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FLOOD INUNDATION MAPPING OF KUSHIYARA RIVER USING HEC-RAS 1D/2D COUPLED MODEL

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ABSTRACT

Bangladesh is a flood-prone country.It consists of the flood plains of the Ganges, the Brahmaputra and the Meghna rivers and their numerous tributaries and distributaries. As a low-lying country, at least, 20 % areas are flooded every year and in case of severe flood 68% areas are inundated in Bangladesh.The north eastern part of Bangladesh is accountable to not only the monsoon flood but also the flash flood caused by the hilly regions of India. The Kushiyara River crossing through three districts (Shylet, MoulviBazar and Sunamganj) plays the major role in the flooding of this regions especially in the Shylet and Moulovibazar district. The most catastrophic flood event on this area was originated during the year 2004, and also in the year 1998. The major objective of the study is to generate floods maps of these years including the year 2015, and then to show the comparison of inundated area and the extent of the flood between 1998, 2004 and 2015 flood events. Another purpose of the study is to generate a calibrated 1D-2D model for the Kushiyara river floodplain.

To achieve the objectives the 1D model was generated using the Hec-GeoRAS and the HEC-RAS 5.0.5 model and the Manning's n was calibrated for the year 2015 and validated for 2004 and 2016. After generating a calibrated model of Kushiyara river,a 2D simulation was performed for the monsoon period (May-November).Boundary conditions for upstream and downstream were defined by discharge and water level for operating the 1D and 2D model. After the simulation of the 1D-2D coupled model, the flood inundation boundary was exported in GIS and flood inundation boundary map was generated using the map layers of GIS.

The study founded the Manning's n value as .020 after the calibration and validation was performed. The study has founded that the area of flood extent varies from 7-26 % of the total land area of the floodplain and the floodplain boundary consists of the area of the thana's through which the river flows .And the effect of the flood was comparatively catastrophic in 2004 than the other two years based on the available data of the first three months of the monsoon. And the comparative analysis shows that generally the flood extent is maximum in the later monsoon and the inundated area gradually increases from May to November in 2015 flood and maximum is August and September in 1998 flood in the respected floodplain.

***Keywords**: Kushiyara river, HEC-GeoRAS, HEC-RAS, Flood inundation.*

1. INTRODUCTION

Flood can be defined as the temporary overflow of a normally dry area due to overflow of a body of water, unusual build up, runoff of surface waters or abnormal erosion or undermining of shoreline. Flood can also be overflow of mud caused by build-up of water underground (BusinessDictionary, 2019). Bangladesh is under sub-tropical monsoon climate where annual average precipitation is 2300 mm, varying from 1200mm in the north-west to over 5000 mm in the north-east (FFWC, Flood Annual Report, 2015).The country is mostly flat with few hills in the southeast and the north-east part (Rahman & Hossain, 2014). It consists of the flood plains of the Ganges, the Brahmaputra and the Meghna rivers and their numerous tributaries and distributaries.

The Ganges, Brahmaputra and Meghna river systems together, drain the huge runoff generated from large area with the highest rainfall areas in the world (FFWC, Flood Annual Report, 2015). Country has experienced seventeen highly damaging floods in the 20th century (Rahman & Hossain, 2014).Since independence in 1971, Bangladesh has experienced floods of a vast magnitude in 1974,1984,1987, 1988, 1998, 2000 & 2004 (FFWC, Flood Annual Report, 2005). The largest recorded flood in depth and duration of flooding in its history was occurred in 1998 when about 70% of the country was under water for several months (FFWC, Flood Annual Report, 2015). The recent catastrophic floods had caused losses from one to over two million tons of rice, or 4-10% of the annual rice production (Islam, Bala, & Haque, 2010).

Floods are the most significant natural hazard causing suffering to a large number of people and damage to property in Bangladesh. Different reports estimate that the flood damage was US $ 1.4, 2.0, 2.3, and 1.1 billion in the 1988, 1998, 2004 and 2007 severe flood's year in Bangladesh respectively.

In the flood event of 1998, 32 of 64 districts in Bangladesh were affected, 1050 deaths reported, 30 million people were affected, 25 million people were homeless, 26000 live stocks lost, 575,000 hectares of crops were destroyed, 200000 schools and other educational facilities damaged, 300,000 tube wells damaged, 16,000 km of roads were flooded and 45000 km of river embankments damaged. (Aid, 1998). In the North Eastern region of Bangladesh aside the monsoon floods the flash flood is also a common phenomenon. Flash floods, which are caused by heavy or excessive rainfall in a short period over a relatively small area. During flash flooding, water levels rise and fall rapidly with little or no advance warning. Typically, they occur in areas where the upstream basin topography is relatively steep and the time needed for the water to flow from the most remote point point in the watershed is relatively short. The most flood affected areas are in the Hoar Basin of the northern belt of Bangladesh, which is made up of Sylhet, Sunamganj, Moulavibazar,Habigang and Netrokona Districts, as well as the southeast in the Chittagong, Cox's Bazar and the Bandarban Districts (BWDB, 2014).

Flash floods are most common from April to July and from September to October. Flash floods carry sediment that has eroded from hilly catchment areas. During heavy rainfall in the hilly regions, massive erosion occurs on exposed surfaces of the hills. When there is high rainfall, coarser sediment erodes and moves along the rivers. During a flash flood, sediment transport rates increase significantly in a disproportionate distribution of sediment and changes in channel sizes, shapes and even location (Bangladesh, 2018).

2. METHODOLOGY

2.1 Study Area

Kushiyara is a trans-boundary river. It originates from the Barak river of India and enters Bangladesh in the Boro Thakuria union of Jokigang upazilla of the Shylet district and and falss in the upper Meghna in the Kalma Union of Ostogram Upizilla of Kishorgang district. There is no significant historical change in the discharge, water level or the width of the Kushiyara River but the bank erosion increased with time.

The length of the Kushiyara River is 288 km, and the minimum width 196m and the maximum width is 347m and the average width is 268m. The characteristics of the flow of Kushiyara is meandering and the average slope is 6 cm per kilo-meter. The flow of the river is perennial, and the dry season is February-April where the approximate flow is 25.02 cubic meter and the maximum approximate flow is 2990 cubic meter recorded in the August in the Sheola Station. There is flood protection embankment 118.60 kilo-meter in the right bank. There are also two bank revetments in the left and right bank which are respectively 8.054 km and 1.069 km. There are also two spurs in the river of .30 km and .072 km long in the left and right bank of the river.

This river is used to transport stones to different regions of the country and sand is transported in Shylet. And according to BIWTA the navigation route of Kushiyara is of class 3.

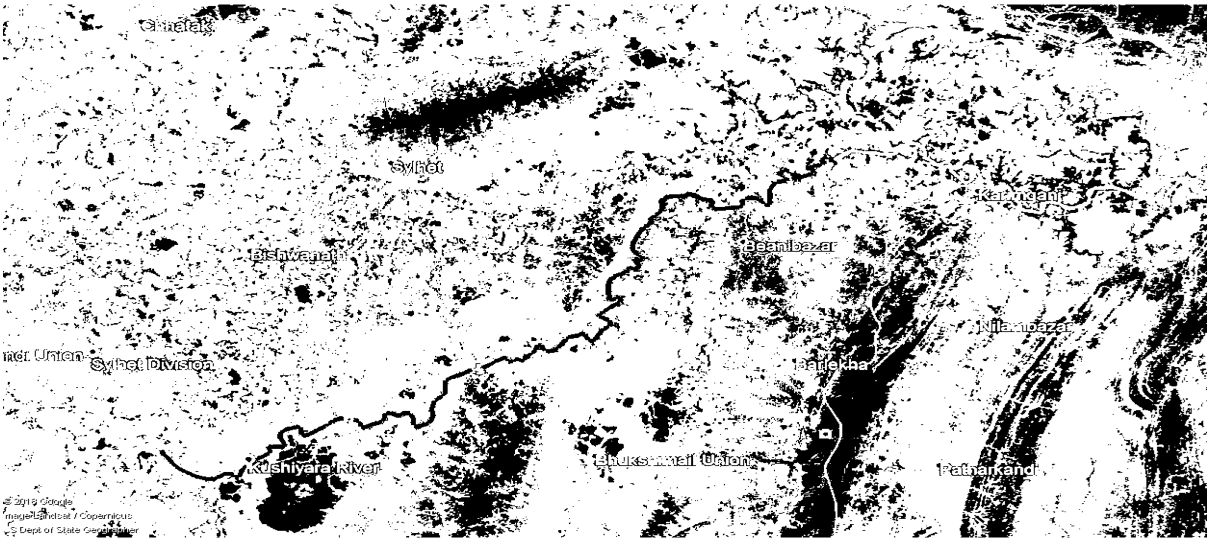


Figure 2-1: Reach of Kushiyara River for the Study

2.2 Data Collection

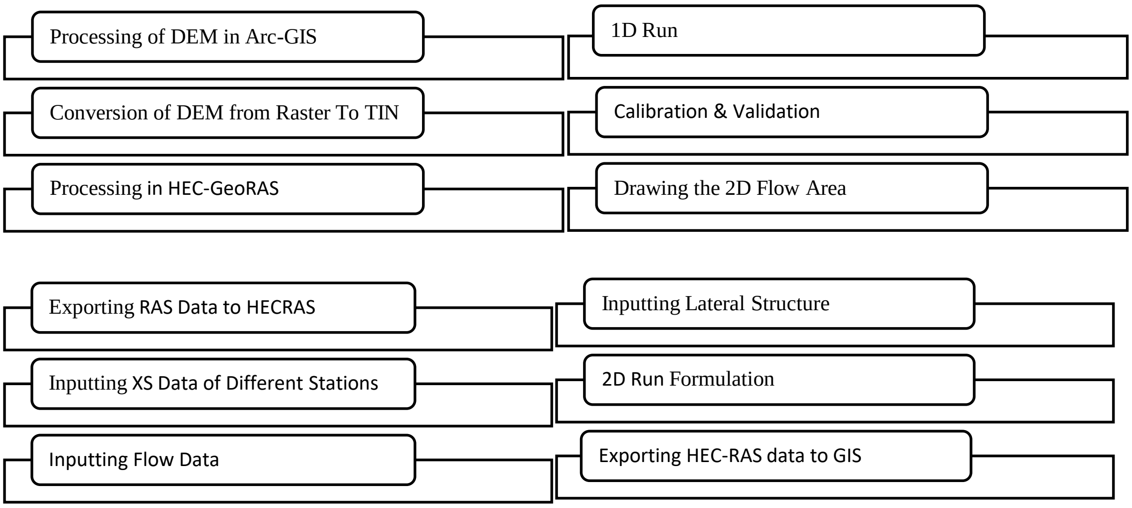
In order to develop the mathematical flood model, various kinds of data, recent and previous years have been collected and compiled. These data also form the basis for further analysis and interpretation of the model results leading to accurate assessment of hydrological condition of Kushiyara River floodplain. According to the modelling requirements, a significant amount of data includes water level, discharge, cross-section have been collected and setup flood model using this data.

Table no 2-1: Type & Sources of Data Sets

Data Type	**Data Source**	**Data Location**	**Position**	**Periods (Year)**
Discharge Data	BWDB	Sheola-173	Upstream	1980-2016
Discharge Data	BWDB	Sherpur-175.5	Downstream	1980-2016
Water Level Data	BWDB	Sheola-173	Upstream	1980-2016
Water Level Data	BWDB	Fenchugang-174	Mid Position	1980-2016
Water Level Data	BWDB	Sherpur-175.5	Downstream	1980-2016
Cross Section	BWDB	RMKUS 1 to RMKUS 12		2004
DEM	USGS	Bangladesh		2014
Satellite Image	Earth Explorer	North-East (NE) of Bangladesh		2018

2.3 Sequential Steps in Model Setup

The following steps was undertaken to setup the HEC-RAS 1D-2D coupled model. At first the Digital Elevation Model (DEM) was processed in GIS using HEC-GeoRAS, then the model was done by HEC-RAS & finally the output maps were generated by using GIS.



3. RESULTS & DISCUSSIONS

3.1 Calibration & Validation Result

The following Table 3-1 shows the calibration & validation result of the 1D-2D coupled model. The table also consists the BWDB station names that was used to carry out the calibration & validation It can be observed from the table that the Mannings roughness parameter was found to be 0.020 for the year 2015,2014 & 1998.

Table 3-1: Calibration & Validation Results

Model Run Year	**Year of Comparision**	**u/s discharge Station**	**d/s Water Level Station**	**Calibrated With Station**	**Manning's n**
2015	2015	SW 173	SW 175.5	SW 174	.020
2014	2014	SW 173	SW 175.5	SW 174	.020
1998	1998	SW 173	SW 175.5	SW 174	.020

The following Figure 3-1 shows the calibration curve, comparing the observed & simulated water level for the station SW 174. The calibration curve shows that the simulated water level follows the pattern of the observed water level founded from the BWDB station data & that indicates that the 1D model was well calibrated for the year 2015.

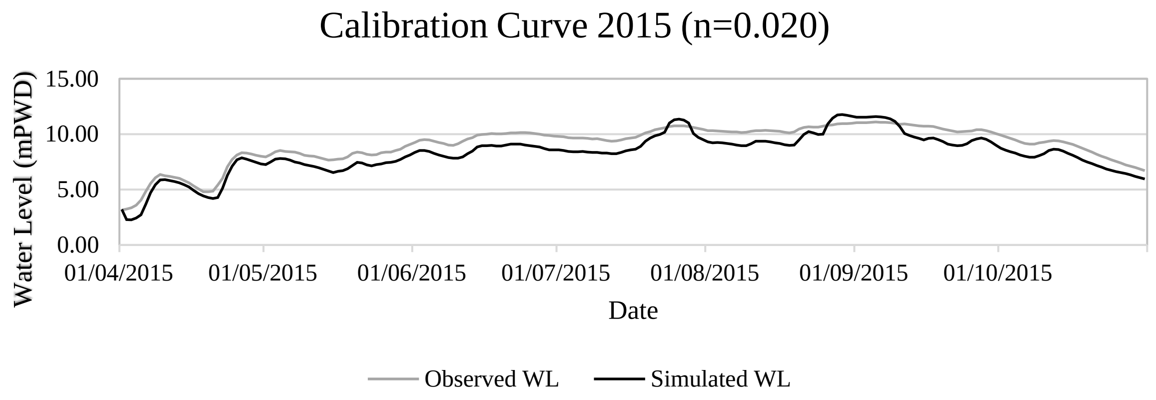
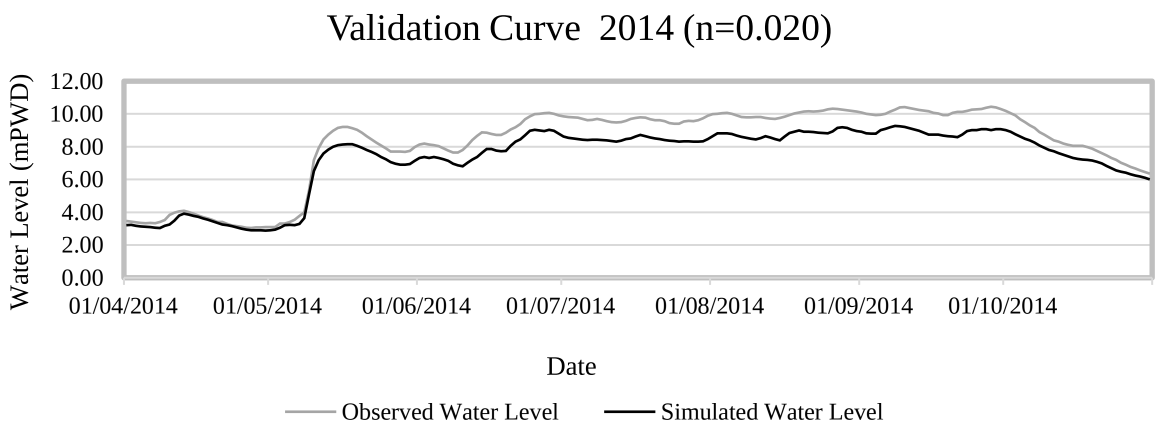


Figure 3-1: Calibration Curve for 2015

In order to find whether the Manning's 'n' value is well suited for the other years as well, a validation was done for the year 2014 & 1998. The following Figure 3-2 shows the validation curve between the observed & simulated water level values of the station SW 174. The figure shows that the Manning's n value remains merely the same in both of the years, that signifies that it took a good amount of time for the morphological change of any river.



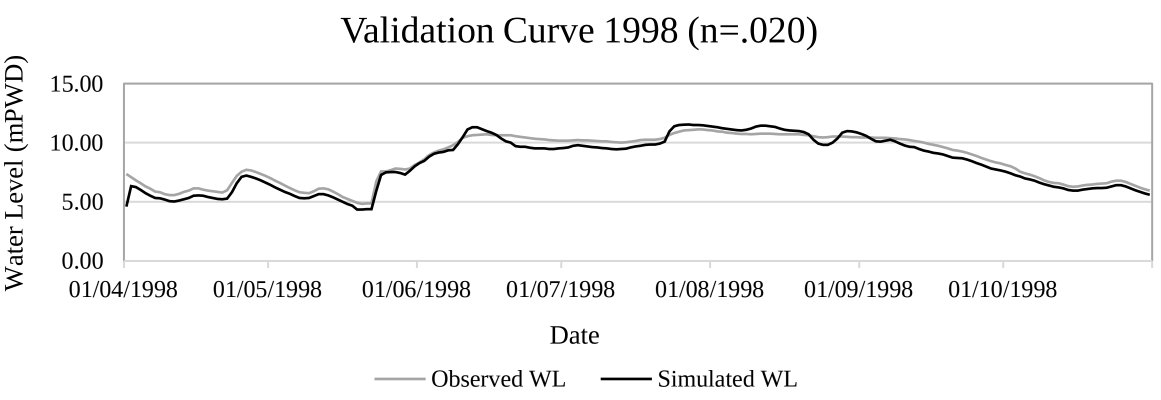


Figure 3-2: Validation Curve for 1998

3.2 Results of Flood Inundation Modeling

The following Figure 3-3 shows the inundation map of the Kushiyara River from the 1D-2D simulation using HEC-RAS 5.0.5. The details analysis of the inundation has discussed on section 3.3.1

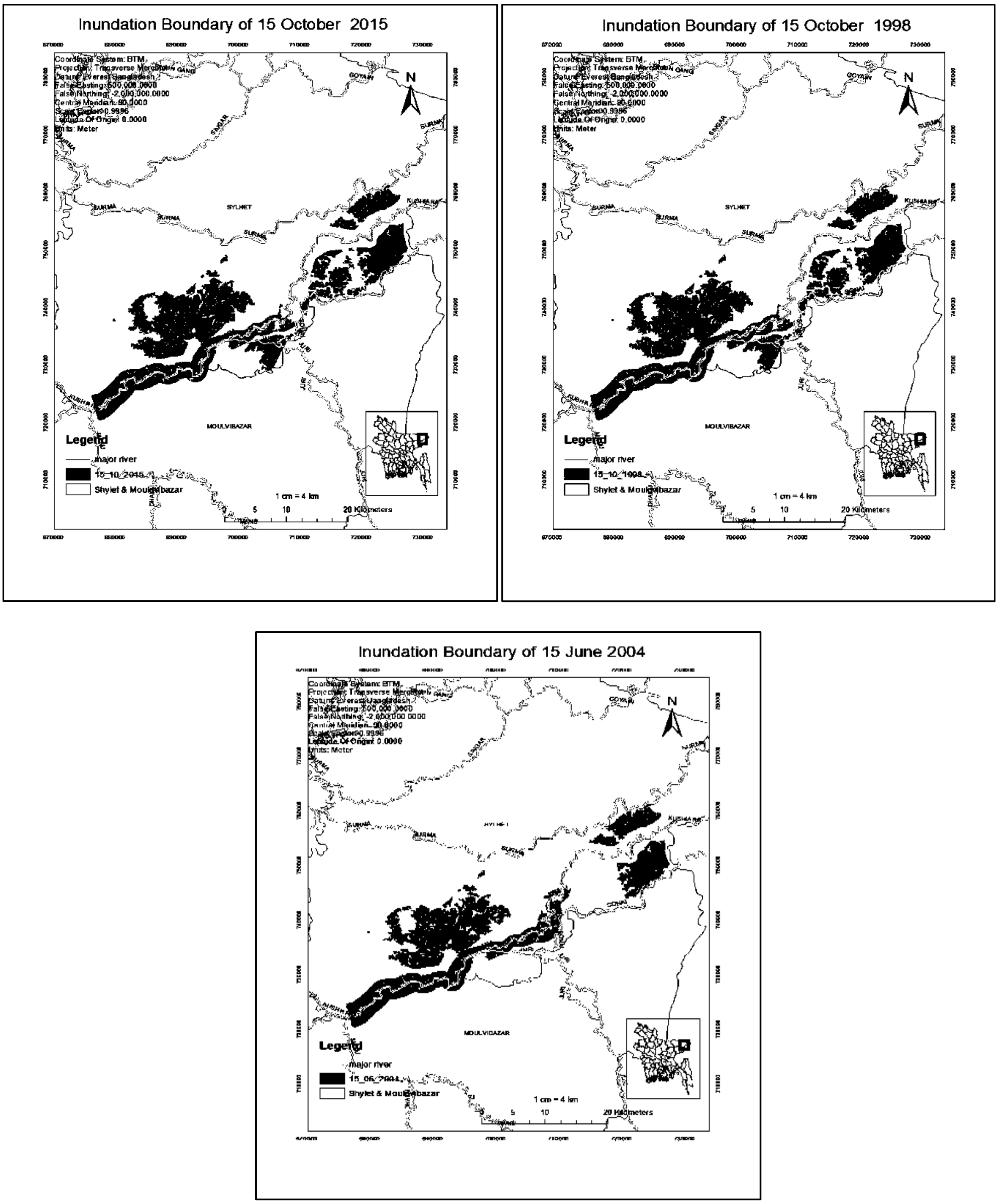


Figure 3-3: Inundation Maps of Year 2015, 2004 & 1998

The comparative analysis of the inundation areas for the different flood years are shown in the following Figure 3-4. It can be observed from the figure that the inundation area is higher for the flood events of 1998 & 2004 compared to the area of 2015.

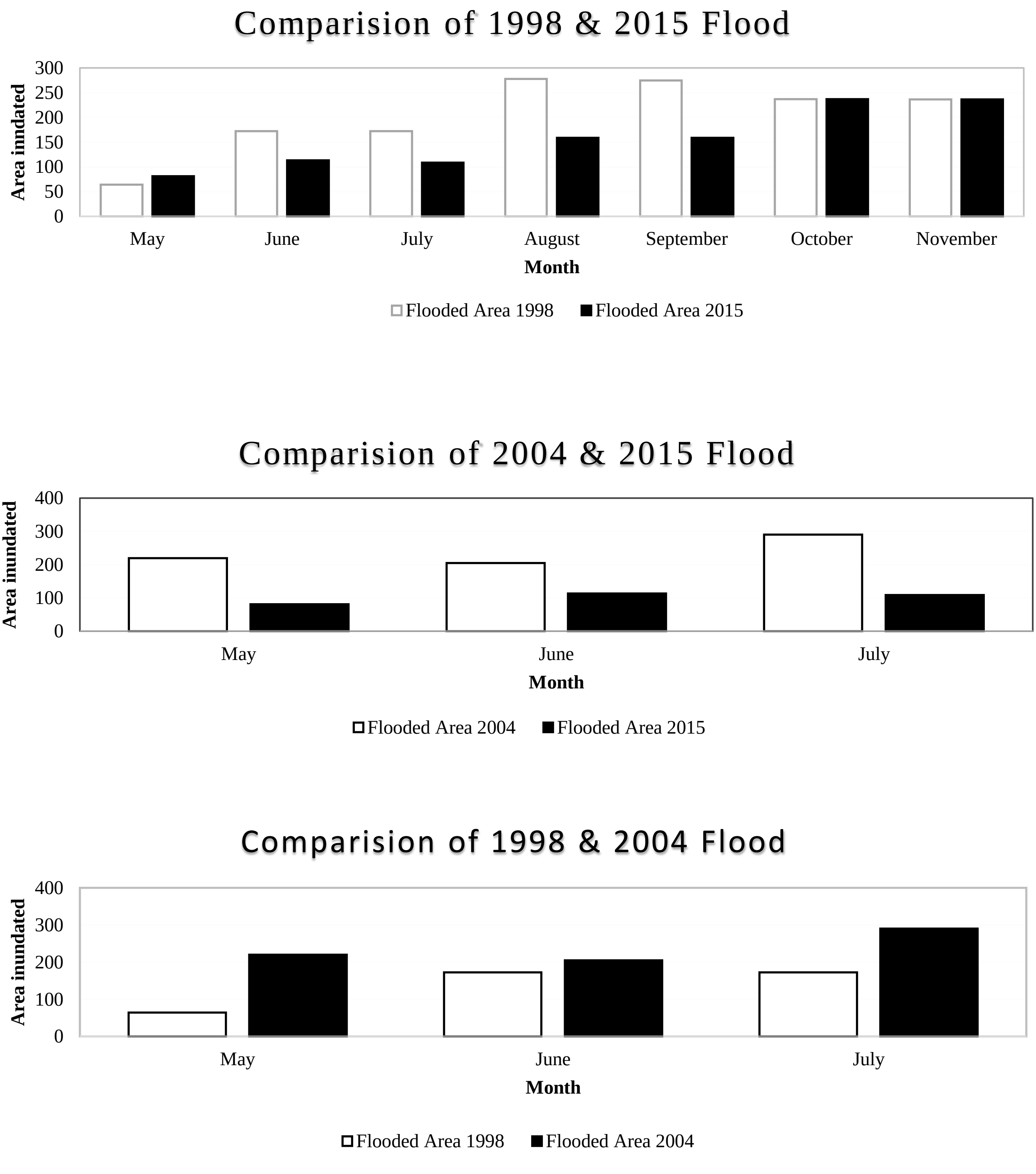


Figure 3-4: Comparative Representation of the Flooding Areas among the Respective Years

The comparison of the inundation areas of different years can be seen in the Figure 3-5, it shows that the 2004 flood was more catastrophic compared to the other to flood years.

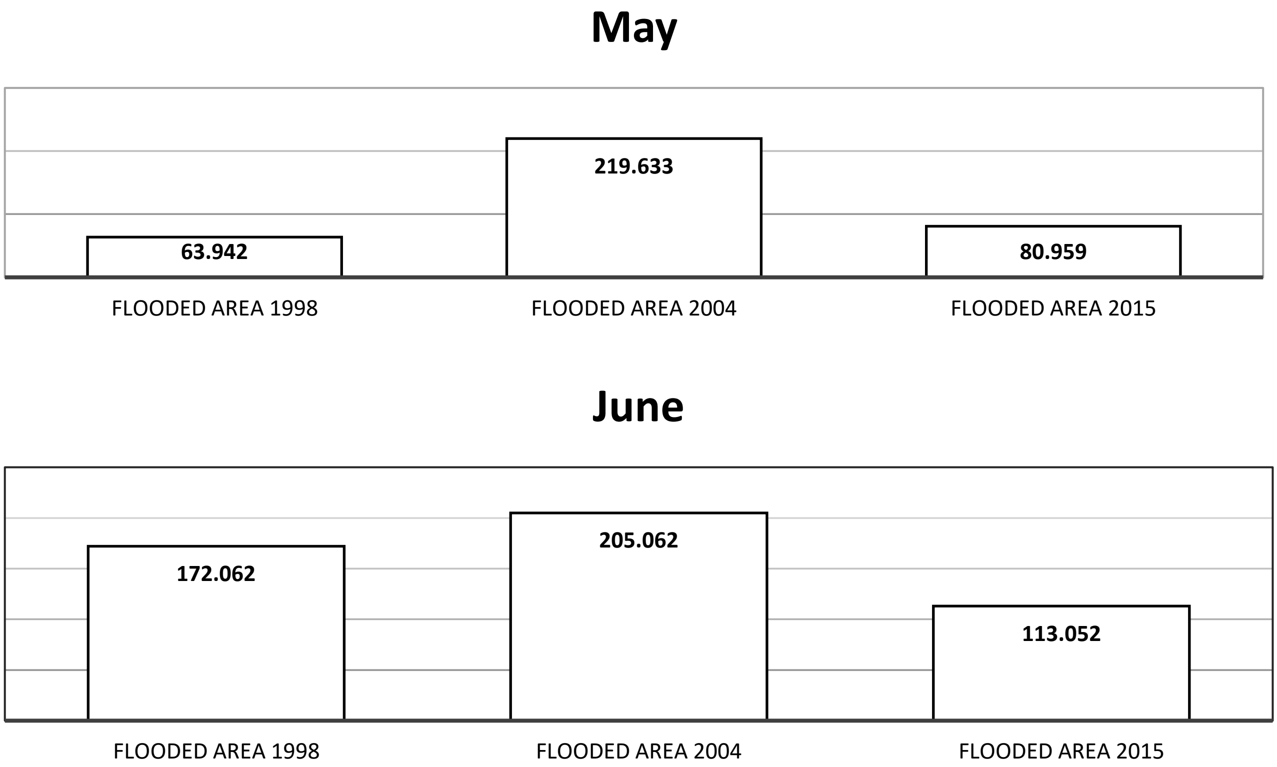


Figure 3-5: Monthly Comparison of Inundation Areas of the Respective Years

The following Table 3-2 shows the percentage of the area inundated in different months of different flood years. The total area of the floodplain was 1116.779 Square Kilometers that consists of Beanibazar, Golapgonj(Partial), Fenchuganj, Balaganj,Rajnarag(Partial) thana's.The table shows that about 26% of the total floodplain area was inundated during the July 2004 flood & more than 12% area was inundated for about 5 months during the 1998 flood event.

Table 3-2: Percentage of Inundation Area of different Flood Years

Area Inundated (Square Kilometer)						
Month/ Year	**1998**	**Percentage of Total Area (%)**	**2004**	**Percentage of Total Area (%)**	**2015**	**Percentage of Total Area (%)**
May	63.94	5.72	219.63	19.66	80.95	7.24
June	172.06	15.40	205.06	18.36	113.05	10.12
July	172.39	15.43	290.38	26.00	108.52	9.71
August	277.53	24.85			158.69	14.21
September	274.89	24.61			158.69	14.21
October	236.98	21.22			236.98	21.22
November	236.43	21.17			236.43	21.17

3.3 Discussions

3.3.1 Analysis of Flood Inundation of Different Years

Analysing the Flood maps of 2015 shows the followings:

- The extent of flood is maximum in the later monsoon, in the October and November and the inundation area is maximum in these two months.
- The Flood extent or the inundated area is very negligible in the pre-monsoon period consisting of the month May, June and July and it gradually increases from the August to the November.

Analysing the Flood maps of 1998 shows the followings:

- The inundation pattern is almost quite similar in the middle of October and November that shows that the flood water stayed for about a month in the respected Floodplain.
- The Flood Maps shows that the upstream portion of the river flooded in the mid of the monsoon where the downstream portion of the river inundated in the later monsoon, that shows that the elevation of the downstream floodplain is higher than the upstream floodplain.

Analysing the Flood maps of 2004 shows the followings:

- The extent of flood in the following three months is comparatively higher than the other years, especially in the May. That shows the possibility of flash flood in the region in the May.
- The extent of the flood in the pre monsoon shows that the flood event of 2004 is most catastrophic and the inundation areas is higher in the later months, but the maps can't be generated due to unavailability of data.

3.3.2 Outcomes of the Study

- The Manning's roughness value is found to be .020 from the study after several trails of different values in the calibration year and was validated for two different years, that was approximately same or having a small change in the value. That signifies that the roughness of the reach remains quite unchanged through the years.
- The model was simulated for three different years. A comparatively low flood year 2015 and for the flood year of 1998 and 2004. The graphical representation shows that the flood event was most catastrophic in 2004 in comparison to other flood events.
- The comparison of 1998 and 2015 flood shows that, the extent of the 1998 flooding was gradually increasing in comparison to 2015 flooding but was nearly same in the later monsoon.
- The study shows that the flooded area is maximum in August and September in the 1998 flood event and in October and November in the 2015 flood event in the designated floodplain boundary.
- But there is a severe change in May 2004, the total inundated area is very high that could be the effect of combination of both the higher monsoon flood and the flash flood.
- The percentage of inundated area compared to the area of the three districts varies from 7-26% according this three year and the extent of the flood is maximum in the Shylet district rather than Moulovi-Bazar.
- This calibrated model can also be used for generating Risk Map of the area and also for future inundation mapping on the availability of generated hydrologic datasets.

  The calibrated model can also be used for determining the crest level of levee for the flood protection measure.

4. CONCLUSIONS & RECOMMENDATIONS

In comparison with the extent and effect of flooding in Bangladesh, the study modelling for flood inundation has not been done with a great extent so far. And especially for the flash flood in the north-eastern region of Bangladesh where flash flood is of great interest as well as the monsoon flood. This study has tried to generate the flood condition of the flood years conducting unsteady flow using discharge and water level data sets of different stations. The model is not capable of representing the actual scenario of the river, as only the hydrologic data and the cross-section data sets does not represent the morphologic and bed characteristics of the river but can give a brief idea about the flood scenario of different years.

- The most important part of the model is the DEM (Digital Elevation Model) file, which has of spatial resolution of 30m*30m. The DEM of such spatial resolution does not represent the actual morphologic characteristics of the region, so DEM of higher spatial resolution should be used to get a better scenario of flood inundation.
- In this study the HECRAS 5.0.5 was used, though it is the latest version of HEC-RAS but the model gets unstable some of the time while computing a large number of datasets in a comparatively shorter interval. So, the simulation capacity of the model could be improved to get better results.
- The collected discharge and water level data were sometimes insufficient to run the model, as like there was no WL data in the d/s station in 2004 after August, hat keeps the mapping incomplete in an important flood year so the data sets should be complete and appropriate.

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