

# Evaluation of Non-structural and Structural Flood Management Measures

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**Abstract—** The flooding can have ruinous impacts on the society and the environment. The cities are mostly located on the banks of rivers, coasts or in the valleys. Urbanisation leads to developed catchments which are densely populated and are centres of economic activities with vital infrastructure. The loss of assets is directly related with flood exposure. The thorough knowledge of flood exposure helps in developing effective flood management measures. In the present study flood exposure analyses is performed by using GIS tool. The land use and flood map data is integrated in GIS framework to develop flood exposure map. Flood exposure map can be used to compute the flood losses at different locations in the watershed. The existing non-structural flood management measures are evaluated using the flood losses. To protect the lives and properties, structural flood management measure is proposed and evaluated. The proposed methodology is developed for Upper Godavari basin of Nashik city in Maharashtra of India.

**Key words:** Urbanisation, flood exposure, land use patterns, GIS, Non-structural and structural flood management measures, flood losses.

## I. INTRODUCTION

Flooding is a natural and recurring phenomenon. "Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff" [1]. A flood can be defined as "a temporary covering by water of land normally not covered by water" [2]. This includes floods from rivers, floods from heavy rain and floods from the sea.

### Causes of flooding

The flooding can be caused by natural as well as anthropogenic activities. The factors that causes flooding are mainly meteorological, hydrological and human factors and are shown in table below.

Table 1. Causes of flooding [3]

METEOROLOGICAL FACTORS	HYDROLOGICAL FACTORS	HUMAN FACTORS
<ul style="list-style-type: none"> <li>• Rainfall</li> <li>• Cyclonic Storms</li> <li>• Temperature</li> <li>• Snowfall/ snowmelt</li> </ul>	<ul style="list-style-type: none"> <li>• Soil moisture level</li> <li>• Ground water level before storm</li> <li>• Natural surface infiltration</li> <li>• Presence of impervious cover</li> <li>• Channel cross-sectional slope &amp; roughness</li> <li>• Presence or absence of over bank flow, channel network</li> <li>• High tide impeding drainage</li> </ul>	<ul style="list-style-type: none"> <li>• Land use change</li> <li>• Occupation of flood plain obstructing flows</li> <li>• Inefficiency/non maintenance of infrastructure</li> <li>• Climate change affects magnitude and frequency of precipitations and floods</li> <li>• Lack of flood control measures</li> <li>• Multiple authorities in the area but owning responsibility by none</li> </ul>

Flood losses: The flood losses can be categorized as

- 1) Direct losses– Losses due to direct contact with flood water, to buildings and infrastructure, crops and animals.
- 2) Indirect losses– Losses resulting from the event but not from its direct impact, e.g. transport disruption, business losses that can't be made up, losses of family income, utility supplies and communication losses etc.
- 3) Tangible losses– Loss of things that have a monetary value, for e.g. buildings, livestock, infrastructure etc.
- 4) Intangible losses– Loss of things that cannot be bought and sold, for example, lives and injuries, heritage items, increase in ill health, homelessness, loss of livelihood etc. [3]

Flood management measures:

The ultimate aim of flood management is to minimize human losses and economic damages, while making use of the natural resources for the benefit and well being of the people.

These are of two types, structural and non-structural as shown in table below,

Table 2: Structural and non-structural flood management measures [4]

S.No.	STRUCTURAL FLOOD MANAGEMENT MEASURES	NON-STRUCTURAL FLOOD MANAGEMENT MEASURES
1	<i>Storage and detention reservoirs</i>	<i>Flood plain zoning</i>
2	<i>Flood embankment</i>	<i>Flood forecasting/warning</i>
3	<i>New flood channels</i>	<i>Evacuation and relocation</i>
4	<i>Channel improvement</i>	<i>Flood insurance</i>
5	<i>Watershed management</i>	

Objectives of the study

- 1) To develop flood exposure map by integrating the landuse and flood map data in a GIS framework.
- 2) To evaluate non-structural flood management measure.
- 3) To evaluate structural flood management measures.
- 4) To propose structural flood management measures.

## II. METHODOLOGY

The GIS based flood information provides detailed information on flood exposure and flood management measures to different users. The flood management measure to adopt is decided after evaluation of the measures. The flow chart below shows the methodology used for the development of flood management measures.

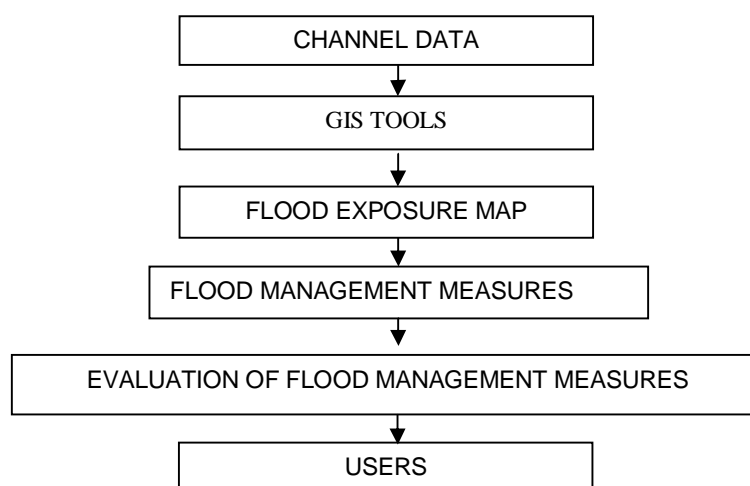


Fig.1.:Flow chart for development of flood management measures

## III. CASE STUDY

Nashik city is situated on the banks of river Godavari and its tributaries in the state of Maharashtra. It is developed on both the banks of river Godavari and extends east west along the banks of river and its sub-tributaries. Total area of Nashik municipal corporation is 264.23 sq.km and height from M.S.L is 1001 mt. Population of Nashik city is 14.86 lakhs (census 2011). Gangapur dam which is the nearest storage dam is at 15 km away from Nashik city. To cater the growing need of tourists and industries, hotels and lodges have been constructed on both the banks of river disturbing the original channel. New development such as residential colonies, schools, colleges, is also taking place along the river banks. Also slum settlement has taken place at number of places.

Flood plains previously used for agriculture are now converted into plots for the construction of buildings. In many areas river width is less than 60 meters. During monsoon the discharge in river Godavari increases and creates problems in low lying areas on the banks of river. Heavy rains in 2005, 2006, 2007, 2008 and 2009 [5,6] have created flooding problems in Nashik city due to large discharge of water from the dam. The shifting of affected people and submergence of houses is every year's problem.

Channel data –The channel data is prepared by demarcation of study area features.The study area is between the Indraprastha bridge and Kanmwar bridge of Nashik city.Inbetween there are areas near Ramwadi bridge, Ahilyabai Holkar bridge,Gadge Maharaj bridge.

The study area features i.e.residential buildings, slums, open plots, farmland, roads, bridges, flood lines (blue and red lines) and Godavari river banks are marked.The map below shows the demarcated features in the study area.

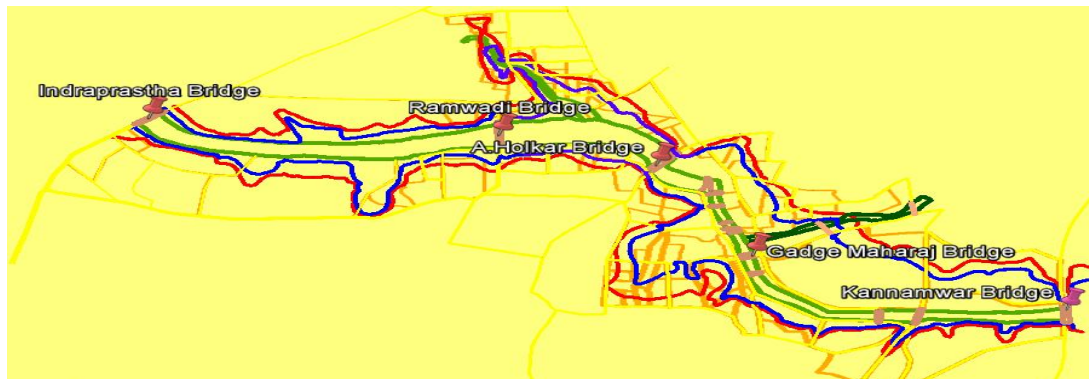


Fig.2 Map of demarcated features in the study area.

*Flood exposure map* - The demarcated map of the study area is used to develop flood exposure map.It gives the types of landuse patterns and areas of the residential buildings, slums, open lands and farmlands.The figure below shows the flood exposure map.

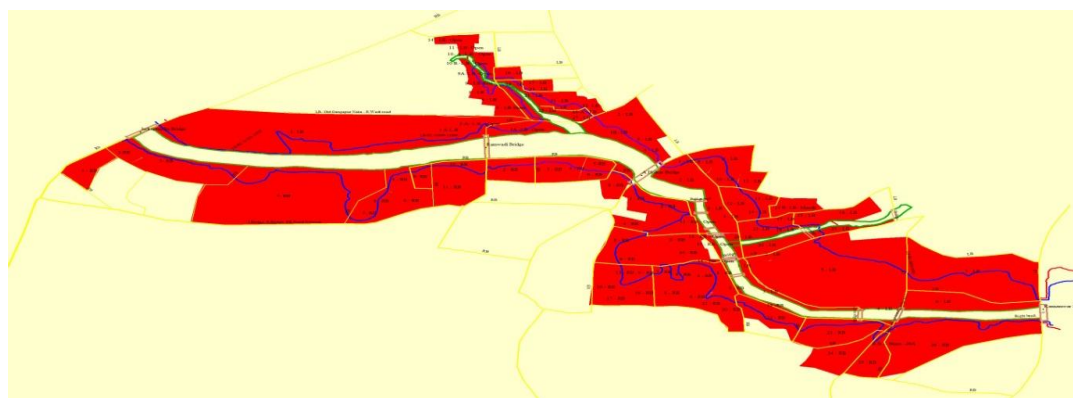


Fig.3Flood exposure map of the study area

*Evaluation of non-structural flood management measures* - The flood exposure map gives us the areas of the landuse patterns in the study area.It is multiplied by the current market rate to obtain the probable flood losses in the study area.The table below shows sample calculations for the losses for a small area(fig.4)The costs of the flood affected area shwos us the evaulation of the non-structural flood managementmeasures.



Fig.4Flood exposure map

Table.3 Flood losses calculations

S.No.	LAND USE	AREA (M2)	CURRENT MARKET RATE(RS./M2)	LOSS (RS.)
1	Residential Bldg	309	54000	16686000.00
2	Slums	412	27000	11124000.00
3	Open plot	182	65000	11830000.00
4	Farm land	222	40000	8880000.00
			<b>Total</b>	<b>48520000.00</b>

#### Evaluation of structural flood management measures

For the study area Gabion wall is proposed as structural flood management measure..Gabion wall is a structure constructed by using the stone boulders .The boulders are packed by means of G.I.cage. It should be constructed along the banks of Godavari river at places as shown in the table.

Table.4 Proposed width of river channel and height of gabion wall for 100 years return period flood

S.No.	River Section	River width (m)	Proposed width (m)	Ht.of wall (m)	
				Left bank	Right bank
1	I.Br.	80	80	-	-
2	RWB	85	85	3	3
3	AHB	35	54	10	10
4	GMB	35	54	10	10
5	TMB	40	54	3	3
6	KNB	50	50	-	-

The table above shows that for the study area it is essential to increase the width of river channel and construct retaining wall between Ahilyabai holkar bridge and Talkuteshwar mandir bridge as structural flood management measure.The maximum proposed height of retaining wall is 10 m where river width is less than 40m and minimum is 3m near Ramwadi bridge.Gabion wall is proposed to as retaining wall.

#### IV. RESULTS AND DISCUSSION

The non-structural flood mitigation measure used to control the flood impact and guidelines are useful for city growth.The probable losses for the landuse patterns those falls in the redline and blueline i.e. residential buildings,slums,open plot and farm land amounts to Rs.4, 85, 20,000=00 as shown in the table. The current study demonstrates the impact of non-structural measures on community and this lead to search of structural flood management measure as Gabion wall.

#### V. CONCLUSIONS

The present study analyses flood exposure in the Upper Godavari River basin for large region.The flood exposure informaton is suitable to different users: public, decisionmakers and water management professionals. The complex interaction between development processes and flood exposure genesis requires a clear conceptual framework which is supported by appropriate organisational and institutional mechanisms to develop and implement surface water management plans. Following issues need to be addressed while developing and implementing such plans.

- 1) The current study demonstrates integration of data from flood map and landuse map in GIS.
- 2) The current study represents methodology of assessment of non-structural and structural flood management measures.
- 3) The recognition of exposure component facilitates the understanding of flood risks because it underlines that only the combination of natural and human factors create flood risks.
- 4) The proposed structural flood management measure, Gabion wall is easy to construct, maintain and also cost effective.
- 5) Community participation in flood exposure assessment, in planning & implementation of flood management measures is key for the success of flood management plans.
- 6) Monitoring and evaluation of implemented measures helps to constantly improve flood exposure management plans.

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