Summary

Chapter 1 Introduction

This chapter introduces the subject of channel dynamics and gives significance of such studies in the present context. It describes the major works on channel dynamics within India and outside the India highlighting the scarcity of such works in the study region and tries to establish the need of this research. The chapter introduces with detailed objectives and method and approaches followed to accomplish those objectives. This chapter also gives the types of data and their sources used in this study. Further it gives details of major literature referred in the present study.

Chapter 2 Study Area

This chapter introduces one with the Chel Drainage basin. It gives details of location and extension of the basin. It describes that with highly dissected northern hilly terrain having high altitudinal variation and gently rolling plains in the south, Chel River basin has a straddle like situation between the upper Eastern Himalayan hill surface and sub Himalayan north Bengal plains. It falls under the unique western portion of Gorubathan recess of the himalayan arc wherein Ramgarh Thrust (Gorubathan-Jiti fault) defines the mountain front rather than the MFT. The basin is unique also in the sense that there is complete absence of Siwalik and Damuda series belt of rocks. The Chel River and its major tributaries namely Manzing and Sukha khola having originated in the higher reaches of Himalaya quickly looses much of surface gradient reaching Putharjhora (300m approx) at the tip of the piedmont within 10kms (approx) from their source. These situations coupled with intense and concentrated rainfall within the basin lays all favorable condition for copious amount of sediment aggradation in the piedmont zone. The aggradational zone of piedmont is growing downwards and also has penetrated to much interior upwards. In consistency the piedmont surface is composed of very deep fine loamy soil (W007) as the most dominant soil group which covers 47.3% of the total Chel basin area. This aggradation zone favours channel diversification and avulsion during high flow. The basin still has good forest coverage. But with less literacy and higher percentage of SC and ST population, the basin portrays social backwardness. Less than 40% work participation and higher percentage of marginal workers within and decadal population growth rate (1991-2011) of 14.12% futher implies higher exploitation of existing natural resources which is getting reflected by increse in areas under agriculture, settlement and sand and boulder river bed whereas a decease in area under forest and water bodies and river (Fig.9.10 chapter 9). A substantial size of population is engaged in low wage menial works which includes sediment mining on the aggradation zone of piedmont after Tea Garden and cultivation.

Chapter 3 Basin Morphometry

Here in this chapter an attempt on morphometric analysis of Chel basin has been carried out based on several drainage parameters with the help of remote sensing and GIS tools. All morphometric parameters were categorized into three aspects namely linear, areal and relief aspect. The study infers that Chel River is a 5th order stream with overall length of 58.23 km. Lower order streams dominate the basin and overall the basin has a dendritic and semi- dendritic drainage pattern which thus indicates prevalence of homogeneous lithology. In general, the stream length in each order increases exponentially with increasing stream order. But in Chel basin stream length is fluctuating with increase in order. The highest stream length (181.54 km) is recorded for 1st order streams followed by 2nd order streams (81.54 km) then comes 5th order stream (39.22 km) followed by 4th order streams (25.27 km) and lastly by 3rd order streams (14.66 km). Chel basin comprises an area of 321 km2 with basin perimeter of 115.21 km. The Stream frequency values decreases with the increase in stream order and vice-versa.

The very low drainage density value (1.07) of the Chel basin suggests permeable subsurface. Large number of small streams disappears under the thick unsorted Himalayan sediment deposits in the piedmont zone (from approximately 15 km to 20 km downstream from source of river Chel), giving rise to coarse drainage in the basin. An elongation ratio value of 0.47 suggests Chel basin is a highly elongated drainage basin. This also suggests that the basin is susceptible to high erosion and thus higher sediment load in the channels.

Chapter 4 Analysis

4.1 Channel geometry, hydraulics and load

This sub-chapter gives an account of the informations relating to channel geometry, hydraulics and load. The entire cross profiles are asymmetric in nature with low flow depths. The mid-channel bars are mostly devoid of vegetation, and are usually composed of coarse bed materials.Much of the length of the study reach, channel banks are composed of coarse material and lacks vegetation; therefore lack of cohesion of channel banks is observable. The study area is characterized by great temporal and spatial variation of depth and velocity, which indicates the unsteady and non-uniform flow of water.The values of Reynolds Number at all the cross sections during both pre-monsoon and post-monsoon are more than 10000, indicating the turbulent flow pattern in the study area.Surface water velocity fluctuates along the channel in both pre and post monsoon depending on distribution of depth, shape, channel widening and contraction, slope of river bed, presence of mid-channel bars and pool-riffle sequence,etc. During pre monsoon the highest surface water velocity is measured at cross profile B-B' (1.11 m/sec) and the lowest velocity was measured at cross profile R-R' (0.46 m/sec). Surface water velocity during post monsoon was recorded highest at cross profile C-C' (2.16 m/sec.) and lowest at cross profile M-M' (0.41m/sec). In general the velocity decreases downstream but a major spike in surface velocity is observed near cross section N-N' immediately below the confluence of Kumlai River with Chel near Rajadanga, due to increase in amount of discharge, and associated reduction in bed friction.Highly fluctuating discharge of Chel River can be well related with the lack of vegetation in- stream and along stream banks which leads to non-cohesive channel bars and boundaries. These non cohesive or less cohesive sediments both in-stream and on channel boundaries are continuously worked and reworked by the flowing water, leading to multi-thread, shallow, ever changing braiding pattern of flow.

SWAT 2012 was run for the estimation of flow out and sediment out of the Chel river basin. The study found a strong correlation between the flow out and sediment out from all the sub-basins. Major peaks in flow out and sediment out were observed during 1980s and another 1999-2000.

4.2 Channel Dynamics

The present sub-chapter an attempt to reconstruct the channel planform changes of the river Chel has been done over the period between 1955-2017 using Topographical sheets, multi- temporal Landsat images and supplemented by field work. The chapter establishes the fact that Chel River has undergone various phases of planform changes during the assessment period of 62 years from1955-2017. The significant changes observed were increased instability in terms of channel widening, increasing number of neck cut-offs, occurrences of avulsions, decreasing sinuosity, braiding intensity and channels' overall westward movement of the river.

4.3 Confluence Dynamics

In the present sub-chapter movements of two confluence points namely, Chel-Kumlai confluence and Chel-Neora confluence in the lower Chel-Neora river system has been analyzed using multi- temporal Landsat Images and topographical sheets. The various fluvial processes responsible for confluence dynamics and the morphological implications of such confluence dynamics have been examined for. The temporal scale of the study spans 62 years (1955-2017) and The study found that there was large variability in the amount of confluence dynamics in the region during the entire study period. The confluence point movements have been erratic without displaying any specific trend. Aggradations, avulsions and river capture processes were found to be the major factors behind the confluence dynamics. Further study coupled with tectonics and long term hydrological data can give deeper insight into the mechanism and causative factors of confluence dynamics of the region.

4.4 Erosion and Accretion

Here in this sub-chapter a study on the computation of areas of erosion and accretion along a reach (Putharjhora- Kranti) of river Chel has been attempted in this chapter over the period of 62 years (1955-2017) using georefrenced topographical sheets, multi- temporal Landsat images, and supplemented by fieldwork. The study shows a phase of major channel widening thus dominancy of channel bank erosion from 1955 to 1976. This phase can be related well with the catastrophic flood of 1968 which damaged Darjeeling Himalaya in a very large scale. Then a major phase of accretion was observed during 1976-1987. Gradually now the channel has attained the earlier width of 1955. Characteristically erosion is dominant along right bank whereas accretion is along the left bank. This implies westward movement of the main channel induced by the tectonic tilt of the basin towards the south-west direction. The study thus documents the fact that the reach under study has experienced large spatio-temporal variation in the areas under erosion and accretion and this variation seems to be largely guided by the flood and tectonic tiltation of the basin.

4.5 Role of Tectonics

In the present sub-chapter an attempt has been made to analyze and elucidate the response of drainage, topography, and watershed as a whole of Chel river basin to the neotectonics of the region, through some selected geomorphic indices computed from SRTM DEM. Relief Ratio (Rh) of 54.12 indicates high gradient, Basin shape index of 3.46, implies an elongated and active basin, Vf values <7 to 10kms from the source indicates then presence of tectonically induced V-shaped valleys in the catchment areas. hypsometric integral value (HI) of 0.15 implies that the basin is active but mature, drainage basin asymmetry factor (Af) of ~40.31 (<50) implies the basin is tilted towards the right (looking downstream), however transverse topographic symmetric factor (T) indicates two directions of tilt, that is, the catchment area above the mountain front of the basin is tilted towards the east whereas the rest of the basin is tilted towards the west (looking downstream). This opposing direction of tilt can be attributed to the prevailing active tectonics along the major Himalayan thrusts. This differential tectonics is reflected in the sudden increase of SL Index values in the reach where the river traverses these active major thrusts. The concave hypsometric curve with steep initial fall with increasing distance from the equilibrium line followed by long gentle slope and finally almost horizontal tail with very low elevation indicates an active but old drainage basin.

This is further supplemented by a concave longitudinal profile with the presence of many knick points in proximity to major thrusts. Altogether it may be concluded that analysis of geomorphic indices suggests Chel river basin has undergone a differential level of neotectonic activity and the trend of severity generally decreases from north to south. The chapter very well explains the tectonic reason behind the west ward movement of the main channel and consequent evolution of channel morphology. There are no right bank tributaries of River Chel except Manzing khola and sukha khola in the upper catchment as main channel flows along the western edge of the basin for most of its length from Putharjora to kranti. Therefore nearly all the tributaries have developed on the left of the main channel and are longer than the west bank tributaries.

4.6 Role of Anthropogenic activities

With the growth of human population in the study region, the Chel River basin has become dominated by anthropogenic activities. The human activities observed in the basin are boulder, pebble and sand mining (especially mechanized in-stream mining), embankment construction, road and Rail Bridge, landuse change, road widening, concretization of flood plains etc. The present sub-chapter seeks to assess, understand and gather the evidences of the role of these human activities on Chel River's dynamism. The study finds that though the net impact is not large yet but the rate is very high and in the future the human impact in channel dynamism is estimated to grow manifold and thus demands greater monitoring of anthropogenic activities at basin level.

Chapter 5 Major outcomes and Conclusion

In this concluding chapter all the works, informations and findings has been synthesized and major findings has been highlighted.

List of publications

1. Morphometric analysis of Chel river basin, West Bengal, India, using Geographic Information System. e-Journal Earth Science India, v. 12, pp. 1-23. https://doi.org/10.31870/ESI.12.1.2019.01
2. Bank erosion and accretion along the Putharjhora-Kranti reaches of the Chel River, piedmont Sikkim Himalaya from 1955 to 2017. e-Journal Earth Science India, v.12(III), pp. 158-172 https://doi.org/10.31870/ESI.12.3.2019.12.
3. Channel confluence dynamics in the lower Chel river system, eastern sub–Himalayan West Bengal, India. pp.-93-102. Indian Journal of Power and River Valley Development, II ISSN 0019-5537, MAY-JUNE 2020.