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Hydrological Characteristics and Fluvial Morphology in the Bhagirathi-Jalangi Floodplains of the Eastcentral West Bengal

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Abstract

The Bhagirathi-Jalangi Floodplain lies in the moribund deltaic Bengal where post – Pleistocene alluvial deposits in the foredeep and relatively high amount of rainfall have facilitated for the storage of huge ground water resource. The low gradient on the other hand has facilitated the river Bhagirathi and Jalangi to oscillate their courses over centuries and even over decades within their meander belts as a result of which numerous interesting fluviomorphic features, like bils, ox-bow lakes, cut-offs, palaeochannels etc. have been evolved. Temporal change in the number and spatial variation in the morphology of the bils are also very important. In terms of hydrological characteristics, there is a direct positive relationship between monsoon rainfall and depth of ground water table. Over-exploitation of ground water for increasing irrigation facility and cropping intensity in the study area; influence gradual depletion of water reserve. The present work has been to make an effort to discuss and analyse the fluvial dynamics in the Bhagirathi-Jalangi Floodplains of the Eastcentral West Bengal.

Objective

The main objective of the present study has been to make an effort to discuss and analyse the hydrological characteristics and fluvial morphology in the Bhagirathi-Jalangi Floodplains of the Eastcentral West Bengal. Changing courses of the rivers Bhagirathi and Jalangi in this moribund deltaic tract form numerous interesting fluviomorphic features, like bils, ox-bow lakes, cut-offs palaeochannels and other features of floodplains. The semi-consolidated to unconsolidated alluvium forms a rich store of ground water. On the basis of comparison, discussion and analysis, the striking features in terms of changes that have occurred in hydrological characteristics and fluvial morphology in the study area have been identified. Therefore, this is a good attempt to highlight the fluvial dynamics of the Bhagirathi-Jalangi Floodplains.

Sources of information and methods

For fulfilling the objectives of the present paper, the study has been made on the basis of maps prepared from the topographical sheets of English and Metric scales. Some relevant figures, data and information have also been collected from Google Earth Satellite Imageries. Ground water data have

been collected from SWID, CGWB and Principal Agricultural Offices of Burdwan and Nadia districts. The study is also based on some observations which have been made during field study.

Study Area

The Bhagirathi-Jalangi Floodplain (BUF) is a part of the lower Ganga delta. 'The deltaic tract is an area enclosed by the distributaries of a river and that it commences from the point furthest upstream whence the distributaries begin to be thrown off (Bagchi, K. 1943). The region covers 545.77 sq km, extending from 23°18'25"N to 23°35'45"N and from 88°11'20"E to 88°32'45"E, (Fig.1). It spreads in four Community Development Blocks namely *Purbasthali-I, Purbasthali-II, Nabadwip and Krishnanagar-II.*

Depending on the state of maturity, the deltaic Bengal has been divided into three parts, *moribund*, mature and active delta. Being located in the *moribund* deltaic part, the area presents a picturesque configuration with palaeochannels, meander scars, *bils*, ox-bow lakes, swamps, marshes, *etc.* Topographically, the study area has two distinct interfluvial zones. The eastern segment (about 40%) is lying between the *Bhagirathi* and *Jalangi* whereas the western part (about 60%) is between *Bhagirathi* and three small rivers namely *Brahmani, Khari* and *Banka*. The general elevation of the study area ranges from 6 metres to 15 metres. The high elevated areas are nothing but the natural levees which are located scatteredly with the association of present and past channels and low lying areas in the form of swamps and marshes. The northern, eastern and central parts of the study area show a height of more than 12 metres while in the southeastern part the height gradually decreases (Chatterjee, 2004).

Geologically, the Bhagirathi-Jalangi Floodplains lies in the 'Garo-Rajmahal Gap' and is composed of recent deposits of the Pleistocene period. The original basement complex has been covered gradually by river borne alluvium. The unconsolidated sedimentary deposits consist of sandy clay and sand along the courses of the rivers, fine silt, sandy loam and loamy soil found in the flatter parts of the plain. The deposits provide enough opportunity to surface runoff and ground water table formation (Prasad, N. & Mukherjee, I., 2008).

The Bhagirathi-Jalangi floodplains, like other parts of lower deltaic Bengal, fall under the 'tropical monsoon climatic region' ('Am' type). Oppressive hot summer with high humidities (75-80%), monsoon rainfall and dry, cold winter season are some of the typical characteristics of the climate of the study area. The average temperature during pre-monsoon summer season is 29.7°C with relative humidity 68%, associated with occasional thunderstorms in the afternoons locally known as *Kalbaisakhi*. Most of the rainfall (80%) occurs during summer monsoon (June to August).The average yearly rainfall is 1200mm. Relative humidity remains very high (>82%) during this period with low air pressure (varies from 997.8mb to 999.2mb). The winter season is cold and

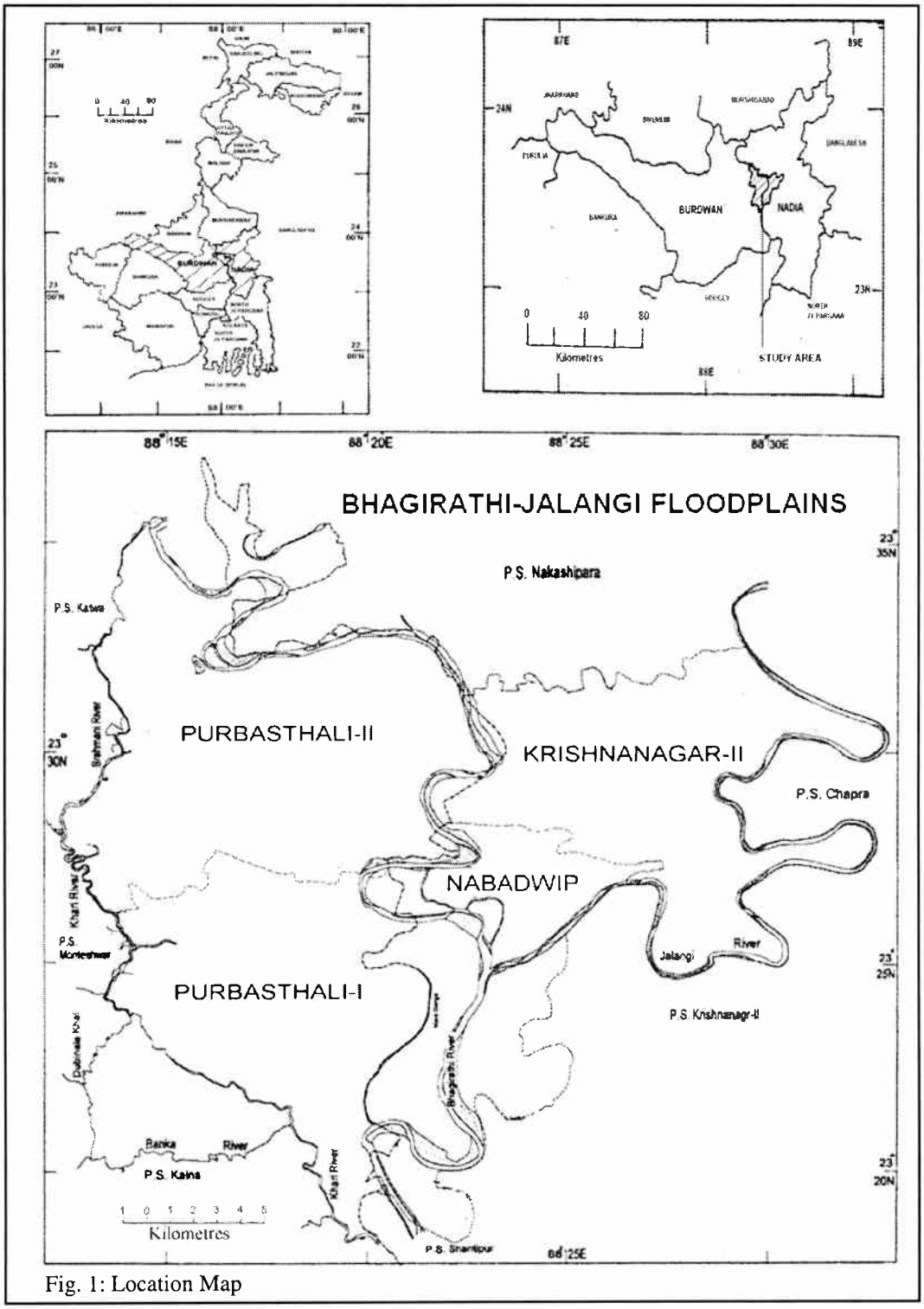


Fig. 1: Location Map

dry with temperature 10°C-18°C and is favoured with occasional visits by western disturbances. Heavy fogs sometimes occur during the winter season.

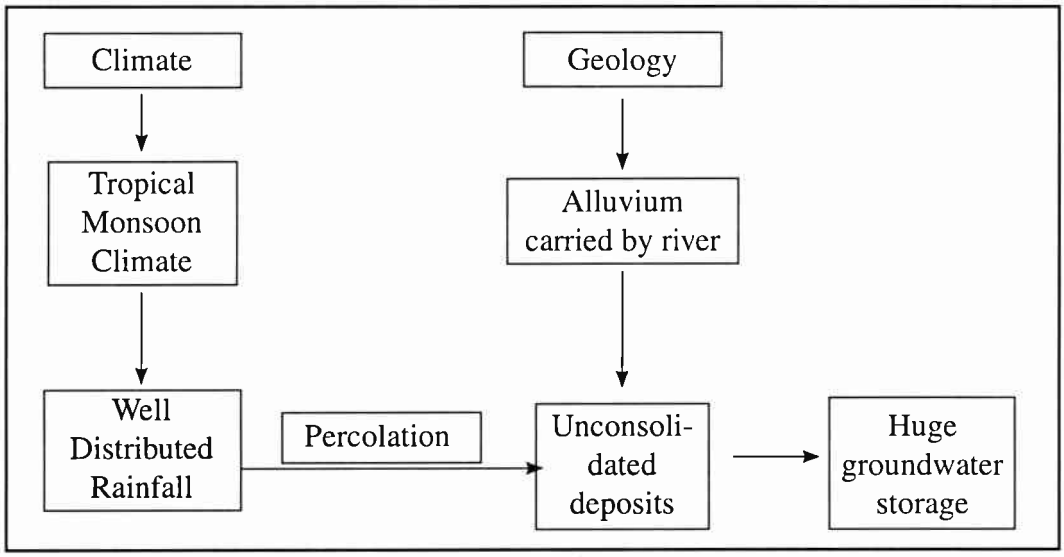
The top surface soil of the study area is recent alluvial formation. Beneath the top surface there is an underlying layer of older alluvium, formed of different materials. The flat low land of black clay soil known as *Kalantar tract* lies between the Bhagirathi and Jalangi rivers. Fine silts and sands along the river channels, with sandy loam, loam and clay in the other parts is the most common soil of the BJF.

The whole study area is a fluvial landscape, dominated by the floodplain character of the river Bhagirathi. The river is flowing from northwest to southeast separating the area into two parts. The river Jalangi meets with the river Bhagirathi opposite to the town of Nabadwip. The western segment is bounded by the rivers almost in all the directions, the *Brahmani* on the northwest, *Khari*, one of many off-shoots of the Damodar on the west, and *Banka*, the principal tributary of *Khari* on the southwest. The rivers are perennial in nature. The water level fluctuates during the pre-monsoon and post-monsoon seasons.

The rich alluvial deposits, dynamic fluvial condition and various floodplain features make the study area an interesting field of research on fluvial morphology and hydrology.

Hydrological characteristics of Bhagirathi-Jalangi Floodplains

Hydrology is the science that deals with water, its properties, and distribution over the earth's surface. Hydrological characteristics mean the distribution of surface as well as ground water which entirely depends on two factors, *i.e,* climate. and geological composition. The Bhagirathi-Jalangi Floodplain lies in the lower deltaic Bengal



where the climatic condition and geological character help to form huge groundwater reserve. On the other hand, deltaic landscape and low gradient facilitate the river channels to form meandering pattern and interesting associated features like ox-bow lakes, *bil's,* point bars *etc.* Figure 2a and 2b depict the channel course observed in 1779, 1927, while fig 3a & 3b show the conditions of channel courses in 1968 and 2008. A close look at these map reveal the dynamics of channel shifts and resulted changes in the marphology of different fluvial features.

Surface Hydrology

Surface water hydrology in the Bhagirathi-Jalangi Floodplain is dominated by rivers and stagnant water bodies (*bils*). The details of surface hydrology have been given in Table 1.

Rivers - *The Bhagirathi*

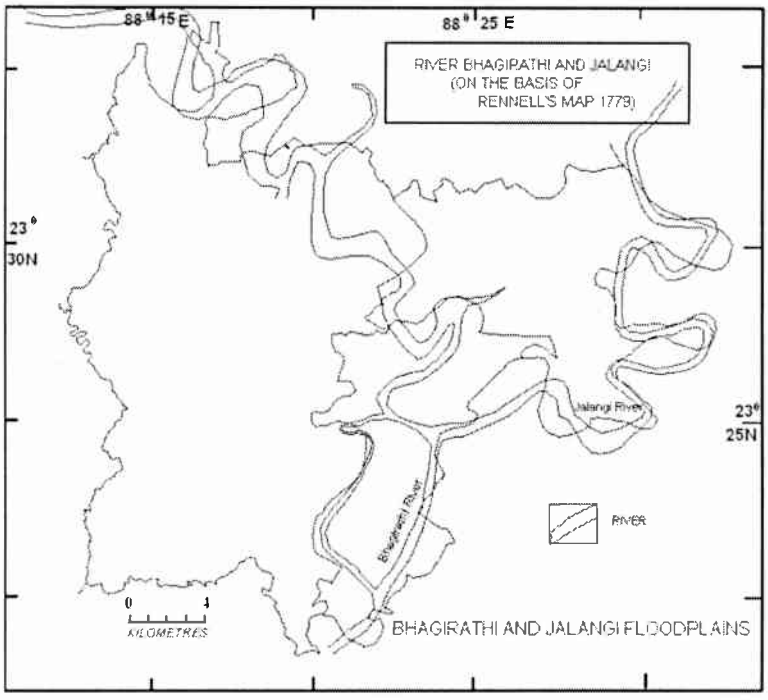
The Bhagirathi is the principal perennial stream of the study area. It enters into the study area in the northwestern part, just few kilometres south of Katwa town. The total length of the river within the study area is about 69.90 km. The river takes a highly meandering course throughout the whole study area and leaves long loops of disused channels which have become ox-bow lakes, *bils* and swamps over time.

The Bhagirathi, in its upper reaches (the reach upward the Nabadwip town) is at present a comparatively insignificant stream, but surrounding country gives evidence of the vast size which it attained

Table 1: Surface Water Hydrology

	Name of the river	Flow direction	Nature	Length within the study area (Km)	Areal coverage (Police station)
	Bhagirathi	NW to South	perennial	69.89	Eastern part of Purbasthali-I & II, middle part of Nabadwip and northwestern part of Krishnanagar-II
Left Bank tributary	Jalangi	NE to West	perennial	59.74	Eastern & southeastern part of Krishnanagar-II & Northeastern Nabadwip
Right Bank tributary	Brahmani	North to South	perennial	8.06	Western part of Purbasthali-II
	khari	West to Southeast	perennial	32.11	Western & southcentral part of Purbasthali-I
	Banka	West to East	perennial	11.26	Southern part of Purbasthali-I

Source: Topographical Sheets No. 79 A/2, 79 A/3, 79 A/6, 79 A/7, Survey of India



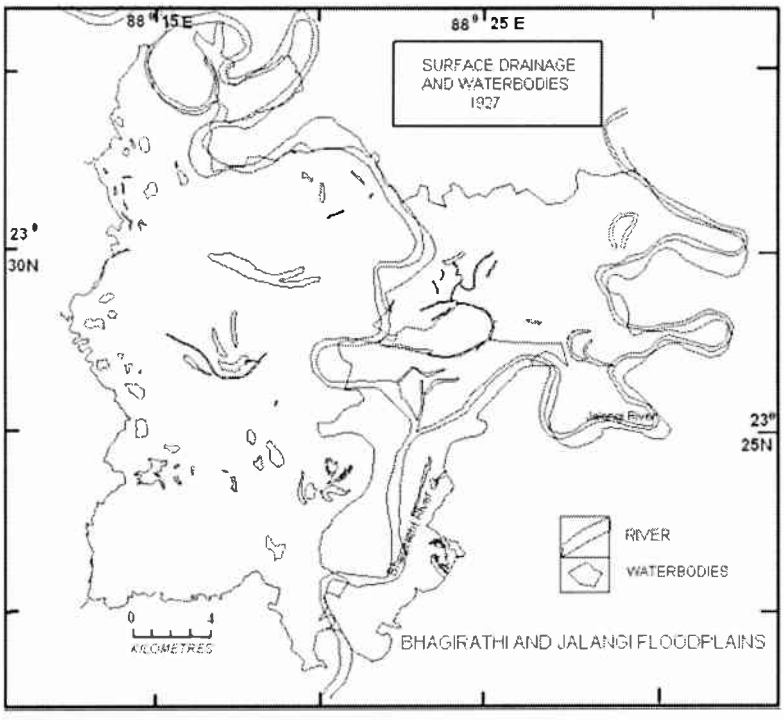


Fig. 2a and 2b: Bhagirathi and Jalangi Flood Plains

when it formed the main bed of the Ganges (Gazetteers, Nadia, April 1978). Alterations are continually taking place, loops being formed, cut through and reformed throughout the whole stretch of the Bhagirathi in its seaward course. So the traces of old channels in the form of semi-circular *bils* or lakes are frequent along the banks.

Table 2 depicts some important morphological aspects of two main rivers in the BJF. The total length of the river Bhagirathi (within the study area) was 73.97 km during 1927, which reduced to 70.47 km in 1968-69 & now it is 69.89 km. However, the number of cut-offs has increased from five in 1927 to nine in 2008. These morphological aspects reveal that the river Bhagirathi is in very dynamic condition and having a tendency to shortening its course by straightening the channel.

The Bhagirathi within this sector is still very dynamic and causes severe bank erosion. The sites of bank erosion are the concave banks of the river channel where steepening of the banks through undercutting causes severe bank erosion. Worst affected areas of bank erosion are Patuli, Majida, Mertala, Jaluidanga, Purbasthali *etc.* Samudragarh located in Purbasthali-I, where the distance between highway and river is just 30 metres and shrinking.

Continuous shifting of the river course threatens the railway lines and roads, settlement, schools, agricultural lands *etc.* The life of people in the area is highly insecure and uncertain.

The Jalangi

The river Jalangi forms eastern boundary of the study area. The total length of the river within the study area is about 59.74 km. For some distance within the study areas it flows in a northsouth direction with a highly meandering course. Thereafter just upstream the Krishnanagar town it turns westwards and falls into the river Bhagirathi opposite the town of Nabadwip. Some cut-off loops are present in the form of *bils* in the eastern part of the Bhagirathi-Jalangi floodplain namely Nawapara *bil* and Hansadanga *bil*. The area in between Bhagirathi-Jalangi is locally known as *Kalantar* that is characterized by black clay soil.

The river Jalangi shows the trend of increasing length. In 1927, the length within the study area was 57.57 km, which increased to 57.76 km in 1968-69 and 59.74 km in 2008. Increase in the number of

Table 2: Some Aspects of Fluvial Morphology

Morphological Properties (within study area)	**Bhagirathi**			**Jalangi**		
	1927	1968-69	2008	1927	1968-69	2008
Actual length of river	73.97	70.47	69.89	57.57	57.76	59.74
Number of meander loops	9	10	8	7	7	8
Number of cut-offs	5	6	9	2	2	2

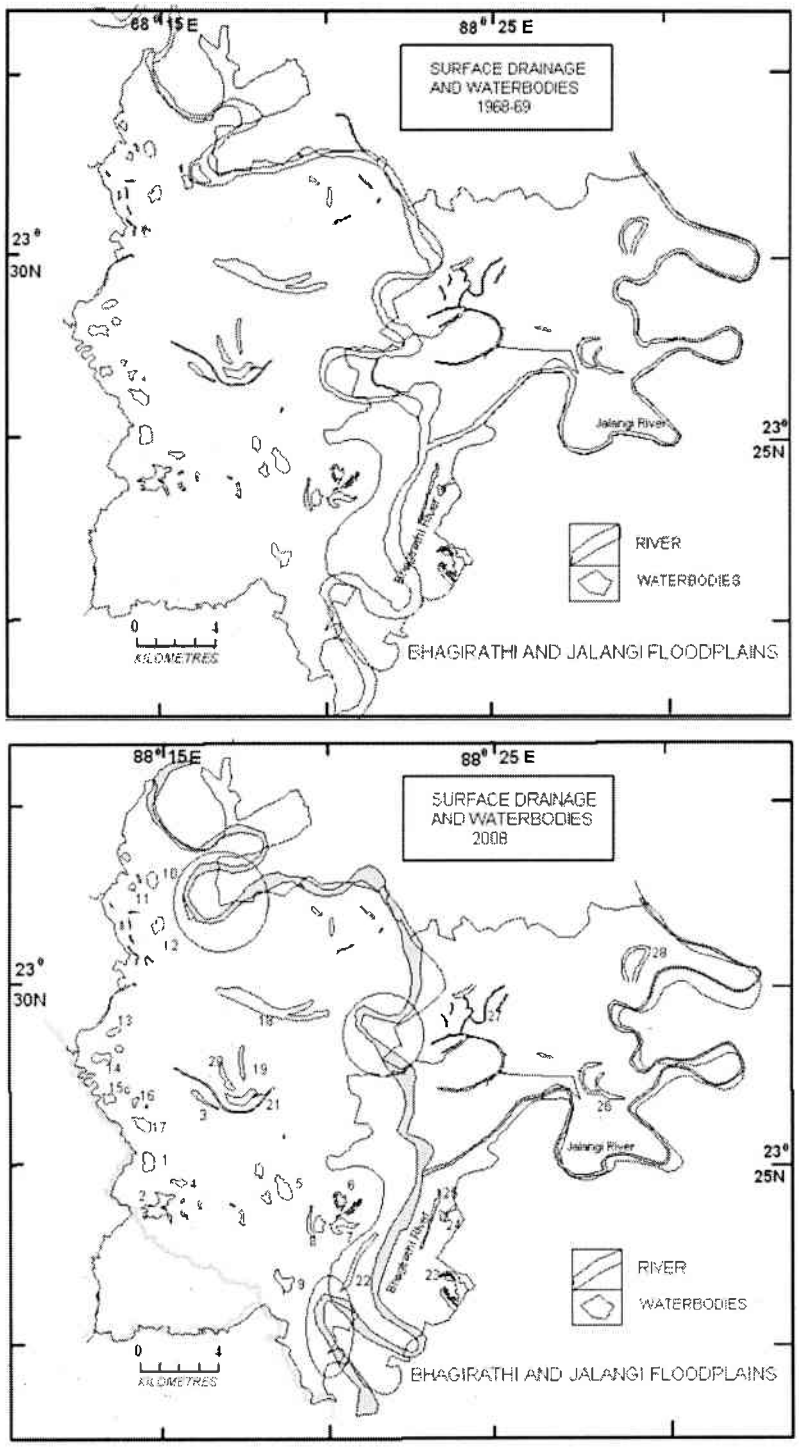


Fig. 3a and 3b: Bhagirathi and Jalangi Flood Plains (for No. 1-28 refer to table)

meander loops is probably the main cause of it.

The Banka

The Banka is the principal tributary of Khari. The river was formerly the one of many spill channels of the Damodar. The river forms the southwestern boundary of the study area. The river first touches the study area at the southern part of village Dirgrapara of Purbasthali-I. Total length of the river within study area is 11.26 Km. Near the village Sammudragarh it joins river Khari. The stream remains dry during the summer season, during the rainy season it is only navigable for a few kilometers upward its confluence with the Khari.

Stagnant water bodies (*Bils*)

Fig. 3b and Table 3 give a detailed picture of the stagnant water bodies of the BJF. Being a deltaic plain, the study area shows an abundance of natural inland wetlands. Extremely meandering courses of the rivers over this *moribund* deltaic tract and an erratic water flow over large area during rainy season causes the formation of natural inland wetlands like cut-off meanders, seasonal waterlogged areas, lakes, marshes *etc.*

About 2.75% (1502.2 hectare) of the total study area has been occupied by different types of wetlands. The western part of the Bhagirathi comprises mainly circular, semi-circular and elongated *bils*, the areal coverage of which is 1182.32 hectares. The *bils* are distributed over the entire study area. Some concentrated patches are observed in the northern, central, western and southcentral parts, these are associated with past channels and inter-levee depressions. Figures 2a, 2b and 3a, 3b clearly show that there exists a close relationship between the wetlands and past river courses.

The eastern part of the Bhagirathi, *i.e.*, the Bhagirathi-Jalangi interfluves has been characterized by the cut-off meanders or ox-bow lakes and meander scrolls in abundance. The wetlands in this part occupy 319.88 hectare area.

Most of the wetlands range in size between 35 and 55 hectares. Some large *bils* like Beten *bil* (312.35 hectares) and Ranipur *bil* (107.20 hectares) of Purbasthali-II, Unir *bil* (113.70 hectares) of Purbasthali-I *etc.*, are also observed. A considerable number of ponds and small depressions are also observed in the western part of the Bhagirathi.

Some important characteristics of these *bils* are as follows:

(a) Considering the surface elevation map and the distribution of water bodies (Fig. 3b) it has been observed that some of the *bils* of the western and southeastern parts are the accumulations of water in the low- lying ground.

(b) There is a striking variation in the configuration of the *bils* in the western and eastern parts of the study area. In the eastern part, the *bils* are mainly elongated because of meander scrolling.

While at the western part, *bils* are circular to semi-circular in shape.

(c) The *bils* of the western part of the Bhagirathi are nothing but the depressions caused by overflow of the rivers. A large number of tanks are also observed here. They are mainly for the daily use of human beings residing there.

(d) Some of the *bils* namely Nartil, Jalangi, Ural *etc.*of Purbasthali-II are observed on a fairly high elevation especially in the northwestern and central parts. Being located sufficiently in the high surface water remains only for some of the months of the year and consequently their use is confined only to grow some crops like mustered *etc.*

(e) The *bils* namely Kalinagar, MaraGanga of Nabadwip, Unir and Salte of Purbasthali-I are associated with the present river courses and are connected with the rivers by small channels.

(f) During the summer months, the overall coverage of water of the *bils* becomes low. Growing population pressure, extension of cultivated area and built up area lead to the transformation of some *bils* for other purposes. One of such example is Mullar *bil* of Purbasthali-I which is now totally used for cultivation.

(g) The origin and morphology of the bils are very interesting because most of them are the left out parts of the river Bhagirathi which has been oscillating constantly over centuries and even over decades in this deltaic plain. The river Bhagirathi comprising of two meandering bends was situated in the middle part of Agradwip. The river took a sharp bend at the northern part of the village Majida, then it moved southwards up to the northern part of the village Sajiara. It is interesting to note that in 1927, another new loop became active near Agradwip (left side of 1779 course) and the meander bend near Patuli was stretched more in northwestwards. The small meander bend, few kilometre downstream of Patuli, started to move westwards in this period, eroding the right bank near the villages like Dampal and Narayanpur. The southward moving straight part became a left-out part namely *Kamakshya Khal* in due course of time and river shifted eastward. There were four meander bends in between the village Mertala and junction of Bhagirathi-Jalangi in 1779, of which eastward moving meander belts near the village Mertala and Char Kasthasali became ox-bow lakes namely *Sujanpur Bil* and *MaraGanga*. Another two bends became active and shifted about 1 to 3 kilometre westward eroding the villages like Gopipur, lower part of Mertala, Sankarpur, Purbasthali of Purbasthali block. The creation of Nawapara *bil* was only remarkable change in the river Jalangi and rest of the river remained relatively stable with its numerous bends. A considerable change has been occurring near Agradwip during the

period 1927, the active loop became palaeochannel namely *Chara Ganga* and the main flow shifted towards the western part (Purbasthali side). Closing of the meander loop and formation of an ox-bow lake, few kilometre upstream of Nabadwip is the most interesting geomorphic feature which has been evolved in this area during last 40 years (1969 to 2008).

Fluvial Morphology of the Bhagirathi-Jalangi Floodplain

Fluvial morphology relates to the features and forms produced by the fluvial activity. Floodplains may be simply defined as the flat areas adjacent to rivers and liable to flooding. Floodplains are also complex assemblages of landforms which include channel features such as bed forms (ripples and dunes) and bars (point bars, mid channel bars *etc.*), channel edge features such as banks, benches and levees. Some of other important features like palaeochannels, scroll bars, ox-bow lakes, back swamps, crevasse-splays *etc.* are also observed.

Channel features are nothing but the organization of bed material in different forms within the channel bed. These features are produced in the condition of excess sediment availability or insufficient flow energy along the channel. Continuous instream sedimentation is likely to occur in the form of different features (Goudie 2004).

Table 3: Bils in the Bhagirathi-Jalangi Floodplains

District and Police Station Name of the bil with number indicated in maps	Primary Position (in respect of river bhagirathi)	Area (hect.)
NADIA		
Purbasthali-I		
1 Salte Bil	RB	50.89
2 Unir Bil	RB	113.70
3 Saguna Bil	RB	27.40
4 Dedab Bil	RB	19.24
5 Santler Bil	RB	64.23
6 Bara Bil	RB	29.94
7 Basadar Bil	RB	49.03
8 Kristabati Chander Bil	RB	35.37
9 Mullar Bil	RB	55.14\
NADIA		
Purbasthali-I		
10 Nartil Bil	RB	32.65
11 Jalangi Bil	RB	9.14
12 Ural Bil	RB	34.27
13 Pharphari Bil	RB	21.48
14 Pandul Bil	RB	39.06
15 Kalre Bil	RB	25.01
16 Athle Bil	RB	10.76
17 Shalkona Bil	RB	46.65
18 Beten Bil	RB	312.35
19 Lohachar Bil	RB	32.06
20 Moalia Bil	RB	35.20
21 Ranipur Bil	RB	107.20
Nadia		
Nabadwip		
22 Kalinagar Bil	RB	34.55
23 Bhagara Bil	RB	14.51
24 Kholra Bil	LB	50.38
25 Kalatala Bil	LB	23.37
Krishnanagar-Ii		
26 Hansadanga Bil	LB	94.64
27 Sujanpur Bil	LB	34.94
28 Nawapara Bil	LB	99.04

Source: Topographical Sheets No. 79 A/2, 79 A/3, 79 A/6, 79 A/7, Survey of India and Google Earth Satellite Image, RB - Right Bank, LB - Left Bank

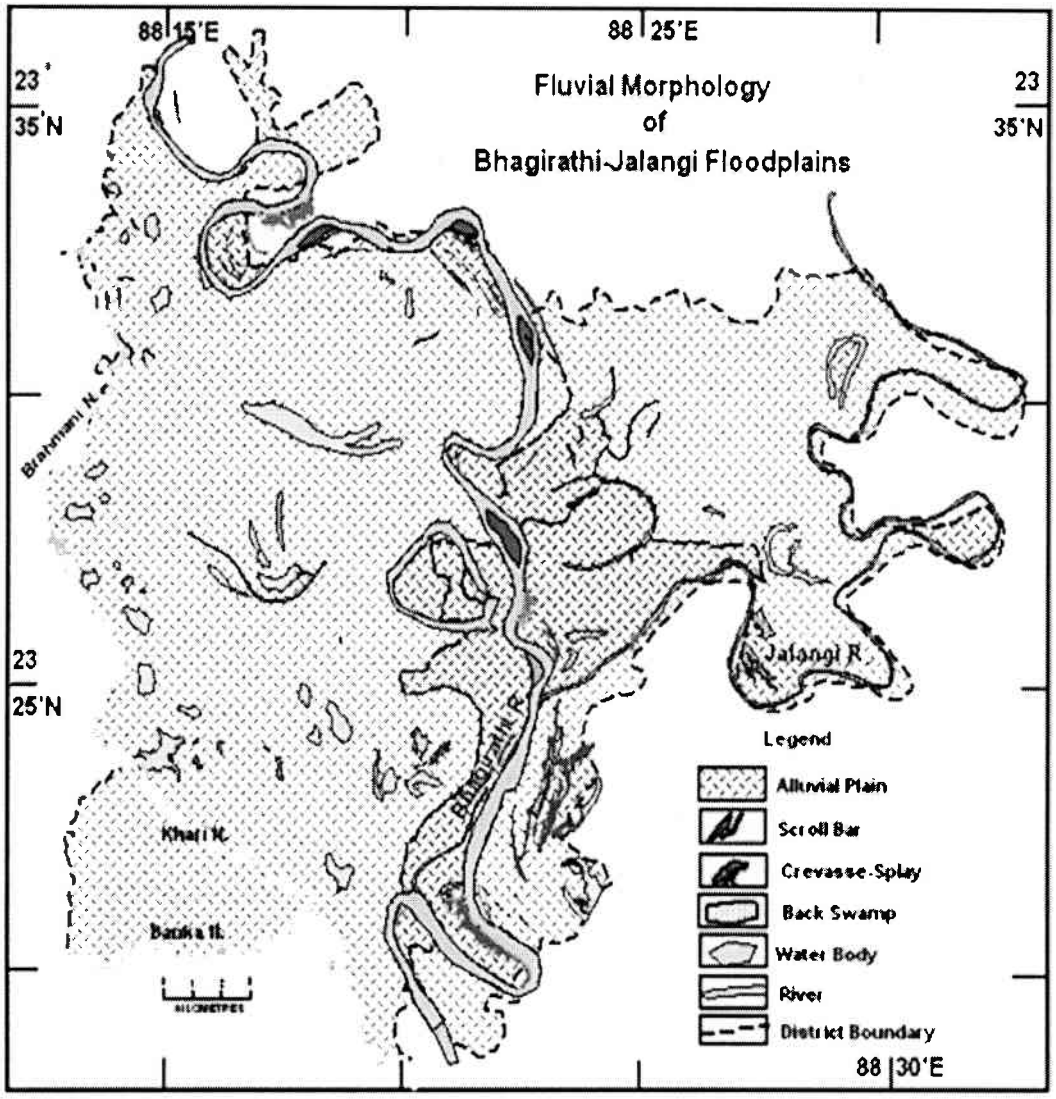


Fig. 4: Fluvial Morphology of Bhagirathi and Jalangi Flood Plains

Point bars are D-shaped feature growing out from the banks into the channel, composed of sand and gravel on inner side of meanders. From Fig. 4 it can be observed clearly that all the rivers have been flowing in a highly meandering course, so point bars are very common in the study area. The length of the point bars along the channels varies between 1.5 km to 6.5 km and the average is around 4.53 km. Average width of the bars is around 0.6 km.

Mid-channel bars are typically lenticular or diamond shaped, caused by flow divergence or by the dissection of

point bars. Fig. 4. clearly shows the position and the shape of the mid-channel bars. The sizes of the bars are ranging between 0.39 hac to 79.75 hac. The mid-channel bars are mainly observed in the stretch upstream the town Nabadwip in Bhagirathi. Some of the mid-channel bars near the village Nawapara (JL-24) and Majida (JL-31) are used for cultivation purpose in the winter season.

Levees are linear mounds of sand or the ridge of channel derived sediment caused by the over bank deposition of sand. Levees are observed along with the association of present channels and past river courses in the study area. As the area is flood prone, the natural levees provide the zone of dry point for settlement and transport routes.

Crevasse-splays are fan-shaped lobes of sand and gravel caused by a breach in the levees, allowing bed material to be deposited on the floodplain flat. These features have been identified as a long strip along with the channel near the villages namely Patuli (JL-17) of Purbasthali-II, Rudrapara (JL-5), Bankar Dhopadi (JL-25) of Nabadwip (Fig.) and many other places also. Crevasse-splays are clearly observable in the Satellite images as a patch of white sand on the ground. Many-a-times face great damage because of sand incursions.

Scroll bars are formed with the lateral migration of channel along the meander belts. In the study area the *bils* namely *Kalatala bil, Kalinagar bil lohachar bil, Moaliabil etc.* are nothing but the scroll bars now forming the stagnant body of water. Recent scroll bars are observed near the villages like Narayanpur (JL-21), Dampal (JL-22), Tegachhi (JL-23) of Purbasthali-II and Jaluidanga (JL-183) of Purbasthali-I where the bank erosion is very prominent. The length varies between 0.5 to 2 km and they are semi-circular to straight in shape.

Cut-offs or ox-lakes are depressions in the floodplain surface formed by the abandonment of a former river channel. The detail description has been given in Table. 3 and Fig. 3b.

Palaeochannels are the old channels which are formed by the change of river course. From Fig 3a. we can observe clearly the past river courses in the northern part

Table 4: Seasonal Variation of Ground Water Table (in metre) in 2004

Location	Pre-monsoon	Monsoon	Post-Monsoon	Fall in water level monsoon to post-Monsoon
Srirampur	-6.45	-2.64	-3.18	0.54
Samudragarh	-5.45	-1.95	-2.68	0.73
Patuli	-7.15	-2.5	-3.4	0.98
Lohachar	-8.5	-3.24	-5.55	2.31
Nabadwip	-4.2	-1.27	-2.2	0.93
Krishnanagar-II	-4.88	-1.34	2.14	0.80

Source: State Water And Irrigation Directorate (SWID)

of the former Agradwip loop now known as Chariganga N. (Fig. 3b). Former active channel at the western part of Nabadwip town now remain as a stagnant waterbody namely Mara Ganga. Alokananda *bil*, Kholra *bil*, Bhaluka *bil etc.* on the eastern part of Bhagirathi are the relicts of former channel Alokananda.

Ground Water Hydrology

The Quaternary alluvial deposits of semi-consolidated to unconsolidated nature form a single unconfined aquifer in the Bhagirathi-Jalangi floodplain area. The ground water table generally consists of the zone of permanent saturation, zone of intermittent saturation and the zone of non-saturation. The depth of ground water table fluctuates depending on the water recharge. Tropical monsoon climate with annual rainfall of 1200 mm helps to form a considerable store of ground water in the BJF.

In order to study the rainfall pattern and the groundwater conditions in the BSF area two years when rainfall conditions were normal (1990) and scanty (2004) have been analysed. The rainfall distribution during these two years clearly indicates the

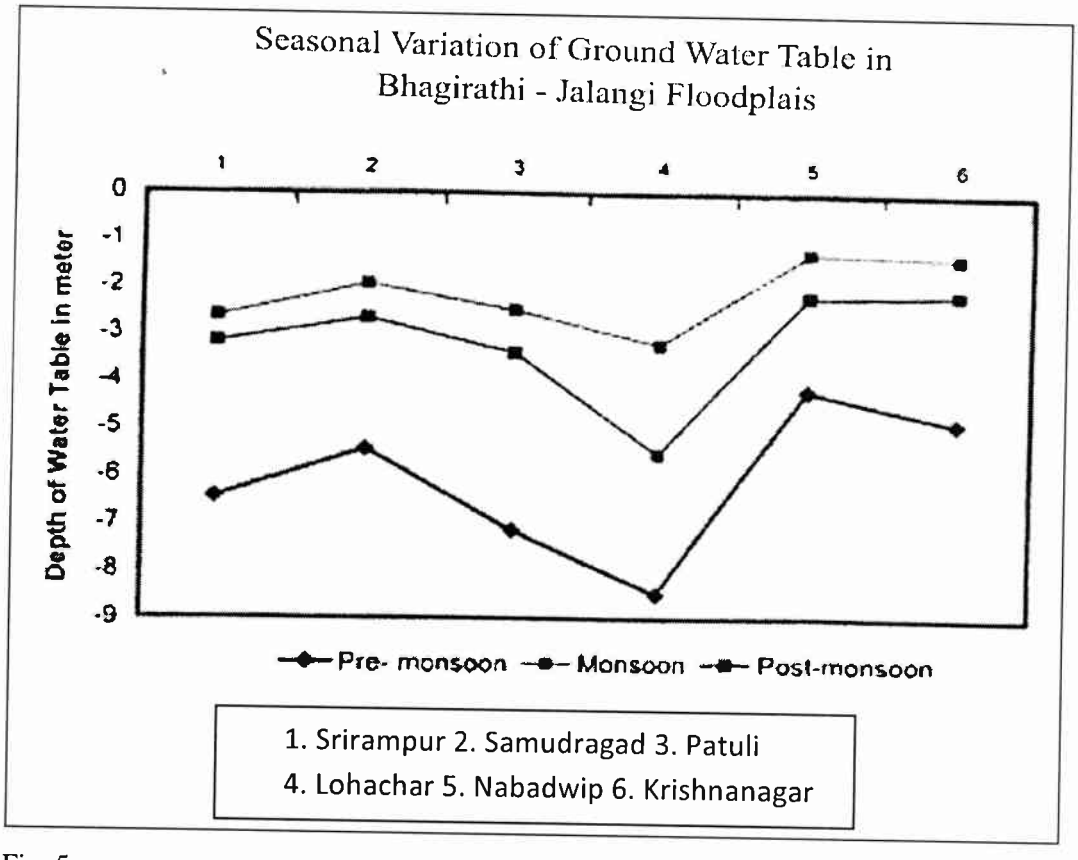


Fig. 5

groundwater levels in the area are influenced by the rainfall distribution. The groundwater table gets raised up during the monsoon period and continues to remain sufficiently high even during post monsoon period. The continuation of high water level in post monsoon season i.e. up to December clearly indicates the effect of the soil condition in the region. In January the water level falls down drastically and continues this trend till May. This trend is seen in both the years; however, the rainfall in 2004 was considerably low. It was also so in the previous year. The water table in the month of May, for year 2004 was -8.5 m as against -6.14 in year 1990.

The water levels observed at six locations in the study area have been shown in fig 5. It may be observed from the curves, that at all the six locations the water levels during monsoon and post monsoon period are relatively close to each other but the curve of pre monsoon falls down drastically. At Lohachar, the water level is as low as -3.24 in monsoon period and during pre-monsoon it falls down to -8.5 m. Compared to other stations the fall in water levels at Lohachar is significant whereas at other stations the fall from monsoon to post monsoon period is much low (less than 1m) at this station it is considerable (2.31m). This is basically the effect of the location of Lohachar that is situated at some distance from any major channel.

From the above discussion, it is clear that there is a direct positive relationship between monsoon rainfall and depth of ground water table. Besides this, the increasing irrigation facility and cropping intensity in the study area influence the water withdrawal. Thus over-exploitation of water for meeting increasing demand of successful agricultural system is the main cause of overall lowering of water table.

Conclusion

The decaying river channels and waterbodies, present in the form of *bils* and extensive store of ground water in the semi-consolidated to unconsolidated Quaternary alluvial deposits are the most important aspects of hydrology in the Bhagirathi-Jalangi *moribund* deltaic plain. These resources are under stress. Growing demand of rapidly increasing population and agro-based economic structure gradually depletes water reserve and resultant arsenic problem is a serious threat for the people residing here. Increasing population pressure creates huge stress on water reserve as well as the areal coverage of surface waterbodies. However, from ecological point of view, attention must be paid to sustainable utilization of surface water resources and minimum use of ground water, for better future.

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