

SEDIMENTATION OF HARI-TEKA RIVER OF THE POLDER SYSTEM IN THE SOUTHWEST REGION OF BANGLADESH

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Abstract

The rivers of the Southwest region in Bangladesh carry a large amount sediment to build up the Bengal delta. The process of sediment deposition and erosion is significant for measuring the rate of sedimentation of a tidal river in delta management. Polder system of the Southwest region isolates the tidal river from the floodplain, which hampers natural sediment management by delta development, and advances waterlogging in the floodplain by creating drainage congestion of the river. The study identifies Hari-Teka River of the Southwest region to measure the rate of sedimentation. It follows the sounding pole method to calculate the depths, and cross-sectional area method to estimate the cross-sections of this river at Chahera and Sholgotia of Dumuria upazila under Khulna district, and Kopalia of Manirampur upazila under Jashore district. This research finds that the rate of sedimentation of Hari-Teka River was $0.43 \text{ m}^3\text{m}^{-2}\text{year}^{-1}$ that was annually 29% regarding the total cross-sectional area. This result has policy implications to remove drainage congestion of the river, and decline waterlogging from the floodplain by facilitating Tidal River Management (TRM) for the sustainable delta management.

Keywords: *sedimentation, Hari-Teka River, Polder, waterlogging, Tidal River Management (TRM), Southwest region.*

Introduction

Bangladesh is a riverine country and belongs to the second largest river system in the world: the confluence of the Ganges (Padma), Brahmaputra (Jamuna), and Meghna Rivers (originating from the world's largest mountain range, the Himalayas) and their tributaries flow through the country passing Nepal, China, and India and fall to the Sea Bay of Bengal, evolving into the Bengal Delta (Hellin *et al.*, 2004). This is both a blessing, as it carries the huge nutrient-born sediment that makes agricultural land fertile for good crops, and a curse, as the monsoonal floods in the floodplains of the delta cause disruption to agricultural production, contamination of drinking water, and the displacement of thousands of people (Adri, 2009). There were devastating floods in the Southwest region of Bengal Delta in 1954, 1955, and 1956, which seriously hampered the agriculture and livelihoods of coastal people. The East Pakistan (former name of Bangladesh) government felt the necessity to establish an agency named the East Pakistan Water and Power Development Authority (EPWAPDA) in 1959 in order to manage rivers, control floods, and increase agricultural production by providing proper irrigation facilities (Kibria, 2011; Mutahara, 2018; Masud and Azad, 2018b). EPWAPDA was recommended by the Krug Mission of United Nations, and is presently known as the Bangladesh Water Development Board (BWDB) (PDO-ICZM, 2002; Gain *et al.*, 2017a).

EPWAPDA took on a highly ambitious project (Gain *et al.* 2017a), inspired by the Dutch experience, named the Coastal Embankment Project (CEP). This was mostly financed by the USAID (Tutu, 2005), and involved building high earthen embankments along the tidal rivers of the southern coastline to protect the agricultural land from the tidal influx of saline water as well as from floods and cyclones (Shampa and Paramanik, 2012; Talchabhadel, 2017; Mutahara, 2018). There were several types of drainage structures; for example, regulators and sluice gates (De Die, 2013) were installed across river and canal sections and along the tidal basin in the CEP for managing tidal rivers in the coastal area. BWDB, the government authority, built a coastal embankment in the 1960s and installed 37 polders in the Jashore-Khulna districts under CEP to protect agriculture and settlements from saline water and floods (Gain *et al.*, 2017a; Mutahara, 2018; Masud *et al.*, 2018a). The polder system was effective in safeguarding agricultural land from brackish water due to tidal effects, protecting the coastal community from floods and cyclones (De Die, 2013; Paul *et al.*, 2013), yielding two to three crops per annum, intensifying crop production, and bringing prosperity and joy to coastal people up until the 1980s (Kibria, 2011). However, it was not fruitful (Masud and Azad, 2018b) in the long run due to lack of consideration of the geo-physical settings and hydro-morphological characters of the Southwest region (Roy *et al.*, 2017). The coastal embankment failed to ensure proper

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management of tidal rivers (Gain *et al.*, 2017a, 2017b). As a result, the tidal rivers of the Southwest region have been silted up and are going to dry one after another due to the consequences of CEP. It created troublesome waterlogging in *Beel Dakatia, Beel Bhaina, Beel Khukshia, Beel Buruli, Beel Madhugram, Beel Kopalia, Beel Bakor, Beel Patra, Beel Baruna, Beel Kaderia* and another 20-30 *beels* in the Bhabadaho area (De Die, 2013; Gain *et al.*, 2017a; IWM, 2017). Coastal people were exposed to great danger; they had no experience of waterlogging before the 1980s. Mainly, they had experienced floods in pre-polders, where the flood water returned to the sea within one or two weeks. However, in waterlogging, flood water was still stagnant not only in agricultural land

but also in the settlement area for six to eight months up to the pre-monsoon season (Masud and Azad, 2018b). Waterlogging was very destructive; it damaged agriculture, destroyed settlements, degraded the environment, and caused ill health, unemployment, and permanent migration for coastal people.

CEP has been hampering the tidal river-floodplain ecosystem by dismissing sediment management (see Figure 1.2), stopping delta development by adding polders to the floodplain, regulators across the tidal river, and sluice gates for connecting canals with the river since the 1960s, and causing waterlogging from the mid-1980s to the present day.

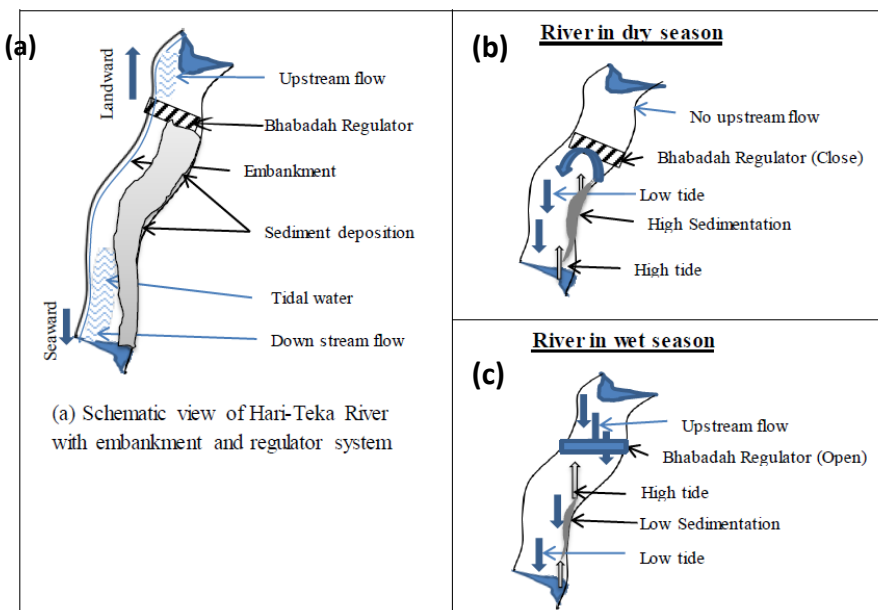


Fig. 1. (a) Aggravation of sedimentation process of tidal river due to CEP, (b) High sedimentation in dry season and (c) Low sedimentation in wet season

Fig. 1 shows that (a) the river was delinked from upstream to downstream by the regulator which reduced upstream flow and increased siltation on river beds, and the embankment restricted over bank flow during monsoon that damaged the sediment balance between tidal river and floodplain; (b) there is no upstream flow during dry season which improves the rate of sedimentation; (c) upstream flow is available during wet season which declines the rate of sedimentation. It is important to ascertain the process of sedimentation and erosion (Deijl *et al.*

2017) for measuring the sediment deposition rate of a tidal river in delta management.

A tidal river has lost its turbulent energy and so suspends sediment in slack tide; this supports deposition for creating a delta (Wright and Schoellhamer, 2005). There are many methods in contemporary literature, e.g. the Bathymetric Survey Method (Takekawa *et al.* 2010), Sediment Coring Method (Jonathan *et al.*, 2001), Sediment Trap Method (Darke and Megonigal, 2003; Deijl *et al.*, 2017), Cross-Sectional Area Method (Masud *et al.*, 2018d) and Sedimentation

Pin Method (Woo *et al.* 2007; Takekawa *et al.* 2010) for observing the sedimentation rate of both the tidal river and tidal basin. This research followed the cross-sectional area method to measure the sedimentation rate of the Hari-Teka River. Therefore, this research fixes two objectives mentioned as below:

- i. To measure the cross-section of the Hari-Teka River and
- ii. To estimate the rate of sedimentation.

Methodology

Sediment deposition is the settled down of suspended sediment or particles (sand, silt, clay, organic and inorganic materials) to the river bed. This settling often occurs when water flow slows down or stops. The high rate of sediment deposition is an environmental concern for tidal river-floodplain ecosystem.

(i) *Cross-sectional area method for estimating the rate of sediment deposition*

In this research, the rate of sediment deposition was estimated by measuring cross-sectional area. The cross-sectional area is calculated by the following formula (Subramanya, 1988):

$$A = \Delta A_1 + \Delta A_2 + \dots + \Delta A_n \quad (1.1)$$

The cross-sectional area of the river (see Figure 4.2) is segmented into 10 to 15 segments (depend on its width).

Area of the first segment and the last segment for the cross-sectional area of a River has made triangular forms and these are measured by the following equations:

$$\Delta A_1 = \bar{W}_1 y_1$$

$$\text{Average width of } (W_1 \text{ and } W_2), \bar{W}_1 = \frac{(W_1 + \frac{W_2}{2})^2}{2W_1}$$

Here, ΔA_1 , y_1 , W_1 are stand for area, depth and width respectively for the first segment and W_2 stands for the width of the second segment.

$$\Delta A_n = \bar{W}_{n-1} y_{n-1}$$

Average width of (W_n and W_{n-1}),

$$\bar{W}_{n-1} = \frac{(W_n + \frac{W_{n-1}}{2})^2}{2W_n}$$

Here, y_{n-1} , W_{n-1} are stand for depth and width respectively of (n-1)th segment and ΔA_n , W_n stand for area and width of nth segment.

Area of the rest segments (from ΔA_2 to ΔA_{n-1}) are measured by the following equations:

$$\Delta A_i = \bar{W}_i y_i$$

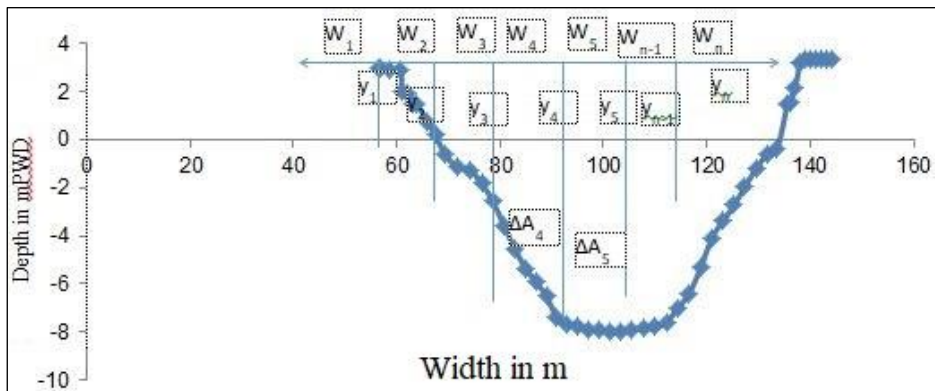


Fig. 2. The cross-section of a river

Note: 'P.W.D' means Public Works Datum

A_{f1} , A_{f2} and A_{fn} as well as A_{l1} , A_{l2} and A_{ln} are the cross-sectional area for n places of a river for the first time and last time respectively of a time period in m^2

L = the assumption length is 1 m for the distance between two places within the river channel in m,

D_t = Total no. of days are required for sediment deposition,

Y_t = Total no. of years are required for sediment deposition.

A rope connected two marking points on the shore (one was placed in the left bank and another was placed in the right bank) across the channel.

The starting point of the rope on the shore was marked as a reference point. The width of the river was divided into several segments by the rope and tags. Then the depth (value for Y axis) was measured by sounding pole for every width of the known distance (value for X axis). A boat was used to conduct the depth measurements. After that, the cross-sectional area was calculated by the values of both axes.

The depths of the river were measured using the sounding pole method during low tide. In basic terms, the water depth was reduced by 1.5m to 2.5m during neap tide of the tidal river. Therefore, it was easy to measure the accurate depths during low tide. First, the lower part (under the surface water) was estimated; after that, the upper part was measured by sounding pole, and then the depths were calculated by integrating the results of both parts.

Selection of the study area

Southwest coastal Delta of Bangladesh is located near the Bay of Bengal where the Ganges-

Brahmaputra Rivers originated from Himalaya Mountain flow into Bangladesh (Kibria, 2011). Its tributaries (Modhumati River, Vairab River, Rupsha River, Pashur River, Kobadak River, Sholmari River, Bhadra River, Hamkura River, Hari River, Gengrile River, Hari-Teka River, Mukteshawri River, Teligati River, Betna River, Moricchap River) that carry a huge siltation (Uttaran, 2013) are flowed over this region and mingled with the sea (Masud *et al.*, 2018a). Anthropogenic and structural initiatives for instance, Farraka barrage since 1975 includes reduced freshwater flow during dry season due to the upstream withdrawal of water (Shampa and Paramanik, 2012; De Die, 2013; GED, 2015; Gain *et al.*, 2017a; Roy *et al.*, 2017). Besides, the coastal polders have prevented silt from the rivers from being deposited on floodplains, causing high rates of sedimentation on the river bed and resulting huge drainage congestion (De Die, 2013; Gain *et al.*, 2017a; 2017b). Therefore, this coastal region has been undergoing water problems and adopting several methods for water resources management since the last quarter of 20th century (Masud *et al.*, 2018a; 2018d).

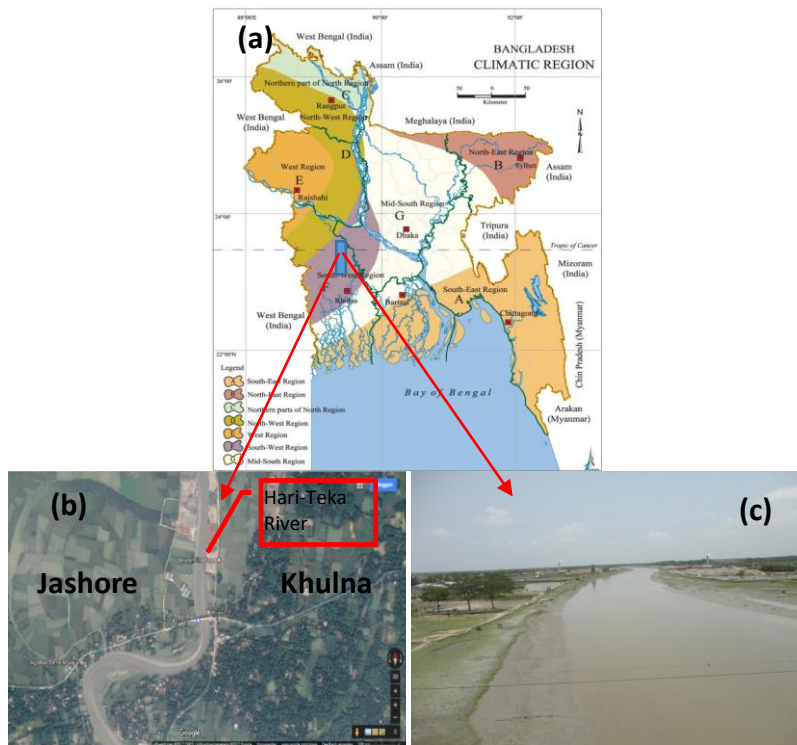


Fig. 3. (a) section F is the Southwest region of Bangladesh (b) Hari-Teka River (Source: Google) of the South west region (c) Hari-Teka River flows to the upstream at Sholgotia bridge, Dumuria, Khulna

The study selected Hari-Teka River (see Fig. 3) which is important for Bhabadah area to drain out excess water during monsoon from 52 *beels* (EGIS, 1998) of the Jashore and Khulna districts. This river is connected with the lower Bhadra River and Teligati River at downstream, and Mukteshawri River and Bhairab River at upstream. Bhabadah area has been facing waterlogging problems since the 1980s. There three TRMs (Tidal River Management) i.e. *Beel Bhaina*-TRM, *Beel Kaderia*-TRM and *Beel East Khukshia*-TRM have been implemented through Hari-Teka River in the first age of the 21th century to solve waterlogging problems of the Bhabadah area (Mutahara, 2018; Masud *et al.*, 2018d).

Therefore, this research selected three locations i.e. Chahera and Sholgotia of Dumuria upazila under Khulna district and Kopalia of

Manirampur upazila under Jashore district (from downstream to upstream) of the Hari-Teka River to measure the cross-sectional areas in April, August and December of 2018 and estimate the rate of sedimentation without TRM intervention under polder.

Results and Discussion

(i) Measurement of the depths of tidal river

The study measured depths (see Fig. 4) regarding the distance from East bank of Hari-Teka River at Chahera, Sholgotia and Kopalia in different months of 2018 by sounding pole method. Land elevation of the bank shore for every location was 3 m. Firstly, we measured the depth in m then it converted into m PWD.

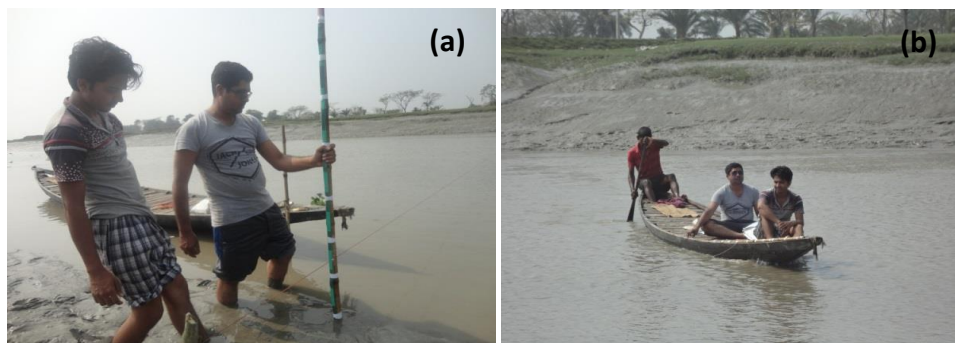


Fig. 4. (a) Measuring the depth of Hari-Teka River at Chahera of Dumuria upazila under Khulna district (b) the boat was used for measuring cross-section of Hari-Teka River.

Table 1. The depths of Hari-Teka River at Chahera in 2018

April' 2018		August' 2018		December' 2018	
Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)
0	3.06	0	2.96	0	3.11
1	2.67	1	2.72	1	3.08
4	2.53	4	2.62	4	2.87
6.3	2.37	7	2.4	7	2.65
9.3	2.13	10	2.12	10	2.47
13.8	1.62	13	1.79	13	2.34
16.8	1.27	16	1.41	16	2.13
18.3	0.59	19	0.75	19	1.77
21.3	0.36	22	0.47	22	1.56
24.3	0.02	25	0.24	25	1.39

April' 2018		August' 2018		December' 2018	
Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)
27.3	-0.22	28	0.04	28	0.84
30.3	-0.43	31	-0.17	31	0.26
33.3	-0.54	34	-0.26	34	-0.07
36.3	-0.59	37	-0.33	37	-0.49
39.3	-0.89	40	-0.51	40	-0.57
43.3	-1.08	43	-0.61	43	-0.72
45.8	-0.81	46	-0.29	46	-0.65
48.8	0.12	49	0.89	49	-0.11
51.8	1.53	52	1.73	52	1.37
54.8	2.32	55	2.44	55	2.99
56.3	3.1	56.2	2.99	56	3.19

Source: Field survey, 2018

Table 1 presents the width of Hari-Teka River was 56.3 m, 56.2 m and 56 m and the maximum depth was -1.08 m PWD at 43.3 m distance, -0.61 m PWD at 43 m distance and -0.72 m PWD at 43 m distance from East bank of the river respectively on 21 April, 14 August and 27 December in 2018 at Chahera.

Table 2. The depths of Hari-Teka River by distance from West bank at Sholgotia

April' 2018		August' 2018		December' 2018	
Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)
0	3.06	0	3.01	0	2.76
1	2.25	1	2.37	2	2.55
4	1.75	4	1.91	5	0.66
7	0.77	7	1.02	8	-0.44
10	-0.23	10	-0.02	11	-0.51
13	-0.86	13	-0.56	14	-0.9
16	-1.52	16	-1.05	17	-1.4
19	-2.51	19	-1.97	20	-1.64
22	-2.12	22	-1.63	23	-1.03
25	-1.83	25	-1.19	26	-0.55
28	-1.34	28	-0.96	29	0.6
31	-0.75	31	-0.34	32	1.39
34	-0.21	34	0.51	35	2.13
37	0.68	37	1.47	38	2.42
40	1.27	40	2.16	41	2.44
43	2.15	43	2.61	44	2.89
46	2.37	46	2.67	46	2.83
49	2.29	49	2.55	48	2.78
52	2.45	52	2.57	50	2.8
53	2.99	52.9	2.95	52.5	2.84

Source: Field survey, 2018

Table 2 presents the width of Hari-Teka River was 53 m, 52.9 m and 52.5 m and the maximum depth was -2.51 m PWD at 19 m distance, -1.97 m PWD at 19 m distance and -1.64 m PWD at 20 m distance from West bank of the river respectively on 21 April, 14 August and 27 December in 2018 at Sholgotia.

Table 3. The depths of Hari-Teka River regarding distance from South bank at Kopalía

April' 2018		August' 2018		December' 2018	
Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)	Distance from bank (m)	Depth (m PWD)
0	3.26	0	3.19	0	2.86
1.1	2.71	1.2	2.96	0.5	2.78
2.6	2.36	4.2	2.29	3.5	2.49
5.6	1.89	7.2	1.76	6.5	2.57
8.6	1.17	10.2	0.86	9.5	2.54
11.6	0.55	13.2	0.9	12.5	1.93
14.6	0.18	16.2	0.26	15.5	1.01
17.6	-0.79	19.2	-0.82	18.5	-0.01
19.1	-1.32	22.2	-0.89	21.5	-0.73
20.6	-1.42	25.2	-0.95	24.5	-0.85
22.1	-1.48	28.2	-0.77	27.5	-0.51
25.1	-1.57	31.2	-0.44	30.5	0.74
27.5	-1.34	34.2	0.58	33.5	1.25
28.3	-1.17	37.2	1.64	36.5	1.94
31.3	-0.79	38.7	2.38	39.5	3.05
34.3	0.36	39.2	2.87		
35.8	0.82	40	3.12		
37.3	1.39				
38.8	2.52				
40.3	3.11				

Source: Field survey, 2018

Table 3 exhibits that the width of Hari-Teka River was 40.3 m, 40 m and 39.5 m and the maximum depth was -1.57 m PWD at 25.1 m distance, -0.95 m PWD at 25.2 m distance and -0.85 m PWD at 24.5 m distance from South bank of the river respectively on 22 April, 14 August and 28 December in 2018 at Kopalía.

(ii) Measurement of the cross-sectional area of tidal rivers

The study measured cross-sectional area by the widths and depths for every location following equation (1.1). Cross-sectional area was reduced

with progressing time for Hari-Teka River due to sedimentation. The rate of sedimentation was estimated from the changes in cross-section of a time period following equation (1.2).

Table 4. The cross-sectional area of Hari-Teka River at Chahera on April

X (Distance)	Y (Depth in m PWD)	Width (m)	Depth (m)	Average Width (m)	Area (m ²)
0	3.06	W ₁ =4	y ₁ = 0.53	$\bar{W}_1= 4.02$	$\Delta A_1= 2.1$
4	2.53	W ₂ = 6.8	y ₂ = 1.03	$\bar{W}_2= 6.4$	$\Delta A_2= 6.6$
10.8	2.03	W ₃ = 6	y ₃ = 1.79	$\bar{W}_3= 6$	$\Delta A_3= 10.7$
16.8	1.27	W ₄ = 6	y ₄ = 2.91	$\bar{W}_4= 6.75$	$\Delta A_4= 19.6$
22.8	0.15	W ₅ = 7.5	y ₅ = 3.49	$\bar{W}_5= 6.75$	$\Delta A_5= 23.6$
30.3	-0.43	W ₆ = 6	y ₆ = 3.65	$\bar{W}_6= 6.5$	$\Delta A_6= 23.7$
36.3	-0.59	W ₇ = 7	y ₇ = 4.14	$\bar{W}_7= 5.5$	$\Delta A_7= 22.8$

X (Distance)	Y (Depth in m PWD)	Width (m)	Depth (m)	Average Width (m)	Area (m ²)
43.3	-1.08	W ₈ = 4	y ₈ = 3.45	$\bar{W}_8= 3.5$	$\Delta A_8= 12.1$
47.3	-0.35	W ₉ = 3	y ₉ = 2.35	$\bar{W}_9= 3$	$\Delta A_9= 7.1$
50.3	0.75	W _{n-1} = 3	y _{n-1} = 1.25	$\bar{W}_{n-1}= 3.38$	$\Delta A_{n-1}= 4.2$
53.3	1.85	W _n = 3	y _n = 0		
56.3	3.1				A= 133 m ²

Source: Calculation based on field survey data, 21 April 2018

Table 4 shows that the cross-section of Hari-Teka River was segmented into 11 segments. Then the cross-sectional area was measured following equation (1.1) by the summation of small areas of the segments. The area was 133 m² at Chahera on 21 April 2018. Similarly, the cross-section of Hari-Teka River was measured on 14 August and 27 December in 2018, and it was respectively 115 m² and 108 m² at Chahera.

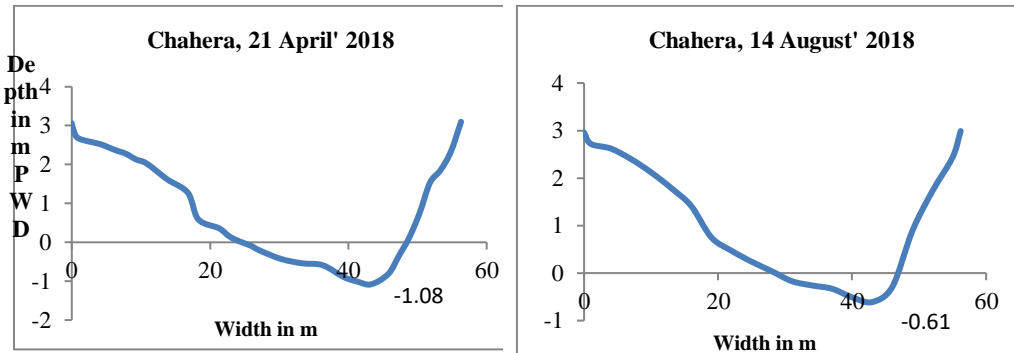


Fig. 5. Cross-sections of Hari-Teka River at Chahera

Fig. 5 presents the width was reduced by 0.1 m and the depth was reduced by 0.47 m from April to August in 2018.

Table 5. The cross-sectional area of Hari-Teka River at Sholgotia on April

X (Distance)	Y (Depth in m PWD)	Width (m)	Depth (m)	Average Width (m)	Area (m ²)
0	3.06	W ₁ = 4	y ₁ = 1.31	$\bar{W}_1= 4.1$	$\Delta A_1= 5.4$
4	1.75	W ₂ = 6	y ₂ = 3.29	$\bar{W}_2= 6$	$\Delta A_2= 19.7$
10	-0.23	W ₃ = 6	y ₃ = 4.58	$\bar{W}_3= 4.5$	$\Delta A_3= 20.6$
16	-1.52	W ₄ = 3	y ₄ = 5.57	$\bar{W}_4= 4.5$	$\Delta A_4= 25.1$
19	-2.51	W ₅ = 6	y ₅ = 4.82	$\bar{W}_5= 6$	$\Delta A_5= 28.9$
25	-1.83	W ₆ = 6	y ₆ = 3.74	$\bar{W}_6= 6$	$\Delta A_6= 22.4$
31	-0.75	W ₇ = 6	y ₇ = 2.31	$\bar{W}_7= 6$	$\Delta A_7= 13.9$
37	0.68	W ₈ = 6	y ₈ = 0.84	$\bar{W}_8= 6$	$\Delta A_8= 5$
43	2.15	W _{n-1} = 6	y _{n-1} = 0.7	w _{n-1} = 8	$\Delta A_{n-1}= 5.6$
49	2.29	W _n = 4	y _n = 0		
53	2.99				A= 147 m ²

Source: Calculation based on field survey data, 21 April 2018

Table 5 provides that the cross-section of Hari-Teka River was segmented into 10 segments at Sholgotia. The area was 147 m² at Sholgotia on 21 April 2018. Similarly, the cross-section of Hari-Teka River was measured on 14 August and 27 December in 2018, and it was respectively 122 m² and 104 m² at Sholgotia.

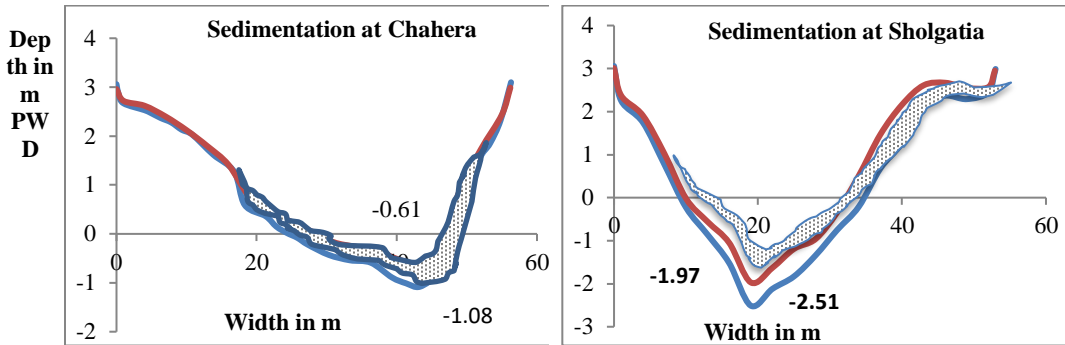


Fig. 6. Sedimentation of Hari-Teka River at Chahera

Fig. 6 demonstrates the sedimentation of Hari-Teka River at Chahera and Sholgotia from April to August in 2018. The cross-sectional area was declined by 18 m² and 25 m² respectively at Chahera and Sholgotia.

Table 6. The cross-sectional area of Hari-Teka River at Kopalia on April

X (Distance)	Y (Depth in m PWD)	Width (m)	Depth (m)	Average Width (m)	Area (m ²)
0	3.26	W ₁ = 4.1	y ₁ = 1.22	$\bar{W}_1= 4.2$	$\Delta A_1= 5.1$
4.1	2.04	W ₂ = 6	y ₂ = 2.72	$\bar{W}_2= 6$	$\Delta A_2= 16.3$
10.1	0.54	W ₃ = 6	y ₃ = 3.41	$\bar{W}_3= 6$	$\Delta A_3= 20.5$
16.1	-0.15	W ₄ = 6	y ₄ = 4.74	$\bar{W}_4= 4.5$	$\Delta A_4= 21.3$
22.1	-1.48	W ₅ = 3	y ₅ = 4.83	$\bar{W}_5= 3.1$	$\Delta A_5= 15$
25.1	-1.57	W ₆ = 3.2	y ₆ = 4.28	$\bar{W}_6= 3.1$	$\Delta A_6= 13.3$
28.3	-1.17	W ₇ = 3	y ₇ = 3.9	$\bar{W}_7= 3$	$\Delta A_7= 11.7$
31.3	-0.79	W ₈ = 3	y ₈ = 2.75	$\bar{W}_8= 3$	$\Delta A_8= 8.25$
34.3	0.36	W _{n-1} = 3	y _{n-1} = 1.72	w _{n-1} = 3.4	$\Delta A_{n-1}= 5.8$
37.3	1.39	W _n = 3	y _n = 0		
40.3	3.11				A= 117 m ²

Source: Calculation based on field survey data, 22 April 2018

Table 6 shows that the cross-section of Hari-Teka River was segmented into 10 segments at Kopalia. Then the cross-sectional area was measured by the summation of small areas of segments. The area was 117 m² at Kopalia on 22 April 2018. Similarly, the cross-section of Hari-Teka River was measured on 14 August and 28 December in 2018, and it was respectively 99 m² and 70 m² at Kopalia.

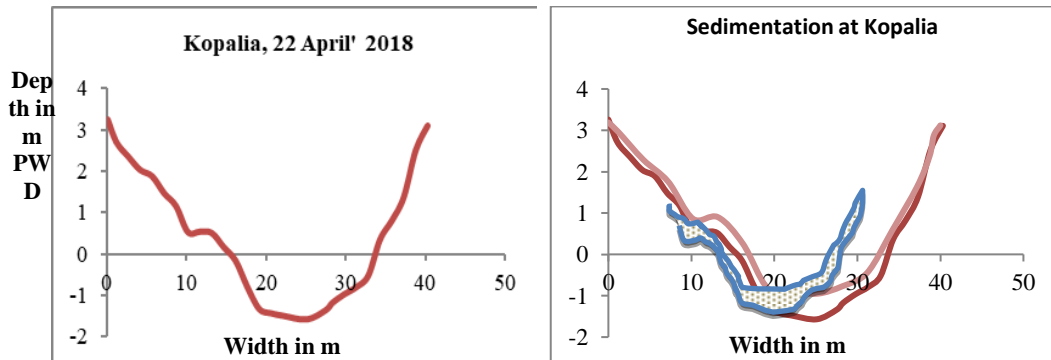


Fig. 7. Sedimentation of Hari-Teka River at Kopalia

Fig. 7 illustrates the sedimentation of Hari-Teka River at Kopalia from April to August in 2018. The cross-sectional area was declined by 18m² at Kopalia. Estimation of the rate of sedimentation

The study calculates the reduction of cross-sectional area due to sediment deposition on the riverbeds for Chahera, Sholgatia and Kopalia of

Hari-Teka River from April to December in 2018. Then it estimates the rate of sedimentation from the mean cross-section of these locations.

Table 7. The rate of sedimentation at different locations of Hari-Teka River

Location	Measurement of Cross-sectional area (m ²)			Reduction of Cross-section (m ²)	No. of days	Rate of Sedimentation (m ³ m ⁻² day ⁻¹)
	April	August	December			
Chahera	133	115	108	25	250	0.00075188
Sholgatia	147	122	104	43	250	0.001170068
Kopalia	117	99	70	47	250	0.001606838

Note: 21 April to 27 December = 250 days

Table 7 illustrates the sedimentation of Hari-Teka River at Chahera, Sholgatia and Kopalia from April to December in 2018. The rate of sedimentation was 0.00075 m³m⁻²day⁻¹, 0.00117 m³m⁻²day⁻¹ and 0.00161 m³m⁻²day⁻¹ for Chahera, Sholgatia and Kopalia respectively.

Therefore, by following equation (2.2) the sedimentation rate of Hari-Teka River was 0.00118 m³m⁻²day⁻¹ or 0.43 m³m⁻²year⁻¹. Besides, the annual sedimentation rate regarding cross-sectional area was 43%. It means that 43% of total cross-sectional area was silted up from Chahera to Kopalia (around 7 km) due to sedimentation of Hari-Teka River. For this reason, it creates drainage congestion which leads to waterlogging in the Bhabadah area.

Conclusion

TRM is considered as an eco-technical and indigenous management practices which allow temporary open the polder (by cutting a small section of the embankment) to connect the tidal river in to the floodplain for sediment management, delta development and removal of waterlogging in the Southwest region (Nowreen et al., 2014; van Staveren et al., 2017; IWM, 2010, 2017; Masud et al., 2018a). In this study, for the first time, we provide a quantitative assessment on sedimentation of Hari-Teka River by applying innovative methods such as cross-sectional area method with involving sounding pole method. After ending *Beel East Khukshia*-TRM in 2012, Bhabadah area went under close polder system again to progress sedimentation of the Hari-Teka River although there were several excavation projects to the upstream (near Bhabadah regulator) in 2017-18 and 2018-19 fiscal years. The renovation works from the government authority (BWDB) do not stop

sedimentation of the Hari-Teka River. This research finds that the maximum depth was reduced from -1.08 m PWD to -0.72 m PWD, -2.51 m PWD to -1.64 m PWD and -1.57 m PWD to -0.85 m PWD, and the cross-sectional area was declined by 25 m², 43 m² and 47 m² at Chahera, Sholgatia and Kopalia respectively. The rate of sedimentation of Hari-Teka River was 0.43 m³m⁻²year⁻¹ and it was advanced from downstream (Chahera) to upstream (Kopalia). The result of annual sedimentation was 29% regarding the total cross-sectional area remarks that the river will be totally silted up (ending tidal flow) from 4 to 5 years if this sedimentation continues without TRM operation. Although the sounding pole method has few limitations regarding placing the pole rightly to measure the depth due to strong current of the river and monitoring the marking points (bamboo sticks) of the cross-section for a long period (for 8 months), it is easy and inexpensive method to provide accurate results for the shallow river. Therefore, TRM is inevitable for sustainable delta management to solve waterlogging and drainage congestion problems in the Southwest region. In this study, we only assess the sedimentation of Hari-Teka River. Further research is needed to assess the benefits of TRM operation.

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