POLICY PAPER, APRIL 2022

Sustainable management of sedimentation risks in coastal rivers in Southwest Bangladesh: Findings from REACH Khulna Observatory

Md. Saif Uddin [A, B], Rezaur Rahman [B], Mashfiqus Salehin [B] ([A]Bangladesh Water Development Board, [B]Bangladesh University of Engineering and Technology)

Summary:

Despite ongoing efforts by government agencies, riverbed sedimentation and associated waterlogging in Southwest coastal Bangladesh has continued to rise. A comprehensive data measurement campaign in the Hari-Ghengrail-Sibsa river system has shown instances of tidal asymmetry, characterized by flood tide dominance (i.e., shorter flood tide and longer ebb tide durations, along with longer highwater slack), leads sediments to deposit onto riverbeds during spring tides. This is most critical in the reach from Khornea to Bhabadah, where sediment concentration is at maximum. While both sediment movement and concentration are much higher in monsoon season, sedimentation risk appears to be greater in the dry season, reflected in less sediment during ebb tide compared to that during flood tide, owing to less sediment resuspension and sediment movement downstream during ebb tide. Lack of upstream flow in monsoon at Bhabadah and low flow in the entire river system during the dry season exacerbates sedimentation risks. The findings imply that instead of confining interventions to specific sedimentation risk zones (e.g. dredging of riverbed from Bhabdah to Khornea carried out by the Bangladesh Water Development Board (BWDB)), systems-wide thinking is necessary for effective and sustainable solutions. Interventions (e.g. dredging, tidal river management, etc.) need to consider the processes in the entire river system, and a major focus ought to be on augmenting freshwater flow during dry season as well as in monsoon at the upper reaches.

Introduction

In the Ganges-Brahmaputra-Meghna (GBM) delta, the largest on Earth and one of the most dynamic tide-dominated deltas, sedimentation risks in rivers and associated waterlogging within polders is a major water security issue, affecting 1.3 million people from severe waterlogging since early 1990s. Reduction of tidal prism and restriction on tidal floodplain sedimentation during flood tide by polder embankments, and exacerbation of the situation by decreases in upstream flow, are generally understood as the dominant reasons for silt deposition in riverbeds.

Despite several efforts by the Bangladesh Water Development Board (BWDB), in the form of Tidal River Management (TRM) at specific locations and dredging of rivers in critical areas, the extent of waterlogging has continued to rise over the years due to a lack of understanding of the sedimentation processes. Bhabadah area, spreading over 487 sq.km. and 200 villages, is perennially considered a symbol of suffering. The gap in knowledge about the processes surrounding sedimentation risks in rivers has long been considered a barrier to successful interventions, which has also been duly acknowledged in the Bangladesh Delta Plan 2100. The knowledge gap is principally the result of the lack of adequate and systematically measured hydro- and morpho-dynamic data along the coastal rivers.

In this REACH project, we characterize the hydrodynamic processes and sediment transport dynamics, to understand their relationship, and provide implications for policy interventions.

We implemented an extensive hydrologic and morpho-dynamic measurement (i.e., water level, velocity, discharge, and sediment concentration) campaign along a 70 km reach on the Hari-Ghengrail-Sibsa river system from Bhabadah in the north to Garkhali in the south, at different spatial (at 10 locations within) and temporal (seasonal, spring-neap and diurnal) scales **(Figure 1)**.

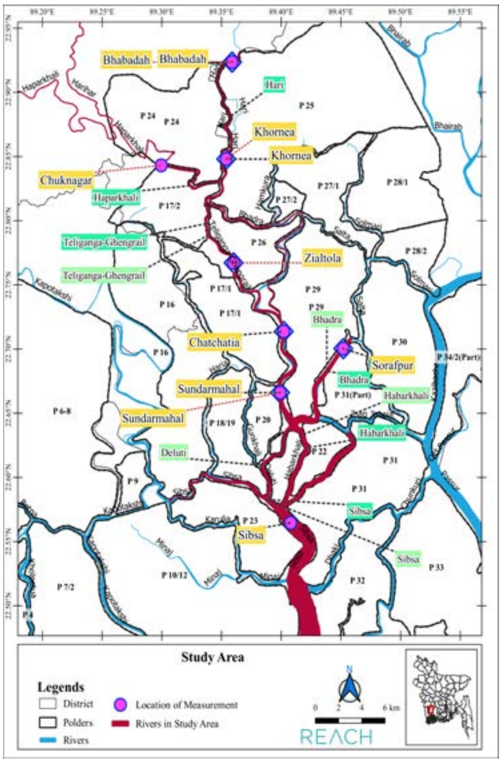

Figure 1: Map of the study area

Finding one

Tidal asymmetry is a significant contributor to increased sedimentation.

Tidal asymmetry (the ratio between the flood tide period and the ebb tide period) is a major phenomenon in the Hari-Ghengrail-Sibsa river system, with much higher ebb tide period insinuating flood tide dominance. This phenomenon persists during both spring and neap tides and in all seasons. Tidal asymmetry increases progressively towards upstream, at maximum mostly during spring tides. The maximum tidal asymmetry is found at Bhabadah, with flood and ebb tide durations being 3.5 hours and 9 hours, respectively **(Figure 2).**

In coherence to this observation, the High-Water Slack (HWS) (duration with almost stagnant water as flood tide turns and changes direction to ebb tide) is also found higher than the Low-Water Slack (LWS) (duration with almost stagnant water as ebb tide turns and changes direction to flood tide) in all cases, which again indicates flood tide dominance throughout the estuary.

This indicates that water enters the Hari River in a short period of time and remains in the river for a longer time before flowing back downstream. This gives more opportunities for sediment in the water column to deposit onto riverbeds.

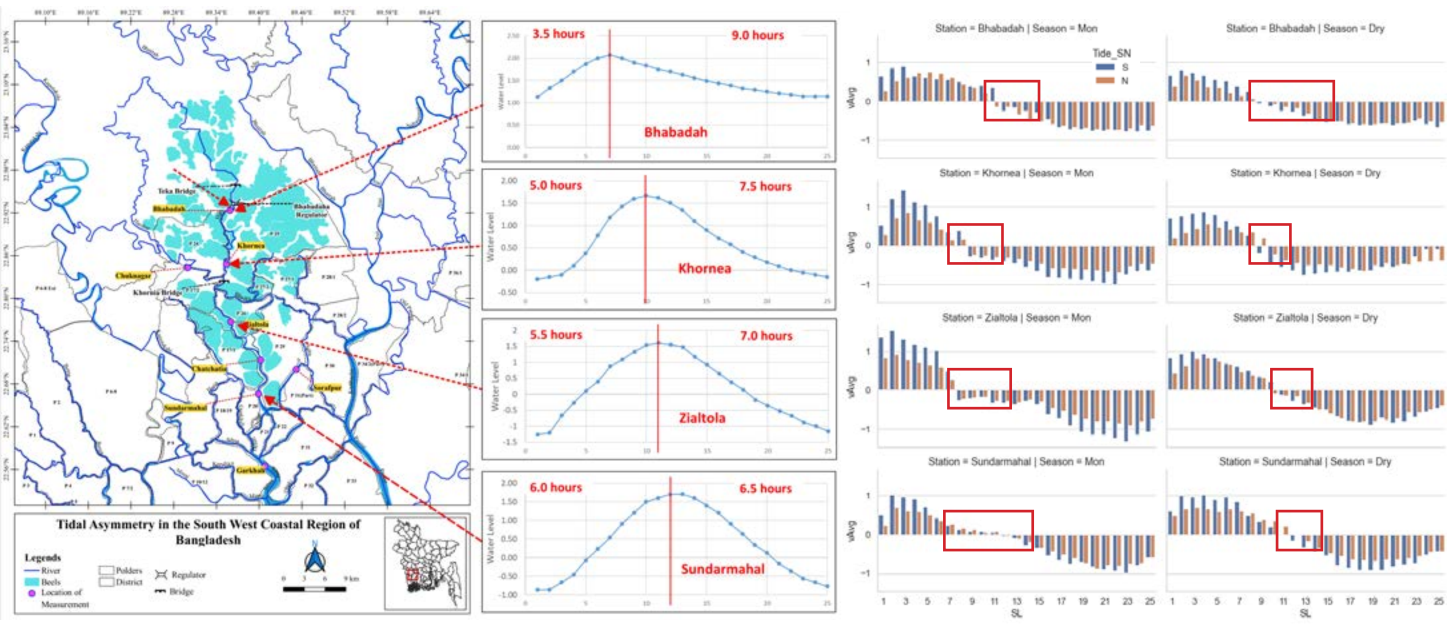

Figure 2: Formation of tidal asymmetry along the Passur estuary

Finding two

Spatiotemporal variation of sediment dynamics impacts critical sedimentation zones

Spatial variation. Suspended sediment concentration increases from downstream to upstream, with the rate of rise being maximum from Zialtola to Khornea, and the maximum sediment concentration being attained not at Bhabadah but at Khornea, a little downstream of Bhabadah, then decreasing again from Khornea to Bhabadah, in all seasons, irrespective of spring and neap or flood and ebb tides **(Figure 3).**

Seasonal variation. While the difference in concentration between the post-monsoon and dry seasons is minimum, the difference between the monsoon and the dry season concentration is very high. While sediment concentration is maximum at Khornea, the fluctuation between monsoon and dry seasons is highest at Bhabadah, with monsoon sediment concentration about 3.5 times higher than dry season sediment concentration **(Figure 3).**

Spring-neap variation. During neap, sediment concentration and variation is very low, indicating less sedimentation risk during neap tide during all seasons. But sediment concentration during spring tide is substantially higher than that during neap tide, gradually becoming comparatively higher from downstream to upstream, the ratio becoming maximum at Khornea and then decreasing again towards Bhabadah (spring concentration at Bhabadah is 24 times more than neap concentration).

Flood-ebb variation. Flood-ebb fluctuation is one dominant factor in the dynamics of estuarine sediment movement, indicating the residual sediment patterns. The difference between flood and ebb is more prominent during the dry season than during the monsoon, implying increased sedimentation risk during the dry season **(Figure 4).**

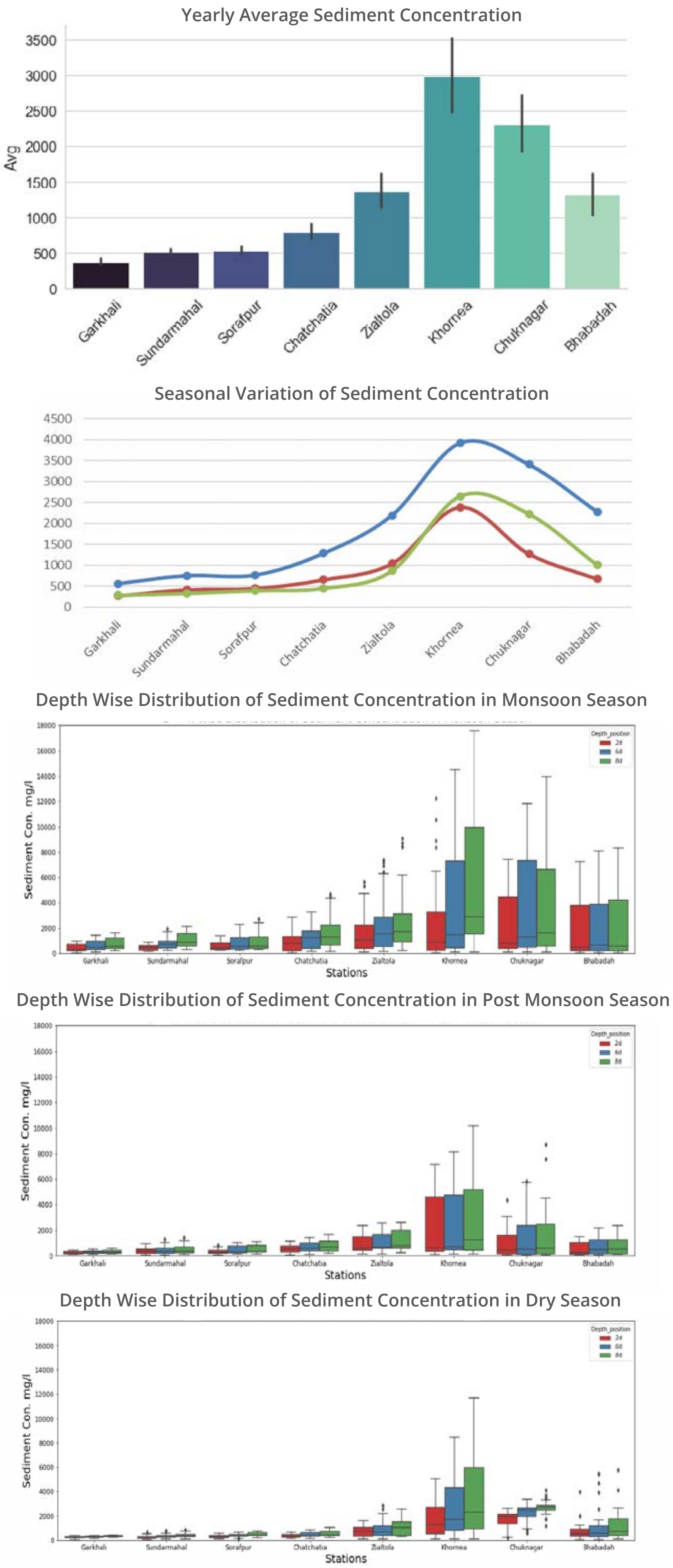

Figure 3: Spatiotemporal variation of sediment concentration

This is prominent in the reach from Khornea to Bhabadah, with the ratio of average sediment concentration during flood and ebb tides being 2.5 at Khornea and 2.6 at Bhabadah during the dry season. This is further evidenced by high sediment concentration during the start of flood tide at Khornea and Bhabadah (~4000 mg/l at Bhabadah during dry season), which drops dramatically while transiting from Flood to Ebb (~350 mg/l at Bhabadah during dry season), with a higher HWS, before gradually rising again (~1370 mg/l at Bhabadah).

This implies an alarming condition between Khornea and Bhabadah, especially during the dry season, when large amounts of sediment enters in a short period of time, while less amounts of sediment leaves, depositing a large amount of sediment in the process onto the riverbed **(Figure 4)**. During the monsoon ebb tide, a higher sediment concentration near Khornea station suggests that deposited sediment during the slack water period is resuspended and carried to downstream **(Figure 5)**. Contrarily, during the dry season's ebb tide, lower concentrations imply that less sediment is moved downstream, resulting in increased deposition between Khornea and Bhabadah stations.

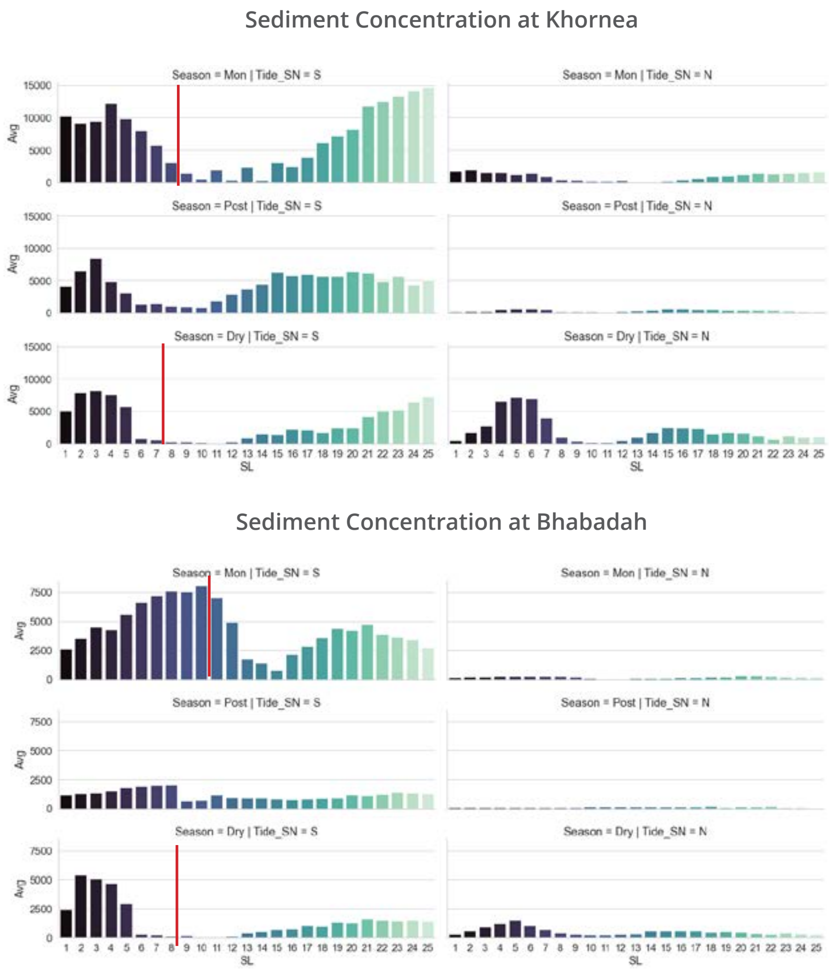

Figure 4: Seasonal and Spring Neap variation of sediment concentration

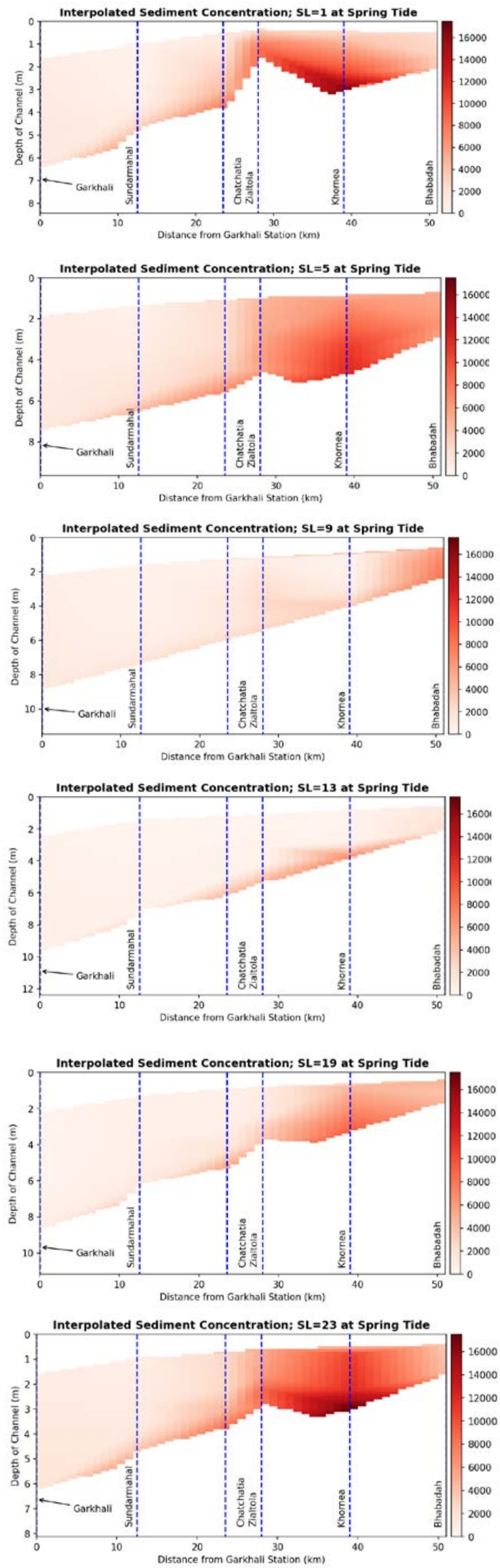

Figure 5: Maximum sediment concentration zone during monsoon over a spring tidal cycle

Finding three

Lack of upstream flow at Bhabadah even in monsoon exacerbates sedimentation risks

While net positive discharges (flood discharge-ebb discharge) are found during monsoon throughout the reach from the catchment (tributaries and drainage from within the polders) indicating possibilities for flushing of sediments, albeit at various capacities, almost no upstream flow is available during monsoon at Bhabadah location because of non-functioning river-floodplain connectivity due to channel siltation. Lower dry season flow from upstream provides even lesser opportunities for flushing of sediments.

Finding four

The reach from Bhabadah to Khornea is the most critical sedimentation zone

More sediment is transported during monsoon than in the dry season; however, riverbed sedimentation is not only confined in Bhabadah but more or less uniformly distributed in the reach from Bhabadah to Zialtala. During the dry season, sediment transported upstream along the estuary is comparatively much less; however, sedimentation takes place between Bhabadah and Khornea in the amount almost three times that in monsoon **(Table 1).**

Table 1: Riverbed sedimentation along the Hari-Gengrail-Sibsa river system

Season	Sundarmahal to Chatchatia (m)	Chatchatia to Zialtola (m)	Zialtola to Khornea (m)	Khornea to Bhabadah (m)
Dry	0.37	-0.83	-0.39	1.46
Monsoon	-0.38	-0.05	0.61	0.55
Total	**-0.01**	**-0.87**	**0.23**	**2.00**

Policy implications

The findings presented above have direct implications for the interventions practiced or planned to solve riverbed sedimentation risks and associated waterlogging problems in the polders.

1. Instead of confining interventions to specific sedimentation risk zones, systems-wide thinking is necessary for effective and sustainable solutions.
2. Excavation of the river from Khornea to Bhabadah, carried out by BWDB on a regular basis, has not been sustainable because of the unique hydro- and morpho-dynamic characteristics, defined by high sediment concentration, tidal asymmetry, and high flood-ebb tide variation. Sediment trapped in the pool area of excavated bed cannot be flushed due to inadequate upstream flow and bed shear force.
3. Interventions need to be considered with a view to reducing critical sedimentation zones and distributing the sedimentation over a wider reach, thus minimizing the sedimentation problem for the whole system. Examples may include augmenting freshwater flow during dry season and restoring upstream river-river and river-floodplain connectivity to ensure adequate flow in the monsoon in the river system; or dredging the whole river system instead of focusing on only the critical sedimentation zones.

Acknowledgements

Mohammad Saif Uddin is a PhD Fellow at the Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET). His research contributes to the REACH 'Coastal Water Security' Observatory, in Khulna district, which aims to understand the links between coastal water security and poverty, and ultimately identify sequences of interventions for improving water security for the coastal poor.

This document is an output from the REACH Programme funded by UK Aid from the UK Foreign, Commonwealth and Development Office (FCDO) for the benefit of developing countries (Programme Code 201880). However, the views expressed and information contained in it are not necessarily those of or endorsed by FCDO, which can accept no responsibility for such views or information or for any reliance placed on them.

www.reachwater.org.uk