

Sediment Transport Modelling using MIKE 11: A case Study of Koshi River

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Abstract

This study was initiated to better understand the sediment transport capacity of a reach on Koshi River at downstream of Koshi Barrage in a length of 21 km approximately. Koshi River, a vital watercourse in the Himalayan region, plays a pivotal role in the lives of millions of people residing in its basin.

The primary objective of this research is to gain a deep understanding of the hydrodynamic and sediment transport patterns within the Koshi River, particularly focusing on seasonal variations and sedimentation rates. These insights are critical for informed decision-making and the sustainable management of this vital natural resource.

One of the standout findings from this study is the discernible monthly variation in water discharge observed within the river. The discharge data, acquired through hydrodynamic simulations, exhibits a characteristic sinusoidal pattern, akin to wave-like phenomena seen in the natural world. Within this pattern, the peak discharge occurs during the monsoon season, coinciding with heavy rainfall and an abundant inflow of water. Conversely, the pre-monsoon and post-monsoon periods witness significantly lower discharge levels, attributed to reduced rainfall and diminished water inputs. This seasonal variation in discharge is crucial for understanding the river's response to climatic changes and its impact on the surrounding ecosystem. Furthermore, an analysis spanning from 2003 to 2012 reveals a consistent decline in water discharge within the Koshi Basin. This temporal trend holds significant implications for local ecosystems, water resources, and communities dependent on the river, necessitating adaptive measures to address the consequences of this decline.

The sediment transport component of this study unveils the intriguing sedimentation patterns within the river. It is evident that the Koshi River model domain has experienced substantial sedimentation over time. This accumulation of sediment, including sand, silt, and other particles, can significantly alter the riverbed's morphology, with far-reaching implications. The research identifies the upper reach of the Koshi River as a significant contributor to the river's sediment load. This region, characterized by extensive sediment erosion, underscores the importance of understanding sediment dynamics in both upstream and downstream sections. The analysis also reveals that the rate of sedimentation varies significantly along the river's length. While the upstream portion exhibits lower sedimentation rates, the middle and lower reaches experience higher rates of sediment deposition. This non-uniform distribution highlights the need for tailored management strategies along different river segments. Notably, the simulation indicates a gradual decrease in the rate of sedimentation over time, a finding with potential implications for river health and long-term riverbed projections.

Chapter 1

Introduction

1.1 General:

Rivers have played a vital role throughout human civilization. Their provision of freshwater, facilitation of transportation and trade, contribution to economic activities, and cultural significance have made them indispensable to human societies. Rivers have shaped the development and prosperity of civilizations, offering resources, connectivity, and inspiration. As we continue to navigate the complexities of the modern world, it is crucial to recognize the value of rivers and strive to preserve and manage these invaluable natural resources for future generations.

One of the primary reasons for the importance of river management is the provision of water for drinking, irrigation, and sanitation. Ancient civilizations understood the value of rivers as a freshwater source and developed sophisticated systems to harness and distribute water to their communities. Effective management ensured a reliable supply of clean water, leading to improved public health, agricultural productivity, and the growth of settlements.

Another crucial aspect of river management is flood control. Rivers, with their ability to carry large volumes of water, have the potential to cause devastating floods. Throughout history, communities have faced the challenges of flood risks, prompting the development of strategies to manage and mitigate these hazards. Early civilizations constructed flood protection structures such as dikes, levees, and canals to channel and control river flows, protecting settlements and agricultural lands.

Uncontrolled riverbank erosion and sedimentation can lead to habitat degradation, loss of biodiversity, and changes in the hydrological balance. To mitigate these effects, river management has involved measures such as riverbank stabilization, reforestation, and the

creation of protected areas to preserve the ecological integrity of river systems.

River management has advanced significantly throughout history, driven by the need to address various challenges and optimize the use of rivers for human benefit. Over time, societies have developed increasingly sophisticated approaches and technologies to manage rivers effectively.

Early civilizations, such as those in Mesopotamia and Egypt, recognized the importance of managing rivers for irrigation and agriculture. They constructed canals, dikes, and reservoirs to control river flows and store water for dry periods. These early river management practices formed the foundation for future developments.

During the Middle Ages, societies in Europe focused on improving navigation on rivers. They built dams, locks, and weirs to regulate water levels, facilitating the movement of goods and people along inland waterways. These advancements in river engineering contributed to the economic growth of riverine regions.

The Industrial Revolution brought about significant changes in river management. The construction of canals and locks expanded, connecting rivers and enabling efficient transportation of goods. Engineers and scientists began to study river hydraulics and sediment transport, developing new techniques for river channelization and flood control.

The 20th century saw significant advancements in understanding river dynamics and the development of quantitative approaches to river management. Scientists and engineers started using mathematical models to simulate river behaviour, sediment transport, and flood forecasting. These models provided valuable insights into the impacts of interventions and aided in decision-making for river management projects.

Modelling of rivers has advanced significantly with the integration of field data, remote sensing, and computational techniques. These models are valuable tools for river managers, researchers, and policymakers, providing insights into complex river processes, supporting sustainable river management, and guiding decision-making for the protection and restoration of river ecosystems.

Sediment transport modelling is of paramount importance for rivers. Sediment, consisting of sand, silt, and clay particles, plays a crucial role in shaping river channels, affecting water quality, and influencing ecosystem dynamics. Sediment transport models provide insights into channel morphology changes, erosion, and deposition patterns, aiding in the

understanding of river behavior and evolution (Yang et al., 2008). By simulating sediment transport, these models contribute to the evaluation of water quality dynamics, including channel capacity changes, and the effectiveness of flood management strategies (Julien, 2010).

Koshi River is one of the major tributaries of the Ganges, originating from the Himalayas. It is a trans-boundary river that flows through both Nepal and India (Fig. 1), covering a watershed area of approximately 69,300 km². The mountainous region surrounding the river is characterized by active sediment production, resulting in a significant amount of sediment being transported into the Koshi River basin. This excess sediment supply leads to the aggradation of the riverbed, gradually reducing its conveyance capacity. Consequently, bank erosion, channel shifting, overbank flows, and even channel avulsion occur.

The avulsion phenomenon has brought about drastic changes in the river's channel location. Historical records indicate that the Koshi River has migrated approximately 150 km from east to west within the last 200 years (Chakraborty et al., 2010). Furthermore, the avulsion results in a substantial amount of sediment being deposited in the floodplain. This channel migration, combined with the transport of sediment to the floodplain, contributes to the formation of an alluvial fan known as the "Megafan." These characteristics of the Koshi River's evolution suggest that this river basin is highly susceptible to disasters associated with flooding and sediment transport.

Therefore, sediment transport modelling plays a crucial role in understanding the unique dynamics of the Koshi River, which carries one of the highest sediments loads globally (Xu et al., 2010). Accurate modelling enables the assessment of erosion and deposition patterns in the Koshi River, providing insights into channel shifting, bank erosion, and sediment accumulation (Nakamura et al., 2007).

River flow and sediment transport calculations are complex and finding analytical solutions for river engineering problems was challenging prior to the 1970s. The computational requirements of these problems made numerical solutions impractical without high-speed computers. As a result, physical models, laboratory experiments, and site investigations were commonly used during that time. However, recent technological advancements have made computational models more accessible in river engineering.

Computational models offer different approaches, such as one-dimensional (1D), two-

dimensional (2D), and three-dimensional (3D), depending on the complexity of the problem. These models have become a more efficient and cost-effective alternative to physical models. Physical models, although providing visible results, are expensive and time-consuming. Constructing a well-scaled physical model is challenging due to the intricate characteristics of flow and bed change processes in rivers. In contrast, computational models offer real-scale assessments and are less expensive than physical models. The reliability of computational models depends on the mathematical representation of physical phenomena, the solution method used, and the trustworthiness of the software (Wu, 2008).

Numerous numerical modeling tools have been developed to address the challenges associated with sediment transport modeling. Each tool offers unique functionalities and advantages, allowing for comprehensive analysis and prediction of sediment transport phenomena. One widely used tool is MIKE 11, developed by DHI, which is extensively utilized for simulating water flow and sediment transport in rivers and channels. MIKE 11 has the capability to predict bed morphology changes by incorporating sediment transport principles. This feature allows users to assess the long-term evolution of river channels and helps guide management strategies to mitigate erosion or promote desired channel adjustments.

Other numerical modeling tools, such as HEC-RAS, TELEMAC, Delft3D, and STEM, have revolutionized sediment transport modeling by offering advanced capabilities for simulating and analyzing sediment dynamics in river systems. These tools have empowered researchers and engineers to enhance river management practices, mitigate flood risks, and promote sustainable development along river corridors.

The development of hydrodynamic and sediment transport models has progressed from 1D to 2D and 3D representations. However, it has been observed that 1D models can still be effectively utilized for long rivers when employing small time steps and incorporating precise bathymetric data (Nistoran et al., 2017). In 1D models, computations are limited to cross sections, providing results primarily specific to those locations.

Both hydraulic models and sediment transport models were included in studies using the MIKE11 software to analyze both sediment transport and hydrodynamic aspects of flow.

1.2 Motivation:

The Kosi River, often referred to as the 'Sorrow of Bihar,' poses significant challenges to the communities living along its banks. Year after year, devastating floods caused by the river bring havoc to extensive agricultural lands, resulting in severe disruptions to the rural economy. A notable instance of its destructive power took place in 2008 when the river breached the embankment in Kushaha, Nepal, and dramatically changed its course, shifting 108 kilometres to the east.

The primary cause of the hardships faced by the Kosi River communities lies in the remarkable accumulation of sediment between the Chhatra and Birpur gauge stations, located in the upstream region. An astonishing estimate suggests that the total mass of sediment amounts to approximately 1,082 million tonnes. This corresponds to a massive volume of 408 million cubic meters, which accumulates at an average rate of 5.33 centimetres per year, as revealed by the findings of Sinha et al. in 2018. The continuous deposition of silt leads to the elevation of the riverbed, disturbing its natural straight course. Consequently, the river seeks alternative lateral pathways, either to the left or right, in search of a new direction. In this process, it alters its course, breaching the embankments along the newly formed path. These breaches in the embankments result in catastrophic floods, imposing significant challenges and hardships upon the communities living in the vicinity.

It is of utmost importance to develop a comprehensive understanding of the sediment transport dynamics in the Kosi River to effectively address these pressing issues. By delving into the intricacies of sediment transport, valuable insights can be gained, paving the way for sustainable development practices and enhancing the resilience of the communities residing in the Kosi River basin. Continued and comprehensive research efforts in this field will undoubtedly contribute to a holistic understanding of the river's behaviour and enable the implementation of effective management strategies. Such endeavours are crucial to ensure the long-term sustainability and well-being of the Kosi River, safeguarding it for future generations

1.3 Objective:

This study aims to achieve a comprehensive understanding of the hydrodynamic behavior and sediment transport characteristics of the Koshi River. The primary objectives are as follows:

- 1) To assess temporal variations in discharge for the considered stretch of river.
- 2) To examine long-term trends in discharge and sediment movement.
- 3) To assess and characterization of sediment transport patterns.

Chapter 2

Literature survey

2.1 General:

Comprehending the movement of sediment is crucial to anticipate the transportation of sediment and pollutants in surface water systems. The foundation of current research on sediment transport can be attributed to the contributions of du Boys (1879), Einstein (1950), and Vanoni (1975).

Engelund, F., & Hansen, E. (1967) played a significant role in the development of sediment transport formulas. They formulated the Engelund-Hansen sediment transport formula, which takes into account the effects of sediment concentration, flow velocity, and bed roughness on sediment transport rates.

The work of van Rijn, L. C. (1984) is widely recognized as pioneering in the field of sediment transport. Van Rijn, L. C. (1984) developed empirical formulas, known as the van Rijn equations, for sediment transport. These equations consider the characteristics of non-uniform sediment mixtures and the influence of secondary currents. By accounting for these factors, the van Rijn equations improved the accuracy and applicability of sediment transport models.

These advancements in sediment transport research have provided valuable tools and insights for understanding and predicting the movement of sediment in water systems. By incorporating these formulas and empirical relationships into sediment transport models, researchers and engineers can better assess and manage sediment-related challenges in rivers, estuaries, and coastal areas.

Sivapalan, M., & Rupp, D. E. (1997) made significant contributions to sediment transport modelling by developing a stochastic framework. This framework considers the temporal and spatial variability of sediment transport processes, leading to an improved understanding of sediment transport dynamics and the associated uncertainties.

In a case study conducted by Vaithiyanathan P. et al. (1992), the authors highlight the important role of natural factors and dam construction in shaping sediment transport in the Cauvery River. The study reveals the dominance of fine-grained sediments and the occurrence of selective deposition at dam sites. Additionally, the mineralogical composition of the suspended sediments is considered, contributing to a better understanding of sediment dynamics in the river. The study also emphasizes the influence of sediment characteristics on the distribution of trace metals, shedding light on the environmental implications of sediment transport processes in the Cauvery River.

These research efforts provide valuable insights into the complexities of sediment transport and its environmental implications in specific river systems. By considering stochastic frameworks and studying the interplay between natural factors, human activities, and sediment characteristics, scientists and policymakers can enhance their understanding of sediment transport processes and develop effective strategies for managing sediment-related challenges in river ecosystems.

Neary et al. (2001) conducted a case study utilizing the MIKE 11 sediment transport module. The study focused on the Napa River, which is prone to flooding, aiming to investigate the impact of sediment on floods in the river and assess potential maintenance needs. For this purpose, the Van Rijn Method was chosen as the sediment transport formula, validated through previous studies, and calibrated based on water depth observations. The study revealed minor morphological changes in the river over a short-term period as a result of sedimentation during tidal cycles.

Kiat et al. (2008) conducted a case study on the Kulim River, highlights the impacts of rapid urbanization on catchment hydrology, sediment transport, and river morphology. The utilization of the FLUVIAL-12 model facilitated a comprehensive assessment of the river's stability under existing and future conditions. The results underscore the significance of considering sediment transport dynamics and channel morphology when assessing the impacts of urbanization on river systems. The findings suggest that the Kulim River is predicted to remain stable in most locations despite significant changes in sediment size and

channel geometry. This research contributes valuable insights into the management and planning of river systems in urbanizing catchments, assisting in the development of strategies to mitigate the adverse effects of urbanization on river morphology and flooding risks.

A case study conducted by Grozav et al. (2017) in Caras-Severin Country focused on sediment transport modelling using the MIKE11 software, specifically in the Mehadica River. The research highlighted the significance of considering sediment characteristics in river bed modelling and emphasized the need for collecting and analyzing bed sediment samples to ensure accurate results. By utilizing the MIKE11 software, particularly its Hydrodynamic (HD) module based on the Saint-Venant equations, the study successfully simulated water flow and integrated various modules for a comprehensive analysis of the river system.

Azarang et al. (2015) conducted a study on Karun River, Iran. They estimate the total sediment load of the Karun River using the HEC-RAS model over a 10-year period from 2001 to 2011. The findings reveal that the Karun River has experienced sedimentation in most of its cross-sections, while erosion has been relatively rare. The study suggests that the Englund-Hansen and Ackers-White sediment transport functions yield better results in understanding the river's changes. Based on the HEC-RAS results and measured data, the paper emphasizes the need for river training through dredging, particularly in the urban areas of Ahvaz.

Mohammed et al. (2018) carried out a study on Euphrates River, Iraq at downstream of Al-Abbasia City bridge's in a length of 6 km utilizing the HECRAS model. They observe that for the straight parts on the studied reach the discharge increasing gives less sediment transport capacity while the meandering parts of the reach were in reverse behaviour.

Azarang et al. (2015) conducted a study on Karkeh River, Iran. The MIKE 11 model is employed for simulating flow and sediment transport in the river. The study incorporates geometric, hydraulic, and sediment data from the Abdolkhan and Hamidiyeh hydrometric stations along the Karkheh River. A Manning's roughness coefficient of 0.025 is applied to represent the roughness characteristics of the river, and the computational results are compared and evaluated against observed data.

The study calculates the cross-sectional changes in the upstream portion of the Karkheh River (Abdolkhan hydrometric station) and identifies the best approaches for predicting these

changes. The research finds that the Engelund-Hansen and Ackers-White equations offer better predictions for the alterations in the river shape. Additionally, the study estimates the longitudinal bed level changes along the Karkheh River, from upstream to downstream. By utilizing the MIKE 11 model, the researchers obtain elevation changes in the riverbed at the Abdolkhan (upstream) and Hamidiyeh (downstream) hydrometric stations. The results demonstrate significant changes in the riverbed shape of the Karkheh River.

Huang et al. conducted a study a one-dimensional numerical model for predicting sediment transport and bed evolution in natural rivers that have floodplains. The modified GSTARS2.1 is used to simulate the sediment transport and bed geometry in a stretch of the Rio Grande between San Acacia Diversion Dam and a cross section 10 miles downstream of San Marcial, New Mexico. The total length of this stretch is 86 km (54 mi). The time period between 1972 and 1992 is simulated. It observed bed profile change from 1972 to 1992.

Timbadiya et al. (2014) conducted a study which utilized one-dimensional hydrodynamic modelling using MIKE11 software to analyse flooding and stage hydrographs in the lower Tapi River in India. The objective of the study was to develop an accurate model for simulating flood behaviour and stage hydrographs in the area. The results demonstrated the successful application of the one-dimensional hydrodynamic model, with the simulated stage hydrographs closely matching observed data. The study's findings provide valuable insights into flood dynamics in the lower Tapi River, contributing to flood management strategies in the rivers.

Chapter 3

Models and methodology

3.1 General:

This chapter presents the methodology and approach employed in this study to create a numerical model for the Koshi River.

3.2 Study Area:

The Kosi River drains the northern slopes of the Himalaya in the Tibet Autonomous Region and the southern slopes of the Nepal Himalaya before it finally enters the Bihar plains in India and meets the Ganga River (Fig.3.1). The mountain-fed Kosi River has a total basin area of 84,739 km² and spans a total length of 730 km up to Baltara (Gole and Chitale, 1966; Sinha and Friend, 1994). The Tibetan region of the Kosi basin comprises 22% of the total drainage area and is characterized by high elevation and flat plateau on the leeward side of the Himalaya with a large number of glaciers and glacier lakes (Bajracharya et al., 2007). About 40% of the drainage area of the Kosi basin lies in the Nepal Himalaya and is characterized by alpine and mountainous areas. The alluvial part of the Kosi basin in the Bihar plains in India comprises 38% of the total drainage area and comprises low elevation and flat plains with high population density.

The distance from Khocherdewa to Dhamara Ghat which is the objective area of present study is about 21 km (fig.3.2)

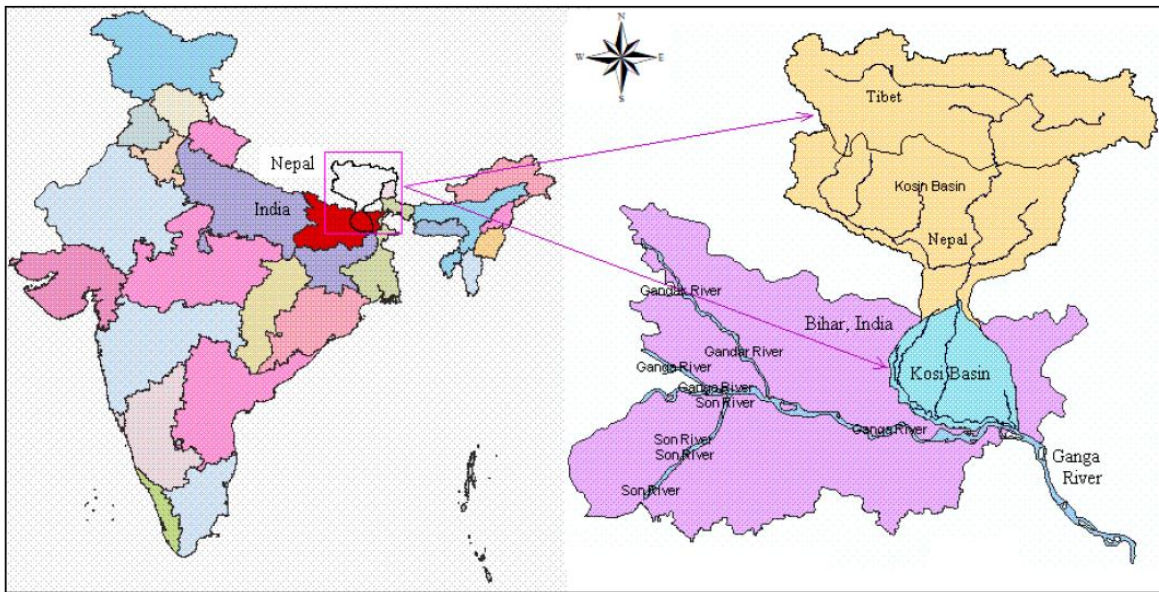
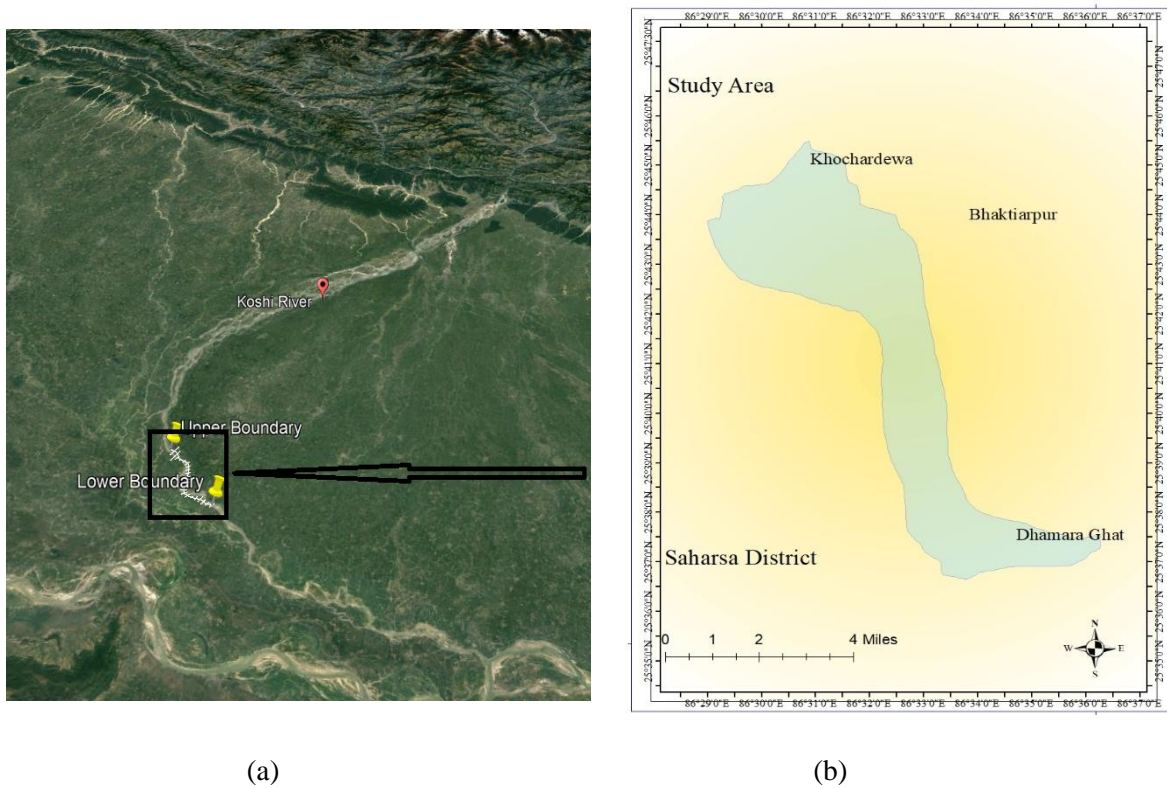


Figure 3-1 Index map of Koshi basin



(a)

(b)

Figure 3-2 (a) Satellite image (b) Study area

3.3 Model Selection

The MIKE 11 model has been selected as the most suitable numerical model for sediment transport modeling in the Koshi River. This widely recognized and extensively used model offers a one-dimensional approach, ideal for representing flow dynamics and sediment transport patterns in rivers.

The MIKE 11 model utilizes the Saint-Venant equations averaged over cross-sectional segments, providing an accurate representation of water flow and sediment transport processes. These equations have been extensively tested and validated in various river systems worldwide, instilling confidence in their reliability.

In terms of simulation capabilities, the MIKE 11 model encompasses comprehensive features that consider crucial aspects such as bedload and suspended load transport, bed shear stress, sediment concentration, and grain size distribution. This ensures a detailed and realistic representation of sediment transport dynamics in the Koshi River.

Notably, the MIKE 11 model is known for its computational efficiency and its ability to generate reliable results with minimal data requirements. This is particularly advantageous for the Koshi River, where acquiring extensive field data can pose challenges due to the scale and complexity of the river system.

The MIKE 11 model is based on the principles of one-dimensional open channel flow and utilizes the Saint-Venant equations to simulate water flow and sediment transport in rivers. These equations describe the conservation of mass and momentum in a reach of the river.

The continuity equation, which represents the conservation of mass, is given by:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \quad (1)$$

The momentum equation, which represents the conservation of momentum, is given by:

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \left(\alpha \frac{Q^2}{A} \right) + gA \frac{\partial h}{\partial x} + \frac{gQ|Q|}{c^2 AR} = 0 \quad (2)$$

Where Q – discharge, (m³/s)

A – flow area, (m²)

q – lateral inflow, (m²/s)

-
- h – stage above datum, (m)
 - C – Chezy resistance coefficient, (m^{1/2}/s)
 - R – hydraulic or resistance radius, (m)
 - α – momentum distribution coefficient.

The four terms in the momentum equation are local acceleration, convective acceleration, pressure, and friction (Source: www. dhigroup.com).

Sediment transport module has been used for simulation of sediment transport for computing morphological changes. The model is based on a one-dimensional equation of mass conservation of suspended or dissolved materials (Advection-dispersion equation) as shown in Eq. 3. Description of sediment settling with different settling velocities (flocculation) is included in the model. Bottom shear stress is calculated considering river bed velocity. Storage capacity of different cross sections in flood plain is computed with elevation curves.

$$(1 - C')^m C' V_p^\infty + \epsilon_s \frac{dC}{dy} = 0 \quad \dots\dots\dots(3)$$

Where, the C' , V_p^∞ and ϵ_s are the volumetric concentration, the terminal settling velocity of a single particle in still clear water and turbulent diffusion coefficient respectively. (MIKE 11, 2014).

3.4 Sediment Transport Calculation

Several sediment transport calculation methods are investigated throughout many studies. The selection of a suitable method for calculating sediment transport depends heavily on the specific characteristics of the study area and the availability of data (van Rijn, 1993).

the MIKE 11 Model uses nine equations to calculate total sediment load of the river. These equations include:

- Ackers and White.
- Ashida and Michiue Ashida.
- Takahashi and Mizuyama.
- Engelund and Fredose.
- Lane and Kalinske.
- Meyer-Peter and Muller.
- Kikkawa and Ashida.
- Smart and Jaeggi.

- Van Rijn.

In sediment transport modeling, accurately simulating the movement of sediment particles is essential for understanding river dynamics and managing water resources. The MIKE 11 model, widely used for river systems, incorporates sediment transport equations to predict sediment transport rates. One commonly used equation in the MIKE 11 model is the Ackers-White equation, which provides a reliable estimation of sediment transport in rivers.

3.4.1 Ackers-White Equation

The Ackers-White equation is widely used in the MIKE 11 model for simulating sediment transport in rivers. To incorporate the equation into the model, relevant parameters such as sediment characteristics and channel slope are required. Their proposed formula was follows.

$$C_t = C_s G_s \left(\frac{d_{50}}{h} \right) \left(\frac{V}{U_*} \right)^{n'} \left[\left(\frac{F_{gr}}{A_1} \right) - 1 \right]^m$$

The dimensionless particle d_{gr} is calculated by:

$$d_{gr} = d_{50} \sqrt[3]{\frac{g(G_s - 1)}{v^2}}$$

The particle mobility factor F_{gr} is calculated by:

$$F_{gr} = \sqrt{\frac{U_*^{n'}}{(G_s - 1)g d_{50}}} \left[\frac{V}{5.66 \log \left(\frac{10 h}{d_{50}} \right)} \right]^{1-n'}$$

3.5 Development of model

To simulate data in the MIKE 11 hydrodynamic module, several steps are involved. Firstly, the network is prepared, assuming a straight stream channel. Then, the cross section and hydrodynamic parameters are determined. Additionally, boundary parameters are set up. Water level, and flow are created in a compatible MIKE 11 time series format and stored in a separate file. These time series files serve as inputs for the parameter editors during the simulation process.

3.5.1 The River Network File:

In a river system, the network data consists of various components such as reaches, nodes, and cross sections. A reach serves as a connection between two nodes in the network, having an upstream and downstream end. To specify a position along a reach, the distance from the upstream end is measured and referred to as chainage. The shape of the cross section and the level of friction may vary along the length of the river reach. Nodes represent points that correspond to the ends of reaches and junctions, with each reach having a node at both ends. A junction can be associated with one or multiple reaches that converge at a common node.

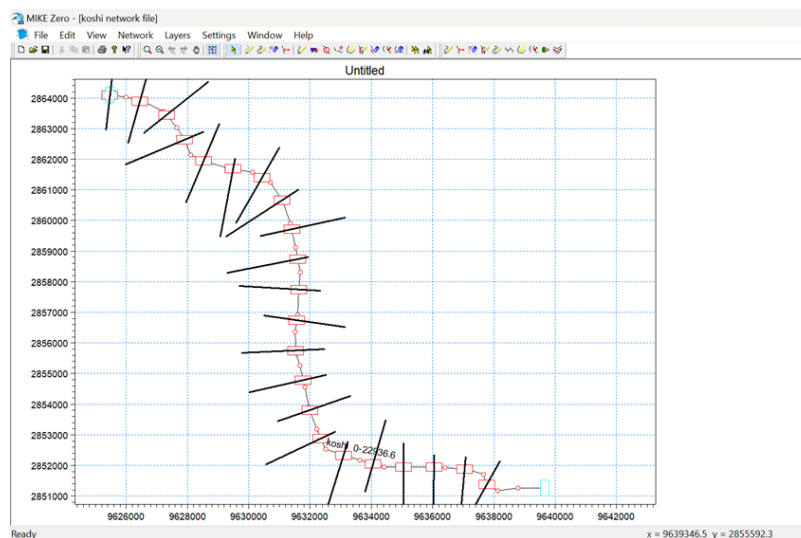


Figure 3-3 River Network

3.5.2 Cross section File

Characterizing a cross section can be done using two methods: raw data and processed data. Raw data consists of (x, z) coordinates representing the shape of the cross section, where x indicates the transverse distance from a reference point (often the left bank) and z represents the corresponding bed level. On the other hand, processed data involves generating tables that provide simplified characteristics of a reach, such as storage width, flow area, resistance number, and hydraulic radius, for different water levels. This processed data is used by the flow computation engine. In this study, 22 cross sections were extracted from the river

network at 1000m intervals using SRTM data and observed data from USGS EARTH EXPLORER. A representative cross section at Chainage 14 km is shown in Figure 3.2.

In this study, a 21 km stretch of the Koshi River in Saharsa district, Bihar has been selected as the study area. The river network has been modeled numerically using data from Google Earth and SRTM. The network data includes reaches, nodes, and cross sections. Reaches connect nodes in the network and have an upstream and downstream end, with position measured using chainage. Cross sections are profiles perpendicular to the flow direction, determining water volume and flow speed. Accurate cross section data is crucial for simulations. The study focuses on understanding the river system dynamics in this particular area.

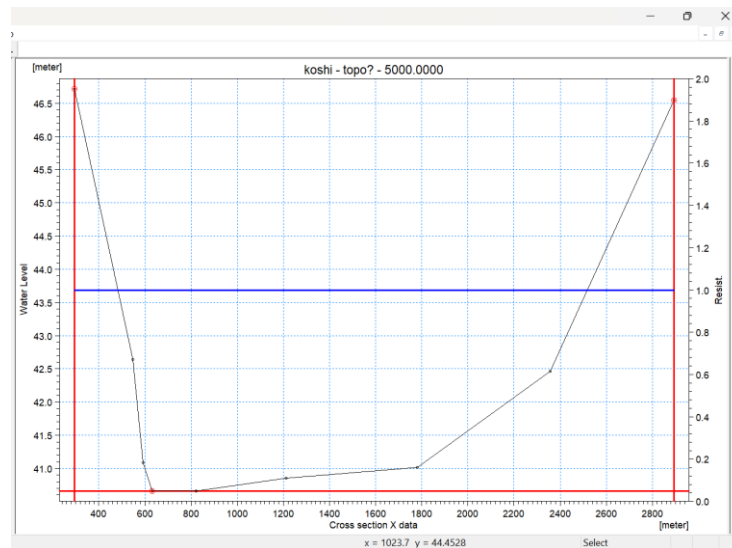


Figure 3-4 Koshi River Cross-Section at chainage 5000 m from Upstream of Dangrahi Ghat

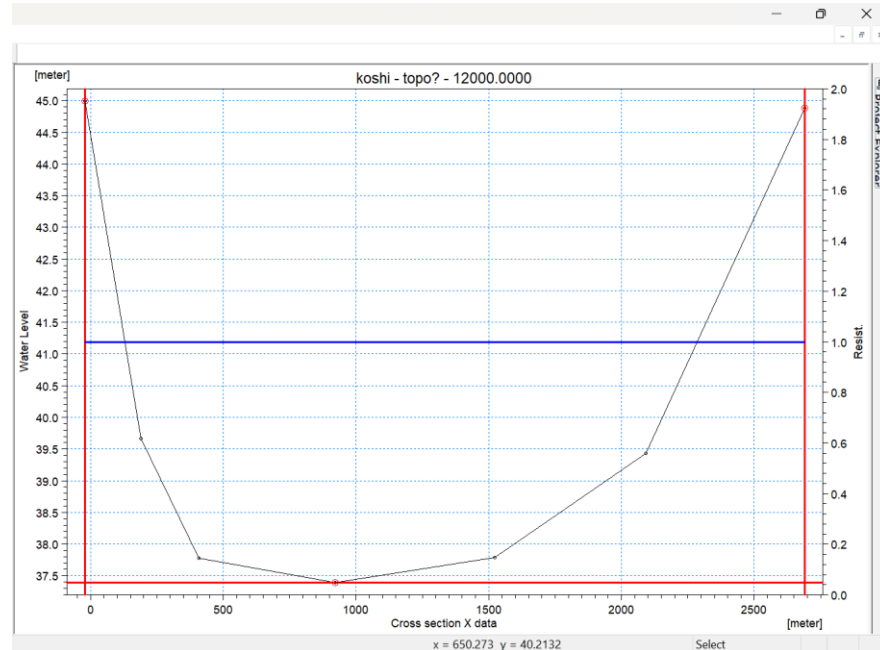


Figure 3-5 Koshi River Cross-Section at chainage 12000 m from Upstream of Dangrahi Ghat

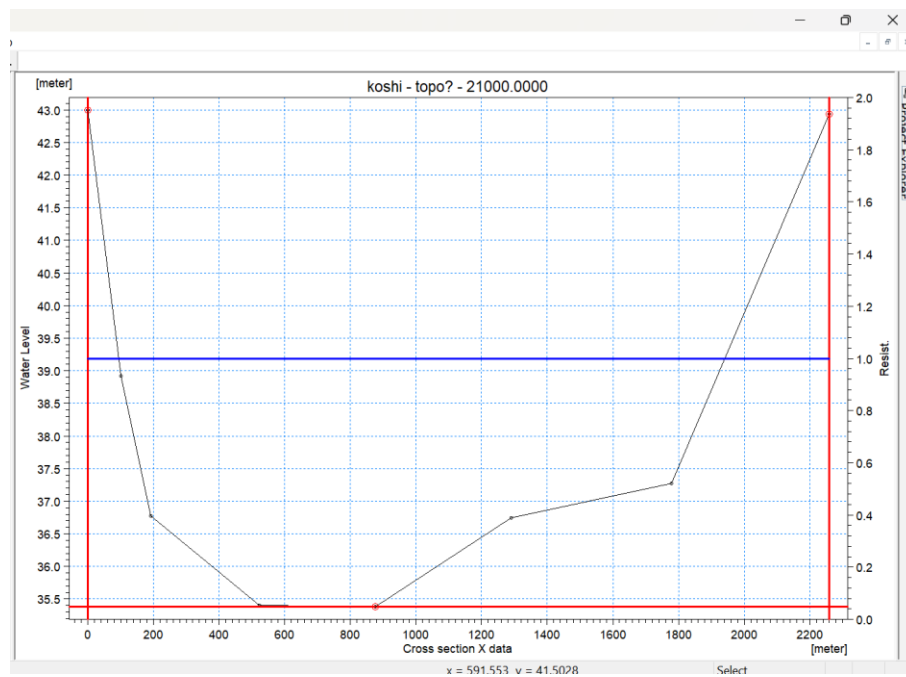


Figure 3-6 Koshi River Cross-Section at chainage 21000 m at Dhamara Ghat

3.5.3 Hydraulic roughness (Manning's n)

The formula developed by Manning can be expressed using the equation provided below

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \quad (4)$$

Where, V is Flow Velocity, (m/s)

N is Manning's 'n'

R is Hydraulic Radius, (m)

S is Bed Slope of the channel

The equation is utilized to predict the velocity or discharge of water if the width, depth, and slope are given. Manning's 'n' is a measure of the flow resistance, and it is affected by various factors that can impact it directly or indirectly. With the continuous advancements in technology, particularly in computational resources, it has become possible to adjust the value of Manning's 'n' to match the observed water levels with the simulated values. This process of calibrating and validating the value of Manning's 'n' is now feasible due to technological progress.

3.5.4 The boundary File

The boundary editor is a tool used to define boundary conditions in a MIKE 11 model. It provides information about various types of boundaries, such as open, closed, point source, distributed source, and more. The open boundary is typically set at the upstream and downstream ends of the model domain. When selecting the open boundary option, it is necessary to specify the branch name and chainage to determine the location of the boundary. Parameters like discharge, water level, and rating curve can be specified at an open boundary. Water level boundaries can be defined at locations such as downstream river boundaries, outlets to the sea, water level control points, and similar locations.

In this study, an open inflow boundary is set at Khochardeva Village, with a chainage of 0. The inflow hydrograph for water and sediment is prepared using discharge data and suspended sediment concentration data obtained from water resource

department, Govt. of Bihar. The downstream boundary condition is set at a chainage of 21 km, with specified water level data collected from RRI.

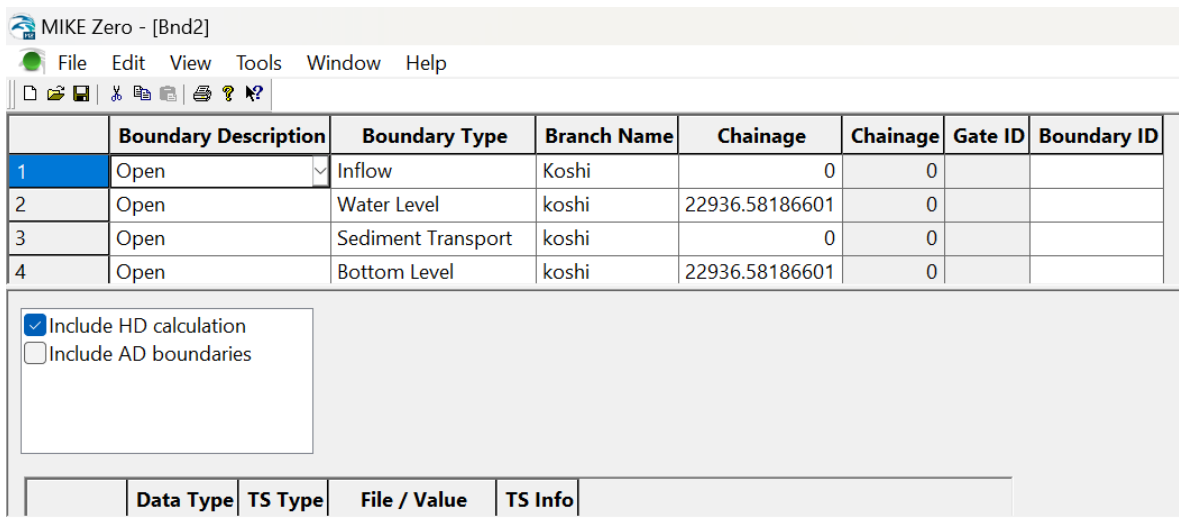


Figure 3-7 MIKE 11 Boundary editor File

3.5.5 Hydrodynamic Parameter File:

The Hydrodynamic Parameter file requires bed and floodplain resistance data for the river network. The differentiation between the streambed and flood plain along the river network is accomplished at each cross-section in the Cross-section file.

The daily discharge data of Koshi River as observed in gauge point basin during the period from 2001 to 2013 was collected from water resources department, Government of Bihar, in order to calculate the catchment runoff.

3.5.6 Sediment Transport Parameter File:

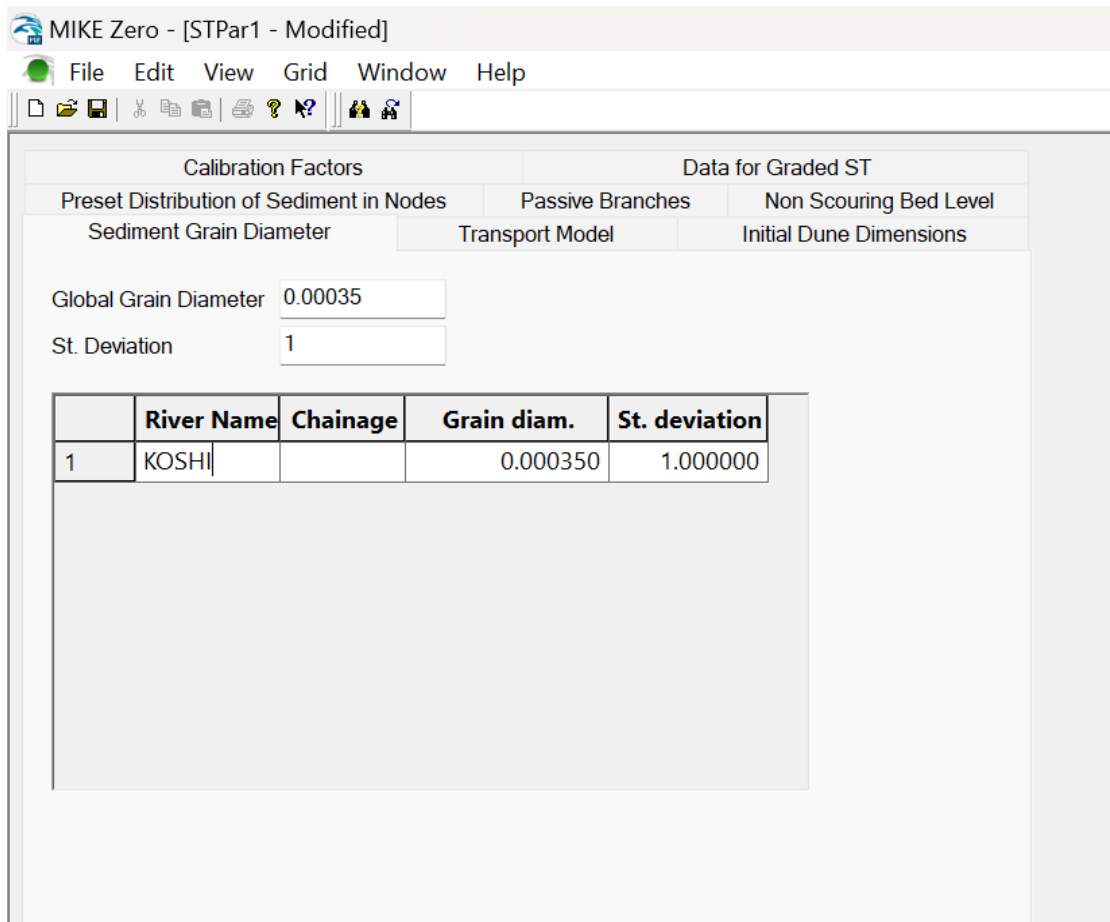


Figure 3-8 MIKE 11 Sediment transport parameter file

3.6 CALIBRATION AND VALIDATION OF A MODEL

The hydrodynamic and sediment transport model for morphodynamical analysis was simulated from the year 2003 to 2013. Daily discharge data at the Khochardewa Village were used as input in upstream boundary condition and Water Level data at the 1Km downstream of Dhamara Ghat was used as downstream boundary condition of the model.

3.6.1 Hydrodynamic calibration

Manning's coefficient of roughness (n) was used as a model calibration parameter for hydrodynamic calculation. In the initial stage, approximations for the Manning's coefficient of roughness (n) for the channel were taken from available literature (RRI Report) for a similar area. The ' n ' value was varied from 0.028 to 0.04 during the model calibration process and finally to match with the observed scenario the value was fixed at 0.031. The calibrated results of observed and simulated water elevation at chainage 14 km are shown in Figure 9.

Further surface water elevation at Dhamara Ghat (Chainage 21Km) was extracted from the model which was found to be quite close to the observed data recorded on 08.08.2016 (Table 3.1).

Table 3-1 Calibration Table

OBSERVED POINT	DHAMARA GHAT	MANNING'S 'n'	WATER LEVEL(m)	
			Observed Value	Predicted Value
DATE	June,2004	0.028	37.13023	36.68
		0.031	37.13023	36.94
		0.035	37.13023	37.74

3.6.2 Hydrodynamic Validation

The model was validated for the period 2003 to 2013 using the above model calibrated parameters. The validated results of observed and predicted values are shown in below table.

Table 3-2 Validation Table

OBSERVED POINT	DHAMARA GHAT	MANNING'S 'n'	WATER LEVEL(m)	
			Observed Value	Predicted Value
DATE	June,2007	0.031	37.13023	36.94

Chapter 4

Results and discussion

4.1 Analysis of Hydrodynamic module:

The water level, water depth data for longitudinal profile and a typical chainage of 5000m has been extracted from hydrodynamic simulation result file and given below

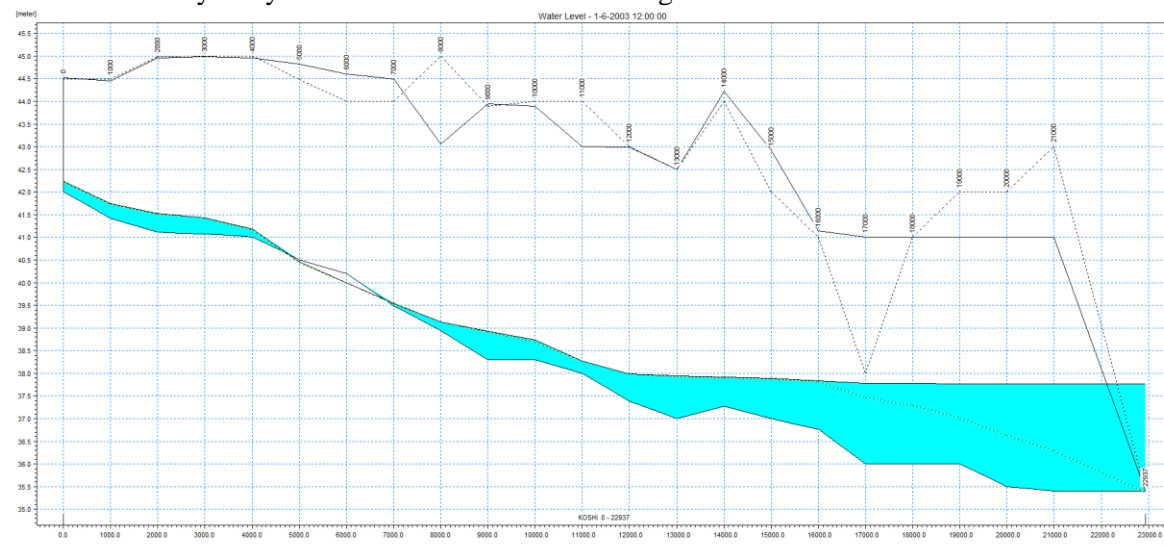


Figure 4-1 Longitudinal Profile, Water levels with min. and max

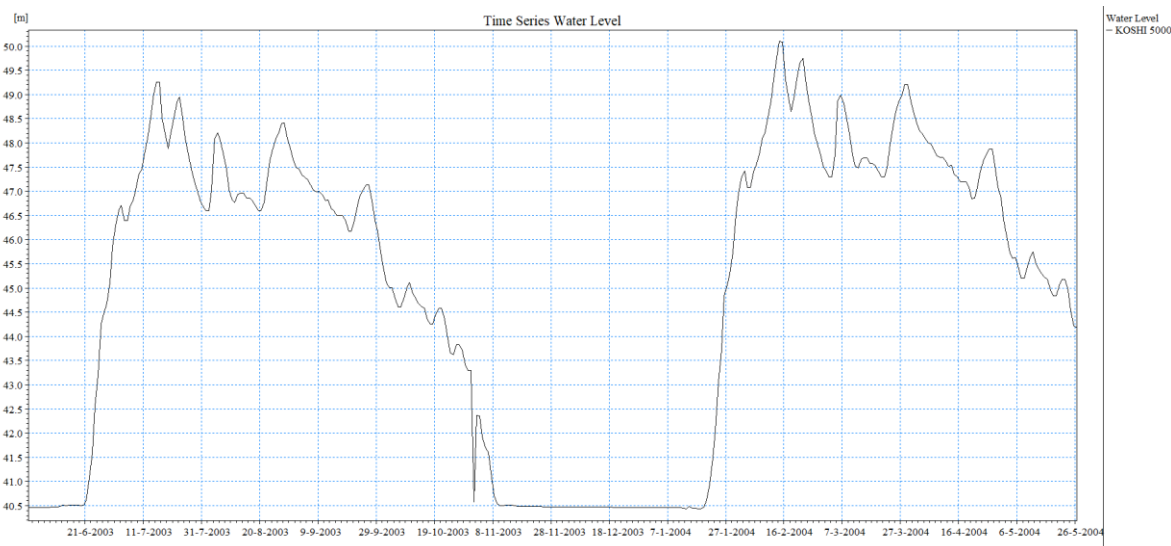


Figure 4-2 Changes of water level with Time

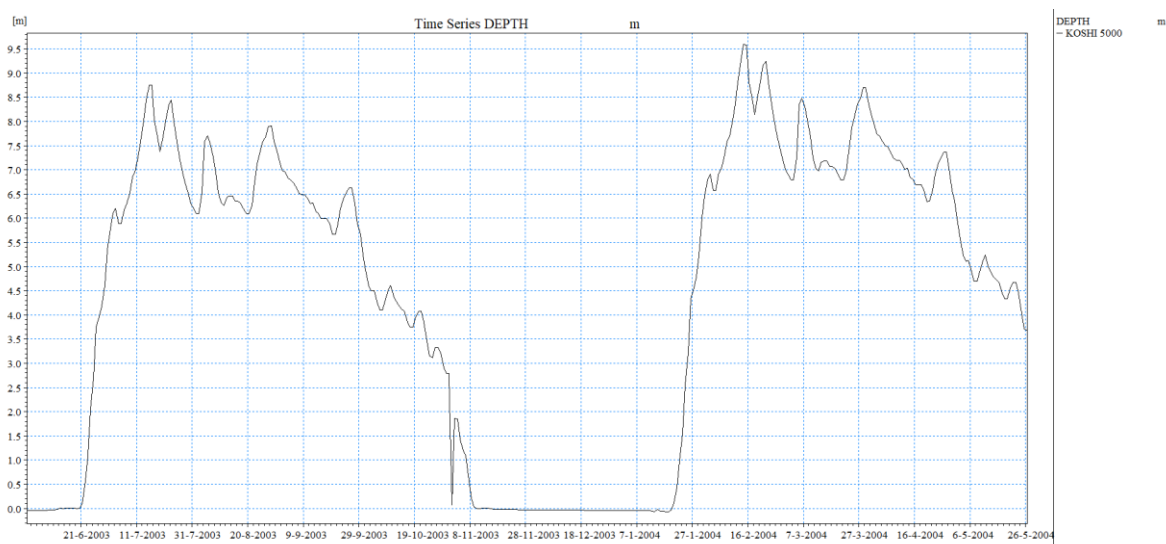


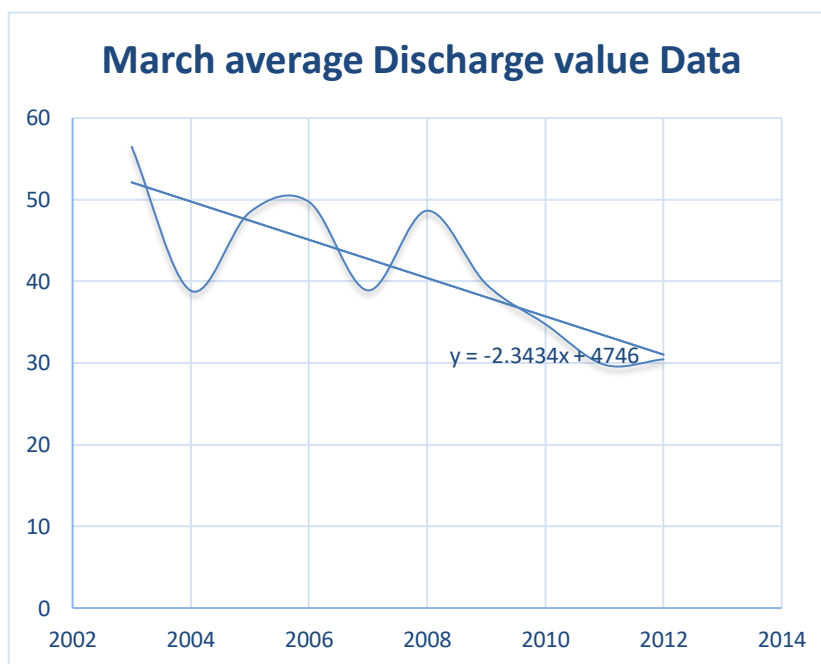
Figure 4-3 Changes of bed elevation by passing the time at the stations

4.1.1 Discharge data:

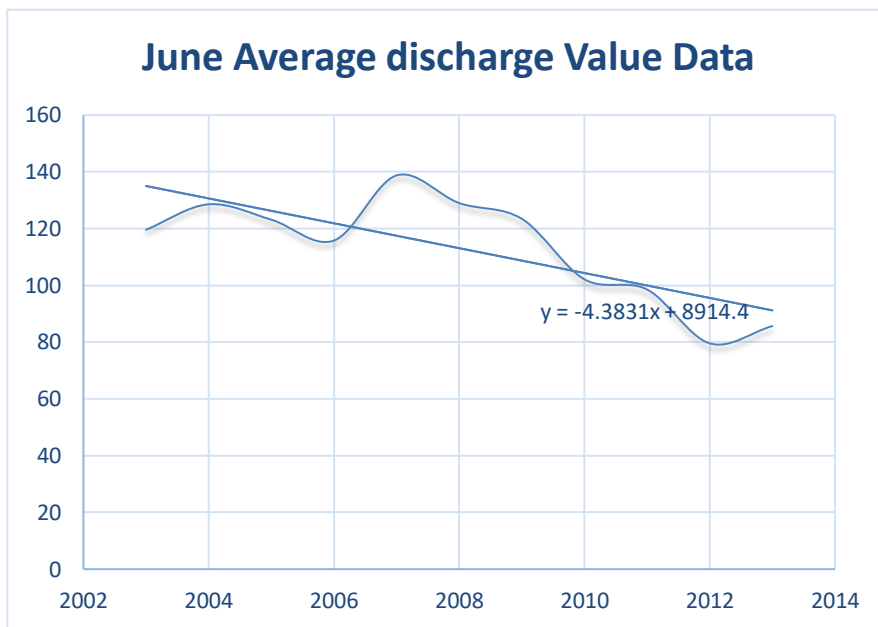
1. Monthly Variation in Discharge: The data obtained from the hydrodynamic simulation reveals that the discharge of water in the study domain exhibits a distinctive pattern over the course of a year. This pattern resembles a sinusoidal curve, which is a characteristic shape similar to the wave-like behaviour often associated with natural phenomena. (Fig no 4.4-e)
2. Peak Discharge During Monsoon: Within this sinusoidal pattern, the highest discharge occurs during the monsoon season. This suggests that the study area experiences a significant influx of water during this specific period, which is typically characterized by heavy rainfall. The monsoon season is often associated with increased river flow due to the abundant precipitation. (Fig no 4.4b)
3. Lower Discharge in Pre-Monsoon and Post-Monsoon: In contrast to the peak discharge during the monsoon, the discharge in the periods before and after the

monsoon season is considerably lower. This indicates that the flow of water in the study area decreases significantly outside of the monsoon season. The reduced discharge during these pre-monsoon and post-monsoon periods could be due to reduced rainfall and lower overall water inputs. (Fig no 4.4-a)

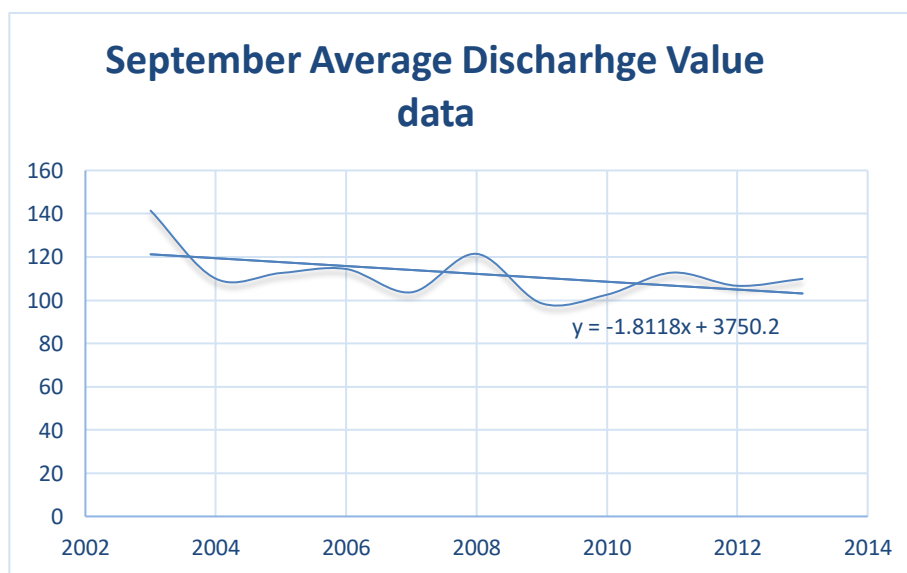
4. Declining Discharge in Koshi Basin (2003-2013): Additionally, the data reveals a noteworthy trend in the discharge pattern within the Koshi Basin specifically. Over the span of the years 2003 to 2013, there is a consistent decrease in the discharge in this region. This temporal trend might have significant implications for the local ecosystem, water resources, and any dependent communities. (Fig no 4.4-(a-f))



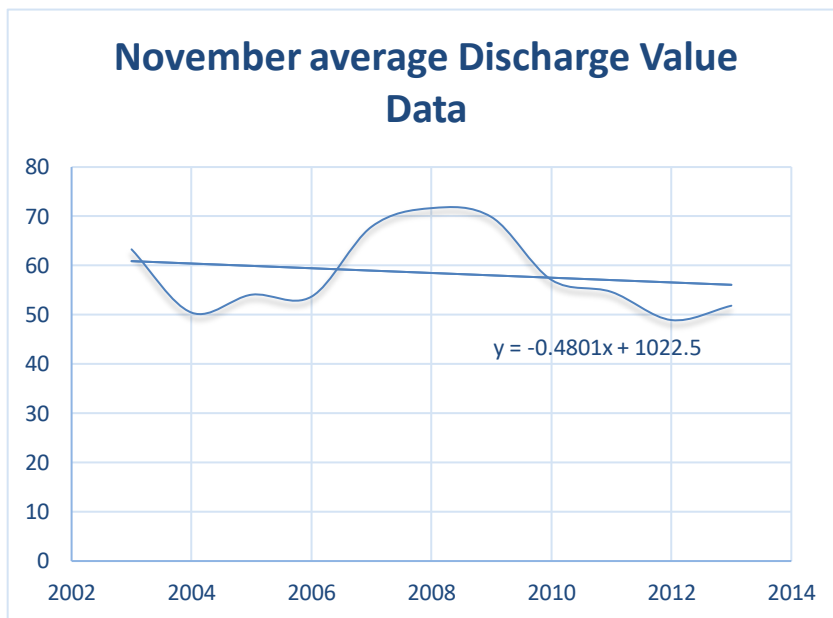
(a)



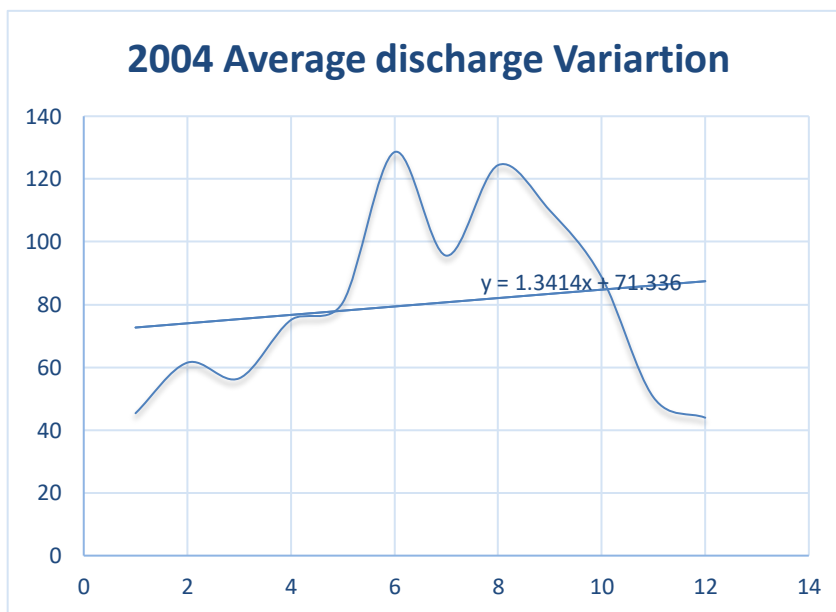
(b)



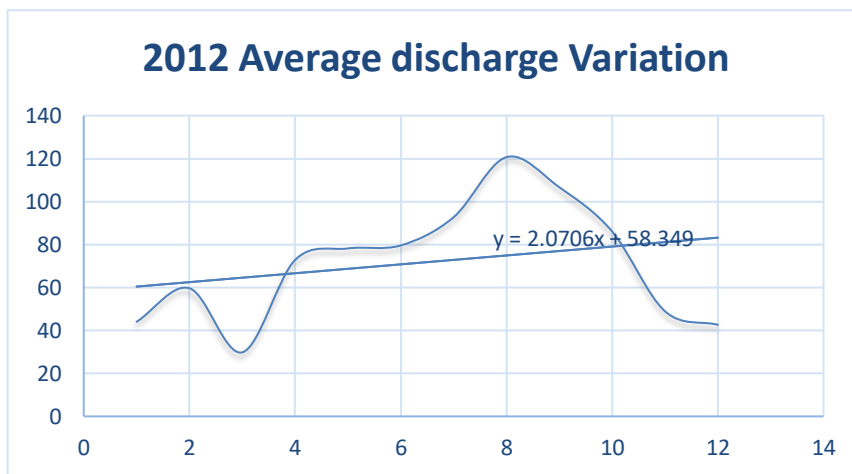
(c)



(d)



(e)



(f)

Figure 4-4 (a-f) chainage 21000 m discharge data

The statement describes observations related to water level data collected at two different chainage points, 12000 meters and 21000 meters, likely along a river or waterway. These observations highlight distinct trends in water level variation throughout different periods of the year, and the underlying reasons for these trends. Let's elaborate on these observations:

1. Water Level Data at Chainage 12000m:

Pre and Post Monsoon Period: During the pre and post monsoon periods, the water level data at chainage 12000 meters shows a decreasing or linear trend. This means that, outside of the monsoon season, the water level consistently decreases or remains relatively stable in this particular section of the waterway. The decreasing trend might be attributed to lower rainfall and reduced water inflow during these periods.

Monsoon Period: Conversely, during the monsoon period, the water level data at chainage 12000 meters displays an increasing trend. This indicates that, when the monsoon rains arrive, the water level at this point rises. The increased rainfall during the monsoon season leads to a higher volume of water flowing through this section of the waterway, causing the water level to rise.

4.1.2 Water Level Data at Dhamara Ghat:

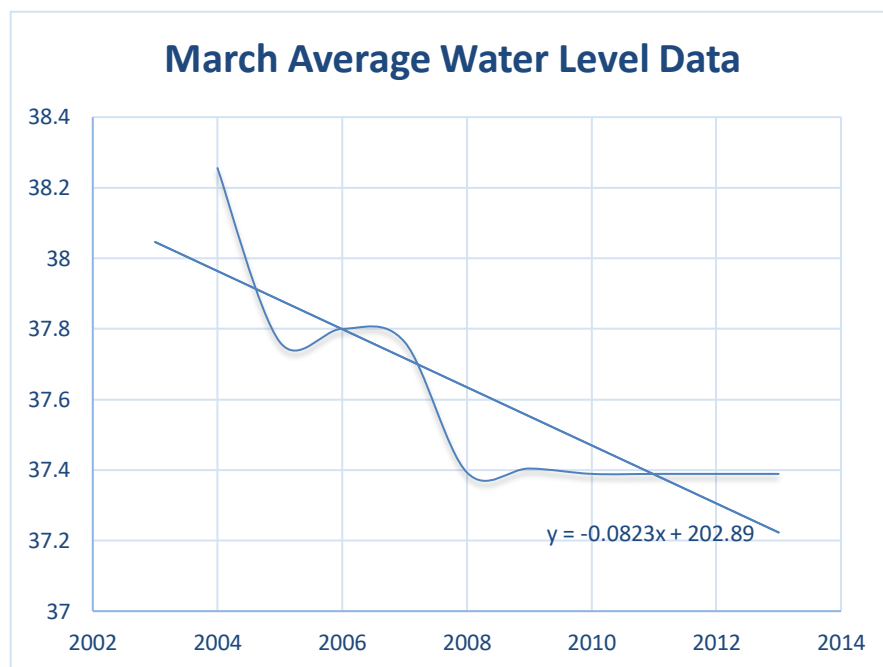
Constant Increase in Water Level: At chainage 21000 meters, the water level data exhibits a constant and consistent increase over time. This means that, regardless of the season, the water level is steadily rising at this specific location.

Sharp Increasing Trend of Bed Level: The statement attributes this phenomenon to a sharp increasing trend in the bed level at chainage 21000 meters. In other words, the riverbed or channel bottom at this point is gradually rising. This is an important factor contributing to the rising water level observed in this section. When the riverbed rises, it reduces the overall capacity of the channel to contain water, which can lead to an increase in water level even during non-monsoon periods.

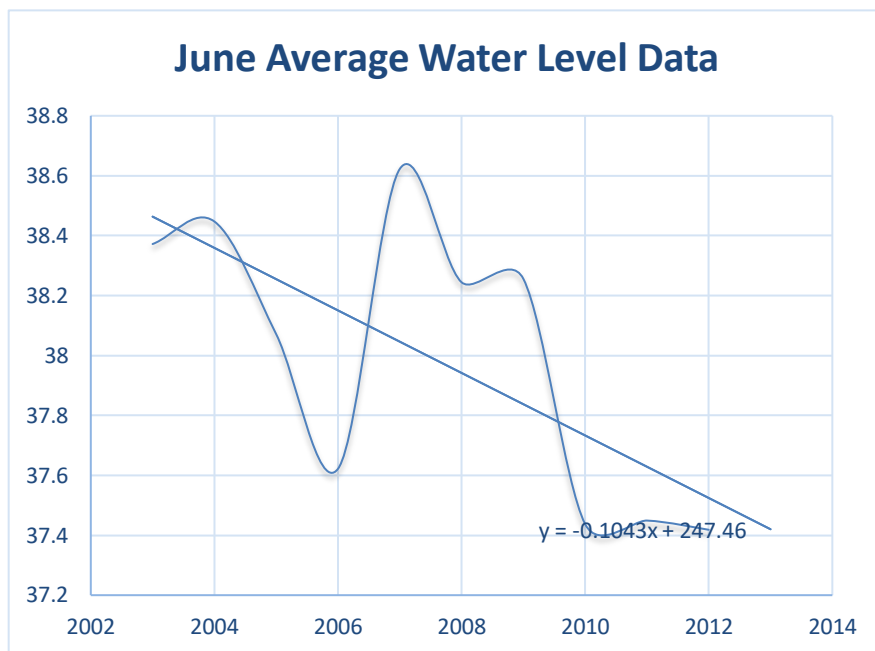
In summary, the observations suggest that there are distinct patterns of water level variation at these two chainage points:

- Chainage 12000m experiences seasonal fluctuations, with decreasing or stable water levels in pre and post monsoon periods and increasing levels during the monsoon season, which is typical for areas influenced by monsoonal rainfall.

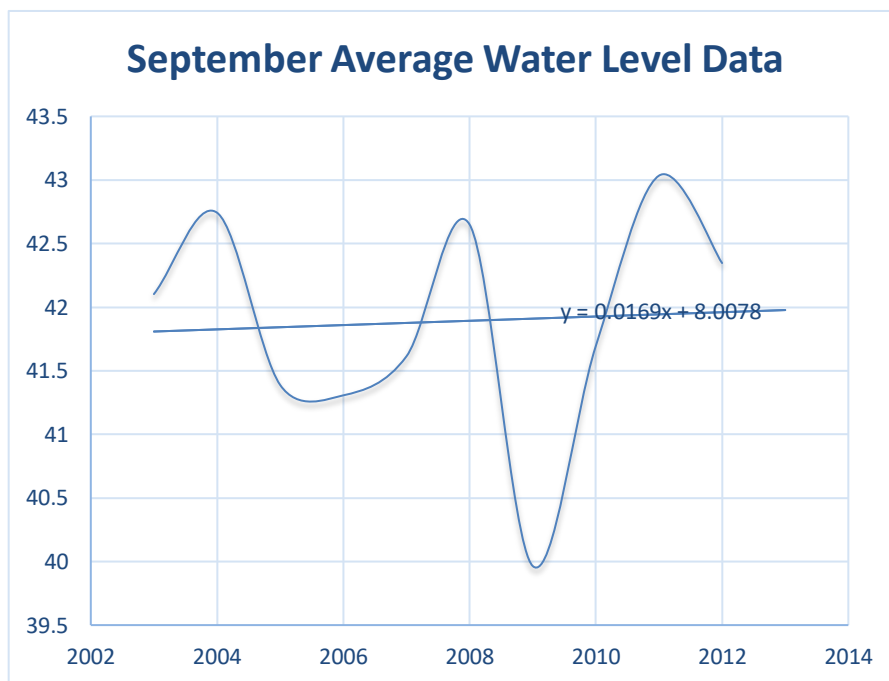
- Chainage 21000m, on the other hand, has a constant and consistent increase in water level due to the sharp rising trend of the riverbed at that location. This increase can have important implications for water management, infrastructure planning, and flood risk assessment in the area, as it indicates a reduced capacity for water storage within the channel.



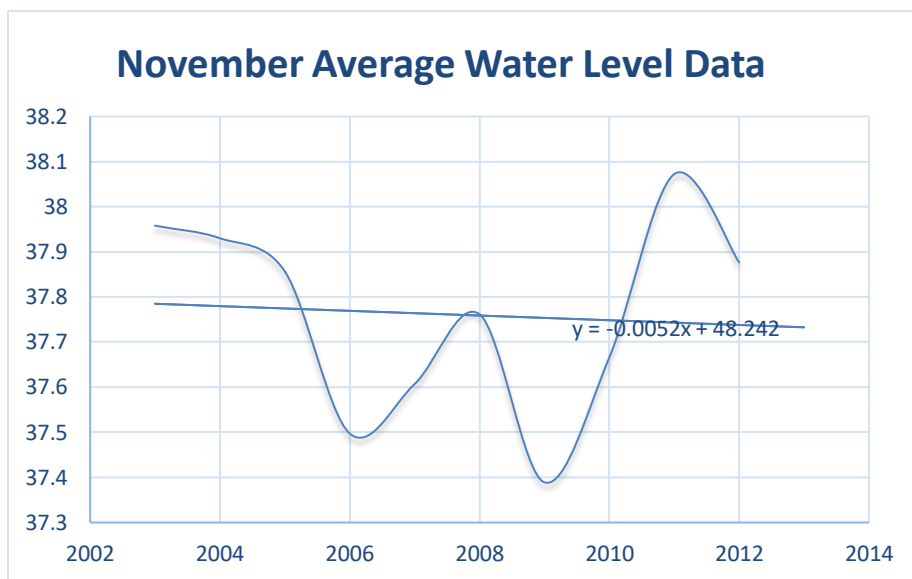
(a)



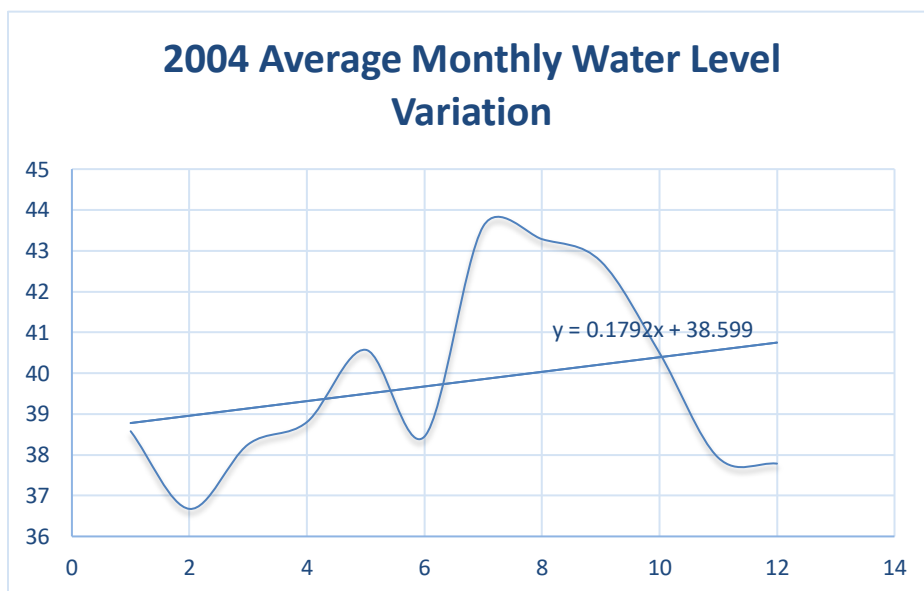
(b)



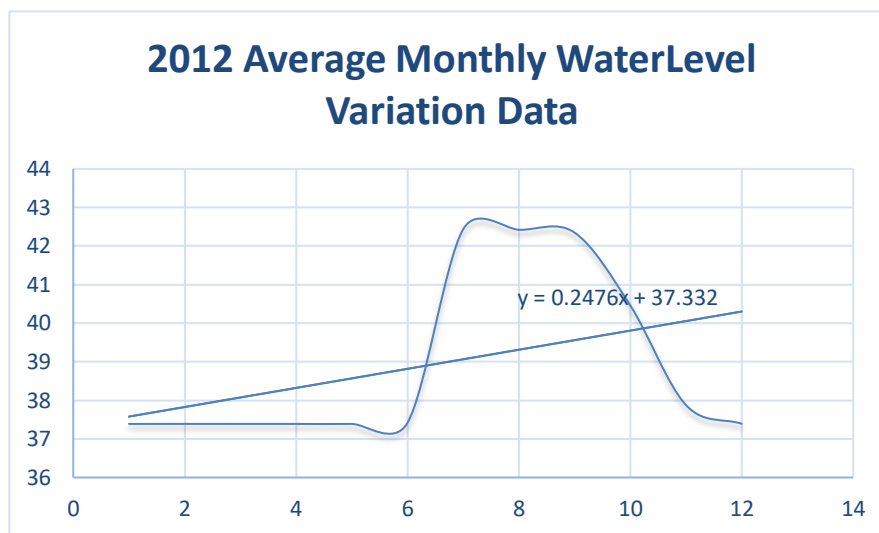
(c)



(d)



(e)



(f)

Figure 4-5(a-f) Dhamara Ghat Water level data

The provided information pertains to the results obtained from a sediment transport simulation conducted in the model domain of the Koshi River. The simulation has yielded several noteworthy observations, which is elaborated below:

1. Massive Sedimentation in the Koshi River Model Domain:

The simulation has revealed that the Koshi River model domain has undergone significant sedimentation. This means that over time, a substantial amount of sediment, such as sand, silt, or other particles, has been deposited within the river channel. Sedimentation is a common phenomenon in rivers that carry a heavy sediment load.

2. Heavy Sediment Load from the Upper Reach:

The Koshi River carries a substantial sediment load from its upper reach. This implies that the river collects a large amount of sediment as it flows downstream. Sediment is typically eroded from the river's upper catchment area and is transported downstream by the river's flow.

3. Reduction in Velocity Due to Reduced Slope:

One of the causes of massive sedimentation in the middle stretch of the Koshi River model domain is a reduction in slope. As the river's slope decreases, the velocity of the water flow also decreases. When water velocity decreases, it loses its ability to transport sediment efficiently, leading to sediment settling and accumulating in the riverbed.

4. Varied Rates of Sedimentation in Different Chainages:

The rate of sedimentation is not uniform along the entire length of the river. It has been observed that the rate of sedimentation is much lower in the upstream portion (chainage 0 to 12000m) compared to the downstream portion (chainage 12000m to 21000m). This suggests that sediment deposition is more pronounced in the middle and lower reaches of the river.

5. Decreasing Rate of Sedimentation Over Time:

Over time, there has been a decrease in the rate of sedimentation. This means that the rate at which sediment accumulates in the riverbed has slowed down. This could be due to various factors, including changes in the river's flow dynamics, human interventions, or alterations in sediment sources.

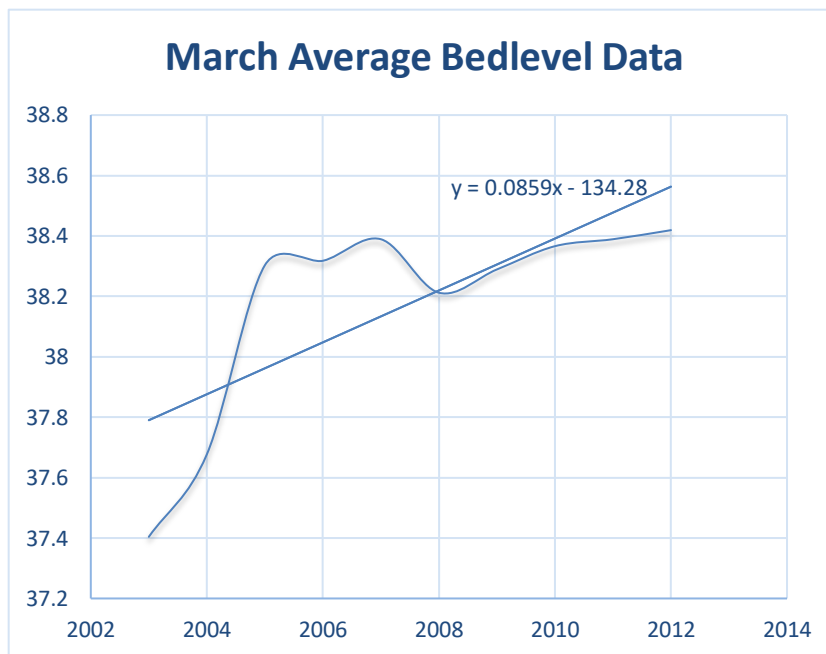
6. Areal deposition at Specific Chainages:

In the year 2004, the simulation indicates that the total areal sedimentation at chainage 12000m was 80 square meters, whereas in 2012, it decreased to 35 square meters. Similarly, at chainage 21000m, the annual areal sedimentation increased significantly from 120 square meters in 2004 to 320 square meters in 2012.

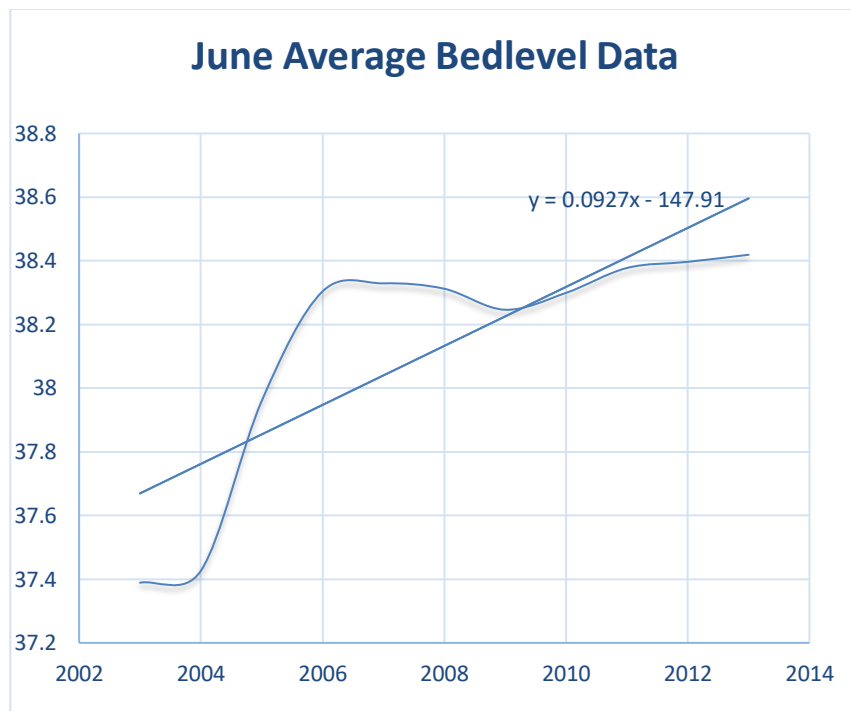
7. Seasonal Variation in Bed Level Changes:

Most of the changes in bed level have been observed to occur during the monsoon period, specifically in August and September. This suggests that the monsoon season, characterized by heavy rainfall, plays a significant role in altering the riverbed topography by transporting and depositing sediment.

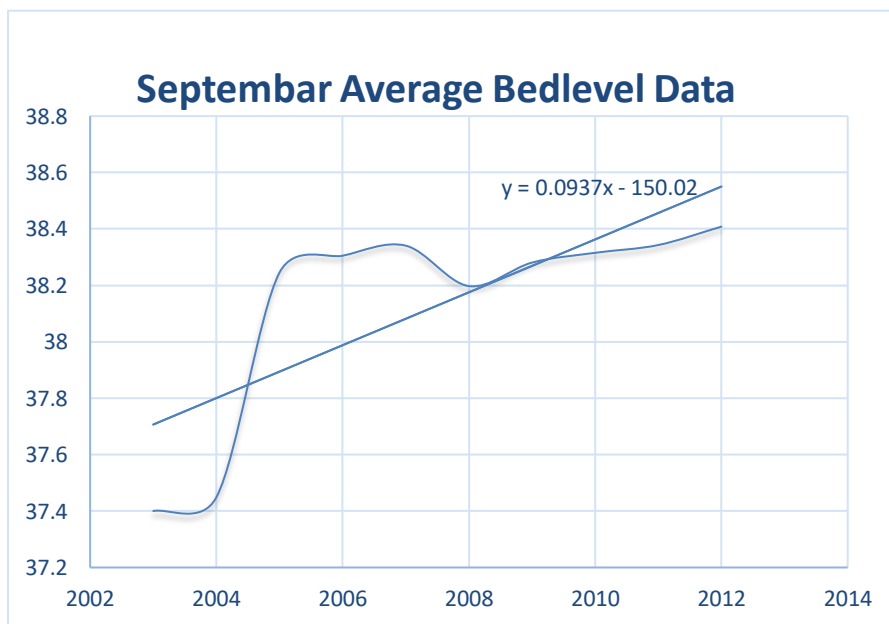
In summary, the sediment transport simulation has provided valuable insights into the dynamics of sedimentation in the Koshi River model domain. These findings can have implications for river management, flood risk assessment, and infrastructure planning in the region, particularly in understanding how sedimentation patterns evolve over time and their relationship with seasonal variations.



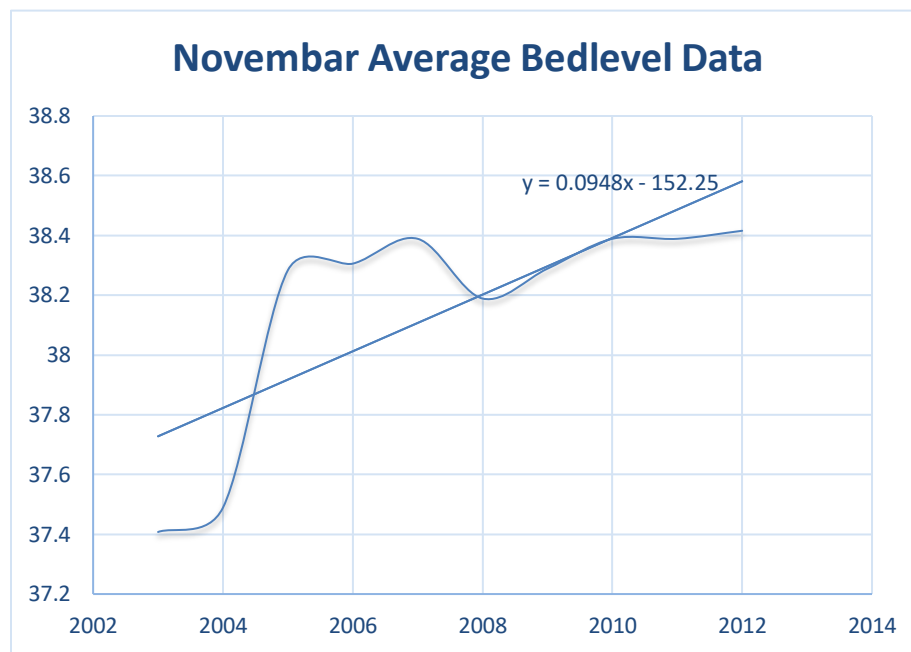
(a)



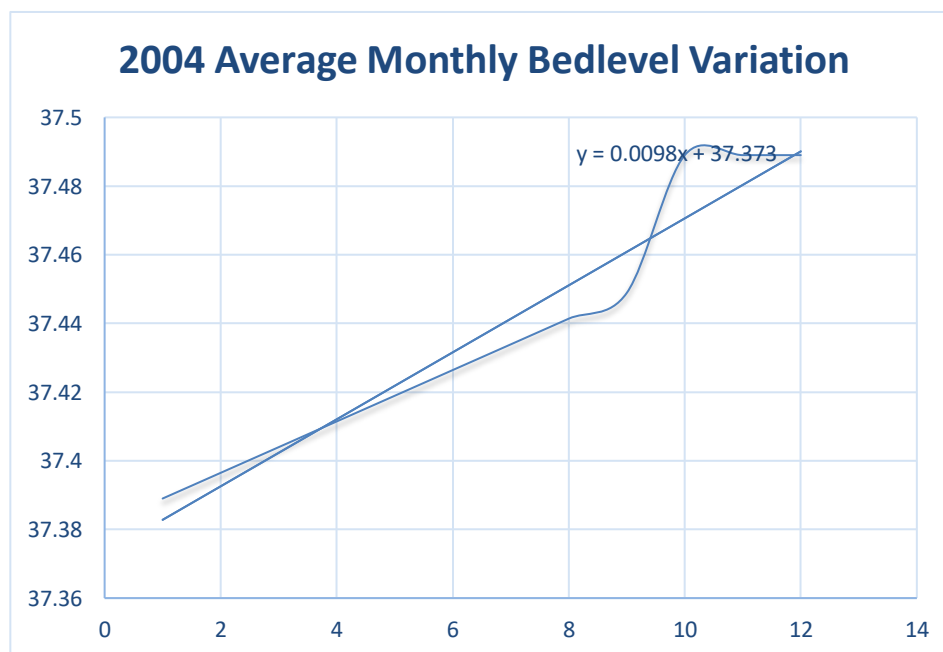
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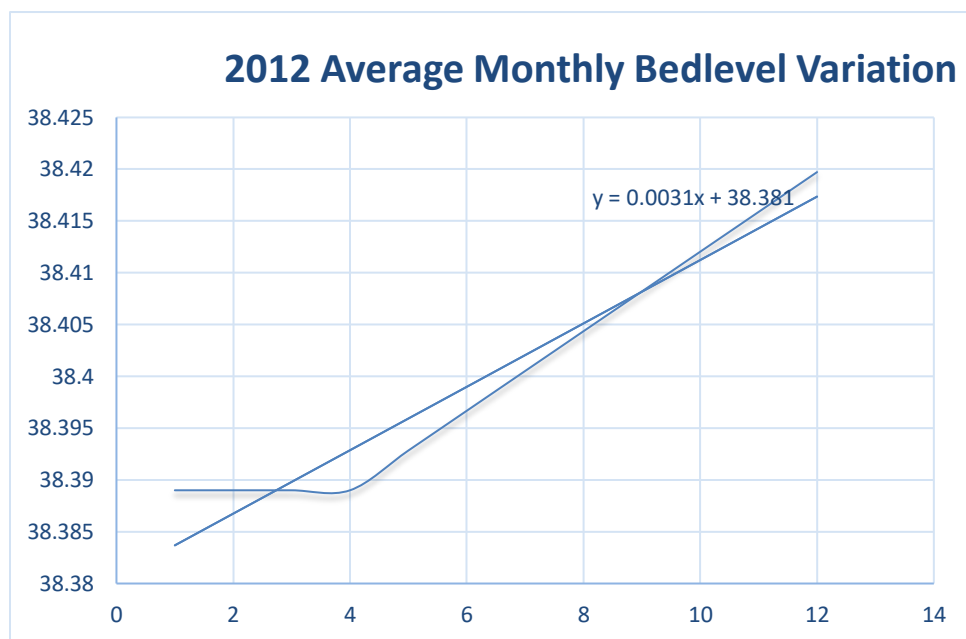
(c)



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(f)

Figure 4-6(a-f) chainage 12000 bed level graph

The simulation has provided data regarding the distribution of two types of sediment loads: suspended load and bed load.

4.1.3 Higher Amount of Suspended Load:

Suspended Load: Suspended load refers to the fine sediment particles, such as silt and clay, that are carried within the water column of a river or stream. These particles remain suspended in the flowing water due to their small size and are transported downstream. Suspended load can contribute to the turbidity of the water and is often associated with water pollution reduced water clarity.

Bed Load: Bed load, on the other hand, consists of larger and heavier sediment particles, such as sand and gravel, that roll or slide along the riverbed. Bed load typically moves closer to the riverbed and can cause abrasion and erosion of the riverbed. This type of load is less likely to remain suspended in the water column for extended periods.

The key observation from the sediment transport simulation is that the cross section at the 5000-meter chainage exhibits a significantly higher amount of suspended load compared to bed load. This means that the simulation has shown that a substantial portion of the sediment being transported through this particular section of the river consists of fine particles that are suspended in the water.

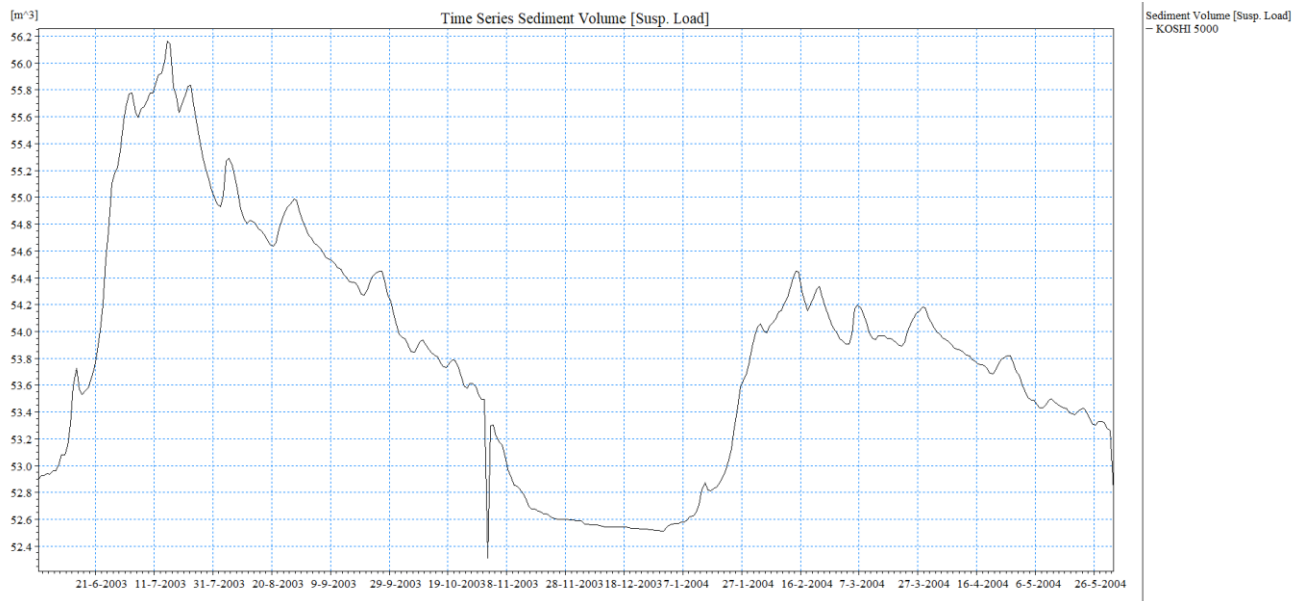


Figure 4-7 Suspended load

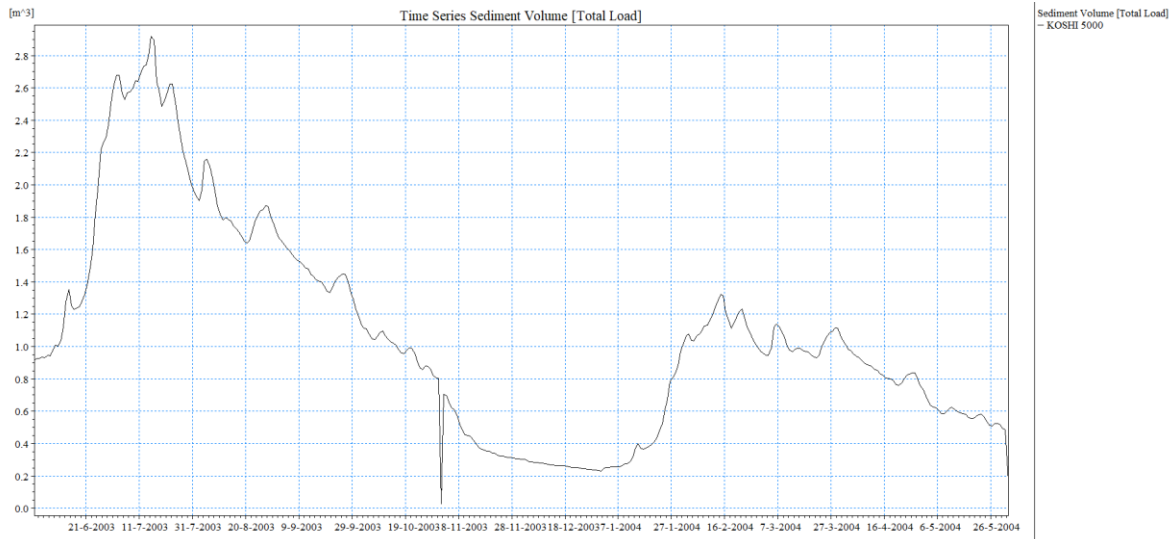


Figure 4-8 Total load

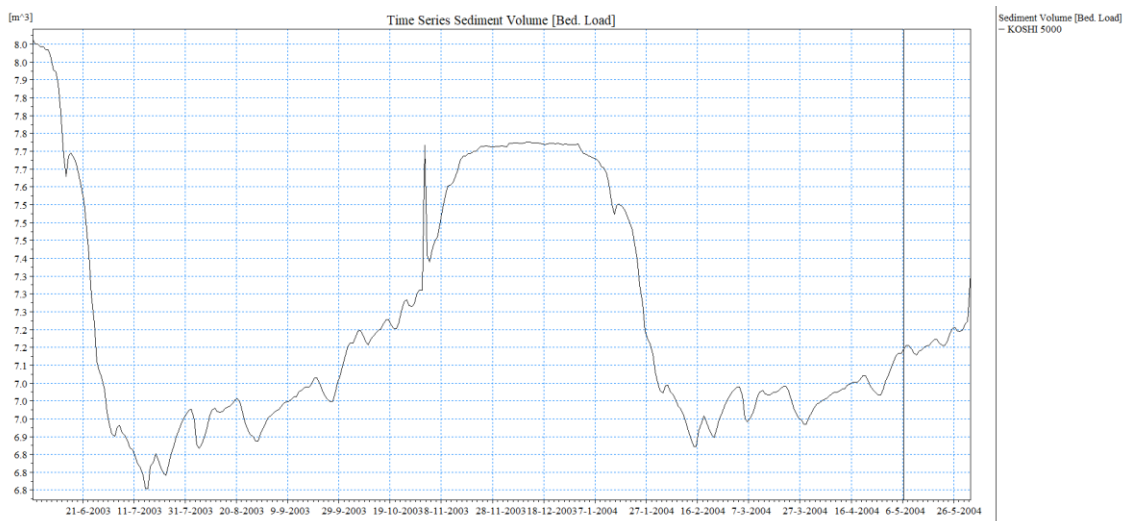


Figure 4-9 Bed load

Chapter 5

Conclusion

The comprehensive hydrodynamic and sediment transport simulation undertaken in this study has delivered profound insights into the intricate behaviour of the river within the designated study domain. The meticulous examination of the river's responses to a spectrum of hydrological and environmental factors has enabled us to create a nuanced depiction of the changes in both riverbed morphology and water levels over time. By closely scrutinizing these dynamic variations, we have laid the foundation for a comprehensive understanding of how the river evolves and adapts.

Moreover, the identification of depositional patterns has illuminated the precise locations where sediments accumulate within the river. This knowledge is of paramount importance for future riverbed projection, as it enables us to anticipate how the river's topography might transform in the years to come. Such predictive capacity has far-reaching implications for urban and infrastructure planning, helping to safeguard critical structures and mitigate potential flood hazards.

Furthermore, our analysis of sediment transport characteristics has shed light on the mechanisms that govern the movement of sediment within the river system. Understanding whether sediment predominantly exists in a suspended or bed load state is instrumental in assessing the overall health of the river, predicting sedimentation rates, and mitigating the risk of erosion.

Most significantly, the findings of this study hold enormous promise for water resource management. They provide a robust, data-driven platform on which to base well-informed decisions concerning water allocation, flood prediction, and the protection of essential infrastructure lining the riverbanks. This knowledge is not only pivotal for the sustainable management of the river's resources but also for the preservation of ecosystems that depend on its dynamics.

As we look to the future, the insights derived from this simulation serve as an invaluable starting point for further research and strategic action. They will guide the development of adaptive, sustainable water management strategies capable of navigating the evolving river dynamics, particularly in response to seasonal fluctuations and the formidable challenges posed by climate change. In essence, this study constitutes a cornerstone in the ongoing pursuit of resilient and environmentally responsible river management practices.

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