**FLOOD IN THE LOWER DAMODAR BASIN AND CHANNEL MORPHOLOGY: A CASE STUDY AT THE BIFURCATION ZONE INTO DAMODAR AND MUNDESWARI RIVER, WEST BENGAL**

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**ABSTRACT**  
River is a dynamic and important part of physical environment, where erosion, transportation and deposition done by exchange of energy and matter. Behavior of river at a cross-section and in its downstream reflects the integrated effect of channel and fluid dynamics. Space and time are two independent factors which control river characteristics through process and form. Riverine Flood is not a process or form, rather than it is a combined event of process and form with high discharge at a particular point and its downstream where channel runoff exceeds carrying capacity of channel. Spatial interpolation technique has been used to study which focus the effect of channel Morphology on the flood of the Damodar River at the bifurcation zone of Damodar and Mundeswari River, West Bengal. Application of Topographical map, ASTER data, LISS-III Image and field measurements are the main sources of the interpretation.

**Keywords:** Flood; Channel Morphology; Bifurcation; Channel Shifting; Channel Bars

**INTRODUCTION**  
River Damodar rises in the Palamau hill of Jharkhand plateau at an elevation of about 609.57 meter from Mean Sea Level (Sen, 1991; Chandra, 2003; Bhattacharyya, 2011). It flows south-easterly direction entering the deltaic plains below Raniganj. Near Chanchai (some 38km below Burdwan town), the river abruptly changes its course to a southerly direction and it is bifurcated into the Kanki-Mundeswari and the Amta-Damodar channel and also joins with the Hooghly River at Faulta some 48.27 km below Calcutta. Its slope for the first 241.35 km is about 1.89 m/km, for the next 160.9 km about 0.568 m/km and the last 144.8 km it is about 0.189 m/km. The total length of the river is nearly 547 km and a total drainage basin area is 23683.43 sq. km. The principal tributary Barkar joins the Damodar after travelling for about 241 km. Damodar basin lies in the states of Jharkhand and West Bengal. Flood is a common phenomenon in lower Damodar Basin. Both natural and anthropogenic causes are responsible for flood. This work is mainly concentrated in the river geomorphology and flood in the bifurcation zone of Damodar River for devastating flood in lower Damodar basin.

**MATERIALS AND METHODS**  
Explanation of past, present and future of any geomorphological event require a particular approach and methods for analysis. The following methods have been applied in this study. Field observation involves qualitative as well as quantitative method of data acquisition (Singh, 1998). The data has obtained through extensive field observation in the form of numerical and informative are given below.

a) Measurement of channel geometry in the study area has been done by analyzed long and cross profile of the river and bed configuration by GPS survey.

b) Calculation of present condition of the channel morphology.

c) Measurement of embankment condition in the study area by the quantitative analysis of slope.

d) Measurement of channel fluid dynamics to analysis the flow pattern has been done by using discharge equation. (Q = A*V, where. A = area and V = Mean velocity at a cross section).

Discharge (Q) is the function of Area (A) and Velocity (V) of any particular cross-section.  
\[
Q = (A \cdot V) \text{ in m}^3/\text{s}
\]
Research Article

And as discharge is equal to the carrying capacity of the channel, so in occurrence of flood, discharge plays an important role. In this work, to calculate the discharge data, we have used the Dury’s formula.

\[ Q = W^{1.18} \text{ or } Q = (0.83A)^{1.09} S \]

\[ Q = (W^{2.99})^{1.18} \]

\[ Q = (0.83A)^{1.09} S \]

\[ ... \quad (Dary, 1976) \]

Manning’s equation has been used to calculate the flow velocity (V) in lower Damodar River and the Manning roughness coefficient (n) may be taking as 0.035 for Manning equation as it is a regular large channel (width > 30m) with lacking boulders or vegetation.

\[ V = K \left( \frac{R^{2/3} S}{n} \right) \]

Manning Equation (1889) \[ V = K \left( \frac{R^{2/3} S}{n} \right) \]

Beided Index has been used to know the changing channel bed configuration and bed roughness.

\[ BI = \frac{2 \text{ sum of length of all islands or bars in a reach}}{\text{length of reach measure midway between banks of channel belt.}} \]

Informative data are collected through perception survey of local people. These are

a) How was the river characteristic at past?

b) What is the present condition of the River?

Laboratory observation involves experimental and laboratory based work, helps us to conceptualize the processes, generation of data, mapping of data which are constructed from the field. Microsoft office 2007, Arc GIS 9.3, Erdas Imagine 9.1, Google Earth, Bhuvan (ISRO) are the main softwares that havebeen used in this purpose. Official observation involves different source of data in the form of qualitative and quantitative format, which has been used to analyze the research work.

Data processing, data analysis, interpretation and future prediction involve in this stage. In this work hydraulic geometry, channel geomorphology of the Damodar River and flood vulnerability in the study area has been calculated. For this study several types of maps, data, literature and photographs are used.

Study Area

The study area is a part of Riverine depositional plain which is known as paradeltic surface of Damodar basin. On the basis of physiographic division of West Bengal it comes under the Ganga-Damodar depositional plain. Elevation of the study area is varying from 12 m to 25 m above mean sea level. Geologically the floodplain of this area belongs to the west of the Bengal Basin and geomorphologically it is a mature delta sloping towards east – south east. Regional stratigraphy reveals that three Quaternary formations are found here, viz. Sijua, Chuchura and Hooghly formation/surface. From the relationship between different litho-unit the tentative local stratigraphy has been given below. Q1-2 s Sijua formation is the older formation. Floodplain of Khari, Banka and Damodar River, having undulating terrain, composed mainly by hard, sticky, brownish to yellowish grey clay enriched with “caliche” with small rounded ferruginous concretion (iron oxide concretion). Chuchura Formation occupies the southernmost low lying area including Bardhaman town along the left bank of Damodar properly (Ghosh, 2012). Hooghly Formation comprises recent sediments on present day floodplain of Damodar and its tributaries and channel bars on Damodar River (Figure 4.2). Panchet Formation, Super Panchet Formation, Debrajpur Formation, and Rajmahal Formation are the major groups of formation at the Damodar Valley basin of Upper Gondwana Sequence. The formation comprises a succession of alternating bands of felspathic, micaceous and cross bedded sandstone, thin beds of shales and variegated clay beds (Kumar, 2006). Lower Gondwana Sequences in the Damodar Valley is known as Damoda Group consists of over 2000 meter thick cyclic succession of conglomerates, grits, sandstone, and black shales in cyclic order. The Damoda Group has been subdivided in the
Damodar valley type area into three formation, viz., Barakar Formation (Lower Permian), Kulti Formation (Upper Permian) and Raniganj Formation (Upper Permian) (Kumar, 2006).

According to Chatterjee (1969), the lower Damodar basin has seven soil groups, viz. Damodar Highland, Damodar Flatland, Damodar Rajmahals and Kasai Riverine, Red Soil, Laterites, Ganga Flat land and Ganga low lands (Ghosh, 2012,)

These two rivers are non-perennial in nature and flow discharge is very low through the year except monsoon season. In the monsoon period this two rivers, particularly lower catchment area are not able to carry the total flow of the catchment area. So the main objectives of this paper are;

1) Measurement and Calculation of present condition of the channel morphology.
2) Measurement of channel fluid dynamics in the study area for analysis of the flow pattern.

RESULTS AND DISCUSSION
Long Profile Morphology and Planimetric Characteristic
River increase in size at downstream, as tributaries increase the contributing draining area and thus the discharge increases (Leopold, 1969). Channel width and depth with the downstream, bed particle size decrease and the gradient generally flattens. River longitudinal profile is such a graph of which height (H) is plotted against downstream length (L), simply expressed by formally as \( H = f(L) \) (Knighton, pp-147). so it is the curve showing the elevation of the valley and correspondent distance from the source to the mouth (Sen, 1993) and in general long profile is concave to the sky.
So channel bed slope is closely related to the long profile of river bed and it is very important parameter of channel morphology. Angle of the long profile control the movement of water flow at a particular point, especially at downstream. For the analysis of flood and long profile in the study area data is taken from SRTM image.

Long profile of the lower Damodar shows a remarkably low gradient of only 0°1΄ Slope and discharge are proportionally related to each other, \( s \propto Qm \) (Knighton, 1987) and the low gradient of lower Damodar indicate low discharge in its downstream. During the period of monsoon, low discharge creates water pressure in channel bank and cause of spill over of water into adjacent floodplain area.

**Flood Frequency and Flood Probability Analysis of Lower Damodar Basin**

First recorded flood was in 1730. Since then, 37 floods of different magnitudes have occurred in every 8 to 10 years with a peak flow of 8496m³/s or more, between the years 1823 to 2007 (Bhattacharyya, 2012). probability of largest flow (between 1958 to 2007) occurring is 1.96% or 0.0196, i.e. 1.96 flows out of 100 flows will be equal to or higher than the largest discharge of the next 50 years.

Figure 5.1 shows the plot of flood discharge data and from it we can find that the mean flood flow is 3597.39 cumecs and the probability of the recurrence interval of highest flow which occurred 1/p=1/0.0196=51 years, it is the pre dam recurrence interval of the highest flood of lower Damodar basin. From the flood probability diagram it shows that the probability of mean discharge flow is about 0.45 or 45%, so the recurrence interval is 1/0.45=2.27 years.

It has been found by study of data that once in every 2.33 years an average highest flow of the year will equal or exceed the mean of the flood over a long time (Smith and Stopp, 1984). It has been found from the calculation of discharge data that the recurrence interval of average flood flow is 2.27 which is almost equal to 2.33 years.
Figure 4: (a) Cumulative curve flood discharge and (b) Correlation between flood discharge and recurrence interval

From the cumulative curve of flood discharge (Figure 4 and table 1) it is possible to say that the 50% mean value of cumulative flow is around 2600 cumecs and the flow more than 3597.39 cumecs (average discharge from 1958 to 2007) are very much less, e.g. 70% or 70 years out of 100 years flood discharge does not exceed 3597.39 cumecs and only 10% of the years discharge exceed 6500 cumecs. Only 20 flows out of 100 floods flow discharge will be between 3600 cumecs – 6500 cumecs.

Table 1: It is possible to conclude that the probability of flood recurrence in future at lower Damodar River or basin with an average flow of greater than 3600 cumecs is 2.27 years

<table>
<thead>
<tr>
<th>Flood discharge</th>
<th>Recurrence interval</th>
<th>‘r’ value</th>
<th>Degree of freedom</th>
<th>Calculated ‘t’ value</th>
<th>Tabulated ‘t’ value at significant level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.8216</td>
<td>(50-2)= 48</td>
<td>9.98</td>
<td>2.68 (1%)</td>
</tr>
<tr>
<td>Flood discharge</td>
<td>Recurrence interval</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of Channel Geomorphology and its Relation with Flood
It is clearly identified that width gradually decreases towards the confluence point. Near the Paikpara average width of the channel is 140 meters, and at Sonargoria, Pursurah and confluence point (Falta) it is 140 meters, 130 meters and 150 meters respectively (width of Amta channel). On the other hand, width of
Mundeswari River at Horinkhala is 400 meters, at Digruighat it is 250 meters and 500 meters at confluence point with Rupnarayan.

**Table 2: Discharge Capacity at Different Cross-Section of Damodar River**

<table>
<thead>
<tr>
<th>Cross-Section Line</th>
<th>Width (W) in m.</th>
<th>Average Depth (d) in m.</th>
<th>Cross-Section Area (A) in sq.m.</th>
<th>Standard Sinuosity Index (s)</th>
<th>( Q = \left( \frac{W^2}{2.99} \right)^{1.18} ) (in cumecs)</th>
<th>( Q = (0.83A)^{1.09}S ) (in cumecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>640</td>
<td>6</td>
<td>3840.00</td>
<td></td>
<td>16528.02</td>
<td>7377.90</td>
</tr>
<tr>
<td>C-D</td>
<td>370</td>
<td>4.5</td>
<td>1665.00</td>
<td></td>
<td>6190.28</td>
<td>2967.25</td>
</tr>
<tr>
<td>E-F</td>
<td>400</td>
<td>5.5</td>
<td>2200.00</td>
<td>1.12</td>
<td>7059.33</td>
<td>4020.26</td>
</tr>
<tr>
<td>G-H</td>
<td>143</td>
<td>3.8</td>
<td>543.40</td>
<td></td>
<td>1096.96</td>
<td>875.57</td>
</tr>
<tr>
<td>I-J</td>
<td>670</td>
<td>3.6</td>
<td>2445.50</td>
<td></td>
<td>17956.87</td>
<td>4510.62</td>
</tr>
</tbody>
</table>

*Source: Field Survey, 2013*

**Table 3: Estimation of Bank-full Discharge of Damodar River at the Bifurcation using Manning Equation**

<table>
<thead>
<tr>
<th>Cross-Section Site</th>
<th>Width (W) in m</th>
<th>Hydraulic Radius (R) in m.</th>
<th>Slope (s) in m/m.</th>
<th>Manning roughness coefficient (n)</th>
<th>Manning Equation (v) in m/s</th>
<th>Cross-Section Area= W.d</th>
<th>Discharge (Q=A.v) in m3/s</th>
<th>Discharge (after minimized the 40% error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>640</td>
<td>6</td>
<td></td>
<td>12.18</td>
<td>3840.0</td>
<td>43839.36</td>
<td>17535.74</td>
<td></td>
</tr>
<tr>
<td>C-D</td>
<td>370</td>
<td>4.5</td>
<td></td>
<td>10.04</td>
<td>1665.0</td>
<td>16716.6</td>
<td>6686.64</td>
<td></td>
</tr>
<tr>
<td>E-F</td>
<td>400</td>
<td>5.5</td>
<td>0.01</td>
<td>0.035</td>
<td>2200.0</td>
<td>25256</td>
<td>10106.00</td>
<td></td>
</tr>
<tr>
<td>G-H</td>
<td>143</td>
<td>3.8</td>
<td></td>
<td>8.96</td>
<td>543.40</td>
<td>4877.05</td>
<td>1950.80</td>
<td></td>
</tr>
<tr>
<td>I-J</td>
<td>670</td>
<td>3.6</td>
<td></td>
<td>8.74</td>
<td>2445.5</td>
<td>21366.33</td>
<td>8546.53</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Field Survey, 2013*

From this table (Table 2 & 3) and figure (Figure 5 A & B) it is clear that after bifurcation of Damodar River (near Paikpara) the cross sectional area has decreased. Decreasing cross sectional area of lower Damodar River are responsible for flood in the study area as well as its downstream because cross sectional area are related to the carrying capacity of the channel. Discharge is a product of channel geometry which is equal to the carrying capacity at a particular cross section and as discharge is higher than the carrying capacity of lower Damodar River, so floods frequently occur in the study area and it’s downstream.

If we consider velocity as constant, then with decreasing area of lower Damodar River carrying capacity proportionally decrease up to the confluence point.
Near Paikpara discharge capacity of the channel is 17535.74 cumecs but just after bifurcation it is 8,546.53 cumecs and 1950.80 cumecs for Mundeswari River and Amta channel respectively. And the total carrying capacity of these two rivers is 10497.33 cumecs.

So the channel Damodar, after its bifurcation is not able to carry this huge amount of water and as a result flood occurs almost every year in lower Damodar basin.

If we look about the relationship of different variable of channel geometry, it is clear that all are in moderately positive relation, as for example, the co-relation (r) between discharge (Q) and channel width (W) as well as discharge (Q) and depth (d) are 0.766 and 0.506 respectively (Figure No. 5,A & B). So, it is clear that,
Spatial Pattern of Channel Shifting, Channel Bed Morphology and its Relation with Flood

Figure 5: (a) Changing course of Damodar river and (b) Erosion and deposition of sand bar

Table 4: Braiding Index of Lower Damodar River from Jamalpur to Amarpur (1972-2001)

<table>
<thead>
<tr>
<th>Year</th>
<th>Braiding Index (BI) from Jamalpur to Amarpur</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>1.37</td>
</tr>
<tr>
<td>1990</td>
<td>1.50</td>
</tr>
<tr>
<td>2001</td>
<td>1.79</td>
</tr>
<tr>
<td>2011</td>
<td>1.99</td>
</tr>
</tbody>
</table>
After analysis of braiding index and sand deposition on river bed, we have been found that (Table 4 & 5 And Figure 5).

(i) Increasing length, number and depositional area of bars are responsible for more braiding, channel degeneration and decreasing channel depth cause decreasing caring capacity of river. As a result lower Damodar River has flooded in rainy season.

(ii) Increasing area of bars cause increasing bed roughness which increase the intensity of sand deposition at the time of flood and after flood.

(iii) From 1972 to 2011 increasing braiding index and from 1936 to 2011 increasing river bed depositional area indicates degeneration of Damodar River.

(iv) Mouth of the Mundeswari River has blocked by sand deposition. After 2001 River Mundeswari completely dry except rainy season.

(v) Right bank of the river more eroded than left bank.

**Conclusion**

Floods in the lower Damodar Basin have been almost an annual occurrence in the consequence of high discharge. Damodar is a well known famous river in South Bengal due to its devastating flood. In lower Damodar basin, after its bifurcation into Amta channel and Mundeswari River, flood is a common phenomenon every year. This zone characterized with high flood intensity and frequent floods. In my research observation the major causes of flood are:

(i) Funnel shaped river basin with 23683.43 sq. km area; generate huge runoff in the catchment area during the monsoon period which cross the discharge capacity of Mundeswari and Amta channel and spill over into the surrounding flood plain area.

(ii) Carrying capacity of channel depends on width and depth of channel. In case of lower Damodar basin, Channel width and depth of both river decrease towards the confluence point. Channel gradient is remarkably low and the concentration of sediment in the mouth of Mundeswari River obstructs the flow, which reduce the velocity of running water and create flood situation.

Now, in present day’s different discipline follow different approach for flood maintenance, we should follow the eco-centric approach in the flood management. Therefore, in case of flood management non-structural measures are the important method. In that time, for flood management planning requires right information about the channel geometry and floodplains, particularly the identification of floodways in relation to local geomorphology. We should try to reduce the vulnerability of flood by introducing the proper lifestyle and proper steps should be taken during the pre-flood, flood and post-flood. In Flood Management, approach should be to encourage the philosophy of ‘Living with floods’. Flood control is not possible completely. Therefore, we need to reduce the ‘Intensity of flood’ by modifying the channel carrying capacity, flood forecasting, flood warning, flood insurance, general information, education and flood relief.

I. To decrease the flood risk, we need to reduce the surface runoff by increasing infiltration through appropriate afforestation in the catchment area, limiting discharge by developing detention basin and reservoir by contracting a series of check dams.

II. Encroachment of flood ways should not only be discouraged but banned.

III. Classification of flood prone area, the natural water regime of river and the past occurrences of floods should be intimately studied.

From the above research work it can be concluded that channel morphology of lower Damodar River influence the magnitude and intensity of flood.
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