CHAPTER–9

MANAGING THE DISTRIBUTARIES

9.1 HUMAN INTERVENTIONS ON THE DISTRIBUTARY COURSES

In 2011, about 9.2 million people resided in the UBGI (CoI, 2011). The region is comprised of 2861 mouza-s and 32 towns, which includes the district headquarters of Baharampur (Murshidabad district) and Krishnanagar (Nadia District). The largest land port of India, Petrapole (near Bangaon in the North 24 Parganas District, bordering Bangladesh), is also located in this region. The population density of this ~7,900 km\(^2\) region has increased from 1060 persons per km\(^2\) in 2001 to 1238 persons per km\(^2\) in 2011 (CoI, 200001, 2011). The average decadal change of population in 35 Community Development (CD) blocks of the study area is 16.1\% between 2001 and 2011 (Table 9.1).

**Table 9.1: Population density and decadal change of population in the CD blocks of the UBGI**

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<tr>
<td>Murshidabad</td>
<td>1</td>
<td>Raghunathganj II</td>
<td>2238.4</td>
<td>3085.3</td>
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<tr>
<td></td>
<td>2</td>
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<td>1522.1</td>
<td>1910.3</td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td>Bhagwangola I</td>
<td>1061.9</td>
<td>1313.0</td>
<td>23.6</td>
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<tr>
<td></td>
<td>4</td>
<td>Bhagwangola II</td>
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<td>980.9</td>
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<td>5</td>
<td>Raninagar I</td>
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<td>1217.6</td>
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</tr>
<tr>
<td></td>
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<td>Raninagar II</td>
<td>730.2</td>
<td>895.7</td>
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<tr>
<td></td>
<td>7</td>
<td>Jalangi</td>
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<tr>
<td></td>
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<td>Domkal</td>
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<tr>
<td></td>
<td>11</td>
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<td>1060.4</td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td>Nowda</td>
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<td>840.8</td>
<td>15.7</td>
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<td></td>
<td>13</td>
<td>Beldanga I</td>
<td>1422.2</td>
<td>1752.5</td>
<td>23.2</td>
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<tr>
<td></td>
<td>14</td>
<td>Beldanga II</td>
<td>964.0</td>
<td>1200.0</td>
<td>24.5</td>
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<tr>
<td>Nadia</td>
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<td>1020.3</td>
<td>10.1</td>
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<td></td>
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<td>941.6</td>
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<td>749.6</td>
<td>841.9</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Tehatta II</td>
<td>737.7</td>
<td>831.8</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
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<td>Kaliganj</td>
<td>857.4</td>
<td>987.2</td>
<td>15.1</td>
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<tr>
<td></td>
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<td>Nakashipara</td>
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<td>Chapra</td>
<td>861.1</td>
<td>982.4</td>
<td>14.1</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Krishnaganj</td>
<td>957.5</td>
<td>1053.1</td>
<td>10.0</td>
</tr>
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</table>
Decadal change of population is very high in a few CD blocks of the Murshidabad District—Raghunathganj-II, Lalgola, Bhagwangola-I and II, Raninagar-I and II, Beldanga-I and II (Table 9.1). Barring the last two, all the other CD blocks are neighboring Bangladesh in the north (separated by the Ganga River). A number of distributaries (Bhagirathi–Hugli, Bhairab) and palaeodistributaries (Gobra Nala, Bhandardaha and Sialmari) traversed through these CD blocks, which have become susceptible to the threats associated with the human interventions. Of late, the human interventions in the UBGI distributaries have been getting serious attention (Khasnabis and Chakraborty, 1989; Mavalankar and Shankar, 2004; Sengupta, 2005; Ghosh and Singh, 2009; WBPCB, 2009; DoIW–GoWB, 2011; DoPHE–GoWB, 2012; Akter, 2015; Basu et al., 2015; Shanmugapriya et al., 2015; Chowdhury, 2016). Besides affecting the degenerated distributaries, activities like paddy farming, brick production, sand quarrying from the river bank and riverbed, release of industrial and household effluents into the river and garbage dumping have aggravated the ongoing decay of the Bhairab–Jalangi, Mathabhanga–Churni and Ichhamati Rivers.

9.1.1 Paddy Farming

Paddy transplanting involves transfer of pre-germinated seedlings from a seedbed to the wet field (IRRI, 1999). It requires less seed and is an effective method for controlling weeds. In the eastern part of India, seedlings are normally transplanted by hand, thus making it a labor-intensive process. In the UBGI, seedlings of Boro rice (sown during winter season) are grown in a bunded area on a relatively drier part of the riverbed (Plate 9.1). These seedlings grow there for about a
month before being transplanted to the field. This process is prevalent due to easy access to the riverbed, especially at the lean season as the water table goes down. The *Boro* cultivation technique not only uses river water, but also causes sedimentation on the riverbed and eventually the lean season flow through the distributary channels gets hampered. It is quite common in the courses of the Bhairab–Jalangi, Mathabhanga–Churni and Ichhamati.

*Plate 9.1:* Bunding on the Bhairab riverbed for seed germination of *Boro* rice. Location: Islampur, Murshidabad District. *Photograph taken on 8 January 2012.*

*Plate 9.2:* Quarrying of sediments from the dry riverbed during lean season. (a) Riverbed of the Bhairab at Islampur in the Murshidabad District. *Photograph taken on 11 January 2011.* (b) Riverbed of the Bhagirathi near its off-take in the Murshidabad District, *Photograph taken on 3 March 2012.*
For the *Boro* cultivation in the UBGI floodplains, the extraction of groundwater using shallow-well pumps is common during the lean season. This significantly lowers the groundwater table, eventually hampering the base flow toward the channels and causing water scarcity.

### 9.1.2 Sand Quarrying

During the dry season, sand quarrying is common from the dry beds of the distributaries (Plate 9.2). It is mainly used for constructional purposes. Not only the riverbed is dug up, the makeshift road used for sand transportation distorts the natural environment. Besides, most of the quarrying activities are carried out illegally.

### 9.1.3 Brick-Field and Kiln

In the Ganga delta, the brick manufacturing units usually open up narrow channels from the rivers to the low-lying fields adjacent to the brick-kilns, where the incoming flow from the river deposits sediments during the monsoon months. During post-monsoon, the deposited materials (composed of silt and clay) are dried-up in the open and go through the other stages of brick manufacturing. Most of these brick-fields and kilns are located very close to the present distributary channels. The diversion of the river flow by brick manufacturing units was mentioned by Hirst (1915) in his account on the Nadia Rivers. The brick-kilns disturb the river bank morphology, eventually making those areas exposed to river bank erosion and flooding.

![Figure 9.1: A series of brick-fields/kilns (identified by numbers) on the left bank of the Jalangi River near Krishnanagar in the Nadia District. Image: WorldView-2 (GE), 20.02.2016.](image)

The brick-fields and kilns are abundant near the lower part of the Jalangi River (Fig. 9.1, Plate 9.3) and the upper part of the Ichhamati River. Verbal interactions with the officials of Department of Irrigation and Waterways of West Bengal (DoIW–GoWB) revealed that any
brick kiln should be located at least 100 m away from the river channel. However, in reality, many of the brick making units of the Murshidabad, Nadia and North 24 Parganas Districts are located very close to the river bank (within 30–50 m). Moreover, some of the brick-kiln owners do not even possess any official permit for brick manufacturing.

Under present circumstances, it is essential to regulate the rapidly increasing unauthorized brick-kilns by implementing a strong policy. In May 2015, the Government of West Bengal passed a memorandum to regularize the brick-fields and kilns which erected on agricultural fields (LLRD–GoWB, 2015). It carried a specific guideline on non-regularization of any brick field/kiln located within 200 m from the river bank—a restriction that might be reviewed under specific circumstances. The memorandum also put forward operational guidelines of the brick-kilns by considering the pollution related aspects and constituted a committee for regularizing the unauthorized brick-fields and kilns. Furthermore, in May 2016, the National Green Tribunal ordered that the brick kilns shall not operate until consent to operate is granted to them by the concerned pollution control board (IEP, 2016).

### 9.1.4 Waste Disposal

Many small and medium-scale industries are present in the cities like Baharampur, Krishnanagar and Ranaghat. Waste materials released from these industries and other sources drain into the distributary channels. The effluents released by the sugar industries of Bangladesh are carried downstream by the flow of the Mathabhanga River (Biswas and Panigrahi, 2014). Disposal of solid waste materials (sourced from households and industries) into the rivers and palaeochannels is a common practice in this region. As a result, all the active rivers and non-active palaeocourses get polluted frequently (Plate 9.4).

9.1.5 Aquatic Vegetation Growth

Water Hyacinth (*Eichhornia crassipes*; known as *Kachuripana* in West Bengal) is the most common aquatic plant that grows in all the palaeocourses and present distributaries of the UBGI except the Bhagirathi–Hugli (Plate 9.5). It is a free–floating perennial hydrophyte native to the tropical and sub-tropical regions (Sullivan and Wood, 2012). Characterized with broad, thick, glossy and ovate leaves, Water Hyacinth may rise above the surface of the water for about 1 m. As one of the fastest growing plants, it is known to double its population in a couple of weeks in the southeastern part of Asia (Matai and Bagchi, 1980). Among the other aquatic plants, Taro (*Colocasia esculenta*; known as *Kachu* in West Bengal) and Nut Grass (*Cyperus rotundus*; known as *Patighas* in West Bengal) are found in the palaeocourses like Sialmari,
Anjana, Jamuna and Padma. These species grow in still or slow-moving water up to 1 m deep. Common Duckweed (*Lemna minor*; known as *Sheola* in Bengali), a free-floating small aquatic plant, is also found in the palaeocourses during the monsoon months.

![Figure 9.2: Water Hyacinth and Common Duckweed blocking the courses of the (A) Jalangi (Location: Karimpur, Nadia District) and (B) Ichhamati (Location: Majhdia, Nadia District). The red/pink color on channels represent the existence of aquatic vegetation. Images: (A) Resourcesat-2 LISS-4 fmx (Path-108, Row-55, Sub-scene A), 19.03.2013; (B) Resourcesat-2 LISS-4 fmx (Path-108, Row-55, Sub-scene D), 19.03.2013.](image)

When not controlled, aquatic vegetation could cover the entire waterbody, hence blocking the flow of water and hampering the aquatic ecosystem. The spread of aquatic vegetation is related with eutrophication (Khan and Mohammad, 2014). Eutrophication is normally induced by the discharge of phosphate-containing detergents or fertilizers used in agricultural lands or sewage into any aquatic system like rivers. Important distributaries like the Jalangi and Ichhamati are choked up at several places by aquatic vegetation growth (Fig. 9.2), which is caused by excess nutrient supply due to increasing anthropogenic activities.
The physical control of aquatic vegetation in the UBGI is performed by machines like aquatic weed harvester. Sometimes, it is done manually. However, these removal methods provide short-term solution to the problem. In recent times, spherical or rectangular aligned fishing nets (attached with wooden faggots) are placed at the channel edges to control the growth of the aquatic plants (Fig. 9.3). However, no specific proposals have come from the government agencies till now to clear off these weeds.

Figure 9.3: Controlling of Water Hyacinth growth by spherically or rectangularly aligned fishing nets in the Jalangi River near Krishnanagar in the Nadia District. Image: WorldView-2 (GE), 17.02.2016.

Plate 9.5: Growth of Water Hyacinth in the distributaries. (a) Sialmari Palaeochannel at Domkal in the Murshidabad District (Viewing upstream). Photograph taken on 11 January 2011. (b) Ichhamati River at Bangaon in the North 24 Parganas District (Viewing downstream). Photograph taken on 31 August 2016 (Courtesy: Kapil Ghosh).

9.2 MANAGEMENT SCHEMES

The UBGI is traversed by numerous distributaries of the Ganga River, most of which are either decayed or expected to get abandoned in the future. The region is susceptible to natural hazards
like river bank erosion, floods and problems related to human interventions such as eutrophication and groundwater contamination (Table 8.3 in Chapter-8). The impacts of these hazards include loss of property and life, displacement from the place of residence, economic stalemate and infrastructural damages. Since this region is densely populated, the adversities related to these problems are bound to increase manifold. In the last 200 years, a number of efforts were made to resuscitate the decaying distributaries, most of which brought little results.

9.2.1 Previous Management Schemes

Prior to the development of advanced railway and road network, the Nadia Rivers were used as primary transportation routes. Therefore, it was necessary to maintain the flow through these rivers as obstacles were plenty due to sedimentation on the riverbed. In the early 19th century, attempts were made by the Public Works Department (PWD) of Bengal Presidency to revive the condition of the distributaries (Hirst, 1915; Reaks, 1919; Stevenson-Moore, 1919). During the British Raj, it was predicted that the revival of the distributaries would be difficult, owing to the incessant geomorphic changes in the Ganga channel at their off-take regions.

9.2.1.1 Bandaling and Dredging

Initially, the ‘bandal’ system (a permeable, oblique weir placed in order to narrow a wide shallow channel which improves by subsequent scouring along the face of the bandals, owing to the rush of water under them) was in use in the Nadia Rivers, which improved the downstream portions of the rivers (Reaks, 1919). The Bandals were also used to prevent the erosion of the cut banks of meanders. During 1823–26, dredging machines were used at the headwaters of the Bhagirathi and Jalangi Rivers, which temporarily opened up these distributaries by clearing off the sediments deposited at their entrances. However, due to shifting of the off-take points, these rivers suffered heavily during the 1830s. In 1828–29, dredging was attempted in the Mathabhanga channel near the bifurcation point of one of its distributaries—Kumar, located ~55 km downstream of the Mathabhanga entrance. But the yielded result was far from satisfactory. It was impossible for the large boats to pass through these channels during the lean season (Reaks, 1919).

The dredging work on the Nadia Rivers was initially stopped in 1835, since the obtained results were not worth the cost (Reaks, 1919). In 1838, the uppermost entrance of the Bhagirathi (also the widest) was improved significantly. Until the dry season of 1841, large boat traffic was permitted through it. After 1842, all the entrances of the Bhagirathi deteriorated significantly. The northern entrance of the Jalangi River was deepened considerably, but bars located downstream were extremely obstructive. After the monsoon of 1853, the large sandbanks of the Ganga completely blocked the flow through the Jalangi entrance, making further revival attempts impossible (Lang, 1854). It was also a very challenging task to keep the Mathabhanga open, as its distributaries in the Jessore region used to take away three-fourths of its spill supply. Major Lang’s report on the Nadia Rivers (1851) revealed the difficulties of maintaining the depth of the distributary channels due to unfavorable conditions at their off-takes. Later on,
between 1902 and 1918, five modern dredgers were employed to improve the navigability of the Ganga, Bhagirathi–Hugli and Bhairab Rivers (Reaks, 1919). In the beginning, dredging attempts were successful at the Bhagirathi entrance. Afterward, alarming decrease of inflow from the Ganga between 1912 and 1917 forced the shelving of the dredging operation. Dredging at the Bhairab Off-take was also necessary, as the Bhairab used to maintain the lower part of the Jalangi River. Dredging took place at the Bhairab Off-take only between 1905 and 1908. Due to the unavailability of large dredgers, high operational cost and high amount of silt discharge into the Hugli, the dredging operations ended during the 1920s.

![Figure 9.4: Flood embankments on the left (eastern) bank of the Bhagirathi River in the Murshidabad District. Source: Atlas of India sheet # 120, surveyed during 1849–55.](image)

9.2.1.2 Embankments

During the early 19th century, a couple of embankments were constructed on the left (eastern) bank of the Bhagirathi River in the Murshidabad District—(i) the Laltakuri embankment, which extended from Keshabpur to Laltakuri, and (ii) a cross embankment from Jiaganj to Bhagwangola. Also, in the east of Keshabpur, another embankment was constructed in order to connect the Laltakuri embankment with the Ganga embankment running along its right (southern) bank from Chintamoni to Akheriganj (Fig. 9.4). These embankments were aimed to prevent the natural spilling of the Ganga and Bhagirathi Rivers (Reaks, 1919). In spite of these constructions, the embankment breaching by spill water occurred at least ten times between 1838 and 1915, causing widespread inundation in the Murshidabad and Nadia Districts. As a result, the Laltakuri bund was abandoned in the early 20th century and the Jiaganj–
Bhagwangola embankment was built. Apart from the main embankments, numerous *zamindari* bunds of about 1 m height used to prevent the spill from disseminating freely (Hirst, 1915). Also, by then, the region had another line of defense against heavy spill in the form of railway embankment, which extended up to Lalglola as a part of the Sealdah–Lalglola railway line. On the left bank of the Mathabhanga River, the Kachikata embankment was built (presently in Bangladesh), which was not as vulnerable as the Bhagirathi embankments (Reaks, 1919).

9.2.2 Present Management Schemes

Barring the FBP, the present management strategies in the UBGI are mostly focused on the river bank protection and construction of flood embankments. While the FBP and associated structures are controlled by the Ministry of Water Resources of India (MoWR–GoI), the other protective works are done by the DoIW–GoWB of West Bengal. In the last few decades, several drainage schemes were undertaken involving the western tributaries of the Bhagirathi–Hugli River. However, no long-term strategies were introduced for reviving the other decaying distributaries of the delta.

9.2.2.1 Schemes Associated with the FBP

The Bhagirathi–Hugli River was the primary outlet of the Ganga until the 16th century (Sherwill, 1858; Fergusson, 1863; Oldham, 1870; Hirst, 1915; Reaks, 1919; Fox, 1938; Bhattacharya, 1941; Bagchi, 1944). The deterioration of the Bhagirathi–Hugli started with the prominence of the Padma channel over it (discussed in Section 3.3.1.1). Among the delta distributaries of the Ganga, the Bhagirathi–Hugli is considered as the most important, as the Kolkata port—once the largest port of India—is nourished by its flow. During the British Raj, it was understood that the construction of a barrage across the Ganga River would be the best technical solution to counter the decay of the Bhagirathi–Hugli (Parua, 2002b). The Hooghly River Commission, set up by the Government of India in 1853-54, reported the gradual deterioration of the Bhagirathi–Hugli, owing to shoaling and contraction of its channel by accumulation of silt (Parua, 2010). The commission also predicted that the deterioration would be progressive.

The entry of discharge through the Bhagirathi Off-take was erratic during the 19th century and early 20th century. Since the mid-20th century, the Bhagirathi remained disconnected from the parent river except for the monsoon months (Parua, 2002b). The water level and discharge at the off-take of the Bhagirathi gradually fell with time, which also affected the vessel movement to and from the Kolkata port (Parua, 2002b, 2010).

The construction of Farakka Barrage commenced in 1961, which was supervised by the FBP authority. The project was commissioned in May 1975. The authority was given the responsibility to operate and maintain the FBP complex comprising of the Farakka Barrage, Jangipur Barrage, a Feeder Canal connecting the Ganga and Bhagirathi–Hugli Rivers, and other associated structures (MoWR-RD-GR–GoI, 2015). The 2.24 km-long Farakka Barrage comprises of 112 gates (108 main gates and 4 fish lock gates) and 11 head regulator gates for
the diversion of maximum 1132 cumecs (40,000 cusecs) discharge into the Feeder Canal (Fig. 9.5, Plates 9.6-9.7). The structure was planned to raise the dry season level of water in its upstream, so that the discharge can be transferred to the Bhagirathi–Hugli through the Feeder Canal (Bandyopadhyay et al., 2014). The designed crest and pond levels of the Farakka Barrage were 14.3 and 21.9 m, respectively (Basu, 1982).

The main objectives of the FBP are:

(i) To divert adequate quantity of the Ganga discharge to the Bhagirathi–Hugli River through the 38 km-long Feeder Canal for preservation and maintenance of the Kolkata Port by improving the regime and navigability. The discharge through the Feeder Canal expected to flush out the sediment accumulation near the Kolkata port, thereby minimizing any need of regular mechanical dredging.

(ii) To increase the discharge through the Bhagirathi–Hugli, which would reduce salinity and ensure sweet water supply to Kolkata and surrounding areas.

(iii) Establishing direct road and rail communication link to the northeastern states of India through the rail-cum-road bridge built over the Farakka Barrage across the Ganga River.

(iv) Formation of a part of the Haldia–Allahabad Inland Waterway (National Waterway No. 1) through the Bhagirathi–Hugli River, Feeder Canal and the navigation lock at Farakka.

(v) Supplying water to the Farakka Super Thermal Power Project of National Thermal Power Corporation (NTPC) Limited.
Plate 9.6: The head regulator gates of the FBP Feeder Canal for diverting the Ganga discharge toward the Bhagirathi–Hugli River. Location: Farakka, Murshidabad District. Photograph taken on 13 April 2017 (Courtesy: Soyl Samad Sekh).

Ever since it started to function, the questions were raised by the researchers like Bhattacharjee (1961), Emery and Aubrey (1989), Khalequzzaman (1989), Rudra (1996, 2002) about the location of the barrage and the ill-effects of erosion, siltation on riverbed, shifting possibility of the main Ganga channel through its ancient paths, restriction of fish movement toward upstream and ecological degradation. However, most of these arguments were not supported by any conclusive factual observation (Bandyopadhyay, 2007b; Bandyopadhyay et al., 2015; Parua, 2002b, 2010).

There is a long-standing dispute between India and Bangladesh regarding the water sharing of the Ganga River in the lean season (1 January to 31 May), which is related to the commissioning of the Farakka Barrage. In order to resolve the water sharing issue, successive bilateral treaties were signed in 1975, 1976, 1977, 1982 and 1985, all of which failed to yield desired results. While Bangladesh repeatedly accused India of depriving the rightful share of the Ganga water (Haq, 2012), India had to remain satisfied with 49% less discharge than its minimum requirement for scouring the deposited silt and for reducing the capacity of the Bhagirathi–Hugli near the Kolkata Port (Parua, 2010).

In 1996, a comprehensive 30-year treaty on sharing of the Ganga water was signed between India and Bangladesh. According to the treaty, the Ganga water would be distributed from Farakka between January 1 and May 31 each year on the basis of an agreed formula, and that
India would make every effort to maintain the flow at Farakka at the average level of previous 40 years (Haq, 2012). At any critical period, Bangladesh would get a guaranteed flow of 992 cumecs (35,000 cusecs). The two countries, in this occasion, also recognized the need for mutual cooperation in the long-term augmentation of the Ganga flow.


9.2.2.2 River Bank Protection

Since 2005, the FBP is entrusted with the additional responsibility of undertaking anti-erosion works in its extended jurisdiction along the Ganga course from 40 km upstream of the barrage to 80 km downstream (MoWR-RD-GR–GoI, 2015). In order to fulfil protective requirements,
structures like marginal bund, afflux bund, inspection road, navigation locks, culverts etc. were built. Beyond the jurisdiction of the FBP, the river bank protection work in the Murshidabad District along the Ganga (Padma) course has been monitored by the DoIW–GoWB, aided by the funds awarded by the 10th and 11th Finance Commissions of India (DoIW–GoWB, 2012). Maximum priority is given to the river bank protection works at Akheriganj and Jalangi in the Murshidabad District, since bank erosion is severe in these areas.

River bank erosion is quite common along the Bhagirathi–Hugli course (Figs 9.6-9.7). The anti-erosion works along its course have been undertaken by DoIW–GoWB at locations like Jiaganj, Beldanga, Palashi, Nakashipara, Nabadwip, Niamatpur and Malopara. Boulder pitching accompanied by rock-filled rolls contained with nylon netting at the lower part of the bank is common along the river course, apart from the stacked sand-filled bags (Plate 9.8).

- **Boulder Pitching:** It is also referred as stone pitching or rip-rap. This technique is used for river bank protection during high discharge events. Presently, stone mattress in wire crated mesh is also used extensively in many places instead of loose pitching due to the chance of boulders being carried away during floods. Size and weight of stone and thickness of mattress are very important in order to resist the erosive forces (Mazumder, 2010). Size and weight, gradation, shape and angularity of the boulders/stones and proper positioning over a layer of graded filter or geo-synthetic textile (woven or non-woven) are essential to prevent the wearing away of bank materials through the pores and joints of the pitching.

- **Rock Roll:** It is an elongated collation of crushed rocks contained with nylon netting at the bank toe to prevent undercutting and fluvial scouring. Rock rolls can tolerate the velocities up to 4 ms⁻¹. The design provides inbuilt flexibility while allowing the plants to develop in stable conditions adding to its durability (EA–GoUK, 2010). However, the application of rock rolls can be limited due to cost of installation and chances of damage of the netting by moving boats. In spite of these drawbacks, this structure provides a flexible solution to the bank undercutting.

- **Sand Bag:** Usage of sand-filled geotextile bags is a cost-effective, environment-friendly and sustainable technique to prevent river bank erosion. These bags are fabricated from engineered materials and capable of retaining fine sands. Initially, in the deltaic set up, the usage of geotextile bags yielded positive results and fared better than the orthodox methods like concrete revetments (Oberhagemann and Hossain, 2010). However, this technique needs systematic monitoring and evaluation before being used regularly.

Earlier, the above-mentioned techniques were employed in the Ganga course without much success. If unable to withstand the stress of excessive current in the upcoming monsoon seasons, these structures might wear down by hydraulic action and intensify the bank erosion in the previously affected areas.

The other distributaries like the Bhairab–Jalangi and Mathabhanga–Churni, especially in their upper parts, are less prone to bank erosion due to low discharge intake from the Ganga. These rivers are more susceptible to erosion near their confluence with the Bhagirathi–Hugli. More
recently, protection works have been undertaken to prevent the bank erosion of the Jalangi River at Ghurni and the Churni River at Rabonbore in the Nadia District (Fig. 9.7). In the Ganga River alone, expenditure for erosion prevention works between 1977-78 and 2010-11 was in tune of 8.32 billion rupees, in which the West Bengal State Government contributed about 52% (DoIW–GoWB, 2011). Still, the river bank protection works of the Ganga within West Bengal, as in many other rivers, did not yield encouraging results. Discontinuance of erosion at a given locality can be ascribed to natural processes rather than the success of these tried bank protection measures (Bandyopadhyay et al., 2014).

Figure 9.6: River bank erosion along the Bhagirathi–Hugli course between 2006 and 2010. Location: Malopara, Nadia District (23.0650°N, 88.4626°E). The extent of erosion is ~400 m where the river bends toward south. The blue arrow shows the flow direction of the river. Images: WorldView-2 (GE), 06.01.2006 and 14.02.2010.
Figure 9.7: The present river bank erosion hotspots and flood embankments in the UBGI. The arrows show flow directions of the active distributaries. Compiled from various sources.
Plate 9.8: River bank protection works along the Bhagirathi–Hugli course. (a) Stacked up sand-filled bags on the left bank at Malipota in the Nadia District. Photograph taken on 3 March 2013. (b) Boulder pitched banks (upper part) along with rock filled rolls (lower part) on the left bank at Niamatpur in the Nadia District. Photograph taken on 28 March 2015.

9.2.2.3 Flood Embankments

As of now, embankment construction is the only structural measure which provides respite to the people of West Bengal from the menace of flood during monsoon season (DoIW–GoWB, 2015a). The UBGI suffers from flooding caused by the high intensity rainfall during the monsoons, inflow of flood discharge from the Ganga at its high spate and drainage congestion at the confluences due to the high stage of the Bhagirathi–Hugli coupled with tidal activity (DoIW–GoWB, 2015b). Since 1954, the construction and maintenance of the embankments
have been done regularly the DoIW–GoWB. Along the course of the Ganga near the off-take of the Bhagirathi River, a number of flood embankments were built since the 1970’s as a part of the FBP (discussed in Section-3.2.3). These embankments are maintained by the FBP authority (Fig. 9.7, Plate 9.9).

Plate 9.9: Flood embankments on the left bank of the Bhagirathi River. (a) Inspection road on the flood embankment maintained by the FBP authority (viewing northwest, toward upstream). Location: Chintamoni, Murshidabad District. (b) Newly built embankment after the 2000 floods, maintained by the DoIW–GoWB (viewing south, toward downstream). Location: Kalukhal, Murshidabad District. Photographs taken on 11 March 2013.

During the 2000 floods, the Bhagirathi received enormous discharge from the Massanjore Dam in Jharkhand (located in the Mayurakshi catchment area), which added to the high stage of the river caused by incessant rainfall in the Upper Bhagirathi catchment region in the Murshidabad District. A large volume of the Bhagirathi discharge breached the embankments at several places on the left (eastern) bank, thereby flooding 46% of the 7,900 km² study area (discussed in Section-7.4.2.3). After this incident, the DoIW–GoWB has remodelled and strengthened the embankments ravaged by the 2000 floods, alongside constructing a number of new marginal embankments on the left bank of the Bhagirathi River (Fig. 9.7, Plate 9.9).
9.3 IMPACT OF THE FBP

9.3.1 Effects on the Bhagirathi–Hugli

The non-tidal upper part and tidal lower part of the Bhagirathi–Hugli are rejuvenated by the FBP (Parua, 2010). The Kolkata Port is partially revived by the augmented flow. Due to the much disputed India–Bangladesh water sharing issue, much lesser than the agreed discharge quantity of 1,132 cumecs (40,000 cusecs) passed through the Feeder Canal until 2009, which was not sufficient enough to restore the navigation to the early 20th century condition (Parua, 2010). The initial positive impacts of the FBP on the Bhagirathi–Hugli course are as under:

(i) Reduction of siltation and scouring of the deposited silt on the riverbed.
(ii) Flow augmentation facilitating the visit of large-draft vessels up to the Kolkata Port, thus saving time and cost on dredging.
(iii) Decreasing frequency and intensity of tidal bores, thereby safeguarding the port.
(iv) Improved water quality due to reduced salinity.
(v) Facilitation of year-round navigation through the river.
(vi) Improvement of riverine environment and ecology.

However, even before 1990, it was realized that the augmented flow was unable to flush out the silt deposition in the lower estuary below Kolkata up to the estuary head at Diamond Harbour (75 km downstream from the Kolkata Port), which settled there due to reduced upland flood-tide velocity. Because of this, the main purpose of the FBP has not been fulfilled. The Kolkata Port is still heavily reliant on its adjunct Haldia Dock Complex, located near the outfall of the Hugli into the Bay of Bengal.

As far as the fluvial activities are concerned, the augmented flow has improved the upper course (Bhagirathi) significantly. The channel width and channel area coverage of the Bhagirathi improved remarkably after the commissioning of the FBP (discussed in Section-4.5.3.1). The shifting of channel course is significant within its meander belt, as evident from the cutoff formations (discussed in Section-6.4.1). Understandably, there are some erosion-prone segments present in the Bhagirathi–Hugli course. The mid-channel bars have been forming in the Bhagirathi–Hugli course. In fact, there is more than two-fold increase in the total area occupied by the mid-channel bars between 1965–67 and 2001–07 (discussed in Section-4.5.3.3). This indicates the inability of the augmented flow to flush out the deposited silt on the riverbed.

The gates of the Farakka Barrage have been operational since 1975. In February 2012, a couple of gates got broken, which caused an unregulated flow of ~1,331 cumecs (47,000 cusecs) into Bangladesh (Parsai, 2012), resulting ~425 cumecs (15,000 cusecs) of additional discharge. This had triggered a reduced flow through the Bhagirathi for about a week. Immediately after that incident, the Union Minister of Water Resources of India stated that all sluice gates of the barrage would be replaced with new ones in the next five years (PTI, 2012). However, the gates
are still not been replaced. In March 2015, one of the gates got broken again, leading to excess flow toward Bangladesh and shortage of flow through the Bhagirathi–Hugli (DT, 2015).

9.3.2 Effects on the Other Distributaries

The Farakka Barrage does not have any reservoir in the upstream. It only regulates the water through the Ganga and the Feeder Canal into the Bhagirathi–Hugli. The off-takes of the two other active distributaries in the study area—the Bhairab and Mathabhanga—are located about 94 and 152 km downstream of the Farakka Barrage, respectively. Both these off-takes are too far away to be directly controlled by the FBP. However, the FBP has decreased the flow through the Ganga during the lean season, which considerably affected these off-takes. Besides, the flow through these entrances has further diminished with time as the main channel of the Ganga shifted toward north (discussed in Sections 3.3.3 and 3.3.6). There is a possibility that the Ganga might shift toward its previous position again, which could open up these entrance points.

The augmented flow through the Bhagirathi–Hugli indirectly affects the confluence regions of the Jalangi and Churni, as these two rivers receive the inflow from the Bhairab and Mathabhanga, respectively. Especially during the monsoon months, the backflow during the high tides in the Bhagirathi–Hugli may cause flooding around these confluence regions.

9.4 VIABILITY OF RESUSCITATION PROJECTS ON OTHER DISTRIBUTARIES

The improvement potential of the UBGI distributaries is not very bright. For resuscitating the degenerating rivers, dredging is often advocated and practiced. However, in most of the cases, it is difficult to sustain a dredged channel in an abandoned delta, unless maintenance dredging is routinely carried out. But it is time consuming and incurs a huge amount of cost. In many areas, the capacity of the channels shrunk considerably due to lateral accretion, decline of discharge or land use changes like extension of agricultural area, fisheries, sand mining, construction-related activities—all of which increase soil loss and sedimentation in the riverbed. For revival of these channels, large-scale excavation is required which would spread over hundreds of kilometers. Moreover, even if the channels are dredged or excavated, there is no assurance of unhindered inflow from the Ganga River, due to its oscillating braids. Possibility of constructing another barrage over Ganga for reviving the distributaries like the Bhairab–Jalangi or Mathabhanga–Churni must be ruled out, as it could forever disrupt the geopolitical stability between India and Bangladesh, given the previous experiences pertaining to the FBP.

The inhabitants of the UBGI have interacted with the rivers for centuries. They traditionally depended on these rivers for food, communication and basic survival. The inhabitants of the UBGI are culturally linked with these distributaries. As the time progresses, the over-utilization of river water and riverbed has degraded the riverine environment at many places. Resuscitation of the decaying distributaries may help to restore natural landscape features that improves the overall quality of life. The revival of distributaries may also ensure the smooth
functioning of water cycle, maintenance of river ecosystem and adaptation to the recent climatic changes.

In order to ensure smoother flow through the distributary channels, human interferences should be constrained. There was a successful drive from the State Government to clear the Lower Ichhamati channel from illegal encroachments following the 2000 floods, but it did not extend to other areas of the delta. The government agencies should come up with strong policies regarding the waste disposal management or controlling the growth of aquatic vegetation in the active channels, besides properly implementing the guidelines related to the regulation of brick-kilns. Agricultural activities on the riverbed should be stopped in the areas like Ichhamati headwaters, where the riverbed has significantly raised due to years of lean season cultivation, thus reducing the channel capacity and increasing the susceptibility to flood hazard. Also, the usage of shallow-well pumps needs to be checked in order to prevent the rapid lowering of the groundwater table during the lean season. Additionally, the cultivation methods may include the planting of a variety of cover crops which helps to avoid the intense use of irrigation systems, thereby reducing the impacts of crop production on the distributaries.

Amongst the decaying distributaries, the excavation of channel bed is only feasible in the Upper Ichhamati, where only first 5 km of course needs to be unearthed to receive the Mathabhanga discharge throughout the year. However, it might reduce the flow through the Churni channel. The resuscitation of the Mathabhanga and Ichhamati Rivers will be difficult as these are the transboundary rivers, and thus would always be subjected to geopolitical agenda. In the present situation, it seems that the adaption to the changed environment should be the best long-term fix to the issue of degenerating distributaries.
SUMMARY OF PART–IV

The UBGI is a highly populated region. It is experiencing rapid population growth (1.6% per year in the last decade), which has put added pressure on the ecology, land-use and economy of the region. With growing population, human interventions have affected the riverine environment with the activities like cultivation, brick production, sand quarrying, effluent release, solid waste dumping and sanitation-related usage. These have intensified the decay of the distributaries flowing through the region.

After many failed efforts to revive the Nadia Rivers during British Raj, the Government of India came up with a more convincing plan after the independence of India to resuscitate the flow in the Bhagirathi–Hugli River and to save the Kolkata Port. The FBP was commissioned in 1975 to augment the Bhagirathi–Hugli flow. Although the execution of the FBP in flushing out the downstream silt failed, the project has enjoyed some success in partially restoring the original flow condition of the river. Thus, landform development is still occurring around the Bhagirathi–Hugli course. Barring the FBP, no other restoration-project has been carried out in the UBGI at present.

Apart from the FBP, the protective works at the river banks of major rivers were completed without much success. The embankments were made sturdier to combat with any major flood in the future.

Except for some rare requirements of dredging or excavation work, any other major resuscitation project is not viable in the distributary courses at present. It is important to restore the natural environment so that the existing rivers could flow without being obstructed by the human interventions. It seems that adaption to the changed environment is the best possible way to restrict the degeneration of the distributaries.