Review of IWM study of river bank erosion management in Polder 29, Khulna, Bangladesh

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Deltares

Title
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Euroconsult Mott MacDonald	1221278-000	1221278-000-ZWS-0009	4

Keywords
River bank erosion, bank protection, hydrodynamic modelling, river morphology, groynes

Summary
Polder 29 in Khulna, Bangladesh, has been experiencing bank erosion problems for a long time. The embankment was retired several times due to severe erosion along the right bank of the Lower Bhadra river near Chandgar and Baroaria. The Institute of Water Modelling carried out a study to improve the river bank erosion management at this polder (IWM, 2015). Blue Gold engaged Deltares to review this report and to formulate advice on low-cost interventions for bank protection.

The IWM (2015) report provides good insight in the conditions on the rivers at Polder 29, based on field measurements and 2D depth-averaged hydrodynamic modelling. The numerical modelling does not provide precise information on the near-bank flow conditions after implementation of the permeable groynes, because the morphological changes induced by the groynes are not taken into account.

The IWM (2015) report does not present any economic underpinning of the proposed bank protection works. It also does not present any in-depth comparison of alternative solutions, or any in-depth structural design. It is therefore recommended to set up the project from a wider perspective that includes economic underpinning and structural design issues in a more thorough manner.

A Building-with-Nature type of low-cost intervention could be considered in the wide river area at Chandgar. It might be possible to dredge the dying bend of this area and to dump the dredged material in the channel along the actively eroding bank. A feasibility study for this solution is recommended.

References
Contract for support by Deltares to IWM for erosion control of Polder 29 of the Blue Gold program, November 2015, signed by Euroconsult Mott MacDonald on 7 December 2015 and Deltares on 10 December 2015.

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Contents

1 Introduction

Blue Gold is a collaboration programme between the Government of the Netherlands and the Government of Bangladesh. Its overall objective is to reduce poverty for 150,000 households living in 160,000 ha of selected coastal polders in Khulna, Satkhira and Patuakhali by creating a healthy living environment and a sustainable socio-economic development.

One of these coastal polders, Polder 29, has been experiencing bank erosion problems for a long time. The embankment was retired several times due to severe erosion along the right bank of the Lower Bhadra river near Chandgar and Baroaria. Blue Gold engaged the Institute of Water Modelling for a study to (i) identify the underlying causes of erosion; (ii) find the extent of erosion in order to control the erosion by providing mitigation and protective measures; and (iii) develop a comprehensive, ecologically sustainable and innovative adaptive approach for the planning, design and implementation of the erosion protection work on the proposed site. The outputs of the study were specified to be:

- Flow conditions in the peripheral rivers of Polder 29;
- Erosion and deposition pattern based on model results and data analysis;
- Area vulnerable to erosion;
- Critical location for erosion;
- Most appropriate approach for erosion protection;
- Comprehensive design parameters on the basis of the developed, updated, calibrated, validated and simulated model results;
- Detailed design of river bank protection work and allied works;
- Cost estimate of protective work;
- Recommendation on the monitoring and maintenance needs on the basis of response analysis.

The Institute of Water Modelling reported the results of its study in a draft report dated 10 November 2015 (IWM, 2015).

Blue Gold engaged Deltares to review the report by IWM (2015), to evaluate the data, to review selected experiences in Bangladesh with alternative measures of bank protection, and to formulate advice on low-cost interventions for bank protection. The findings are reported in the present document.

2 Points of review

2.1 Formulation of the assignment

The current management of river bank erosion along Polder 29 is based on the principles of “adaptive delta management” and “living with water”. Wherever bank erosion threatens the embankments, the embankments are retired to a new location. The evolution of river planforms in the 25 years between 1984 and 2010, presented in Figure 2.1 of the present document, demonstrates that the river banks are mostly relatively stable. The planimetric changes due to bank erosion are small compared to the planimetric changes of the major rivers Brahmaputra-Jamuna, Ganges and Padma. The current adaptive approach thus seems feasible. The objective of the study, however, is to develop an approach for erosion protective work, irrespective of the costs involved. This leads to proposing bank protection over a length of in total 3 km. The capital investment for this protection can be estimated roughly to be in the order of a million euro, entailing subsequent maintenance costs in the order of 100,000 euro per year. The report does not present any economic underpinning for this solution. The costs have been compared neither with the annual damage due to erosion nor with the costs of retiring the embankments. Such a comparison is recommended for a good evaluation of different alternative solutions.

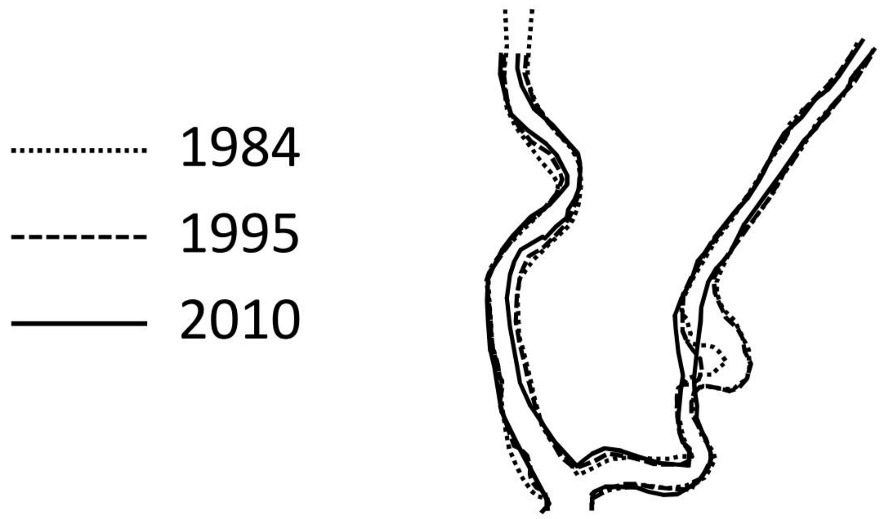

Figure 2.1. General river planform development around southern part of Polder 29 in period 1984-2010 (source: Landsat images at http://world.time.com/timelapse/).

Section 1.4 includes the following products in a list of study outputs: detailed design of river bank protection works; validated model results, cost estimate of protective work; and recommendation of the monitoring and maintenance needs on the basis of response analysis. None of these products are presented in the report.

2.2 Data collection and data analysis

IWM (2015) analyzed river planform evolution on satellite images from 2000 to 2015. In order to extend the period of observation, Figure 2.1 of the present document presents the river planform evolution on satellite images from 1984 to 2010. The river banks are mostly found to be relatively stable, with the exception of the bank at Chandgar. Here prominent bank erosion occurs in relation to the straightening of a river bend. Figure 2.2 of the present document shows this development along with an interpretation of the associated main bank erosion. Extrapolation of this development suggests that substantial bank erosion may proceed to Jaliakhali and even the bank East of Baroaria. Figure 5.8 shows, however, that no protection is planned along that vulnerable bank.

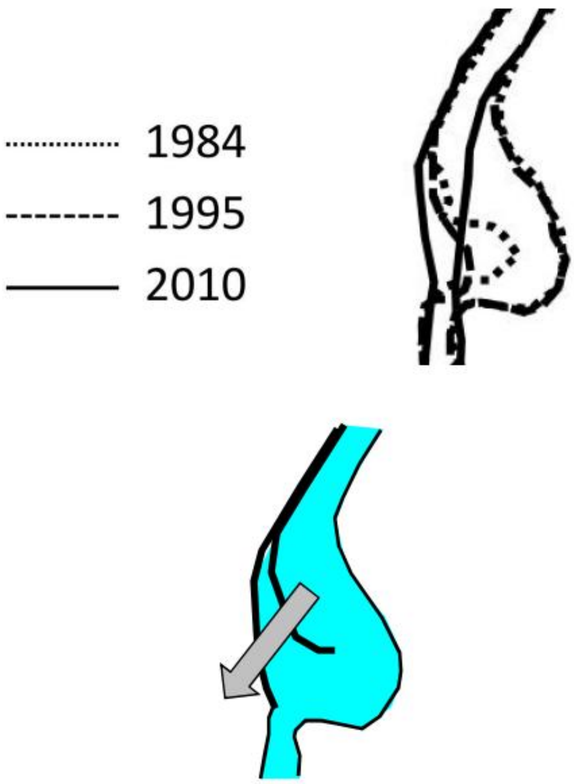

Figure 2.2. Local river planform development (top) and corresponding interpretation of main bank erosion (bottom) at Chandgar in period 1984-2010 (source: Landsat images at http://world.time.com/timelapse/).

Section 5.2.2 states on page 34 that available satellite images of 2000, 2009 and 2015 were analyzed. However, Section 3.3.1 mentions on page 22 the purchase of satellite images of 2011 and 2015. Why was the 2011 image excluded from the analysis?

Figure 5.4 shows banklines, but its caption suggests it shows a cross-sectional profile.

Page 38 concludes from an image analysis that the river shifted towards East. This must be towards West.

According to page 42, the locations of deep scour holes are among the criteria for selecting areas that are vulnerable to erosion. However, the report does not show any information on these locations.

2.3 Numerical modelling

The first equation of Section 4.1 represents conservation of mass. Hence S is not an energy source-dissipation term but a source term for mass supply or withdrawal.

Flow velocities have overbars in the equations of Section 4.1, but these overbars are not explained. The overbar is missing in the second term of the second equation.

The minus sign at the end of the second equation suggests that the equation is not complete. The pressure, p_a, is not explained in the text. On the other hand, τ_{sy}, τ_{by} and T_{ij} are explained in the text but do not appear in the equations.

The fourth paragraph of Section 4.1 refers to Equations 13 and 14. However, the equations in the report do not have numbers.

The fourth paragraph of Section 4.1 refers to processes in the near-shore coastal zone. This is not appropriate for the present study on river bank erosion. Similarly, one would expect a bankline instead of a coastline in the first paragraph of Section 4.2.

Section 4.3 has the title “Calibration and validation”. However, the section presents only a calibration, no verification or validation.

According to Section 6.4, the model results lead to the conclusion that groynes making an angle of 40º to the bankline are the most suitable for bank protection. It is not clear, however, how these groynes have been represented on the computational grid of Figure 4.1. Deviations between groyne alignments and grid lines produce numerical artefacts that do not have any physical meaning.

It would be useful to reflect on the information that can be derived from the numerical modelling. The modelling provides good insight in the present conditions, but it does not provide precise information on the near-bank flow conditions after implementation of the permeable groynes, because it does not take into account the morphological changes induced by the groynes. A morphological computation might be proposed, but that would not solve this as it would reproduce neither the local scour around the piles nor the resulting attraction of the thalweg towards the bank upstream and downstream of the protection (Mosselman & Sloff, 2002).

2.4 Selection of measures

The selection of measures has not considered the full range of possible options. Considerations of costs are missing too. Table 2.1 might be helpful in this respect.

Table 2.1. Costs of structures built on Brahmaputra-Jamuna river between 1994 and 2000 (courtesy Dr Knut Oberhagemann, Northwest Hydraulic Consultants, published previously by Mosselman, 2006).

Location	Structure	Total cost (million US$)	Protected length (km)	Cost per protected length (million US$/km)
Banghabandhu Bridge	two guide bunds with revetment	288.2	6.4	45.0
Sirajganj	revetment	73.5	2.5	29.3
Sariakandi	groynes	52.1	4.5	11.5
Bahadurabad	revetment	8.1	0.8	10.1
Bhuapur	revetment	6.8	1.55	4.3
Ghutail	revetment	3.2	0.55	5.8
Kamarjani	permeable groynes	11.8	1.7	6.9
Kazipur	groynes	5.1	3.0	1.7
Shovgacha	groynes	1.9	1.4	1.3

Experiences with bank protection and river training in Bangladesh in the past 20 years have shown that revetment structures with geobags are among the most effective and cost-effective solutions. Based on these experiences, groynes, whether permeable or impermeable, are no longer recommended. River bank protection using geobags is one of the most innovative recent developments in Bangladesh, owing much to their promoter Dr Knut Oberhagemann of Northwest Hydraulic Consultants. However, the report does not consider geobags.

The report explains the functioning of bottom vanes from helical flow, diversion of slower-moving bottom water towards the bank, sediment pick-up from the suction side of vanes and sediment deposition at the pressure side. In reality, the diversion of slower-moving water hardly plays a role. The other mechanisms do play a role, but do not represent the full picture. A field test of bottom vanes in the Elanjani river (Tangail) by BUET and Delft University of Technology (Hossain & Mosselman, 2006) has shown that overall flow deflection and increased turbulence are important mechanisms too. Figure 2.3 of the present document shows the bottom vanes of the field test under construction. This successful application in Bangladesh is worth mentioning in addition to the failed application in the Meghna Estuary on page 44. Nonetheless, the experiences from the Elanjani river confirm the IWM (2015) assessment that bottom vanes are not suitable for the rivers around Polder 29. Their applicability is limited to relatively small rivers or river channels with a well-defined geometry that experiences only slow changes in time.

Figure 2.3. Bottom vanes under construction in the Elanjani river (Tangail).

For bandalling, page 45 refers to recent experiences on the Ganges in India. However, well-documented experiences are available from pilot tests on the Brahmaputra-Jamuna river in Bangladesh too (Jamuna Test Works Consultants, 2001a). Figure 2.4 of the present document shows the high-water bandals that were tested in this framework at Katlamari. Similarly, page 46 refers to experiences with permeable groynes in Europe and North America, whereas one of the most extensive and well-documented field tests has been carried out on the Brahmaputra-Jamuna river in Bangladesh (Jamuna Test Works Consultants, 2001a). Figures 2.5 and 2.6 of the present document show the corresponding permeable groyne test structures at Kamarjani. It is recommended to review and use the lessons learnt in these Bangladeshi field tests when selecting and designing bank protection along the rivers at Polder 29.

Page 46 proposes the absence of dead water zones as an advantage of permeable groynes. However, the areas between impermeable groynes do not present dead water zones either. The flow in these areas circulates in eddies and is refreshed by turbulent mixing in the vortex street that arises at the interface with the main flow.

Figure 2.4. High-water bandal test structure in the Brahmaputra-Jamuna river at Katlamari.

Figure 2.5. Permeable groyne test structure in the Brahmaputra-Jamuna river at Kamarjani in the dry season.

Figure 2.6. Permeable groyne test structure in the Brahmaputra-Jamuna river at Kamarjani in the wet season.

2.5 Design considerations

Figure 5.8 shows that no protection is planned along the bank at Jaliakhali. Extrapolation of the interpretation of bankline development in Figure 2.2 of the present document suggests, however, that substantial erosion may be expected there in the near future. This erosion might proceed even further up to the bank East of Baroaria.

The upstream and downstream terminations of river bank protections require special care, as they tend to become exposed by continued bank erosion. As a result, they are attacked from behind, upstream because the presence of the bank protection attracts the thalweg towards the bank, and downstream because flow separation may generate an eddy with returning flow. Moreover, in case of a continuous revetment, flow separation may increase turbulence and thereby produce additional local scour at the downstream termination. The report does not present any information on the design of these upstream and downstream terminations. The oblique groynes at the upstream and downstream ends of the bank protection structures in Figures 6.1 and 6.2 can be expected to increase the vulnerability of the terminations. They promote outflanking, which would enhance the bank erosion around the groynes at the terminations (Die Moran et al, 2013).

Page 46 states that the permeable groynes can be constructed with wooden piles, without providing any considerations on the required length of the piles. The river near the bank at Chandgar is about 12 m deep. This depth will increase around the piles due to local scour. Additionally, the piles will have to penetrate sufficiently deep into the river bed for structural stability. Another point on page 46 is that the diameter of these long wooden piles is 1 m. This may pose serious challenges to pile driving.

More generally, the report does not provide information on the considerations behind the 50 m groyne length, 50 m groyne spacing and 1 m diameter. No relation is given between the hydraulic loads and the details of the design. It is recommended to use the guidelines and design manual for standardized bank protection structures by Jamuna Test Works Consultants (2001b), albeit with caution because much of its contents has been derived from a single project without thorough testing for other cases. Apparently the guidelines and design manual have been updated later. Dr Knut Oberhagemann of Northwest Hydraulic Consultants might be the best informed person on this.

Page 55 states that groynes making an angle of 40º to the bankline are the most suitable for bank protection. This does not comply with common practices in river training. Apparently this statement is based on the results of hydrodynamic modelling that excludes 3D flow effects, morphological response and local scour. Moreover, Section 2.3 of the present document argues that the representation of these groynes on the computational grid of Figure 4.1 may have produced numerical artefacts without physical meaning.

Page 55 recommends the use of top-blocked permeable groynes as they will provide a deeper navigation channel. This will require special attention to the floating debris that will pile up against these blocked tops during floods, exerting additional loads on the structure.

2.6 Editorial comments

The present review did not include close reading to identify all errors in spelling and grammar. Just a few cases are noted because they would not be found by a spelling checker (e.g. “eco-sounder” must be “echo-sounder” on page 13). Furthermore, some general guidance is given.

Romanization of Bengali names has not been applied consistently. Although there is no official standard for transcription, it is recommended to be consistent at least within the bounds of a single report. The present report by IWM (2015) uses the names “Baro-Aria” (p. 4), “Baraharia” (p. 6) and “Baroaria” (p. 13) for the same village. Similarly it uses “Chandgar” (pp. 4, 6) next to “Chadgar” (pp. 15, 30, 32) and “Cgadgar” (p. 30), “Salta” (p. 6) next to “Shalta” (pp. 7, 11), and “Gengrail” (p. 6) next to “Gangrail” (p. 7) and “Gangreil “ (pp. 18, 19).

It is recommended to observe the rules of science and technology for the notations of physical units. This implies:

- A space is compulsory between number and unit. For instance, “100m” and “250m” must be “100 m” and “250 m” on page 13;
- The symbol for “hectare” is “ha”, not “Ha”, cf. pages 6, 36 and 38;
- A valid unit of distance is km (kilometre), not Km (Kelvin metre), cf. page 15;
- Exponents must be written as a superscript. Hence 2228m3/sec must be 2228 m^3/s on page 29;
- The symbol for second is “s” instead of “sec”. Hence 2228m3/sec must be 2228 m^3/s on page 29;
- A double slash is not allowed. Hence “ha/km/yr” must be “ha/(km.yr)”, “ha/(km yr)” or “$ha^1 km^{-1} yr^{-1}$ ”, cf. pages 36 and 38;

- Section 5.1.1 states that the dry-period tidal prism in the Lower Bhadra is about 50 Mm^3 = 50 cubic megametres = $50 \cdot 10^{18}$ m^3. This might be visualized as the volume of a 50,000 km high tower on a square surface of 1,000 × 1,000 km^2. This is incorrect. Correct ways of writing the intended volume are “50 million m^3 ” or “50 hm^3 ”.

The report contains various literature references, such as SWAIWRMP (2004), O’Brien (1931, 1969), Lily (1989) and Khaleduzzaman (2004), but no list of references. This list needs to be added.

Page 13: “eco-sounder” must be “echo-sounder”.

The term “bathymetric survey” on page 15 suggests that the measurements focused on water depths. Figure 5.3 shows, however, that river bed elevations have been measured with respect to Public Works Datum (PWD). This is indeed the correct input for the model. It is therefore recommended to use the term “bed topography survey” instead of “bathymetric survey”, or to explain how bed topographies have been derived from bathymetries.

Page 16: “Aqoustic” must be “Acoustic”.

Presumably one of the two last columns of Table 3.2 on page 18 must refer to ebb tide instead of flood tide.

Page 18, Section 3.2.4, line 4: “gradation” must be “spatial distribution”.

The report uses the different terms “groyne”, “groin” and “spur” for the same transverse river training structure. For easier readability it is recommended to use one of the three terms only. The spelling “groin” is correct in the United States of America, but not in Europe and Canada. In Europe and Canada, it is “groyne” that refers to a transverse river training structure, whereas “groin” refers to the part of the body where the two legs meet.

Important places such as Chandgar and Baroaria are missing in the study area map of Figure 2.1. They are also not found in the maps in Figures 3.1, 4.1, 5.1 and 5.2. The first time their locations are shown is in Figure 5.3. It is recommended to show them in the beginning of the report.

The purpose of Section 2.4 is not clear. The formula for the effect of salinity on the settling of sediments does not play any role in the remainder of the report.

3 Conclusions and recommendations

3.1 Review of report by IWM (2015)

The report provides good insight in the conditions on the rivers at Polder 29, based on field measurements and 2D depth-averaged hydrodynamic modelling. The numerical modelling does not provide precise information on the near-bank flow conditions after implementation of the permeable groynes, because the morphological changes induced by the groynes are not taken into account.

The report does not present any economic underpinning of the proposed bank protection works. It also does not present any in-depth comparison of alternative solutions, or any in-depth structural design.

It is therefore recommended to set up the project from a wider perspective that includes economic underpinning and structural design issues in a more thorough manner.

3.2 Advice on possibilities for low-cost interventions for bank protection

Flat slopes and accreting environments offer possibilities for Building-with-Nature-type of solutions. Figure 2.2 of the present document suggests that the wide river area at Chandgar might be suitable for this. It might be possible to dredge the dying bend of this area and to dump the dredged material in the channel along the actively eroding bank. A feasibility study for this solution is recommended.

4 References

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