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Closure of offtakes in Bangladesh: use of numerical models to overcome data scarcity for the initial assessment of remedial measures

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Introduction

Variable flows and fast morphological changes characterize the river system of Bangladesh, which includes the downstream reaches and delta of the Ganges and Brahmaputra rivers, two of the largest rivers in the world. In contrast, fresh water supply around the country largely depends on much smaller distributaries that take off from those large rivers.

With the arrival of the dry season and the drop of water levels in the rivers, some of the distributaries become disconnected during several months from their parent rivers because of aggradation at the offtake during the monsoon season.

Analysing the evolution of such offtakes from a morphodynamic perspective is fundamental for the definition of effective measures to prevent their closure. However, bed elevation data required to perform such analyses are rarely available, and bathymetric surveys of large rivers are costly and quickly outdated by fast morphological changes.

Physics-based numerical models provide a way to fill the gap of unavailable data, while also allowing to explore river morphodynamics beyond the setting of existing rivers.

Problem analysis

Four major offtakes in Bangladesh are considered in this study, each one with its own characteristics. From literature review, we determined which parameters are relevant in the closure of these offtakes.

It seems that sediment transport during the monsoon season has a dominant role in changing the morphology of the fluvial system, affecting the connection of the parent rivers with their distributaries (Delft Hydraulics and DHI, 1996). Another cause for offtake closure is the amount of flow in the parent rivers during the dry season, which in the Ganges River is reduced by operation of the Farakka Barrage in India (Mirza, 2006; CEGIS, 2012). The configuration of an offtake in relation with its parent river seems to play an important role in the closure of these four offtakes. This depends on the location along an inner or outer bend, the bifurcation angle (see Fig. 1) and the presence of bars near the offtake.

Because of the need of fresh water, remedial measures are being considered in order to anticipate these morphologic changes. The present approach to offtake maintenance lacks a global understanding of the processes that govern the evolution of these bifurcations. We focus on one of the major offtakes in Bangladesh: the connection between the Ganges and Gorai rivers.

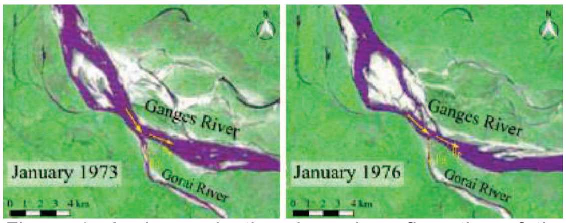

Figure 1. A change in the channel configuration of the Ganges River increased the bifurcation angle of the Gorai offtake, which closed during the winter of 1976.

Method

To overcome lack of data, we use a morphodynamic numerical model based only on the most significant characteristics of the offtake system.

We analysed the relevant physical processes for the evolution of offtakes before setting up the numerical model, concluding that processes such as helical flow, gravity pull or retarded scour need to be taken into account. The choice is for a 2-D depth-averaged model using the software Delft3D. We used a schematised geometry roughly based on the Ganges and Gorai rivers and offtake, starting with a flat bed of constant slope.

We compared the order of magnitude of model results with observations of the river system for hydrodynamic and sediment transport processes; and with satellite images for the morphological evolution of bars and channels. We then analysed the simulated offtake behaviour and used this as reference scenario for the assessment of different engineering measures.

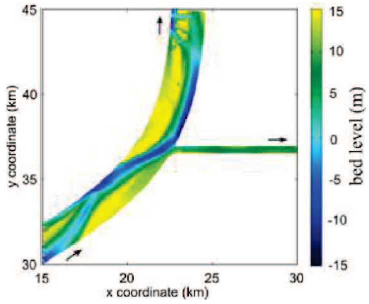

Figure 2. Bed levels simulated with the numerical model and used as reference scenario for the assessment of remedial measures.

Results

After the spin-up of the model, the resulting bed topography generated by the morphodynamic module presents a number of bars which migrate downstream in the parent river as well as the formation of a meandering planform at the distributary channel (Fig. 2). Fig. 3 shows the effects of a measure implemented in the model, displaying erosion and accretion after two years of simulation without any intervention, when the closure of the offtake takes place (top), and with dredging of the dry-season channel in the distributary river (bottom). This shows that dredging at the distributary river improves the flow conditions during two years.

Discussion

Comparison of model with real river system

The model is able to reproduce the behaviour of the Gorai offtake in agreement with flow velocity measurements and discharge distributions between Ganges and Gorai available from CEGIS (2012). Bar dimensions and yearly migration rates agree with observations from satellite images.

Offtake closure process

Discontinuation of flow in the distributary river is observed after 4 years of simulation (with variable discharge). This discontinuation occurs because: (1) the bar upstream of the offtake reaches the bifurcation point and increases the sediment load into the distributary; and (2) the bed level of the bend crossings at the distributary river increase during peak flows whereas retarded scour after the monsoon is insufficient to erode the bed to the previous elevation. These processes were identified as potential causes of the closure of different offtakes in Bangladesh.

Remedial measures

Different remedial measures are schematically introduced in the model, including dredging of the distributary channel, erodible weirs, dredging at the parent river, construction of a flow divider and longitudinal training walls. The only measure that seems effective is dredging of the distributary river.

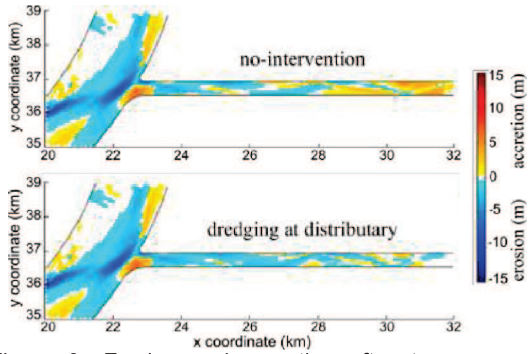

Figure 3. Erosion and accretion after two years of simulation without any intervention (top) and after dredging at the distributary river (bottom).

Conclusions

It is possible to reproduce some of the most relevant processes for the evolution of a distributary offtake using a physics-based numerical model set up with the basic characteristics of the real river system in Bangladesh. The results obtained from this model are accurate enough to analyse the general behaviour of the offtake and to assess the effectiveness of remedial measures.

Dredging of the distributary channel is effective for at least one season, and it can also influence positively the following year.

Dynamics of the rivers discourage the implementation of hard structures because they cannot adapt to changing conditions. Other remedial measures, such as submerged weirs or improved alignments of parent rivers with dredging, revealed less effectiveness and required relocation of huge amounts of sediment. This is surely more expensive and more difficult to implement than recurrent dredging.

Development of relatively cheap tools is of major importance if data are scarce. Such tools can help understand the river system and are useful for the comparison of effects of engineering interventions.

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