# Chapter 2
# Climate and Hydrography

**Abstract** The Thakuran Basin is an ideal example of a region with a tropical climate with hot, rainy and humid summers and dry winters. The monsoon is normally characterised by the presence of cyclonic storms which bring large-scale littoral drift and coastal modifications. The Thakuran River belongs to a meso-macrotidal regime with semidiurnal tides for its entire 80 km length. Separation of flood and ebb channels in the river basin is controlled by the principle of Coriolis force. Time-velocity asymmetry of the tidal current is appreciable and marked by bedform configurations related to flood and ebb channels.

**Keywords** Tide · Rainfall · Temperature · Salinity · pH · Wind velocity · Semidiurnal tide · Meso-macrotidal regime · Froude number · Reynolds number · Thakuran river · Sunderbans

The climate of the Sunderbans including the Thakuran basin is tropical oceanic. Three seasons viz., winter (November to February), summer (March to June) and monsoon (July to October) are easily recognizable. Winter temperature ranges from 10 to 25 °C and summer temperature from 28 to 36 °C. The annual rainfall ranges between 1470 and 2210 mm. Salinity of coastal water ranges between 22 and 31 ‰, while becoming less in the estuaries. The pH of coastal water ranges from 7.5 to 8.5. The generally mesotidal coast (tidal amplitude 2–4 m) is macrotidal (tidal amplitude >4 m) at the funnel mouths of estuaries and large rivers. The tides are semi-diurnal with slight diurnal inequality (Das 2015). The heavy rainfall during the monsoon influences the tidal interactions in almost all the rivers of the Sunderbans, and flood- and ebb-tidal currents fluctuate with the seasons. The maximum wind velocity is 16.7–50 km/h (April to June) and the minimum wind velocity is 10.7–11.8 km/h (December to February). West Bengal is cyclone prone, with three to four severe cyclones per year. The wind velocity during cyclones often ranges from 80 to 140 km/h. Cyclones also initiate large-scale littoral drift and lead to devastating coastal modifications. Wave heights range from 0 to 0.6 m with a



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wave period of 5–7 s during the calm winter season, whereas, these become 1.8–2.4 m and 12–14 s respectively during the rough summer seasons. Wave height can exceed far above 2.5 m in the event of cyclonic storms.

## 2.1 Wind, Temperature and Rainfall

Three climatic seasons of a year are recognisable in the Hugli-Matla estuaries of the Sunderbans. These are: (i) dry season (pre-monsoon) Feb to May, (ii) rainy season (monsoon) June to September; and (iii) winter season (post monsoon)—October to January. Seasonal variations of wind velocity, wind direction and rainfall during pre-monsoon, monsoon and post-monsoon are quite significant in this tropical area.

The mean wind velocities during the three principal seasons, i.e. pre-monsoon, monsoon and post-monsoon, are 11.5, 11.1 and 6.65 km $h^{-1}$ respectively. The south-southwest to southwest wind direction of pre-monsoon and monsoon changes to north-north east to northeast during the post–monsoon times. The percentage of rainy days sharply rises to 65.79 % during monsoon, from the pre-monsoonal 20.35 %, and again declines to 14.81 % during the post–monsoon times.

Rainfall data measures a mean annual value of 1908.4 mm. This became slightly higher to the tune of 1949.4 mm during the years 1991–1993. The three-year

**Table 2.1** Seasonal variations of water salinity and water temperature in the Thakuran River

| Parameters | Pre-monsoon | Monsoon | Post-monsoon |
|---|---|---|---|
| Water Salinity (‰) | 16.8–28.4 | 8.6–13.6 | 15.1–23.6 |
| Water temperature (°C) | 28.4–31.7 | 28.3–29.9 | 25.3–26.9 |

**Table 2.2** Variations of salinity and pH along the stretch of the Thakuran River

| Location | Salinity (ppt) | pH |
|---|---|---|
| Jata | 15 | 7.81 |
| Bhubaneswari | 16 | 7.77 |
| Saheber Ghat | 17 | 7.73 |
| Nandir Ghat (Maipith) | 21 | 7.81 |
| Harinala khal | 20 | 7.53 |
| P. Sripatinagar | 20 | 7.74 |
| Chilkamari | 21 | 7.63 |
| Hazarbigha | 21 | 7.65 |
| Lakshmi Janardanpur | 21 | 7.15 |
| Upendranagar | 21 | 7.91 |
| Rakhalpur | 22 | 7.85 |
| Sridharnagar | 23 | 7.88 |
| Dhanchi II | 21 | 7.69 |
| Dhanchi III | 20 | 7.66 |
| Dhanchi IV | 23 | 7.23 |
| Dhanchi South | 23 | 7.61 |

average (1991–93) of evaporation data was recorded as 977 mm, and this implies an excess of annual precipitation in the area over annual evaporation.

Table 2.1 presents salinity and temperature variations in the waters of the Thakuran River. Salinity varies from 8.6 to 28.4 ppt from monsoon to pre- and post-monsoon times (Table 2.1). On the contrary, the salinity of open seawater off the mouth of the rivers varies between 23 and 31 ppt. The pH of the river water varies between 7.15 and 7.91 (Table 2.2).

## 2.2 Tropical Cyclones

Tropical cyclones with variable wind speeds (63–87 km $h^{-1}$) are regular phenomena in the Sunderbans area. "Tropical cyclonic depressions" with wind speed <63 km $h^{-1}$ pass over the area during July to September. "Cyclonic storms" with wind speed ranging from 63 to 87 km $h^{-1}$ strike the area during June to September. Most of destructive "severe cyclones" with wind speed >87 km $h^{-1}$ affect the area particularly during May and September. The average occurrences of cyclonic depressions, cyclonic storms and severe cyclonic storms over the study area are twice a year, once every three years and again once every three years, respectively. The 2009 cyclone that crossed Sunderbans on 25th May was the most recent major event until this writing. Its maximum surface wind speed reached 130–148 km $h^{-1}$. This storm caused wide-spread damage in the coastal area of West Bengal and the adjoining country Bangladesh.

## 2.3 Tides

The entire coastline of West Bengal with its highly indented nature is the outcome of differential erosion and accretion caused by fluvio-tidal and tidal processes in an estuarine delta framework. The perpendicular-to-shore orientation and elongated shape of most of coastal islands reflects the impacts of flood- and ebb-tidal currents in a macrotidal coastal environment (Davies 1972). The intertidal landforms also result from high tidal fluctuations with unequal inundations and exposures.

The Thakuran River is tidal for its entire 80 km length and belongs to the meso-macrotidal setting. At the sea face, the mean tide is 5.5 m whereas, in the middle stretch, it declines to 3.5 m. At Sagar Island, the mean maximum spring tidal range varies between 6.5 and 7.5 m and the mean minimum neap between 2.0 and 2.5 m. The highest yearly tides are experienced from August to September, while the lowest occur from February to March.

The tide in the Thakuran River is semi-diurnal with little diurnal inequality (Fig. 2.1). The mean ebb velocity is 58 cm/s, whereas, the mean flood velocity is 48 cm/s. Time velocity asymmetry (Fig. 2.1) controls both bedform configurations and their orientations on the flood and ebb channels. Flood and ebb discharge data,

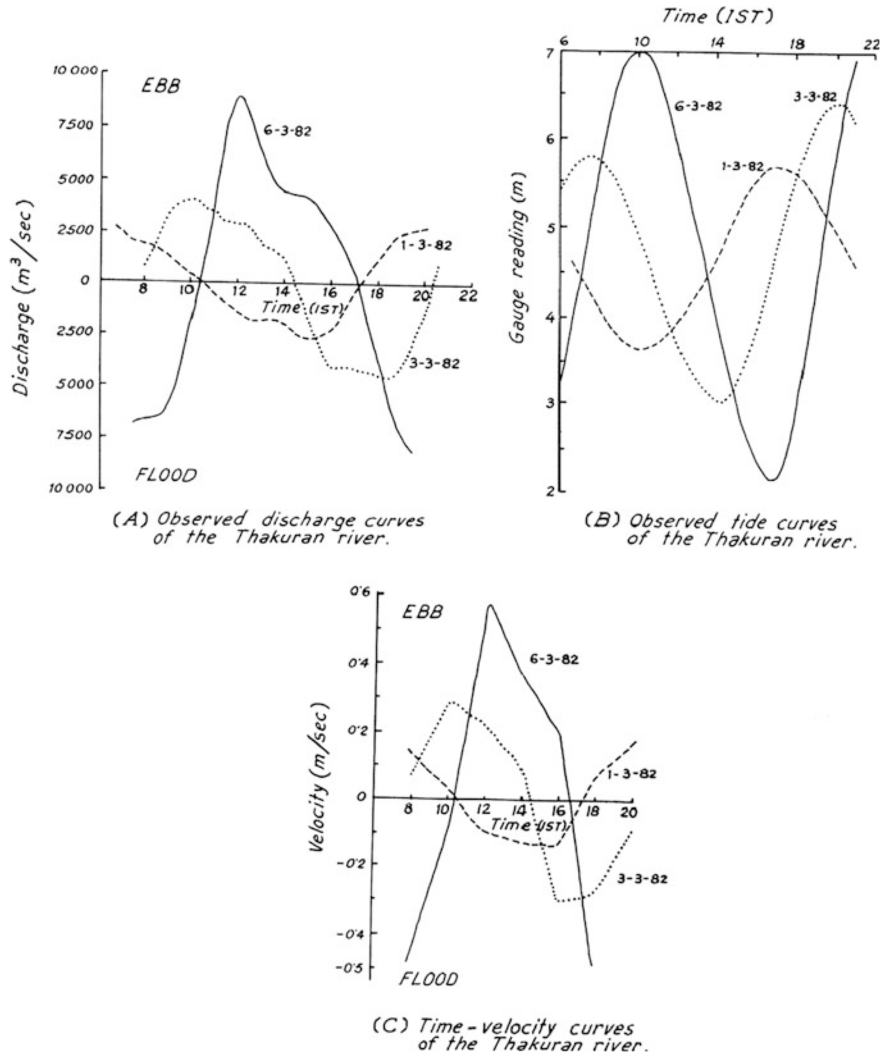
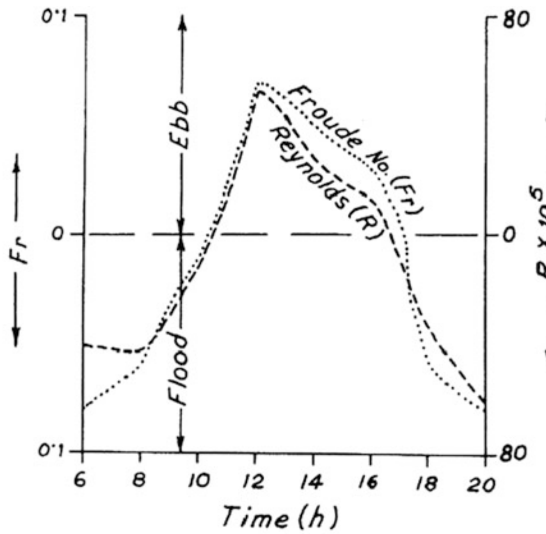



**Fig. 2.1** Tidal charts of the Thakuran River

**Table 2.3** Variations in ebb-flood discharge, flow velocity and water volume in the Thakuran (RRI, W.B.)

| Tide | Discharge (cubic m/s) | | Flow velocity (cm/s) | | Water volume (millions of cubic metres) | |
|---|---|---|---|---|---|---|
| | Ebb Max | Flood Max | Ebb | Flood | Ebb | Flood |
| Neap | 2400 | 2600 | 26 | 26 | 36.2 | 35 |
| Mean | 5150 | 5150 | 58 | 48 | 78.1 | 71 |
| Spring | 8000 | 7700 | 91 | 69 | 120 | 107 |



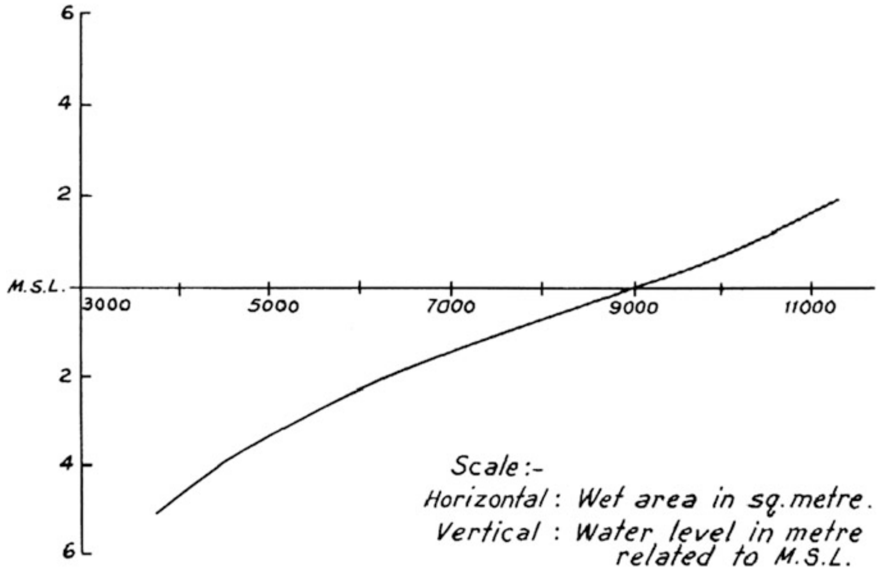




**Fig. 2.2** Relation between water level and wet cross–sectional area of the Thakuran River

variations in ebb and flood velocities, and variations in ebb and flood volumes of the Thakuran River in Sunderbans, as obtained from the River Research Institute, Govt. of West Bengal, are summarized in Table 2.3.

The eastern margin of the riverbed is generally dominated by ebb flows, whereas, flood flows dominate along its right-margin thalweg. The ebb and flood channels of the Hugli River below Diamond Harbour also follow the same pattern

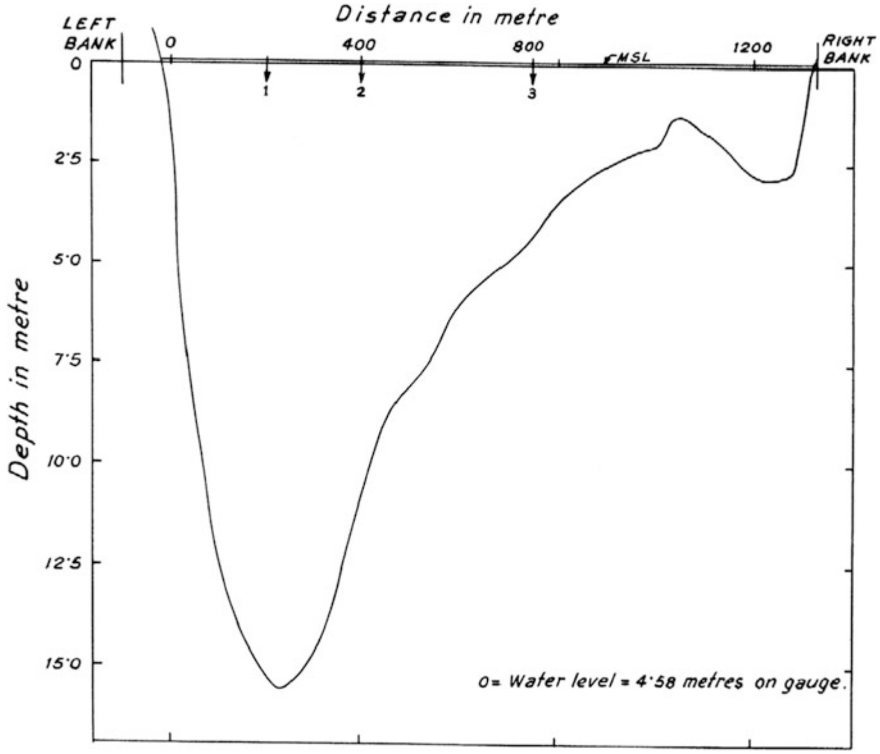



**Fig. 2.3** Cross section of the river 40 km upstream from mouth showing asymmetric nature of bottom topography

(Chakraborty and Sen 1972). This separation of flood and ebb channels in the majority of the rivers of coastal West Bengal is hypothesised to take place according to the principle of Coriolis force (Dyer 1986).

Spring tidal data and the corresponding tidal curves of the Thakuran River near Damkal Dwip (40 km upstream) are available from River Research Institute (RRI), Govt. of West Bengal (Fig. 2.1). The relationship between the water level and wet cross-sectional area at this place of the river is shown in Fig. 2.2. The cross section of the river clearly reveals an asymmetric bottom configuration (Fig. 2.3).

## 2.4 Tidal Flow Regime

The changes in the Froude number (Fr) and Reynolds number (R) corresponding to flood and ebb flows of the Thakuran measured near Damkal Dwip, as a case study, are shown in Fig. 2.2 and Table 2.4. The curves for the Froude number (Fr) and

**Table 2.4** Variations of Reynolds number (R) and Froude number (Fr) at a cross section near Damkal Dwip over time in a tidal cycle

| Time in hours | Reynolds number (R) (X $10^5$) | Froude number (Fr) |
|---|---|---|
| 6 | 43.8 | 0.08 |
| 8 | 45.8 | 0.06 |
| 10 | 11.01 | 0.01 |
| 12 | 56.73 | 0.07 |
| 14 | 27.0 | 0.05 |
| 16 | 13.84 | 0.03 |
| 18 | 33.72 | 0.06 |
| 20 | 67.14 | 0.08 |

Reynolds number (R) exhibit a close similarity in pattern and designate a lower flow regime in which only ripples of different scales are generated. The calculated value of the Reynolds number (R) from the same area (Table 2.4) reveals that the flow, except for a short period, is turbulent almost throughout the tidal cycle. The term unsteady flow implies that the velocity at a point varies with time. Non-uniform current signifies variations of velocity in space, and turbulence means random variation of instantaneous velocity with respect to both time and space about some mean value.

## 2.5 Summary

The Thakuran River bed of Sunderbans offers a unique opportunity for the study of unsteady flow in natural settings. The unsteady flow conditions of the river generally arise from: (i) the fluctuations of depth and velocity within ebb and flood periods; (ii) flow reversals associated with ebb and flood periods; and (iii) variations between neap and spring tidal flow. There may be even longer cycles to control such conditions. Thus, many of the bedforms cannot be explained with the classical flow-regime concept valid for the steady-flow conditions (Simons and Richardson 1962; Harms and Fahenstock 1964).

Bedforms like 'skewed spurs', ripple fan, planed-off crests of megaripples and micro-deltas are some of modification features arising from fluctuating velocities and variable depths within ebb and flood periods. Reversals of flow lead to modifications of bedforms where flood–oriented megaripples exhibit slight rounding of crests accompanied by small asymmetric ebb-oriented aprons (Elliot and Gardiner 1981; Bhattacharya 1993). Decaying megaripples and partly reversed and asymmetrical megaripples reflect modifications due to the contrast between neap and spring levels.

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