Environmental Science and Engineering

Raj Kumar Bhattacharya
Nilanjana Das Chatterjee

River Sand Mining Modelling and Sustainable Practice

The Kangsabati River, India

Springer

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ISSN 1863-5520 ISSN 1863-5539 (electronic)
Environmental Science and Engineering
ISBN 978-3-030-72295-1 ISBN 978-3-030-72296-8 (eBook)
https://doi.org/10.1007/978-3-030-72296-8

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To my Grandmother,

Late Uma Bhattacharya

Foreword

Healthy ecosystems are the most critical components of the natural environment that are indispensable for human wellbeing and sustainable development. However, the ever-expanding human aspirations, economic developments and urbanization have imposed immense pressure on the natural resources. Indiscriminate extraction of natural resources, especially the building materials, for meeting the rising demand in the construction sector has imposed dire concern to the environment. The river ecosystems are severely impacted by the environmental consequences as they are the first to hit the adversities of economic developments. Among the various kinds of human interventions, mining for aggregate materials like sand and gravel is the most disastrous as the activity threatens the very existence of the river ecosystems. At the same time, the continued supply of aggregate materials like sand and gravel is to be ensured to maintain the pace of developments and economic activity. Such continued human–environment interaction invokes the need for a balanced approach between sand and gravel extraction, and environmental protection. In this context, the effort of Dr. Rajkumar Bhattacharya and Prof. Nilanjana Das Chatterjee in bringing out the book "River Sand Mining, Modelling and Sustainable Practice—The Kangsabati River, India" receives considerable significance and relevance.

The book offers a wide spectrum of subject components covering almost all the essential aspects of river sand mining practice, by considering the case study of Kansabati River in India. Various chapters in this book are grouped under three parts. The first part comprises three chapters dealing with the global scenario, geomorphic threshold of sand mining and seiment budget assessment. The second part embodies four chapters delineating the sediment grain size characteristics, hydraulic variables of flow and sediment regime, channel morphology and ecology. The third part includes sand resources estimation, optimum utilization and identification of sustainable mining sites. This book provides a compelling evidence on the need of environmental conservation and sustainable resource extraction for developmental requirements.

I am sure the book will be very useful for academicians, researchers and students, and also a valuable source material for the decision/policymakers at different levels and the people at large. I congratulate the authors for bringing this crucial geo-environmental aspect to the focus and wish them all the very best.

Padmalal.D

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Preface

In this era of urbanization, worldwide demand for sand and gravel are increasing day by day to meet huge requirement of construction sector, land filling and transportation sector based infrastructural project etc. It results in over extraction of sand from channel bed, and hampers the natural renewal of sediment, geological setup and morphological processes of the riverine system. Many researchers have addressed that irrational sand and gravel mining are associated with channel hydraulics, morphology and riverine biota especially in alluvial channel. In contrary, optimum sand mining (SM) must be needed for the continuation of rational economic activity. But some crucial research questions are raised: (1) what is the optimal amount of SM in respect to resilience of stream hydraulics, morphological and river ecosystem variables, (2) how to determine the river health response in between pre and post mining stages or sites, and (3) how to propose sustainable SM sites following healthy premises of riverine process-response system (RPRS).

After the critical analysis between geomorphic threshold and geo-environmental consequences of instream SM, sediment budget (SB) is a crucial requirement for the determination of under, optimum and over SM with respect to natural sediment replenishment and sediment extraction. On the other hand, several validated geospatial models are adopted to find out the various responses of instream SM in accordance to pre-mining or sandbar, mining and post-mining stages or sites. Optimization models (Ops) of annual SM rate and environmental impact assessment (EIA) of mining consequences both are final assessment techniques for the determination of overall interrelationship between response factors and responding variables in upper, middle and lower reach, respectively. All of the applied methodologies predicted fruitful results that are summarized from channel geomorphological threshold to sustainable SM based proposed mining sites in this book.

In India, illegal SM (alluvial channel) and gravel mining (perennial channel) are one of the important anthropogenic issues that hamper the sustainable drainage system. SM consequences are more serious and disturbing in an alluvial reach of the Kangsabati River. Construction of Mukutmonipur dam (1958) on the river causes huge sediment deposition along the middle and downstream due to abruptly break of slope. Over extraction of instream and floodplain SM can be especially seen in Mohanpur and Kapastikri (middle and downstream) with a rate of extraction 474926.59 cu ft. out of 588155.6 cu ft. of Kangsabati River (2012–2016, DLRO Paschim Midnapore and Bankura, West Bengal).

Objective of SB in this work is to understand the stability status of channel segments through the assigning of sediment source and sink. Revised universal soil loss equation, sediment delivery distributed model, sediment extraction record datasets (2002–2016) are used to estimate the SB throughout the channel. SB revealed that instream mining leads to interruption of sediment grain size deposition processes along the channel bed incorporate with shear stress which is needed for particle movement. G-STAT, Grad-Stat, Sedlog and linear discrimination function are used to determine the mean, shorting, peakness and skewness of sediment grain size distribution. DuBoys equation and Shields formula are applied for assessment of shear stress and critical shear stress in threshold range between erosion and deposition in mining and sandbar sites. As a result, three different disruption or consequences are occurred i.e. hydrological, morphological and ecological consequences, respectively.

In term of stream hydrological consequences, well known established hydraulic equations along with Acker-White (1973) and Meyer-Peter-Muller methods (1948) are used to derive the hydraulic response on bedload transport and mining intensity, and also tries to determine the effects of mining intensity on bedload sediment transport and pit migration with the presence of instream shear force from sandbar to mining sites. In term of morphological consequences, digital shoreline analysis system based statistical models of end point rate and linear regression rate for estimating the riverbank shifting and resultant erosion-accretion rate, bank erosion hazard index for prediction of bank erosion vulnerability zone, geometrical indices for estimating of channel planform change, are used to compare geomorphic responses in mining and sandbar sites. In terms of ecological consequences, water quality index and habitat suitable index integrated with multiple logistic regressions are applied for the detection of water quality deterioration, three tier habitat transformation and degradation caused by instream SM.

Ops and EIA both have find out the over, optimum and under mining sites as well as to propose potential mining sites with the respect of threshold values of several variables. Based on field experience and scientific analysis, sustainable mining sites have been suggested following resilience state of river dynamic variables, assessed by Ops and EIA.

This book demonstrates the geospatial models along with Ops and EIA techniques for better understanding the resilience state of stream hydraulics, morphological and river ecosystem variables during pre-mining and post-mining using of micro-level datasets. In this context, this book attempts to apply many established models with real datasets in the case study of Kangsabati River. The pragmatic training of utilizing geospatial techniques would be helpful for the students, researchers, academicians, decision makers and practitioners to using those techniques for their own purpose at large scale.

The exceptionality of this volume is its style of presenting the separate methodologies and models are adopted to validate the issue for each chapter along with citing case studies, which will grow up the interests of the scientific reader community. These modern techniques could be facilitated for that community due to present of detail models clarification along with analysis of enough comprehensive algorithms; as a result, they could apply those models as per their choices for the present of lucid writing style.

This book proposed specific practicable measures to minimize the environmental consequences of instream mining in respect to optimum SM. We will discuss how the threshold limits of each variable in stream hydraulics, morphological and river ecological regime, as well as find out the most affected variables. Consequently, all outputs will be very useful for the readers to create their own model in respect to RPRS.

Midnapore, India

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Nilanjana Das Chatterjee

Acknowledgements

We are taking this opportunity to pay respect to the teachers in the Department of Geography, Vidyasagar University. We are highly obliged to Dr. D. Padmalal, Scientist-G and Head, Hydrology Group, ESSO-National Centre for Earth Science Studies (NCESS), Ministry of Earth Science, Government of India, who helped immeasurably towards the completion of this book. We do express gratitude to A. C. Dinesh, Geologist, Marine wing, GSI, Mangalore for providing many technical supports and useful suggestions. We are obligated to the Irrigation Department of West Bengal, D.L & L.R.O of Paschim Medinipur, and Bankura for their continuous co-operation and support. We are especially thankful to the administrative authorities of our sole institutions for extending their supports to access USIC laboratory, Departmental laboratory and library.

We are grateful to Mr. Kousik Das, UGC Junior research fellow, Vidyasagar University, for his constant technical support in preparing this research work. We also thank students of Geography department for their rigorous efforts during field visits.

Valuable editorial advice including thorough guidance from Doris Bleier, Publishing Editor of Springer Nature continuously helped us to enrich the content and improve the quality of this book. We are indebted to Mr. Chandra Sekaran Arjunan, Project Coordinator, Books, Springer, who took the responsibility of the project coordination and supervised the entire production process.

Last, but not least, we would like to thank our families for their continuous support, understanding the importance of the work and encouragement during the entire work.

Raj Kumar Bhattacharya
Nilanjana Das Chatterjee

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