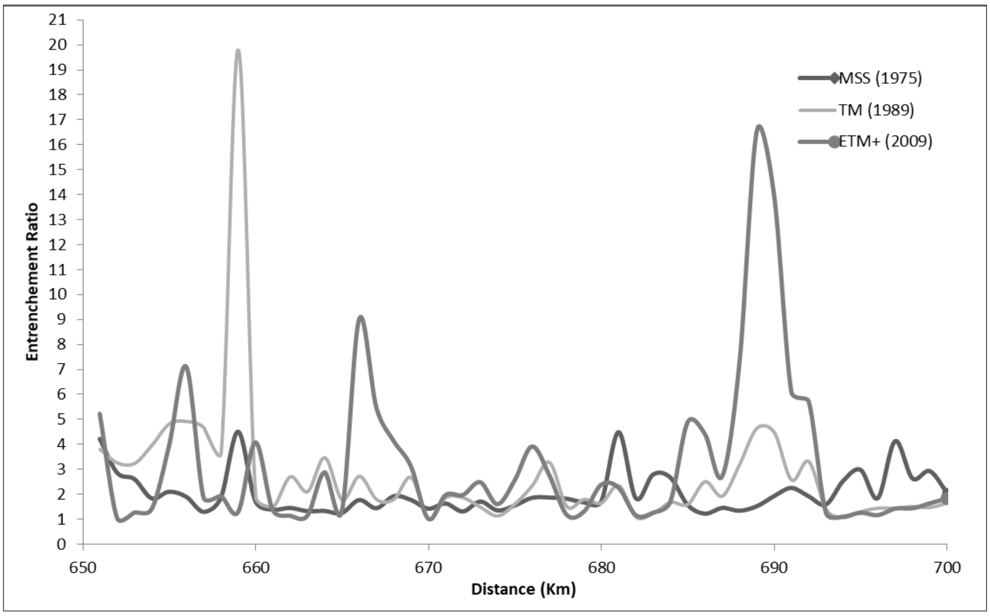

Fig 4: Mean Entrenchment ratio of the river from 650 to 700 km downstream

3.3 Sinuosity Index of the river

Peninsular rivers flow exhibit inherent flaw in existing indices which suggests that all streams with a value of unity are straight, because in nature all streams have significant departures from a straight-line course and, hence possess some degree of sinuosity (Mueller, 2005) [14], therefore the river has been classified into three categories namely straight where the sinuosity index is less than 1.05, sinuous where the sinuosity index is 1.05 to 1.5 and meandering where the sinuosity index is more than 1.5 as per (Brice, 1964; Ahmed and Fawzi, 2009) [3, 1].

3.3.1 Identification of the river lengths as straight
We observed that throughout the length of the river, the sinuosity index of the river is never found to be less than 1.05 in our study period, hence all along the course of the river, no length of the river has not been fall in this category Fig 5.

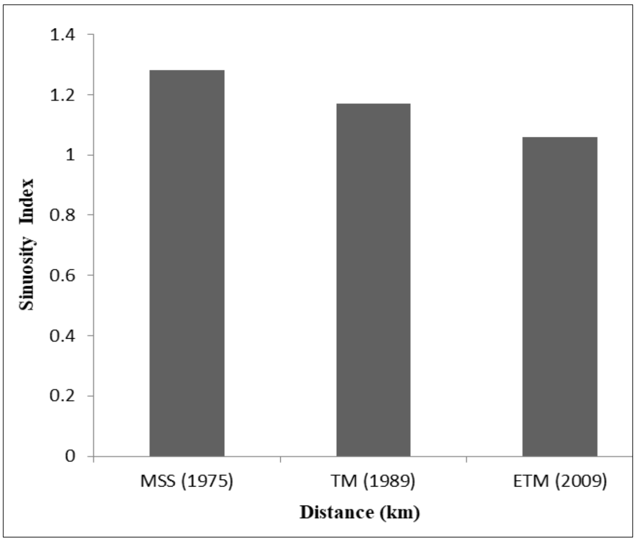

Fig 5: Sinuosity Index of the river from 650 to 700 km downstream

3.3.2 Identification of sinuous length of the river
The MSS 1975 data revealed that the river fall under the category of sinuous. After a time interval of 10 years 1989, it has been observed that the river is sinuous and in the year 2009 it has been observed that the river is again sinuous in river flow, our result show that the characteristic of the river flow dynamics is stable at study length. We report in the past 37 years the river Tapti is sinuous throughout, at a distance between 650 to 700 km downstream Fig 5.

3.3.3 Identification of meandering length of the river
We report the meandering nature of the river is extremely dynamic. Land sat imagery 1975, 1989 and 2009 played important role in our study area. Meandering of river has been determined by using Sinuosity Index. Meandering is the natural geomorphologic feature of rivers.

4. Discussion
Minimum spatial change in entrenchment ratio indicates that the river is stable. The study period showed a decrease in erosion and increase in sedimentation up to 270 ha with time. We studied fluvial processes across all scales in order to understand the complete impact on sedimentation into river basins. The sedimentation within drainage systems and sedimentary basins are a consequence of the inherent instability in transport processes. The cause of fluctuations are because of change in factors endemic to the supply of sediment but which are at least partly independent of erosive forces and changes in the magnitude of forces available to transport sediments. Fluctuation at spatial scales from minutes to millennia has been discussed and evaluated in our study. The irregular patterns of bed break-up during erosion can generate bed forms that are recorded in deposits, the passage of waves of sediment can cause cycles of incision and aggradations in a reach, large flood events will flush sediment into Deccan Plateau and will be recorded as an identifiable 'package' deposits. One of the challenge in the coming decade is to move away to study long-term averages of sedimentation, a geomorphological process, (Frostick and Jones, 2002) [7]. We found River Tapti does not indicate to be a river that has well develop flood plains. Large lengths of the river are still in the channel incision phase. The flood prone width and bankfull width adjacent to the stream provides extremely important geological impact that not only determine the integrity of specific stream which also influence downstream stream channel condition because the flow and boundary shear stress fields in meander bends are strongly affected by the presence of point bars, a phenomenon called topographical steering, found that forces arising from topographically induced spatial accelerations are of the same order of magnitude as the downstream boundary shear stress and water surface slope force components. In fact, some of the result showed that the forces arising from topographic tearing were of greater magnitude than the water surface slope force component, (Dietrich and Smith, 1983) [6].

Our method is allowed for stream sinuosity to those rivers which have down cut floodplain. Therefore, all stream-occupied valleys in the old stage of river cannot provide a sinuosity value greater than unity. (Kale, 2005) [11] studied gorge structure by the help of field measurement in same study length of the river but we report the use of RS and GIS tool in the estimation of characteristic of the river is found to be much more superior than estimating entrenchment ratio using field crew measurement because the meandering pattern and the cutoff meanders are another features observed normally in mature and old stage of the rivers (Ramasamy, 2005) [17]. The river cut off meander indicate that the river was once flowing in sinuous paths and subsequently meander may be due to hard rocks and soft rocks, and due to the increase in the land. The cut off meanders in particular zone should be given considerable attention at the time of planning permanent construction.

5. Conclusion
RS and GIS analysis proved efficient tool to find successful outcome of the study area through our study, because geomorphologic structure of the study is very dynamic due to volcano rocks of Deccan Plateau but some soft rock are also deposited in between the hard rock, which shows cut of meander, therefore field investigation confuse results. Analysis of data revealed that the change in land surface to water body is due to sedimentation lead to appear new land for Rural and Industrial development. It has been observed in our study that some of the land surface disappears completely due to migration of river, whereas in other new lands appear. The erosion and sedimentation has been explained by using Landsat imagery and analyzed the migration of river accurately. The process of sedimentation is in dynamic state along the river. Effects of sedimentation in rivers result change the natural waterway.

The geomorphological study plays an important role in planning, designing and maintaining river. To better understand the river problems on the basis of land surface, proper planning and designing of hydraulic projects must require, the geology and behaviour of the river are prerequisites. To successfully implement to improve 'the science of structure of form' proper geological and fluvial morphology technologies should be approach by hydraulic engineers for development of the study area. Introducing the principles of fluvial morphology and geology is necessary for hydraulic engineers to understand the problems arise due sedimentation and land slide brought by transportation and hydraulic deposition is required for further research.

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