Computation of Runoff Using SCS Curve Number

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ABSTRACT

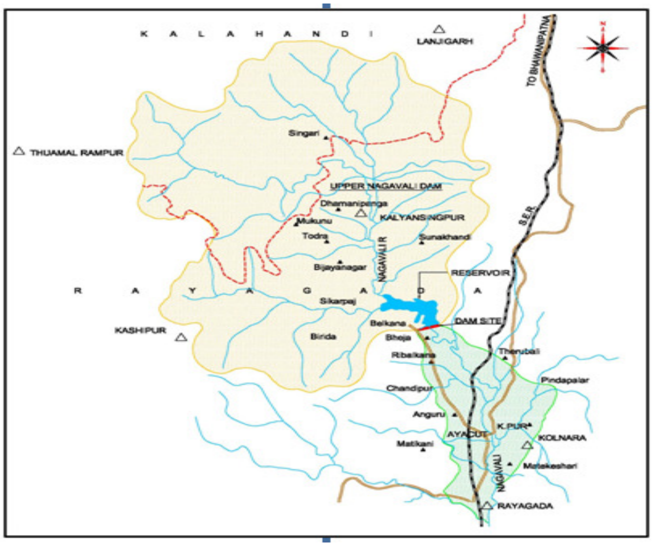
Estimation of peak discharge and/or hydrograph is often used for small to medium sized un-gauged catchments for the design of hydraulic structures. Different models are put up in practice depending on the type of problems, its capability, available data and the prevailing runoff mechanisms for the catchment. This paper discusses the applicability of the curve number procedure developed by the US Soil Conservation Service (SCS) to estimate runoff from the available information on antecedent soil moisture condition of the catchment. Rainfall data is collected from 1977 - 78 to 2000- 2001 for the catchment lying in the state of Odisha. The geographic co-ordinates of the river are north latitudes 18^0 -10' to 19^0- 44' and east longitudes of 82^0-53' to 84^0-05'. The proposed area is located in geographical latitude 19^0 – 23' N and 83^0 – 21' – 45"E longitudes. The study area is marked from the Survey of India Topo-sheets and the Digital Elevation Model (DEM) is generated. SCS-CN method is used to calculate runoff from the rainfall and then the results are compared with the observed data. In the approach, different parameters like soil information, rainfall, storm duration, soil texture, type, amount of vegetation cover and conservation practices are considered. Based on the soil classification, the given area falls under the soil; groups B, C and D with soil moisture condition of AMC-II. Fairly comparable values are found between the observed and computed runoff values. Standard error estimate are computed between the observed and computed values.

Keywords: Watershed, Land use and land cover, curve numbers, Runoff, Rainfall runoff modeling, DEM

1. INTRODUCTION

A rainfall-runoff model is a mathematical model describing the rainfall - runoff relations of a catchment area, drainage basin or watershed.. The transformation of rainfall into runoff over a catchment is known to be very complex hydrological phenomenon, as this process is highly nonlinear, time-varying and spatially distributed.The most important spatial data required for hydrological modelling is the land surface elevation, commonly represented as a digital elevation model (DEM)(Zhou and Liu, 2004; Wang and Liu, 2006). The current availability of high-resolution remote sensing imagery and DEM data makes it possible to integrate both technologies to advance the computation and simulation of surface water flow processes.The Soil Conservation Service (SCS) Curve Number (CN) rainfall runoff technique, is a well-known method, widely used to estimate runoff, and thus, water recharge, stream flow, infiltration, soil moisture content, from precipitation.The SCS method uses three factors to influence S: season of year, ANTECEDENT MOISTURE CONDITION(AMC)& precipitation which together, provide a rough measure of the expected value of soil moisture

2. THE STUDY AREA

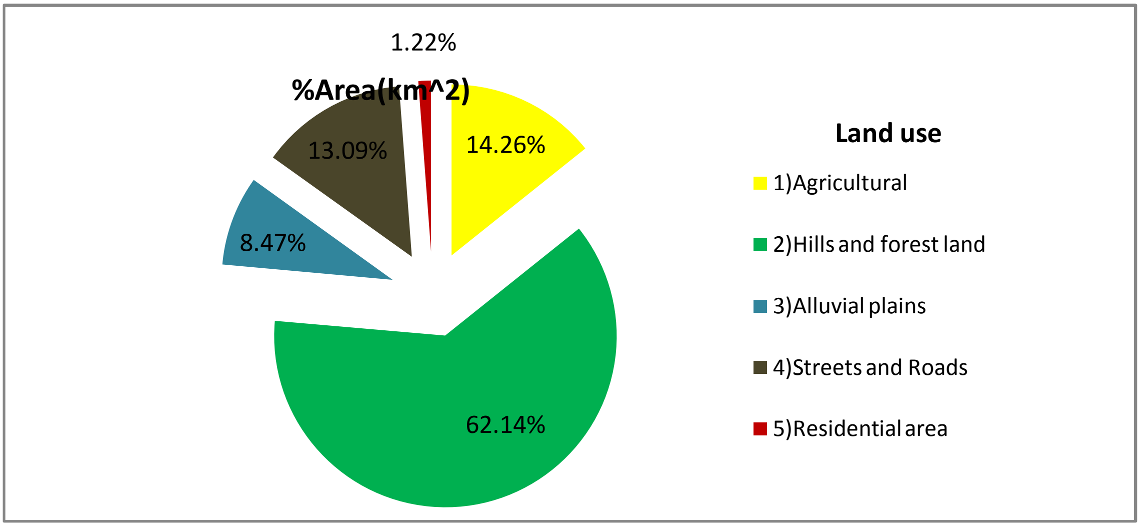


The project is proposed across river Nagavali, in the Nagavali basin. The river, originates from the hilly area of Eastern Ghats near village Bijapur in Kalahandi district at an elevation of about 1000m. The total basin area of Nagavali is 9275 sq. km. The catchment area lying within Orissa is 4500 sq. km.. The total length of the river is about 256 km of which about 161 km lies in Orissa, 2 km form the boundary between Orissa and Andhra Pradesh and about 93 km lies in Andhra Pradesh.

The catchment area intercepted upto proposed dam site is 1176.84 sq. km. After accounting for the projects lying in the upstream, the free catchment for the project works out to be 681.84 sq. km. There are two rain gauge stations, namely **Rayagada** and **Kalyanasinghpur** influencing the catchment area. The rainfall data of the above two stations have been found to be consistent. a weighted average has been considered for the two sites, with Rayagada contributing **94%** to the weighted average, and Kalyanasinghpur contributing **6%.**

Area wise distribution

Land Use	Area(km^2)
Agricultural and waste land	167.7
Hills and forest land	730.79
Alluvial plains	99.64
Streets and roads	163.57
Residential area	14.34



Methodology

1. The first step is to determine the hydrologic soil group(HSG) of the particular soil to be. All soils are classified in one of four different categories-ranked A-D on the basis of their runoff potential.

- **Class** A soils mostly consist of deep, welldrained sands and gravels with low runoff potential and high infiltration and water transmission rates **k sat > =0.3in/hr e.g-sand, loamysand and sandy loam.**
- **Class B** soils have moderately fine to moderately coarse textures and are considered to have moderate infiltration rates when completely wet. **k sat < 0.3in/hr. e.g-silt loam or loam.**
- **Class C** soils have moderately fine to fine textures with slow infiltration and water transmission rates.**0.04<ksat<0.15 in/hr e.g-sandy clay loam.**
- **Class D** soils are primarily clay soils or soils with clay pan that have slow infiltration rates when wet. **ksat<0.04in/hr. e.g-clay loam, silty clay loam, sandy clay, silty clay or clay**

2) Next step is to determine the five-day antecedent moisture condition of the particular soil from the daily precipitation record. It s an index for basin wetness.One series of five-day precipitation totals is applied to the dormant season and a second series of five-day precipitation totals is used during the growing season.

3) The third step is to decide-on the basis of the land cover, the cultivation treatment, the hydrologic condition of the soil, and the hydrologic soil group of the particular soil-the actual runoff curve number to use in determining daily runoff from precipitation. (SCS, 1972)

Weighted CN computation of different land use types & s-value

Table 1

Land Use	% area	Area(km^2)	Cover Treatment	Hydrologic condition	HSG	Curve Number(AMC-II)	S value-(2540/CN)-25.4))
1)Agricultural and wasteland	14.26%	167.7					
a) Fallow Row Crops		110.682	Contoured	Good	C	82	5.57
b)Fallow row crops	-	57.01	Bare Soil	-	C	91	2.51
2)Hills and forest land	62.14%	730.79					
a)				Poor	C	77	7.58
b)				Fair	C	73	9.39
3)Alluvial plains	8.47%	99.64			B	76	8.02
4)Streets and Roads	13.09%	163.57					
a)Paved Curbs		102.25			D	98	0.51
b)Dirt		61.32			D	89	3.13
5)Residential area	1.22%	14.34					
a)1/8 acre		6.45			B	90	2.82
b)1/4 acre		5.01			B	83	5.2
c)1/3 acre		2.86			B	81	5.95

The above table (Table 1) is a representation of the Hydrological Soil Group (H.S.G) and the corresponding Curve Number values, based on the cover treatment nnd hydrological condition of that particular area.Subsequently the S-value or the potential maximum retention was also computed **Contured cover treatment** indicate that fields are farmed as closely as possible on the contours. **Bare cover treament** means land has a high runoff potential**.**The values of CN for AMC-II condition were selected from the tables given by S.C.S (TR-55). The value of CN is lower for soils with high infiltration. A **poor** condition refers to heavily grazed pastures with almost no vegetation.A **good** condition refers to lightly grazed with 75% or more land covered with plants.If the area consisits of patches of land then a **composite curve number (CN)** for the watershed can be obtained by weighing them in proportion of the area.The following calculation of the concerned catchment area illustrates the fact.

Weighted CN Value

CNw=(A1CN1+A2CN2+A3CN3+A4CN4+A5CN5+A6CN6+A7CN7+A8CN8+A9CN9A+A10CN10+A11CN11)/(A1+A2+….A11) = 91891.61/1176.04=78.13

S value (in cm)= (2540/CNw)-25.4)) =7.10

Computed run off depth value of land use areas in monsoon season

	MONTH		JUN		JUL		AUG		SEPT		OCT	
	Avg Monthly Rainfall in (cm) (P)		16.83		30.49		26.7		20.48		12.73	
Land Use	S Value(cm)	CN	Qd (cm	%	Qd (cm)	%	Qd (cm)	%	Qd (cm)	%	Qd (cm)	%
1)Agricultural and waste land												
a) Fallow Row Crops contoured	5.57	82	12.38	73.58%	25.51	83.66%	21.82	81.72%	15.84	77.32%	8.6	67.58%
b) Fallow Row Crops bare	2.51	91	14.52	86.29%	28.05	91.98%	24.28	90.94%	18.12	88.48%	10.51	82.57%
2)Hills and forest land												
a)Poor	7.58	77	11.26	66.92%	24.06	78.90%	20.44	76.54%	14.6	71.27%	7.65	60.12%
b)Fair	9.39	73	10.39	61.76%	22.87	75.00%	19.32	72.34%	13.62	66.50%	6.94	54.54%
3)Alluvial plains	8.02	76	11.04	65.60%	23.76	77.92%	20.15	75.48%	14.35	70.06%	7.47	58.68%
4)Streets & Roads												
a)Paved Curbs	0.51	98	16.31	96.91%	29.96	98.27%	26.17	98.03%	19.96	97.45%	12.21	95.95%
b)Dirt	3.13	89	14.04	83.41%	27.5	90.18%	23.74	88.93%	17.61	85.99%	10.07	79.08%
5)Residential area												
a)1/8 acre	2.82	90	14.28	84.83%	27.77	91.07%	24.01	89.92%	17.86	87.22%	10.29	80.79%
b)1/4 acre	5.2	83	12.61	74.94%	25.79	84.60%	22.09	82.75%	16.08	78.53%	8.8	69.13%
c)1/3 acre	5.95	81	12.16	72.24%	25.22	82.72%	21.55	80.70%	15.59	76.11%	8.41	66.05%

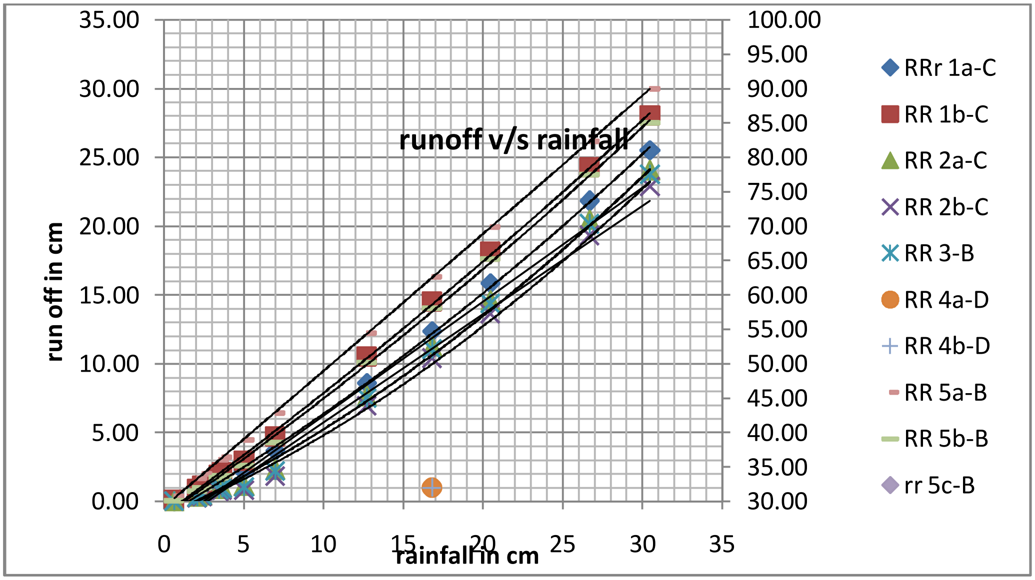
Table 2

Q_d=(P-(I_a))^2/(P- I_a +S)) - (i), I_a=0.2S

Runoff depth percent=(Qd/P) - (ii) Qd-Runoff depth(cm), P-rainfall(cm)

Table 2 is a representation of runoff depth **‘Qd’** calculated using S.C.S Curve Number formulae given in equation (i) for the different land use areas of the concerned catchment.In the equation I_a is the initial losses consisting of interception, depression storage and infiltration.

Subsequently the **runoff depth %** using equation (ii) has also been calculated. It means that for a given mean average rainfall(cm) for a particular month (i.e from Jun-October) over a period from 1977-78 to 2001-02 what is the percentage converted to runoff. It is clearly evident from the table that higher the value of curve number, lower is the maximum potential retention and higher are the values of runoff depth and runoff depth percent. This is because higher vaues of curve number corresponds to higher runoff and low infiltration.



Graph 1 rainfall runoff curve no. graph Comparison between computed and observed values using standard error estimate

Table 1

	1977-78 - 2001-02	
MONTH	∑((yoi-yei)^2	Std error of estimate
		sqrt((sum(yoi-yei)^2)/N)
JUN	5372.34	14.65
JUL	16682.86	26.93
AUG	22373.74	29.91
SEPT	5227.42	14.46
OCT	1061.07	6.51

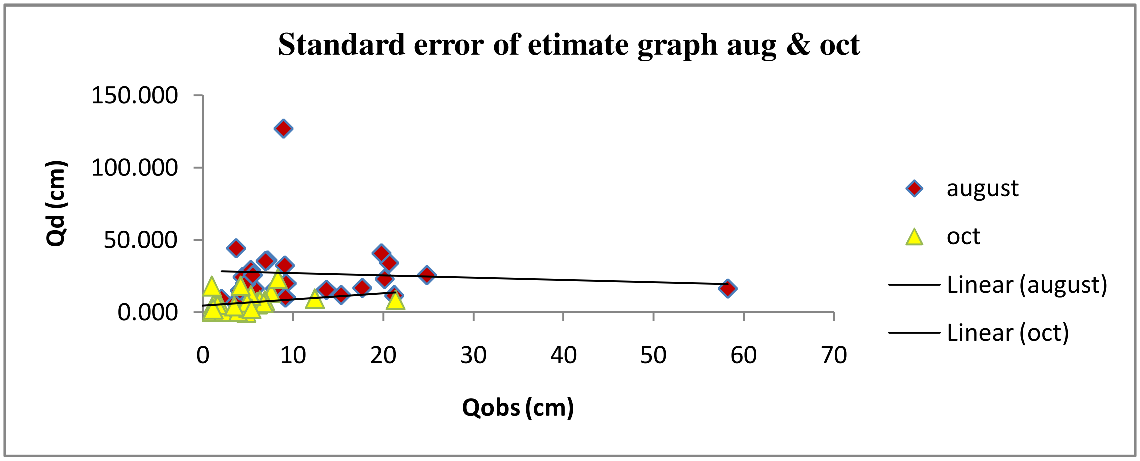
The standard error of estimate is the standard deviation of the prediction errors. It is computed like any other standard deviation - the square root of the error sum of squares divided by the degrees of freedom. It is given by the equation:

$\mathrm{sqrt}((\sum (y_{oi}-y_{ei})^2)/N)$ – (iii)

y_{oi}-observed data, y_{ei}-estimated data,

N- no of pairs of data points

It measures the spread of points around the fitted curve. The minimum value is 0,higher the value of error more spread out the points will be,lower the value more closely fitted the points will be.



Graph2 :std error of estimate graph between observed Q_{obs} and computed Q_d value

3. CONCLUSION

1. The SCS-CN model facilitates runoff estimation and improves the accuracy of estimated data. Fairly comparable values are found between observed and computed values indicating a fair correlation.

2. Proper calibration of data is highly important for S.C.S-CN method. It is highly essential to assign Curve Number based on H.S.G, land cover and A.M.C conditions judiciously, because chances of errors are very high.

3. Higher the value of curve number, lower is the maximum potential retention and higher are the values of runoff depth and runoff depth percent. This is because higher values of curve number correspond to higher runoff and low infiltration.

4. Standard estimate of errors shows that lower the value of error, more closed spaced the points will be, whereas higher the value of error, more dispersed the points will be (see graph2).

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