Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

GENERATING INUNDATION MAP OF ATRAI RIVER USING HEC-RAS 1D/2D COUPLED MODEL

Proma Maria Rozario[1], Kazi Mushfique Mohib[2], Sahika Ahmed[3], Purnima Das*[4] and Md. Sabbir Mostafa Khan[5]

[1]Graduate Student of Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, e-mail: rozarioproma@gmail.com
[2]Graduate Student of Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, e-mail: kazimushfique23@gmail.com
[3]Graduate Student of Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, e-mail: sahika.buet14@gmail.com
[4]Graduate Student of Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, e-mail: pinkiwre10@gmail.com
[5]Professor at Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, e-mail: sabbbirkhanbuet@gmail.com

***Corresponding Auther**

ABSTRACT

Bangladesh is a densely-populated, low-lying and mainly riverine country located in South Asia at the downstream of three major river basins name by the Ganges, Brahmaputra, and Meghna. Straddling the Tropic of Cancer, Bangladesh has a tropical monsoon climate characterized by heavy seasonal rainfall, high temperatures, and high humidity. For these geographical characteristics it has become a flood prone country and in recent years the frequency of abnormal floods has increased substantially, causing serious damage to lives and property.

Besides other major rivers, Atrai River is one of the leading causes of flooding in certain areas. It flows in West Bengal and northern parts of Bangladesh covering Dinajpur and Naogaon district and serves as a perennial fishing ground. During rainy season (July to September) higher discharge can be observed ranging with 2000 to 3000 cubic meter per second in Atrai and flood occurs due to overflow of the river water along the riverbanks. The main purpose of the study is to setup a HEC-RAS 1D/2D coupled model for generating flood inundation map of lower Atrai River as an accurate flood mapping can help to indicate the vulnerable zones and to take proper measures that can reduce the flood damages. In this study, 1D/2D coupled hydrodynamic model as long as HEC-GeoRAS have been used to develop flood inundation model of Atrai River floodplain and simulated for 2004, 2012 and 2016. The study shows that the flooded area is maximum in September and October in the 2004 and 2016 flood event in the designated floodplain boundary. The overall analysis is actually helpful to describe the 2D flow simulation with 1D in HEC-RAS and the results of the whole study can be useful to create the facility of early warning system with sufficient lead time, hydrologic and hydrodynamic model will help to mitigate the effect of flooding in those surrounding high inundation areas of Atrai river and will help to visualize where flood protection is needed and where not.

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

1. INTRODUCTION

Floods are the most significant natural hazard causing suffering to a large number of people and damage to property in Bangladesh. In recent years the frequency of abnormal floods in Bangladesh has increased substantially for many reasons (Khalequzzaman, 1994). As a natural phenomenon cannot be prevented totally so concern have to raise on how to mitigate that. Flood mapping is a great way to fulfil this purpose.

In this research, flood mapping has been done for Atrai River that flows in West Bengal and northern parts of Bangladesh. Specifically the Lower Atrai that renters Bangladesh through Naogaon district and falls upon Hurasagar River in Shirajgonj district (Figure 1). Length of the river is approximately 390 kilometer, Average width is 177 meter, maximum depth of the river is 30 m.

During January to April the discharge of the river becomes very low but in rainy season discharge becomes higher and flood occurs due to overflow of the river water along the riverbanks.(Information source: Wikipedia and Rivers of Bangladesh book by BWDB). It was observed that the 2017 floods broke the historic record crossing the danger levels in several stations of many river, Mohadebpur in Atrai was also one of them (Rahman, 2017). In 2017, during middle of August, water in the Atrai River was currently 214 cm above the danger level. Dams are breached in more than 100 villages across the district. Ten villages were flooded near the Dhamirhat border after the Atrai River broke through dams in the area (Islam, 2017).

Hence the main objective of the study is to deal with the flood propagation with time in monsoon season by generating map of the study area. As HEC packages are freeware, this study will apply HEC packages to develop flood inundation map by hydrological and hydro-dynamic analysis by using mainly HEC-RAS 1D/2D coupled model. 1D is used for creating the features of the river by providing necessary discharge and water level data, for proper calibration and validation. Then 2D part of HEC-RAS has been introduced to generate the floodplain of Atrai. So the ultimate combination of HEC-RAS 1D and 2D was capable to create the whole scenario of the flood map of Atrai River.

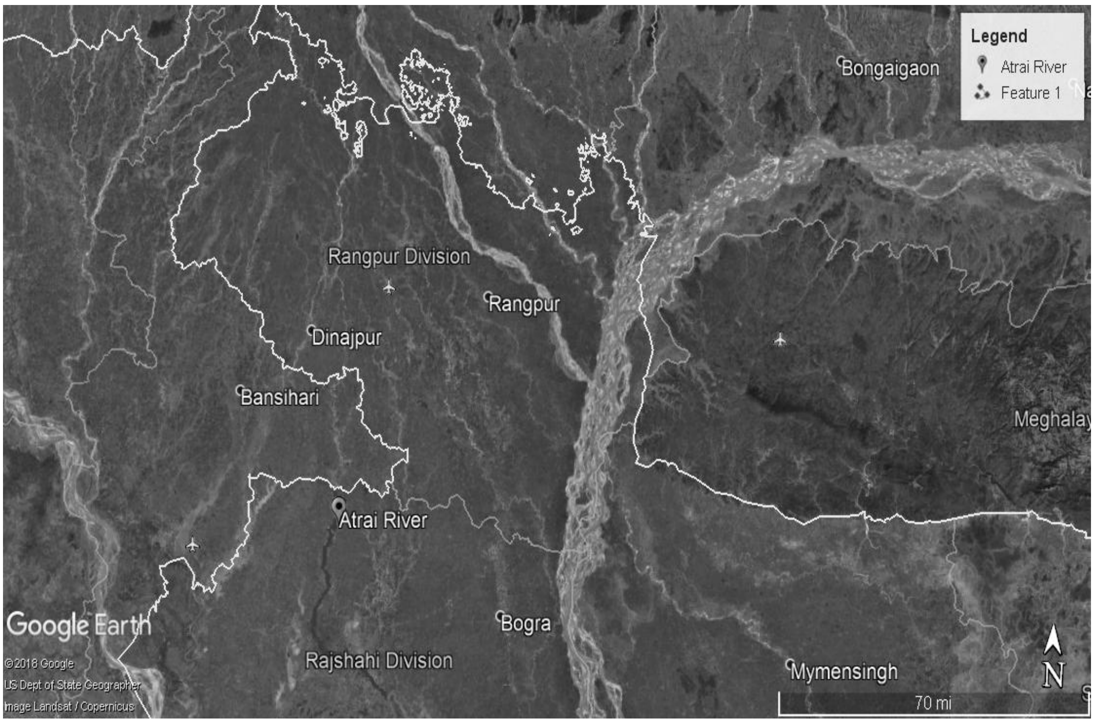


Figure 1: Google earth image of study area (Atrai River)

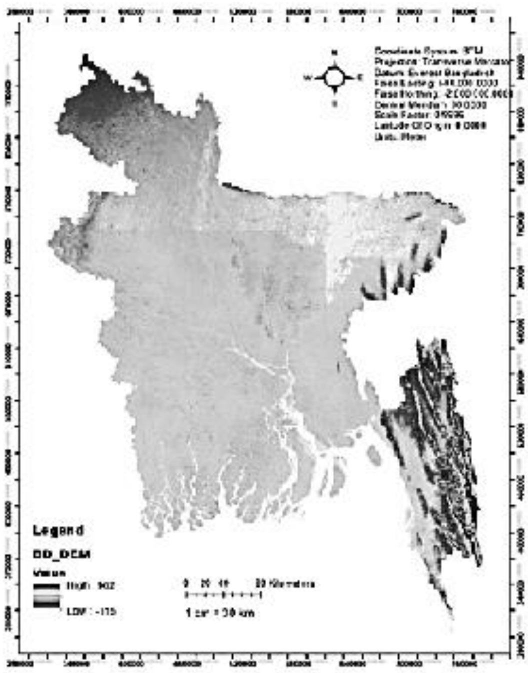
2. METHODOLOGY

2.1 Preparation Phase

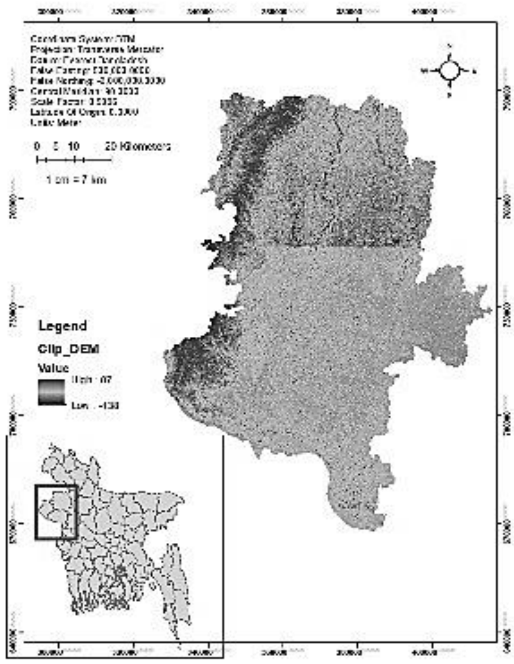
In this study, ArcGIS 10.4.1, HEC-GeoRAS, HEC-RAS 5.0.5 etc. were the softwares that have been used here. At first a reach of Chakhariharpur to Atrai Rly Bridge was selected for the analysis. Then all hydrological data and necessary images of specific years were collected from BWDB, USGS website and from Google earth.

Now, the analysis was started with ArcGIS 10.4.1 by modification of Digital Elevation Model (DEM) of Bangladesh. As the DEM was in geographical coordinate system (GCS_WGS_1984), so it was converted into Bangladesh Transverse Mercator (BTM). And also as the elevation of the DEM is measured with respect to the mean sea level but the collected data of river cross sections, water surface elevation etc. have been considered are measured from Public Work Datum (PWD), so to adjust this difference in elevation, a slight modification of the collected DEM has been done.

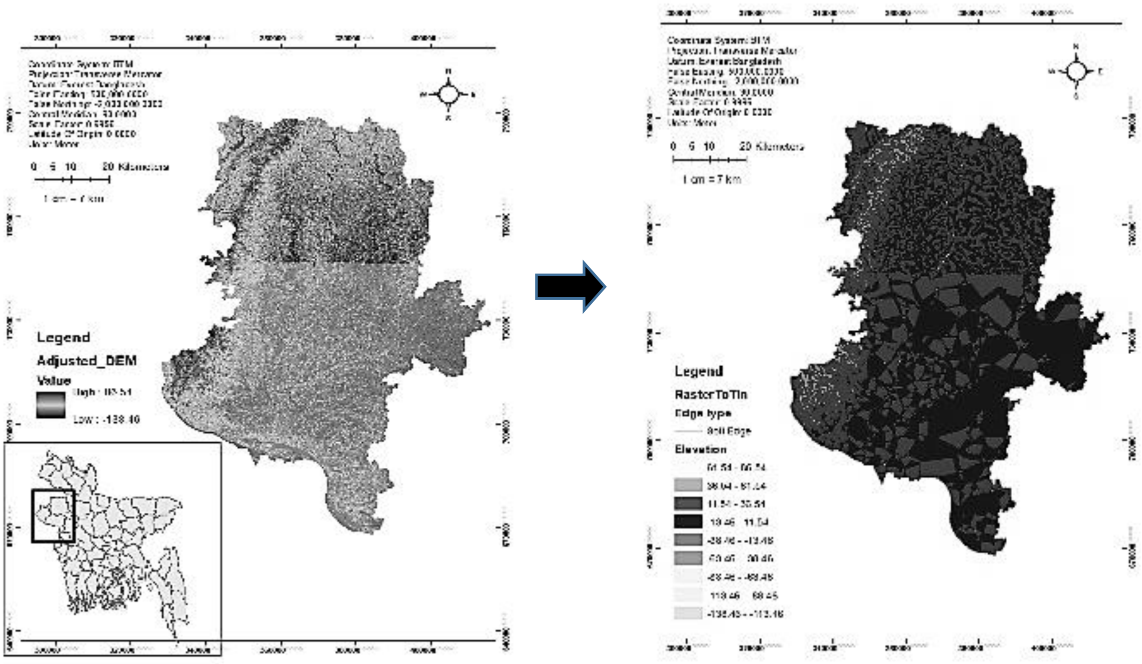
After taking the modified DEM of Bangladesh, two districts- Naogaon and Rajshai which covers the floodplain area of Atrai, has been clipped from the modified digital elevation model using the Clipping Tool in Arc Toolbox. Further it was converted from raster to TIN. The purpose of the Raster to TIN tool is to create a Triangulated Irregular Network (TIN) whose surface does not deviate from the input raster by more than a specified Z tolerance. It is used to convert raster from a DEM to a TIN surface model. It is done by using the Raster to TIN tool in the Arc Toolbox. All the stages mentioned above have been shown in Figure 2.



DEM of Bangladesh



DEM (Before modification)



DEM (After modification)

Raster to TIN formation of

Figure 2: Different stages of Preparation Phase

2.2 Executive Phase

2.1.1 Pre-processing in HEC-GeoRAS

HEC-GeoRAS is an Arc GIS extension specifically designed to process geo spatial data to incorporate with the Hydrologic Engineering Center River's Analysis System (HECRAS). The extension allows users to create an HEC-RAS import file containing geometric attribute data form an existing digital terrain model (DTM) and complementary data sets. So, after converting the DEM from Raster to TIN, a complete modified bathymetry was prepared in Arc-GIS with the help of HEC-GeoRAS by developing river centreline, river banks, flow paths and cross sections as shape files with the help of Ras Geometry by all layers for the GIS model**.**

2.1.2 Processing in HEC-RAS

Then after importing the DEM from HEC-GeoRAS to HEC-RAS and providing required flow and stage hydrographs (Figure 3 and Figure 4), 1D hydrodynamic model was created.

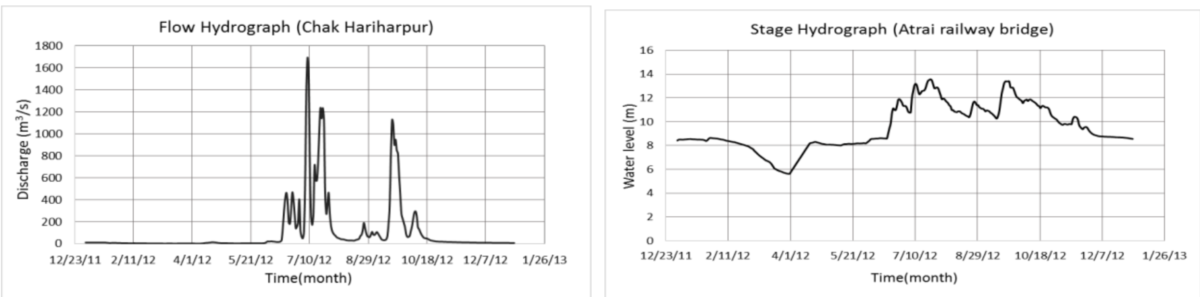


Figure 3: Flow and Stage hydrographs of Atrai River (2012)

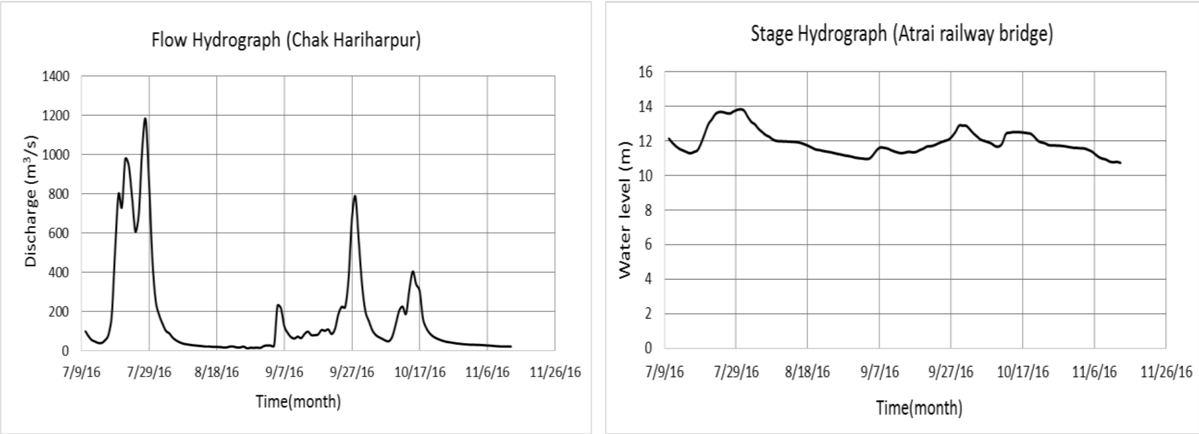


Figure 4: Flow and Stage hydrographs of Atrai River (2016)

To ensure the model's performance, the degree of accuracy of the model was checked by calibration and validation. The calibration was done for 2012 and validation was for 2016 for Manning's n=.026, shown in Figure 5.

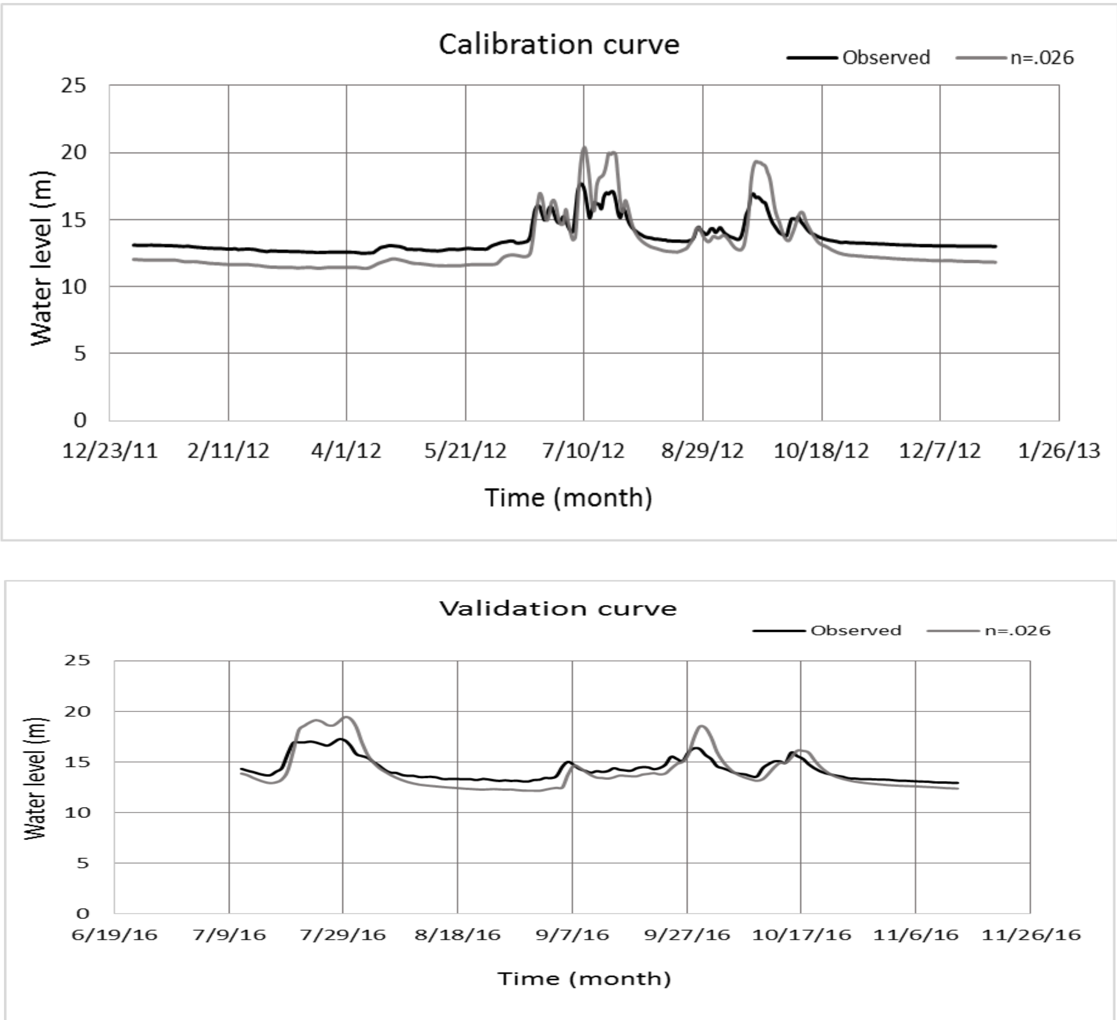
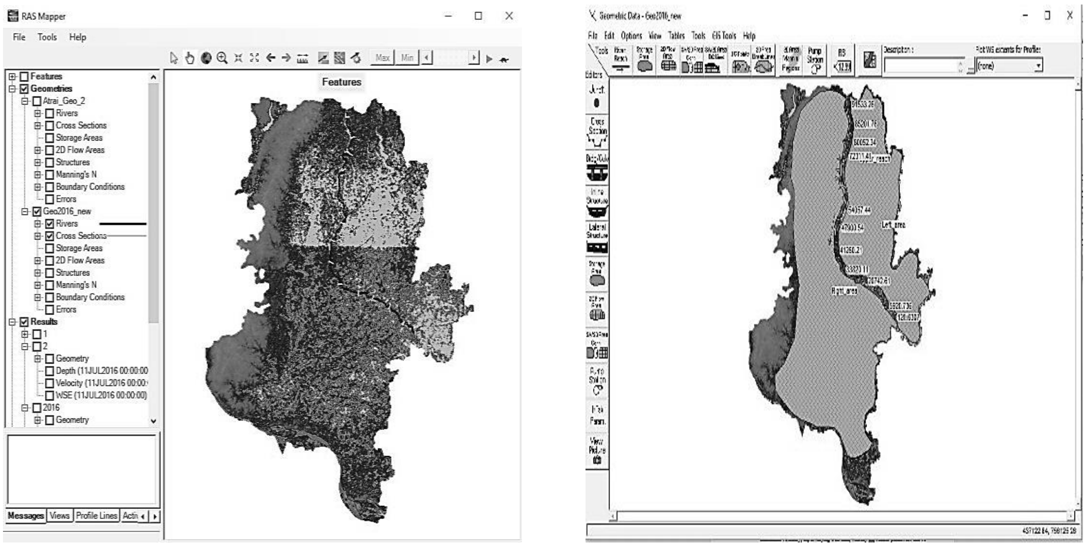


Figure 5: Calibration and Validation curve for Atrai River

Hence coupling of 1D and 2D model was done after assigning the floodplain area of Atrai River and inundation map was generated in RAS Mapper by developing the terrain of the existing DEM. While coupling, two levee as lateral structure were built in both banks of the upstream of Atrai. The height of the levees were slightly higher than the Ground level of the banks of the river. (Figure 6)



Creating Terrain in Ras Mapper

2D flow area computational mesh

Figure 6 Processing in HEC-RAS

Finally on total three models have been generated for year 2004, 2012 and 2016. In the final stage, inundated area for several months in different years were determined with respect to total floodplain area.

3. RESULTS AND DISCUSSIONS

3.1 Figures and Graphs

The model was calibrated for the year 2012 and Manning's roughness coefficient was found as 0.026. In unsteady calibration, the coefficient of determination R^2 have been found 0.9234 which indicate that the simulated value is closer to the observed value (Figure 7). This 'n' value was further rechecked by validation with the year of 2016 to analyse whether it was correct for that year too or not.

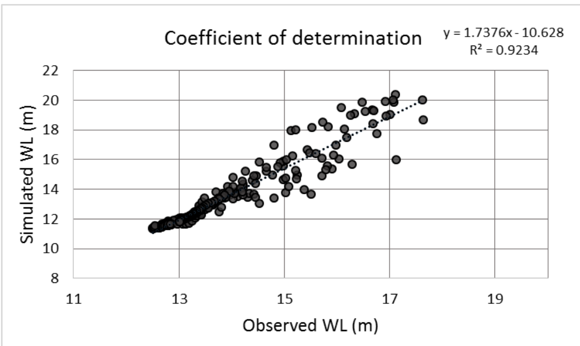


Figure 7: Measuring coefficient of determination

Then generation of flood inundation map of lower Atrai River is successfully done for 2004 and 2016 by creating map for several months (May to November) of these years. And percentage of inundated area were calculated by RAS Mapper. Inundation maps of 13th October for both 2004 and 2016 have been shown in Figure 8 and inundated areas have been given in following tables, Table 1 and Table 2.

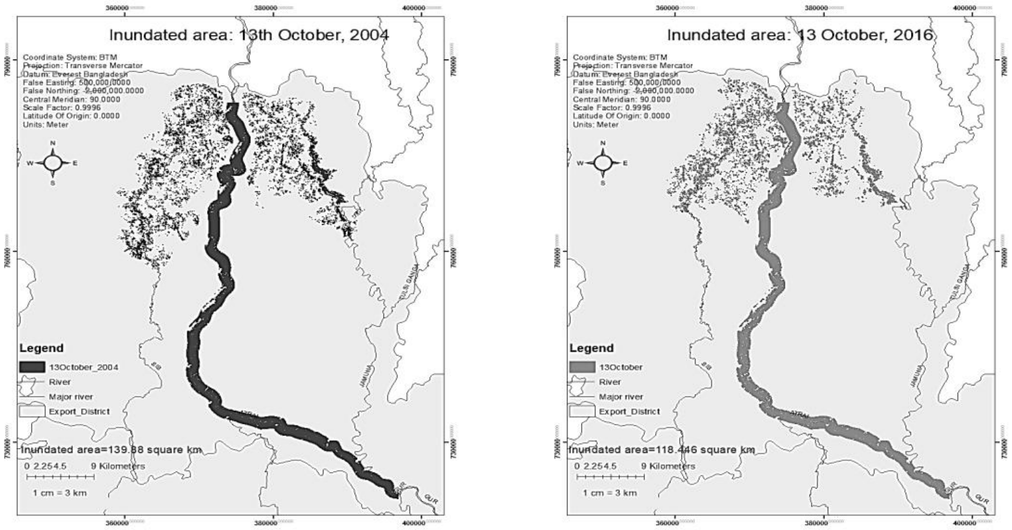


Figure 8: Inundation map for 13th October of 2004 and 2016

3.2 Tables

Table 1: Analysis of percentage of inundated area of 2004

Year	**Inundated area**	**Inundated area**	**Area of Floodplain**	**Inundated area**
2004	(square m)	(square Km)	(square Km)	(Percentage)
13th May	57123884.4	57.12	1484.79	3.85
13th June	75340927.22	75.34	1484.79	5.07
13th July	114247320.5	114.24	1484.79	7.69
13th August	117469300.9	117.46	1484.79	7.91
13th September	128435541.9	128.43	1484.79	8.65
13th October	139880852.5	139.88	1484.79	9.42
13th November	102338256	102.33	1484.79	6.89
Max	168035770.8	168.03	1484.79	11.32

Table 2: Analysis of percentage of inundated area of 2016

Year	**Inundated area**	**Inundated area**	**Area of Floodplain**	**Inundated area**
2016	(square m)	(square Km)	(square Km)	(Percentage)
13th July	84106809.02	84.11	1484.79	5.67
13th August	98974453.64	98.97	1484.79	6.67
13th September	102341860.4	102.34	1484.79	6.89
13th October	118445886.4	118.45	1484.79	7.98
13th November	92900605.58	92.9	1484.79	6.26
Max	148360377.3	148.36	1484.79	9.99

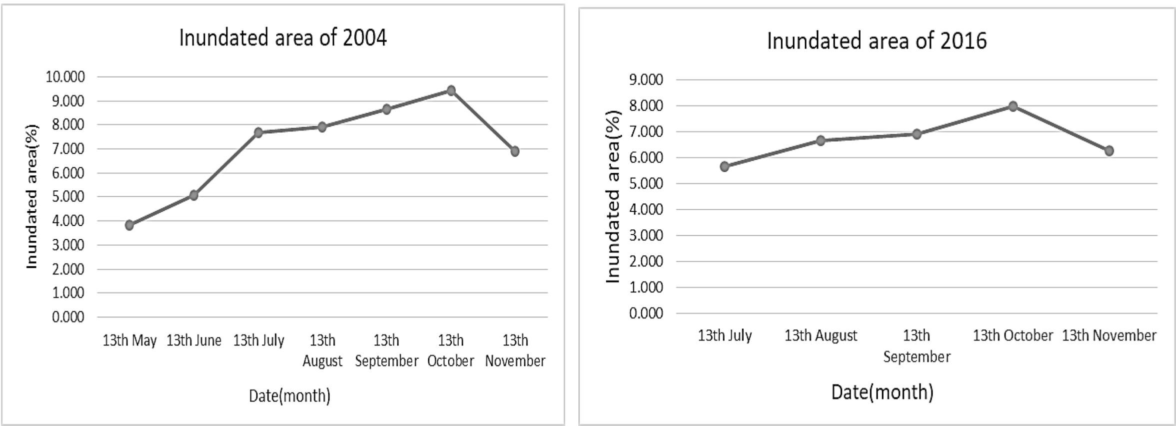


Figure 9: Percentage of inundated area for 2004 and 2016

The percentage of inundated area compared to the area of the two districts (Naogaon and Rajshahi) varies from 3-12% and the extent of the flood is in Dhamoirhat, Patnitala and Mahadebpur Thana. Here percentage value of inundated area are found very small as because the inundated area is comparatively too small then the total assumed floodplain area (1484.799 sqkm). But it can be clearly observed that the percentage of inundated are is smaller in 2016 than 2004 (flood year). And also from the following tables it can be observed that the inundated area (in square Km) gradually increase from May to October and decrease in November in both 2004 and 2012 because of the natural rain and discharge pattern of the environment. The tabulated forms of the analysis can be represented graphically as Figure9.

4. CONCLUSIONS

In this study, 1D/2D coupled hydrodynamic model has been used to develop flood inundation model of Atrai River floodplain and simulated for 2004, 2012 and 2016. The study shows that the flooded area is maximum in September and October in the 2004 and 2016 flood event in the designated floodplain boundary. The overall analysis is actually helpful to describe the 2D flow simulation with 1D in HEC-RAS and the results of the whole study can be useful to create the facility of early warning system with sufficient lead time, hydrologic and hydrodynamic model will help to mitigate the effect of flooding in those surrounding high inundation areas of Atrai river and will help to visualize where flood protection is needed and where not. Moreover this model can further be used for risk map analysis, sensitivity analysis and effect of the variation in levee height for measuring the proper height of the protection.

ACKNOWLEDGEMENTS

The authors acknowledge the support from the Department of Water Resources Engineering, BUET during this study.It is also a great pleasure for the author to express her gratefulness to Sarder Udoy Raihan, Sub-Divisional Engineer, Flood Forecasting and Warning Center, Bangladesh Water Development Board for supporting author during her entire data and necessary maps collection period and for giving suggestions while needed.

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