



Volume: 2, Issue: 6, 92-98
June 2015
www.allsubjectjournal.com
e-ISSN: 2349-4182
p-ISSN: 2349-5979
Impact Factor: 3.762

Avijit Guray
M.Phil Scholar in Geography
Mewar University,
Chittorgarh, Rajasthan

Mandira Ghosh
Assistant Professor in
Geography, David Hare
Training College
Kolkata, West Bengal

A morphometric analysis of linear aspects of Usri river basin

Avijit Guray, Mandira Ghosh

Abstract

The Usri river basin is a portion of the Chotonagpur highland in the district of Giridih of the Bihar province in India. Geology of the basin is bewildering in complexity. From the Archaean to the recent Alluvium-all formations with their striking individuality are present here. The paper takes into account morphometric analysis of selected linear aspects of Usri River basin. The river basin is endowed with rich mineral resources and a proper understanding of these would lead to better utilization.

Keywords: River basin, Morphometric analysis, Stream ordering, Bifurcation ratio, Sinuosity index

Introduction

The drainage basin is considered as the fundamental unit of study. The importance of the drainage basin owes to its dynamism as an open system in the geomorphic process and landforms development such a system operation of drainage basin has been recognized for a long period of time. The measurement of various properties of a drainage basin is popularly known as morphometry. A drainage basin or fluvial morphometry includes the consideration of linear, areal and relief aspects of a fluvially originated drainage basin. Human activities such as agriculture, industry, communication system, settlement etc. have direct and indirect impact on the entire drainage system. From the perspective of holistic development of a region, morphometric analysis of the concerned drainage basin is necessary. Keeping in tune with this fact the present study is oriented towards a morphometric analysis of selected linear aspects of Usri river basin.

Objectives Every field study has one or several objectives to reach the pre-defined goals. Here the goal is to access the geomorphic significance and a complete evaluation of the Usri river basin in this tectonically important zone in quantitative terms. The study is made to clarify the role of geological structures on the development of linear properties at present time. Besides this, our aim was to study the drainage system and find out if there are any breaks in the course of the river. We tried to find that the drainage has adjusted to the structure or not, is the river rejuvenated or not. Also tried to make out the longitudinal profile in the Usri river and if it shows composite in nature or not. Does the fall mark is the present Knick-Point of erosion? And further tried to study the linear properties of the basin with a view that whether it follows the general laws or rules of linear properties of river basin or not.

Thus the main objectives of the study are:

1. Quantitative analysis of linear properties of the Usri river basin
2. Bi-variate and Multi-variate analysis of linear properties of Usri river basin.

Data sources and methods

Much of the morphometric analysis is commonly undertaken with the help of Indian Topographical Sheets (73 L/2, 3, 4, 7, 8) on a R.F. of 1:50,000 with contour interval of 10 metres. The toposheets are published in 1978 (1st edition).

The geological maps, physiographic maps and other related information are collected from various related text books. Also the geographic information about Giridih and its surroundings are collected from the website www.wikipedia.com.

The SRTM (2000, Shuttle Radar Topography Mission) elevation data of 90 m resolution has been gathered from the website www.GLCF.UMICS.UMD.EDU and www.srtm.csi.cgiar.org. The Landsat satellite image (1992) of the study area is collected from the website www.DLCF.umises.umd.edu. Also the google earth helped to see the basin in details.

Correspondence:
Avijit Guray
M.Phil Scholar in Geography
Mewar University,
Chittorgarh, Rajasthan

Methodology of the study is discussed under the following heads:

1. Pre-field study: At that time we have undergone through different concepts related to the study. Then we have collected the toposheets of the basin area and other necessary information.
2. Field study: We tried to collect all the necessary data and information required for the research work. At first, We tried to collect the data of cross profile and long profile of river Usri by Dumpy level, Theodolite and GPS. During the field study, there was no water on the Usri river, so we failed to measure the speed of water of this river.
3. Post-field study : In this phase, we have tried to reach our goal by preferring maps and diagrams from the collected data, prepared proper tables by the tabulation of data, we have prepared the cross and long profile of the river Usri, sinuosity index-all these works we have done by collecting data from scanned toposheets and using different types of softwares.

The Study Area Comprising an area of about 810 km² and lying between latitudes 24° 04' N to 24° 32' N and longitudes 86° 05' E to 86° 26' E. The Usri river basin is a portion of Chotonagpur highland in the district of Giridih of the Bihar province of India. The basin shares 11.74% of the total area of Giridih district lying in the mid-eastern part of the district. It comprises some portion of the five blocks viz. Giridih, Gande, Jamua, Bengadad and Deori (Fig. 1). There is only one urban centre i.e. Giridih town, which lies in the south-western part of the basin. The maximum north to east extension of the basin is about 27 km. The Usri basin is elongated in shape tapering north to south.

The basin is delimited by the drainage basins of the Ajoy and its tributaries in the east, Irga in the West, Burnur and Knuda in the north and Khako and Barakar in the south.

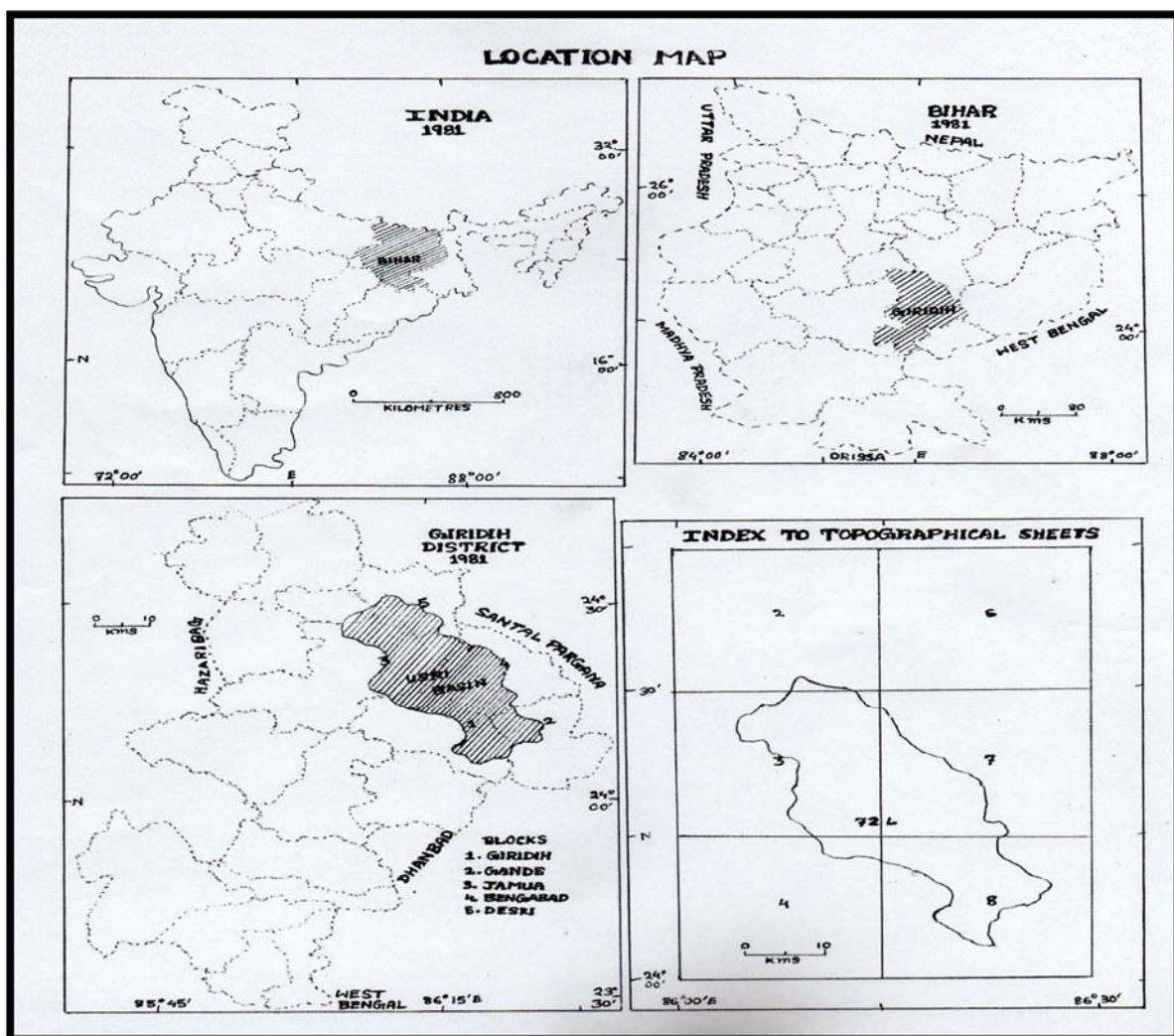


Fig 1: Location map of Usri river basin

Results and discussions

Morphometric analysis of linear aspects of Usri river basin: The morphometric analysis of linear aspects of Usri

river basin has been conducted with the help of the surface drainage map of Usri river basin (Fig. 2).

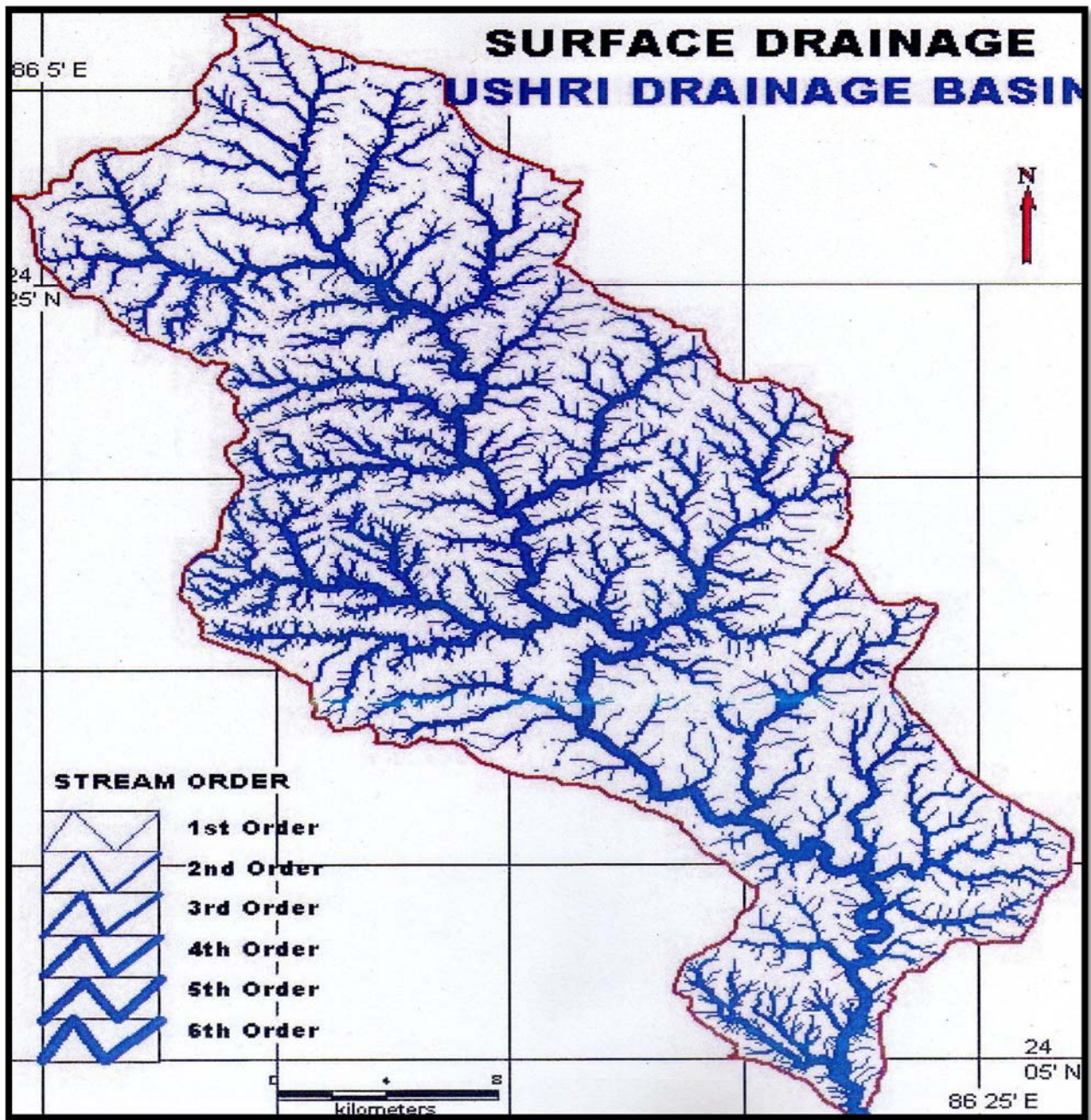


Fig 2: Surface drainage map of Usri river basin

1. Stream Ordering and Bifurcation Ratio: The first step in linear properties analysis is designation of stream order following a system introduced by Horton (1945) and modified by Strahler (1952). Assuming that one has an available channel network map including all intermittent and permanent flow lines located in clearly in defined valleys, the smallest fingertip tributaries are designed order 1, where two 1st order channels join a channel segment of order 2 is formed and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order.

Then Bifurcation Ratio (Rb) is developed considering the ratio between segments of required order and segments of the next higher order. It is assumed and proved that the calculated values tend to be a constant throughout the series. This observation is the basis of Horton’s Law of stream numbers and it follows the exponential relation.

The prepared stream ordering map (Fig. 2) and following table (Table 1) give the actual prevalent condition of the drainage network.

Table 1: Stream Ordering and Bifurcation Ratio

Order (U)	No. of Stream Segments (Nu)	Bifurcation Ratio (Rb) = Nu/Nu+1
1	2139	5.03
2	425	5.24
3	81	3.68
4	22	4.4
5	5	5
6	1	Mean Rb = 4.67

- i) Rb between 1st and 2nd order, 3rd and 4th order is high which is relevant in this plateau region.
- ii) The mean Rb gives the value of 4.67 which is between 3.0 to 5.0, then it indicates the highly dissected and high absolute region. It reveals the absence of flat and rolling up land.
- iii) It depends on geological structure, rocks, vegetation density, supply of run off water and steepness of slope in the basin.

iv) The average bifurcation ratio of this river basin is 4.67 which indicates that the basin belongs to the stage of late youth and early mature stage.

2. Long and Cross Profile: The actual profile of the Usri river shows upconcavity under a wide range of climatic and geological conditions. Upconcavity reveals a persistent downstream decrease in gradient. Gilbert had given an explanation of that upconcavity in his law of increasing activity. It is explained that upconcavity is an effect of increasing stream discharge in the downstream area. His law of deactivities states that gradient bears an inverse relation to

discharge because as discharge increases, channel cross section increases, reducing proportionately the functional losses of the stream and enabling it to carry its bed load. The concept is applicable here also because cross sections of different points approaching confluence indicate widening of valley and minimum depth of erosion.

The exponential curve of the Usri river shows the empirical graded river condition and equilibrium long profile. But the actual profile is far from equilibrium stage. The upper reach of river thalweg reveals the less erosiveness due to hard resistant rocks, the middle reach shows erosion and the lower reach shows deposition of sediments.

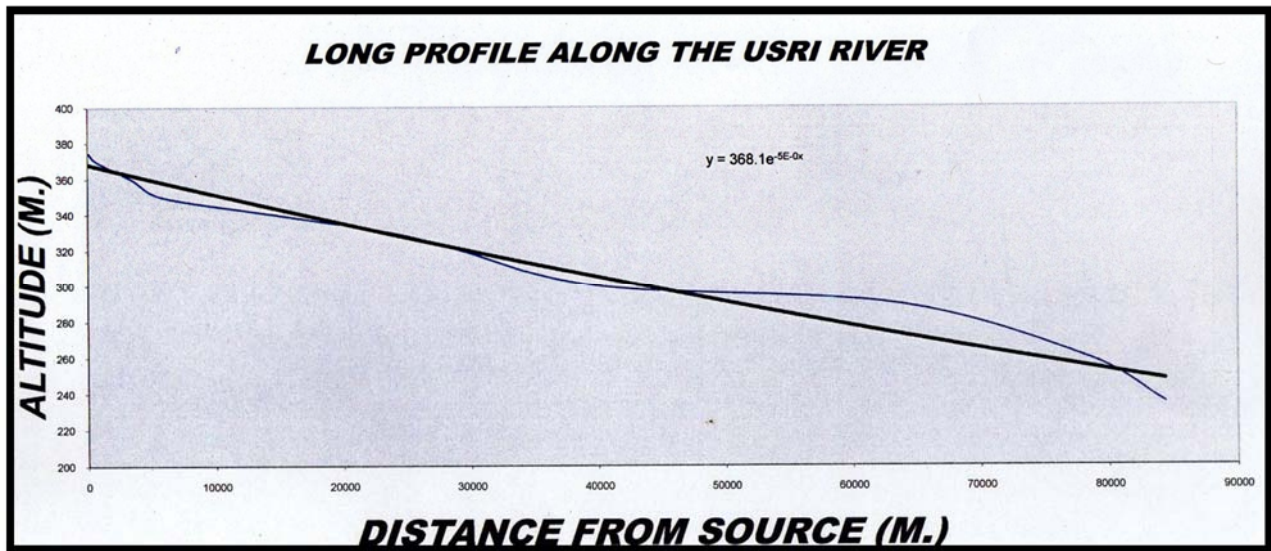


Fig. 3: Long Profile along the Usri River

There is one major break of slope near the falls of Usri river in the long profile. There has been upliftment of the entire basin in the tertiary period in two times. The basin has completed one cycle of erosion and now going through 2nd cycle of erosion.

Table 2: Location of Cross Profiles

Serial No. of Cross Profiles	Location	
	Latitude	Longitude
1st	24 ^o 27' N	86 ^o 05' E - 86 ^o 15' E
2 nd	24 ^o 22' N	86 ^o 10' E - 86 ^o 21' E
3 rd	24 ^o 17' N	86 ^o 07' E - 86 ^o 28' E
4 th	24 ^o 13' N	86 ^o 10' E - 86 ^o 23' E
5 th	24 ^o 08' N	86 ^o 20' E - 86 ^o 25' E
6 th	24 ^o 05' N	86 ^o 20' E - 86 ^o 23' E

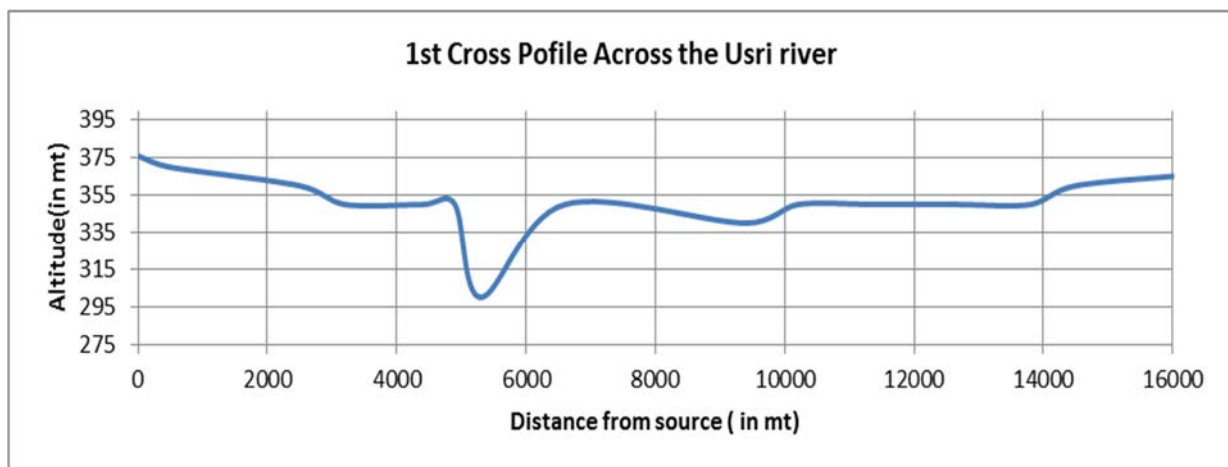


Fig. 4: 1st Cross Profile

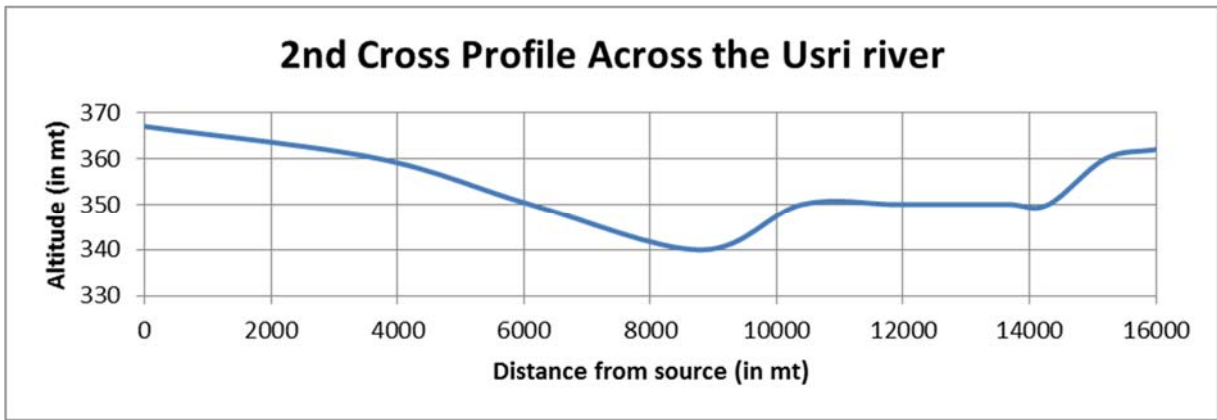


Fig. 5: 2nd Cross Profile

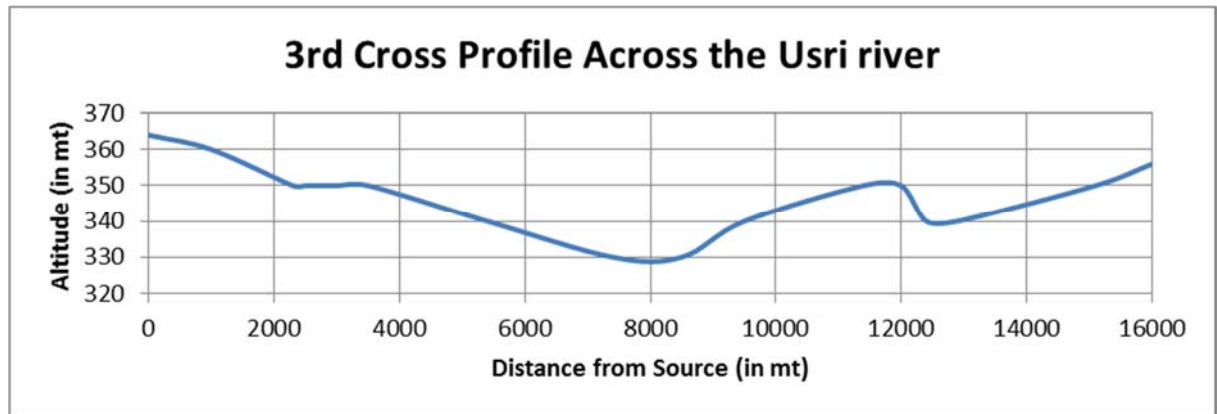


Fig. 6: 3rd Cross Profile

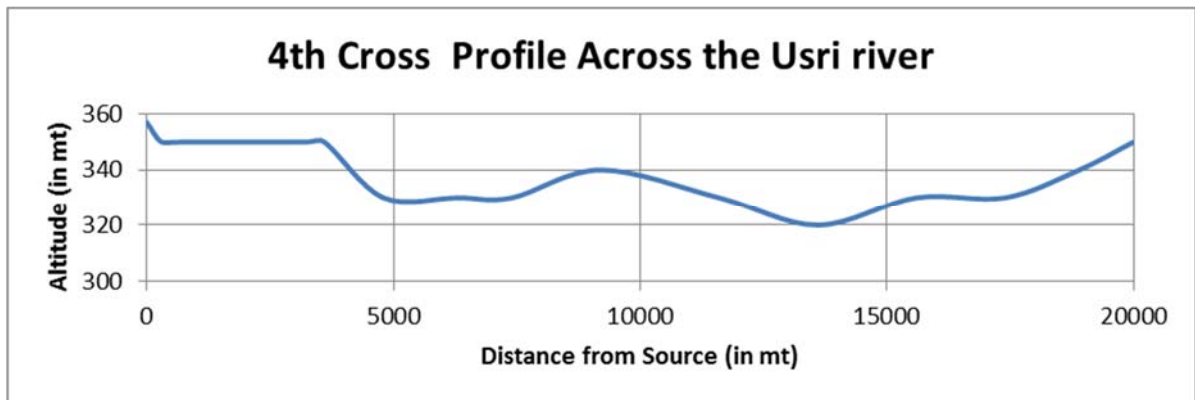


Fig. 7: 4th Cross Profile

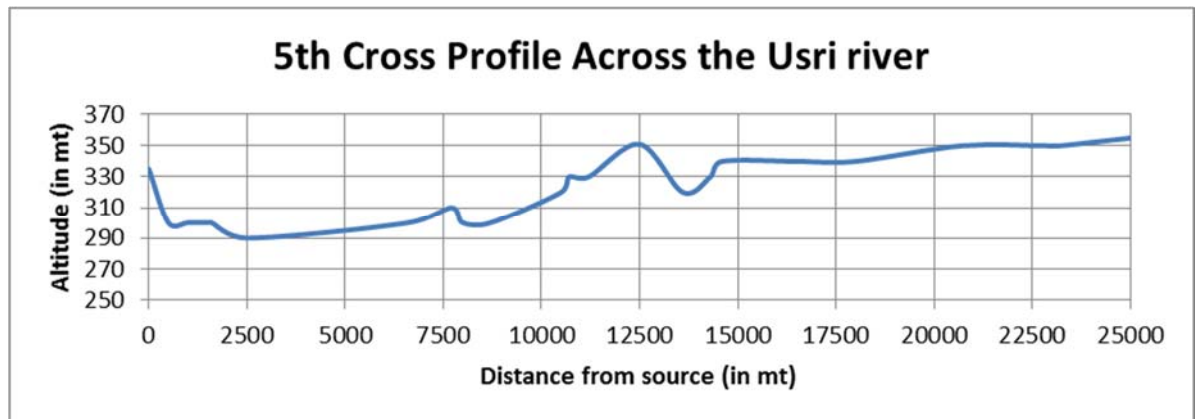


Fig. 8: 5th Cross Profile

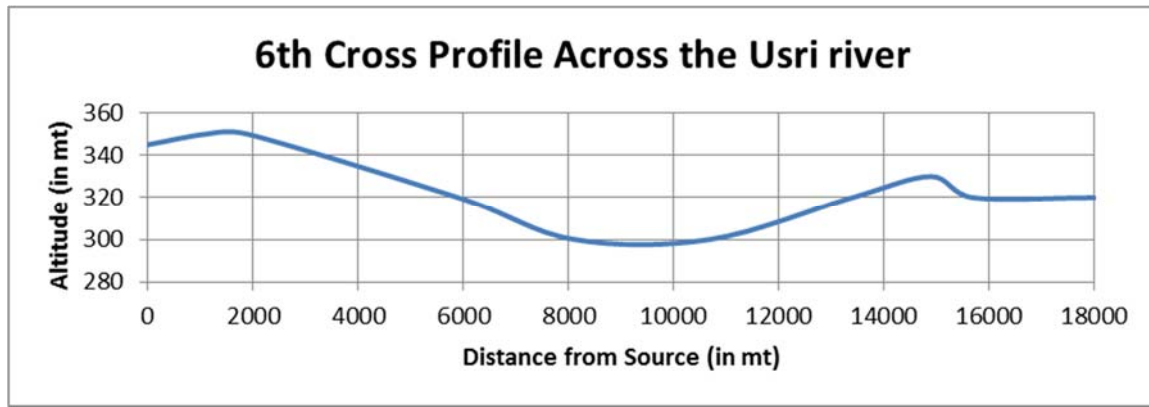


Fig. 9: 6th Cross Profile

3. Sinuosity Indices: Sinuosity of a stream denotes the degree of deviation of its actual path from expected theoretical straight path. The analysis of deviation of the course of drainage line from the straight path, say sinuosity may help considerably in studying the effect of terrain characteristics on the river course and vice-versa. Simultaneously the degree of

sinuosity may give a vivid picture of the stage of basin development as well as landform evolution.

The value of unity (1.0) of standard sinuosity index is indicative of straight river course where an index value between 1.0 and 1.5 put the river in sinuous shape and the value more than 1.5 represents the meandering course.

The sinuosity indices of the Usri river basin:

i. Channel Index (CI) = Channel Length (CL) / Air Length (AL) = 70.50 / 45.93 = 1.53

ii. Valley Index (VI) = Valley Length (VL) / Air Length (AL) = 70.64 / 45.93 = 1.54

iii. Standard Sinuosity Index = Channel Index (CI) / Valley Index (VI) = 1.53 / 1.54 = 0.99

iv. Hydraulic Sinuosity Index (HSI) = $\frac{\text{Channel Length} - \text{Valley Length}}{\text{Channel Length} - \text{Air Length}} \times 100 = 0.57\%$

v. Topographic Sinuosity Index (TSI) = $\frac{\text{Valley Length} - \text{Air Length}}{\text{Channel Length} - \text{Air Length}} \times 100 = 100.56\%$

From the above calculation it is found that the river Usri, flowing on planated rocky undulating surface have quite low HIS (0.57%) and high TSI (100.56%) values. From the values of SSI, it is clear that the river (Usri) course is straight because the value lies near 1 (0.99).

The value of TSI and HSI indicates the stage of Usri basin development. The TSI (100.56%) dominates over HIS (0.57%). So the river is on late youth and early mature stage (if other factors remain constant).

4. Relation between Stream Order and Stream Number:

The law of stream number relates to the definite relationships between the orders of the basin and stream numbers. If the order and number of streams are plotted on Cartesian coordinates with order along the X axis on an arithmetic scale and number along the Y axis on logarithmic scale, the points will fall on a straight line showing a negative exponential

relation i.e. decreasing exponentially with increasing order. Since it is only an empirical relationship, any such departure will have to be accounted for in the light of the structure, lithology, tectonics or other catchment characteristics.

Table 3: Stream Order Vs Stream Number

Order (X)	No. of Streams (y)	Y=log _e y	X ²	XY	Yc=ab ^X
1	2139	3.33	1	3.33	1960.75
2	425	2.63	4	5.26	431.37
3	81	1.91	9	5.73	94.90
4	22	1.34	16	5.36	20.88
5	5	0.67	25	5.35	4.59
6	1	0	36	0	1.01
21	2673	9.88	91	23.03	

The exponential relation of order and number of stream is $Y_c = ab^X$ or $Y_c = 0.22(8912.51)^X$

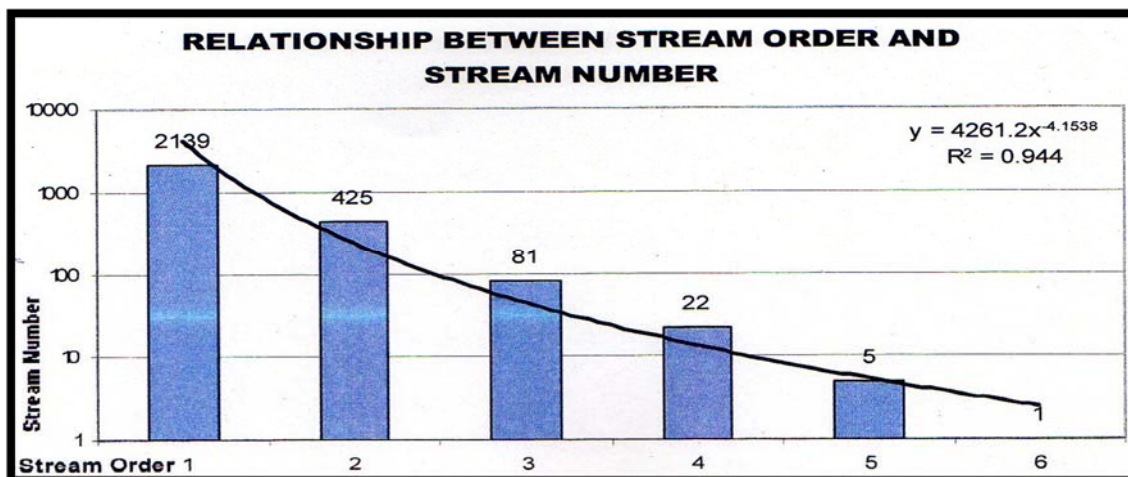


Fig 10: Relationship between Stream Order and Stream Number

5. Relation between Stream Order and Average Stream Length: The mean cumulative length of the stream orders increases exponentially to form a geometric series, beginning from the first order segment length according to constant length ratio. On a graphical representation with order on

arithmetic scale along X axis and mean cumulative lengths on a log scale the points corresponding to orders will fall on a straight line showing a positive exponential increase with increasing order.

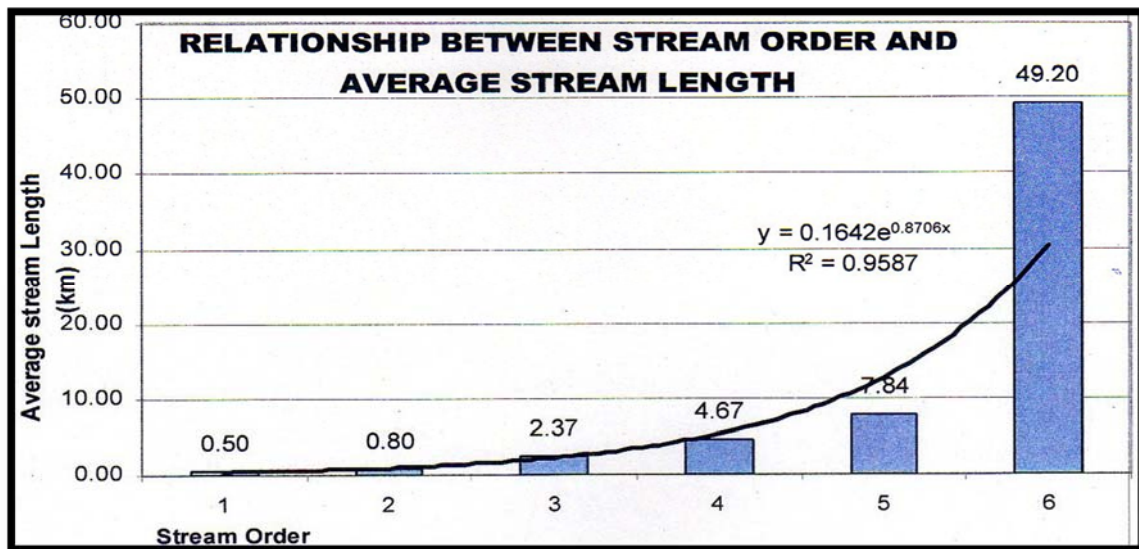


Fig. 11: Relationship between Stream Order and Average Stream Length

Conclusion

From the background discussion it can be easily said that the Usri river basin geologically and structurally displays very complex characteristics. From the long and cross profiles one major break can be identified which indicates the presence of a knick point near the Usri fall. So, it may be said that, this river basin belongs to the stage of second cycle of erosion. The relationships between stream order and stream number and stream order Vs stream length refer that the present position of this river basin is on late youth and early mature stage. That's why in this river basin erosion is high than the deposition. These help to formation of various erosional features like water falls, rapids, potholes, plunge pull etc. Being a part of Chotonagpur plateau, there is great possibilities of tectonic movements in future which will take this basin in the stage of third cycle of erosion. The Usri river basin is highly rich in mineral resources. Coal is the main natural resource of this region. Different types of economic activities are developed on the basis of coal. The river basin is less influenced by human activities still now. So different types of laws regarding linear properties are still now very much applicable in this particular river basin.

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