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Morphometric Study on River Yamuna: A Review

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Abstract—*The morphometric analysis of the drainage basin and channel network play an important role in understanding the geo-hydrological behaviour of drainage basin. River basin morphometric elements provide the valuable information for groundwater potential, runoff and geographic characteristics of the drainage basin. The various morphometric properties depend on various aspects like geology, geomorphology, vegetation and climate etc. Morphometry incorporates quantitative study of the area such as altitude, volume, slope, profile of the land, sediment yield and other drainage characteristics. Morphological characteristics such as drainage order, drainage density, channel slope, relief, length of overland flow, drainage frequency and other morphological aspects of watershed are important to understand the artificial recharging sites and detailed hydrology. Morphometric analysis of a drainage basin indicates the changes that occur due to climatological, hydrological and geo-morphological changes over the space and time. It is helpful in predicting floods, their extent and intensity. In this paper a review on various morphological studies carried out on Yamuna river basin is carried out to examine the impact of morphometric parameters on the Yamuna river basin. The study is found very useful for identifying and planning the groundwater potential zones and watershed management.*

1. INTRODUCTION

River Morphometry is the measurement and mathematical analysis of the configuration of the natural streams, shape, size, elevation, drainage density, stream density, drainage pattern, slope, surface and subsurface runoff, vegetative cover, sediment erosion and sediment yield of catchment. Morphometric analysis of a watershed provides a quantitative description of the drainage system and the connection between various drainage parameters and other morphometric factors. Literature survey reveals that some of the important parameters of a drainage basin namely,: stream order, bifurcation ratio, stream length, stream length ratio, drainage pattern, areal aspect, form factor, circularity ratio, elongation ratio, drainage density, and stream frequency are discussed by many investigators. Several studies have been conducted on the morphometric factors influencing the characteristics of Yamuna river basin. In this paper a review is made on various morphological studies carried out on Yamuna river basin to examine the impact of morphometric parameters on the Yamuna river basin.

2. A REVIEW OF THE STUDIES ON RIVER YAMUNA:

A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape (Abrahams, 1984). The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992). The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The influence of drainage morphometric is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Geographical Information System (GIS) techniques are now a days used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. It is important to study the source of river Yamuna, its origin, its tributaries and its different segments starting from Yamunotri.

2.1 Yamuna River

Yamunotri, which is north of Haridwar in the Himalayan Mountains, is the source of the Yamuna. The river Yamuna, a major tributary of river Ganges, originates from the Yamunotri glacier near Banderpoonch peaks (38^0 59' N 78^0 27' E) in the Mussourie range of the lower Himalayas at an elevation of about 6387 meters above mean sea level in district Uttarkashi (Uttranchal). In its first 170 km stretch, the tributaries Rishi Ganga Kunta, Hanuman Ganga, Tons and Giri join the main river.

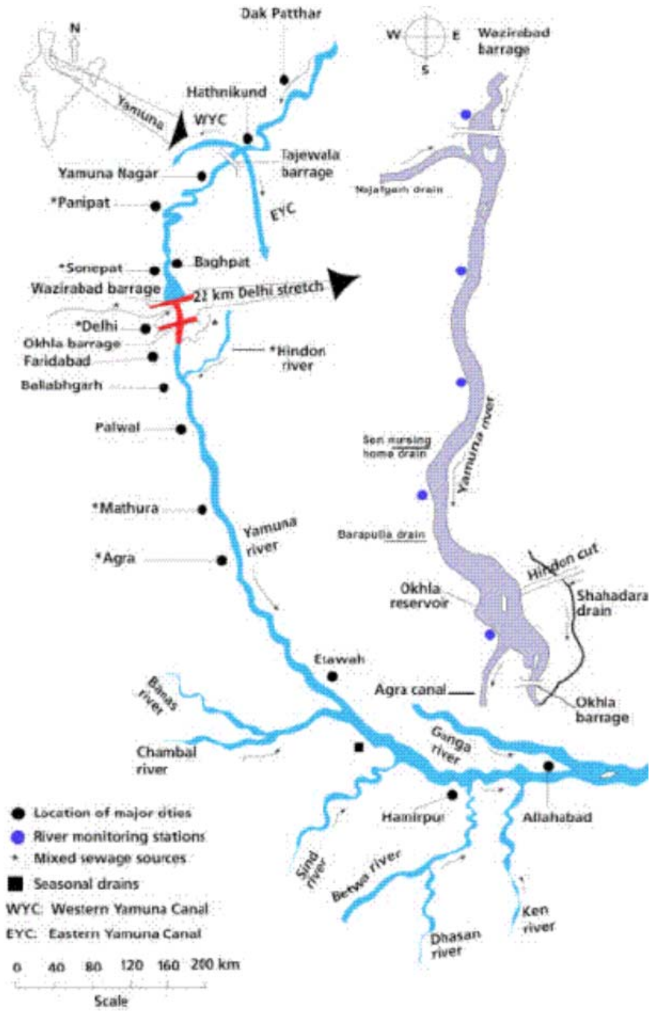

Fig. 2.1: River Yamuna

Arising from the source, river Yamuna flows through a series of valleys for about 200 Kms, in lower Himalayas and emerges into Indo-Gangetic plains. In the upper reaches, the main valley is overlooked by numerous hanging valleys, carved by glaciers during the last ice ages. The gradient of the river is steep here and the entire geomorphology of the valley has been influenced by the passage of the river. In the upper stretch of 200 Km, it draws water from several major streams. During dry season, only environmental flow of 160 cusec is allowed to flow in the river downstream to Tajewala barrage and the river remains dry in some stretches between Tajewala & Delhi. The river regain water because of ground water accrual, contributions of feeding canal through Som nadi (seasonal stream) upstream of Kalanaur and through drain no.8 upstream of Palla. It enters Delhi near Palla village after traversing a route of about 224 km.

2.2 Segmentation of Yamuna River

Distinguished Independent Segments of River Yamuna (Fig, 2.1)

Himalayan Segment -From origin to Tajewala Barrage (172 kms)

Upper Segment- Tajewala Barrage to Wazirabad Barrage (224 kms)

Delhi Segment- Wazirabad Barrage to Okhla Barrage (22 kms)

Eutriphicated Segment -Okhla Barrage to Chambal Confluence (490 kms)

Diluted Segment- Chambal Confluence to Ganga Confluence (468 kms)

Sharma et al. [2015], evaluated the change of course of River Yamuna in Haryana and also described its impact on their study area. For this the authors surveyed India toposheets and remote sensing data. They found after the overlapping of the images that the river Yamuna changes its course every time because in that area river Yamuna is fast flowing and also the rate of erosion and deposition is very high. At the top of the river, channel pattern is meandering and in the low lying areas it is braided. The authors showed that the river Yamuna is shifted in both the directions i.e. right and left bank. They found that the net river course shifted was 12 sq.km towards Uttar Pradesh between 1972 to 1992 whereas, the net river course shifted was 66 sq. km towards Uttar Pradesh between 1972 to 2012.

Srivastava et al. [2014] studied morphometric analysis of a semi-urban watershed, which is a constituent of trans Yamuna river basin, Allahabad. They surveyed Indian topographical maps in 1 : 50000 scale and CartoSat-1 DEM with 30 m spatial resolution. They also used ArcGIS-9.3 software to calculate the length of streams, area of watersheds and stream ordering. They used various morphometric parameters to study the under consideration.

Stream Order: It refers to the initial step of quantitative analysis. Its usefulness lies in the fact that is sufficiently large sample is treated then order number is directly proportional to size of the catchment which is contributing to dimensions of the channel and to stream discharge at that place.

Bifurcation Ratio: It can be defined as the ratio of number of segments of given order to the number of segments of the higher order.

Stream Length: It is defined as the ratio of total length and the number of stream segments.

Stream Length Ratio: It is the average length of stream of any order divided by the average length of streams of the next lower order.

Drainage Pattern: It is formed by the streams, lakes and rivers in a particular drainage basin. They depends on the topography of the land.

Areal Aspect: It can be defined as the total area contributing overland flow to the river segment of given order.

Form Factor: It is the ratio of catchment area and the square of length of the catchment.

Circularity Ratio: Area of catchment divided by the area of the circle having same circumference as the perimeter of the watershed is referred as Circularity ratio..

Elongation Ratio: It is the ratio of diameter of the circle having the same area as the Catchment and maximum length of basin.

Drainage Density: It can be defined as the ratio of total stream length of all stream order and that total area of catchment.

Stream Frequency: It can be expressed as the number of stream segments per unit area.

They concluded that in the evaluation of drainage morphometric parameters and their influence at river basin level CartoSAT-1 DEM with GIS techniques is more appropriate than other conventional methods.

Bawa et al. [2014] studied the factors that control the morphological variation of river systems. Stream power distribution and sediment load are used to analyze the morphological variability. For this geomorphic mapping and analysis of LandSAT satellite data for the year 2010 was done. ERDAS software, ArcGIS and Global mapper were used for image processing of remote sensing data and for GIS analysis. The three major process domains namely natural, anthropogenically altered and rejuvenated zones were governed by anthropogenic disturbances and major tributary influence. They analyzed that stream power variability successfully explained morphological variability in the upstream natural domain but it fails in the downstream anthropogenically altered and rejuvenated zones domains. Its role was confined in defining the geomorphic diversity of the whole Yamuna river. It was also reported that the stream power with sediment load can provide an important tool for geomorphic variability They concluded that the basin scale approach is more important than isolated local scale analysis in river system.

Khan et al. [2014] studied the narrowing of Yamuna river floodplains in Delhi region. He finds that Delhi is facing a serious problem due to scarcity of groundwater. The limited groundwater reservoirs do not have any recharging source except rainfall and Yamuna River. The rapid rate of urbanization /settlements acquired most of the floodplains of the river Yamuna, thus leaving a very small area for recharging groundwater reservoirs and also as the water level in the river Yamuna remains low throughout the year except in rainy season it also not fully contributes to the recharge of groundwater reservoirs. As the recharging rate is quite slow than pumping rate, it caused the underlying sediments to compress thus resulted into ground settlements at many places, due to the collapse of groundwater reservoirs. The authors suggested the method to increase groundwater potentials and management practices in the area.

Ahmed et al. [2014] analyzed the discharge and gauge levels of the river Yamuna between Hatnikund and Okhla barrages for three locations at old railway bridge Delhi. In this study he found that the river Yamuna crosses the danger mark for several times in the past 30 years, so, there occurs the threat of flood over Delhi whenever the gauge level crosses the danger mark in the river Yamuna. He observed that the main reason behind this flooding was the release of water through Hatnikund barrage in Haryana and this becomes significantly high with the rainfall. He found that due to silting in the vicinity of bridge of old railway bridge, even the flood of small magnitude can completely cover the whole old railway bridge. The authors concluded that the new railway bridge should be constructed near old railway bridge.

Vijay et al. [2009] attempted a hydrodynamic approach of the river Yamuna under different flood flows to represent the available land under existing and modified river geometry. For this RiverCAD model has been used for the hydrodynamic simulation and different frequency distribution functions are used for estimating flood flows for various return periods namely once in 10, 25, 50 and 100 years which were based on past 41 years of recorded data. The river stretch of 23 kms from Wazirabad barrage to Okhla barrage was considered. They showed that for higher flood flows most of the river bed gets inundated, so to avoid flood hazards, marginal bunds should be raised on both the banks.

Vijay et al. [2007] provided the flood levels and the land available at different cross-sections of the river Yamuna to conceive the submergence due to floods and to compute the possibilities of riverbed development. For this purpose they used RiverCAD model for hydrodynamic computation of river Yamuna and specific discharges for the evaluation of water surface profiles and submergence scenarios are evaluated and compared using different flood frequency distribution functions. Gumbel's method was used as it gave better results than others. The model was applied for the stretch of 23 km between Wazirabad barrage at upstream and Okhla barrage. Based on previously recorded flow data for the period of 1963 to 2003 flood flows for various return periods namely once in 10, 25, 50 and 100 years were estimated. Their analysis showed that the illegal intrusion in various stretches of the riverbed was one of the reason for change in river course. These unplanned activities needs preventive measures and warning in case of high flood flows to avoid flood hazards, and this can be achieved by increasing the height of bunds.

Kaul et al. [2004] studied the surface changes of Delhi region and also calculated the changes in the drainage pattern of the river Yamuna. For this purpose, the slope studies and detailed analysis of migration of river Yamuna for the last 200 years were calculated. The topographical maps of the Delhi region for 1807 and 1980 were studied. Their results showed that the river had undergone a fairly wide migration zone i.e. 8 km in the North and 5 km in the south.

Gopal et al. [2002] studied the need for the increment of flow in River Yamuna at Delhi. In this study he observed due to total absence of flow in the Tajewala barrage downstream and also due to increasing discharge of partially or no treated sewage the river has turned into a sewer. The report highlights that except rainy season river, Yamuna does not receive any flow along its 200 km stretch between downstream of Tajewala barrage and upto Delhi. At several places the floodplains are completely eliminated. In the past 30 years or so, the river has shifted its course and meandering has decreased. The river channel is bounded by 3 to 4m high natural levees. Wide sand bars and several sandy islands are formed. In most of the places the channel width has decreased and also the water in the main channel is very less. Due to excessive extraction and lack of recharge of water, the groundwater has been greatly depleted.

3. CONCLUSION

Sharma et al. reported shifting of river Yamuna by about 12 sq.km towards Uttar Pradesh during 1922 to 19992. Srivastava et al. reported that in the evaluation of drainage morphometric parameters and their influence at river basin level CartoSAT-1 DEM with GIS techniques is more appropriate than other conventional methods. Bawa et al**.** indicated that the basin scale approach is more important than isolated local scale analysis in river system. Khan et al. suggested the method to increase groundwater potentials and management practices in the area. Ahmed et al. found that due to silting in the vicinity of bridge of old railway bridge, even the flood of small magnitude can completely cover the whole old railway bridge. Vijay et al. (2009) infer that for higher flood flows most of the river bed gets inundated, so to avoid flood hazards, marginal bunds should be raised on both the banks. Vijay et al. (2009) showed that the illegal intrusion in various stretches of the riverbed was one of the reason for change in river course. Kaul et al. showed that the river had undergone a fairly wide migration zone i.e. 8 km in the North and 5 km in the south. Gopal et al. highlights that except rainy season river, Yamuna does not receive any flow along its 200 km stretch between downstream of Tajewala barrage and upto Delhi.

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