CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Floods, earthquakes and forest fires are the most threatening natural hazards in the world and claim thousands of life and destroy properties every year (WBGU, 1999). Flood refers to the phenomenon of influx of water beyond its normal confines to an area resulting in disruption of normal human activities, destruction of properties, loss of animal and human lives, and environmental damages. Flood can be in the form of local inundation due to heavy rain or due to accumulation of runoff/discharge after heavy rain in the catchments and/or due to breach of embankment. The main causes of flood in India are: (i) high accumulation of water due to localized heavy rainfall, (ii) excessive accumulation of runoff after heavy rainfall, (iii) high discharge from upper basin areas, (iv) poor drainage condition of rivers/canals/dykes etc, (v) inadequate shape and size of the catchments area, and (vi) inadequate shape and strength of river/coastal embankments.

In India, during 1953 to 2004, about 397 Mha areas have been affected due to floods as reported by CWC (2005). During these years, about 185 Mha crop land has been affected damaging over 6.4 crore houses; affecting lives of over 1.7 billion people and killing over 49 lakhs of cattles. Thus understanding of rainfall pattern, river flow dynamics and mapping of floodplain during monsoon season is the key to minimize the risk of flood around a river basin. This study concentrates on the analysis of discharge pattern of the Subernarekha River and estimates the flood hazard zones in and around the river basin.

1.2 BACKGROUND OF THE STUDY

The Subernarekha River is one of the longest flowing inter-state rivers in the eastern part of India. It flows through the state of Jharkhand, West Bengal and Orissa. The river basin lies within north latitudes of $21^{\circ} 33'$ to $23^{\circ} 32'$ and east longitudes of $85^{\circ} 09'$ to $87^{\circ} 27'$. The river originates near Nagri village in Ranchi district of Jharkhand at an elevation of 600 m and flows about 395 km before discharges into the Bay of Bengal. The principal tributaries of the river are the Kanchi, the Kharkai and the Karkari. From 1960 to 2006, 14 major floods had occurred on the banks of this river. These floods affected lives of thousands of people and destroyed crop land and properties especially in the plains of West Bengal and Orissa. The Kharkai and the Gara nallah flow through the uranium and copper mining sites located in the state of Jharkhand. During floods, waste materials from outside dumps may be carried away through the river and its tributaries to a long distance into the downstream. For these reasons, flood inundation mapping and flood hazard assessment of the Subernarekha River is of utmost important to the concern mining companies, state government and local inhabitants. It has become a real challenge for central government as well as state government agencies to combat flood consequences almost every year. There has been no scientific study conducted to model the flood behaviour of this river to provide forecasting of floods for years to come. To our belief, this is the first study of its kind conducted for this river and the results of this study will immensely help to the Central Water Commission (CWC) and Water Resources Departments of the states, West Bengal and Orissa to make necessary decision for mitigating measures.

Over the years, in India, flood inundation mapping and flood hazard assessment have been prepared manually. Manual analysis can only provide maps of the flood inundation area and it is difficult to identify specific land use and land cover classes which are affected in a floodplain. In recent years, remote sensing and GIS techniques have encouraged researchers to perform similar tasks almost automatically and more accurately. Using these tools, extent of flood with depth of water levels, mapping of velocity, discharge and identification of affected land use and land cover areas in a floodplain are possible with much improved presentation capabilities. This information is useful in flood warning systems, evacuation of people in the flood hazard zones and for taking necessary action plans for the reduction of loss of lives and property. Floodplain mapping of the Subernarekha River has not been conducted yet to estimate its damage potential in future years. It is then become imperative to conduct this study for forecasting future flood events along the reaches of this river.

A further important aspect which limits the use of hydrologic and hydraulic approach in flood forecasting of different return periods is the lack of sufficient data related to water levels and discharge at number of gauging sites. Due to this reason, flood frequency analysis cannot be performed with desired degree of accuracy. In this context, regionalization improves the flow statistics at sites where records are limited. Regional flood frequency analysis essentially identifies a single frequency distribution for the sites by pooling of the data of all gauging stations in a given region. In this study, L-moment statistics have been used for estimating and selecting a suitable regional frequency distribution of the river. L-moments have the theoretical advantages over conventional moments which are able to characterize a wider range of distributions, more robust to the presence of outliers in the data and are less subjective to bias in estimation (Hosking and Wallis, 1997).

While conducting regional frequency analysis using L- moments approach, it has been observed that a set of frequency distribution might be possible candidates to represent the frequency distribution of the data. Therefore, a new methodology termed as “composite model” has been proposed for the first time to model the regional frequency distribution of the data. This model integrates the outputs of the different candidate distributions to produce the regional frequency distribution of the river utilizing neural network modeling approach.

In general, flood forecasting for future years is carried out using the outputs of flood frequency analysis and wide or sharp flow hydrographs of past flood years. In this study, analysis of last 20 years flood hydrographs reveals that wide flow hydrograph of 1997 is extreme in nature and distinctly different from other flood years. It has been realized that this traditional approach would over-predict flood events, and the design consideration based on this hydrograph would be a very conservative representation of future flood events. Hence, a novel approach, using a 'bump function', has been proposed in this study to categorize the hydrographs into severe, moderate and normal flow hydrographs. Based on this, future flood hazard mapping has been performed.

Moreover, hydrodynamic modeling of the river has also not been conducted to simulate the discharge and to determine the basic frictional characteristics of the channel and the floodplain. As this river is an important source of water in the eastern part of India and covers about 23,510 ha of crop land, it is imperative to understand the discharge pattern of the river during monsoon period and to forecast flooding events in the future.

1.3 OBJECTIVES AND SCOPE OF WORK

Based on the above background, the following objectives and scope of work are undertaken in this thesis.

(1) Analysis of water level and discharge along the Subernarekha River using hydrodynamic modeling technique.

To fulfill this objective, the following tasks are performed:

- Development of digital elevation model (DEM) of the study area using CARTOSAT-1 stereo data and extraction of river cross sections from the DEM for a reach length of 154 km.
- Collection of river cross sections at available gauging sites from Central Water Commission (CWC) and measurements of cross sections at another 9 locations from Ghatshila to Jamshedpur.

- Development of channel network using Survey of India (SOI) toposheets and satellite images for hydrodynamic modeling of the channel and floodplain.
- Estimation of water levels and discharge at various nodal points along the reaches of the river for the flood years of 1985, 1988 and 1997 and validation with measured data obtained from CWC.
- Development of flood inundation maps of the flood affected years 1985, 1988 and 1997.

(2) Forecasting of future flood events for different return periods using regional flood frequency analysis.

Scope of work for this objective is enumerated below:

- Identification of regional flood frequency distribution using L-moments ratio diagram and Z-statistic concepts. Both individual frequency distribution and composite model distributions have been studied.
- Hydrographs of the years 1985 to 2005 have been classified into "severe", "moderate" and "normal" flow hydrographs using 'bump function' approach.
- Calculation of growth factors and preparation of flow hydrographs for extreme, severe and moderate categories are done for different return periods of 10, 25, 50 and 100 years at 4 gauging stations namely Jamshedpur, Ghatsgila, Jamsholghat and Bhosraghat.

(3) Development of flood inundation maps and assessment of possible flood affected areas using land use and land cover maps.

The tasks of this objective are:

- Development of flood inundation maps using IRS P6 with LISS III for different return periods of 10, 25, 50 and 100 years.
- Preparation of land use and land cover map along the reaches of the Subernarekha River.

- Damage assessment for different land use and land cover classes based on flood inundation maps and depth of water levels for the flood affected years of 1985, 1988 and 1997.
- Hazard assessment for different land use and land cover classes based on flood inundation maps and depth of water levels for different return periods.
- Construction of flood hazard maps for extreme, severe and moderate categories for different return periods and expected hazards for different land use and land cover classes.

1.4 CONTRIBUTION OF THE THESIS

In India, Shuttele Radar Topography Mission (SRTM) imageries are popularly used for the development of DEM in water resources engineering problems. The SRTM has 90 m spatial resolution and hence, it does not provide accurate estimation of river profile. In this study, CARTOSAT-1 stereo images with a resolution of 25 m have been used to prepare the DEM. Application of CARTOSAT-1 imageries in generation of river surface profiles is unique in water resources applications in India and this thesis work marks the first application of CARTOSAT-1 imageries in hydrodynamic modeling purpose. The thesis elaborates the methodology to prepare DEM using CARTOSAT-1 stereo images and will be helpful to the researchers working in the similar field.

A regionalized frequency distribution of the Subernarekha River has been established using L-moment and Z-statistic approach. It is found that Pearson type III is the best suited frequency distribution of this river. Although Pearson type III is the best suited distribution of this river, it has been observed that a composite model constructed by a set of frequency distributions using neural network provides better fit to the observed regional frequency distribution of the data. Further, a simulation study has been conducted to confirm the supremacy of the composite modeling approach over the best suited distribution for regional frequency analysis. The use of composite model is a unique approach adopted in this study.

The traditional approach of selecting wide flow hydrograph for future flood hazard mapping normally exaggerates flood consequences. Any design consideration based on this hydrograph would be a very conservative representation of future flood events. This study has uniquely contributed to the literature by proposing a novel technique to categorize past flood hydrographs into severe, moderate and normal flow hydrographs. Based on the proposed methodology, future flood hazard mapping has been performed considering extreme, severe and moderate hydrographs as boundary conditions of hydrodynamic models.

Finally, assessment of damage of flood affected areas has been prepared and affected land use and land cover (LULC) areas are identified along the reaches of the river for various return periods. This information will be useful to the local administration to mitigate the damage, prepare proper evacuation and support plans to save the lives and property of thousands of people living near this river.

1.5 STRUCTURE OF THE THESIS

This thesis consists of 8 chapters including the introduction chapter. Chapter 1 deals with the introduction of the study covering objectives and scope of work of the study.

This chapter focuses the need and the utilization of hydrodynamic modeling techniques, regional flood frequency analysis and assessment of damage using land use and land cover classification. Chapter 2 discusses the literature review related to various aspects of hydrodynamic modeling techniques, flood frequency analysis, damage assessment, remote sensing, geographical information systems (GIS) and applications of digital elevation model. Chapter 3 deals with the methodology of hydrodynamic modeling, concepts of L-moments, discordancy, heterogeneity measures and GIS applications. Chapter 4 presents the description of the study area giving details of its demographic, climate, geology and other features. Preparation of DEM from CARTOSAT-1 stereo images is also explained in this chapter. Chapter 5 elaborately explains the hydrodynamic modeling, generation of water surface profiles, calibration and validation of hydrodynamic modeling and flood inundation mapping of the Subernarekha River for the flood affected years of 1985, 1988 and 1997. Chapter 6 explains the regional flood frequency analysis including screening of data by discordancy measure, homogeneity measure using heterogeneity test, L-moment ratio diagram and Z-statistic for estimating suitable frequency distribution of the study area. A new methodology termed as "composite model" has been proposed for the first time to model the regional frequency distribution of the data. This approach has been used to estimate growth factor for different return periods and is elaborated in this chapter.

Chapter 7 explains the preparation of wide and sharp flow hydrographs from the historical data using a novel concept called "bump function". The past hydrographs are categorized into "severe", "moderate" and "normal" flow hydrographs and these hydrographs are used as the boundary conditions for the hydrodynamic modeling of return periods. This chapter accounts for damage assessment of flood affected years and the flood hazard assessment for future years. This chapter also deals with the remote sensing techniques i.e image processing, classification procedures, remote sensing applications and analysis of satellite images including land use and land cover classification, classification error matrix and kappa statistics. Finally, summary, conclusions and future works of the present study are described in Chapter 8.