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Estimation of Flood using Unit Hydrograph

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ABSTRACT: Nowadays, flood risk management is gaining importance in order to mitigate and prevent flood disasters, and consequently the analysis of flood risk components is becoming a key research topic. An improvement in flood risk assessment and study of a possible increase in flooding occurrence are therefore needed. To carry out these tasks it is important to have at our disposal extensive knowledge on historical floods and to find an efficient way to manage this geographical data. The findings indicate that floods is a major natural hazard that set back development in the area; spring and winter seasons are the peaks months of rainfall occurrences to rainfall year reflected unusually high claims related to flood damage. While many groups and individuals have already worked on various sections of the city, a systematic collection of the data and a city wide mapping of this information is an essential requisite moving forward. The methodology is based on a mathematical index, which considers local topography and basic information about the flood scenario to reproduce flooding processes. Its application allows for considering different levels of complexity of flood scenarios, from localized flood defence failures to complex hazard scenarios involving river reaches. The methodology synthesizes the spatial distribution of the index values into maps and curves that can be used to rank the susceptibility and implement a vulnerability analysis in the area of interest. The software used in our flood estimation project are HEC-HMS and ArcGIS. The Hydrological Modeling System (HEC-HMS) is designed to simulate the precipitation - runoff processes of dendritic drainage basins. The data collected like soil type data, rainfall data, boundary map and other topographical features are used to process the DEM file which is the basic feature of this project. The first step of the data processing is done in ArcGIS where the Stream network is generated using the elevation data of DEM and then the entire watershed is delineated into several sub basins to make the work easier in the forthcoming works of the project. The results show that the methodology can provide an original and valuable insight of flood susceptibility and vulnerability processes.

KEYWORDS: DEM, Arc-GIS, HEC-HMS.

I. INTRODUCTION

Chennai had experienced record-breaking rains and flooding in 2015 since early November. Beginning on December 1, the rain intensified again creating more flooding and causing thousands of people to be stranded and trapped. An estimated 188 people had died, and over 200,000 had been displaced. Earlier in the week 3500 were stranded at Chennai Airport. The Chennai floods have thrown up some fundamental flaws in our system of urban planning. Across India, city after city has experienced floods, while some others live with the fear of impending disasters.

In Tamil Nadu's hurry to industrialise, these watershed areas have been ravaged, with all the major industries, new educational institutions, housing estates, etc., coming up in the past two decades. Thousands of smaller ponds and streams have been filled up, increasing the surface water flow manifold. The major tanks are silted and the amount of water flowing into them has increased. This increased run-off has found its way into the city. Unprecedented rain, induced by climate change, has compounded the problem. While the disaster has been caused by nature, the impact would not have been so severe but for the man-made factors.

The second dimension of Chennai's flood is another man-made problem. The Adyar River in the south of the original city had a wide estuary and also a wide flood plain. Many areas south of the river have been marshy and low-lying, serviced by small rivulets and canals. The planned developments along the Adyar River that reduced its capacity as a water outlet are largely government-sponsored as the river bed was in government ownership. In the past three decades, massive housing, planned and unplanned, has cannibalised the river bed, leading to increased flooding, and damaged Chennai's technology nerve centres and put millions of residents in danger.

In the first 24 hours the city received 246 mm of rainfall breaking the 1976 record when Madras (as the city was called then) received 452 mm of rain. In many parts of South Chennai, the water was almost five feet in depth, especially those which have been constructed on marshes and swamps. The National Institute of Disaster Management reports that in Chennai, 650 water bodies, which include lakes, ponds, and storage tanks, have been destroyed. Today, sadly, there are just 27 water bodies.



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The main objectives of the studies are to construction of unit hydrograph and estimation of flood from the results and also to create the base map from Arc GIS 10.2 and the flow is to be determined from HECHMS 4.2.1 software.

II. STUDY AREA

Adyar river basin, Tamilnadu, India is selected for the study area. The origin of the adyar river basin is in Kanchipuram (Pillaipakkam and Kavanur Tank Groups). It geographically lies 30°00'49.21''N / 80°15'56.12''E of an area of 860 Sq.km. Maximum length and breadth of watershed are 42.5 kms and 10-200 kms respectively. The average discharge of the river basin for the year was 89.4 MCM. The study area was illustrated in Fig. 1.



Fig. 1. Study Area

2.1 REASON FOR SELECTION

Chennai is a coastal city, where the two rivers, namely Adyar and Cooum, flow through. The Chennai Metropolitan Area (CMA) can broadly be divided into three parts. The northern part lies above the Cooum River, middle region is between Cooum and Adyar Rivers and the southern portion is below Adyar River.Floods hit the Chennai City due to heavy rainfall in its environs in the months of November and December, 2015. Adyar River and Cooum River that flows through the Chennai city caused floods due to high intensity of rainfall. These two river discharges are added to the urban floods (flood due to high intensity of rainfall within the city) and inundated the city. Initially there was a flood like situation in both the rivers during Nov 22 to 24 due to heavy rainfall and subsequently, there is an unprecedented rainfall in the catchment on01 to 02 Dec, 2015, as a result heavy floods triggered in the Chennai City and in its surroundings. The devastating floods that hit Chennai city and other parts of Tamil Nadu during November-December 2015 have claimed more than 400 lives and caused enormous economic damages. This has posed a challenge to the scientific community in developing a comprehensive understanding of the event. A brief hydrological and hydrodynamic modeling study has been carried out on the Adyar river flood for approximate quantification of flood discharges and to forecast the flood discharges (up to 10 Dec 2015).



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2.2 DATA COLLECTION

Data	Source
Boundary map of Adyar river basin	www.wris.nrsc.gov.in/wrpinfo/index.php title=Tamil_Nadu
Land use data and soil type data of Adyar river basin	www.bhuvan.nrsc.gov.in
Rainfall data	State Ground and Surface Water Resources Data Centre, Tharamani
Digital elevation model from Cartosat-1 PAN (2.5m) Stereo Data	http://bhuvan.nrsc.gov.in/data/download/index.php
Other topographical Information	Google earth, Atlas

2.1.1 Boundary Map

The boundary map is nothing but the outline of the place we require. The use of the boundary map in this project is to clip out the region we require from the digital elevation model in Arc-GIS. A Digital Elevation Model (DEM) will be loaded in ArcGIS software irrespective of the boundary conditions we require. Later on the boundary map is uploaded in the software and the required region from the DEM file is cropped out for further use in it.

2.1.2 Soil and Landuse Data

The soil data and land use data plays a vital role in this project. The entire rainfall and discharge is not going to be converted to runoff. This water which flows on the medium called soil. Therefore it is the type of the soil which decides the amount of infiltration, and the remaining runoff. Not only the soil features but also the slope on which it flows the speed of the water are all deciding factors for runoff. Land cover data provides information on how much of region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Land use shows how people use the landscape – whether for development, conservation, or mixed uses. This soil data comes in handy when we work on HEC-HMS where we require Curve numbers for discharge calculation. Also the losses, lag time, time of concentration are some of the important results we can compute and feed it into HEC-HMS for a quite good result in discharge.

2.1.3 Rainfall Data

Date	Nungambakkam	Mylapore	Taramani
29 Nov 2015	0.80	0	0
30 Nov 2015	23.5	24.80	31.4
01 Dec 2015	39.6	49.20	40
02 Dec 2015	291.5	272.80	300
03 Dec 2015	16	21.60	0
04 Dec 2015	5	4.80	5
05 Dec 2015	45.9	57.20	32
06 Dec 2015	21.2	7.20	24
07 Dec 2015	24.6	26.20	22
08 Dec 2015	0	0	0
09 Dec 2015	6.6	6.60	13
10 Dec 2015	1.7	2.40	1
29 Nov 2015	0.80	0	0

III. SYSTEMATIC PROCEDURE

The Surface runoff can be calculated by GIS based SCS-CN method.

3.1 SURFACE RUNOFF ASSESSMENT

Integration of SCS-CN method (USDA 1972) with GIS, used to estimate the surface runoff from the water shed. A lumped parameter runoff watershed model is constructed and loosely coupled with GIS. In this way of approach, GIS



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creates a spatial database that describes the hydrological properties of the watershed. Base map, land use and soil coverage's of the study area are also created using GIS technology. Overlaying tool of GIS is used for computing the appropriate area-weighted curve number. Then the daily rainfall database is fused with the analysis to estimate the direct runoff from the watershed. By this result, water resources can be properly managed and also used for scheduling the irrigation pattern of the watershed.

3.2 GIS BASED SCS-CN METHOD

There are many empirical methods for estimating runoff in hydrological modelling. In that (SCS 1972) Soil Conservation Service-Curve Number Method developed by United States Department of Agriculture and Soil Conservation Service. USDA-SCS is frequently used technique used worldwide for estimating surface runoff. This method is very familiar because of its simplicity, flexibility and requirement of a single parameter called Curve Number (CN) for computing surface runoff. The equation for surface runoff is given by (Ghanshyam 2000). The US Soil Conservation Service has found by experience that,

Ia = 0.2S

The term S is given by

$$S = \frac{25400}{CN} - 254$$

Where, CN indicates Curve Number.

For Indian conditions, some modifications were done by Department of soil and water conservation, Ministry of Agriculture, New Delhi. According to Indian conditions, Ia = 0.3S.

Equation can be written as

$$Q = \frac{(P-0.3S)^2}{(P-0.7S)}$$

By knowing the value of CN, the watershed runoff is obtained from equations. The SCS curve number is the action of capability of soil to permit infiltration of water, usage of land and preceding soil moisture. According to U.S. Soil Conservation Service, soils are categorized into four hydrologic groups such as Group A, Group B, Group C and Group D. With respect to the rate of runoff potential and final infiltration rate (Glenn O. Schwab et al 1981).

The runoff depth or volume from watersheds with distinct land use can be obtained (i) by determining the volume of runoff from each individual land use and then adding these amounts (ii) by calculating an area-weighted curve number for the watershed and then using this single value in equations.

3.3 HYDROLOGICAL SOIL GROUP CONSERVATION

The NRCS curve number relates soil type, land use, soil infiltration capability and the depth level of the seasonal high water table. By the ability to infiltrate, NRCS categorise soils into four Hydrologic Soil Groups (HSGs) were used.

IV. SOFTWARE USED

The software used in our flood estimation project are HEC-HMS, ArcGIS. These are explained in brief below.

4.1 HEC-HMS

The Hydrological Modeling System (HEC-HMS) is designed to simulate the precipitation – runoff processes of dendritic drainage basins. It is designed to be applicable in a wide range of geographical areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff.

Hydrographs produced by the programs are used directly or in water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The program is a generalized modeling system capable of representing many different watersheds. A model of the water cycle into manageable pieces and constructing boundaries around the watershed of interest. Any mass or energy flux in the cycle can then be represented with a mathematical model. In most cases, several model choices are available



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for representing each flux. Each mathematical model includes in the program is suitable in different environments and under different conditions. Making the correct choice requires knowledge of the watershed, the goals of the hydrologic study, and engineering judgment.

HEC-HMS is a product of the Hydrologic Engineering Center within the U.S. Army Corps of Engineers. The program was developed beginning in 1992 as a replacement for HEC-1 which has long been considered a standard for hydrological simulation. The new HEC-HMS provides almost all of the same simulation capabilities, but has modernized them with advances in numerical analysis that take advantage of the significantly faster desktop computers available today. It also includes a number of features that were not included in HEC-1, such as continuous simulation and grid cell surface hydrology. It also provides a graphical user interface to make it easier to use the software. The program is now widely used and accepted for many official purposes, such as floodway determinations of the Federal Emergency Management Agency in the United States.

4.2 ARC-GIS

ArcGIS is a geographical information system (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analysing mapped information, sharing and discovering geographical information in a range of applications, and managing geographical information in a database. The system provides infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the web. This software allows you to perform one dimensional steady flow, one and two dimensional unsteady flow calculations, sediment transport/mobile bed computation and water temperature/water quality modeling.

A GIS is a powerful tool used for computerized mapping and spatial analysis. It provides functionality to capture, store, analyse, display and output geographic information. The components of ArcGIS 10.2 are ArcMap, ArcCatalog, and ArcToolbox.

ArcMap: It is the main mapping application which allows you to create maps, query, attributes, analyse spatial relationships, and layout final projects.

ArcCatalog: It organizes spatial data contained on your computer and various other locations and allows for you to search preview and add data to ArcMap as well as manage metadata and setup address locator services (Geocoding).

ArcToolbox: It is the third application of the ArcGIS desktop. Although it is not accessible from the start menu, it is easily accessed and used within ArcMap and ArcCatalog. ArcToolbox contains tools for geoprocessing, data conversion, coordinate system, projections and more.

V. RESULTS



Fig 2. Final output from ARCGIS

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Fig 3. Final Ouput from HEC-HMS

Show Elements: All Elements	Start of Run: 29Nov20 End of Run: 10Dec20 Compute Time: 15Mar20	Sortion: Hydrologic v		
Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
Subbasin-2	96	244.8	02Dec2015,00:00	420.89
Subbasin-1	94	236.6	02Dec2015, 00:00	414.31
Subbasin-4	23	56.5	02Dec2015, 00:00	428.56
lunction-1	213	537.9	02Dec2015, 00:00	418.81
Reach-1	213	537.1	02Dec2015, 00:00	418.81
Subbasin-3	133	351.3	02Dec2015, 00:00	442.75
lunction-2	346	888.4	02Dec2015, 00:00	428.01
Reach-2	346	887.2	02Dec2015, 00:00	428.01
Subbasin-6	82	212.2	02Dec2015, 00:00	459.32
Subbasin-5	36	88.3	02Dec2015, 00:00	456.38
lunction-3	464	1187.7	02Dec2015, 00:00	435.74
Reach-3	464	1186.0	02Dec2015, 00:00	435.74
Subbasin-7	86	211.0	02Dec2015, 00:00	456.38
lunction-4	550	1397.0	02Dec2015, 00:00	438.97
Reach-4	550	1395.1	02Dec2015, 00:00	438.97
Sink-1	550	1395.1	02Dec2015, 00:00	438.97

Fig 4. Final result from HEC-HMS

VI. CONCLUSION AND RECOMMENDATION

Many lessons can be learnt from an event of this magnitude to aid better preparedness to face such events in future, not just in Chennai but also in other urban areas in India and elsewhere in developing countries. Herein, some ideas are proposed as recommendations on which attention needs to be focused by the policy makers, administrators and academicians.

Better Understanding of the Weather: It is obvious that flood risk can be minimized if one can predict the occurrence of major precipitation events well in advance. This is especially so for cities like Chennai, where major reservoirs are drinking water reservoirs, and one tends to store as much water as possible when the rains come, and little storage is left for flood mitigation.

Water Wiring of Cities: One of the major issues with regard to management of urban floods in India is the lack of information on them. For example, with regard to flows in major drainage channels during December 2015 floods in Chennai, authors could find data only on the releases from major reservoirs such as Chembarambakkam. Flow data was not available at other locations of the major drainages such as the Adyar River, the Cooum River, or the Buckingham canal. In fact, proper gauging stations are not available on these rivers and continuous flow data is not collected. Also, scientifically collected data on the temporal and spatial variation of depth of inundation during different stages of flooding is not available. It is absolutely essential to deploy sensors at all key locations in the major drainage networks in the Cities and record online the temporal variation in water levels and also the flow rates. Sufficient number of telemetric



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rain gauge stations should be installed. The water level sensors should be not only deployed in channels, but also at key locations in the flood plain and at all major and medium water bodies. All the data should be transmitted to centralized control rooms to provide real time information, flood hazard mapping etc.

Development of Urban Flood Models: Many mathematical models are presentlyavailable worldwide for studying urban floods. However, extensive and proper usage of these models in India is hampered by lack of data for their calibration and validation. There is an urgent need to bridge this gap, and to keep ready calibrated urban flooding models for all the cities which get flooded frequently. Such models can be used for designing flood warning systems, on-line control of urban floods and planning water sensitive urban development.

Maintenance of Drainage System: One cannot over-emphasize the need for keeping all the storm water drains free from blockages due to indiscriminate dumping of solid waste into them. While keeping the major drains clean could be the responsibility of the urban local body, keeping the minor drains clean should be the responsibility of local population. It is not possible to make the entire drainage system work effectively, unless part of the ownership of the drainage system is taken by the local users. It may be worthwhile to encourage the formation of citizen groups which work in close coordination with government.

6.1 PILOT FLOOD FORECAST SYSTEM

A pilot flood forecast system being developed for Chennai by IIT-Madras, IITBombay and Anna University. Even as civic agencies are taking steps to mitigate the effect of rains this northeast monsoon, IIT-Madras, IIT- Bombay and Anna University have come together to develop a pilot flood forecast system for the city.



Fig 5. Pilot Flood Forecast System

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