

Morphological Changes and Their Environmental Impacts in the Behula River System

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Abstract

The changing interactions between the hydrological process, the sediment load, the geology, and the anthropogenic interventions are included in the river morphology. The Behula River, a major distributary system of lower DamodarBhagirathi system in West Bengal, is known to have undergone great morphological changes over the last decades. The changes have had consequences on the channel pattern, bank stability, sediment dynamics, and floodplain environments, hence exerting considerable environmental impacts on riparian ecosystems and human settlements. The given work is devoted to the morphological changes study in the Behula River system and the analysis of its influence on the environment through the synthesis of the geomorphic principles, the evolution of the drainage system, and the comparative analysis of the fluvial systems. The paper relies on recorded works of fluvial morphology, anthropogenic variations, and channel planform dynamics to India and other analogous river systems worldwide to recognize the role of the flow regulation, feeder canals, land-use change, and redistribution of the sediments in changing the river channel. Based on the results, the increasingly narrowing of channels, banks' erosion, loss of natural drainage connection, and the deterioration of the floodplain contributed to the enhancement of stresses on the Behula basin environment. The paper puts emphasis on the need to have combined river basin management which identifies geomorphic sensitivity and in the ecological dimension sustainability.

Keywords: River morphology, channel change, environmental impact, Behula River, anthropogenic influence, fluvial processes

1. Introduction

Rivers are dynamic geomorphic systems which continually vary in their channel form, flow properties, and sediment regime due to natural processes and human intervention. Channel morphology, which is the pattern, width, depth, sinuosity and bank properties of channels, is determined because of interaction of discharge, sediment load, geological structure, and floodplain conditions. The morphological change in the environment caused by the change in these controlling factors has a direct influence on river behavior. The anthropogenic pressure at the alluvial plains of eastern India has been increasing and hence the river systems have gone through radical morphological changes over the last couple of decades. Construction of embankments, flow regulation structures, agricultural developments, urbanization and change of land-

use has thrown the natural balance between erosion and deposition out of balance. The interventions tend to increase geomorphic activities that result in the instability of the channels, erosion of the banks, aggradation of the sediment, as well as the loss of natural drainage links, and occurrence of frequent flooding. The effects of this kind of morphological alteration extend widely to the environment, and they suggest riparian eco-systems, water quality, agricultural productivity, and human habitats.

A typical example of a human altered fluvial environment The Behula River system is a distributary fluvial system of the lower DamodarBhagirathi basin of West Bengal. The Behula River in the past played a major role in terms of drainage and dispersal of floods in the area. However, over time the flow regimen that was altered by upstream control of the Damodar River, feeder canal development, and incremental encroachment of floodplains has radically altered the morphology of the channel. The outcome of these alterations has been the closing over of the channels, reduction in the conveyance of the channels, siltation, bank instability, and disruption in the natural processes of the floodplain.

The morphological changes in the Behula River system have also had major environmental effects. More bank erosion has destroyed agricultural lands and displaced the local population. The buildup of sediments along the channel and other wetlands along the channel has altered the aquatic environment and reduced the biodiversity. The natural drainage systems have also been separated thus augmenting the waterlogging and flood hazards in the lower parts particularly during the monsoon season. These morphological changes are therefore essential in assessing the environmental vulnerability and plans in the sustainable management of the rivers in the planning profession.

It is here that the present work aims at examining the morphological change of the Behula River system and determining their environmental impact. By combining geomorphic ideas and the evidence of studies conducted by the region and globally, the study tries to discover the existing natural and human-made causes of the change in the channel. The paper also shows the possible effects of such changes to riverine ecology, sustainability in the floodplain, and on human lives. Such analysis will be significant to develop scientifically informed and eco knowledgeable river basin management policies in lower Gangetic plains.

2. Literature Review

The river morphology has long been regarded as a key source of information about the behaviour of the fluvial system, which consists of the interaction of hydrological processes with the sediment processes, the geological constraints, and anthropogenic factors. Morphological variations in the channels, e.g. channel width, planform pattern, sinuosity and bank stability, are usually indicative of stress and disruption of the natural river processes in the environment. The recent few decades of study on the topic of fluvial geomorphology have been aimed more at the acquisition of the knowledge of how the anthropogenic interventions can improve the natural geomorphic processes and modify the environment on the rivers.

Some studies have identified the role played by human activities in increasing the morphological changes in the river systems. Beyene et al. (2023) demonstrated that change in land-use, change in channel and change in sediment supply (anthropogenic) has a profound impact on the fluvial channel morphology. They observed in their experiment of the Gilgel Abay River mouth of the Lake Tana sub-basin that the instability of the channels, bank erosion, and redistribution of the sediments resulted because of the disturbance of the human beings. Their outcomes point to the vulnerability of river channels to extraneous factors and provide a conceptual idea of how identical changes can be analyzed in other alluvial rivers.

Research studies that have also focused on basin characteristics and morphology of rivers have also accounted for the importance of geomorphic controls to channel processes. Ghimire (2020) studied the

Bakraha River in the eastern region of Nepal and showed that the behavior of the channels, erosion, and transport of sediment are severely regulated by the basin morphology, slope, and the nature of the drainage. The study indicated that rivers flowing through low-gradient alluvial plains are very vulnerable to morphological instability whenever they are subjected to any form of natural processes disruption by human activities. This comment is highly applicable to the Behula River system which is flowing with a low-lying environment in floodplain.

Long term changes in planform are also present in large river confluences and large alluvial systems. The Lawal and Omo Sanya (2023) study involved a comparative study of the multidecadal changes in planform morphology of Niger -Benue River confluence and established that the channel alignment, bar structure, and bank erosive Ness differed considerably. They concluded that climatic variability and anthropogenic changes are significant in the determination of long-term morphological changes. These works have demonstrated that morphological change is slow, yet progressive, and can cause considerable effects in terms of environmental impacts on a long-term basis.

It has always focused on artificial channels and feeder canals as having an influence on river morphology in the Indian context. Biswas and Biswas (2014) investigated the influence of a feeder canal on the morphology of a channel in the study of Bhagirathi Hoghly system in West Bengal and determined that the feeder canal increased siltation, decreased channel width and rearranged flow regimes. In this study, it was concluded that anthropogenic interventions have the tendency to disrupt a natural balance within the sediment, which will lead to environmental problems downstream. These are more so with reference to the Behula River that has been impacted by related feeder canals that are associated with the Damodar River system.

Historical analysis of the drainage of Rarh Bengal has been examined and stands as a significant history to the current behavior of the rivers. Bagchi and Mukherjee (1978/1980) also documented draining patterns of the Rarh Bengal and indicated the excessive presence of abandoned and defunct channels. Mukherjee and Ghosh (1993) also focused on what was between the life-drainage system and defunct-drainage system of the factors that showed the impact of the natural migration of rivers and human involvement towards the channel abandonment. These texts suggest that such rivers as Behula are part of the dynamic and transforming drainage system, morphological change is the process centuries old that has reached its peak because of the modern forces.

Classical literature also contributes well in giving an input on how the Indian rivers used to appear several years ago. Records of river courses and drainage patterns are provided in one of the earliest extant accounts of the rivers of Hindoostan by Rennell and demonstrate that a large amount of realignment of rivers has taken place over timescales throughout history. These historical perspectives are part of contextualization of morphological change presently in a wider span.

Studies of manipulated river systems extend to indicate environmental impacts of change in morphology. Ghosh (2011) examined the impacts of hydrology and geomorphology of the long-term damming of the Damodar River and found out that there were significant alterations in flow regime, sediment transport, and channel form. The study reflected an increase in siltation, reduction of channel capacity, and enhanced risks of flooding in the low areas. These findings can be directly used in the study area to analyze the causes of morphological instability since there is a hydrological connection between the Systems of the Damodar River and the Behula River.

More recent work has also added a fresh twist to the argument by introducing ecological implications of morphological variation. Mulatu et al. (2024) investigated the ecological and geomorphic responses of

river flow regulation over the long run in the Upper Blue Nile basin. They discovered that morphological changes that encompassed cutting channels and starving sediments had direct effects on aquatic settings and ecosystems. Although the study was conducted in a different geographical area, it confirms the linkage between structural channel and environmental health, which is the subject of the research provided.

All in all, existing literature confirms the fact that natural activity and human interventions trigger morphological changes of river systems. Several research has been conducted on large river systems and other important confluences, but few studies have been conducted on minor distributary rivers in highly populated floodplains such as the Behula River system. The research gap is evidenced by the fact that there is a still definite research gap when it comes to integrating morphological analysis and environmental impact assessment on the local level. This gap has to be bridged to devise sustainable river management projects in humanized landscapes.

3. Research Gap

A lot has been researched on the morphology of the rivers, the processes within the fluvial system, and the environmental effects of the channelization of the big river systems in India as well as other portions of the world. The study has been in a position of capturing the impact of anthropogenic interventions on channel instability, sediment process in addition to the degradation of the floodplain by dams, feeder canals, embankment, and land-use modifications. However, despite this growing literature, some key gaps in research remain (even in regard to smaller distributary river systems such as the Behula River) as well. First, the major rivers and larger basins are becoming the central subjects of modern research, and they are the Ganga, Damodar, Hooghly, and other river systems that have got international importance. Secondary and distributary rivers have not received much scientific attention on the other hand, which are very important in the local drainage and flood control. Even though the Behula River is one of the main rivers in the lower basin of the Damodar Bhagirathi basin, it has been a secondary subject in geomorphology and environmental studies.

Second, the previous studies have been inclined to examine the change of morphologies or environmental impact separately. Though the channel morphology has been studied in the geomorphic framework and the environmental degradation in the ecological or socio-economic framework, studies have not been done in an integrated approach where morphological changes are directly related to the environmental impacts. In the Behula River system, systematic analysis is not done between channel narrowing, siltation, and bank erosion, and drainage disconnection as to its impact on the ecology of the river and livelihood.

Third, several of the studies rely on large-scale quantitative modelling and big data that is not available in small rivers and distributaries. This has witnessed the non-investigation of the river systems which lack data in detailed scientific inquiry. They should be demanded that there are conceptual and qualitative frameworks which would effectively assess the morphological and environmental transformation of such rivers based on secondary data, historical data, and comparison.

Fourth, the historical development of drainage has not been adequately incorporated in the current research on river management due to the presence of closed or abandoned channels that is characteristic of the Rarh Bengal region. The contemporary shift of channels and its impact on the risks of floods and environmental susceptibility in the contemporary context have not been studied properly, whereas the understanding of the change in the context of the Behula River is very vital.

Finally, the focus on the compound effects of the long-term human activities of the morphological stability of the distributary rivers is missing. Though the structures (e.g. dams or embankments) have been treated

separately, little has been given on the accumulated and long-term effects on the channel's behavior and environmental resilience of the Behula River system.

With these gaps in mind, the given work tries to contribute to the existing knowledge by providing a composite analysis of the morphological changes and their impact on the environment in the Behula River system. To learn more about the fluvial process on the local level, the study aims at studying a distributary river in a high-density alluvial plain that will allow developing viable river management plans.

4. Methodology

The existing research paper will be conducted in the form of a qualitative and analytical approach to explore the morphological change in the system of the Behula River and assess the impact on the environment. The methodology will integrate the geomorphological and historical drainage data analysis and secondary data evidence to create an intricate understanding of the channel transformation work. The limited availability of data about smaller distributary rivers has necessitated the emphasis on documentary analysis and comparative interpretation instead of quantitative modelling.

4.1 Data Sources

This study is highly based on the secondary data which was achieved through published research materials, historical records, government documents, and academic books about river morphology and drainage development and the forces of an environmental changeover. The geomorphological studies on the classical geomorphology of the drainage systems of Rarh Bengal and the eastern India were used to find more about the historical context of river development. The existing literature on the feeder canals, dam-controlled rivers and distributary systems in West Bengal provided useful data on the anthropogenic control of the channel morphology.

In addition to this, the topographic maps, drainage maps, and satellite-based interpretations of the past studies were also reviewed to see the difference in the river course, channel-width, and floodplain features as the time changed. These sources were used to deduce the trends of erosion, deposition, and the loss of drainage connectivity in the Behula River system, as well as the narrowing and loss of channel connectivity.

4.2 Analytical Framework

The contextualization of the methodology is established based on fluvial geomorphology and environmental analysis. The morphological changes have been examined depending on such crucial aspects of channels as the channel pattern, the bank stability, the sediment accumulation, as well as connectivity with the floodplain channels and subsidiary channels. These properties have been matched with the natural controlling factors like basin slope, sediment composition and monsoonal hydrology, and the anthropogenic drivers like the flow regulation, embankment construction, and land use change.

It was done through a comparative approach by reference of changes realized and inferred in Behula River to documented case studies as reported in alluvial river systems in India as well as in other locations. The approach helped to isolate the universal geomorphic responses to human interventions and define the general applicability of the findings.

4.3 Assessment of Environmental Impacts

The impacts on the environment were quantified by relating the morphological change to the impact they produced both on the riverine environment and the floodplain. The extra attention was paid to the bank's erosion, siltation, flooding, waterlogging, and deterioration of the ecology. The impacts on agriculture,

aquatic environment, and human settlements were determined through synthesizing published reports and the available records of the regions in literature.

Since morphological instability interacts with environmental vulnerability, the interaction of the two factors was examined to understand the impact of change in channel form on the frequency of floods, the distribution of sediment, and ecosystem wellbeing. The Behula River system possessed the areas of concern and through this qualitative impact assessment they could be identified.

4.4 Limitations of the Study

The researcher underrates the scholar using secondary data and lack of measurements and the high-resolution time series of the field. The discharge, channel migration rates, and sediment load were not evaluated quantitatively. However, the study design remains adequate in achieving the study objectives due to its provision of an effective conceptual and interpretational framework of learning morphological change and environmental mediation in a river system with a limited amount of data.

5. Results and Discussion

Morphological variations in the Behula River system are studied to show a clear tendency of instability of the channels, which is a combination of influence of altered hydrological regimes, altered sediment balance, and human activities. The results indicate that the river has evolved to become a somewhat inactive distributary channel to a restricted and sediment-regulated system that has a significant environmental impact.

5.1 Channel Adjustment and Sediment Dynamics

Among the most striking findings of the study, the dominance of the sediment aggradation in the channel of the river Behula should be mentioned. The river has also lost the sediment carrying capacity due to less discharge by the upstream control of the Damodar River. Thus, fines of transferring monsoon deposited sediments in the channel making it deeper and shallower. The observation aligns with the studies of controlled rivers which shows an increase in siltation and a decrease in channel efficiency further down the flow management structures.

Sedimentation has also contributed towards development of mid-channel bars and shoals, particularly in the low energy reaches. These properties prohibit flow continuity and promote additional deposition that creates a vicious circle that enhances channel erosion rate. The results show that imbalance in sediment is among the causes of the morphological instability in the system of the Behula River.

5.2 Bank Erosion and Channel Confinement

There is also a reduction in the overall discharge, but localized erosion of the banks remains a significant issue on some parts of the Behula River. The results have depicted that the natural lateral realignment of the river has been suppressed by embankments, agricultural encroachments, and artificial straightening of the river channels. The flow of water is cut off along the channel in narrow sections during high monsoons, leading to an increase in the velocity of flow and power of erosion on the banks.

This erosion wave is not uniformly distributed because some areas of erosion are marked by severe bank erosion as opposed to being marked by deposition. This spatial variation serves as a sign of the complex interaction of the channel geometry, sediment load, and human changing. The findings affirm the earlier research findings which hypothesize that channeling enhances erosion rather than stabilizing the riverbanks.

5.3 Loss of Drainage Connectivity and Flood Behaviour

As is described in the research, there is a great loss of hydraulic connectivity between the Behula River

and floodplain channels, wetlands and abandoned river courses. Through historical association, these features provided natural storage facilities, which could absorb excess floodwater and equal the peak flow. This disconnection has significantly contested the deficiency of floodplain storage resulting in more and higher floods.

The results indicate that flooding in the Behula basin is no longer a mere effect of excessive rainfall, but it is also caused by the shrinking of channel conveyance and poor drainage. It has proved to be a recurrent problem that is the cumulative outcome of the morphological decline and obstruction of drains, and results in a problem of waterlogging of farm fields and low-lying settlements.

5.4 Environmental and Socio-Economic Implications

Morphological unsteadiness of Behula River has been quantified in terms of its environmental implications. These have been observed as the siltation, reduced diversity of flows, and the low water quality of the aquatic habitats. The features of natural channels are lost, which affects the reduction of biodiversity shifts in the ecological processes which depend on seasonal flooding and exchanging of sediments.

On the socio-economic level, the results indicate a disposition to increased vulnerability to the riparian communities. Soil has been eroded, resulting in loss of farmlands and frequent floods reduced the yield of agriculture and destroyed the infrastructure of the rural setting. These impacts overwhelm the marginal communities in farming, which makes the correlation of the river morphology to human well-being true.

5.5 Synthesis of Findings

In general, the results confirm that morphological change of the Behula River system is not a one-dimensional process, but a part of a more general process of anthropogenic fluvialization. The system has been created with a reduced resilience to hydrological stress due to the combination of the impact of reduced flow, sedimentation, channel contraction, and drainage disconnection. The discussion reiterates that the distributary rivers should be taken as active participants in the basin-scale processes, rather than as passive receivers of the processes.

These findings justify why geomorphic processes, and long-term morphological trends need to be incorporated in the management of rivers in a sustainable way. Unless the causes of channel instability are fixed, the structural interventions in the Behula River system will unlikely benefit the reduction of the chance of floods or the degradation of nature.

6. Conclusion

The current paper has identified the morphological developments in the Behula River system and has evaluated environmental impacts, which are related to it, within the setting of a humanized alluvial river system. As can be observed, the results show that the river Behula has undergone a drastic change in its channel over the years due to a set of dysfunctional hydrologic systems, sediment imbalance, as well as an excessive anthropogenic intervention. All these have altered the physical appearance of the river and have surpassed its ability to control the flow and sediment.

It can be seen in the discussion that morphological changes most common in the Behula River system are the channel narrowing and siltation, the erosion of the banks, and the connectivity of the drainages. The aggradation and deterioration of channels have been usual in that there has been less amount of discharge in that the amount of sediment being conveyed upstream is reduced. In the meantime, the working of natural channels has been hampered by embankments and encroachment of flood plains and local erosion has made the downstream regions more vulnerable to floods.

The morphological alterations are very important on the effects on the environment. The environmental and socio-economic vulnerability in the river basin has been caused due to the waterway pollution, rise in the flood rate and waterlogs, degradation in agricultural land, degradation in water quality etc. Interruptions in the natural processes have also occurred in the floodplain which has helped to lessen ecosystem resilience and failure to respond to hydrological extreme of the river system.

The paper explains why it is important to employ a hybrid approach in management of rivers like geomorphic sensitivity of the distributary rivers like Behula. The sustainable management plans will be grounded on the restoration of the drainage connectivity, management of the floodplain encroachment and sediment and structural flood control. The fact that geomorphological information is not included in the planning and policy might result in additional ecological decline and the danger of floods.

Finally, the system of Behula River can be considered as a paradigmatic example of predisposition of small distributary rivers upon alluvial plains of high population density towards the morphological instability of the rivers throughout the time. To solve the said problems, the engineering paradigms to the short run solutions ought to shift to the holistic and basin management paradigms which can harmonize human requirements and the natural phenomena of the river systems.

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