FLOOD MITIGATION STUDY IN ADAYAR RIVER USING MIKE-FLOOD

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ABSTRACT: The present paper aims to model the hydrodynamic transport of flood runoff located in Adayar river in Chennai, Tamil Nadu from the Nandambakkam bridge up to the sea mouth of Adayar river through 1D – 2D coupled MIKE FLOOD hydrodynamic models. Secondly, the study aims at finding the specific reason for the occurrence of floods and the promising measure such as to study the impact of bed geometry of Adayar river to be taken for different scenarios and concluded in suggesting site specific preventive measures for the annual floods so that there are no severe flood events occurs in the coming future. The study compares the result obtained from the model with the help of observed flood level taken during 2005 flood event. According to the results from the model, the model was found satisfactory after validated.

Keywords: Hydrodynamic models, MIKE-11,MIKE-21, MIKE- FLOOD,flood inundation simulations and DEM.

1. INTRODUCTION

Accurate representation of elevation data for river channels and floodplain are of great importance for topographic mapping and disaster mitigation. High resolution digital terrain and elevation models (DTM/DEMs) are an important component of this intelligence providing data on surface and feature heights, landform variation, flooding extents and, indirectly flood behavior as per Cobby et al. (2001).Airborne Laser Scanners (ALS) emit millions of high frequency laser beams that interact with surface structures and penetrate vegetation to varying degree. The transmit and reflection times of the laser pulses are recorded and subsequently used to derive the height of ground and above ground features.The costlier LiDAR based DEMs are the best for its unique capability of accurate topographical representation at 30 GSD accuracy. It is best suitable for accurate flood modeling, channel network extraction and channel bed morphology analysis (Cook and Merwade 2009).

The historical records of several catastrophic flooding in Chennai since 1943, 1976,1985,2002,2005 and 2015 are due to heavy rain associated with cyclonic activity. The reasons for the flooding are two- fold. Most of the existing waterways are silted and their flow channels and banks are obstructed with encroachments and structures. Secondly several of the areas under tanks and their anicuts have been developed as residential neighbourhoods over the years which indicate the growth of urban population. Therefore it is high time to review and redesign drainage system to find out the best solutions. Their was a study by Chennai Municipal corporation on Pre-Feasibility Study support for Waterways Rehabilitation and Solid Waste Management in Chennai in association with DHV B.V. Netherlands and with DHV India Pvt. Ltd. After analysis, they concluded with some rehabilitation measures for Adayar river such as 1. Earth work excavation/ dredging by machineries for 2m depth below mean sea level from 0.0 km to 0.5 km; 2. Earth work excavation by machineries to provide gradient to the river bed and bed levels -2m below MSL at 4.2km to 0.5m above MSL at 7km;3. Earth work excavation by machinery to provide gradient to the river bed and bed levels -0.5m below MSL at 7km to 2m above MSL at 12.2km.This study has taken the suggested measures given for Adayar river and incorporated through the hydrodynamic model.

2. STUDY AREA AND DATA USED

The study area covers Adayar watershed of 42.84 sq.km. It lies between the North Latitudes 13°1'8.513'' N and 13°3'29.645''N and East Longitudes 80° 11'9.106''E and 80°15'54.819''E. Figure 3.2 depicts the index map of the study area. The Chennai city is bounded by Thiruvallur district in the north and west, Kancheepuram district in the south and Bay of Bengal in the east. The total length of the Adayar river is 43 km.It originates at the confluence of Thiruneermalai that drains from the upstream area of Chembarambakkam tank and crosses various bridges such as Nandambakkam, Maraimalai Adigal, Kotturpuram and Thiru vi ka across the river and then ultimately reaches the sea. The length of the Adayar river within the city limits is 12.2 km is considered for this study. The maximum elevation is around 320 m above the mean sea level at Thiruneermalai, Pallavaram and Kadapperi Hills and minimum elevation is around 5 to 15 m above the mean sea level. The study area is a low-lying flat, slightly undulating terrain with a gentle slope of 3°-5° toward the North East direction .The city enjoys the tropical climate with the annual rainfall of 1206.5 mm and the north east monsoon contributes almost 60% of total rainfall in this semi-arid region. Most of the rainfall is associated with clear synoptic systems of depressions and cyclones. It is characterized with seasonal variations of winter season from November to February, summer season from March to mid-June and rainy season from mid-June to October. The figure 1 shows the study area of the Adayar river.

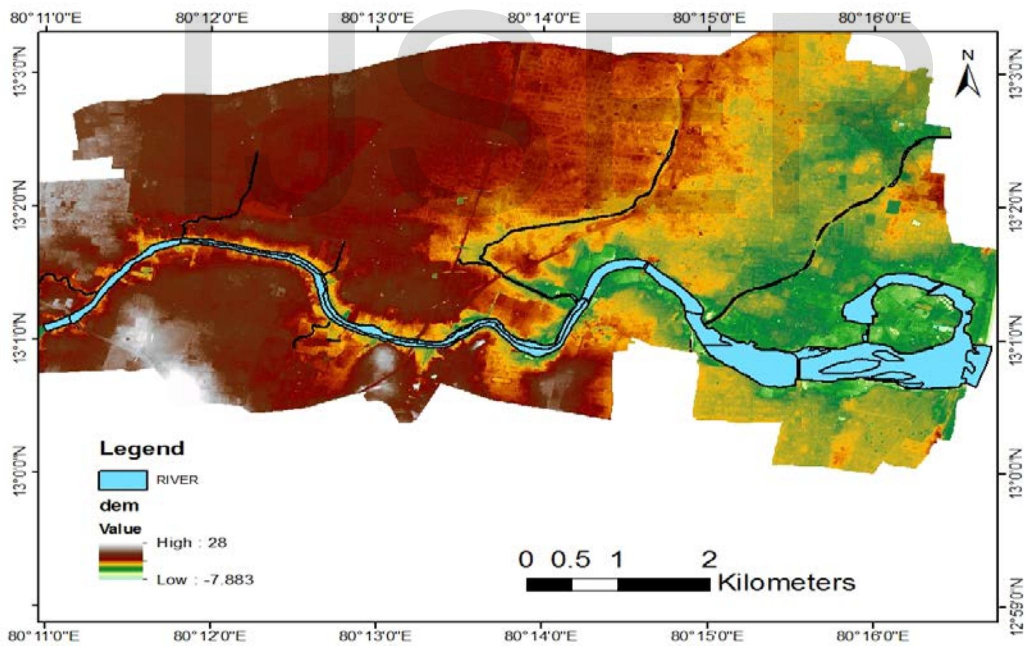

Figure 1: Study area of the Adayar river on the background of DEM

3. RAINFALL-RUNOFF MODEL USINGMIKE URBAN TIME-AREA METHOD

The Time-area (TA) rainfall-runoff model is used to derive the runoff hydrograph based on a given excess rainfall hyetograph. In this method, the watershed is divided into a number of subareas separated by isochrones; i.e. the isolines of equal travel time to the outlet. This process is known as time area histogram. After plotting the time –area histogram the runoff hydrograph may be determined

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by the formula:

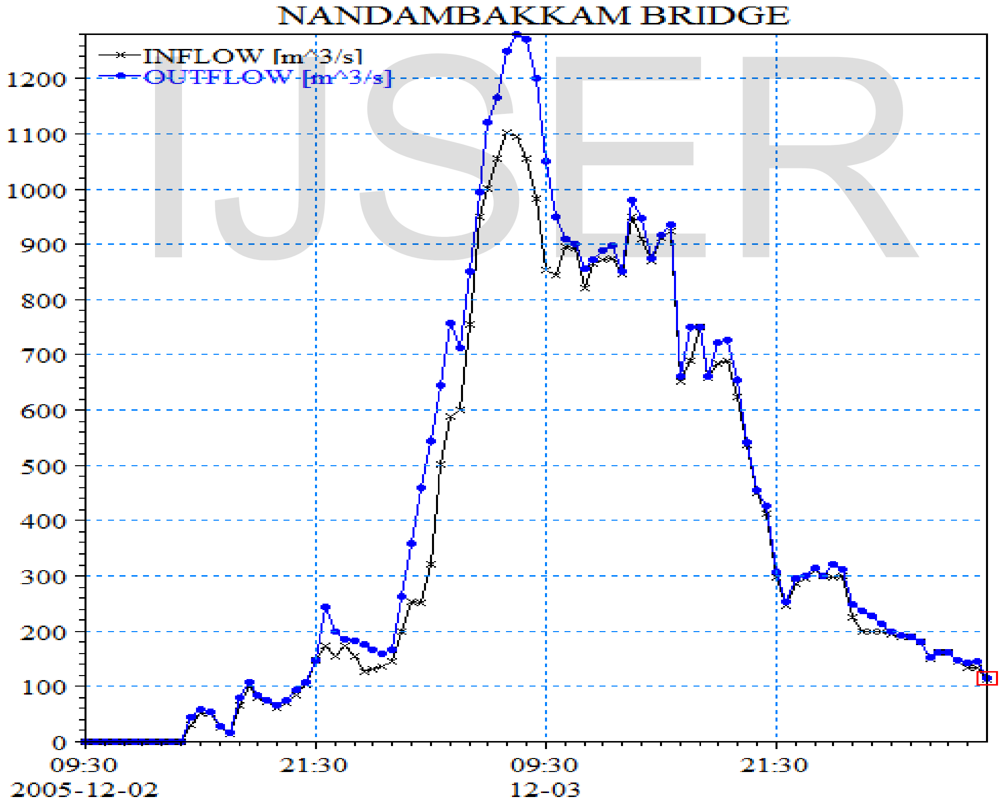
$$Q_j = \sum_{K=1}^{j} E_k A_{j-k+1}$$

Where	j	= Time step number
	Q	= Runoff discharge
	E	= Excess rainfall intensity
	A	= Area bounded by the isochrones

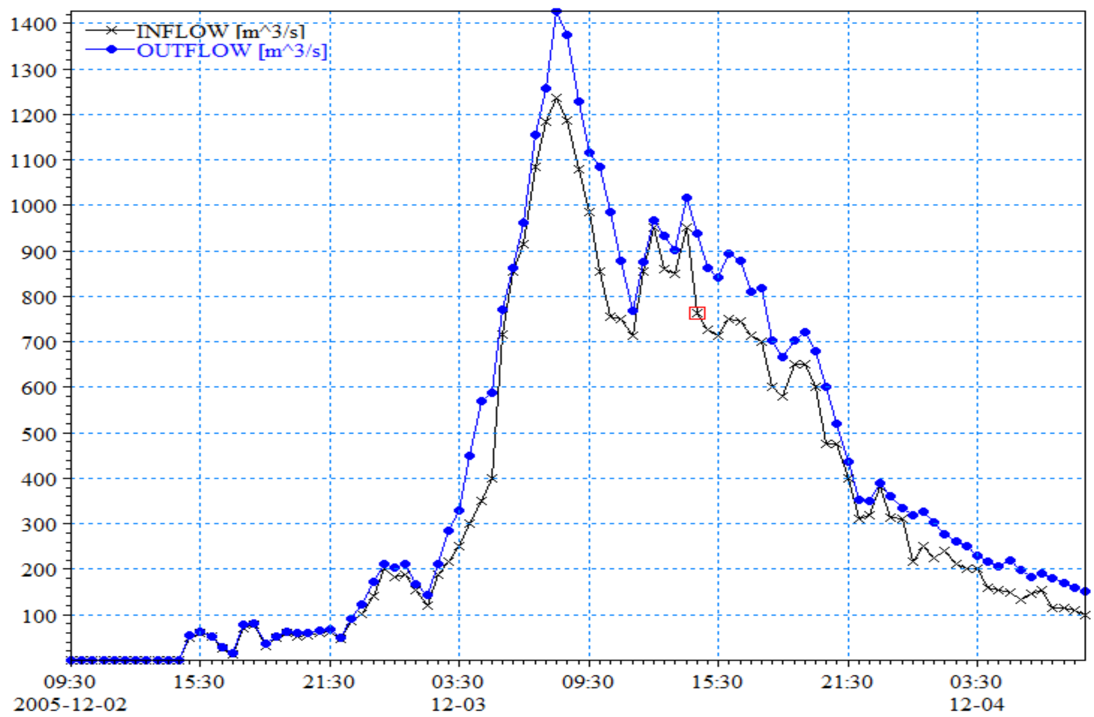
The parameters required for estimation of runoff and flood depth are catchment data which comprises of imperviousness, initial loss, reduction factor, time-area curve type , time of concentration and the head loss, boundary data and the simulation data.

3.1 Runoff hydrograph for selected location across Adayar river

Hourly runoff at various locations on the rivers Adayar was simulated for a rainfall period from 2nd December, 2005 to 4th December, 2005. Figure 2 (a) ,(b) and (c) present a plot of the derived runoff simulations for the Adayar river. These simulated flows have been used as an input in the hydrodynamic study for which results are presented in the text that follows.



(a)



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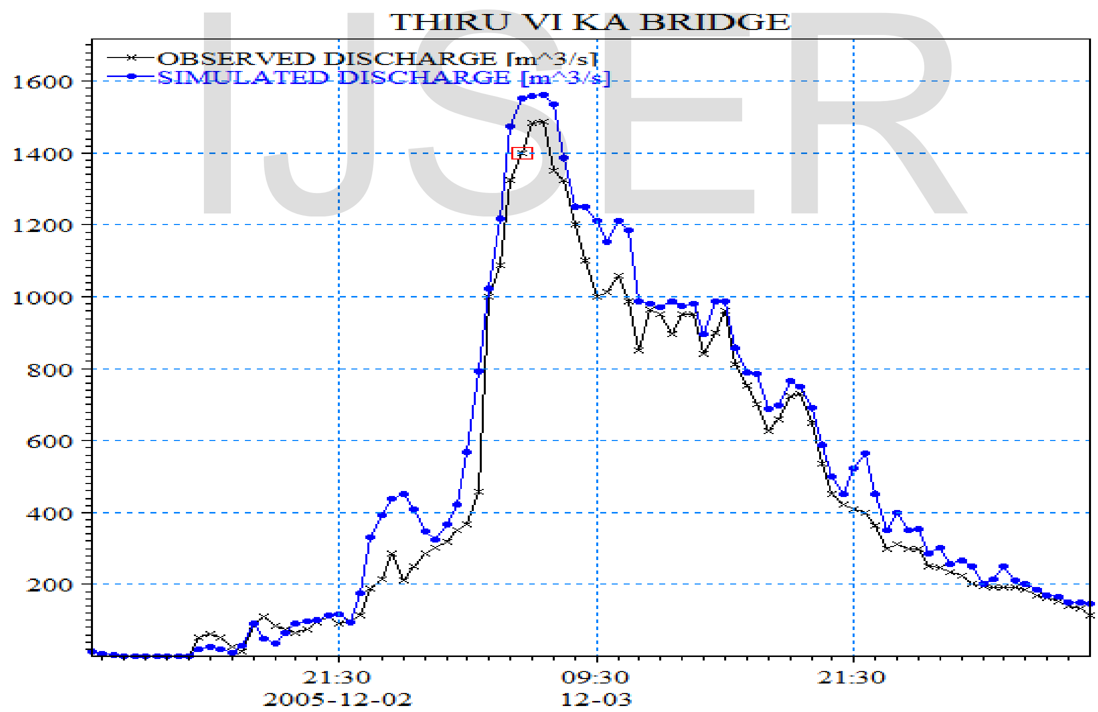


(c)

Figure no:2 Runoff hydrograph at (a) Nandambakkam bridge across Adayar river (b) Maraimagal Adigal bridge across Adayar river (c) Thiru-vi-ka bridge across Adayar river

4. HYDRODYNAMIC MODEL USING MIKEFLOOD

4.1 One dimensional hydrodynamic modeling using MIKE 11

MIKE-11 is a versatile engineering tool for modeling 1D hydrodynamic condition in rivers (DHI, 2009). MIKE-11 HD solves the Saint-Venant equations to obtain the hydrodynamic state of the river networks The hydrodynamic (HD) model is the nucleus of the MIKE-11 modeling system and forms the basis for simulation of flood inundation. The HD model is capable of simulating 1D unsteady flow in a network of rivers using hydrodynamic wave approach. The five basic input parameters to be specified for the MIKE-11 HD setup are the river network layout, cross sections, boundaries conditions, hydrodynamic parameters and simulation parameters. Before running the model simulation, control parameters such as simulation period, simulation time step, data to be stored and storage time were specified. There exists a versatile relationship between the time step and the computational distance to define the Courant number which is widely considered to choose the time step for the model simulation. The river network of the model is shown in the figure 3.

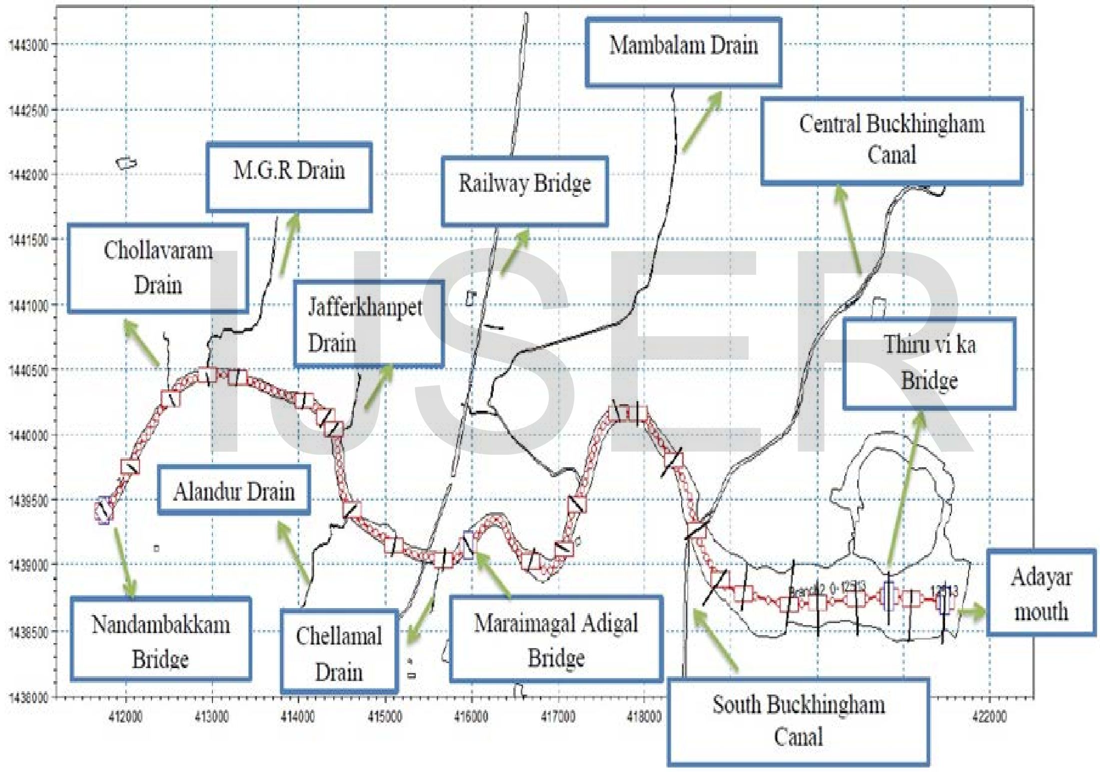


Figure 3: River network of Adayar river inside the MIKE 11model

In order to achieve stable flood simulation the computational time step was brought to a value of 3 seconds. The result of HD simulation consists of a time series of water level and discharges at various points along the river system which can be viewed through MIKEVIEW through graphical and animated interfaces.

4.2 Two-dimensional MIKE-21 HD model setup

MIKE-21 solves the full, time-dependent, non-linear equations of continuity and conservation of momentum. The MIKE-21 resolves the solution using an implicit finite difference scheme of second-order accuracy.

MIKE-21 model input parameter is bathymetry or terrain elevation is the most important input parameter, which contains the information regarding the elevations of the flood plain. The Digital Elevation Model, obtained from LiDAR-DEM for the study area was processed to obtain bathymetry as input for MIKE-21. The resolution of the input bathymetry was 10m x 10 m, so the computational distance was 10m and the time step adopted was 3 seconds for different simulations. The remaining input parameters such as the flood plain roughness coefficient (Manning's n) is kept as 0.038. Figure 4 shows the bathymetry used in the study area.

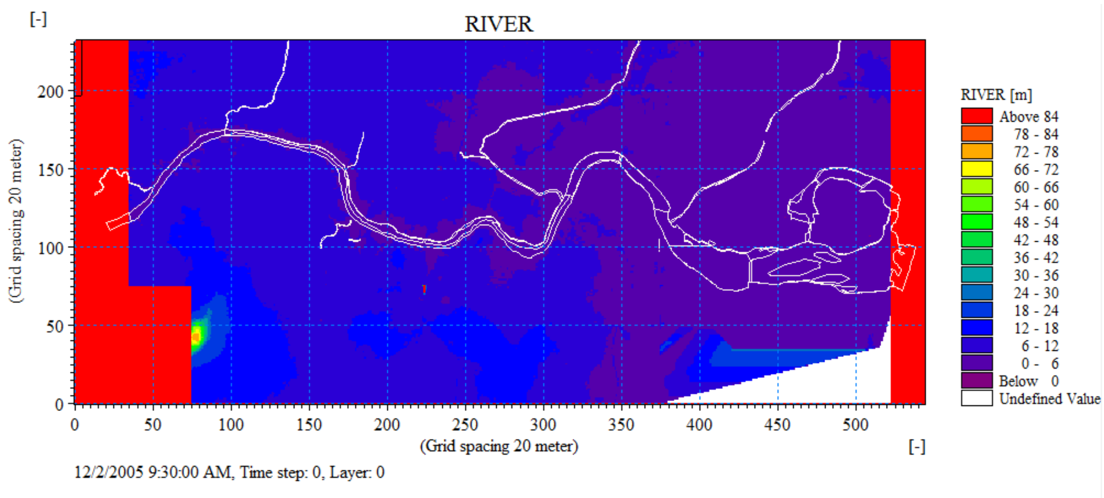


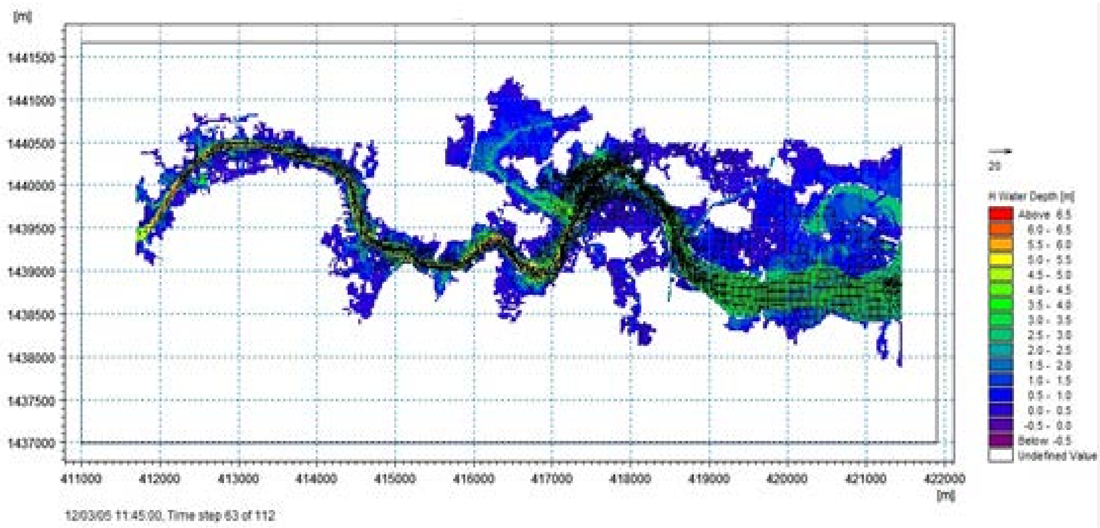
Figure 4: Shows the bathymetry used in the study area

4.3 Hydrodynamic model simulation using MIKEFLOOD

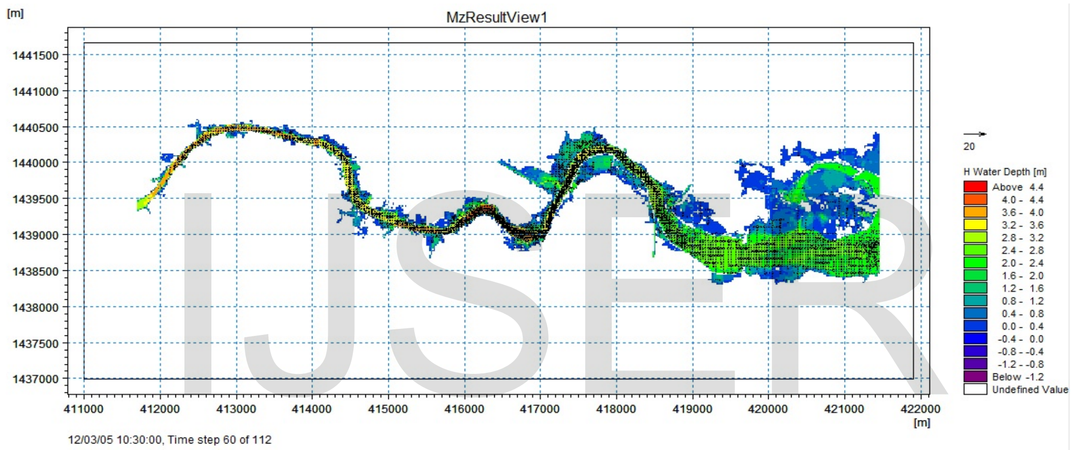
The MIKE-11 river network was connected to the MIKE-21 bathymetry using the lateral link option available in the MIKE-FLOOD (Kadem et al 2012). The river bank was dynamically linked with the MIKE-21 grids using a cell-by-cell approach. Whenever the overtopping takes place from the MIKE-11, the MIKE-21 calculates the discharge over each cell using weir formula. The inundation extent and depth in the flood plain for the overtopping water is calculated by MIKE-21.Other parameters for the left and right bank lateral links, such as momentum factor, weir coefficient and depth tolerance factor are kept at their default values. The Manning's n at all the link points was also kept as 0.038 value. MIKE-FLOOD setup along with the river and both the lateral links is shown in figure 5.Of the three curves in the figure, the central represents the Adayar River and the other two above and below are the left and right links respectively, which connect banks of the river cells of MIKE-11 with the bathymetry in MIKE-21. The simulation period for both MIKE-11 and MIKE-21 was kept the same and model computational time step was brought to a low value of 3 seconds in order to keep the Courant Number (CR) less than or equal to 1 so as to achieve stable MIKE-FLOOD simulation run without any errors.

5. RESULTS AND DISCUSSIONS

The flood inundation map by MIKE-FLOOD for two scenarios has been simulated and validated. From the figure 5 (a) and (b) the maximum flood level reached is 6.5m whereas after modification of the river bed level upto 1m there is a reduction of flood level up to 4.4m.This clearly states the flood mitigation through altering the river bed level has gained beneficial to the society in order to avoid flooding across the river. Since there is lack of observed data for calibration the model couldn't performe calibration but validation of the model have been done with the help of observed water level during the flood event 2005(Ramalingam, M 2007). According to the model results, the model validation was found satisfactory using R^2 goodness of fit of 0.93 at Nandambakkam bridge,0.96 for Maraimagal adigal bridge and 0.93 for Thiru-vi-ka bridge. .



(a)



(b)

Figure: 5 Flood inundation map of Adayar river for two scenarios (a) Surveyed cross-section (b) Modified cross-section up to 1.0 m

6. CONCLUSION

A 1D -2D coupled hydrodynamic model was developed for the Adayar river with the help of the state-of-the-art MIKE FLOOD software package. The model was validated for the year 2005 with little amount of available input data. The overall study helped in easily finding a easy solution to the flood problem. Such modeling study can prove extremely beneficial for many more similar cases that would help in mitigating the flood risk level.

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