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EFFECT OF URBANIZATION ON FLOODING: ADYAR RIVER A CASE STUDY

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Abstract

One of the effects of urbanization is an increase in the magnitude and frequency of floods, and its associated risks to the communities. The growth of urban settlements has put tremendous pressure on water supply, drainage,solid and liquid waste disposal. Urbanization of the catchments brings dramatic changes in hydrology, i.e., decrease in infiltration or increase in runoff, increased peak flow, reduced time of concentration. Two rivers namely Cooum and Adyar flow through Chennai city. These rivers are non – perennial. Due to encroachment along the banks of these rivers and non – implementation of the existing regulations due to fragmented and non – integrated agencies; the effect of flooding tends to be severe. Development along stream channels can alter the capacity of the channel to convey water and can increase inundation levels.

The Adyar river flows through the Chennai Metropolitan Area (CMA), which has very high density of population (Population of CMA: 70.41 lakhs as per 2001 census data). A number of irrigation tanks in the upstream discharge their surplus water into the river. In the years 1976, 1985, 2005 and 2008, the river overflowed on its banks, causing extensive flood damages. Hence, it is essential to analyze the flow pattern of the river to minimize the flood hazard. This study focuses on the present condition of the river and compares it with the conditions of river with 1999 data. Databases were prepared making use of Geographic Information System(GIS) on land use classification for 1976 and 2005.Water surface profiles along the river reach, for floods for various return periods were computed using HEC – RAS model.

Key words: *urbanization; flooding; land use; water surface profile; HEC – RAS ,GIS*

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INTRODUCTION

Urbanization is one of the anthropogenic activities that result in the loss of agricultural land, environmental degradation and decline in natural vegetative cover. The conversion of rural areas to urban areas has increased tremendously which affects the natural functioning of ecosystems. In urban areas, most of the land surface is covered by impervious material which reduces infiltration and accelerates the runoff process leading to the problem of flooding. The land use change has a considerable impact on the runoff nature and its related hydrological characteristics. Significant changes in land use would affect the overall health and functioning of a watershed. Rapid urbanization within river catchments has accentuated the flooding problem. Although flood hazard is natural, human modification and alteration of nature's right of way can aggravate the problem, the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas.

Urbanization is taking place rapidly in South Chennai, a coastal city which is located in North Eastern corner of Tamilnadu State, India. This leads to increase in human settlements, industrial growth and infrastructure development in flood hazard areas thereby decreasing the use of land resources for agriculture and economic development. This substantial change in land cover due to urbanization has magnified the intensity and magnitude of flooding by restricting the natural flow of flood waters. Due to the growth of infrastructure in IT, industries and housing sectors, there is drainage congestion of flood water during monsoon. Hence for the same amount of rainfall, greater is the flooding. The flood events of the years 2002, 2005 and 2008 have been magnified due to improper drainage facilities. Moreover, due to intense urbanization, inundation occurs even for a low intensity – short duration storm. The present work aims to assess the relationship between urbanization and flooding. HEC –RAS simulations were performed to generate water surface profiles.

OBJECTIVES

The objectives of the study are to

- Develop land use map by applying GIS as a tool
- Determine the flood levels along the river bank using HEC RAS for different return periods
- Establish a relationship between urbanization and flooding

STUDY AREA

The micro watershed that contributes flow to the Adyar River is taken and then delineated as study area. The latitudes and longitudes of the study area are 13° 01' 09"N, 80°00' 44"E and 13° 00' 46"N, 80°16' 37"E. The total area is about 146.24 sq km. Figure 1 shows the delineated study area of the Adyar River from the micro watershed.

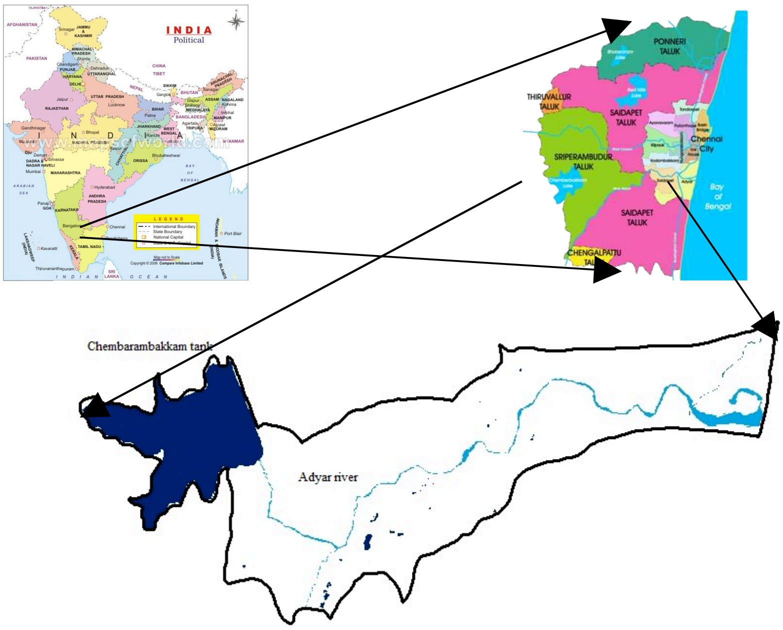

Fig. 1. Study area map

METHODOLOGY

The steps followed in the study are

- Land use classification
- Calculation of time of concentration using Arc GeoHMS
- Calculation of water surface profiles for steady flow using HEC RAS

Land use map (1976) was prepared using toposheet as base map in Arc Map 9.3. LISS III imagery taken in December 8, 2005 was processed and classified using Maximum Likelihood method in ERDAS Imagine 9.0 and digitized in Arc map platform to produce land use map (2005). Figure 2 and 3 show different land uses in the study area for the year 1976 and 2005 respectively. Table 1 shows the change in land use for the year 1976 and 2005.

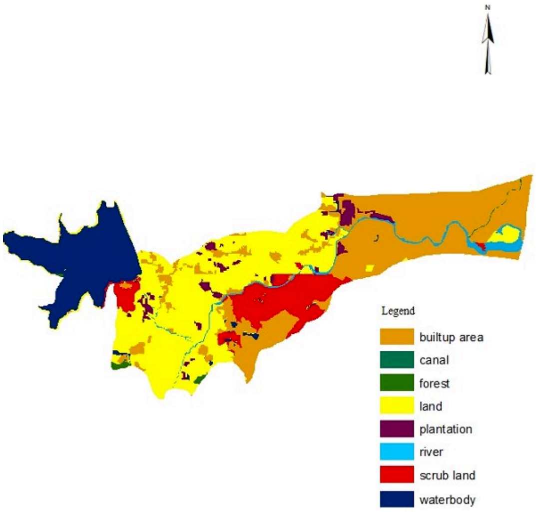

Fig. 2. Land use map (1976)

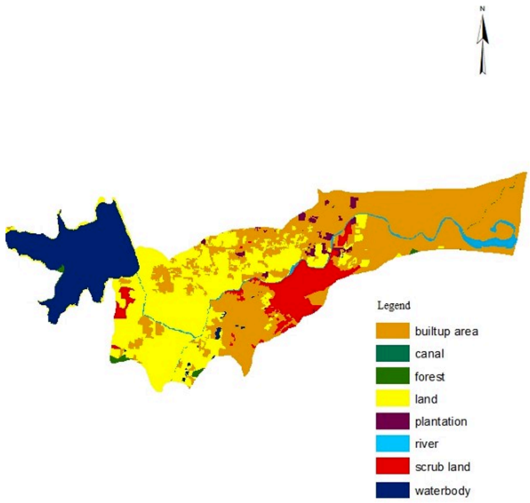

Fig. 3. Land use map (2005)

Table 1. Change in land use

Sl No	Landuse	Area in sq km		% Change
		1976	2005	
1	Built-up area	48.601	63.387	30
2	Canal	0.148	0.073	-51
3	Forest	0.584	0.774	33
4	Land	51.023	43.099	-16
5	Plantation	4.173	1.789	-57
6	River	3.708	3.307	-11
7	Scrub land	14.703	10.886	-26
8	Waterbody	23.28	22.924	-2
	Total	146.22	146.239	

Land use change is a major force altering the hydrological processes over a range of temporal and spatial scales. This can affect the runoff generation and concentration by altering hydrological factors such as interception, infiltration and evaporation, and thus causes changes in the frequency and intensity of flooding. At a catchment scale, such impacts on hydrological processes in turn will significantly influence ecosystem, environment and economy. Therefore a better understanding and assessment of land use change impacts on watershed hydrologic processes is of great importance for predicting flood potential and mitigation of hazard, and has become a crucial issue for planning, management and sustainable development of the watershed (Ying Chen, 2009).

From the table 1, it was found that built area has increased from 33% to 44% and there is a reduction in other land use pattern. The main hydrologic parameters used to represent urbanization conditions are: (a) impermeable area of the basin, understood here as the proportion of the surface area, for which precipitation enters the storm-water network directly; (b) time of concentration or velocity of the flow through the basin (Nestor, 2001). Therefore, time of concentration was calculated using TR 55 (Technical Release 55) method by giving the stream network, Digital Elevation Model (DEM), Curve number from land use maps and precipitation as inputs in Arc GeoHMS. It was found that travel time has decreased from **3.34 hours** (1976) to **2.2 hours** (2005). It reveals that land use change is a major process altering the hydrological processes in the study area. It can also cause changes in the frequency and intensity of flooding.

Hydrologic Engineering Center's River Analysis System (HEC-RAS) is used to perform one dimensional hydraulic calculation for the entire stretch of Adyar River. Geometric data and steady flow data are the main inputs to run HEC RAS model. The basic geometric data consists of the river system schematic, cross section details, reach length etc. The cross sectional details of the river are obtained from Public Works Department (PWD), Chennai. The steady flow data consist of flow regime, boundary conditions and peak discharge. For this study, the flow through the river is assumed as mixed flow. In a mixed flow regime, boundary conditions are necessary at the upstream and downstream ends of the river. For this analysis, normal depth is taken as boundary condition in upstream and known water surface elevation (tide levels) in downstream. The rational method is used to determine the peak discharge using the formula,

$$Q = 0.00278\,CIA \tag{1}$$

Q = Peak discharge (m^3/sec)
C = Runoff coefficient
I = Intensity of rainfall (mm/hr)
A = Drainage area (km^2)

The rainfall intensity is obtained from the I-D-F (Intensity – Duration – Frequency) curve diagram and it was selected corresponding to the time of concentration as duration in minutes for the return period of 1.1, 1.5, 2, 3, 4, 5, 10, 20, 30, 40, 50, 100 and 200 years. Time of concentration for the year 1976 was taken as 202 minutes and for the year 2005 was taken as 132 minutes. The peak discharge is calculated for all the return periods and entered accordingly. The calculated peak discharge for the study area with different return periods for the land use pattern of year 1976 and 2005 are given in figure 4.

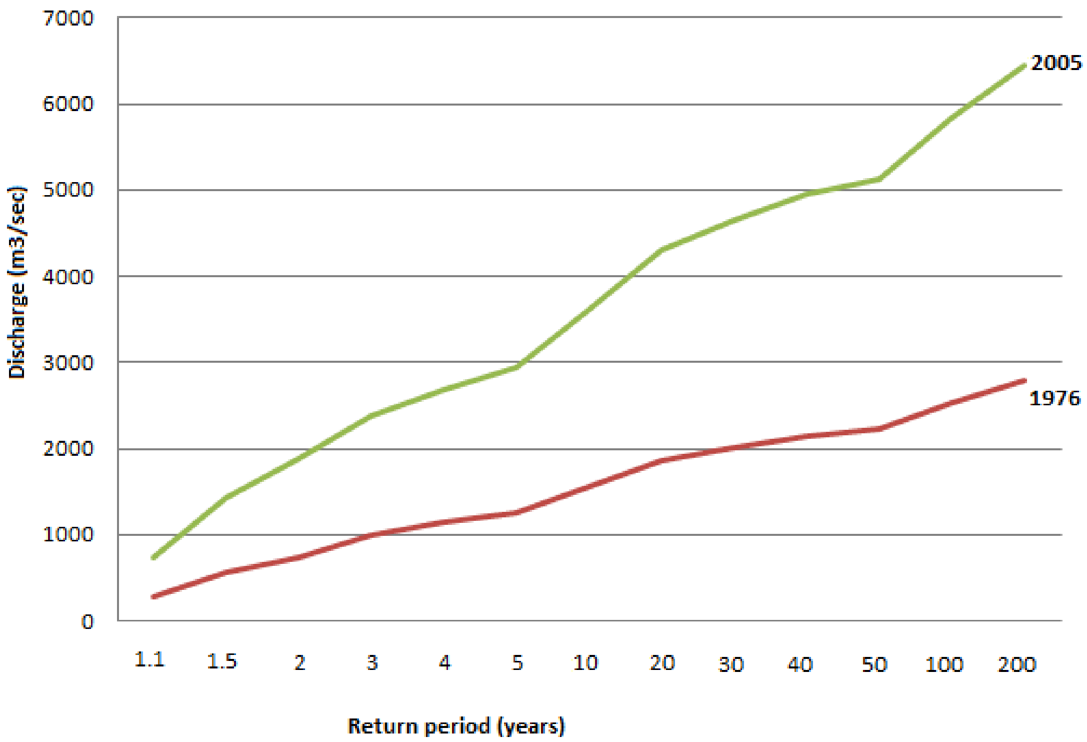

Fig. 4. Peak discharge for the land use in the years 1976 and 2005

. The top width of the river varies from 386.4 m near the sea mouth to 117.97 m at a distance of 7.2 km from the sea mouth. The depth of the river varies from 2.53 m to 10.72 m. The model is run for the years 1976 and 2005 for all the return periods mentioned above. Model results are in the form of water surface profiles, cross sectional plots, cross section profile tables and X-Y-Z perspective plots. It is seen from the results that the model is capable of simulating the flow profiles for different return periods. Figure 5 and figure 6 shows the water surface profiles for the Adyar river from Chembarambakkam tank to sea mouth for the year 1976 and 2005 respectively.

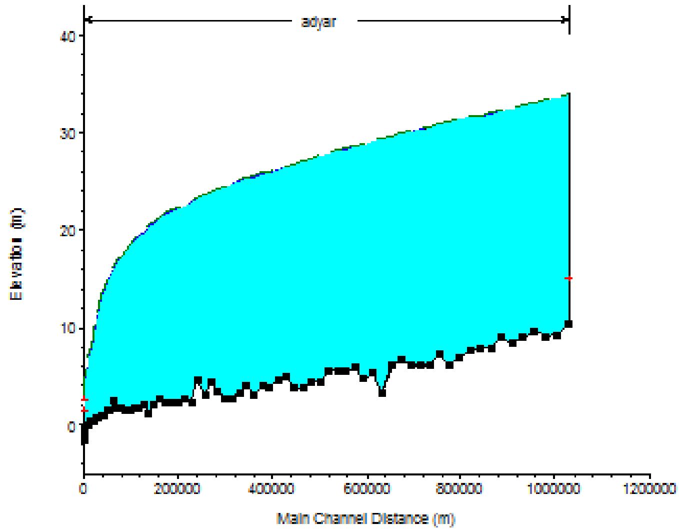

Fig. 5. Water surface profile plot (1976) for the return period of 100 years

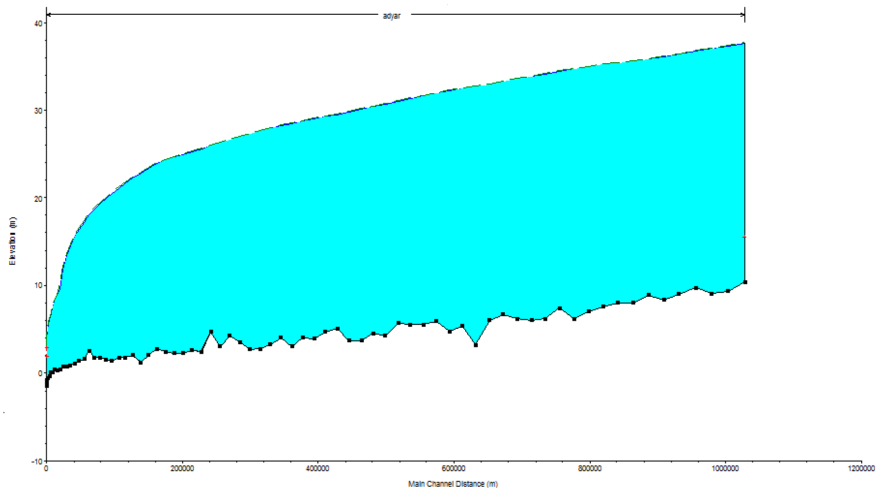

Fig. 6. Water surface profile plot (2005) for the return period of 100 years

CONCLUSIONS

With the change in land use pattern, there has been a rise in impervious area (Figure 3 and Table 1). From the present study it is seen that the peak discharge for a given return period is lower for 1976 land usee pattern. Whereas, for the 2005 land use pattern, flooding occurs even for lower return period and lower intensity of rainfall. Due to increased impervious area, precipitation responds quickly reducing the time to peak and producing higher peak flows in the river. This proves that there is a strong relationship between urbanization and flooding. Proper assessment of increasing flood risk to the study area from rapid urbanization cannot be done without the integration and analysis of land use data. Therefore, planned land use should be explored, proposed and implemented to minimize the effect of flooding. Both engineers and policy makers should come up with innovative ideas for effective flood management strategies, in an integrated framework.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Nestor A. Campana and Carlos E. M. Tucci (2001), 'Predicting floods from urban development scenarios: Case study of the Diluvio basin, Porto Alegre, Brazil', Urban water 3: pp 113 – 124

USACE, 2002, HEC-RAS River Analysis System, User's Manual, U.S. Army Corps of Engineers

Ying Chen, Youpeng Xu, Yixing Yin, 2009 'Impacts of land use change scenarios on storm runoff generation in Xitiaoxi basin, China', Quaternary International, pp 1 – 8