

ABSTRACT

Thesis Title: ‘A STUDY ON FLUVIAL DYNAMICS OF UPPER MAHANANDA RIVER BASIN IN DARJEELING DISTRICT, WEST BENGAL’

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Upper Mahananda River Basin is that part of the Eastern Himalaya where variability of height, slope and weather is observed, along with alarming human interferences in various forms increasing day by day. As a result of the above, naturally or unnaturally the Upper Mahananda River Basin is dynamic in nature. The Upper Mahananda river basin lies between Latitude of 26°40'00''N to 26°55'59''N and longitudinal extension is from 88°17'00''E to 88°30'05''E. This part of the Mahananda river basin mainly falls in Darjeeling district and the rest in Jalpaiguri district. Here one cross-section has chosen after the confluence of river Mahananda and Balason because of comparing the variability of dynamics between after and before confluence of river Balason with the river Mahananda. Change of land use and land cover of the upper Mahananda basin especially in hilly part came with the legacy of the British East India Company showing an imperial to high commercial civil modifications in this so called tract. From that time to now natural forest area is converted to tea plantation and urbanized area, which has accelerated intruding human activities to river system and reduction of surface flow pattern, increasing soil erosion as well as enormous supply of bed load of the hilly part coming down the Upper Mahananda River. The catchment area under study has been witnessed with temporal deforestation and load deposition downslope the landslide scar sites. The channel form has seriously been affected and has been modifying during the last hundred years as viewed through the comparison of SOI topographical maps and available satellite images. The variations in the channel dynamics and its behavior are connected with the increasing population pressure and modification of the channel course which directs to analyse the governing processes behind the channel behavior and hydraulic factors responsible to the morphological outcomes. The channel is experiencing the problems of siltation, bank failure, braiding and channel diversion at sites. To minimize the human suffering from the above said problems, we urgently need proper scientific management. In this study the present researcher has attempted to find out the fluvial dynamics of Upper Mahananda river basin in Darjeeling district to enter into the depth of the research exploration. The work has been framed with the objectives to study the basin morphometry in detail for understanding the geo-physical character of the basin which also proved the fact of temporal loss of vivacity of the channel. To resuscitated the soul of the work the researcher considered some basic hydraulic parameters for studying the forms i.e., cross-sectional area, wetted perimeter, hydraulic mean depth, channel width-depth ratio, velocity, discharge, bank height etc. from cross-sections at selected sites in combination to the degree of channel diversion, braiding and transformation. As to study the hydrological repercussion in connection to the transportation of load to assess the type and size of river load in the downstream direction and variation of their distribution was done in detail by the researcher. The work has also emphasized to study the fluvial dynamics and thereby tried to assess the nature and extent of avulsion, bank line shift, flood etc. as seasonal and temporal reasoning and their impact on the channel form and processes. At last, the impact study was prosecuted to assess the nature and extent of anthropogenic activities on the river Mahananda.

In this present study in order to fulfil the mentioned objectives several methodologies i.e., conventional and modified indices on morphometric study have been carried out and pair-wise relationships among morphometric variables have been performed by correlation and Regression analysis. Hydraulic sinuosity index (HSI), Topographic sinuosity index (TSI), Bank erosion

hazard index (BEHI), Standard sinuosity index (SSI), Braided index (BI) have been used to find out the braiding and sinuous character of the river and the level of oscillation and braiding has found to be excessively high here. Conventional survey techniques have used as the prime methods to measure the hydraulic parameters from the field at selected sites. For preparing longitudinal profile of the river based on SOI topographical maps (1: 50,000), field work was done extensively. For calculation of discharge 'Area-Velocity' method based on field works has been performed case to case and time to time. For water level data same time frame has been selected as specified above through field work. To analyse the modification of channel forms during the past 50 years based on SOI topographical maps, cadastral maps, tea garden maps and satellite images under GIS platform has really found supportive for the work. Questionnaire survey has been executed to evaluate the social perception and the nature and extent of the anthropogenic activities behind the variations of channel dynamics and modification of geomorphological outcomes. GPS survey techniques have also followed along with processing and preparation of bank lines along the vulnerable sites for the post field works. Rate of bank line shifting was measured by superimposing the temporal bank lines under GIS environment. Impact of flood will be studied by identifying the flood imprints in the basin during field.

The study has been arranged into nine chapters. The first chapter I dealt with introduction, description of the study area, objectives, hypothesis, methodologies, and literature reviews. The second chapter has described the geomorphology of the Upper Mahananda Basin in detail. The third chapter explained the hydrological regime of the Upper Mahananda Basin. The fourth chapter incorporated the channel behaviour and pattern of the Upper Mahananda Basin. The fifth chapter is based on channel form and processes. The sixth chapter evaluated the nature and extent of river bed load distribution. The seventh chapter attempts to analyse the impact of flood and bank failures on fluvial dynamics. The chapter eighth incorporated the human interference and fluvial dynamics of Upper Mahananda river basin and finally, the chapter ninth has been presented with summary, major findings, and recommendations.

It was decisively found that the rainfall characteristics of the study area for the years received a specific and typical pattern of symmetric increment from June to diminishing symmetrically towards October with a wide gap of positive variation from June to July and which has directly proportional impetus to the channel gauge height as gauging station data is needful for variety of purposes like flood forecasting, dam installation and water resources planning. The pattern shows late arrival of monsoon in few years resulting into some modifications to the immediate next year. The relation of gauge level increment is directly related with the monsoon storms and its direct impact has resulted into steady flash within the channel. The hydrological regime of the river is primarily and solely dependent upon the heavier rainfall incidences. The depicted trend line showing rainfall events is identifying the scenario with a R^2 value of 0.9997 or 99.7 % significant relation between the selected variables. The river experienced erosion of around 10,245 m² and deposition of approximately 8,02,044 m² throughout the whole river basin during the year 1985 to 2014 as per areal mapping from processed satellite imageries. The upper section of this river basin experiences a significant increase in width due to the rapid rate of expansion. In Reach I, the erosion rate observed between the years 2014 and 2018 was around 1,74,469 m², which demonstrates a significant increase in this particular section of the river. In subsequent years, the rate of erosion and deposition was seen to be around 79,267 and 81,165 m² for the time period spanning from 2018 to 2022, as well as from 1985 to 2022 respectively. In Reach II based on a comprehensive analysis spanning from 1985 to 2022, it has been observed that there was a notable trend of high mean bank line migration at specific locations along the banks of the river.

More specifically, on the right bank, significant migration has been observed at CP3 (313.760 m $\pm$ 348.165m), CP2 (173.467 m $\pm$ 178.486 m), CP1 (112.683 m $\pm$ 72.885 m), and CP4 (46.387 m $\pm$ 51.477 m) from 1985 to 2022.

In Reach III during the period spanning from 1985 to 2022, the minimum coefficient of variation was observed to be 0.921m on the right bank at CP1, and 0.896 m on the left bank at CP2. The observed results indicated a consistent and enduring pattern of migration on both banks of the river. However, it is crucial to acknowledge that significant variations were seen within each distinct temporal interval. In Reach IV between the years 2014 and 2018, the observed rate of erosion and deposition ranged from 18,901 to 149,832 m². Similarly, throughout the period of 2018 to 2022, the rate of erosion and deposition varied from 97,095 to 13,608 m². The observed alteration in the total area resulting from erosion and deposition amounted to 292,691 and 66,821 units of m² throughout the period spanning from 1985 to 2022.

The width of the channel for the two independent time frames i.e., 2011 and 2018 proves the fact that the change rate is quite similar in nature and not so variegated over a time frame of 07 years which also proves the incapacities of the river in respect to its flow and comparatively attainment of high width. Only but the freshet times the capacities of width enlargement are almost nil. More than 87 % values of the C/s-wise width are mare explained as per the R² value being 0.8755. The scenario is stating the increasing incompetency of the river over time due to micro relief changes and flow diversions with haphazard load deposits in bed. To accomplish the degree of bank erosion scenario BEHI technique very popularly known as Bank Erosion Hazard Index with some assumed criteria and further confirmed by ground truthing yielded some specific know-how. Bank height in general has found greater in many cases along the slip on sides and the overall BEHI score was 31 at the vicinity of Devidanga. Low bank heights and sandy materials near Champasari forest contributed to a high BEHI rate (37). A score of 31 indicated increased vulnerability near Gurung Basti. A hazard score 44.5 was attributed to poor root depth vs. density and insufficient surface protection at Noukaghat. Mahananda Para region has minimal surface protection, root density, and low bank angles, resulting in a low score of 31 but higher (BH/BFH) than the Gulma and Champasari sites.

The analysis of the total river bed area vs the total mining area shows that the maximum ratio was attained in 2017 from 2004 phase than 2017 to 2021. In case of all the three reaches such a situation has been witnessed. Most changes have found in 2021 in case of reach 1 which is highly affected by bed mining. Shear stress (τ) with high discharge and governed by high energy dissipation along boundary caused by bed roughness and further by grain resistance is the vulnerable fate of River Mahananda. This consequently involves low critical shear stress (τ_c) and represents even little to no grain mobilization readily within the river bed. The channel is full of bed roughness ($n: > 0.05$; Mannings, 1954) as distribution pattern of the load is not maintaining any sequential sorting and flood impact is high showing haphazard transportation and settling of load character. The R² value of load distribution over the reach is only capable to explain 2-3 % of the variables of load samples and about 97% is unexplained. This does not match with the Bradshaw's model. It is mainly because of slided materials as debris downslope to the channel segment near Gulma and in response to the gravity is heavily stationary. High precipitation and discharge variability during the freshet (monsoon) and non-freshet (non-monsoon months), sufficient colluvium deposits as load overburdens in the aggrading river bed the channel dynamics has increased greatly.

The primary channel width has shrunk as a consequence of the construction of embankments along both sides of the river bank, which has resulted in hydrodynamic alteration of the lower portions of the Mahananda. As a direct and proximate consequence, severe rainfall results into high flow inside the river, which is the primary factor responsible for riverbank erosion and inundation during high spates. Embankment breaching can be a severe phenomenon in future that may also happen in future to result into dynamic threshold exceedance of the river. This problem directly impacts the near bank inhabitants.

Resuscitation of the river is thus very important concomitantly which has endeavoured the researcher to pay attention to study the human interferences into the river regime in chapter 8. The river is receiving serious efficacies of urbanization and unplanned reactions from the societies. The fate has turned into misfeasance for the river Mahananda. Various human activities control the natural dynamism of the river. The reach 1 as per the reach identification for perception study is controlled by bed load lifting, embankments etc., but reach 2 and 3 is mainly modified by settlement encroachment, construction of embankment and bridges, waste disposal which has hindered the vivacity of the river.

The Mahananda River, in brief, has a significant influence on the region. It aids agriculture and food growth for farmers, and has the ability to produce power, and has to have its water levels constantly monitored to avoid inundation and flood. Continuous studies and project work on its fluvial dynamics are essential in future and in present also because the river is ever changing in view of load characters and also degenerating due to human interferences. From recommendation point of view human awareness, campaign programmes and river restorations plans are to be initiated to secure the life to the lifeline of Siliguri and to restore the sustainable advancement of the future civilization.


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