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Morphological Study of Surma River: A Geographic Investigation

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Abstract Surma, which is the lifeline of Sylhet region, travelling a long way from the Manipur state of India, divided at the border of Bangladesh and amongst them, one of flow northward that bestow prosperity. Commerce was flourished on the bank of the river and now-a-days, it is remaining as the livelihood center of this region. This river isn't only important for human beings but also for biodiversity which lived in surrounding environment. So, it is needed to learn the morphological characteristics through geographical investigation to adapt with the change of river. To find out present condition, an experimental method was conducted on selected nine cross-sectional points of the Surma river. For trend analysis, selected Landsat and DEM images were purchasing from authentic sources. As well as depth and discharge data (1990 to 2014) were collected from BWDB. Remote sensing and geographic information system provide tools for quantitative and qualitative river morphological analysis. From the analysis of data, it was found out that the depth and gradient of river was high in upstream that gradually decreases towards downstream. The condition was reverse for the width. This investigation supported the theory that upper portions are highly active in the case of erosion and which particles were victimized, flows with the force of water and bit by bit deposited at the down areas. As the depth was shallow at the down part, width of the valley was comparatively higher than upper. From the trend analysis, it was obtained that depth as well as discharge rate of Surma were showed decreasing trend. The SI was respectively high at Up and low at middle part of the river. And the channel was tending to migrate on the northward.

Keywords: *morphology, Surma River, water discharge, geographic investigation, channel pattern.*

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1. Introduction

The Bengal delta which has formed by the combined action of three major rivers including the Ganga-Padma, the Brahmaputra and the Jamuna comprises 100,000Km^2 of riverine, flood plain and deltaic environment [1]. These three great rivers along with other trans-boundary and inland rivers about 230 in numbers [2]. Every year flooding causes severe damage to the crops and other valuable properties. Another disaster is the River bank erosion which causes tens of thousands of people homeless every year [3]. Surma is the longest river of Bangladesh. The river Surma after originating from the bifurcation of the Barak river at Amalshid runs towards west through Sylhet until it meets the Balui river and collects inflow from the 56% area of the Surma basin which occupies most of the southern slope of Shillong Platueau and receives world's highest rainfall [4]. The Surma is a meandering and dynamic river. It has travelled 215 km inside Bangladesh from the Indian boundary up to Sunamganj district [5]. From its source in the Manipur Hills near Mao Songsang, the river is known as the Barak River. At the border with Bangladesh, the river divides with the northern branch being called the Surma River and the southern the Kushiyara River. This is where the river enters the Sylhet Depression (or trough) which forms the Surma Basin. The Kushiyara receives tributaries from the Sylhet Hills and Tripura Hills to the south, the principal one from the Tripura Hills being the Manu. The Kushiyara is also known as the Kalni River after it is joined by a major offshoot (distributaries) from the Surma. When the Surma and the Kushiyara finally rejoin in Kishoreganj District above Bhairab Bazar, the river is known as the Meghna River. The Surma passes through many haors [6]. The Surma River conveys a part of the Barak river discharge and the discharges of its right bank tributaries. At the bifurcation near Amalshid, the channel bed of the Surma is higher than that of the Kushiyara; as a result the inflow from the Barak River into the Surma is less. It varies from about 40% of the Barak discharge at high stages to zero at the low stages [7].

Surma is the third largest river in the Meghna region which was originated from the hilly river Barak that divided near Zakiganj upazila of Sylhet district, flows through Sylhet and Sunamganj district and finally fall into Meghna river. Total catchment areas are approximately 8176 square kilometers (BUET) respectively stretched in India and Bangladesh.

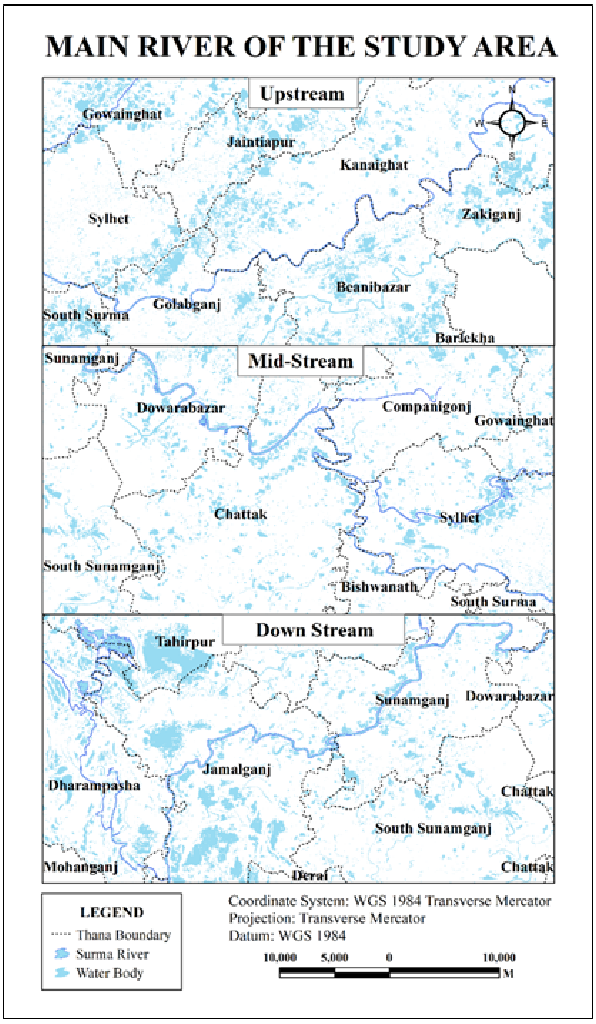

Figure 1. Surma River (Source - USGS NASA (LP DAAC), Prepared by Author)

As morphological shape of Barak river started shifting after the year of 1960s, Kushiyara river received major discharge of water flow. Surma received only 20 percent water flow. Due to this fact, river bed is silted up with a consequence of decreasing the depth at a large context. Because of Surma river holding capacity of hilly rain water with turbulent flow is decreased, water surges overtop on both banks and disastrous erosion occurs in adjacent community.

The most important feature of this river is its catchment area included Southern facing slope of Shillong Plateau in Meghalaya, Cherapunji, which are the wettest part of the Earth. During the period of monsoon, inflows of the river was responsible to create flash flood with peak flows that causes continual erosion and sedimentation which affect river banks stabilization, navigation, flood control, fisheries, and agriculture.

Due to the action of hydraulic and geomorphological forces on river bed and banks, an alluvial river always changes its flow path and shape. So, it is important to understand the characteristics and nature of such type river. This study has been conducted to investigate the morphological features of Surma river as well as trying to build a relationship between various variables, so that easily can identified which are the most dominated items. Along with that figure out the morphological trend which may be helpful for overall management and design a framework to prevention of loss that might be occur because of chronical shifting characteristics.

2. Aim and Objectives

1. To investigate the present morphological conditions of Surma river for the selected cross-sectional areas.
2. To assess the morphological trend of Surma river.
3. To analyze the relationships between various morphological features of Surma river.

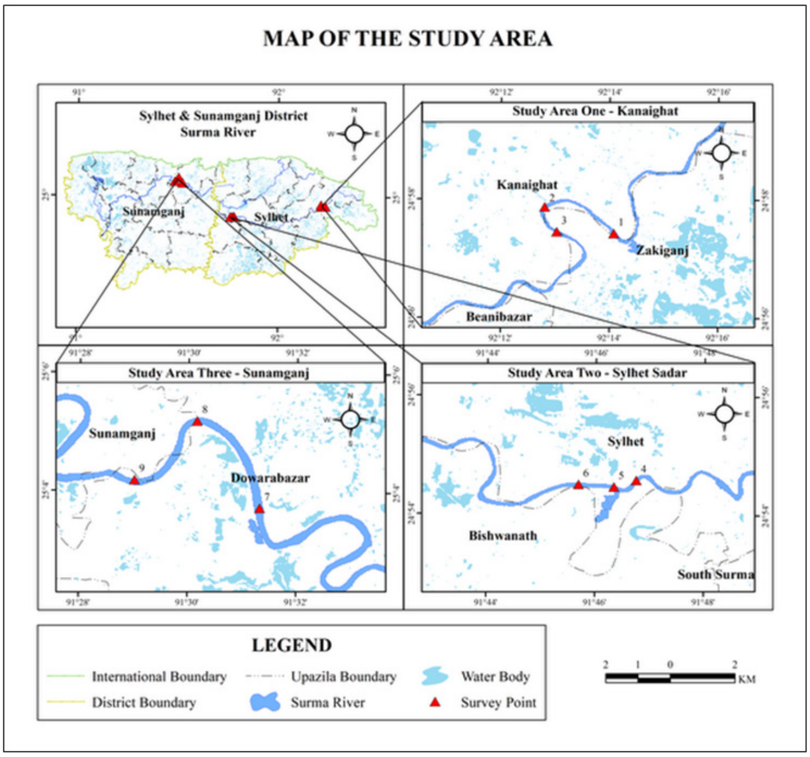

Figure 2. Map of the Study Area (Source - USGS NASA (LP DAAC, Prepared by Author)

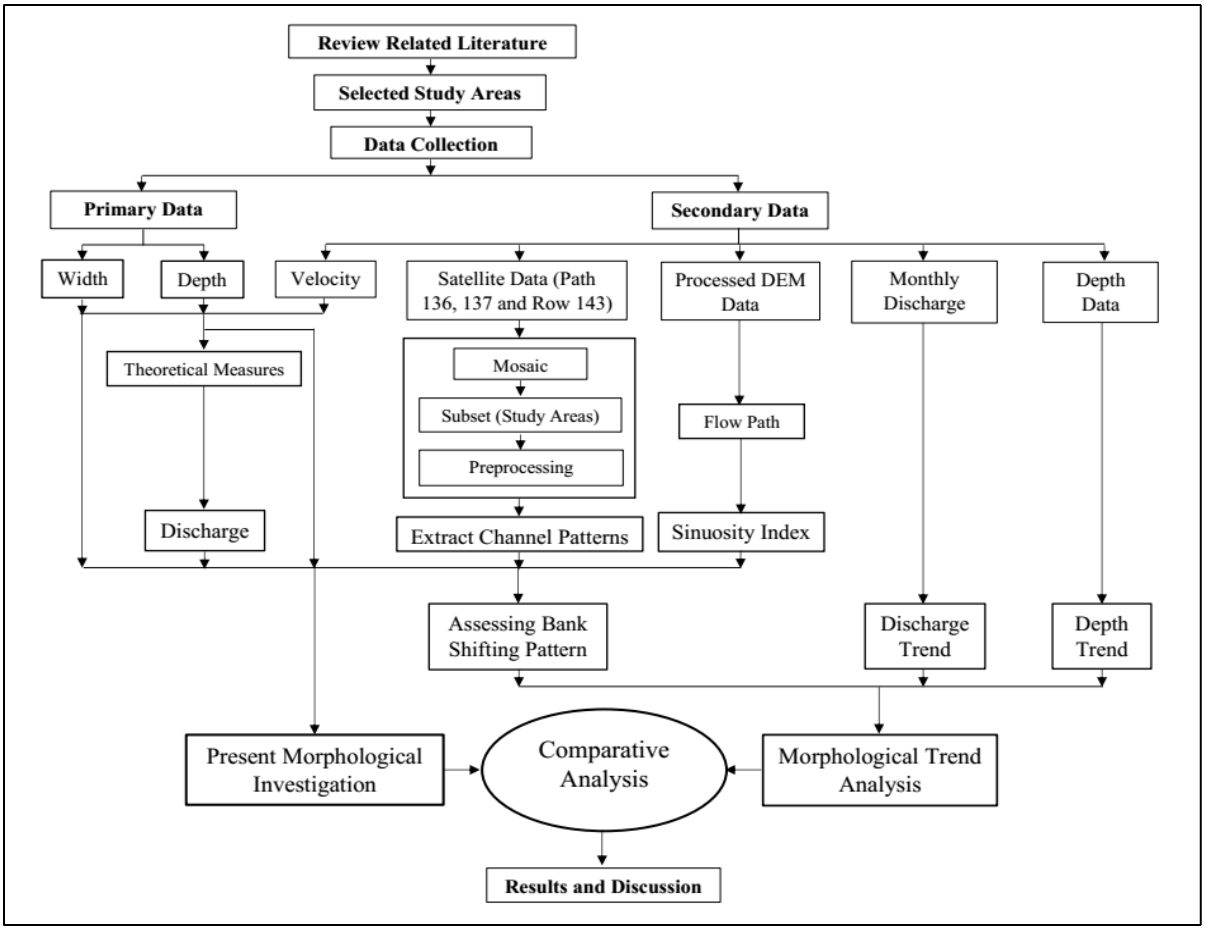

Figure 3. Framework of the Study

3. Methodology

In order to determine the morphological characteristics, first of all the river was divided into three segments from where necessary data was collected during April 2015 to June 2015.

First one is situated in Borodesh Bazar near Kanaighat upazilla as an upper stream. Then Tuker bazaar area, which is fall under Sylhet Sadar, was selected as middle portion. Third point situated between two Upazilla named Sunamganj and Doarabazar. Then, each area had been divided into three categories randomly for the purpose of rational analysis. From those points, width and depth was measured manually as well as velocity that helped to evaluate the discharge of Surma river. Along with that, on the basis of points location, sinuosity of the river was determined by stream gradient and sinuosity calculator tool. In this regard, flow line was assessed through detrend tool that was under by River Bathymetry Toolkit (RBT) and after that used this calculator which is mainly based on python script. Satellite images of Landsat - Operational Land Imager (OLI) (2015), Thematic Manager (TM) (1990 and 2000) and Enhanced Thematic Mapper Plus (ETM+) (2010) were available to study the shifting of channel. On the time of using images, it was assured that data was georeferenced in a proper way which lead to less error and better interpretation. In this contrast, ERDAS Imagine 2015 and ENVI 5.1 were used for processing satellite images. Arc Map 10.5 had been used for analyzing river bank data. Used correlation and regression analysis to compare between various variable like width, depth, discharge etc. that certified about the fit of data.

4. Results and Discussion

A Physio- morphological survey that has been conducted at three Stream Zone of Surma Rivers represents a partial condition of the River. This paper deals with river depth, water velocity, discharge amount and the width of the Surma River.

4.1. Present Morphological Condition

In this regard, general morphological characteristics of this river was discussed.

4.1.1. Depth of Surma River

In the downstream zone has lower depth (8.80 meter) than the others two zones. The upper stream zone (15.27 m) is deeper than the middle stream zone (10.65 m). The average depth of total sampled area is 11.58 meter. This depth has been measured in 2015. But average depth of these three points was 13.86 meter that has been measured in 1993. These values clearly indicate that river beds of three different stream zones are going through a tremendous change. Due to various sediment materials that coming from upper stream zone increased the rate of deposition in the downstream which lead to decrease the depth of river at that portion and increased the chance of inundation. From the investigation, an interesting fact was found. The depth in the middle portion of riparian side was lower than the bank side.

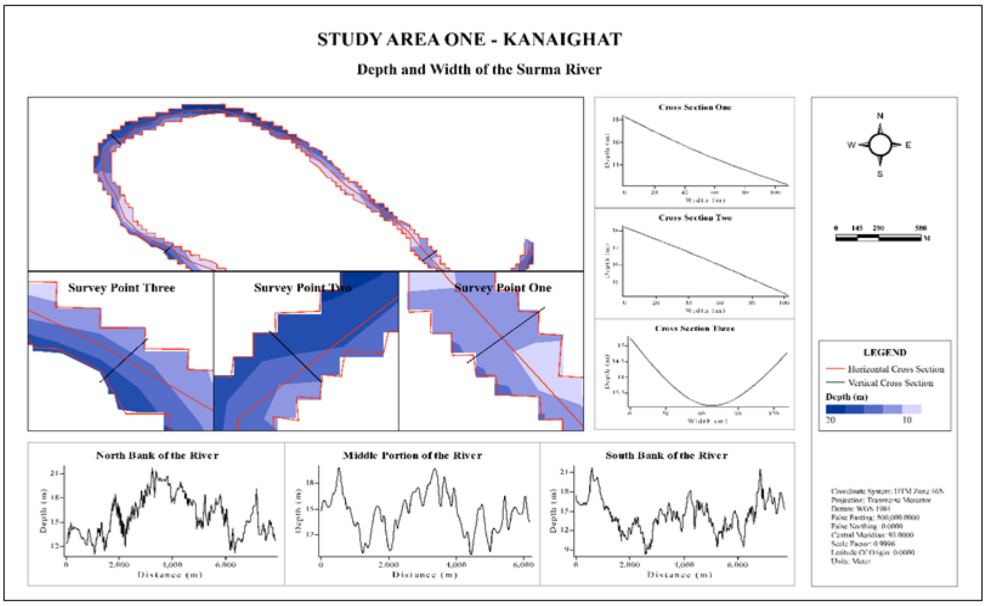

Figure 4. Width and Depth of Kanaighat Point (Source - USGS NASA (LP DAAC), Prepared by Author)

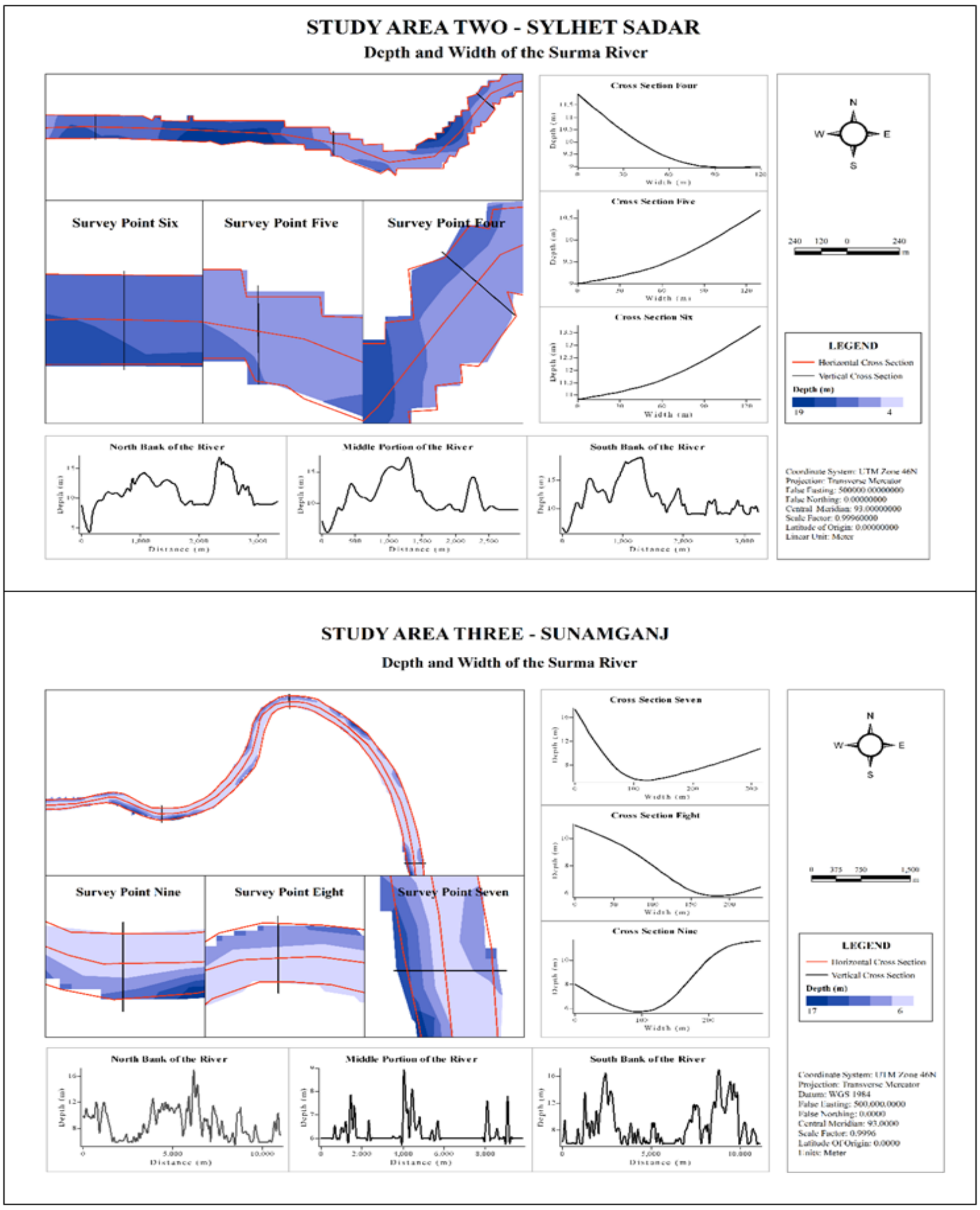

Figure 5. Width and Depth of Sylhet and Sunamganj Point (Source - USGS NASA (LP DAAC), Prepared by Author)

4.1.2. River Width

From the WC Morris Cycle of Erosion, it is known that river width gets increase from upper stream to downstream zones because of activation of lateral erosion. The data that obtained from the selected areas also reveal the same result. The river width gradually increases with distance from the source region of the Surma River.

4.1.3. Water Discharge in Various Points of Surma River

Investigation revealed that discharge rate was higher in the downstream zone (Sunamganj point) (2951.85 m^3/s) though it was the lowest depth region, since it had a wide range of width (277.20 m). Interesting factor is that middle channel of this river had lowest rate of discharge (1623.50 m^3/s) despite of considerable width (126.87 m).

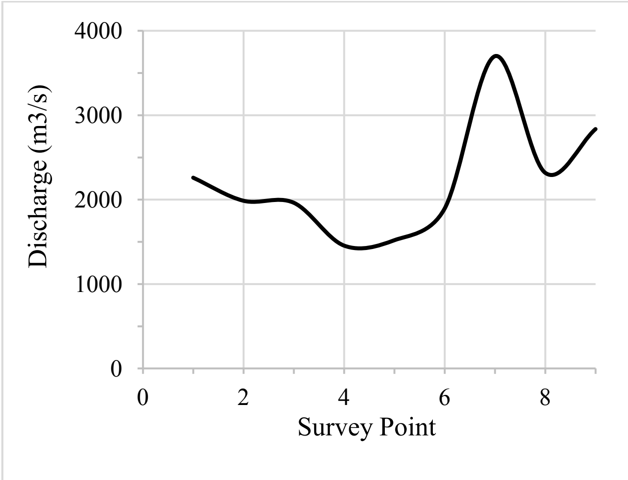

Chart 1. Discharge Rate at Surma (Source - Field Survey 2015)

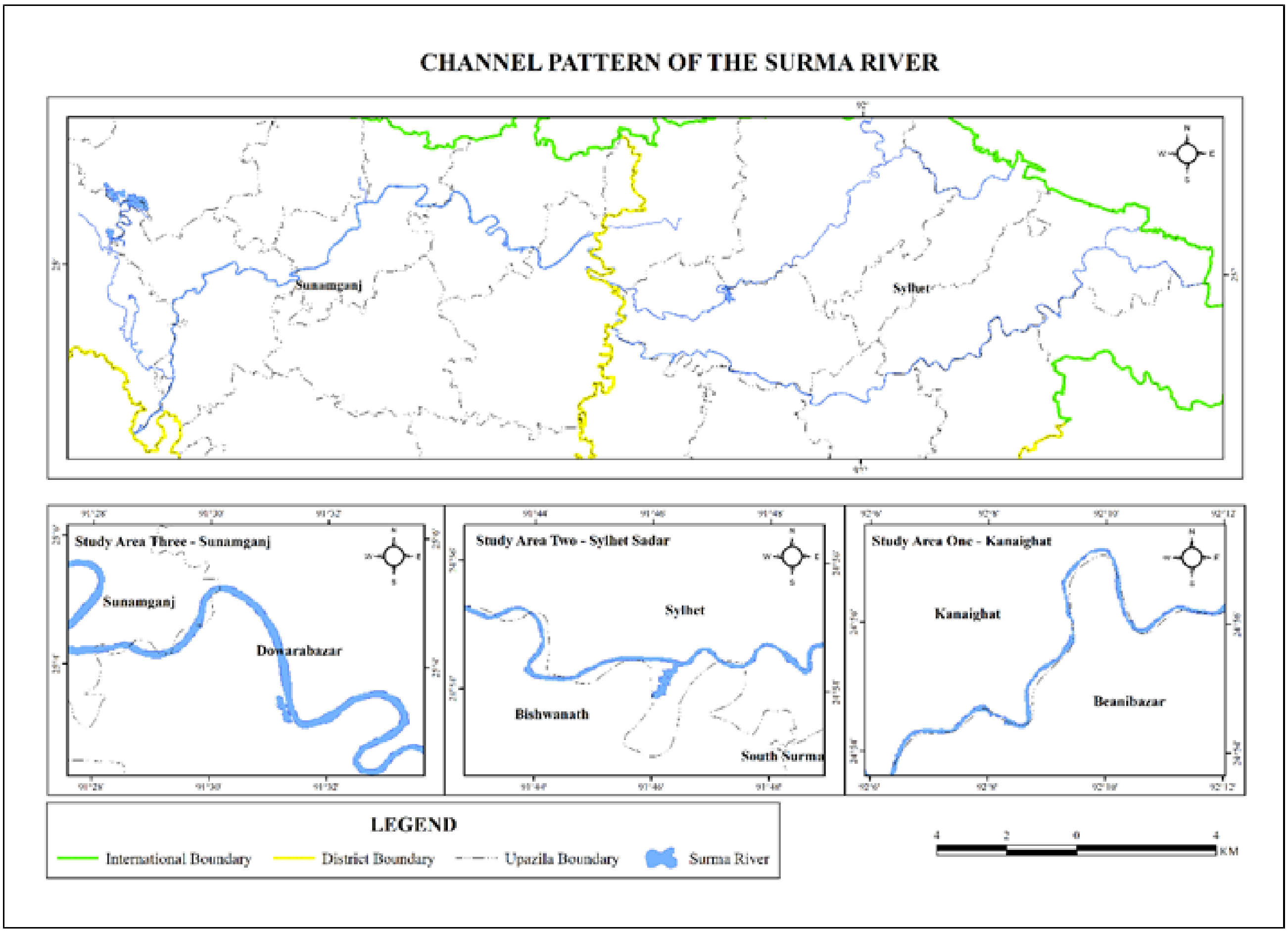

Figure 6. Channel Pattern of Surma River (Source - USGS NASA (LP DAAC), Prepared by Author)

4.1.4. Channel Pattern of Surma River

Surma River is a meandering river. It can easily be called meander because in many parts it's moving water in a stream erodes the outer bank and widens its valley.

Small parts of this river may be called straight but major parts of this river are meandering. The middle part between Lamakazi and Deglee (near Gobindaganj) is straight. Well-defined meandering nature characterizes the river reach.

4.1.5. Sinuosity

Surma river whose bed and banks are comprised of sediment being transported by water, it is an alluvial river and can be categorized into a meandering platform type. Leopold and Wolman [1] originally proposed a sinuosity of 1.5 as the boundary between straight and meandering. Brice [2] suggested that if sinuosity is less than 1.05, the channel is straight; if sinuosity is within 1.05 - 1.50, the pattern is sinuous, and if it is greater than 1.5, the river is meandering. On the basis of this classification, it can be said that meandering site was found near the area of Kanaighat while others have sinuous pattern.

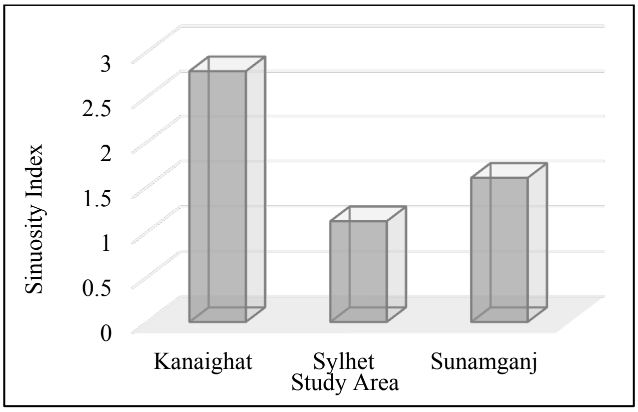

Chart 2. Sinuosity Index (Source - USGS NASA (LP DAAC))

4.2. Morphological Trend

4.2.1. Changing Trend of Depth

A systematic depth comparison is shown in the Chart. It shows the depth in 1990 and 2015. All sampled station's depth has been gone through a change within 22 years. At Sunamganj point the change is most variable. But the chart clearly indicates the changes of river bed. As the river depth is decreasing day by day, so the water holding capacity of the river is getting decreased. If this change continues, the river bed would be loaded by sedimentation. It might cause a frequent flood of the catchment area.

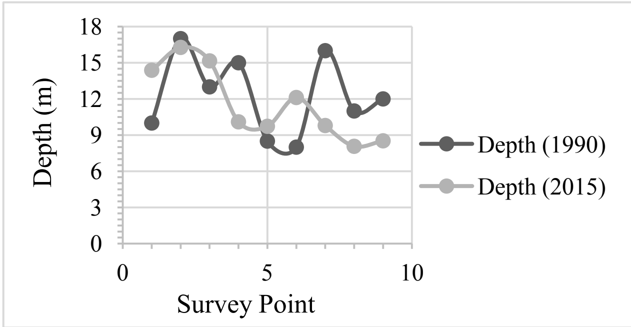

Chart 3. Depth Comparison between 2015 and 1990 (Source - BWDB)

4.2.2. Analysis of Discharge Trend

The previous study and present investigation in 2015 show that there is no tremendous change in amount of discharging. But a five years wave frequency is seen in discharge amount. In 1980, the discharge amount was lowest but an average it was increased in 1985 and again it decreased 1990. This up and down continues through the year's up to 2015. So, it indicates a 10 years frequency to high level of flood. As there is no significant change in discharge amount but the depth is decreasing, it indicates I near future the number of flood would be increase.

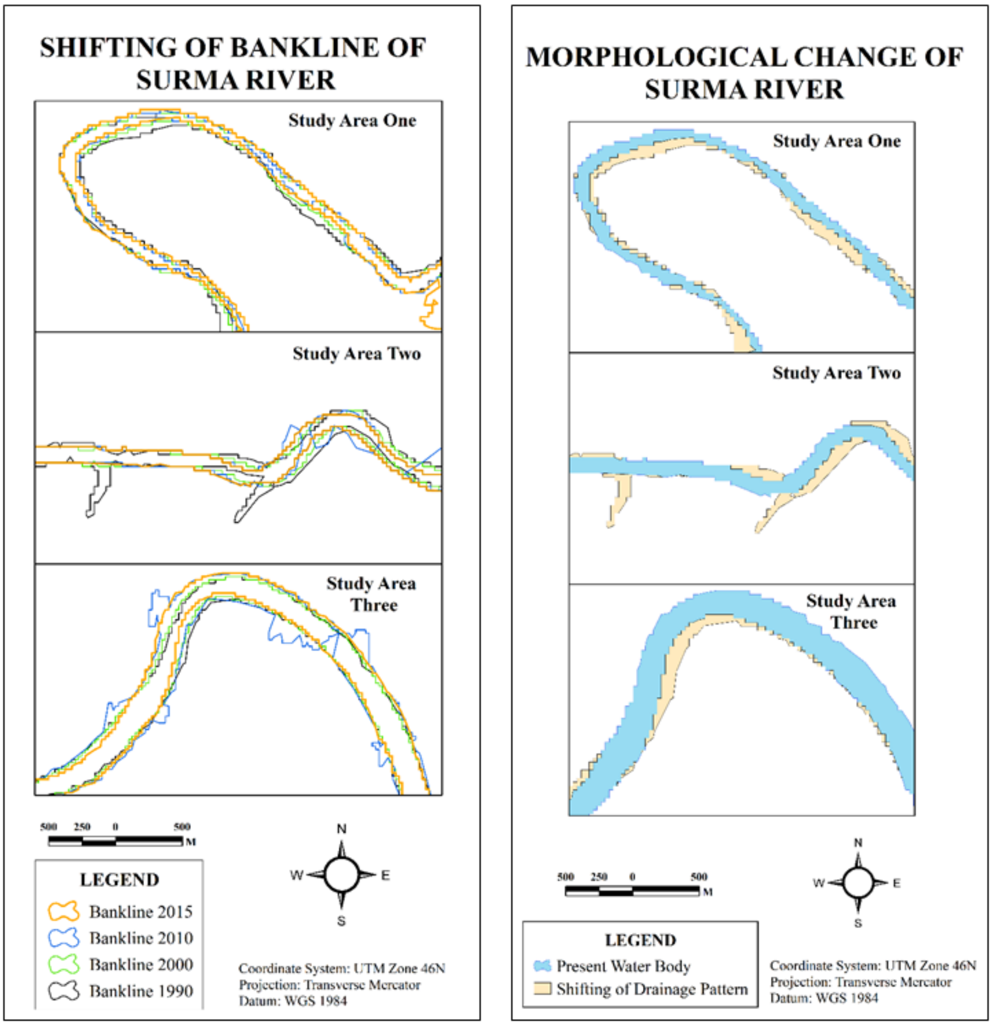

Figure 7. Trend of Channel Change (Source - USGS NASA (LP DAAC), Prepared by Author)

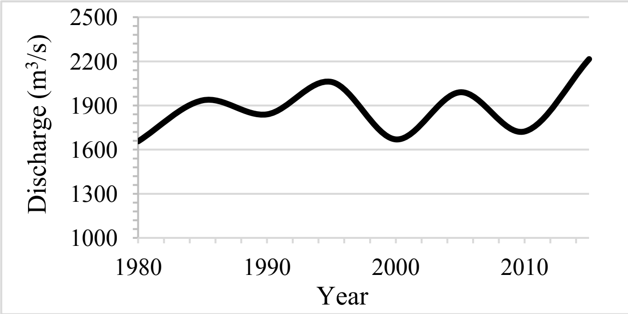

Chart 4. Discharge Comparison (1980 - 2015) (Source – BWDB)

4.2.3. Assessing the Historical Bankline Shifting

Bank-line migration is a direct consequence of interactions and interrelationships between various aspects like extent of river activities (erosion, transportation, and deposition), volume of water during peak season, soil and geological structure including mass human interference with the river.

Growth of meanders and development of cut-off are important parameters in changing platform geomorphology. Although erosion and northward channel shift is common in north bank but it is not so as alterations and modulations in the controlling factors (structure, process and stage as envisaged by Davis) of the dynamic river tend to bring dynamism in the resultant landforms. Historically, at Kanaighat, the channel had shifted towards east, north - west and north - east direction which means that area was compressed from both side and if the trend continues then in near future it may be subject of cutoff; at Sylhet, the channel shift was observed mainly towards north and north - west direction; and at Sunamganj it had been observed to move towards north - west direction. This type of migration was created due to activity of tectonic plate that is responsible to create an uplift of southern part of river valley inducing a general tendency of the river to move towards north direction.

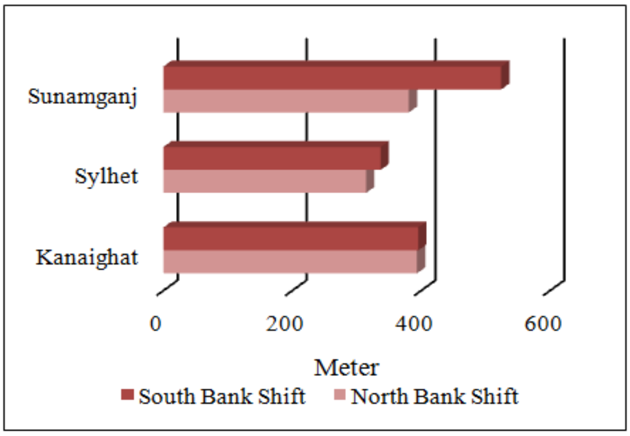

Chart 5. Bankline Shifting (1990 - 2015) (Source - USGS NASA (LP DAAC))

Shifting of river channel of Surma doesn't indicate only erosion of riverbank. It means either erosion or deposition. However, in most cases, in this study, erosion of riverbank was observed. Moreover, location and direction of erosion and deposition of riverbank is neither identified in this study. General trends of channel shifting at different locations had been being changed since 1990 to 2015 was studied.

4.2.4. Changing Pattern of Sinuosity Index (SI)

The average sinuosity index (SI) between 1990 and 2015 was observed to be highest in Kanaighat followed by Sunamganj and Sylhet. The SI of entire stretch of the river in study area was also high but was lower than that of the study area one. Between 1990 and 2010 the SI was observed to have increased for all the selected areas but in the year of 2015, this was slightly decreased. The SI for the entire stretch also exhibited the same pattern.

Based on classification given by former, while Kanaighat point (2.57 - 2.89) was meandering and Sylhet (1.12 - 1.18) and Sunamganj (1.58 - 1.62) were sinuous; and the stretch of Surma was meandering (1.76 - 1.90).

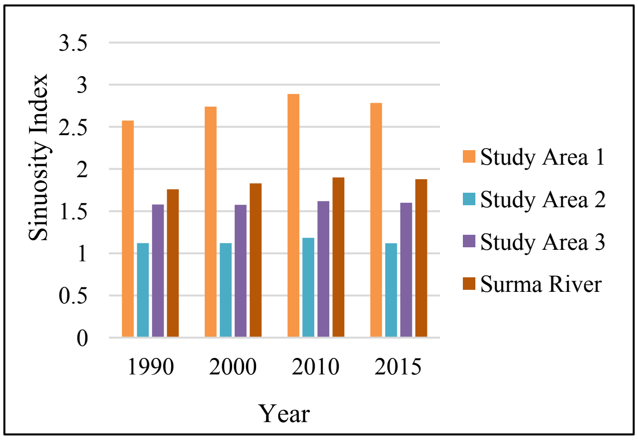

Chart 6. Sinuosity index (Source - USGS NASA (LP DAAC))

4.3. Comparative Analysis

For comparative analysis between the variables, used Pearson's Coefficient Correlation and regression formula. r^2 value was also determined. P and F value was access to find out the reliability of data.

Width and depth values are generally independent variable because of their own changeable characteristics (may be influenced by nature or anthropogenic fact but in this regard, those are considered independent). On the other hand, discharge values mainly depend on three variables respectively width, depth, and average velocity of a river.

4.3.1. Width and Depth vs Discharge

The relation between all these threes were heavy strong which was supported by the value of r (0.98). P value was also significance (0.005). Width and depth of this river directly control the discharge rate (hence r^2 was 0.97). Only 3% was other driven force.

4.3.2. Width vs Discharge

If only considered the relationship between width and discharge, it was proportional correlation (from the graphical analysis) which means with the increase of width, the amounts of discharge also get increased. The value of correlation is 0.87 which interpret a strong positive relationship between width and discharge. According to the value of P, correlation is significant. Value of r^2 is 0.77 which means 77% variables of discharge in the Surma river can be explained by the river width. The rest (23%) was controlled by other phenomena.

Table 1. Correlational Values of Different Variables

Variable		Multiple Correlation Coefficient (r)	The Coefficient of Determination (r^2)	Significance F	P-Value	Remarks
Independent Variable	Dependent Variable					
Width and Depth	Discharge	0.98	0.97	1.21516E-05	0.005	Strongly Significant
Width	Discharge	0.87	0.77	0.002	0.017	Significant
Depth	Discharge	0.27	0.07	0.486333	0.021	Non - Significant

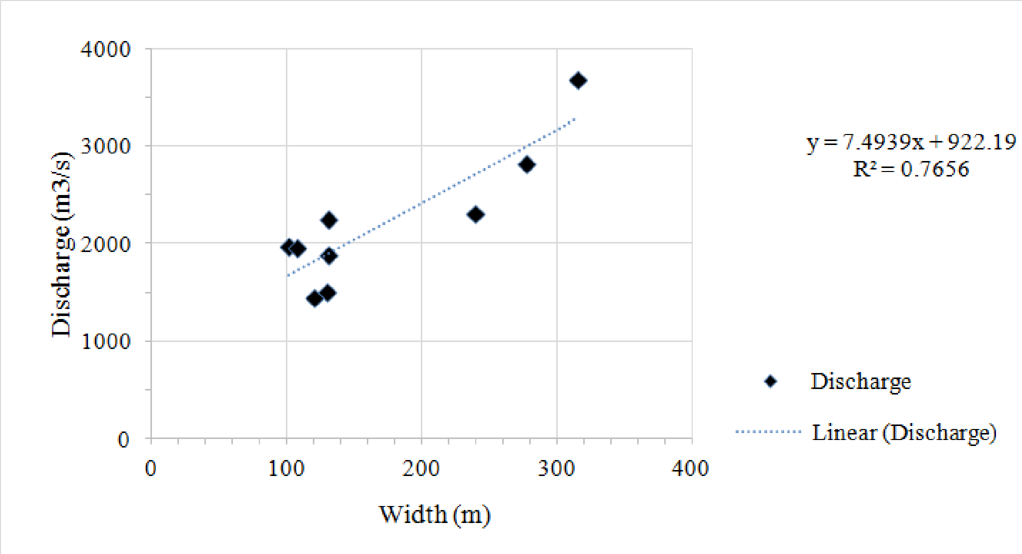

Chart 7. Width vs Discharge (Source - Field Survey 2015)

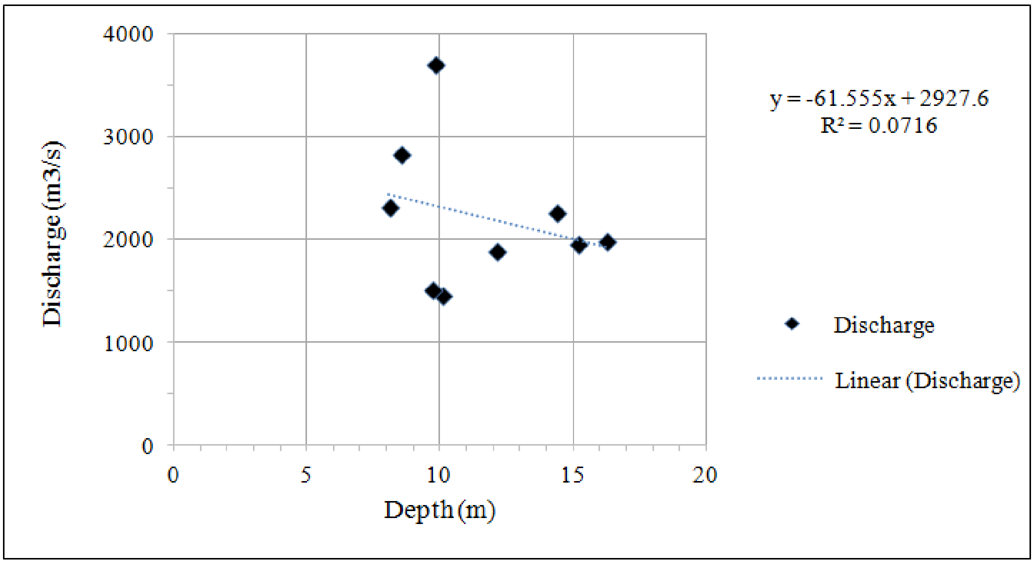

Chart 8. Depth vs Discharge (Source - Field Survey 2015)

4.3.3. Depth vs Discharge

When it was about depth vs discharge, then the relationship was light as the value of coefficient was 0.27 and that supported by P value. Along with that from this statistical analysis it was found that only 7% discharge controlled by depth.

5. Conclusion

Surma river is one of the most important rivers in Bangladesh. Peoples who lived alongside of the river, depends mainly on it as well as many commercial activities are running. But in the recent past, this river faced precarious situation because of political crisis. Without appropriate concentrations, lots of construction activity were done and riverine people payed heavily for these mistakes. So, if we want to recover our mistakes, there is a need to run a geographic investigation based on morphological characteristics.

The first important characteristics of a meandering river is its sinuosity index (SI). The sinuosity was high at the upper stream which slowly decreased at the middle stream especially around Sylhet City Corporation (SCC) area, where urbanization was expanded (this area had lowest sinuosity index). In this area, embankment controlled the river along with guide line. Again, SI was increased at the downstream area.

The width of channel varies place to place. The river valley looked like V-shaped at the upstream due to the activation of vertical erosion and because of that reason, channel flow path was narrow but depth was high. With the increase of distance, gradually lateral erosion was more active than vertical which was responsible to increase the width of a river as well as decrease the depth.

From the analysis, it was found that the depth was decreasing by years, which indicates wide range of deposition at the riverbed. As the river bed is getting changed, the morphological shape of the river is also changing. To meet the high demand of increasing population, natural resources are overexploited at the upper stream that causes deforestation and rising the rate of erosion. The eroded particles flow through stream channel and deposit gradually at the riparian region that decreasing the navigability day by day. Along with that river capacity and competence also decreased.

In this study, it was obtained that discharge rate showed an up-down characteristic (from 1980 - 2015). Various anthropogenic activity and natural calamities may be blame for this reason. To use the water for irrigational purposes or hydroelectricity, created dam at the upstream act as an artificial barrier in the flow path and due to that reasons, riparian areas feel shortage of water. Also, human treatment river body as a dustbin and throw their daily waste products there. To acquisition of new agricultural land, natural vegetation cover was interrupted by human without any second thought. It reduces the lag time and peak discharge was achieved instantly but due to low holding capacity, inundation was occurred in the urban area. Natural phenomena also control the rate of discharge. Discharge of a rive generally depends on area and velocity. The relationship is here proportional. And this theory was supported by this investigation. Kanaighat which was upper part had narrow area and because of that Surma's discharge was low but at the Sunamganj area, it was high because of larger area along with considerable depth. The rate depends not only on width, depth, or velocity, but also meteorological factors like temperature and rainfall. With the increase of temperature, evaporation rate is also increased which helps to dry up the river. Rainfall intensity helped the river to fill up its shortage through runoff. Sylhet is one of the hydrological region of Bangladesh that received highest annual rainfall as well as high land surface temperature which hang around between 24° to 26°C. Rainfall intensity increased in this region because of several atmospheric factors. This region is situated on the wind ward side of Meghalaya Hilly Range and subjected of orographic rainfall. Along with that La Nina and El Nino act as a dynamic force which is created in the Pacific Ocean and controlled the whole South - East Asian climate. In the year of strong El Nino Southern Oscillation (ENSO), this region faced driest period because of alteration of pressure. That time evaporation rate was increased and water in the soil pores also dried. The frequency of rainfall in that period is low but the intensity rate is high which means in the short period of time, a region received high rainfall. The amount of water received by the earth surface, are subject to high runoff and in short time, the river reached its peak discharge rate along with steep falling limb line which indicate low holding capacity of water that decrease the annual discharge rate. During the period of before and after 1980, occurred strong ENSO and that time, this region received lower rainfall than its average amount. And, due to that reason average discharge rate was lower than other years. The river was turned into desiccated condition in the year of 2010, and in the behind, was lying El Nino. In the year of strong La Nina, Surma river gained highest discharge rate. Some years may be different because of other atmospheric factors. To find out that discrimination, we need to conduct further research.

Remote sensing and GIS technology is an excellent tool to understand the behavior of an active channel. In this study, multi-Landsat data were used to find out the shifting pattern. It's revealed that the Surma channel was shifted slowly toward north and north-east mainly. The river was highly active to go toward northward because of subsidence of tectonic plate.

Acknowledgements

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