Precipitation Run off Simulation Study of Kharkai Basin

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***Abstract*: Hydrological modeling is a commonly used tool to estimate the basin's hydrological response to precipitation. To compute runoff volume, peak runoff rate, base flow, loss rate, various hydrologic as well as hydrodynamic models are used. Rainfall runoff model is such a model which is used to simulate the rainfall- runoff process in a basin. This model is also very effectively used for flood forecasting and flood plain mapping, which is a natural demolishing phenomenon of high importance. Estimation of rainfall-runoff and flood is a difficult task due to influence of different factors. So far, different models have been proposed and used effectively to analyse such phenomena. In view of the above, the present study has been conducted in the basin of Kharkai River (Eastern India) in Jharkhand and Odisha State using Hydrologic Engineering Centre Hydrologic modeling system (HEC-HMS) model. In this study HEC-HMS hydrological model has been used to simulate the flow in the hydrological units of the area and has helped to compute runoff volume, peak runoff rate, base flow, loss rate of the basin. In the present study for calibration and validation of the model the rainfall data for the basin for the period June 2008 and September 2011 and the observed flow at Adityapur gauging site has been considered. For calibration and validation of HEC-HMS model, the observed flow at Adityapur gauging site has been considered. For calibration of HEC-HMS parameters the guidelines available in the manual has been followed strictly. The calibrated and validated model is tested with Nash Sutcliff efficiency which shows that the model can simulate the rainfall runoff process with an efficiency of 82.3% (tested in validation). The result also shows that the parameter which affects the rainfall-runoff simulation process depends on the intensity of rainfall, land use and land cover of the catchment, catchment characteristics and topography of catchment to a great extent. The results can remarkably contribute to the monitoring system of the flood in both catchment and inundation area of the basin. The result can also effectively used for flood forecasting and flood plain mapping in the deltaic area of the catchment.**

***Keywords:* HEC-HMS, Kharkhai basin, Nash Sutcliff efficiency, Rainfall-runoff simulation**

I. INTRODUCTION

Precipitation is all forms of water that reach the earth from the atmosphere. The usual forms are rainfall, snowfall, hail, frost and dew. Of all these, only the rainfall and snowfall contribute significant amounts of water. Rainfall being the predominant form of precipitation causing stream flow, especially the flood flow in a majority of rivers in India. The HEC-HMS is designed to simulate the precipitation-runoff processes of a watershed system. Its design allows the applicability in a wide range of geographic areas for solving diverse problems including large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Therefore, because of its ability in simulation of short term events, ease to use and use of common methods it became very popular worldwide.Knebl et.al (2005) studied the framework for regional scale flood modeling that integrates NEXRAD level III rainfall,GIS and a hydrological models(HEC-HMS) in the San Antonio River Basin in Central Texas, USA. The aim of this study was to benefit future modeling efforts by providing a tool for hydrological forecasts of flooding on a regional scale. In another study, Yener et. al (2006), by modeling studies with HEC-HMS and runoff scenarios in Yuvacik Basin, Turkiye resulted that the simulated runoff values can be used for flood control and flood damage estimation studies.Yusop et.al (2007) calibrated and validated the rainfall-runoff process in a small oil palm catchment(8.2 ha) in Johor, Malaysia.The result of this study was to suggessted that an oil palm plantation would be able to severe reasonably well in regulating basic hydrological functions. Arekhi(2012) applied HEC-HMS model and verified sifferent methods for evaluation of runoff losses.The results showed that Initial and constant loss method among six events, in four events by fitting with percent error in peak and in five event by fitting with percent error in volume had better results rather than Green and Ampt method which in three events by fitting with objective function of percent in error in peak and in one event by fitting with percent error in volume had less variation coefficient of observed discharges compared to simulated discharges. Majidi et. al (2012) used the HEC-HMS model to simulate the rainfall-runoff process in Abnama watershed located in south of Iran. The results showed that lag time is a highly sensitive parameter.

II. METHODS

Study Catchment

The present study was undertaken in Kharkai Basin which flows through Adityapur region of Jamshedpur. It originates from the Mayurbhanj district, Odisha, on the north slopes of Darbarmela Parbat and the western slopes of Tungru Pahar, of the Simlipal Massif. It flows past Rairangpur and heads towards north to Saraikela & then towards east to join river Subarnarekha near Adityapur in Jamshedpur. Its major tributary is the Sanjai, entering from the left, about 17 kilometers above its mouth. The latitude, longitude and altitude of the watershed area are 22˚0′N - 22˚45′N and 86˚13′ E - 86˚25′E and 928 m above the mean sea level respectively. The area falls under the sub-tropical climatic condition in the eastern part of the country. The area is characterized by a hot summer, chilling winter with good precipitation. The watershed having a total length of 166 Km flows for a length of 55 Km in Orissa and 111 km in Jharkhand. The major distributary of the Kharkai River is the Sanjai River. The Surface water potential of the Kharkai river basin is 1085 million cubic meter while the ground water potential in the basin area is 242 million cubic meter. It covers the two areas Jamshedpur in Jharkhand and Mayurbhanj district in Odisha.The Kharkai Catchment recieves an annual rainfall of 1420mm and most of the rainfall occurs during the rainy season.The model was applied to the Kharkai basin (Eastern India) has a total area of 5815 Sq. Km. It has total number of three rain gauge stations: Jamshedpur, Tiring, and Rairangpur.

Data Used

The details of data used to prepare the model are (i) Toposheet of Kharkai basin and daily rainfall data for the year June 2008 and September 2011 was collected from the Water Resource Department of Orissa.(ii) The soil characteristics of Kharkai river basin was collected from the study conducted on Hydrological Inventory of South Bihar River Basin conducted by NIH, Roorkee. (iii)The daily discharge data of gauging site Adityapur was collected for the year 2008 and 2011 from Ground water Department, Ranchi.

Software Used

HEC-HMS Model

HEC-HMS is a physically based, semi-distributed hydrologic model developed by the US Army Corps of Engineers to simulate the hydrologic response of a watershed subject to a given hydrometeorological input(Scharffenber et al, 2010). The model can simulate individual storm events as well as continuous precipitation input at minute,hourly or daily time steps.

Parameters in HEC-HMS

The HEC-HMS offers a variety of model options to simulate productions.These include Initial and Constant Method, Synder Unit Hydrograph and Recession methods which are necessary to calculate water losses, runoff transformations and baseflow rates.

Initial and Constant Loss Method

Initial and Constant Loss rate include two parameters of constant rate and initial loss which show the physical characteristics of soil, land use and antecedence conditions of basins (Radmanesh et.al ,2006).

If the basin be in saturated conditions, I_a tends to zero. When the soil of basin is dry, I_a will increase and show the maximum height of rainfall that can not be changed into runoff. According, to American standards, range of I_a in forest area is between 10 to 20 percent of rainfall and it varies between 0.1 to 0.2 inches in urban areas. Constant loss rate shows the final capacity of soil.

Synder Unit Hydrograph Method

The Synder Unit hydrograph is a synthetic unit hydrograph method. A Synthetic Unit hydrograph relates the parameters of a parameteric UH model to watershed characteristics.

Recession Base Flow Method

The Recession base flow is designed to approximate the typical behaviour observed in watersheds when channel flow recedes exponentially after an event. This method is intended primarily for event simulation.

Calibration of HEC-HMS Model Parameters

In the present study the rainfall recorded at the rain gauge stations namely, Jamshedpur, Rairangpur and Tiring for event 9th June 2008 to 21st June 2008 have been used in the model and adjusted to match the observed discharge. The input parameters like initial loss, constant rate, impervious factor, standard lag, peaking coefficient, recession constant were adjusted such that the observed and simulated peak and discharge matches more precisely. The final adjusted set based on 9th June 2008 and 21st June 2008 were subsequent simulation for all of the events. The calibration was focused on the peak of flow, volume, time of peak and the best statistical criteria by looking for reasonable values of the parameters.

Storm Event at 08:00 hours	Observed Discharge (Cumecs)	Simulated Discharge (Cumecs)
9 June 2008	6.71	6.8
10 June 2008	13.762	56.6
11 June 2008	10.734	147.3
12 June 2008	7.039	168.4
13 June 2008	6.886	101.9
14 June 2008	7.74	33.7

15 June 2008	7.86	177.2
16 June 2008	47.601	389.9
17 June 2008	246.284	733.0
18 June 2008	5855.719	5065.5
19 June 2008	4368.767	4599.8
20 June 2008	930.396	991.1
21 June 2008	672.137	932.5

Table Comparison of observed and simulated discharge at outlet (calibration)

Validation of HEC-HMS Model Parameters

In the present study to validate the model, the rainfall data recorded at the rain gage stations namely Jamshedpur, Rairangpur and Tiring for an event 3rd Sept 2011 to 15th Sep 2011 have been used. The model was validated manually for the event on 3rd Sept 2011 to 15th Sep 2011 with the observed discharge at the Adityapur gauging site.

Storm Event	Observed Discharge	Simulated Discharge
2nd Sep 2011	763.0	762.0
3rd Sep 2011	600.0	744.2
4th Sep2011	324.8	683.8
5th Sept 2011	451.1	570.9
6th Sept 2011	458.5	532.2
7thSep2011	372.0	537.7
8thsep2011	1744.0	1669.5
9th Sep2011	1589.8	1655.8
10th Sep2011	1220.0	522.8
11th Sep2011	441.7	433.6
12th Sep2011	325.8	329.2
13th Sep2011	302.6	306.8
14th Sep2011	222.0	276.1
15th Sep2011	763.0	762.0

Table Comparison of Observed and Simulated Discharge (Validation)

III. RESULT AND DISCUSSION

Calibration of HEC-HMS Parameters

In the present study, the catchment parameters which affect the rainfall runoff process in the Kharkhai River basin were calibrated manually. Before calibration three rain gauge stations namely, Jamshedpur, Rairangpur and Tiring present within the catchment of the basin are considered and rain gauge weights are assigned using thiession polygon approach. For the purpose of calibration the rainfall data from 8th June 2008 to 21st June 2008 and the discharge data at Adityapur site are considered. The calculated initial parameter values were first used in the HEC-HMS Model for calibration and different parameter like runoff depth and peak discharge were simulated. These parameters were adjusted manually so that the observed and simulated values of the flow hydrograph obtained at the Adityapur gauging site are as close as possible. Considering the calibrated parameters the computed and observed discharge at the Adityapur Gauging site are compared and the efficiency of the model is tested using Nash Sutcliff efficiency test and the efficiency of the model is 97.25%. As the efficiency of the model appears satisfactory, the calibrated parameters were considered for validation. Figure 1 shows the comparison of observed and computed hydrographs obtained during calibration.

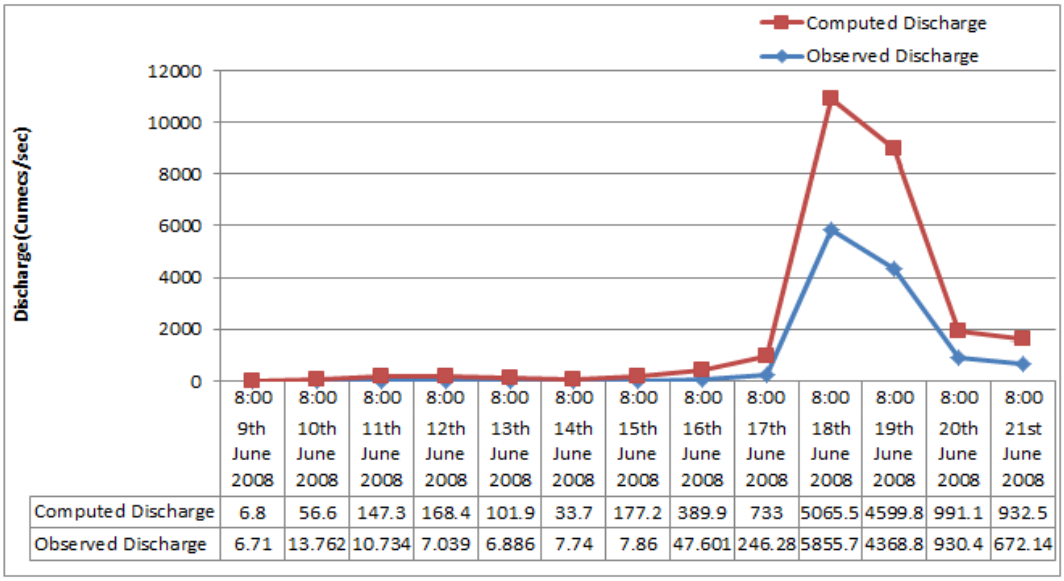
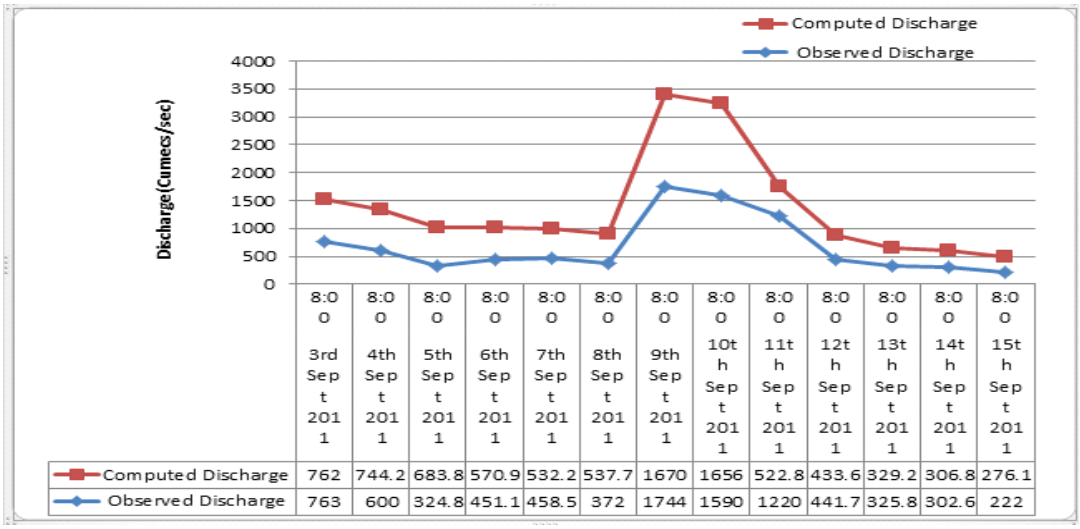


Fig. Comparison of Computed and Observed Hydrograph (Calibration)

Validation of HEC-HMS Parameters

Considering the calibrated parameters as mentioned in the model is validated. For validation, the simulated data as predicted by the model is computed with the observed data and statistical tests of error must be carried on. If the values of error functions are very small then the model is validated. For validation of model, 3rd Sept 2011 to 15th Sept 2011 rainfall event were considered. Similarly the observed discharge for the above period is considered for validation. The observed and computed values of the discharge at the gauging site during the above period (which is different from the calibration data) are compared. Figure 2 shows the comparison of observed and computed hydrographs obtained during validation. The efficiency of the model is than tested using Nash Sutcliff efficiency shows the efficiency of the model which comes to be 82.3%. As the efficiency of the model is above 80% it can be considered as satisfactory.



	8:00 3rd Sept 2011	8:00 4th Sept 2011	8:00 5th Sept 2011	8:00 6th Sept 2011	8:00 7th Sept 2011	8:00 8th Sept 2011	8:00 9th Sept 2011	8:00 10th Sept 2011	8:00 11th Sept 2011	8:00 12th Sept 2011	8:00 13th Sept 2011	8:00 14th Sept 2011	8:00 15th Sept 2011
Computed Discharge	762	744.2	683.8	570.9	532.2	537.7	1670	1656	522.8	433.6	329.2	306.8	276.1
Observed Discharge	763	600	324.8	451.1	458.5	372	1744	1590	1220	441.7	325.8	302.6	222

Fig. Comparison of Computed and Observed Hydrograph (Validation)

IV. CONCLUSION

In the present study the HEC-HMS hydrological model has been used to simulate the flow in the hydrological units of the area. For calibration and validation of the model the rainfall data for the basin for the period June 2008 and September 2011 respectively has been considered. Similarly the observed flow at Adityapur gauging site has been considered for calibration and validation of the model. For calibration of HEC-HMS parameters the guidelines available in the manual has been followed. The calibrated and validated model is tested with Nash Sutcliff efficiency. The calibration result shows that the model can simulate the rainfall runoff process with an efficiency of 97.25%. However in validation the model shows the efficiency of 82.3%. The result also shows that the parameter which affects the rainfall-runoff simulation process depends on the intensity of rainfall and impervious factor of the catchment to a great extent. The results can remarkably contribute to the monitoring system of the flood in both catchment and inundation area of the basin. As discussed above, the model can predict the peak flood volume and time to peak accurately based on the available historical flood data. This shows that HEC-HMS is suitable for the Kharkhai catchment effectively. From the results, we can also conclude that the complexity of the model structure does not determine its suitability and efficiency. Though the structure of HEC-HMS is simple, it is a powerful tool for flood forecasting. Despite difficulties, limitations and uncertainties associated with obtaining observations and measured parameters, this study ended up with optimistic results for the simulation of precipitation runoff process and hence the HEC-HMS model may be used to simulate precipitation runoff process in the Kharkai watershed. The model can also help to save time and money in obtaining the runoff data rather than measurement of runoff in the watershed. Moreover, it may help to simulate runoff in un-gauged watershed where there is no gauging stations to measure runoff.

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