Indexing vulnerability of an embankment reach against breaching: A remote sensing and hydrodynamic based study

B. Talukdar*, A. Baid and R. Das
Civil Engineering Department, Assam Engineering College, Guwahati, Assam, India
‘e-mail: bipulaec@gmail.com

Abstract: Floods of high magnitude are one of the major problems in the north-eastern region of India. Approximately 4464 km of embankments are being constructed in the Brahmaputra basin itself. The embankments are highly vulnerable to flood and flood disaster for embankment breaching is frequent in Assam. Remote Sensing data of a river system of highly unstable bank has been analyzed in GIS environment for identification of river bank erosion as well as reaches of embankment vulnerable to breaching. A case study was carried out in the Nona River, a tributary of river Brahmaputra, to identify reaches of embankment vulnerable to breaching during the flood time. Temporal dataset of satellite imagery for several years along with the topographical maps from Survey of India (SOI) were used for mapping the flow channel of river Nona. Based on the degree of convergence and narrowness between the flow channel and embankment observed from the digitized images of Nona River from 1999 to 2014, some reaches of embankment which are vulnerable to breaching were selected for the study. Hydrodynamic analysis by MIKE 21C – Curvilinear Flow Model was conducted on those vulnerable reaches in order to validate whether the embankment is going to breach due to change of flow pattern of the river observed from the digitized images of the river. Results obtained from remote sensing data and flow velocity profile from hydrodynamic analysis were split into different categories ranging from 0 to 10 which indicate the vulnerability of an specific embankment reach against breaching.

Key words: Vulnerability, Embankment, Breach, Hydrodynamic

1. INTRODUCTION

Floods of high magnitude are one of the major problems in the north-eastern region of India. Heavy flooding causes abrupt changes in the flow pattern of the rivers. The river Brahmaputra shows significant amount of erosion and deposition in the basin. The study area i.e. the Nona River Basin is a major tributary basin of the Baralia river catchment Brahmaputra basin in India.

Embankments are the structures constructed parallel to the river utilizing mostly the materials in situ. Due to the meandering nature of the river, the geometry between the flow channel of the river and the embankment does not remain parallel to each other. More the angle between these two more the thrust of water flow on the embankment resulting high probability of embankment breaching.

Integration of Geographic Information System (GIS) to RS, make it appropriate and ideal for studying and monitoring of river bank erosion, changes of channel configuration and the orientations between the river channel and its embankments. Various studies in this regard have been carried for some major rivers (Surian 1999, Yang et al. 1999, Fuller et al. 2003, Li et al. 2007). Several investigators have been used RS data for mapping and ascertaining the channel changes of different rivers in the world (Bardhan 1993, Naik et al. 1999, Gogoi and Goswami 2014).

2. METHODOLOGY

Resourcesat - 1-IRS-1D LISS III imagery obtained from North Eastern Space Application Centre, Shillong, Meghalaya have been used in this study. To study the changes in the flow pattern of the Nona River, five different year data over a span of seven years (1999-2006), six years (2006-2012), one year (2012-2013-2014) have been considered so that short as well as long term
flow pattern change in the Nona River can be seen.

First, geo-referencing of all the LISS III images were carried out with reference to the ground co-ordinates of Survey of India (SOI) Topographical maps 78-N-10 and 78-N-11 (Toposheet) in ERDAS Image Processing Software.

After geo-referencing, digitization of Nona River for each LISS III images was carried out using ArcGIS in scale of around 8000-10000 and considering standard RGB Composite as 3 2 1 and geographic coordinate system of WGS 1984. Using the Google Satellite Image, latest outline of embankment of Nona River has been digitized as shown in Figure 1.
3. IDENTIFICATION OF VULNERABLE EMBANKMENT REACHES

Identification of embankment reaches which are vulnerable to breaching due to bank erosion is carried out based upon the change of flow pattern of river towards the embankment observed from the digitized images of Nona River from 1999 to 2014 (Talukdar and Das 2015).

From the digitized images of river, fourteen vulnerable points as shown in table number 1 were selected and from each points distance were measured from the bank line to the embankment for all selected years i.e. 1999, 2006, 2012, 2013 and 2014.

4. VALIDATION OF VULNERABLE POINTS USING DHI MIKE 21-C

From those vulnerable reaches, a part of river channel was selected for the simulation in MIKE 21C –Curvilinear Flow Model containing three vulnerable points i.e. 1, 2, and 9 as shown in Figure 2, in order to validate the remote sensing data observed from the digitized images of the river (DHI 2014).

The effective area under consideration is 1100 m x 650 m. The individual cells and grid points (a cell being what is defined by four grid points in the corners of the cell) are addressed by indices j and k. The whole study area is covered by the grid, having 100 × 60 cells, so j = 0-98 and k = 0-58, j being used in the direction of the rivers and k is across the river. Thus each cell dimension being 10 m x 12 m. A view of the generated grid in MIKE 21C is shown in Figure 3. For making bathymetry, depth value from bathymetric survey and corresponding contour map has been given at each cell as input (Deka 2014, Purkayastha 2014).

![Figure 2. Vulnerable section used in MIKE 21 and satellite image of the site.](image)

Hydrodynamic calibration and model validation is done by first simulating the present condition and then by comparing discharge values at upstream inlet section 1-1 and at downstream outlet section 2-2, which shows good agreement with each other. This indicates that the model is stable and continuity is maintained. Next the velocity profile around the vulnerable area near upstream side is observed and is found to be near the range of observed maximum velocity of 1.7 m/s at vulnerable points.

5. RESULTS AND DISCUSSION

The digitized images of multi date satellite images showed variation in the fluvial features. From this data it was very clear that both the banks have simultaneously undergone erosion and deposition which is clear from Figure 1.

From MIKE 21C it was observed that around point 1 and 2, the velocity of the river is around 1.5 to 2.0 m/s having a discharge of 160 m³/s whereas at point 9 it is varies from 0.45-1.2 m/s.

Results obtain from remote sensing data and flow velocity profile from MIKE 21C, the
vulnerable points can be split into different categories ranging from 0 to 10 (Table 1) which will indicate the vulnerability of embankment breach based on the degree of convergence and narrowness between the flow channel and embankment observed from the digitized images of Nona River.

![Diagram of Nona River embankment](image)

Table 1. Vulnerability index of various points.

<table>
<thead>
<tr>
<th>Vulnerable Points</th>
<th>Distance from the Embankment</th>
<th>Vulnerability</th>
<th>Range 0 to 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10.3845</td>
<td>Very Highly Vulnerable*</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>10.6547</td>
<td>Very Highly Vulnerable</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>14.3141</td>
<td>Highly Vulnerable*</td>
<td>9.5</td>
</tr>
<tr>
<td>4</td>
<td>20.0563</td>
<td>Vulnerable</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>22.6116</td>
<td>Vulnerable</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>24.7652</td>
<td>Vulnerable</td>
<td>7.5</td>
</tr>
<tr>
<td>11</td>
<td>27.9931</td>
<td>Moderate Vulnerable</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>30.8302</td>
<td>Moderate Vulnerable*</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>39.8443</td>
<td>Low Vulnerable</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>42.4196</td>
<td>Low Vulnerable</td>
<td>5.5</td>
</tr>
<tr>
<td>14</td>
<td>46.8441</td>
<td>Low Vulnerable</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>55.4613</td>
<td>Low Vulnerable</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>56.0845</td>
<td>Low Vulnerable</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>59.7736</td>
<td>Low Vulnerable</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Based on the degree of convergence and narrowness between the flow channel and embankment observed from the digitized images of Nona River, Point 1 and 2 are Highly Vulnerable as their distance from of bank line is less than 10m and if the velocity of the river is around 1.5 to 2.0 m/s during monsoon season based upon the simulation of MIKE 21-C, there is a chances that embankment near to the point 1 and 2 may get breached.

6. CONCLUSION

The method may be a good tool for predicting embankment vulnerability to breaching as well as understanding the problems caused by continuous change in the fluvial patterns of the river channels, amount of bank erosion, rate of sedimentation which can be implemented for planning of river bank protection work and preparedness in flood prone state like Assam.

REFERENCES


