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Tidal Characteristics of Selected Stretch of Hugli Estuary, Related with Suspended Sediment Concentration

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Abstract – *The three stations (Achipur, Raichak, Kulpi) those were chosen for tide monitoring that are located on the bank of Hugli river in South 24 Parganas, because Kulpi is near the mouth of the sea of Bay of Bengal and Achipur is inside the river up to where tidal water reaches and Raichak is the middle station between Kulpi and Achipur. So spatial change of the tide can be shown along the Hugli river from mouth to inside.*

Key Words: **Tide, Suspended Sediment, Monsoon, Pre-Monsoon, Bore Tide, Hydraulic Gradient, Tidal Asymmetry**…

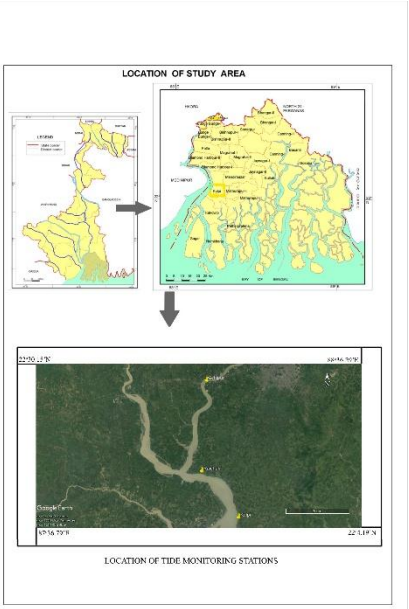
1.Introduction:

1.1 Conceptual Background

The Hugli River or the Bhagirathi-Hugli, traditionally called 'Ganga', is an approximately 260km long distributaries of the Ganges River in West Bengal, India. Our study area Achipur, Raichak and Kulpi are located on the left bank of this river. The tidal character of Hugli River is basically of progressive type. Time and velocity asymmetry becomes more pronounced as it propagates along the channel. Tide first reach in Kulpi, then Raichak and then Achipur. The Hugli also experiences the remarkable example of the fluvial-marine phenomenon known as a 'tidal bore', when the tide rises very rapidly and produces a tidal bulge, usually not experienced during high tide. This consists of the head-wave of the advancing tide, hemmed in where the estuary narrows suddenly into the river. This study aims to establish the **Tidal Characteristics of selected stretch of Hugli estuary** in the stations of Achipur, Raichak and Kulpi. In Hugli River sediment concentration is relatively high. SSC rate is also higher in monsoon condition than in pre monsoon condition. Tidal rate is also higher in monsoon condition than pre monsoon condition. The Hugli is a funnel shaped estuary, the breadth and cross sectional area at the mouth if 25km and 156250m^2 and this decreases to 6km and 36,799m^{2}at the head. A deep relation between the tide and SSC can be seen in case of the Hugli. Hugli's main problem is siltation. A large amount of sediment is accumulated in high tide time and tidal bore. So dredging is important for removal of excessive sediment. This study aims to understand the tidal process operating in Hugli river and find out its relation with the high sedimentation rate.

1.2 Location of Study Area

The study area is located in the district of South 24 Parganas. The three stations Achipur, Raichak and Kulpi are situated on the left bank of Hugli river. The latitudinal and longitudinal extension of the study area is 22°30.15'N to 22°4.19'N and 87°36.7'E to 88°36.29'E. Total distance of the study area is 58.17km. The distance between Achipur and Raichak is 36.29km and the distance between Raichak and Kulpi is 21.88km and Kulpi is near the mouth of the Hugli river near Bay of Bengal.



1.3 Objectives

The main objective of the study is to find out the tidal character of Hugli river. Overall want to know how actually the tide behaves and how tide affects the whole sedimentation process. To fulfill the main objective, other various sub objectives are derived

- To show the trend of tidal cycle at three stations within a span of 9-10 hours in two seasons. The relationship between tide and suspended sediment concentration.

- To identify the time span of high tide between the mouth of the sea and inside the river and tidal asymmetry.
- To understand outgoing and incoming tidal water level of the river of two seasons.
- To understand the incoming and outgoing amount of sediment of each station in two seasons.

1.4 Methodology

Pre-field study:

Some satellite imagery was collected of the area from the Google Earth. Staffs were brought before going to field and some articles help in work.

Field study:

Tide monitoring was done (after Glen 1979) by the monitoring we wanted to reveal the tidal behavior of this area. Tide monitoring had done for 9hrs in full moon condition and tide data are collected in interval of 5minutes sometimes 10minutes. The tide monitoring was conducted in low-high to high-low tide condition. Tide monitoring was done by two staffs. At first tide monitoring is done by one staff then when water level is increasing rapidly then second staff is placed. Then two staffs are reading simultaneously. After that when water level is decreasing slowly then again one staff can be read. By this method tide monitoring was done of three stations.

Water samples were collected at one hour interval to know amount of sediment with incoming and outgoing tide by standard filtration method. Total sample of incoming water on monsoon and pre-monsoon season in 6 and total sample of outgoing water in both season is 4.

Post-field study:

Firstly in the laboratory filter papers was taken and weighted them. Then put them on the cylinder then poured the water through the filter paper. After pouring all the sediment laden water, the filter papers are again weighted. Then the final weight of the sediment is calculated. The sediment concentration per 1000ml. was calculated.

Tidal data were calculated specifically actual levels were determined by adjusting chart datum value and calculate it.

All the data collected from the survey were put into excel sheet and different types of cartographic representations were made.

2. PHYSICAL SETUP OF AREA:

2.1 GEOLOGY:

The predominant geological formation of south 24 parganas was mainly classified according to the geological time period. They belong to the quaternary period and tertiary period. Quaternary deltaic sediments are composed of silt, clay and sand of various grades, gravels, and pebbles etc underlying upper tertiary formation. The quaternary sediments consist of clay, silt, and several grades of sand and gravel. These sediments are sandwiched between two clay beds: the lower one at a depth of 250-650m(820-2130 f) the upper one 10-40m(30-130f).

2.2 CLIMATE:

South 24 parganas has a tropical wet and dry climate (Koppen climate classification Aw). The district is characterized by hot and humid climate. It receives adequate rainfall from North-East and South-West monsoon which sets in the latter half of June and withdrawn by the middle of October. Pre-monsoon rains are received during March-April. Summers are hot and humid with temperature in the low 30°C and during dry spells the maximum temperature often exceeds 40°C during May and June. Winter tends to last for only about two and a half months, with seasonal lows dipping to 9°G11°C between December and January. The highest recorded temperature is 43.9°Cand the lowest is 30°C

2.3 SOIL:

The soil type of this district is divided into three groups namely 1) Entisols 2) Alfisols 3) Aridisols. The entisols are present in the western corner of the district, the Alfisols which are typically deltaic alluvium soils are present in central portion and the aridisols which are saline and saline-alkali in nature are present in the southern part of the district.

2.4 DRAINAGE:

Hugli, Matla, Raimangal, Saptamukhi rivers and their tributaries are the main drainage in this region. The study area is located on the left bank of Hugli River. The main river Ganga after entering West Bengal is bifurcated near Dhulian, one branch is named Hugli while the main branch is named Padma. The Ganga catchment area is a vast region.

3. RESULT AND DISCUSSION:

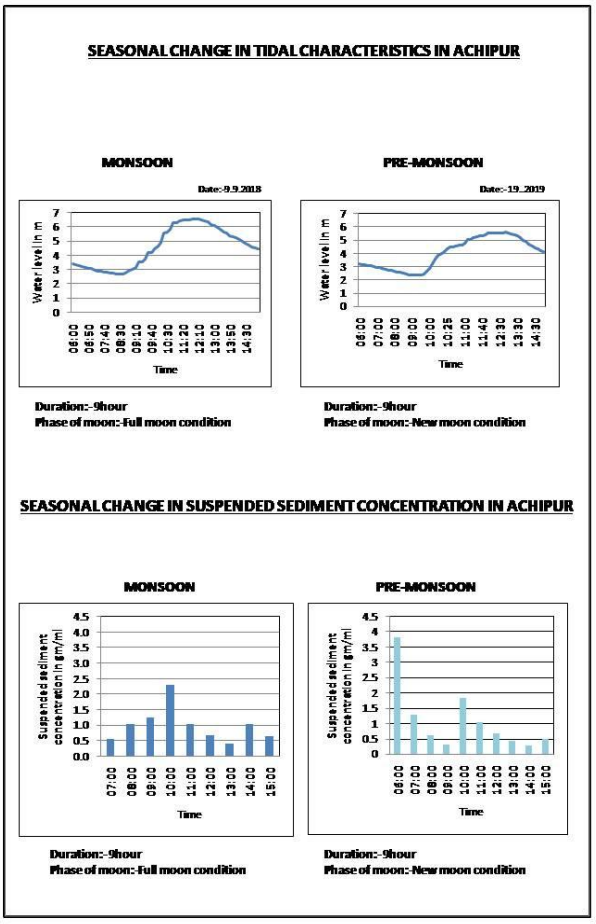
We observed that tidal behavior of two seasons is different and also we can observe tidal asymmetry and lag time of high tide of two stations in two seasons. Suspended sediment concentration can relate with tidal curve. Incoming water level is increasing up to 11:00a.m after that outgoing rate is increasing both the season. We can also observe that incoming average suspended sediment is increasing in Achipur and Raichak station and also opposite situation is seen in Kulpi station. In Kulpi station incoming and outgoing rate is opposite in monsoon and pre-monsoon season.

3.1 Tidal characteristics of Achipur, Raichak and Kulpi

Achipur: At the phase of the new moon in case of station Achipur in monsoon condition. Water level is totally declined at 8:20a.m when water level is measured as low tide was 2.705m. Then it is starting to rising of water at around 10:20a.m and thus is taking to be highest water level at 6.56m At 12:00p.m. So rising of water is to be taken only 3hrs 40mins and the range of tide is 3.855m. In case of Achipur rising rate of tide is 0.016m/hr and the falling rate of tide is 0.012m/hr.

At the phase of full moon in case of station Achipur in pre-monsoon condition water level is totally declined at 9:30a.m when ware level is measured as low tide was 2.36m. Then it is starting to rising of water at around 10:10a.m and thus is taking to be highest water level at 5.61m at 12:50p.m. So rising of water is to be taken only 3hrs 20mins and the range of tide is 3.25m. In case if rising rate of tide is 0.016m/hr and the falling rate of tide is 0.011m/hr which can be seen in table: 1

Table:1	Achipur	
	Monsoon(9.9.2018)	Pre-monsoon(19.4.2019)
Rising rate(m/hr)	0.016	0.016
Falling rate(m/hr)	0.012	0.011
Range(m)	3.855	3.25
HT time	12:00	12:50
LT line	8:20	9:30



Raichak: At the phase of the new moon in case of station Raichak in monsoon condition. Water level is totally declined at 6:40a.m when water level is measured as low tide was 2.79m. Then it is starting to rising of water at around 8:10a.m and thus is taking to be highest water level at 6.53m At 10:40p.m. So rising of water is to be taken only 2hrs 30mins and the range of tide is 3.74m. In case of Raichak rising rate of tide is 0.016m/hr and the falling rate of tide is 0.011m/hr.

At the phase of full moon in case of station Raichak in pre-monsoon condition water level is totally declined at 7:20a.m when ware level is measured as low tide was 0.74m. Then it is starting to rising of water at around 9a.m and thus is taking to be highest water level at 6.06m at 11:50p.m. So rising of water is to be taken only 4hrs 30mins and the range of tide is 5.32m. In case if rising rate of tide is 0.015m/hr and the falling rate of tide is 0.011m/hr which can be seen in table: 2

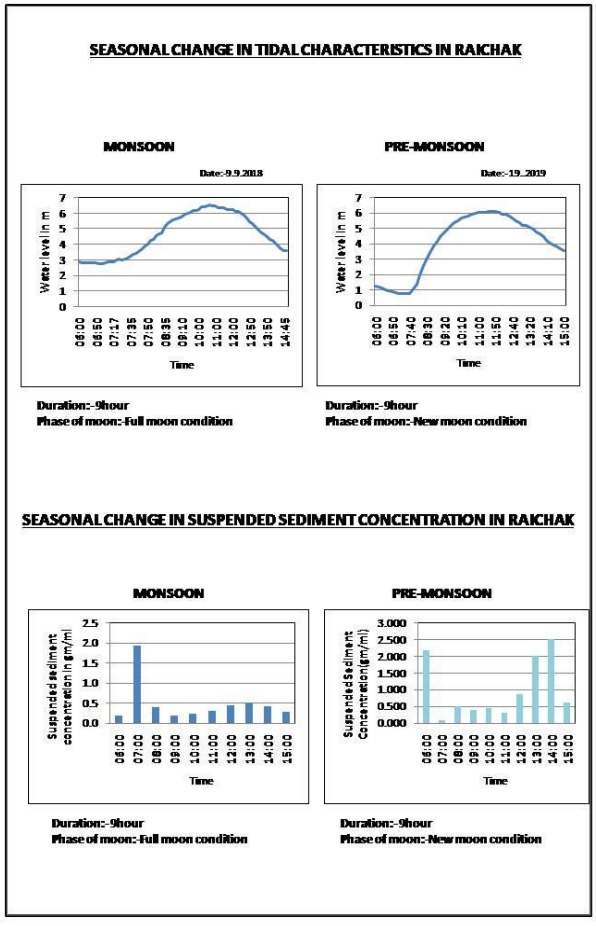


Table:2	Raichak	
	Monsoon(9.9.2018)	Pre- monsoon(19.4.2019)
Rising rate(m/hr)	0.016	0.015
Falling rate(m/hr)	0.011	0.011
Range(m)	3.74	5.32
HT time	10:40	11:50
LT line	6:40	7:20

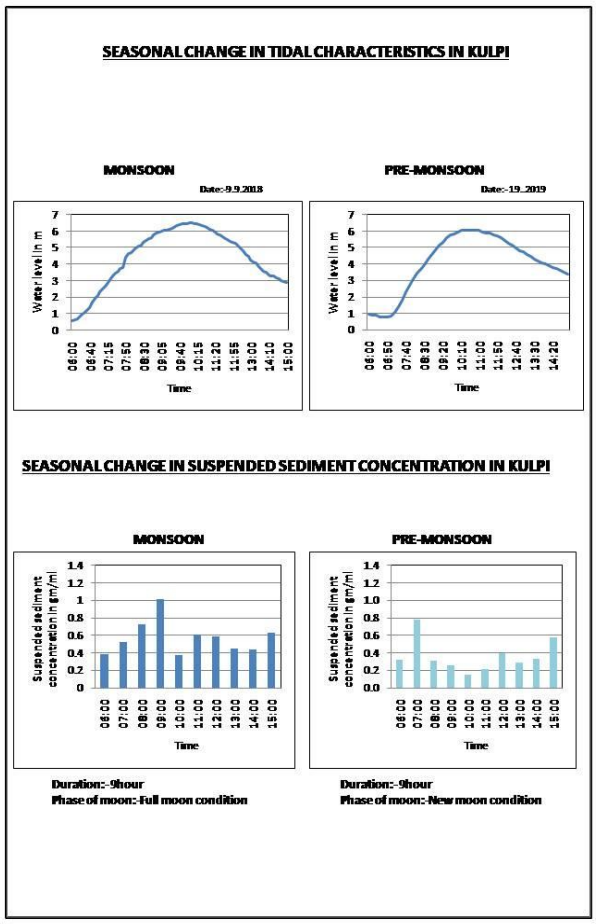
Kulpi:

At the phase of the new moon in case of station Kulpi in monsoon condition. Water level is totally declined at 6:00a.m when water level is measured as low tide was 0.59m. Then it is starting to rising of water at around 7:50a.m and thus is taking to be highest water level at 6.53m At 10:05p.m. So rising of water is to be taken only 4hrs 05mins and the range of tide is 5.94m. In case of Kulpi rising rate of tide is 1.456m/hr and the falling rate of tide is 0.736m/hr.

At the phase of full moon in case of station Kulpi in pre-monsoon condition water level is totally declined at 6:50a.m when ware level is measured as low tide was 0.79m. Then it is starting to rising of water at around 8:40a.m and thus is taking to be highest water level at 6.06m at 10:20p.m. So rising of water is to be taken only 3hrs 30mins and the range of tide is 5.27m. In case if rising rate of tide is 1.506m/hr and the falling rate of tide is 0.565m/hr which can be seen in table: 3

Table:3	Kulpi	
	Monsoon(9.9.2018)	Pre-monsoon(19.4.2019)
Rising rate(m/hr)	1.456	1.506
Falling rate(m/hr)	0.736	0.565
Range(m)	5.94	5.27

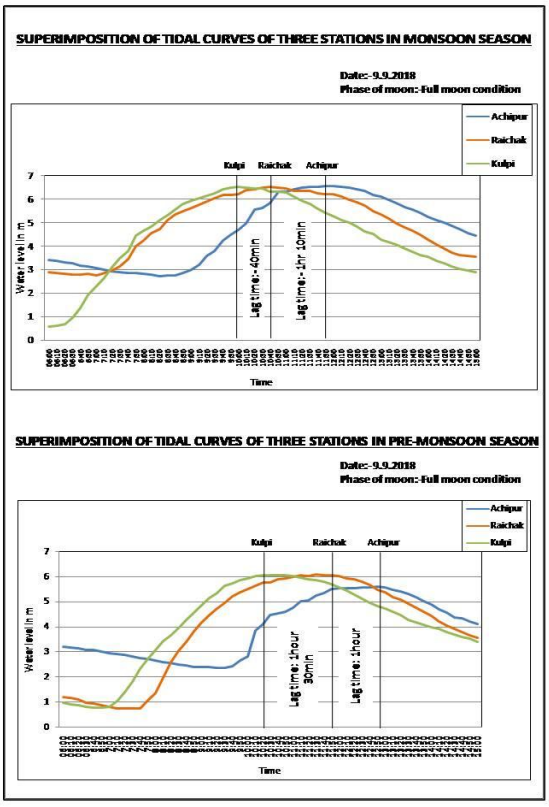
HT time	10:05	10:20
LT line	6:00	6:50

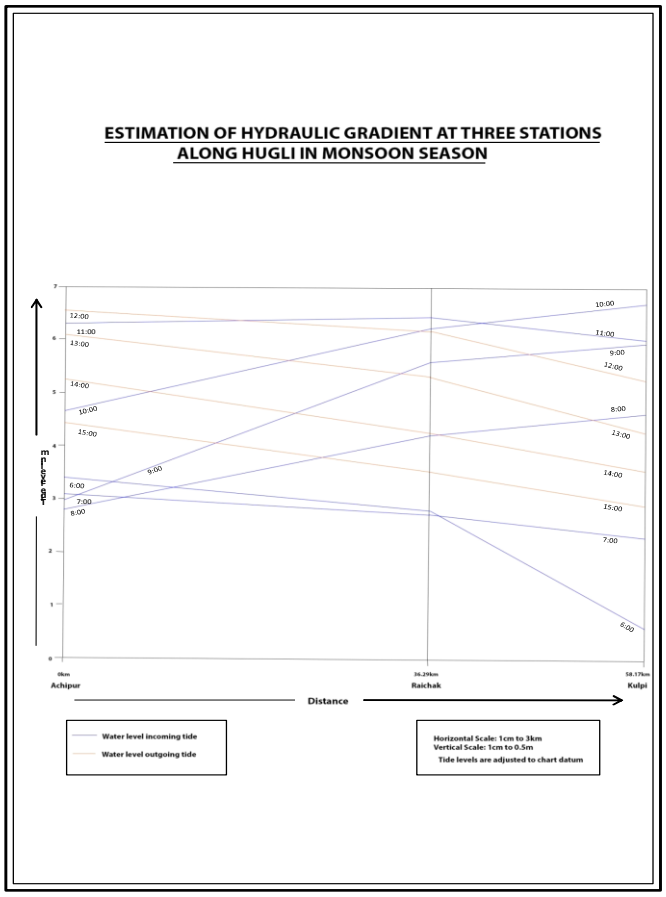


3.2 Superimposition of Tidal Curves of Three Stations

This is the superimposed diagram of water levels curves of three stations of two seasons at the same time have been plotted on excel sheet. In monsoon season, the diagram is showing starts of first rising of water level at Kulpi in the morning 6:10a.m(0.64m). After that water level is increasing up to 10:05a.m. Then water level is gradually decreasing. On the other hand Achipur and Raichak taking too late to rising of water level at the same time. Raichak is taking to start of rising of water level at around 6:50a.m. Then the falling starts from 10:50a.m and Achipur is taking to start of rising of water level at 8:30a.m and falling starts from 12:10p.m. We have been shown that the lag time of increasing of water level with distance. Between two stations of Achipur and Raichak where showing highest peak of water rising of two stations and shown a sharp distance of 36.29km from one station to another which is taking 1hour 10min to reach highest water level. Between two stations of Raichak and Kulpi where showing highest peak of water rising of two stations and shown a sharp distance of 21.88km from one station to another which is taking 40min to reach highest water level.

In Pre-Monsoon season the first rising of water level at Kulpi starts in the morning 7a.m. after that water level is increase up to 10:20a.m. Then water level is gradually decreasing. On the other hand Achipur and Raichak taking too late to rising of water level at the same time. Raichak is taking to start of rising of water level at around 7:30a.m. then falling starts from 12:00p.m. Achipur is taking to start of rising of water level at 9:50a.m. and falling starts from 1p.m. We have shown that the lag time of increasing of water level with distance. Between two stations of Achipur and Raichak where showing highest peak of water rising of two stations and shown a sharp distance of 36.29km from one station to another which is taking 1hour to reach highest water level. Between two stations of Raichak and Kulpi where showing highest peak of water rising of two stations and shown a sharp distance of 21.88km from one station to another which is taking 1hour 30min to reach highest water level.





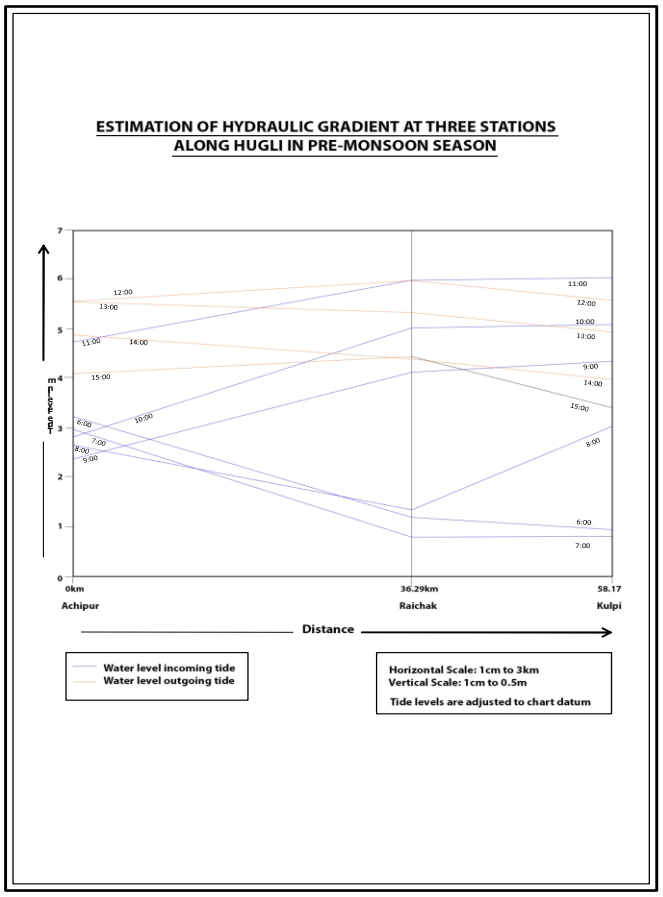
3.3 Hydraulic Gradient

Hydraulic gradient for monsoon season:

Hydraulic gradient for three stations Achipur, Raichak and Kulpi(north to south) has been prepared by showing water level in y axis and distance in x axis. This graph depicts the progressive nature of the tide as the peak is achieved first at the southernmost station Kulpi then it moves northward. The water level is already high Achipur at 6 am while it is ebb at Kulpi hitting the lowest water levels. After an hour water levels starts receding from Achipur and by that time tidal level is high at Kulpi. At 8 am water level at Achipur is lower than Kulpi as the tidal water has started to come out from the northern station and water from the ocean rushes in as it approaches flood tide at Kulpi. Same trend continues till 10 am. The highest water level is reached around 10:00 hrs at Kulpi. At 11:00 hrs it can be seen that both Kulpi and Achipur are having lower water levels than Raichak as highest water level is recorded at Raichak around 10:30 hrs. From 12:00 hrs till 15:00 hrs water recedes from Kulpi as ebb tide is marked. After 11:00 hrs water levels rise at Achipur as the peak is recorded at 12:00 hrs and water levels fall till 15:00 hrs.

Hydraulic gradient for pre monsoon season:

In the pre monsoon season the water level is low at Kulpi at 6:00 hrs and water level lowers till 7:00 hrs as the ebb tide level is marked at 6:50 hrs. After 6:00 hrs water level goes down at Achipur and after 7:00 hrs water level increases at Kulpi. Water level goes down till 10:00 hrs at Achipur as ebb is achieved at 9:30 hrs. Water level goes up till 11:00 hrs at Kulpi. Soon after Kulpi peak is marked at Raichak around 12:00 hrs so water level at this time is high a Raichak and low at both Achipur and Kulpi. From 11:00 hrs to 15:00 hrs water level goes down at Kulpi while water starts to recede at Achipur from 13:00 hrs.



3.4 Interpretation of Suspended Sediment Concentration of three stations

Achipur:

Suspended Sediment Concentration(SSC) at outgoing tide in monsoon condition at Achipur is measured lower is 0.417gm/'000ml at 1p.m. The higher in incoming tide is 2.313gm/'000ml at 10a.m. and this time Bore tide is coming when highest SSC becomes higher.

Suspended Sediment Concentration(SSC) at incoming tide in pre-monsoon condition at Achipur is measured lower is 0.287gm/'000ml at 2p.m. The higher incoming tide is 3.828gm/'000ml at 6a.m. and this time highest SSC become higher.

Raichak:

Suspended Sediment Concentration(SSC) at outgoing tide in monsoon condition at Raichak is measured lower is 0.190gm/'000ml at 6a.m. The higher in incoming tide is 1.949gm/'000ml at 7a.m. and this time Bore tide is coming when highest SSC becomes higher.

Suspended Sediment Concentration(SSC) at incoming tide in pre-monsoon condition at Raichak is measured lower is 0.090gm/'000ml at 7a.m. The higher incoming tide is 3.518gm/'000ml at 2p.m. and this time highest SSC become higher.

Kulpi:

Suspended Sediment Concentration(SSC) at outgoing tide in monsoon condition at Kulpi is measured lower is 0.374gm/'000ml at 10a.m. The higher in incoming tide is 1.014gm/'000ml at 9a.m. and this time Bore tide is coming when highest SSC becomes higher.

Suspended Sediment Concentration(SSC) at incoming tide in pre-monsoon condition at Kulpi is measured lower is 0.151gm/'000ml at 10a.m. The higher incoming tide is 0.782gm/'000ml at 7a.m. and this time highest SSC become higher.

3.5 Bore Tide

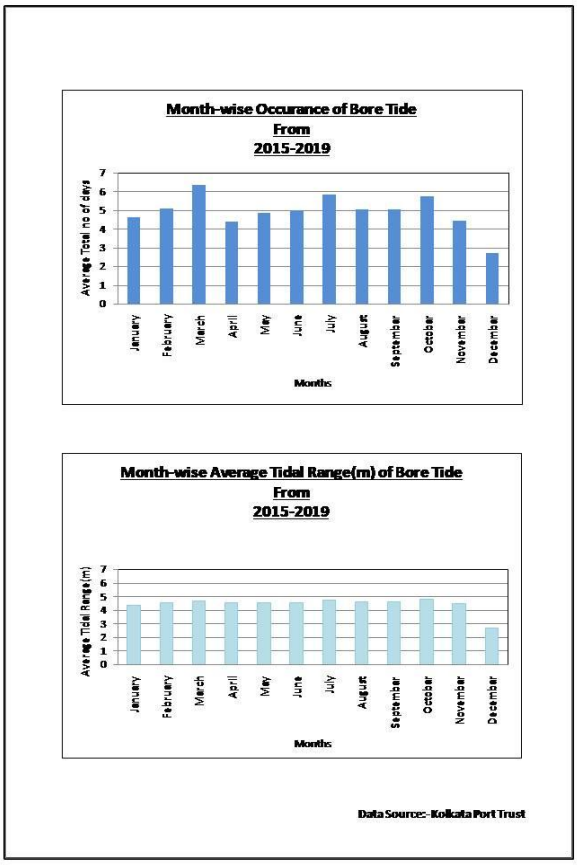
We got a data from Kolkata Port Trust from the year 2015-2019. The occurrence of bore tide came mainly in the months of March, July and October but in December tidal bore did not come in 2015 and 2019, so the tidal range become very low. It is seen that the average range is maintained through the year 2015-2019 at an average range of 4-5m.

Monsoon

We faced the tidal bore in the station Achipur on 9.9.2018. Tidal Bore suddenly came at 9:30a.m. with a high range of water and suspended sediment. Due to this bore the suspended sediment concentration reach 2.313gm/ml, after 1 hour it lasts and reach 1.049gm/ml.

Pre-Monsoon

We again faced the tidal bore in the station Achipur on 19.4.2019. Tidal Bore suddenly came at 10:00a.m. with a high range of water and suspended sediment. Due to this bore, the suspended sediment 1.837gm/ml, after 1 hour it lasts and reaches 1.053gm/ml.



4. CONCLUSION

From the above discussion we can conclude that tidal behavior of Hugli River is dynamic both spatially and temporarily. Tidal range is varying and maximum range is above 5m. Changing of tidal outgoing and incoming water level effects, the variation of average incoming and outgoing sediment. Because in form the above discussion it can be said that the flood velocity is more than the ebb velocity. The hydraulic gradient indicates the faster rate of withdrawal of water at the mouth than the interior lo0cation. At the last time of ebb tide all water passed out through the mouth but Achipur and Raichak which are far from the mouth where some water could not pass out because the flood tide stated(progressive condition). Thus the suspended sediments are getting time to deposit in flood tide condition.

The deepest portion is the near the mouth and towards the bank it becomes shallower. This result may sediment deposition. From these indications it can be concluded that siltation problem increase towards the interior the river. But it may be temporarily sort by dredging processes which is helping the river to flush out water and sediment.

Incoming water level is increasing more than outgoing water level so a large volume of sediment is entering in high tide relatively less amount of sediment goes out from the river and all the discussion reveal that rising rate is more than falling rate and tidal range asymmetry in flood tide and ebb tide are also changing with season.

After interpreting the tidal data for the three stations for monsoon and pre monsoon season it can be concluded that overall water level remains higher for all three stations in the monsoon season very obviously due to addition of rainwater. Individual graphs for these three stations for both the season also shows the same trend. It is interesting to note that highest water level remains a little higher (6.56m) at Achipur in monsoon than than the rest two stations(6.53 m) but highest water level remain lowest (5.61m) at Achipur in the pre monsoon season.

Range of tide is higher in monsoon season for two stations Raichak exceptionally recorded higher range in pre monsoon season (5.32m). Among the three stations range is highest in Kulpi(5.94m) in both the seasons. Raichak is showing the lowest range (3.78m) in monsoon season.

Due to the progressive nature of the tide the water achieves the peak first at the southern most station Kulpi then the water rushes upstream. In the monsoon season there is a lag of 1hour 40 min between the northernmost station Achipur and southernmost station Kulpi. While in the pre monsoon season is greater and about 2hour 30 min.

Suspended sediment concentration is high in pre monsoon season than monsoon season and Achipur the northern most station has highest concentration in both seasons. The monsoon season Achipur recorded the highest suspended sediment concentration while Raichak had the lowest sediment concentration. In the pre monsoon season also Achipur recorded the highest suspended sediment concentration while Kulpi has the lowest rates.

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