Morphometric Analysis of Mej Sub-Basin, Rajasthan, India, using Remote Sensing & GIS Applications

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Abstract: The morphometric analysis of Mej River sub-basin and its influence in different geological, geomorphological & hydrological parameters have been delineated in this study. For detailed information, we used SRTM (DEM) of 90m resolution for the analysis of linear, aerial and relief aspects. The Mej River sub-basin is developed in the Chambal thrust fault of Aravalli Super Group in Rajasthan, India, has been studied to understand the tectonic and geomorphic evolution on the basis of ground truth data & morphometric analysis. Most of the part of the basin is occupied by agradational landforms such as alluvial fans & River terrace deposits. The development of this linear basin is the result of Aravalli fault which brings the Vindhyan basin against the Aravalli rocks. This overall research reveals that the Mej sub-basin is rectangular in shape due to guiding effect of Chambal thrusting faulting event. Nearly straight flow path of Mej River indicates that the River is not sinuous in nature. So, the deposition has taken place in the form of lateral bar, channel bar. However, the transverse profile study of River reveals the confined margin found at mature stage and partially confined margin at old stage. The 6th order stream in sub-basin shows moderate stream frequency with more or less stream segments of different orders are affected by rainfall. The drainage density (Dd=0.39km/km2) reveals that the Mej sub-basin has moderately permeable River bed. The lemniscates (k=3.6) value defines that the sub-basin has partially affected by soil erosion. The mean bifurcation ratio (Rbm=1.9) value indicates that the drainage pattern of the basin is moderately affected by structural disturbance. Relief ratio (Rhl=4.5) indicates that the discharge capacity of sub-basin is very high with less ground water potential. This research study is very important in sub-basin management planning in hard rock terrain with semi-arid region for agricultural and settlement of the area.

***Keywords* -: Morphometric analysis, Mej sub-basin, SRTM (DEM), GIS**

I. INTRODUCTION

If we see the natural resources status in developing country like India then found bigger ratio difference between natural resources and population means population rate is so high as compared to natural resources. However, we are continuing moving towards the over exploitation of different resources, in which water is important resource to survive life. In the case of increases in the usage of water has affected both surface and groundwater supplies, resulting in an acute water crisis. This over exploitation of ground and surface water lead to drying up of the aquifer zones of different parts of India. So, it is necessary to recharge the basin for the water management program. On the basis of different uses of water in different sectors like irrigation, industry and most important use is drinking by human, animals and plants. In this study, we reveal the different parameters of water management of Mej River which is distributed in Rajasthan. On the other hand, the quantitative morphometric analysis is calculated by different mathematical parameters of the configuration of the earth's surface, shape and dimension of its landforms . The advantage of this GIS application is to enhance the large area information in terms of geology, geomorphology, climate and environmental aspects and to create and interpret spatial data accurately and precisely. The morphometric analysis of basin gives brief information of quantitative and qualitative description of the drainage system, which is an important aspect of the characterization of Sub-basins (Strahler, 1964). However, the morphometric analysis of Mej sub-basin is to represent a beautiful geological, hydrological and geomorphological network of River.

II. STUDY AREA

The Mej River is one of the main tributary of Chambal River in Rajasthan. The Mej sub-basin has semi-circular in shape includes 45O/02, 45O/03, 54O/04, 54O/06, 54O/07, 54O/08, 54O/09, 54O/10, 54O/11, 54O/12, 54O/13, 54O/14, 54O/15, 54O/16, 54C/01, 54C/03 and 54C/06. This sub-basin occupies an area of 24,848 sq. km. with perimeter of 1104 km in Rajasthan. Mej River has originated from Mandalgarh district (toposheet no. 45O/8) from Aravalli rock terrain at latitude 25°12'50.40"N and longitude 75°18'13.09"E an elevation of 1687ft and completes its 190 km flow journey with confluence (toposheet no. 54C/06) in Chambal River at latitude 25°40'30.73"N and longitude 76°17'34.18"E with elevation of 709ft in the sandstone rock of Vindhyan Super Group in Rajasthan.. The Mej River flows toward the NE direction and follows its 190 km path. There is one small tributary Kuralnadi pouring into the left bank of Mej River near Pipalda village and no major tributaries are on the right bank (Figure 1). For further detailed information of geology of Mej sub-basin is done by Geological Map of India proposed by Geological Survey of India which is digitized in Arc GIS 10.3 software. Some geologist and geomorphologist like Alexander (1979) et.al have also contribute their hard science work role in providing basic and notable geological information of India. In this research studies, we can define the different geological rock succession of Mej sub-basin comprises of hills of horizontal Vindhyan Super Group with basaltic Aravalli Super Group.

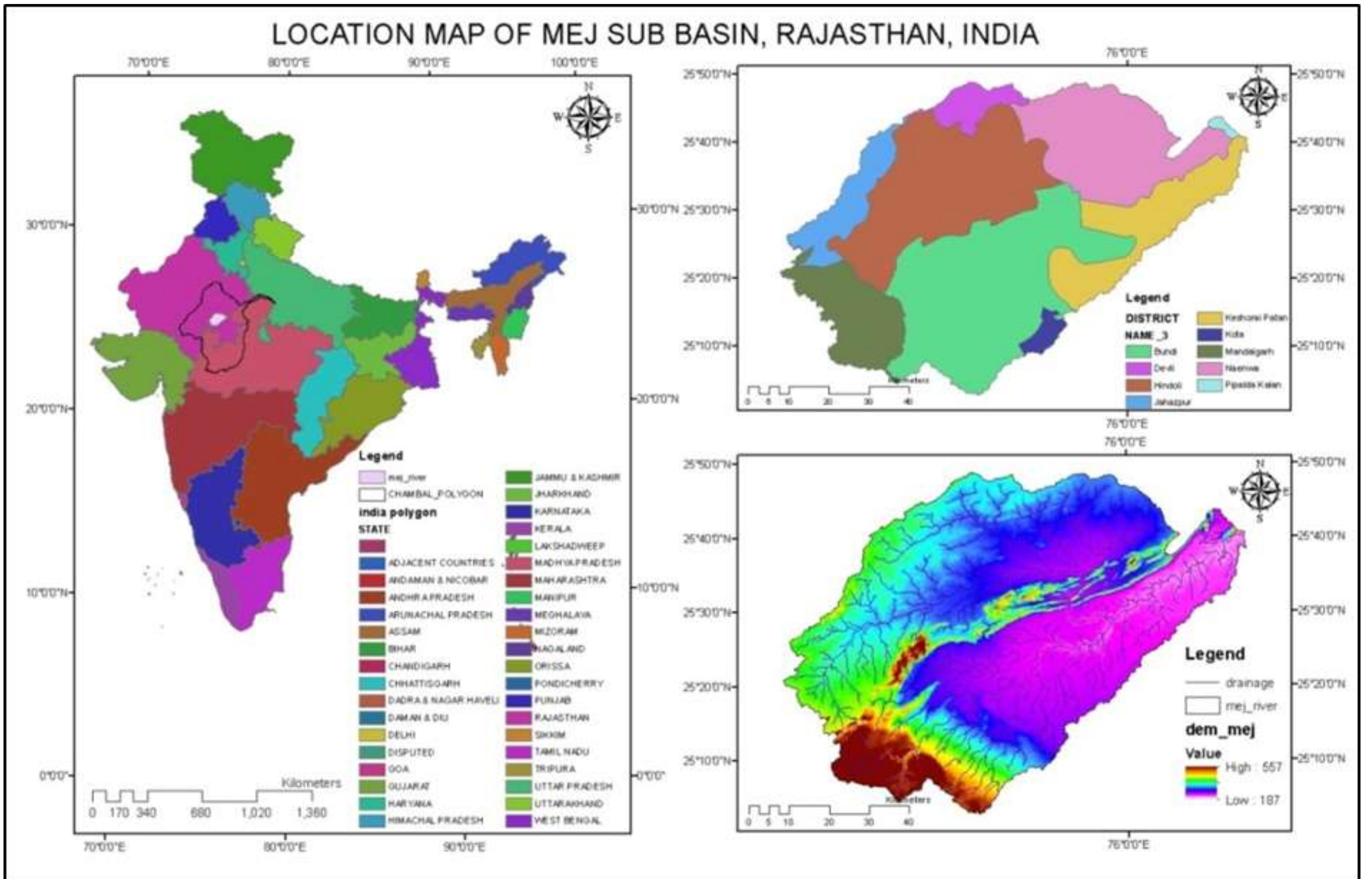

Figure.1: Location map of Mej River sub-basin

With respect to geological investigation of Mej sub-basin the area reveasl that the basin covers Vindhyan Super Group formation Bhander, Semri, Kaimur and Rewa, Mangalwar complex and Hindoli group of western Rajasthan which is associated with Berach Archean Granite and Vindhyan Bhander group. The geology of Mej sub-basin shows complex distribution of Archean. The small scale lineaments occur between the boundary of Bundi, Hindoli Naeinwa, Kishoraipathan which bring drastic change around 45° angle in Mej River flow path around 25 to 30 km, afterwards Mej River continuing flowing along the Chambal thrust fault (fig.2). Structurally the area shows anticline folds at and around Bundi district, Rajasthan. Geomorphologically, the area shows some eroded Aeolian landforms with Aravalli, Bundi hills and denudational landforms. The braided (around 1.2 km in width) condition in River is seen between the Aravalli faults. In Mejbraided condition formed due to change in slope after upliftment and then continuing deposition had taken place (fig.2). The soil and land is essential and important natural resource like flora and fauna conditions for balancing the cycle of ecology and surrounding environment. This is embodies soil, air, water and associated flora and fauna including the total ecosystem. General information by using spatial distribution of LULC categories and different pattern of their changes conditions in watershed management and utilization on land resources of the case study area. The land use pattern of Mejterrain is a proof of the complex sub surfaces physical processes which is acting upon hard rock terrain. These processes include impact of climatologically, geologically and topographically conditions with different distribution of occurrence of soils, vegetation with water. For better understanding the development and watershed management of the sub-basin areas, it is necessary to have basin information on geomorphological as well as pollution eco-environmental status.

Climatic condition of Mej sub-basin occupied under semi-arid climate. In semi-arid region the localized people depend on the groundwater and other anthropogenic process like dams, tanks, ponds etc. So, in that case the Mej River is only source of water in that major district like Bundi, Hindoli, Pipalda, Devil, Jahazpur,Naeinwa and Kishoraipathan. By using different Quantitative measurements of morphometric parameters is a important tools to make inferences about particular characteristic of an area like different scale of tectonic activities. Besides it, Some geomorphic tools like drainage basin analysis ie;, different stream length gradient index with sinuosity index are used to measure of active tectonics. The Landforms of Mej sub-basin are created via erosional and depositional processes and this drainage geometry is controlled by the shaping processes. Morphometric analyses is important tool require to measurement of linear features, gradient of channel network and also contributing lots of affections in ground slopes of the drainage basin (Nautiyal, 1994). The different quantitative morphometric analysis for individual sub basins has been achieved through measurements of linear, aerial and relief aspect of the basin and slope contribution.

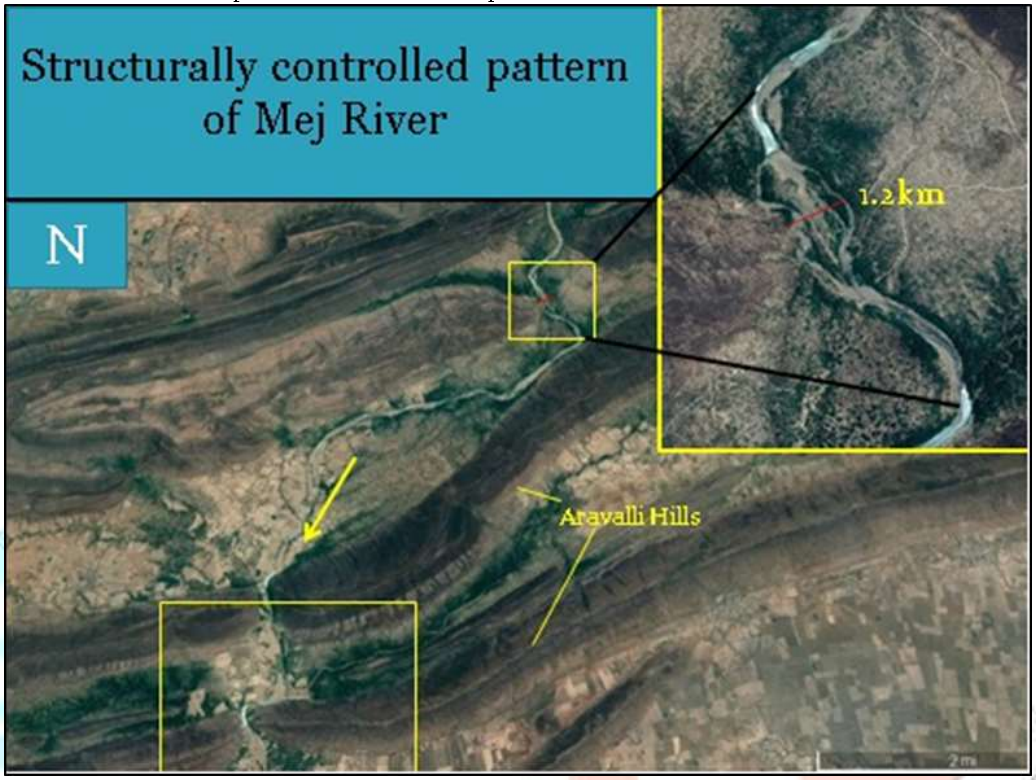

Figure.2: Mej River suffered by tectonic structures

III. METHODOLOGY

Morphometric analysis gives information regarding the hydrological and geological background of different rock formations which cover the drainage network of basin. It's also explained the permeability, water storage capacity of rock in terms of aquifer and gives the different yield of the basin. Geographic Information Systems and remote sensing, is very efficient tools in delineation of drainage network pattern and different geometric morphometric analysis by different methodology of geomorphological and watershed management. So, GIS has been widely used on large scale in several flood management, and environmental applications (Kaushik.P, Ghosh.P.2015). However, Applications of Geographical Information Systems (GIS) to geomorphological research have been increasing with the increasing complex morphometric evolution of large and restricted area. The morphometric characteristics at the sub-basin scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the sub-basin (Singh, 1992). The different morphometric parameters have been studied in this research on the basis of aerial aspect, linear aspect, relief aspect i.e., fill, flow direction, flow accumulation, stream order, sub-basin area, slope, hillshade, contours, aspect, topographical, longitudinal and transverse profiles etc. which define the basin geometry and drainage texture of Mej sub-basin (Fig.3).

The database required for quantitative morphometric analysis of Mej sub-basin is topographical map of Survey of India (1:50,000 and 1:250,000 scale toposheet,) SRTM (DEM) with 90m spatial resolution, Remote Sensing Data of LANDSAT satellite imagery with 79mspatial resolution (Table.1).

Table.1

Data used / Software	Resolution	Sources
SRTM DEM data	90 m Resolution	Cgir.com/download
Landsat Image	79m Resolution	Landsat.org, GLCF website
SOI Toposheet	1:50,000 scale and 1:250,000	Survey of India

GIS Software	Arc GIS 10.3	Remote sensing lab facility of Department of Geology, BHU

In Morphometric analysis, drainage basin analysis include meaurment of stream profile and stream gradient index by Hack (1973) is another important tool in morphometric analysis. Most of the geomorphologist used this method to developed by these pioneers to quantitatively computing and the drainage basin as a tool used for landscape analysis (Sharma, 1987, Raj et. al., 1999, Awasthi and Prakash, 2001, Phukon, 2001, Sinha- Roy 2002).

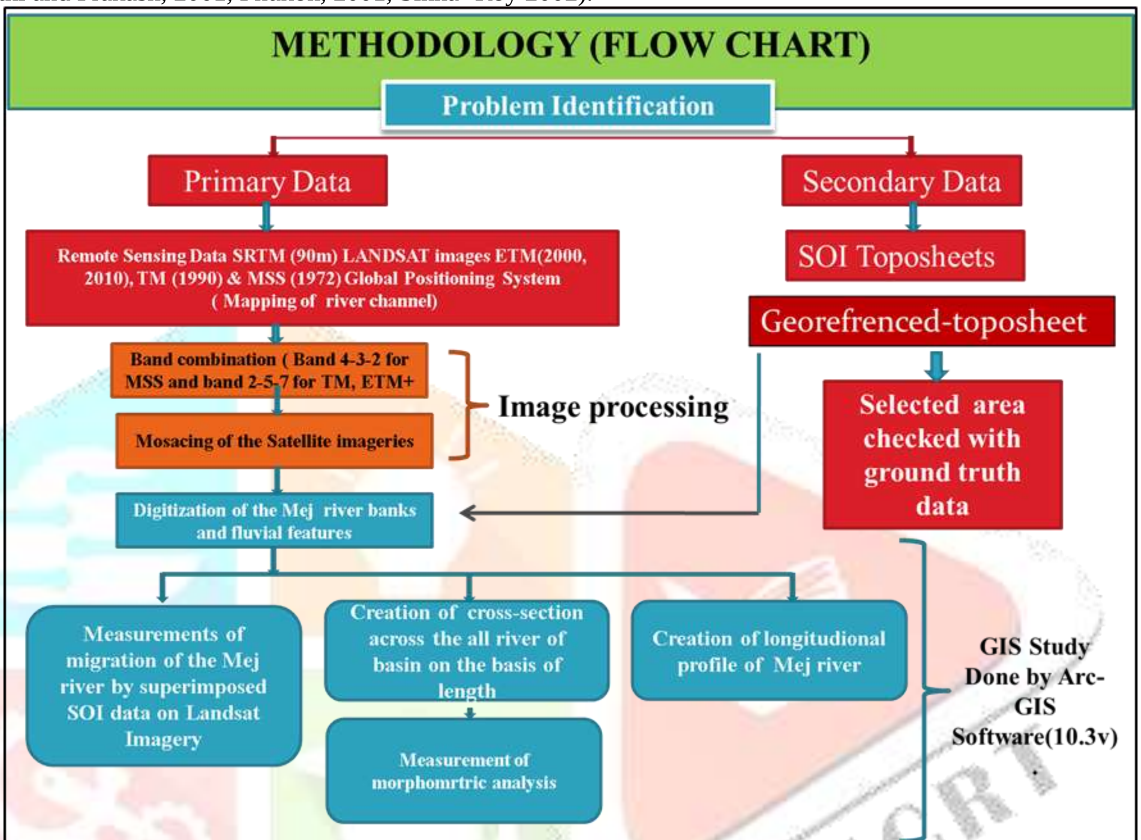

Figure.3

IV. RESULT AND DISCUSSION

The quantitative morphometric analysis is very useful to understand the River basin evolution, water and soil conservation, different low relief and high relief areas, suitable area for construction of check dams and embankment. To mitigate the flood, we should know the water velocity and active flood plain area with different soil types. The Fluvial geomorphology of Chambal River basin and its tributaries Mej River is so vast in terminology; therefore remote sensing and GIS application and technique to analyzing the whole Mej sub-basin geomorphology in interval of space and time has been used(Kaushik.p, Ghosh.p.2015). Christian, Jenning and Tuidale (1957), Dury (1952) applied different quantitative morphometric mathematical parameter calculations on interpretation of landform and valley development of basin, which represent in different results presented in the form of graphs and maps or statistical indices excel. Some and most important emphasis in geomorphology over the last in past several decades is on the development of quantitative physiographic methods which lead to describe the evolution, behavior of sub-surface drainage networks of basin (Leopold & Maddock, 1953; Horton, 1945; Abrahams, 1984). The different and main source of the drainage network lines of basin have been discussed by sub surface fluvial runoff processes which represent different climatic, geological and flora and fauna effect (Malinand Edgett, 2000; Haberle, 1998; Pieri, 1976, 1980; Cabrol and Grin,2001; Gulick, 2001; Carr and Clow, 1981; Carr, 1999; Baker, 1982, 1990; Sharp and Malin, 1975; Higgins, 1982; Mars Channel Working Group, 1983; Laity and Malin, 1985; Gulick and Baker, 1989; Malin and Carr, 1999; Grant, 2000; Goldspiel and Squyres, 2000; Williams and Phillips, 2001; Craddock and Howard, 2002; Carr and Head, 2003; Hynek and Phillips,2003; Craddock et al., 2003; Howard et al., 2005; Stepinskiand Collier, 2004; Pareta, 2004). The detailed study of geological, hydrological, and geomorphological parameters have been used to calculate the basin analysis. For better understanding the behavior of stream/River in drainage system, we interpret lithological and structural control pattern of underlying rock beds. The different scale of measurement with quantitative mathematical analysis of the configuration of the earth's surface and of the shape and different dimension of its landform provides the basis of the investigation of maps for a geomorphological survey (Bates & Jackson, 1980). This definition is most famous termed which we called as morphometry or quantitative morphometry. The area, altitude, volume, slope, topographical, longitudinal and transverse profile of Mej sub-basin with associated different rock bed texture of surrounding landforms that comprise principal parameters of investigation. The morphometric analysis of the Mej sub-basin was analyzed by different toposheets of Survey of India and SRTM-DEM 90 m spatial resolution in ArcGIS 10.3 software. The linear aspect method was the first step to analyze the drainage network of River. These methods were used by Chorley (1957), Horton (1945), Strahler (1953). The second one was areal aspects using those of Schumm (1956), Strahler (1956, 1968), Miller (1953), and Horton (1932), and the last and third one was relief aspects which enhance the landform elevation and the methods of Horton (1945), Broscoe (1959), Melton (1957), Schumm (1954), Strahler (1952), and Pareta (2004) have been used. The average slope analysis of the basin was done by using Wentworth (1930) method.

4.1 Drainage Network Geometry

Stream Order (Su)

Firstly, Horton in 1945 defines the Stream order. Afterwards Strahler (1952) is proposed his idea after modified Horton law. On that basis, the Mej sub-basin is defined into 6th order rank. The stream frequency of drainage basin is inversely proportional to stream order. As stream order increases, stream frequency decreases. So, the Mej sub-basin has high stream frequency.

Stream Number (Nu)

Horton (1945) proposed that the numbers of stream segments of each order has an inverse geometric sequence. So, the total number of stream decreases as the stream order increase (See table 2).

Bifurcation Ratio (Rb)

The bifurcation ratio is defined by the ratio of the number of the stream segments of given order 'Nu' to the number of streams segment in the next higher order (Nu+1). The most common relation between bifurcation ratio and stream length ratio is calculated by physiographical, geological, and hydrological parameter. The bifurcation ratio of basin is dimensionless quantitative property which varies from 3.0 to 5.0 (Strahler 1964). The mean bifurcation ratio of Mej sub-basin indicates the drainage network of basin is 3.15 which show the area is less suffered by structural disturbance. If the basin has higher values of Rb then it represents strong structurally control on the drainage pattern (see table 2).

Stream Length Ratio (Lurm)

Horton in 1945 definethe stream length ratio as the ratio of the mean of segments of stream orderto mean length of stream segments of the next lower order which is constant in all successive orders of a basin by and different changes in stream length ratio of 1st order to 6th order indicating their late youth stage of geomorphic development (Singh and Singh, 1997). The stream length ratio also gives a general information regarding difference in slope and topographic condition of Mej sub-basin. (See table.3)

Stream Length (Lu):

The stream lengths of the Mej sub-basin increases in the 1st order stream and decreases with 6th order stream (Hortan,1945) . This brings change in stream flow of higher altitude which shows steep slope under different lithological characteristic. Therefore, the total stream length of Mej River is 2372 km.For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

Su: Stream order	Nu :Number of streams	Rb: Bifurcation ratios
I	275	
II	79	3.48
III	24	3.29
IV	6	4.00

V	2	3.00
VI	1	2.00
Total	387	15.77
Mean		3.15 (Rbm: mean Rb)

Table.2-Drainage network analysis

Mean Stream Length (Lum)

Mean Stream length of Mej sub-basin reveals characteristic size of components of a drainage network and its contributing sub-basin surfaces (Strahler, 1964). The values of mean stream length computing against respective stream order. Which shows the positive relationship between mean stream length and the stream order for each drainage basin.

Length of Main Channel (Cl)

Length of main Channel is defining the total length of main channel or River. It is calculated by Arc GIS software using measurement scale tools. So, the length of Mej River is 190 km in length.

Channel Index (Ci) & Valley Index (Vi)

Muller.et.al, (1968), and Sinha (1998) define channel index and valley index on the basis of dividing River segment for analysis the sinuosity Index morphometric parameter. The minimum aerial distance of Mej River sub-basin is 111 km by which we can calculate the channel index is 0.58 and the valley index is 1.51.

Table.3

Su: Stream order	Lu: Stream length	Lu/Su	Lur: Stream length ratio
I	1157	4.20	
II	628	7.94	1.89
III	297	12.3	1.54
IV	151	25.1	2.04
V	85	42.5	1.69
VI	54	54	1.27
Total	2372		8.43
Mean			1.40 (Lurm: Mean stream length ratio)

Rho Coefficient (ρ)

Horton in 1945 defines the Rho coefficient that is correlated with the drainage density to physiographic development of basin and demonstrates the capacity of storage water in drainage network. However, Rho coefficient is used to identify the stage of drainage development in basin. The different climatic, geological, flora and fauna factors, different geomorphological aspect and anthropogenic factors is alsorepresent the different condition of changes in this morphometric parameter (Kuldeep.et.al 2011). Rho values of the Mej sub-basin is 0.44, which indicate the area is less prone to flood but moderate hydrologic storage during annual rainfall pouring water into the Mej River and effect the area by less surface run off.

Fig. 4 & 5 represents DEM with the highest and lowest elevation value in Mej sub-basin. Represent the flow direction of different drainage network stream which represent the flow direction from 1, 2, 4, 8, 16 to128 mean the flow from northern to eastern direction. Flow accumulation and flow length map represent the area where the stream accumulates water in flood prone condition. Relief aspect map represents different value of slope direction, slope variation in degree, Drainage density variables and contours of Mej sub-basin. For detail morphometric analysis of the drainage at first the fifth order sub basins are delineated from the available SOI toposheet and computed the 'stream order' of Mej sub basin segments following the law Horton's (1945) method which is modified by Strahler's (1952). In morphometric analysis of Mej sub-basin of entire 5th order sub basins are selected for the morphometric analysis in following different categories i.e.

[1] Linear Aspects : which is one dimension parameter
[2] Areal Aspects : two dimensions parameter
[3] Relief Aspects : three dimensions parameter

The most important and essential objective in morphometric analysis is to interpret the different drainage characteristic of Mej sub-basin. In Morphometric analysis has composition of different important parameter with respect to Linear, aerial and relief aspects of the basin were also computed in GIS software (10.3v) in pollution free environment which followed by linear regression analysis to see the mutual dependency of some extra variables. For Longidutional analysis with the drop in elevation and distance covered by Mej River which is generated by the SRTM DEM (90 m) revolution data. The drainage network is used to explain transport capacity of sediment by the agency of water, which is marked like maximum stream order of the basin and conventionally the highest order stream available in the basin considered like the stream order of the basin. The length and size of Mej Rivers and Mej sub-basin basins varies gradually with the order of the basin. Ordering of streams parameter is the first analysis in drainage basin parameters.

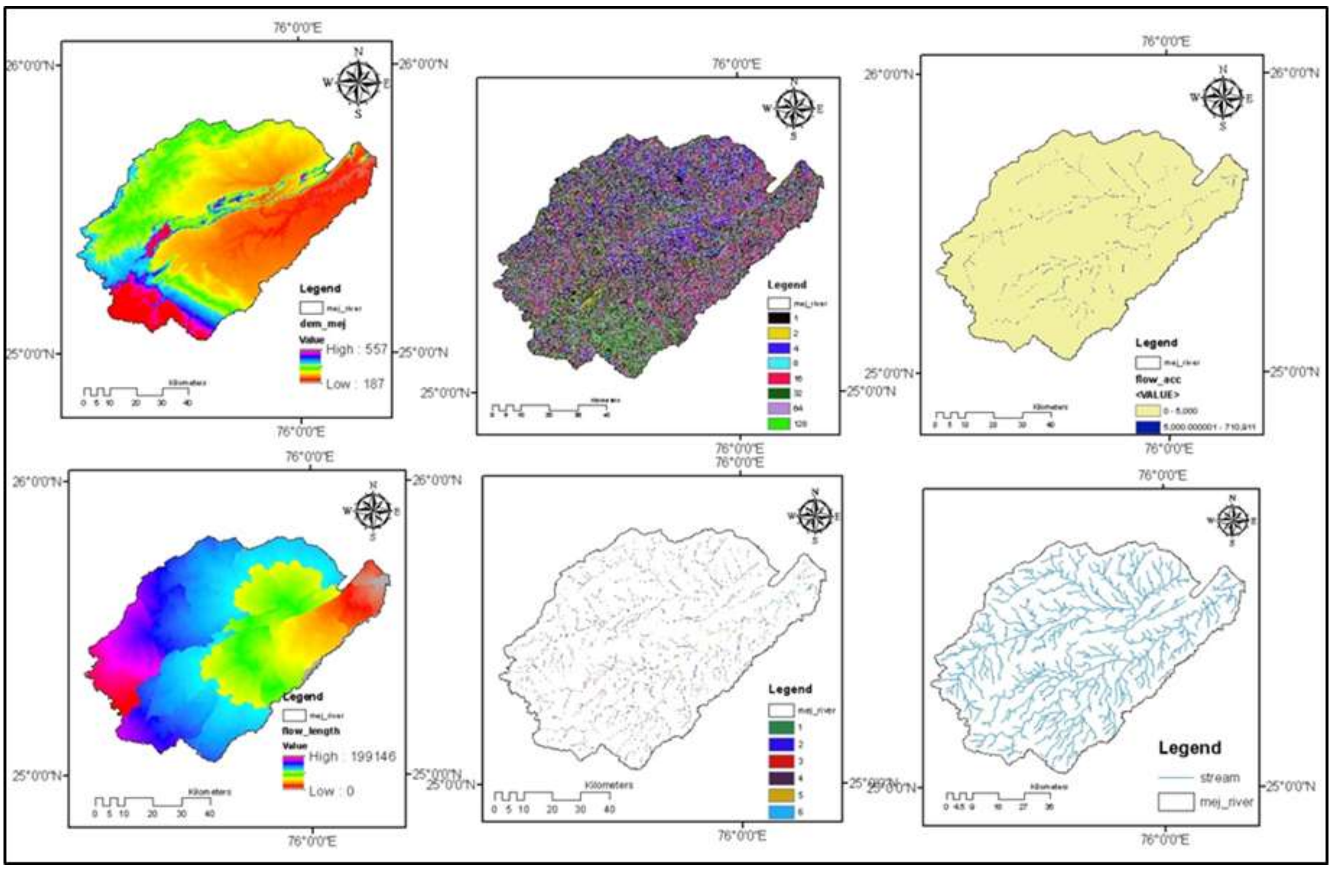

Figure.4. Linear aspect map of Mej sub-basin

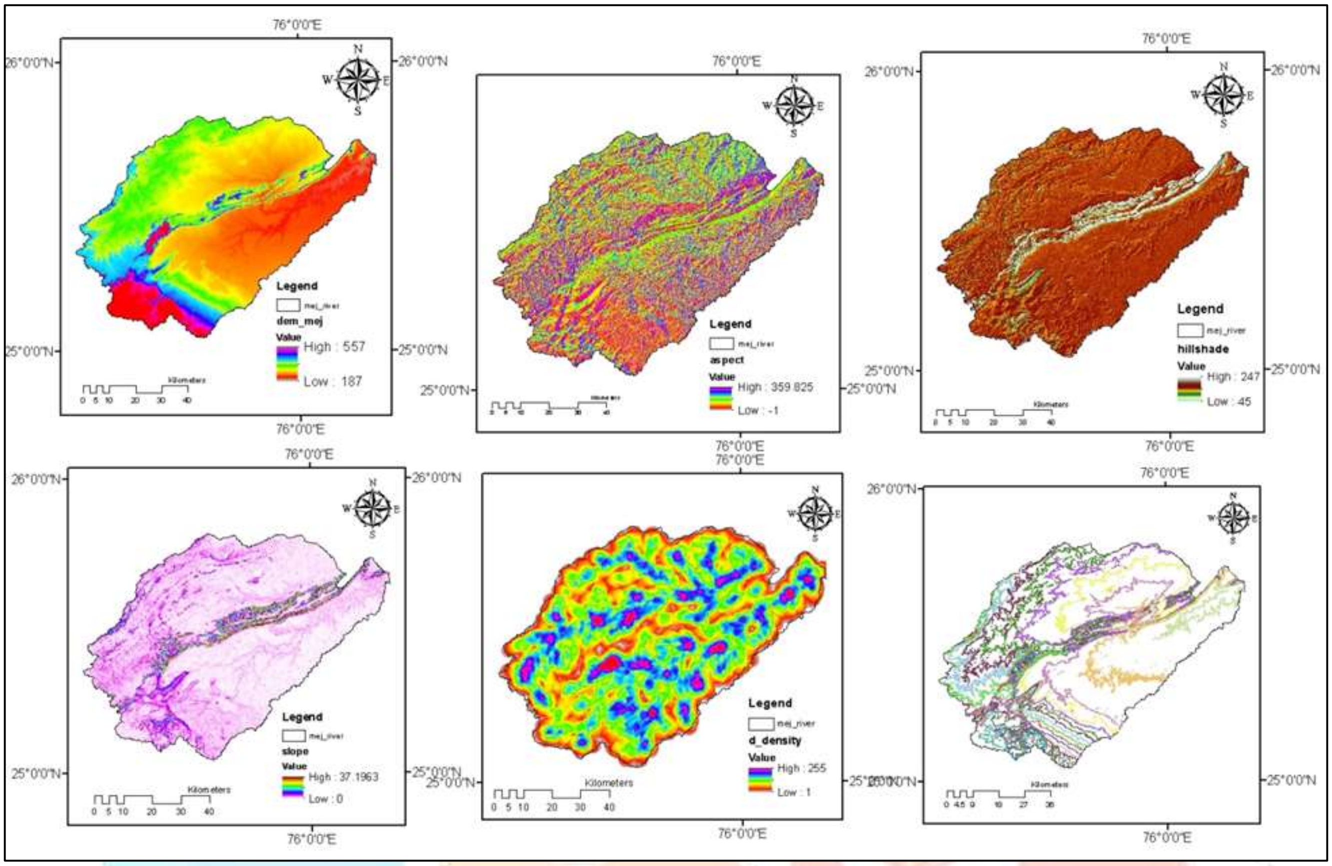

Figure.5. Relief aspect map of Mej sub-basin

4.2 AERIAL ASPECT GEOMETRY OF MEJ SUB-BASIN

Basin Area (A)

Schumm in 1956 proposed a quite interesting relation between the total basin areas and the total stream lengths, which is continuing supported by the contributing areas of different basin major and minor Rivers. The analysis the area of Mej sub-basin is quantative morphometric geometry parameter in our study area. However, by using Arc GIS 10.3 software, we calculated the total area of Mej sub-basin is 24,848 sq. km.

Basin Perimeter (P)

Basin perimeter is the area of outer boundary basin that enclosed in its area. It is analyzed under Arc GIS software and it used as a sign of sub-basin shape and size. This research calculates the Mej sub-basin perimeter is 1104 km.

Length of the Basin (Lb)

The length of the basin is defined by different geomorphologist on the basis of different geomorphological aspecst. Schumm in 1956, states that the basin length is the longest dimension of the basin parallel to the principal drainage line. Whereas, Gregory and Walling in 1973, defined the basin length is longest in the basin in which the end to the mouth. The length of the Mej sub-basin is 168 km.

Lemniscate's (k)

Chorelyin 1957 define the lemniscate's value to analysis the different kind of slope of the basin i.e. gentle or steep etc. He defines different abbreviations and its correlating value i.e. Lb2 / 4 * A, where, Lb is the basin length in term of Km and A is the area of the basin in km^2. Therefore, the lemniscate (k) value for the Mej sub-basin is 1.13, which reveals the Mej sub-basin is to cover a maximum area with lower order streams.

Form Factor (Ff)

Horton in 1932 defines the form factor is the ratio of basin area to square of the basin length. This value is less than 0.754 for predict the circular shape of basin. However, smaller the value of form factor, the shape of the basin is going to be a semi-circular. If the basin has high value of form factors reveal high peak flows for shorter duration, on other hand, in the case of semi-circular sub-basin with low form factor ranges from 0.42 indicating, it has semi-circular in shape and show flow for longer duration (Kuldeep et.al, 2011). The form factor value of Mej sub-basin is 0.88.

Elongation Ratio (Re)

Schumm (1965) explains that elongation ratio is the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Whereas, Strahler defines that this ratio runs between 0.6 and 1.0 over a wide range of climatic and geological structure. These different slopes of Mej sub-basin can also be classified with the help of the different index table of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less semi-circular (0.7-0.8), semi-circular (0.5-0.7), and more semi-circular (< 0.5). The elongation ration of Mej sub-basin is 1.05, which is representing the sub-basin moderately rectangular in shape.

Texture Ratio

Schumm in 1965 defines the texture ratio in drainage network with morphometric analysis which is depending on the underlying lithology of River bed, infiltration capacity of basin and relief aspect of the hard rock terrain. The texture ratio is the ratio between the first order streams and perimeter of the basin (Rt = Nl/P) and it also depends on the River bed, different relief aspects of the basin hard rock terrain infiltration capacity of basin rock bed. This research reveals the moderate nature of texture ratio of the Mej sub-basin which is 0.24.

Circularity Ratio (Rc)

Miller in 1953 defines shape of the basin on the basis of circularity ratios which is ranging from 0.4 to 0.5. This value indicates the basin has strongly and highly permeable homogenous or heterogeneous geologic structural materials. Whereas, Strahler (1964) has also defined Rc as ratio of basin area of a circle having the same perimeter as the basin and it is predict by different lithological character of the basin. The circularity ratio value of the Mej sub-basin is 0.25 which indicates that the sub-basin is rectangular in shape with moderate discharge of runoff with carried permeability characteristic.

Drainage Texture (Dt)

Drainage texture is most important morphometric parameter in geomorphic analysis which reveasl the story of how much relative spacing between the drainage lines of basin is present. It also helps in identify the River bed lithological characteristics, infiltration capacity with runoff and different relief aspect of the basin terrain. In the case of Smith in 1950 who classified that drainage texture into five different textures categories i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). However, drainage density is also defined by Horton (1945) as total number of stream segments of all orders per perimeter of that area. However, the drainage texture of the sub-basin is 0.35. It indicates that category is very coarse drainage texture.

Sinuosity Index (Si)

Wolman and Miller (1968) defined sinuosity deals with the pattern of channel of a drainage basin. Sinuosity has been defined as the ratio of channel length to down valley distance. Sinuosity index value differs from 1 to 4 or ongoing. Therefore, the Rivers which is characterized by sinuosity has value 1.5 and the River carry meandering properties then it has above 1.5 sinuosity index value. Mueller (1968) proposed to analyses different types of sinuosity indices values i.e., topographic and hydraulic sinuosity index influence with the flow of main stream courses and with the valley development with flood plains, active and alluvial plains. The Mej River has 1.71sinuosity index.

Stream Frequency (Fs)

Horton (1945) proposed stream frequency (Fs) as the number of stream segments per unit drainage network area. This research reveals that the stream frequency of the Mej sub-basin is 0.15. Stream frequency has inversely proportion to stream order of basin.

Drainage Density (Dd)

Drainage density is very important morphometric parameter to explain different dissection and analysis of landform under different climatic conditions, lithological and geological structures (Horton, 1945; Strahler, 1952, 1958; Melton 1958). The drainage density is defined by stream length per unit area in region of sub-basin is another element of drainage analysis. Nag in 1998 defined moderate drainage density in which the basin will have moderate permeable sub-soil and thick vegetation cover. Drainage density of Mej sub-basin is 0.95m/km^2 or 1.0 (approx.) indicating straight moving river.

Infiltration Number (If)

The Infiltration number of a Mej sub-basin is defined as the product of drainage density (Dd) and stream frequency (Fs) which define the different infiltration factor of the sub-basin.. The Infiltration number of Mej sub-basin is 0.136. The higher the infiltration number, the lower will be the infiltration and the higher surface and soil ran-off.

Drainage Intensity (Di)

Faniran (1968) defines the drainage intensity as the ratio of the stream frequency to the drainage density. This low value of drainage intensity implies that drainage density and stream frequency have little effect (if any) on the extent to which the surface has been lowered by agents of denudation. With these low values of drainage density, stream frequency and drainage intensity, surface runoff is not quickly removed from the sub-basin, making it highly susceptible to flooding, gully erosion and landslides. This study shows a low drainage intensity of 0.16 for the sub-basin.

Drainage Pattern (Dp)

The Drainage texture throws a light on different effect of climate of study area, vegetation permeability of rocks and relief ratio etc. The formation of a dendritic pattern occurring from the regional slope of originated area of River. In the Mej sub-basin, the drainage pattern reflects the effect of slope, lithology and geological structures. Therefore, this study reveals the different process of valley development in cycle of erosion and the geology of the basin with the strike and dip of depositional and erosional landforms of rocks which is associated with different existence of faults, joint and folds. It defines basic information regarding geological structure from drainage patterns like trellis, rectangular, parallel in Mej sub-basin. Howard (1967) who related drainage patterns to the geological information of basin. In this research dendritic pattern is usual drainage network in basin composed of homogeneous rock without any control by River bed which is characterized by geological structures of Mej sub-basin.

Length of Overland Flow (Lg)

The length of overland flow of the Mej sub-basin is 5.44 km, which shows high surface runoff of the study area.Land of overland flow actually defines the length of the run of the rainwater on the ground surface before it is pouring into definite channel. Horton in 1945 explained length of overland flow, at an average, is about half the distance between the stream channels and had taken it to be roughly equal to half the ratio of the drainage density of the sub-basin.

4.3 Relief Aspect Geometry of Mej sub-basin

Relief Ratio (Rhl)

The relief ratio proposed by Schumm, (1956) may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line. He defined the elevation between the highest point (H) of a Sub-basin and the lowest point on the valley floor (Lb) is known as the total relief of the River basin. Schumm also explained that sediments erode or loose per unit area is closely correlated with relief ratios. In the Mej sub-basin, the value of relief ratio is 3.31. It reveals that the areas with low to moderate relief and slope are characterized by moderate value of relief ratios. Low value of relief ratios indicate the resistant basement rocks of the basin and low degree of gentle or steep slope.

Ruggedness Number (Rn)

Strahler (1968) defined ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. Calculated Mej sub-basin has a ruggedness number of 0.50. If the value is low of ruggedness of sub-basin implies that area is slow rate of soil erosion and have intrinsic different structural complexity in association with relief and drainage density.

Channel Gradient (Cg)

The accurate total drops in elevation from the source to the mouth were we found out in Mej sub-basin, and horizontal distances were measured along their channels. We have prepared the longitudinal profile by using Arc GIS software and computed the channel gradient, which is 2.82 m/Km. It has seen from that the mean channel slope decreases with increasing order number. On the basis of gentle and steep slope in that graph, we can divide the Mej River into 3 stages, i.e., younger, mature and older stage. At younger stage the Mej River has high steep slope with high gravitational potential energy. The River starts to narrow with down cutting and shows V shaped valley. At mature stage this GPE converts into high kinetic energy and starts lateral erosion due to high velocity in stream frequency. At older or rest stage of River, it has low kinetic energy and River starts to deposit their sediments in the form of braided, flood plain and active flood plain like channel bar, point bar and lateral bar. Therefore, the River shows partially U-shaped valley with River terraces at older stage. Here the River terraces are formed by rejuvenation in River.

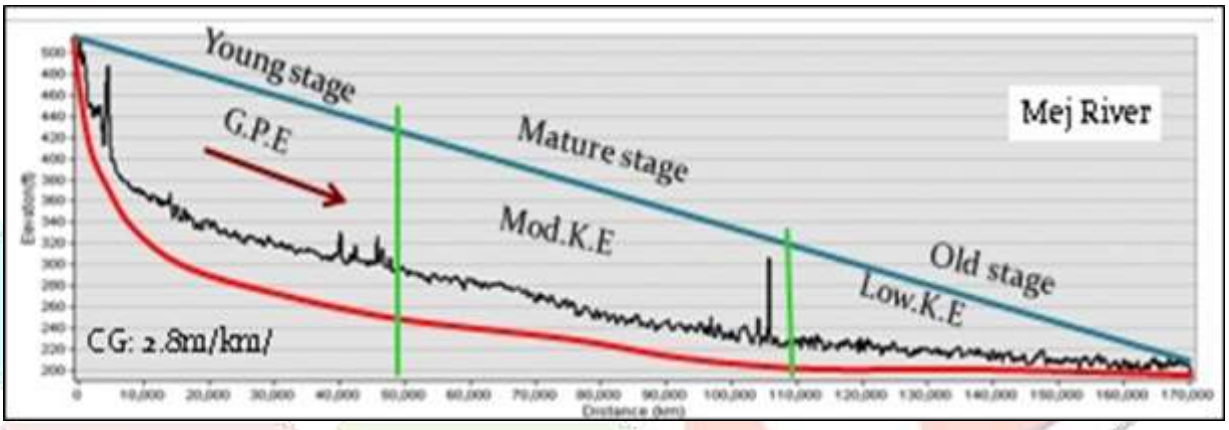

Figure.6 Longidutional profile of Mej River

The longitudinal profile of a stream is a property of stream geometry that can provide point to analyses and interpret to understand the underlying rock or river bed as well as insights into different geologic processes and geomorphic history of an area (Hack, 1960). The longitudinal profile of a stream channel may be shown graphically by a plot of altitude (ordinate) as function of horizontal distance in (abscissa). The longitudinal profile is a graph of distance verses elevation. The construction of longitudinal profile provides an interpretation of the surface history as they are the erosional curves and the river course flows from the source to mouth at any stage of Mej sub-basin geomorphic evolution.

Table 4

Morphometric Parameter	Formula	Reference	Results
Drainage Patterns: Dendritic,, Trellis, Rectangular			
Stream Order (Su)	Hierarchical Rank	Strahler (1952)	1to 6
1st Order Stream (Suf)	Suf = N1	Strahler (1952)	1157
Stream Number (Nu)	Nu = N1+N2+…Nn	Horton (1945)	387
Stream Length (Lu) Kms	Lu = L1+L2 ……Ln	Strahler (1964)	2372
Stream Length Ratio (Lur)	-	Strahler (1964)	8.43
Mean Stream Length Ratio (Lurm)	-	Horton (1945)	1.40
Bifurcation Ratio (Rb)	Nu/Nu+1	Strahler (1964)	15.77
Mean Bifurcation Ratio (Rbm)	Rb/Su-1	Strahler (1964)	3.15
Main Channel Length (Cl) Kms	GIS Software	-	190

Valley Length (Vl) Kms	GIS SoftwareAnalysis	-	168
Minimum Aerial Distance (Adm)Kms	GIS SoftwareAnalysis	-	111
Channel Index (Ci)	Ci = Cl / Adm (H& TS)	Miller (1968)	0.58
Valley Index (Vi)	Vi = Vl / Adm(TS)	Miller (1968)	1.51
Rho Coefficient (ρ)	ρ = Lur / Rb	Horton (1945)	0.44
Basin Length (Lb) Kms	GIS SoftwareAnalysis	Schumm(1956)	168
Mean Basin Width (Wb)	Wb = A / Lb	Horton (1932)	147
Basin Area (A) SqKms	GIS SoftwareAnalysis	Schumm(1956)	24848
Basin Perimeter (P) Kms	GIS SoftwareAnalysis	Schumm(1956)	1104
Relative perimeter	Pr= A/P	Schumm (1956)	22.5
Lemniscate's (k)	k = Lb2 / A	Chorley (1957)	1.13
Form Factor Ratio (Rf)	Ff = A / Lb2	Horton (1932)	1.08
Shape Factor Ratio (Rs)	Sf = Lb2 / A	Horton (1956)	1.13
Elongation Ratio (Re)	Re = 2 / Lb * (A /π) 0.5	Schumm(1956)	1.05
Texture Ratio (Rt)	Rt = N1 / P	Schumm(1965)	0.24
Circularity Ratio (Rc)	Rc = 12.57 * (A / P2)	Miller (1953)	0.25
Drainage Texture (Dt)	Dt = Nu / P	Horton (1945)	0.35
Fitness Ratio (Rf)	Rf = Cl / P	Melton (1957)	0.17
Wandering Ratio (Rw)	Rw = Cl / Lb	Smart &Surkan (1967)	1.13
Sinousity Index	Si= CL/AD*	Mueller(1968)	1.71
Stream Frequency (Fs)	Fs = Nu / A	Horton (1932)	0.15
Drainage Density (Dd) Km / Kms2	Dd = Lu / A	Horton (1932)	0.91
Constant of Channel Maintenance(Kms2 / Km)	C = 1 / Dd	Schumm(1956)	1.09
Drainage Intensity (Di)	Di = Fs / Dd	Faniran (1968)	0.16
Infiltration Number (If)	If = Fs * Dd	Faniran (1968)	0.13
Length of Overland Flow (Lg) Kms	Lg = A / 2 * Lu	Horton (1945)	
Height of Basin Mouth (z) m	GIS Analysis /DEM	-	216
Maximum Height of the Basin (Z) m	GIS Analysis /DEM	-	557
Total Basin Relief (H) m	H = Z - z	Strahler (1952)	341
Relief Ratio (Rhl)	Rhl = H / Lb	Schumm(1956)	3.31
Channel Gradient (Cg) m / Kms	Cg = H / {(π/2) * Clp}	Broscoe (1959)	2.82
Watershed slope (Sw)	Sw = H / Lb		2.02
Ruggedness Number (Rn)	Rn = Dd * (H1000)	Patton &Baker (1976)	0.50
Contour Interval (Cin) m	GIS Software Analysis	-	20

CONCLUSION

The morphometric analysis of Mej sub-basin is revealing about geographical, hydrological, geomorphological evolution of an area. The different results of linear analysis show that the area is characterized by erosional homogenous weathering. The different relief aspect analysis represents the Mej sub-basin has low relief and the basin is rectangular in shape which shows low runoff with flat flood plain area. At younger and mature stages of Mej River it flows through Aravalli Super Group rocks and shows mainly dendritic, parallel to rectangular drainage pattern which reveal heterogeneity in drainage texture and stream is less suffered by geological structures. For better understanding of ground water development and water management plan the drainage analysis can be done by using GIS and toposheet data. The artificial water recharge is successful in sub-basin because of the natural ground water discharge area and rainfall. However, this study also provides information regarding permeability of rock formation of Mej sub-basin which shows the area has ground water recharge potential. Other parameters like stream frequency and drainage density which are low in

Mej sub-basin also indicate higher permeability in subsurface rock formation. This is important reason that the basin covers in mild drought area (map of drought condition of India, 2012). The variation in stream length ratio might be due to change in slope and topography profile. The bifurcation ratio of the basin is 3.15 which indicates normal sub-basin category means less structurally disturbed. The value of stream frequency indicates that the Mej sub-basin has positive correlation with increasing stream population with respect to increase drainage density. The value of form factor and circulator ration suggests that Mej sub-basin is semi-circular in shape. However, different morphometric parameters resulted by using remote sensing and GIS approach are very useful to understand the terrain parameters like run-off, infiltration capacity and landforms and geomorphic process with basin evolution. Different geomorphic landforms were also identified in the Mej sub-basin based on SRTM (DEM) data with 90 m spatial resolution, and GIS software. This GIS application works with accurate analysis and different mapping and graph measurement which prove to be a perfect tool in morphometric analysis.

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References

[1] Bhoj.R, Nautiya. A, Sharma.R (2012) Regional structural style of Chambal valley Vindhyan basin, Rajasthan, India. Search and discovery article.

[2] Horton, R.E (1932), "Drainage Basin Characteristics", Transactions, American Geophysical Union, 13, pp 350-361.

[3] Horton, R.E (1945), "Erosional Development of Streams and their Drainage Basins", Bulletin of the Geological Society of America, 56, pp-275-370.

[4] Sharma.H.S (1979).The physiographic of the Lower Chambal Valley & its agricultural development study in applied geomorphology(Book)

[5] Alexander, P.O (1979), "Age and Duration of Deccan Volcanism: K. Ar. Evidence",Deccan Volcanism Geological Society of India, Memoir No. 3, Bangalore, pp 244-257.

[6] Broscoe, A.J (1959), "Quantitative Analysis of Longitudinal Stream Profiles of Small Watersheds", Project N. 389-042, Tech. Bep. 18, Geology Department, Columbian University, ONR, Geography Branch, New York.

[7] Chorley, R.J (1972), "Spatial Analysis in Geomorphology",Mathuen and Co. Ltd., London.

[8] Chorley, R.L (1967), "Models in Geomorphology", in R.J. Chorley and P. Haggett (eds.), Models in Geography, London, pp 59-96.

[9] Dury, G.H (1952), "Methods of Cartographical Analysis in Geomorphological Research", Silver Jubilee Volume, Indian Geographical Society, Madras, pp 136-139.

[10] Faniran, A (1968), "The Index of Drainage Intensity - A Provisional New Drainage Factor", Australian Journal of Science, 31, pp 328-330.

[11] Gold, D. P (1980), "Structural Geology", Remote Sensing in Geology, edit by Siegal, B. S. and Gillespie, A. R., John Wiley, New York, pp 410-483.

[12] Gregory, K.J. & Walling, D.E (1968), "The Variation of Drainage Density within a Catchment", International Association of Scientific Hydrology - Bulletin, 13, pp61

[13] Pareta, K (2003), "Morphometric Analysis of Dhasan River Basin, India", Uttar Bharat Bhoogol Patrika, Gorakhpur, 39, pp 15-35.

[14] Pareta, K (2011), "Geo-Environmental and Geo-Hydrological Study of Rajghat Dam, Sagar (Madhya Pradesh) using Remote Sensing Techniques", International Journal of Scientific & Engineering Research, 2(8) (ISSN 2229-5518), pp 1-8.

[15] Pareta, K. and Koshta, Upasana (2009), "Soil Erosion Modeling using Remote Sensing and GIS: A Case Study of Mohand Watershed, Haridwar", Madhya Bharti Journal, Dr. Hari Singh Gour University, Sagar (M.P.), 55, pp 23-33.

[16] Kaushik, Pradeepika, & Ghosh P "Geomorphic Evolution of Chambal River Origin in Madhya Pradesh using Remote Sensing and GIS." International Journal of Advanced Remote Sensing and GIS [Online], 4.1 (2015): pp. 1130-1141. .

[17] Pareta, K (2004), "Hydro-Geomorphology of Sagar District (M.P.): A Study through Remote Sensing Technique", Proceeding in XIX M. P. Young Scientist Congress, Madhya Pradesh Council of Science & Technology (MAPCOST), Bhopal.

[18] Pareta, K (2005), "Rainfall-Runoff Modelling, Soil Erosion Modelling, Water Balance Calculation, and Morphometric Analysis of Molali Watershed, Sagar, Madhya Pradesh using GIS and Remote Sensing Techniques", Proceeding in 25th International Cartographic Congress, INCA.

[19] Schumm, S.A (1954), "The relation of Drainage Basin Relief to Sediment Loss", International Association of Scientific Hydrology, 36, pp 216-219.

[20] Schumm, S.A (1956), "Evolution of Drainage Systems & Slopes in Badlands at PerthAnboy, New Jersey", Bulletin of the Geological Society of America, 67, pp 597-646.

[21] Schumm, S.A (1963), "Sinuosity of Alluvial Rivers on the Great Plains", Bulletin of the Geological Society of America, 74, pp 1089-1100.

[22] Shreve, R.L (1966), "Statistical Law of Stream Numbers", Journal of Geology, 74, pp17-37.

[23] Smith, G.H (1950), "The Morphometry of Ohio: The Average Slope of the Land (abstract)", Annals of the Association of American Geographers, 29, pp 94.

[24] Strahler, A.N (1952), "Hypsometric Analysis of Erosional Topography", Bulletin of the Geological Society of America, 63, pp 1117-42.

[25] Strahler, A.N (1956), "Quantitative Slope Analysis", Bulletin of the Geological Society of America, 67, pp 571-596.

[26] Strahler, A.N (1964), "Quantitative Geomorphology of Drainage Basin and Channel Network", Handbook of Applied Hydrology, pp 39-76.

[27] Pareta, K, Upasana.P.(2011), "Quantative morphometric analysis of a watershed of Yamuna basin, india, using ASTER (DEM) data and GIS", International Journal of Geomatics and Geoscience, 2(8) (ISSN 0976-4380), pp 248-268.

[28] Wentworth, C.K (1930), "A Simplified Method of Determining the Average Slope of Land Surfaces", American Journal of Science, 21, pp 184-194.

[29] Kaushik. Pradeepika, Ghosh. P (2015).3D DEM delineation of Chambal river basin from SRTM data using remote sensing and GIS technology, International Journal of Advanced Remote Sensing and Geoscience ISSN No: 2319-3484. Volume 4, Issue 4, July 2015

[30] West, W.D. and Choubey, V.D (1964), "The Geomorphology of the Country around Sagar and Katangi (M.P.)", Journal of Geological Society of India, 5, pp 41-55.