# Rapti River as a Civilizational Corridor of Vishal Bharat: A Geospatial Assessment of Hydrodynamics, Settlements Heritage and Cultural Landscape in Eastern Uttar Pradesh, India

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## *Abstract*

*River basins have produced many of the world's most prosperous civilizations. Nepal's culture is closely linked to water and rivers, despite the country's lack of significant rivers. In Nepalese society, rivers are connected to every significant life event, from birth to death. Nepali deities are thought to reside in rivers and ponds. It is acknowledged that the deities connected to rivers are Jalkanya and Jaladevi. In Nepal, many holy places are located beside rivers. By the river are places like Varahakshetra, Bishnupaduka, Devaghat, Triveni, Muktinath and other important Tirthas. Many Nepalese people decide to bury their departed loved ones along the river. The Tirthas in these regions also carry out death-related ceremonies. The Rapti River represents a microcosm of the larger river based civilization processes that shaped Vishal Bharat, where hydrological systems functioned not merely as physical resources but as carriers of Culture, Settlement, Community and Heritage Landscape.*

*The Rapti River is one of the most important left-bank tributaries of the Ghaghara River. Originating at an elevation of approximately 3,048 meters in Nepal, the river rises south of a prominent east-west ridge line located midway between the Mahabharata Range and the western Dhaulagiri Himalaya. In western Nepal, the Rapti River is diverted for nearly 100 km by the Dundwa*

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*Range of the Shiwaliks before flowing southward towards the Ganga. Nepal's rivers possess immense cultural significance, as they serve as centers for sacramental, religious, and cultural activities, including festivals and fairs. Consequently, rivers occupy a central place in Nepalese culture.*

*This study analyses geographical data to examine significant changes in flow patterns, the impact of urbanization, variations in agricultural practices, and sedimentation patterns at selected sites between 2013 and 2021, at intervals of two to three years. Remote sensing and GIS techniques enable continuous monitoring and tracking of temporal variations in the Rapti River's flow patterns.*

*The study further highlights various aspects of the fluvial ecosystem, including channel morphology, natural hazard dynamics, landform changes, and tectonic disturbances.*

***Keywords:*** Rapti River, Mahabharat Range, Civilization and Cultural History, Vishal Bharat, Temporal, Sinuosity, Settlement, Sedimentation, Remote Sensing & GIS Techniques

## Introduction

Rivers have consistently been essential to the growth of civilizations throughout history. They supply water for the residents, catering to both drinking needs and agricultural practices. Furthermore, rivers support fishing, serve as transportation routes and improve soil fertility through the seasonal flooding of adjacent lands. For the populations of the Terai and the Indo-Gangetic Plain in particular, the Rapti River which consists of the East Rapti in Nepal and the West Rapti running between Nepal and India (Figure 3) serves as an essential conduit for life, heritage, cultural history and civilization.

The Rapti River originates in Nepal's Chitwan Valley and flows westward before joining the Narayani River near the Indo–Nepal border. After entering the plains, the river traverses several districts of eastern Uttar Pradesh,


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including Bahraich, Shravasti, Balrampur, Siddharthnagar, Sant Kabir Nagar, Gorakhpur, and Deoria.

During the monsoon season, particularly in the Balrampur and Gorakhpur districts, the river significantly changes its course and flow pattern. These alterations often result in severe flooding, causing extensive damage to agricultural land, infrastructure, and human settlements.

Numerous factors, including channel sinuosity, agricultural practices along riverbanks, rainfall patterns and intensity, soil characteristics, and local geography, influence river channel shifting. Rivers generally alter their course, flow direction, and flow patterns over long periods, typically ranging from 10 to 20 years. However, the Rapti River exhibits unusually rapid changes in its course and flow direction within short intervals of approximately 2 to 3 years.

The continuous and unprecedented shifts in the Rapti River's flow direction, particularly in the Balrampur and Gorakhpur districts, have caused significant damage to agricultural land, altered flow patterns, and affected human settlements and property. These changes have increased the vulnerability of local communities to flooding, erosion, and land degradation.

This Rapti River Day, let's raise awareness about Chitwan's most significant river and urge people to maintain its cleanliness and keep it pollution free. They could access water and most of the herbivorous animals would come to the riverside daily to drink. Thus, rivers served as hubs for both humans and animals. Rivers hold significance for individuals of various religions, beliefs and cultures. The majority of major cities are situated in the river valley. The primary reasons for the establishment of communities in river basins were drinking water, safety and a welcoming environment. Consequently, early humans formed a strong bond with water. Later on, every activity of a man was connected with the river. It is a primary factor influencing the culture of communities along the river. The majority of ancient civilizations arose along riverbanks. Eventually, his connection with the river became constant and many of his endeavors involved water and the river. Nepal is separated into


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mountains, hills and lowland areas. Therefore, individuals from various regions possess distinct cultures. It is because of the influence of geography. The presence of forests and the discovery of mines and minerals also influence the lifestyle of the community.

Natural vegetation has an impact on people's culture as well. As a result, people's culture and civilization are impacted by natural resources. The precise date of man's origin is unknown to us. Nonetheless, it is believed that man began in central Asia. Man spent a considerable amount of time traveling to various locations in the beginning. Around 3500 BC, he began to live along the river's banks. Following that procedure, social organizations were also created. From the Indus Valley to Egypt, such civilizations emerged. Geographically low terrain, a favorable climate and fertile soil were all conducive to the rise of human civilization.

The political system was created by humans throughout the era of civilization. The end of the Neolithic era marked the beginning of civilization. Man found facilities once metal was invented and people moved to new locations. But he kept up a regular relationship with river. As a result, rivers are associated with various types of activities. People who live distant from rivers have a connection to them as well. River culture is the culture that grew up along the banks of rivers. The development of river culture occurred during the period of civilization. As a result, the river valley contains ancient historical evidence. Large towns like Banaras and Calcutta, for instance, were built along riverbanks. Even now, large cities can be found along riverbanks. Rivers are regarded as goddesses by Hindus. They are regarded as sacred centers as a result. During festivals, feasts and other events, a lot of people visit the riverbank to take a sacred bath. Following the bath, many sacramental and religious rituals are carried out along the banks of the river. Similarly, waterways serve as places of prayer for the Ganga. According to the Puranas, Ganga is Lord Shiva's bride and the daughter of Bhagiratha. However, rivers are regarded as Jaldevi. She is worshipped by some ethnic groups in Nepal by macassaring animals and birds.


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Nepal does not have large rivers like Egypt, Pakistan, India or Iraq, and these river basins do not contain the archeological remnants of past civilizations. We three do, however, have a few rivers that are more crucial to the advancement of civilization and culture. The three main rivers in Nepal are the Koshi, Gandaki and Karnali. The largest is Koshi, the deepest is Gandaki and the longest is the Karnali. The Koshi River rises in Tibet and empties into India's Ganga.

Other rivers like Gandaki and Karnali also originate from Tibet, flow through India and reach up to Ganga. Arun and Bhote or Tamba Koshi of Koshi river and Humla Karnali branch of Karnali river are originated from Tibet. In the same way, all the rivers of Nepal reach up to Ganga river of India and flow towards Bangladesh.

The development of a society's culture is greatly influenced by the topography of a region. Geographical features affect communities both directly and indirectly by shaping their lifestyle, occupation, settlement patterns, and cultural practices. In ancient times, nomadic communities lived in forests and moved from place to place in search of food and water. During hunting expeditions, they often relied on large rivers as their primary source of drinking water.

Similarly, wild animals also depended on river basins for water. Most herbivorous animals regularly visited riverbanks to drink water and graze on nearby vegetation. Thus, rivers played a crucial role in sustaining both human and animal life. Over time, human settlements developed near rivers due to the availability of water, fertile land, transportation, and other natural resources. Consequently, geography and river systems significantly influenced the growth of culture, civilization, and social organization.

We classify rivers into three categories based on their sources.

*The first category consists of rivers:* That originate from the Himalayan region. The primary rivers in this category are Koshi, Gandaki and Karnali.


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Each of these rivers has seven branches, referred to as Sapta Koshi (Seven Koshi), Sapta Gandaki (Seven Gandaki) and Sapta Karnali (Seven Karnali). They flow from the eastern, central and western parts of Nepal respectively. These rivers emerge from high mountains and are generally abundant in water throughout the year. However, some of their branches also originate from Tibet. Only a limited number of rivers arise from the Mahabharat or Chure region of Nepal. Most of these rivers flow in a north-to-south direction. The first type of rivers originates from the Himalayas, glaciers, snow-capped mountains and lakes, which provide a permanent water source. Water flows continuously throughout the year in these rivers. The three major rivers are categorized within this group.

*Similarly, the second category of Rivers:* Originates from the Middle Hill Region. These rivers also serve as a water source for the Terai region. They merge with the larger rivers and flow down towards the lowlands. Even during the dry season, water can be found flowing in these rivers. Examples of second category rivers in Nepal include Mechi, Kankai, Kamala, Bagmati, Rapti, Babai, Trijuga, Koka, Kabeli, Teliya, Lambu, Pinguwa, Koyakhola, Banchare Khola, Sabhakhola, Piluwa, Tinau, Banganga, Chepe and Paundikhola. These rivers originate from the Mahabharata range and connect to the larger rivers.

*Some of them flow directly into the Ganges:* While others join the larger rivers in the hills or continue to the lowlands before reaching the Ganga river. Most of these rivers converge with larger rivers in the hills. However, some have traversed the Churia range and flowed towards the lowlands. Rivers such as Mechi, Kankai, Kamala, Thijuja, Rapti and Babai reach the lowlands by crossing the Churia range and flow towards India. The smaller rivers that originate from the Churia hills are classified as third category rivers.

Nepalese culture is fundamentally intertwined with river activities. Rivers serve as the heart of civilization and a significant portion of our cultural practices is associated with them. Many of our religious sites are situated along the banks of rivers, which are revered as sacred centers within our culture. The majority of our cultural practices are linked to the river. Our rituals, spanning


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from birth to death, are connected to rivers and their confluences. In Nepalese culture, rivers are pivotal for bathing, conducting various sacraments and performing worship for deities. The rivers themselves are regarded as goddesses. All rivers in Nepal are referred to as Parvati or holy Gangas. Consequently, a large number of religious, sacramental and cultural activities are concentrated along the riverbanks. The primary cultural activities conducted at the riverside include the following. Organizations of the Festivals embody cultural values, and most are associated with religious practices. Several of these festivals are celebrated along the riverside (Anderson, 1988: 79). Events such as Makarsamkranti, Rishirarpani, Rishipanchami and Chhaith are closely linked to the riverside. During these festivals, people partake in holy baths on the riverbanks. Rivers are considered pure and sacred, serving as a means of cleanliness during festival celebrations. In Nepalese culture, rivers are honored as the goddess Ganga and it is believed that deities also inhabit the riverbanks. Thus, many sacred sites are located along the banks of rivers in Nepal and several festivals are organized in these areas.

According to linked geographical data, the Rapti River, which includes the West Rapti and East Rapti, is an important waterway in Nepal and India, contributing significantly to historical, agricultural, and ecological development. It is a major tributary of the Ghaghra River, which itself is a left-bank tributary of the Ganges. Rivers not only shape the landscape but also play a vital role in ecological and social systems.

The Rapti Basin in Uttar Pradesh is located between East longitudes 81°35' and 83°49' and North latitudes 26°18' and 27°59' (Figure 1), covering an area of 14,658.20 square kilometres. Historically, the Rapti river was known as Iravati. The Rapti river originates in Nepal near Rukumkot in the Mahabharat range of the lesser Himalayas. The river begins in Nepal's Mahabharat range at an elevation of 3,050 meters. The Rapti river basin has a diverse physiography. The entire basin's topography is made up of lofty mountains, inner and outer Tarai and undulating plain regions. Rapti river begins as a small river draining Nepal's Chitwan (Inner Terai) valley and flows west to


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join the Narayani (Gandaki) river a short distance to the north. The Rapti zone is located in Nepal's Middle Hills, between the Karnali and Gandaki Basins.

The Rapti river in both its East and West flows serves as an indispensable natural resource for Nepal and northern India. From sustaining agriculture to sheltering endangered wildlife and shaping cultural identities, the Rapti continues to influence lives and landscapes along its winding path.

Rivers have always been essential to the growth of civilizations. They provide water for drinking, agriculture, and other daily needs of local populations. The annual flooding of rivers also enhances soil fertility, supports fishing activities, and facilitates transportation. The Rapti River, a major tributary of the Ghaghara River flowing through Nepal and Uttar Pradesh in India, serves as an important agricultural and cultural lifeline. It is often regarded as a sacred river in local traditions and supports diverse ecosystems, particularly around the Chitwan region, while sustaining dense human settlements.

The Rapti river is a prominent river in Southwestern Nepal and Northern India, serving as a crucial water source for agriculture, ecology and human settlements in the region. Divided into two main rivers the West Rapti river and the East Rapti river, the system supports diverse landscapes, from Himalayan foothills to fertile plain.

Rivers not only curve the landscape, but also play an important role in ecological and social system. It is important to identify the geomorphic processes of river channel and floodplain, which construct and sustain riverine ecosystem.

Rapti river basin extends from 26°18’00’’ N to 28°33’06’’ N and 81°33’00’’ E to 83°45’06’’ E and covers an area of 25,793 $Km^2$, out of which 41% (10,642 $Km^2$) lies in Nepal and 59% (15,151 $Km^2$) in India. The Rapti river is the largest tributary of the Ghaghra river, which in turns is a major tributary of the Ganges river system (Figure 3). After flowing through the mountainous and steep path in Nepal region, it enters India at Holiya village and flows in Bahraich, Shrawasti, Balrampur, Siddharth Nagar, Sant Kabir Nagar,


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Gorakhpur and Deoria districts of eastern Uttar Pradesh before merging into the Ghaghra river at Kaparwaa ghat. The Rapti river basin is diverse in its physiography because Nepal part of the basin is completely mountainous and river flows in deep gorges, while the Indian part is relatively flat.

The Rapti river is an important foothill-fed tributary of the Ghaghara river in terms of runoff and sediment load. The plan form of the Rapti is highly sinuous in the study area. The present work focuses on the fluvial geomporphological features within the valley margin. The study shows that the flood plain is formed by lateral migration of the channel. In addition, an attempt was also made to study the hydro meteorological conditions of the 2013 to 2021 pre- and post- monsoon season and their impact on channel instability. Lateral expansion, translation of the meander and cut off formation are responsible for changing the plan form of the channel. Based on the ratio of bar area to channel belt area and channel area, we identified a gradational and derivational process. The displacement distance and direction of the January 2013 central line with respect to the September 2021 center line were calculated in the geospatial environment. To completely comprehend an issue, it is imperative to know the reason for the issue. In this case, migration is the problem, which occurs as a result of channel instability. For this study, instability is defined as movement in the channel bed and/or banks. Bed instability results from channel aggradations or degradation, leading to a vertical adjustment. Bank instability results from the removal of bank material through grain-by-grain detachment or mass wasting, leading to a width adjustment. Bed and bank instabilities are linked because one can cause or be the result of the other. An example of this would be if a channel had stable banks but was incising through bed degradation, increasing the bank heights to a point exceeding the critical height, where bank sloughing or bank collapse occurs.

The focus of this study is on the meander migration of alluvial channels, which results primarily from bank instabilities. In describing the process of meander migration Julien (2002) states that migration in meandering rivers is a result of erosion at the outer bank combined with the equivalent sedimentation near the inner bank. In alluvial river systems, it is the rule rather than the exception


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that banks will erode (Richardson et al., 2001). The eroded bank material is transported downstream to the next point bar, where outer bank erosion is usually balanced by bar deposition and advance.

All alluvial rivers flows are classified into three categories namely meandering, braided and straight (Leopold and Wolman, 1957). The meandering streams have a distinct plan form with point and mid channel bars. The sinuosity index of 1.5 and above was defined for meandering streams by Leopold and Wolman (1957). However, the straight channels reflect a sinuosity Index of less than 1.5 (Figure 1 and Table 2).

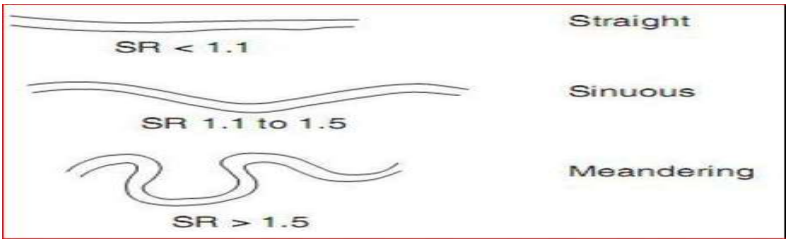


Figure 1. Channel patterns for different Sinuosity ratio

The alluvial rivers are the most dynamic geomorphological agents of the fluvial river landscape. They periodically adjust width, depth area and hydraulic radius in response to fluctuating discharge and sediment feed. The mutilated satellite imagery data are very useful. To accurately quantify these adjustments in a short space of a time. Remote Sensing and GIS plays an important role in decision making during flood, excessive rainfall, river meandering and coarse change of the river. It provides accurate temporal data of the specific region by which precise mitigation and actions can be taken. This will be very beneficial in life saving of humans and animals as well as agricultural activities.


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## Objectives

The primary objectives of this study is to mainly point out the important locations of the Rapti river where the river is changing its coarse within short span of time. The main points of this study are:

1. To relationship between Rapti river to Civilization, Settlements Heritage, Cultural Landscape and Hydrodynamics corridor of Vishal Bharat.
2. To point out the locations where the Rapti river is drastically changes its coarse from 2013, 2017 and 2021 in Balarampur and Gorakhpur districts of Uttar Pradesh, India.
3. To study the impact of Rapti river flow pattern on Ecology, Human Settlement, Sedimentation and Agricultural activities.
4. To locate the year wise (2013, 2017 and 2021) meandering pattern on satellite map.
5. To assess the sinuosity pattern and its impact on river hydrodynamics.

## Geomorphology

The Rapti river basin may be divided into three zones:

1. **The Northern Mountain Zone or Shiwalik Himalaya**: The Northern Mountain Zone, also known as the Shiwalik Himalaya, is the foothills of the Himalayan Range and is primarily composed of Miocene to Pleistocene molassic sediments derived from Himalayan erosion. The Muree and Siwaliks formations are internally folded and imbricated molasses deposits. The sub Himalaya is thrust along the main Frontal Thrust over Quaternary alluvium deposited by Himalayan rivers (Ganga, Indus, Brahmaputra and others), demonstrating that the Himalaya is still a very active orogen.
2. **The Tarai Zone:** The Tarai Zone is traversed by the large perennial Himalayan rivers Yamuna, Ganga, Sharda, Karnali, Narayani and Kosi, each of which has created alluvial fans covering thousands of square kilometers below their exits from the hills.


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3. **The Plain Zone:** The Mahabharat Range is the source of medium rivers like the Rapti. The geological structure of the region is made up of both old and new alluvium, both of which are alluvial deposits primarily composed of sand, clay, silt, gravels and coarse fragments. Every year, fresh deposits brought down by active streams that engage in fluvial action replenish the new alluvium. Old alluvium is found away from river courses, particularly on plains uplands where silting is uncommon.

## Geological Pattern of Rapti River

Geologically, the basin consists of two distinct parts; the great Indo-Gangetic trough and the Himalayan foothills of the Siwalik. The Indo-Gangetic trough consists entirely of the alluvium, a composition of sand, silt and clay in varying proportions. In terms geological age, these deposits correspond to two major divisions of the Quarternary era; the Pleistocene and the recent. The alluvium is found in two large groups, i.e. the older alluvium known as “Bhangar”, the age of which is estimated as middle Pleistocene and the newer alluvium (Khadar) which is more recent and undergoing formations by a gradational work of the rivers.

## Importance of Rapti River

The Rapti River (West) is a critical 776 km transnational river rising in Nepal's Mahabharat Range and joining the Ghaghara River in India, vital for agriculture, biodiversity and culture in both nations (Figure 2). It acts as a lifeline for the Chitwan National Park region, supports diverse wildlife (including dolphins and muggers) and is a major source of irrigation, despite frequent, heavy flooding in lower plains.


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Figure 2. Rapti River, the lifeline of Chitwan National Park is the source of civilization in the Chitwan Valley

The Rapti river (or West Rapti) is a crucial 776 km trans-boundary river flowing from Nepal to India, serving as a major lifeline for agriculture, ecology and transportation in eastern Uttar Pradesh and surrounding regions. It acts as a primary tributary to the Ghaghra River, significantly impacting floodplains, tourism near Chitwan National Park and local livelihoods, while also posing substantial flooding risks.

- **Agricultural and Economic Lifeline:** The river provides essential water for irrigation to the surrounding agricultural lands in Nepal and Uttar Pradesh, India. It supports local communities by facilitating economic activities and providing a source of livelihood.
- **Ecological Significance:** It supports a rich, diverse ecosystem, especially in the Chitwan region (Figure 2) acting as a crucial water source for wildlife, including endangered species. It flows through key areas containing Gangetic dolphins, mugger crocodiles and various bird species.


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- **Biodiversity Conservation:** The river serves as a major habitat for aquatic life and is integral to the biodiversity of the Chitwan National Park.
- **Tourism and Recreation:** The river is a center for eco-tourism activities, including canoe safaris for viewing wildlife, such as rhinos, elephants and tigers in neighboring, protected areas.
- **Cultural and Historical Value:** The ancient Buddhist pilgrimage site of Shravasti is located on its bank, highlighting its historical importance.
- **Flood Management Challenges:** As a "foothills-fed river," it frequently causes significant, localized flooding and changes its course, which requires careful floodplain management for safety and agricultural protection.

The river is essential for the ecological, social and economic stability of the region, despite the challenges posed by its dynamic nature.

## Study Area

The study area lies in the mountainous part of the West Rapti river in the Nepal. The East Rapti river is an ecological treasure, providing sustenance to the rich biodiversity of Chitwan National Park, a UNESCO World Heritage Site (Image 1). The river's ecosystem supports numerous species of mammals, reptiles, birds and aquatic life. The East Rapti river is one of Nepal's prominent rivers, flowing through the Chitwan Valley and forming the northern boundary of Chitwan National Park. Originating from the Mahabharat Hills, this river plays a crucial role in supporting local ecosystems, wildlife and human settlements. Its waters sustain a rich biodiversity, serve as an economic resource and contribute to the growing tourism industry in the region.

Rapti river is an important tributary of Ghaghara river which is a major tributary of the river Ganga. After rising in the Siwalik foothills of the Nepal, Himalayas, the river Rapti drains the Indo-Gangetic plain, where it attains base level of erosion. As a result, the deepening of the river channel replaced by a channel widening. Just after flowing 152 km. through Nepal, it enters Eastern Uttar Pradesh in the village of Kundwa in the district of Bahraich (District


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Gazetteer, Bahraich, 1988). It flows through the districts of Bahraich, Balrampur, Sravasti, Basti and Gorakhpur and joins the Ghaghara on its left bank near the town of Barhaj, Deoria district. The area of the Rapti river basin is 25,793 $km^2$. The Rapti is identified as foothills fed river. It derives enormous amounts of sediment from the foothills of Nepal Siwaliks and also from the plains and a large proportion is re-deposited in the plains after local reworking (Jain and Sinha, 2003). The river is fed by numerous tributaries and affluents. Those of the northern or left bank originated from Siwalik and Bhabar region and on the south represent merely old beds of the river. Important left bank tributaries of the Rapti are Budhi Rapti, Ghonghi, Kain and Rohin. The Bhakla, Ami and Taraina are the noted right bank tributaries (Image 3 and Table 1).

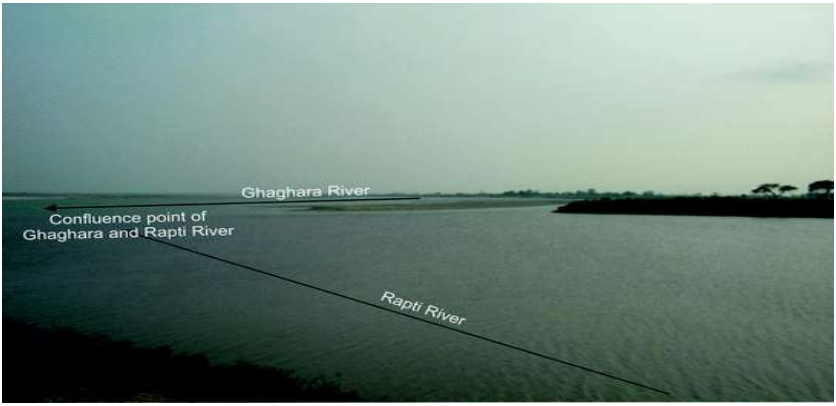


Figure 3. The Rapti River: Odyssey from Nepal to India


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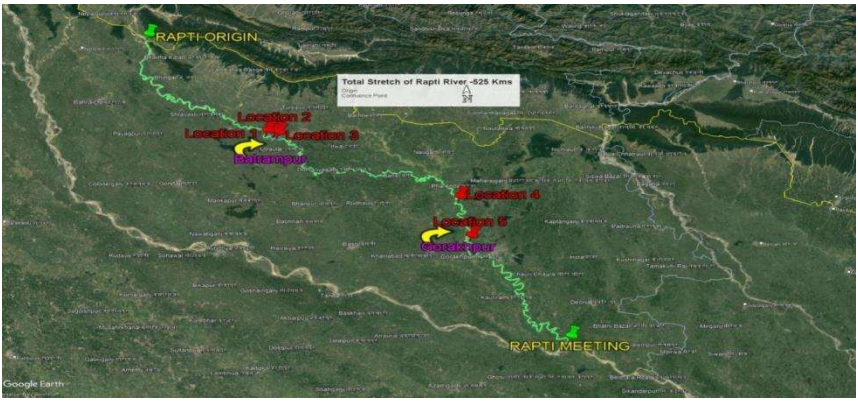


Image 1. Image showing Location of Rapti River, Balarampur and Gorakhpur District, Uttar Pradesh

Table 1. Locations Where Rapti River Changing its Maximum Coarse

| Point No. | Village | Block | Distr ict | Latitude | Longitude |
|---|---|---|---|---|---|
| 1 | Perahwa Chuhchuia | Sriduttganj | Balrampur | 27°13'16.53'' N | 82°20'28.42'' E |
| 2 | Bharbhariya | Balrampur | Balrampur | 27°22'53.58'' N | 82°22'33.15'' E |
| 3 | Majhari Doolha | Sriduttganj | Balrampur | 27°22'51.24'' N | 82°24'8.80'' E |
| 4 | Gaya Ghat | Campierga ng | Gorakhpur | 27°01'50.33'' N | 83°11'10.57'' E |
| 5 | Rajpur Doobi | Jangle Kauria | Gorakhpur | 26°49'53.49'' N | 83°14'35.99'' E |

## Methodology

The present work is based on Hydrodynamics study of Rapti river which is very dynamic in nature in terms of flow, changing direction, sedimentation and sinuosity. The Rapti river is delineated with the help of Arc GIS 10.8, Google map and Google earth pro. Software GIS Arc was used to identify the historical meander changes. The ability to obtain extremely precise


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measurements between places is one of the benefits of using GIS. The Rapti river and its tributaries were then subjected to quantitative study to look at changes in meander shape, meander classification and trend analysis. The channel sinuosity or channel length over valley length has to be calculated and measured. Accordingly, a crucial measure of a river channel's stability is the sinuosity index (Hooke et al., 1992; Rosgen 1994).

Direct measurements of geometric characteristics (e.g. area and perimeter of the river, length and width of streams) are automatically obtained from GIS software. The drainage pattern is dendritic in nature and it is inclined by the general topography of the area. The Rapti River Basin is situated in Bahraich, Shravasti, Balrampur, Siddharthnagar, Santkabinagar, Gorakhpur and Deoria districts of the Eastern Uttar Pradesh. It lies between 27°13'16.53''N latitude and 83°14'35.99''E Longitude. The study area is covers 525 $km^2$. Total number of 5 locations are selected, these villages are, Perahwa Chuhchuia, BharBhariya, Majhari Doolha, Gayaghat and Rajpur Doobi, respectively, for the study of hydrodynamics is based on the maximum shifted of river coarse, cutting of banks and sedimentation. After seduction of points we categorized the temporal satellite data of the year 2013, 2017 and 2021 respectively. Furthermore, the path of flow is digitised on the Google Earth pro software for demarking the changes in the flow pattern. The 2013 year flow is given green color, 2017 year flow is given in blue color and 2021 year flow is given in red color, after that we merged all the three flow path of the river and observed the settlement and route change of rapti river.

## Channel Dynamics

Lateral expansion is the widening of channel across valley floor due to lateral erosion. The displacement of the meander is the downstream movement of the meander without changing its previous shape.

## Meander Trend Analysis: Rapti River

GIS techniques (spatial-temporal analysis of satellite imageries) using advanced remote sensing data over the last 20 years, have been used to identify


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changes in the river course (both river and tributary channels) and further computation has analyzed river shifting and bank erosion. The multi-temporal remote sensing data were individually processed and analyzed in a GIS environmentfor pre-monsoon. Delineation of river course and identification of deposits were digitized into shape files. By overlaying this database location of bank line shifting of Rapti river and tributaries has been identified. The shifted parts of the river are mappedby vectorisations in GIS. The change is detected by superimposing various data sources by mapping calculations. Quantitative data generation and thematic maps have been produced outlining hot spots of high bank erosion at meander. Where the curvature of a river is higher, often there is a higher bank erosion of fertile soil due to active water forces (water velocity is higher). Low vegetation cover increases erosion rates on curvature of bank. Human activities including dredging, agriculture and deforestation may contribute to bank erosion and bank line shifting.

**Floods on Channel Belt Parameters of Rapti River:** A Remote Sensing and GIS approach between 1.2 and 2 for meandering streams and less than 1.2 for a straight stream. Further, the classified alluvial channels are of two major categories i.e. stable and unstable channels. A stable channel demonstrates a fixed bed and bank while an unstable channel shows frequent changes in bed as well as bank position (Table 2).

Table 2. Channel Patterns for Different Sinuosity Ratio

| Point No. | Village Name | Sinuosity | Sinuosity Ratio (SR) |
|---|---|---|---|
| **1** | Perahwa Chuhchuia | Medium Meandering | 1.1 to 1.5 |
| **2** | Bharbhariya | High Meandering | >1.5 |
| **3** | Majhari Doolha | High Meandering | >1.5 |
| **4** | Gaya Ghat | Low Meandering | <1.1 |
| **5** | Rajpur Doobi | High Meandering | >1.5 |

Table 3. Description of Meander Location at Starting, Center & Ending Points, Rapti River


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| | Meanders Locations | | | | | |
|---|---|---|---|---|---|---|
| **Point No.** | **River Name** | **At Starting** | **At Center** | **At Ending** | **Width (Current Sceneario-2021)** | **Remark** |
| **1** | Rapti River | Downward Movement | Flow direction Changes | Downward movement of Channel | Width has increased | At the center flow the direction changed |
| **2** | Rapti River | Upward Movement | Flow Direction Upward | Upward Movement of Channel | Width has increased | The Width of the river has increased |
| **3** | Rapti River | Upward Movement | Flow Direction Downward | Upward Movement of Channel | Width has increased | Meander flow has converted into straight line flow |
| **4** | Rapti River | Almost same flow pattern | Upward Movement | Almost Same Flow Pattern | Slight increased in Width | At the center flow direction changed |
| **5** | Rapti River | Downward Movement | Upward Movement | Upward Movement of Channel | Slight increased in Width | Flow Direction has changed |

The process of sinuosity measurement involved measuring the valley length as a straight line drawn from the starting point to the end point of each sub-reach and the channel length which was a meandering line along the channel axis. The calculation of sinuosity index which was carried out using the database was analyzed through GIS and this formula: Sinuosity Index (SI) = Channel Length (CL) / Valley Length (VL) (Table 3).


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## Result

Details of Point 1, 2, 3, 4 & 5 of Rapti river are discussed below.

| Location Point | Width of the river at starting Point (m) | Width of the river at Center Point (m) | Width of the river at Ending Point (m) |
|---|---|---|---|
| **Point 1** | | | |
| 2013 | 101.59 | 120.72 | 167.62 |
| 2017 | 42.1 | 44.88 | 149.93 |
| 2021 | 188.94 | 218.01 | 281.92 |
| **Point 2** | | | |
| 2013 | 45.99 | 36.44 | 104.26 |
| 2017 | 73.66 | 65.34 | 91.58 |
| 2021 | 319.47 | 262.47 | 156.49 |
| **Point 3** | | | |
| 2013 | 149.19 | 145 | 76.67 |
| 2017 | 158.41 | 204.33 | 133.7 |
| 2021 | 220.43 | 274.36 | 219.86 |
| **Point 4** | | | |
| 2013 | 120.27 | 143.44 | 189.84 |
| 2017 | 163.64 | 94.43 | 141.63 |
| 2021 | 164.17 | 223.62 | 174.62 |
| **Point 5** | | | |
| 2013 | 157.53 | 146.74 | 211.78 |
| 2017 | 106.75 | 81.24 | 108.74 |
| 2021 | 118.18 | 209.95 | 132.08 |

## General Observations of Individual 5 Points

**Point 1:** This point comes under Perahwa Chuhchuia Village, Balrampur district. At starting point from 2013 to 2017 the width decreases (from 101.59 m to 42.10 m) and increases between 2017 to 2021 (42.10 m to 188.94 m), at the center point the width decreases from 2013 to 2017 (120.72 m to 44.88 m) and increases from 2017 to 2021 (44.88 m to 218.01 m) at the end point 2013 to 2017 there is small change in river width (167.62 m to 149.93 m), but during


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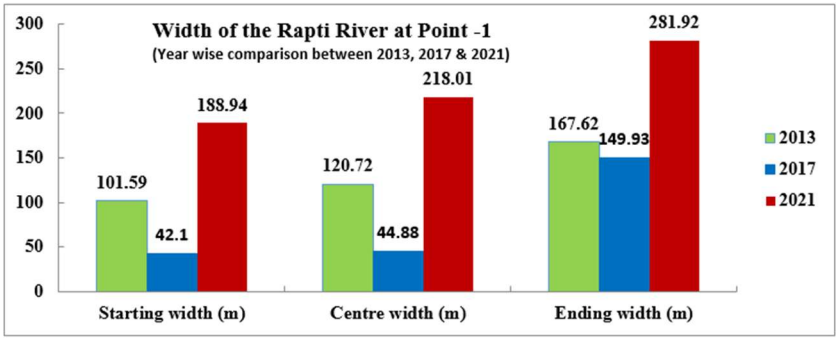
2017 to 2021 the width increases rapidly (149.93 m to 281.92 m). At this point the channel is shifting downwards as showing in image 2.


Image 2. Showing Image Channel Shifting Downwards in Perahwa Chuhchuia Village, Balrampur District




**Point 2:** This point comes under Bharbhariva village, Balrampur district. At starting point from 2013 to 2017 the width increase (from 45.99 m to 73.66 m) and increases between 2017 to 2021 (73.66 m to 319.47 m), at the center point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the width increase from 2013 to 2017 (36.44 m to 65.34 m) and increases from 2017 to 2021 (65.34 m to 262.47 m) at the end point 2013 to 2017 there is decrease in river width (104.26 m to 91.58 m), but during 2017 to 2021 the width increases rapidly (91.58 m to 156.49 m). The river channel shifting towards North direction (Image 3).

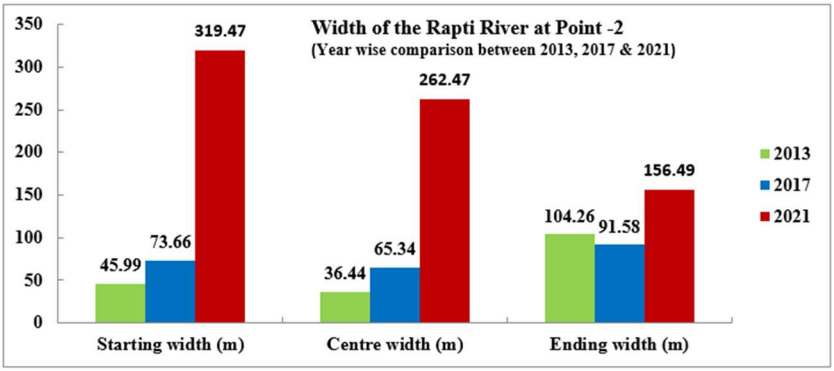



Image 3. Showing Image Channel Shifting towards the in Majhari Doolha Village, Balrampur District

**Point 3:** This point comes under Majhari doolha village, Balrampur district. At starting point from 2013 to 2017 there is small change in width (from


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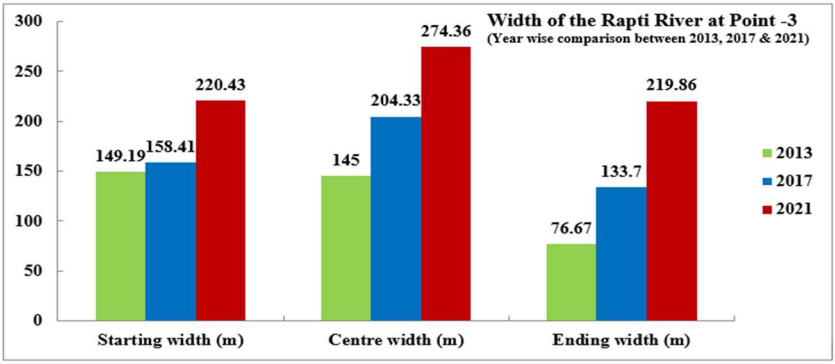
149.19 m to 158.41 m) and increases between 2017 to 2021 (158.41 m to 220.43 m), at the center point the width increase from 2013 to 2017 (145 m to 204.33 m) and increases from 2017 to 2021 (204.33 m to 274.36 m) at the end point 2013 to 2017 there is increase in river width (76.67 m to 133.70 m), but during 2017 to 2021 the width increases rapidly (133.70 m to 219.86 m). The river is shifting towards south direction (Image 4).



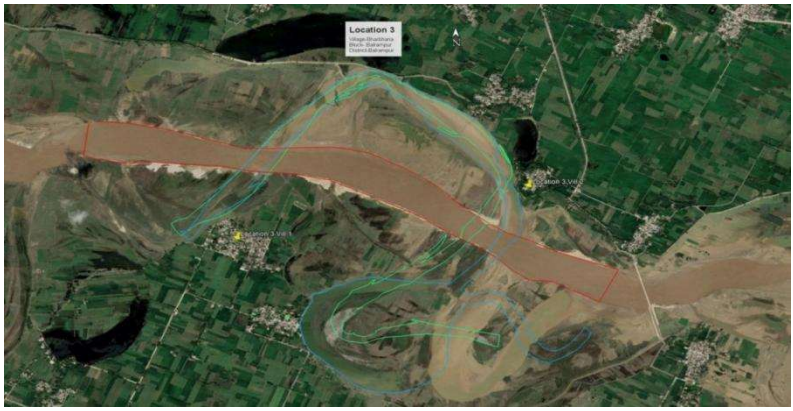




Image 4. Showing Image Channel Shifting towards the South Direction in Bharbhariya village, Balrampur district

**Point 4:** This point comes under Gayaghat village, Gorakhpur district. At starting point from 2013 to 2017 there is increase in width (from 120.27 m to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163.64 m) and almost same between 2017 to 2021 (163.64 m to 164.17 m). At center point from 2013 to 2017 there is decrease in width (from 143.44 m to 94.43 m) and increases between 2017 to 2021 (94.43 m to 223.62 m), at the end point 2013 to 2017 there is decrease in river width (189.84 m to 141.63 m), but during 2017 to 2021 the width increases from (141.63 m to 174.62 m). At this location there is formation of oxbow lake and a new flow pattern arises (Image 5).

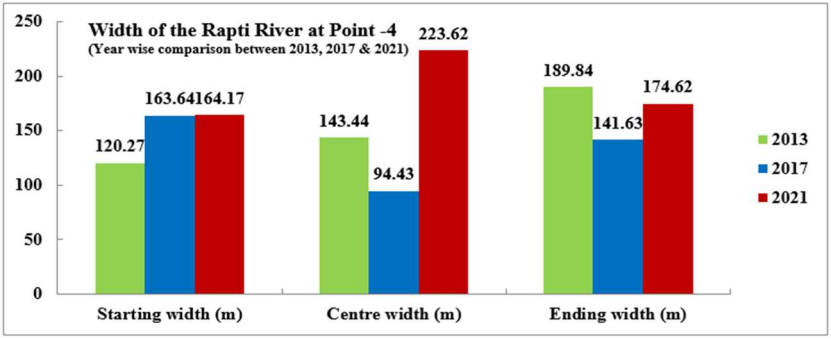



Image 5. Showing Image Formation of Oxbow Lake and New Flow Pattern in Gayaghat Village, Gorakhpur District


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**Point 5:** This point comes under Rajpur Doobi village, Gorakhpur district. At starting point from 2013 to 2017 there is decreases in width (from 157.53 m to 106.75 m) and almost same between 2017 to 2021 (106.75 m to 118.18 m). At center point from 2013 to 2017 there is decrease in width (from 146.74 m to 81.24 m) and huge increase in width between 2017 to 2021 (81.24 m to 209.95 m), at the end point 2013 to 2017 there is decrease in river width (211.78 m to 108.74 m), and during 2017 to 2021 the width increase from (108.74 m to 132.08 m). At this point the channel shifted towards east (Image 6).

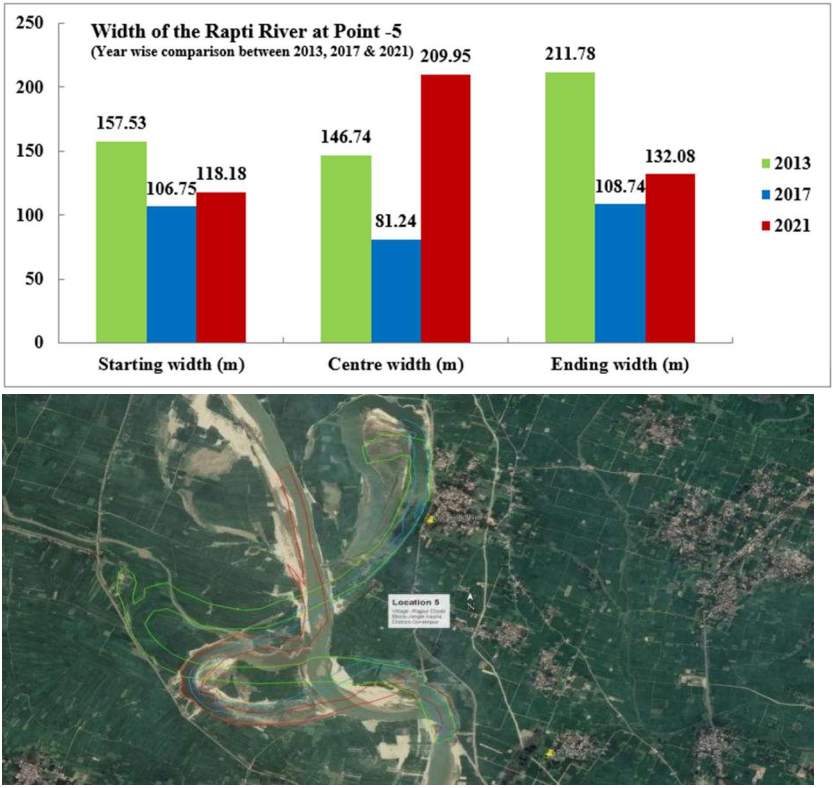


Image 6. Showing Image Channel Shifting towards the South Direction in Rajpur Doobi Village, Gorakhpur District


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## Conclusion

The most significant conclusion of this study is that Rapti River is having very dynamic nature in terms of flow, changing in direction, sedimentation and sinuosity. The study area shows that these points 1, 2, 3, 4 and 5 are facing vary severe meandeaing problem at that locations, because of high flow velocity, high amount of sediment accumulation and low cohesively of sand. It is very clear from the study that from year 2013 to 2021, the Rapti river is showing drastic change in the coarse flow, cutting of river banks, agriculture pattern around banks, settlement of villages and left and right shift in the flow direction. The observations obtained after studying these five points' in-terms of starting, center and ending are:

**Parallel Flow**: Stream velocity/ shear stress removed granular bank material, causing grain-by-grain detachment of bank particles. This leaded to undercutting of the bank, resulting in a cantilever failure.

**Concentrated Flow**: Flow is occurring at an angle to the bank because of obstructions, debris or bar formations. Turbulence, velocity, shear stress, such as bursts and plunges remove bank material. This delivers a more noteworthy impact than that of parallel flow.

**Over Steepening of Bank**: Bank angle greater than cohesive properties of soil.

**Rilling and Gullying**: Uncontrolled channelized runoff from overbank areas.

**Erosion**: Unchannelized surface runoff.

**Piping and Seepage**: Flow through the soil may transport soil particles through the bank surface, leaving a void in the bankmaterial. This leads to cave-ins: Gorakhpur and Balrampur both is rainfall prone zone due to which the cutting of bank and huge accumulated rain fall comes into the Rapti river channel which results in meandering and channel migration.


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The river has undergone significant morphological changes due to unauthorized, unscientific, and unplanned sand and gravel mining activities. These changes include shifting stream banks, riverbed degradation, bank erosion, disruption of sediment balance, and increased threats to hydraulic structures such as bridges and embankments. Excessive extraction of sand and gravel disturbs the natural flow dynamics of the river and adversely affects the surrounding ecosystem.

To manage these morphological changes effectively, replenishment studies are recommended to estimate the sustainable quantity of sand and gravel that can be extracted. Such studies are essential for maintaining sediment balance, minimizing environmental degradation, and ensuring the long-term stability of the river system.

Monitoring and identification of bank line erosion, changes in river course, sedimentation considering the water channel of river is important. Where conventional method of collecting information are tedious and time taking as well, remote sensing and GIS proves as a boon for such studies as they provides accurate spatial and temporal information in a few synoptic coverage. The Rapti river is far more than a geographical entity; it is a profound, albeit tempestuous, cultural landscape that has shaped the history and livelihood of the Himalayan foothills and the Gangetic plains. While its destructive floods (Gorakhpur's Sorrow) present continuous challenges, the river remains an invaluable, living repository of indigenous culture, a cradle of ancient Buddhism and a foundational source of biodiversity and agricultural sustenance, necessitating a balance between development and conservation for its future.

Last but not the least, Nepali culture is intricately connected with rivers and water. Many sacred sites are situated along the banks of major rivers. Locations such as Varahakshetra, Devaghat, Rurukshetra, Maidhar, Kathmandu, Janakpur, Kapilvastu and Muktinath are positioned beside rivers. The rivers themselves are revered as goddesses by the Nepali people, hence, they are referred to as *Mata*, meaning mother. For instance, Kankaimai, Kausikimata,


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and Narayani Mai exemplify the veneration of rivers as maternal figures. Additionally, ethnic communities perform sacrifices of animals in honor of river goddesses. At times, she is also worshipped under the name *Jalakanya*. Culturally, water pollution is forbidden and contaminating water is regarded as a grave sin within the traditional Hindu framework.

Ancient cities were established along riverbanks. For the Nepali people, rivers serve as sites for holy bathing, with confluences being particularly esteemed for this purpose. Various occasions are designated for bathing in rivers, including Kumbha Snana, Makar Samkranti, the commencement and conclusion of Bratas, Chhait, Rishipurnima, and Rishitarpani among others. Nearly all sacraments observed by Nepali people are associated with water and rivers, with most rituals conducted along riverbanks. For example, the disposal of a deceased body occurs in the river. Similarly, other rites related to death are performed there as well. The remaining aspects of the sacraments and other yajnas are carried out following a holy bath in the river. It is believed that deities, goddesses, and ancestors (*Pitris*) inhabit the water and rivers. The deities residing in the water are referred to as *Jaladevata*. Every aspect of Nepali culture is closely intertwined with rivers. Thus, it can be concluded that Nepalese culture is fundamentally a river culture.

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