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A STUDY ON HYDRODYNAMIC AND MORPHOLOGICAL BEHAVIOR OF SARADA RIVER USING DELFT3D MODEL

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Abstract :

the River Sarada is a medium-sized river. The river's physical location is between 17 and 18 degrees north latitude and 82 to 83 degrees east longitude. The basin's catchment area is 2,665 square kilometres. It rises in the Eastern Ghats at a height of 1,000 metres. It travels 122 km in an easterly direction before joining the Bay of Bengal. River Nagavali, River Gosthani, River Gambiramgedda, River Megadrigedda, Bay of Bengal, and the Machhkund sub-basin of the River Godavari all encircle the basin. The largest city in the basin is Visakhapatnam. Important towns in the basin include Yelamanchili and Anakapalli.

Due to its extreme susceptibility to erosion and deposition, the Sarada river, which has historically been thought of as a river that primarily meanders, is transitioning into a braided river. By creating a 2D model with Delft3D, a hydrodynamic and morphological analysis of the Sarada River is carried out to determine its suitable behavior.

With the use of numerical modeling, we will build a semi-circular breakwater at the river's mouth where it entered the Bay of Bengal in this study. Different morphological and hydrodynamic properties, including sediment transport rate and cumulative erosion/deposition, are evaluated. Tidal effects can cause changes in water level, velocity changes, and discharge. The findings show that the tidal range is greatest during the dry season and increases from upstream to downstream of the river. The model confirms the phenomenon and demonstrates that during the rainy season high velocity leads in high sediment transport rate, which ultimately contributes to erosion/deposition of river bed. It is believed that this study's conclusions would assist people grasp the general hydrodynamic and the river's morphological characteristics and potential future development projects are suggested.

Keywords: *Delft3D, hydrodynamic, morphological, Sarada river.*

1. Introduction

The Sarada River, nestled near the coastal city of Visakhapatnam, India, serves as a vital lifeline to the region, providing water for irrigation, domestic use, and supporting diverse aquatic habitats. However, rapid urbanization, industrialization, and anthropogenic activities have raised concerns over the river's ecological health and sustainability. This journal paper presents an in-depth ecological assessment of the Sarada River ecosystem, shedding light on its current state, potential threats, and the critical importance of conservation efforts. Integrating extensive field surveys, water quality analysis, and biodiversity assessments, our study unravels the intricate ecological dynamics at play in this unique riverine environment. Furthermore, we discuss the implications of our findings on the local community, biodiversity conservation, and propose science-based strategies for the sustainable management of the Sarada River ecosystem. By addressing these issues, we aim to foster informed decision-making and inspire collaborative actions towards safeguarding this invaluable natural resource for generations to come.

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APWRIMS claimed that the depth of the Sarada River is nowadays 1 to 1.8 meters at different place. But at least 2.00 to 3.00 meters depth of water have necessary for movement of river transports. APWRIMS also reported that water level is decreasing by 25 centimeters every day. Life this process continues, Sarada River will be turned into a wetland which will affect the navigation, agricultural, fishing, transportation facilities of nearby areas. Finally it will damage the biodiversity and ecological balance of the southern part of Bangladesh. These problems could be solved only when we will be able to know the actual hydrodynamic and morphological behavior of this river. So a hydro morphological study of Sarada River is utmost necessity to identify the hydrodynamic and associated morphological changes of the river.

While numerous modeling studies have been conducted to investigate river behavior in Visakhapatnam, many of these models have proven to be both costly and time-consuming. However, there is a powerful open-source (student version) alternative, Delft3D, which offers a comprehensive understanding and forecasting of river morpho-dynamic behavior. Delft3D incorporates the most relevant factors involved in this process as input parameters and presents a wide array of results in a user-friendly manner.

Two notable research studies have utilized the Delft3D model to explore river morphological changes in Visakhapatnam. Lalith kumar (2019) investigated the Sarada River's morphological changes, focusing on sediment transport rate, erosion and deposition patterns, bed level changes, and the river's shifting process. Meanwhile, P.Sundara kumar (2018) studied the Sarada River basin, employing the Delft3D model to assess the river's response to dredging works under the capital dredging project. The study also quantified the erosion and deposition impact resulting from the capital dredging activities.

By employing Delft3D, researchers in Visakhapatnam can benefit from a cost-effective and efficient tool to better comprehend and manage the dynamic behaviors of their rivers, leading to more informed decisions regarding river management and conservation.

The focus of this research is to conduct a comprehensive hydrodynamic and morphological assessment of the Sarada River utilizing the Delft3D model. The hydrodynamic study aims to provide valuable insights into the river's flow characteristics, such as the periodic rise and fall of water levels due to tides, as well as velocity and discharge patterns. Understanding these flow dynamics is crucial for various applications, including flood forecasting, river navigation, and water resource management.

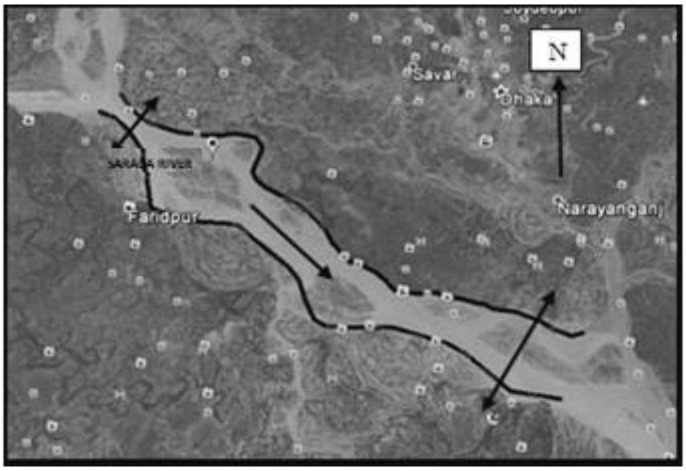
The specific objectives of my study are :

- The research aims to monitor and analyze water level fluctuations at various locations along the Sarada river, resulting from the daily, monthly, and seasonal tidal effects.
- To study the annual variation in velocity and discharge of the river.
- To assess the sediment transport rate and cumulative erosion/deposition at various points along the river.

2. Methodology

2.1 Study area

The selected reach is approximately 10 km long starting from Gokivada Transit at U/S to Rajala Gedda at D/S.



2.2 Data Collection.

Types of Data Collected and their Sources

Data	Location	Period	Source
Bathymetry	Station ID RMP 1-RMP7	2011	APWRIMS & GEBCO
U/S discharge	Gokivada Transit 91.9 L	2011, 2012	APWRIMS
Water Level	Gokivada 93.5L & Rajala Gedda 94L	2011, 2012	APWRIMS
Sediment	Gokivada Transit 91.9L and rajala gedda Transit 93.5 L	Most recent	APWRIMS

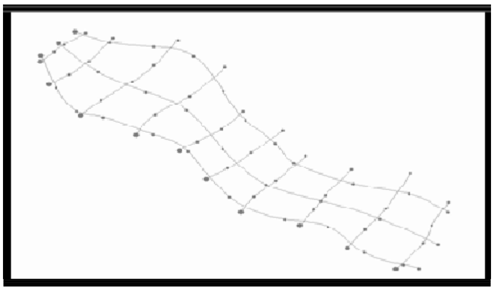
2.2 Data Processing

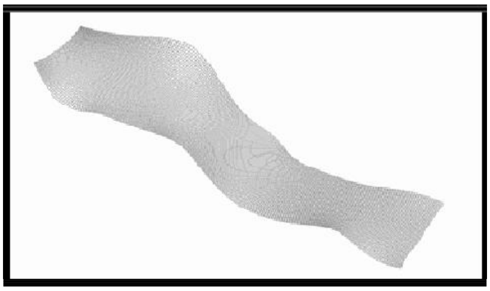
The bathymetry data sourced from APWRIMS and GEBCO were initially recorded as distance-depth measurements along one bank line. However, since Delft3D operates with X, Y coordinates (latitude and longitude), a transformation was performed using Arc-GIS to convert the bathymetry data into X, Y ordinates. Subsequently, the X, Y points were extracted from Arc-GIS attribute table to an Excel sheet, employing the Table to Excel tool.

2.3 Model setup

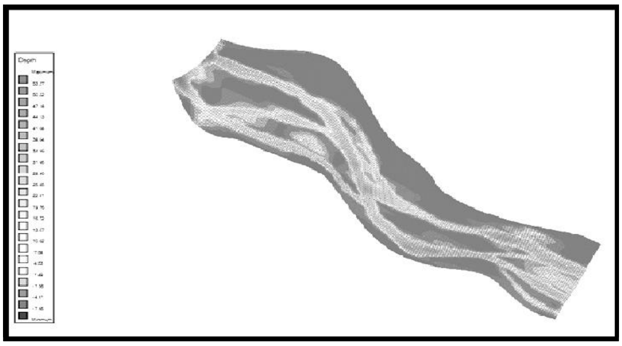
2.3.1 Grid generation

The figure below depicts the grid created to cover the Sarada River using Delft3D. After multiple iterations, with a focus on ensuring orthogonality and aspect ratio, a grid size of M = 223 by N = 56 was ultimately selected.


SPLINES


GRID

2.3.2 Bathymetry Development



Below shows the bathymetry developed for Sarada river using delft3D.

2.3.3 Set Up for Delft 3D Flow.

2.3.3.1 Boundary Conditions and Boundary Set-up

Below table presents the boundary conditions set for the model development.

Boundary Locations

Data	Location
U/S Discharge	Gokivada Transit 91.9L D/S
WL	Rajala Gedda 94L

2.3.3.2 Hydrodynamic Parameters

Table presents Hydrodynamic parameters used in the model where, Manning's roughness n is used as the calibration parameter for the model.

Hydrodynamic Parameters

Parameters	Value
Gravity	9.81m/s^2
Water Density	1000 kg/m^3
Roughness	0.018 to 0.027
Horizontal Eddy viscosity	1 m^2/s

2.3.3.3 Morphological Parameter

Below table presents the morphological parameters used in the model.

Sediment and Morphological Parameters

Parameters	Value
Specific density	2650 kg/m^3
Dry bed density	1600 kg/m^3
D50	0.200 mm
Van Rijn’s reference height factor	1
Threshold sediment thickness	0.05

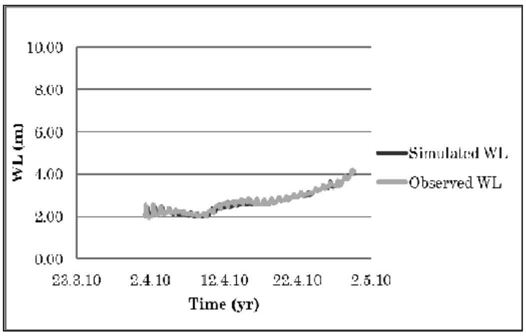
2.4 Calibration and Validation

2.4.1 Calibration

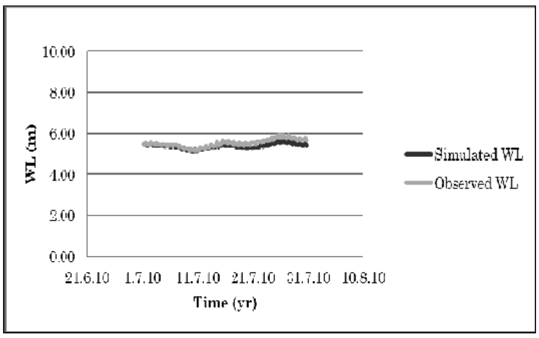
The model is calibrated and validated against the water level at Sarada river stretch for two months April (dry season) andJuly (wet season) of 2010 and 2011 respectively.

2.4.1.1 Calibration for April 2010 and July 2010

Below Figure (a) and (b) show the model calibration results for dry season and wet season respectively. The model iscalibrated using different manning’s n ranged from 0.018 to 0.027.



(a) : Calibration for April, 2010 (dry season)



(b) : Calibration for July, 2010 (wet season)

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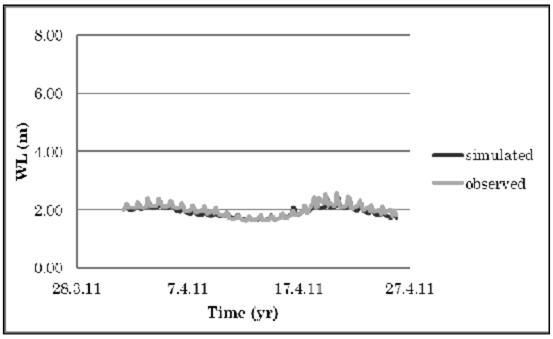
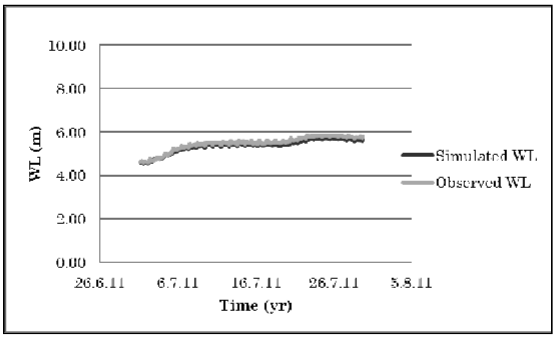
2.5 Validation

2.5.1.1 Validation for April 2011 and July 2011

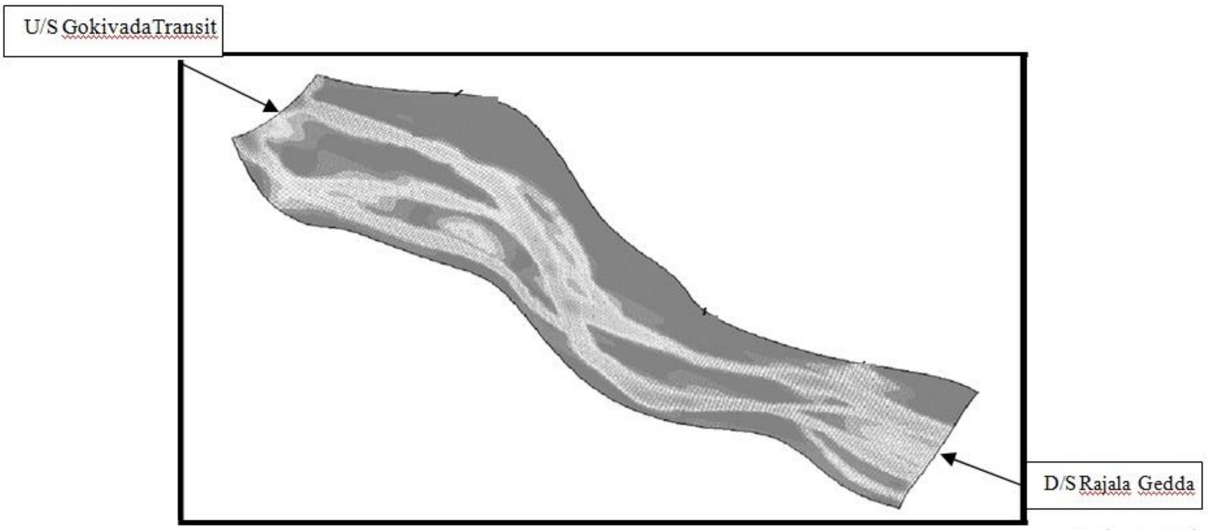
After calibration the model is validated for the month of April and July, 2011. Figure 7 (a) and (b) show the validation results. From the figures it is seen that the model shows good agreement with the observed data.





(a) Validation at Mawa for April, 2011 (b) Validation at Mawa for month July, 2011

3 RESULTS & DISCUSSIONS



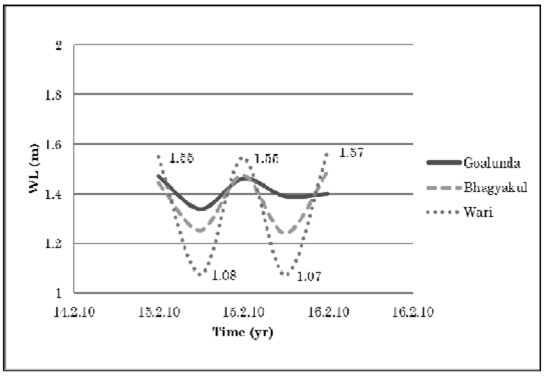
3.1 Hydrodynamic Results

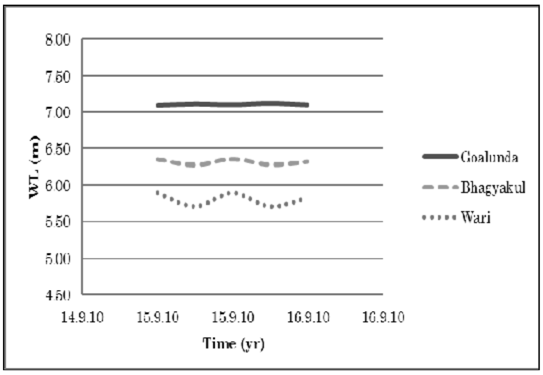
3.1.1 Effects of Tide on Water Level

Sarada is classified as a semi-tidal river, exhibiting no tidal impact on its upstream side but experiencing significant tidal effects on its downstream side. The variation in water level caused by tides is determined based on model results. To investigate the phenomena of high tide, low tide, and tidal range, this analysis focuses on two specific stations along the river: Gokivada (upstream), and Rajalagadda (downstream). Above figure illustrates the different locations along the Sarada River where the assessment of tide-induced water level variations will be conducted.

3.1.1.1 Daily Tidal Effect

Figures (a) and (b) display the daily water level variation due to tides at Gokivada and Rajalagadda, respectively. The model results clearly illustrate that in February, the tidal cycle exhibits a highly sinuous pattern, with a tidal period of approximately 12 hours and 25 minutes. Moreover, two high tides and two low tides occur daily, highlighting the significant tidal effect and tidal range during this month. In contrast, the water level vs. time curve in September no longer forms a sinuous shape; instead, it appears nearly





linear. Hence, it can be concluded that the tidal effect in the Sarada River is negligible during September.

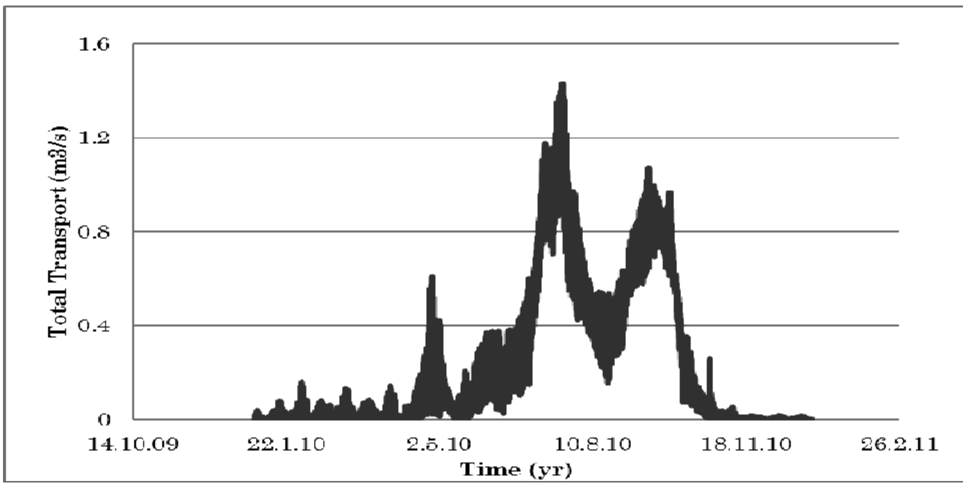
(a) : Daily Tidal Cycle (Feb) (b) : Daily Tidal Cycle (Sept)

3.2 Morphological Results

3.2.1 Variation in Sediment Transport Rate

The figure below illustrates the variation of sediment transport rate, while Table presents the Suspended Transport, Bed Load Transport, and Total Transport data at Gokivada and Rajalagadda throughout the year. Both the figure and table indicate a distinct seasonal pattern in the sediment transport rate, with the highest values recorded in July (wet season) and the lowest in December (dry season).

Furthermore, it is evident from both the figure and table that the mid-section of the Sarada River experiences the maximum sediment transport rate, while Rajalagadda records the minimum. This observation can be attributed to the higher velocity of the river during the wet season, resulting in an increased sediment transport rate. Conversely, the dry season witnesses lower velocity, leading to a reduced sediment transport rate during that period.



Variation of Sediment Transport (m^3/s) over the Year

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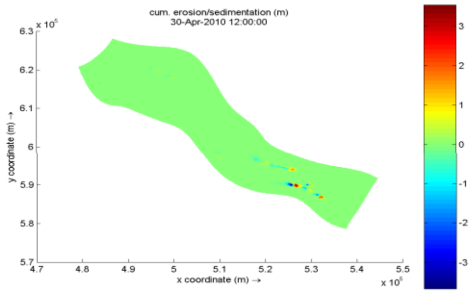
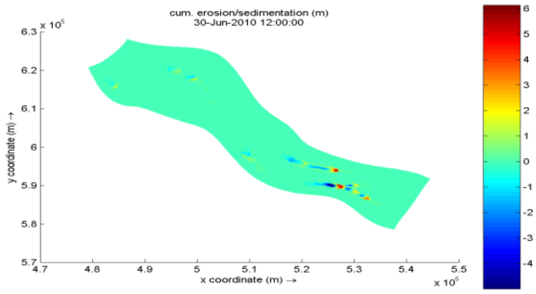
Suspended Transport, Bed Load Transport and Total Transport at Gokivada and Rajalagadda

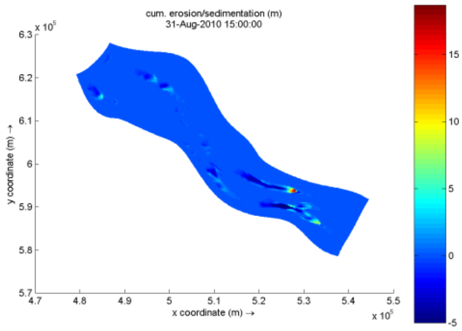
	Suspended Transport (m^3/s)		Bed Load Transport (m^3/s)		Total Transport (m^3/s)	
	Gokivada	Rajalagadda	Gokivada	Rajalagadda	Gokivada	Rajalagadda
Dry season	0.0012	0.009	0.0001	0003	0.002	0.01
Wet season	0.0392	0.106	0.0085	0.008	0.0472	0.118



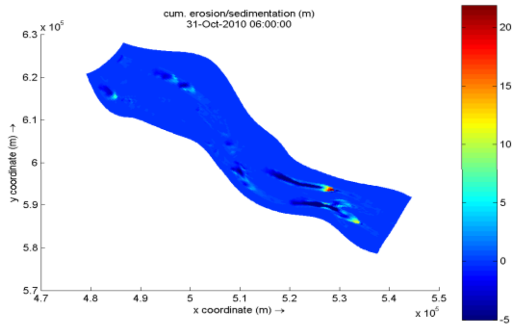
(a) : Cumulative Erosion / Depositionat the End of April



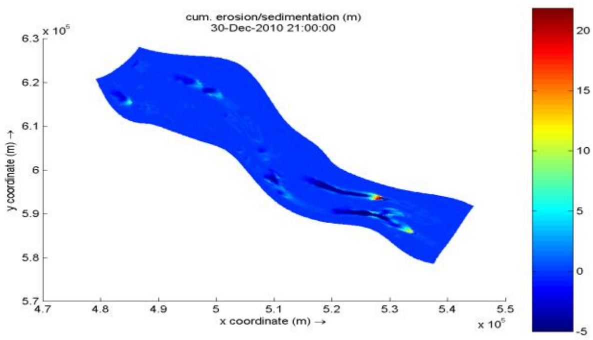
(b) : Cumulative Erosion/Depositionat the end of June



(c) : Cumulative Erosion / Depositionat the End of August



(d) : Cumulative Erosion./Depositionat the end of October



(e) : Cumulative Erosion / Deposition at the End of December

4. CONCLUSIONS

In this research, a 2D model is created using Delft3D, with Gokivada Transit as the upstream boundary and Rajalagadda as the downstream boundary. The model is then simulated for the year 2010 to investigate the hydrodynamic and morphological characteristics of the Padma River. The key findings are summarized as follows:

- The dry season, spanning from November to April, exhibits higher tidal effect and tidal range compared to the wet season from May to October. Furthermore, the tidal range progressively increases from upstream to downstream. Consequently, the downstream section, Rajalagadda, experiences more pronounced tidal effect than the upstream section, Gokivada.
- The wet season records higher velocities compared to the dry season. Notably, the middle section exhibits the highest velocity, while the downstream section, Rajalagadda, has the lowest velocity. The upstream section, Gokivada, falls between the velocities observed at Rajalagadda and the middle section.
- The model results clearly demonstrate a significant increase in discharge during the wet season compared to the dry season. Further analysis reveals that the discharge reaches its peak in September and reaches its lowest point in March when considering monthly variations.
- The study reveals a strong correlation between the sediment transport rate and the river's velocity. Increased velocity leads to higher sediment transport rates, consequently causing notable erosion and deposition of the riverbed. Conversely, lower velocities correspond to reduced sediment transport rates. As a consequence of high velocity, the middle section of the Sarada River experiences the maximum sediment transport rate, while Rajalagadda encounters a lower sediment transport rate due to its lower velocity.
- Erosion and deposition are more pronounced during the wet season than in the dry season, resulting in a significant difference in bed level changes between the two periods. During the dry season, the change in bed level is relatively insignificant compared to the monsoon season.

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