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Discharge modeling in part of Ambika River basin using SWAT model

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Abstract *— Discharge or Runoff is a very important factor of hydrologic cycle and it is useful for watershed management for conservation and development of natural resources and its management. Till now most useful and appropriate method for surface Runoff estimation is Soil Conservation Services-Curve Number (SCS-CN). Remote sensing and Geographical Information System (GIS) is effective tool for extracting watershed parameter and use of mathematical tool is the current trend for hydrologic evaluation of watershed. In present study, QSWAT having an interface with QGIS software was selected for estimation of Runoff for small watershed of Ambika river basin of Gujarat, India. Various parameters Digital Elevation Model (DEM), Landuse/Landcover (LULC) and NBSSLUP soil data and temporal data for temperature and precipitation was used as input for the model to predict runoff at the catchment outlet. The performance of the model in terms of simulated discharge was evaluated using statistical method and compared simulated monthly flow with the observed monthly flow values from 2000 to 2006 to a significant extent. The simulated flows for five years of recorded and results are encouraging. The correlation coefficient for the monthly discharge was obtained as 0.753, 0.936, 0.536, 0.939 and 0.506.*

Keywords- *SWAT, GIS, Discharge, DEM, Threshold, Stream network.*

I. INTRODUCTION

Water is one of the most important natural resources and a key element in the socio-economic development of a State and Country. The optimal water resources management is the necessity of time in the wake of the development and emerging need of population of the India. A watershed is a hydrologic unit or an area of land from which water drains, running downhill, to a shared destination or which produce water as the end product by interaction of precipitation and the land surface. Runoff is very useful parameter for study of hydrology and for watershed management. Surface water and ground water is used for agricultural, industrial and domestic purposes. There are various methods to estimating the runoff in the watershed. However, SCS-CN method is best among all till now. Physiographic characteristic of the basin such as DEM, land use map, hydrologic soil groups, and rainfall data are basic required parameter for SCS-CN method.
GIS is an effective tool in watershed modeling as remote sensing derived information can be well integrated with the conventional database for estimating runoff which can help in planning suitable soil and water conservation measures. Since the modeling of runoff is essential for sustainable development, it is desirable that some suitable methods are used for quantifying the hydrological parameter from all parts of the watershed. Use of mathematical models for hydrologic evolution of watershed is the current trend along with extraction of watershed parameters using remote sensing and Geographical Information System. The current study was undertaken on the application of the SWAT model which integrates the GIS information with attribute database to estimate the runoff. The model application has been demonstrated for a part of Ambika river basin.

II. STUDY AREA

Ambica River is one of the important west flowing rivers with its catchment in Gujarat and Maharashtra. It originates from Saputara Hill ranges near village Kotambi of Surgana taluka in the Nasik district of Maharashtra. After flowing for a length of 136 km it drains in to the Arabian Sea. The important tributaries of the Ambica River are Kapri, Wallan, Kaveri and Kharera. The river Ambica basin lies between 20° 31’ and 20° 57’ North latitude and 72° 48’ and 73° 52’ East longitude with a drainage area of 2715 Sq.km. The Valsad, Dangs and Surat Districts of Gujarat and a small portion of the Nasik district of Maharashtra falls in the basin. The state wise drainage area of the basin is given below**.** There are 30 gauge and 8 discharge sites being maintained by State Government of Gujarat. The climate of the basin is

characterized by a hot summer and in general dry except during the Southwest monsoon season. The maximum,

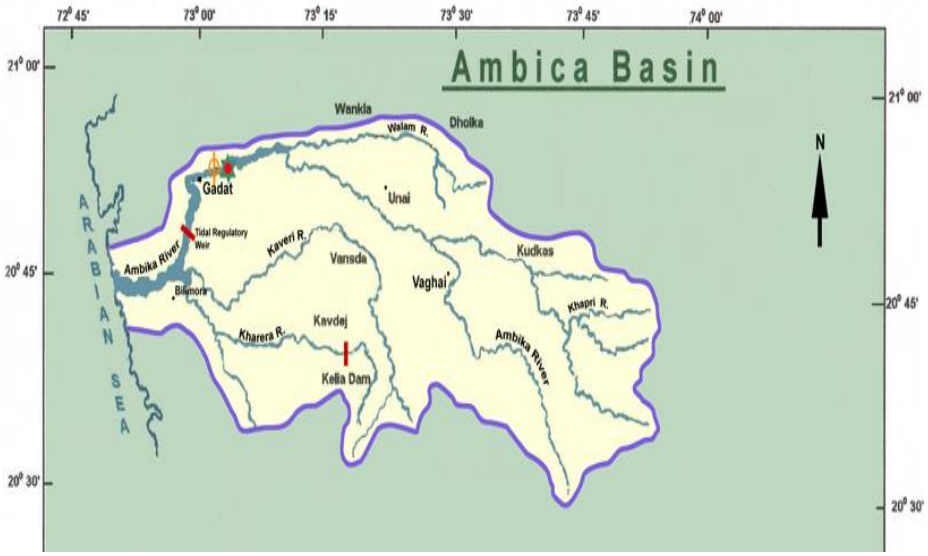

Figure 1. Study Area

minimum temperatures observed vary from 32°C to 40° C and 25°C to 8° C respectively. Soil of Ambica basin can be broadly classified into three groups viz. Laterite soil, deep black soil and alluvial soil.

III. MODEL

3.1. Model description

Soil and water assessment Tool (SWAT) is hydrological mathematical model and developed by Dr. Jeff Arnold for the United State Department of Agriculture, Agricultural Research Service (ARS). SWAT is used for various purpose like a predict impact of land use management practice on water. Sediment yield, agriculture nutrients required and crop growth etc. SWAT used specific information like weather, soil properties, Vegetation, topography and land management practice involved in watershed.

In, SWAT, a watershed is partitioned into a number of sub basins. The use of sub-basins in a simulation is particularly beneficial when different areas of watershed are dominated by land uses or soils dissimilar enough in properties to impact hydrology. Input information for each sub basin is grouped into different categories: climate; hydrologic response units (HRUs); ponds/wetlands, groundwater; and the main channel, draining the sub-basin. Hydrologic response units are lumped land areas within the sub-basin that are comprised of unique land cover, soil, and management combinations.

3.2 Methodology

3.2.1 Database Development for the Study Area

Spatial hydrological and meteorological data was collected for Ambika river basin area. Digital elevation (DEM) is basic or primary input of SWAT. Ambika basin DEM was obtained from SRTM and it is shown in figure 2. The SRTM DEM for the Tapi basin was obtained at 90 m resolution. Out of the Ambika river basin, only a part of lower Ambika basin was considered in the study.

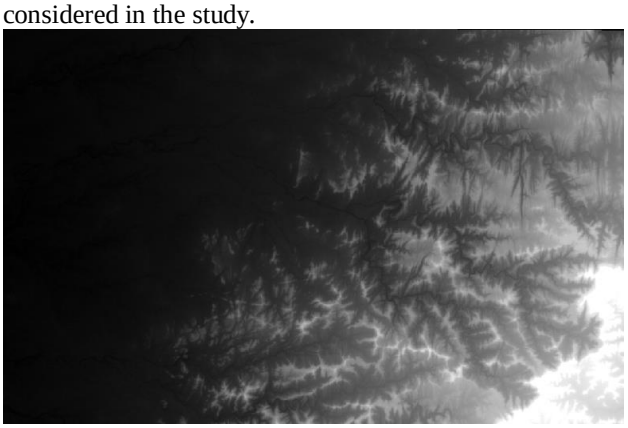

Figure 2. DEM of Ambika river basin

Land use is second important consideration and critical input for the SWAT. Land use is directly affected to surface flow, subsurface flow, soil water storage, water demand for irrigation etc. The area surrounding the Ambika river basin was extracted from the global land use map. Various land use categories and coverage in watershed is shown below figure 3.

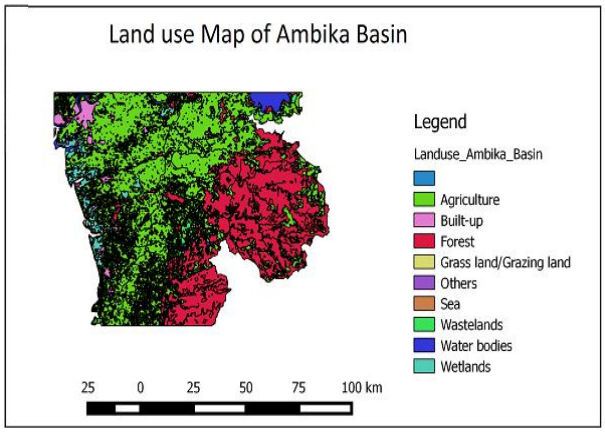

Figure 3. Landuse Map

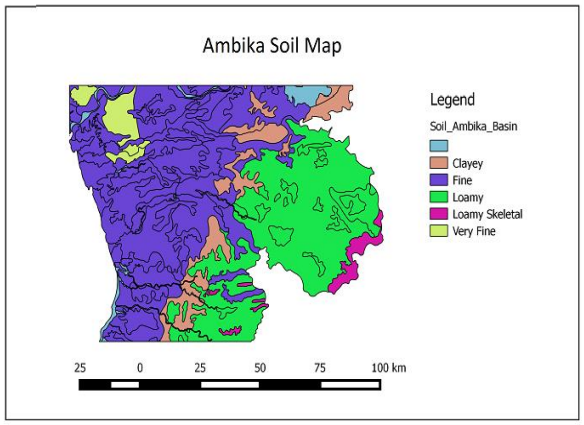

Figure 4. Soil Map

Soil is also third important consideration in various processes of hydrological modeling. In SWAT, various soil parameters like soil texture, water content, hydrologic conductivity, bulk density etc. are essential to make an input to the model. The soil map and it's physical properties for sub basins obtained from global soil and it's use in present study soil map shown in figure 4. SWAT requires daily precipitation, maximum and minimum temperature, solar radiation, wind velocity and relative humidity. The precipitation data table is used to store the precipitation for individual rain gauge station. Daily precipitation data for year 2000 to 2006 was available. The rainfall is observed at 4 station namely Ahwa, Borkhal, Galkund and Saputara. Daily temperature data is also available for 2000 to 2006.

3.2.2 Model Setup

Whole database require by the SWAT model has been developed for the study are (part of Ambika river basin) and the model is setup for the area. Various steps and procedure followed in model application are explained below: SWAT project setup, watershed delineation, HRU generation, write input table, Edit SWAT input, SWAT simulation. The methodology for the runoff modeling at the basin outlet using SWAT is depicted in flow chart (Figure 5).
SWAT automatically delineates a watershed into sub-watershed based on DEM. DEM was imported in the model and the mask is manually created in the model in order to extract out the Ambika sub basin area. The model generated 13 sub-watershed of the Ambika river basin. The outlet is defined at location of river gauging station Waghai. Watershed was delineated for the present study and all parameters were calculated for each sub basin.
HRUs are the Hydrological response unit that divides the watershed into various homogeneous units based on the land use, soil type, and slope at each grid. Hydrologic response units for each sub basin were created. SWAT requires land use and soil data to determine the HRUs for each sub-basin. The land use and soil map have been imported in the model. Land use category is used to specify the land use layer and soil look up table is used to specify the type of soil to be modeled for each category. in the soil layer, linked to the SWAT database and reclassified land use and soil map. The soil map reclassified the database in 4 hydrological soil group (HSG) named A, B, C, D based on their infiltration rate. The lulc map was also reclassified into 6 different categories.

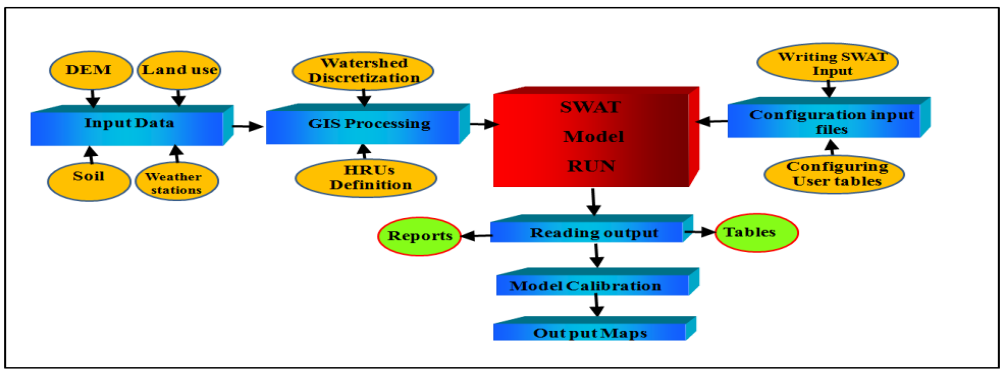

Figure 5. Model flow chart

Land use and soil maps were overlaid. To eliminate minor land use, soil and slope, threshold percentage was adopted, 10% threshold for land use, 10% for threshold for soil and 10% for slope. A total number of 60 HRUs were generated in the Ambika watershed. The model requires daily data for precipitation and temperature that is provided by user in .dbf format and is stored in project database. Weather data like rainfall of 7 years of daily data from 2000 to 2006 in 4 rain gauge station Ahwa, Borkhal, Galkund and Saputara. Maximum and minimum temperature data used from gauging site And available from SWDC (state water data centre). The climatic data for study periods were prepared in .dbf format and then imported in the SWAT model. After importing the climatic data the next step was to set up a few additional inputs for running the SWAT model. The characteristics of the soil data and the properties of the land use were defined in the model as per Indian condition. The files were successfully rewritten and stored in personal geo database of the model. After this step, the model was run to simulate the surface runoff estimate that at which level simulate value fitted with the observed value. It shows the best fitness and efficiency of the model. R^2 describes the proportion of the total variance in the measured data that can be explained by the model. It ranges from 0.0 to 1.0. High values indicating better agreement between observed discharge and estimated discharge.

IV. Result and Discussion

SWAT simulation has been done for five years. It is from January 01, 2002 to December 31, 2007. At the time of SWAT run year 2000 and 2001 have been taken as NY skip (Warm up period for SWAT). The SWAT model has been run for the current study and output was generated at monthly time step for a reach.

5.1 Results of the SWAT

The model was generated discharge series for the study area from January 01, 2002 to December 01, 2007 in cms (m^3/sec) on monthly basis. Monthly observed flow of Ambika watershed at Waghai discharge site were also available for same time period. Therefore, the performance of the model in terms of simulated discharge was evaluated using stastical method and compared simulated monthly flow with observed monthly flow values from 2002 ti 2006 to a significant extent. The coefficient of determination or Correlation coeffficient (R^2) for the monthly runoff values for 2002 to 2006 was observed to be 0.753,0.936,0.5260.939 and 0.506 respectively for discharge. The results are shown in Figure 6 to15. As can seen in the analysis, monthly discharge value for years 2002,2003 and 2005 showed a better correlation for the monthly values for the respective years.

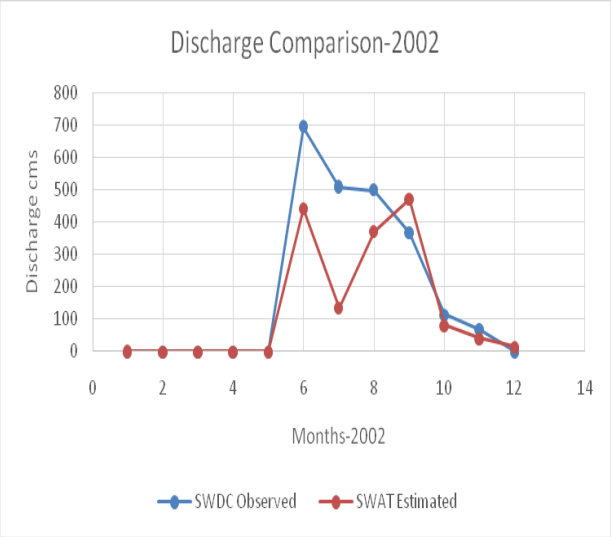

Figure 6. Discharge comparison 2002

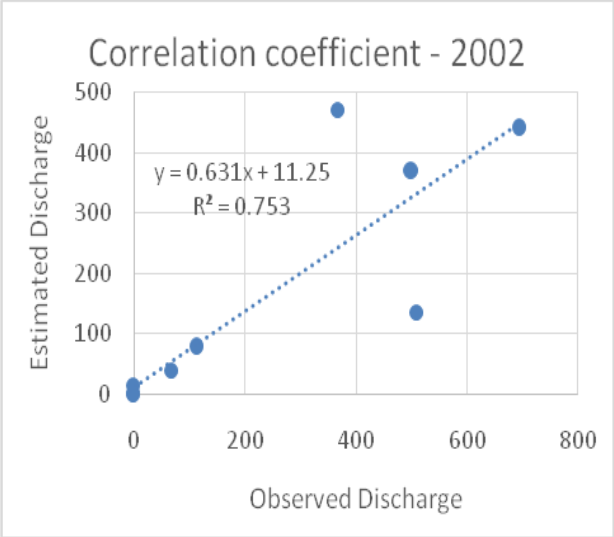

Figure 7. Correlation coefficient-2002

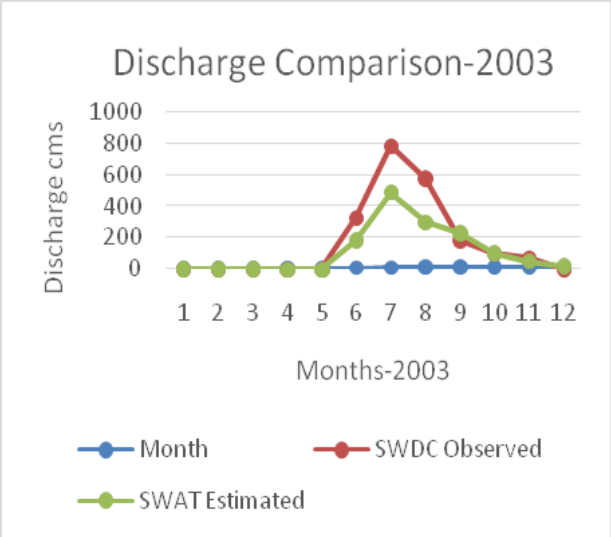

Figure 8. Discharge comparison 2003

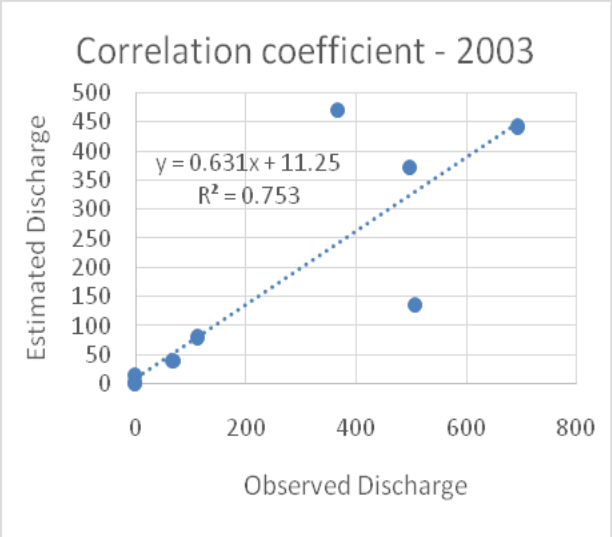

Figure 9. Correlation coefficient-2003

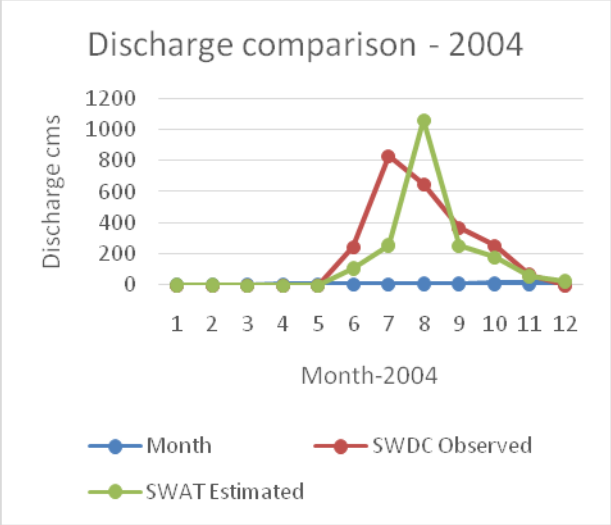

Figure 10. Discharge comparison 2004

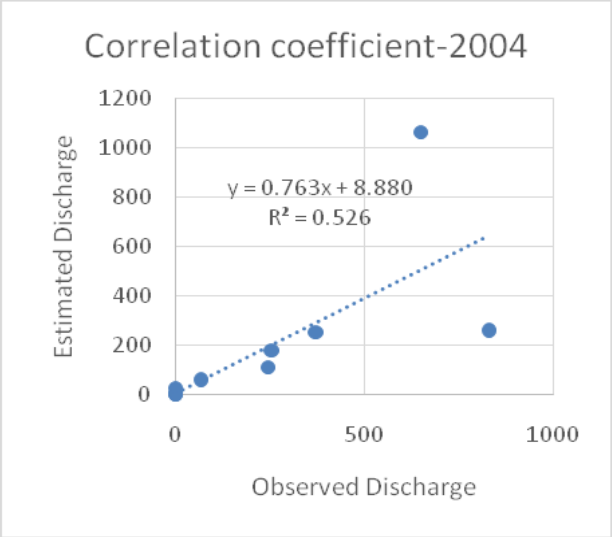

Figure 11. Correlation coefficient-2004

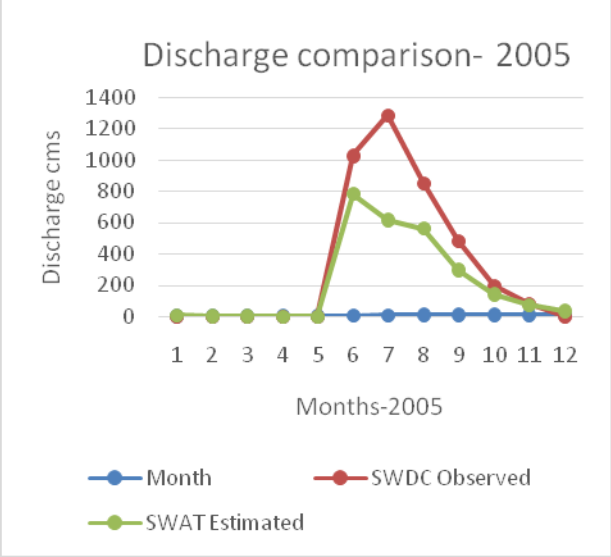

Figure 12. Discharge comparison 2005

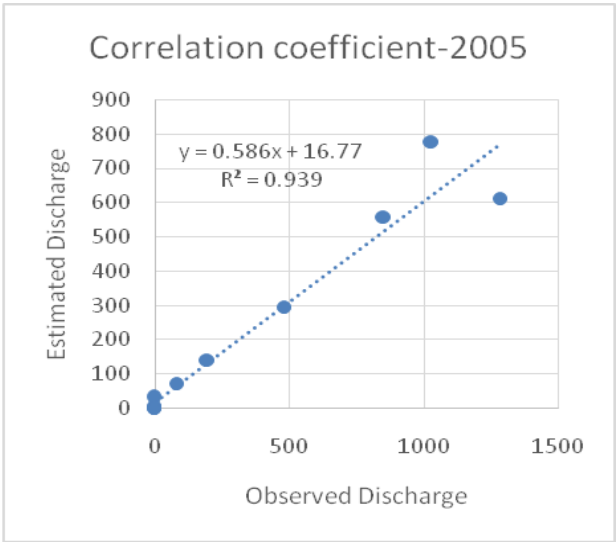

Figure 13. Correlation coefficient-2005

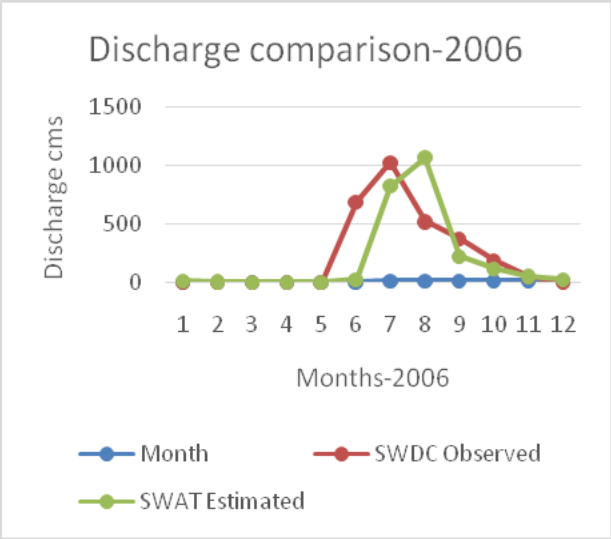

Figure 14. Discharge comparison 2006

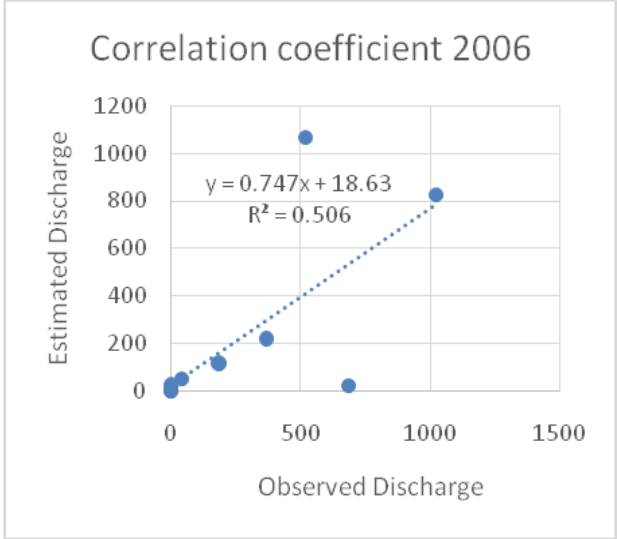

Figure 15. Correlation coefficient-2006

5.2 Conclusions

In the present study, SWAT model has been applied to a part of Ambika River basin for the purpose of simulating the rainfall-discharge process in the sub-basin. SWAT is river basin scale physically based continuous time series model. It requires various parameters and catchment characteristics to perform hydrological modeling. In the present study, hydrological modeling is performed using QSWAT model for the part of Ambika Watershed. The model uses QGIS environment and calculate the discharge at outlet. For the topographic analysis, the SRTM DEM at 90m grid size has been used. All the GIS layers, such as soil map, land use map have been also processed with the same projections parameters.

QGIS has been used to delineate the watershed by threshold value as 3000 ha. A total 13 sub-basins have been generated with this threshold. Using the land use and soil ,multiples hrUs have been generated in each sub basin. Next, the daily rainfall and temperature data of Ambika basin in/around, the study area have been input to model from January,2002 to December,2007. Other data like wind velocity, solar radiation and relative humidity are automatically simulated by QSWAT. The model runs were taken with specified data at daily time step. The simulated flows for five years of recorded and results are encouraging. The correlation coefficient for the monthly discharge was obtained as 0.753,0.936,0.536,0.939 and 0.506. For year 2002,2003 and 2005 it's a satisfactory but for 2004 and 2006 results are not satisfactory.

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