Watershed Resource Management based on Runoff Curve Number using Geoinformatics Techniques: A Hydrological study of Dwarkeswar River Basin of West Bengal

Sujoy Kanti Bhattacharjee, Santasmita Das

Abstract - Water is one of the necessary normal resources, without which life cannot survive. Insist of water is rising with the raise of population. We require water for farming, manufacturing, and person and livestock utilization. Therefore it is very significant to direct this very important resource with sustainable approach. Hence, we should correct supervision and growth development to return or refresh water where overflow is very far above the ground owed to a variety of topographical situation. The Runoff evaluation technique is one of the major RS & GIS tool for prioritization of watershed. Soil Conservation Service Runoff Curve Number is a quantitative descriptor of the land use/land cover, soil composite personality of breaking point and its compute straight runoff during an practical relation that requires the rainwater and watershed co-efficient namely runoff curve number. The SCS Curve Number approach to runoff quantity is naturally consideration of as a technique for generate runoff for unusual actions and not for water feature plan. The parameters were obtained with the help of Erdas Imagine, Arc GIS and MS Office. The methodology modified from SCS method for the continuing runoff opinion for each watershed is how much prioritized. The mean of the minimum flow data collected at the measurement station has been considered as baseflow of the stream in that watershed, which is an important component of total flow. The total flow of these watershed where measurement of flow data has been undertaken been identified by adding the base flow data and the runoff calculated by CN method.

Keywords: **Geoinformatics, Algorithms, Arc GIS, Erdas Imagine, Ms Office.**

Introduction:

A watershed is a model component for administration of natural resources that also supports land and water resource organization for improvement of the impact of natural disasters for achieving sustainable development. The significant factor for the planning and development of a watershed are its physiographic, drainage, geomorphology, soil, land use/land cover and available water resources. (Biswas et.al, 1999).Remote Sensing and GIS are the most proven tools for watershed development, management and also the studies on prioritization of watersheds development and management. We require water for agriculture, engineering, human and farm animal's utilization. Therefore it is very important to handle this very necessary resource with sustainable approach. Hence, we need proper management and development planning to restore or recharge water where runoff is very high due to various topographical conditions. If proper management is planned that will not only control surface soil erosion but also recharge ground water. Remote Sensing and GIS have become proven tools for the management and development of water resources. Several studies have been carried out worldwide and they have shown excellent results. Due to development in satellites and sensing technology, it is possible to map finer details of the earth surface and provide scope for micro level planning and management. (Mahesh, 2007).The study area that is taken has severe water crises during the summer season. This high runoff also causes the erosion of very fertile soil. The present study aims at for the identification of suitable sites for check dam construction by prioritization of watershed based on Morphometric analysis using Remote sensing data and GIS overlaying techniques. This study is mainly helpful for the increasing agricultural based livelihood and also to supplying the greater level of irrigation facilities (Kiran et. al., 2014).

Study Area:

The study area selected for this research work is part of Dwarkeswar River also known as Dhalkisor. It is situated in the western part of West Bengal. The shape of upper part of the Dwarkeswar watershed is semi elliptical. This area is not only the junction of tropical monsoon current from the Bay of Bengal to the subtropical parts of north-west India, but also acts as a gateway between the developed industrial belts of West Bengal and the hinterlands in Orissa, Jharkhand, Madhya Pradesh and Uttar Pradesh.This area is bounded by latitudes $23^0$15´00´´N to $23^0$30'00" N and from longitudes $86^0$30'09"E to $86^0$45'19"E, Midnapore, Bankura and Burdwan districts of West Bengal and Dhanbad, Bokaro, Hazaribagh, Ranchi, West Singbhum, East Singbhum district of Jharkhand State bound this district. The average elevation of the connection is 12 m. from mean sea level. The intersection area is characterized by a succession of pools and riffles. Semi-diurnal tide is active here and tidal impulse penetrates a little beyond Bandar. Tidal bore of lower magnitude is an important phenomenon at that junction.

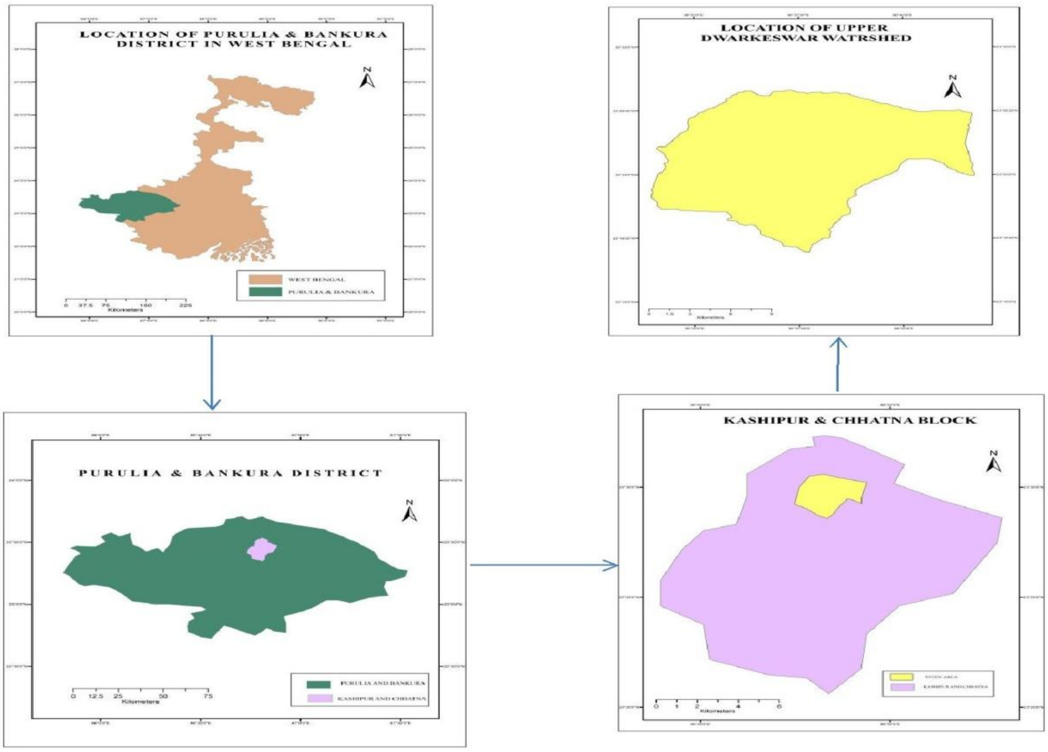


Fig1: Location Map of the Study Area

Methodology:

The methodology can be divided into two parts one is rasterization and other one is vectorization. The rasterization involves creation of mosaicking, sub-set of image, image enhancement and land use/ land cover maps etc. The vectorizations process involves creation of vector layers like; administrative boundaries (i.e. block and village boundaries), watershed boundaries, drainage layers etc (Suresh, 2007). The drainage layer was digitized using Arc/Info tools. The stream ordering was given to each stream is Using Arc Info software by following Strahler (1952) Stream ordering technique. Stream order is a measure of the position of streams in the hierarchy of the tributaries, the first order stream which have no tributaries. Certain limitations were followed in vectorization of micro-watershed to maintain the physical area 5-10 Sq Kms. Supervised classification technique was used to generate the land use/land cover map. (Fig-6). The study area is covered by 73I/11 Survey of India topomaps on 1:50,000 scale and IRS LISS III satellite imagery with 23.5 meter resolutions, The Lambert Conformal Conic projection was used with Everest datum for the georeferencing. An AOI (Area of interest) layer of the study area was prepared and applied to IRS LISS-III data for extraction of the study area. The entire methodology which has been adopted in this study is explained in the flow chart (Fig-2).

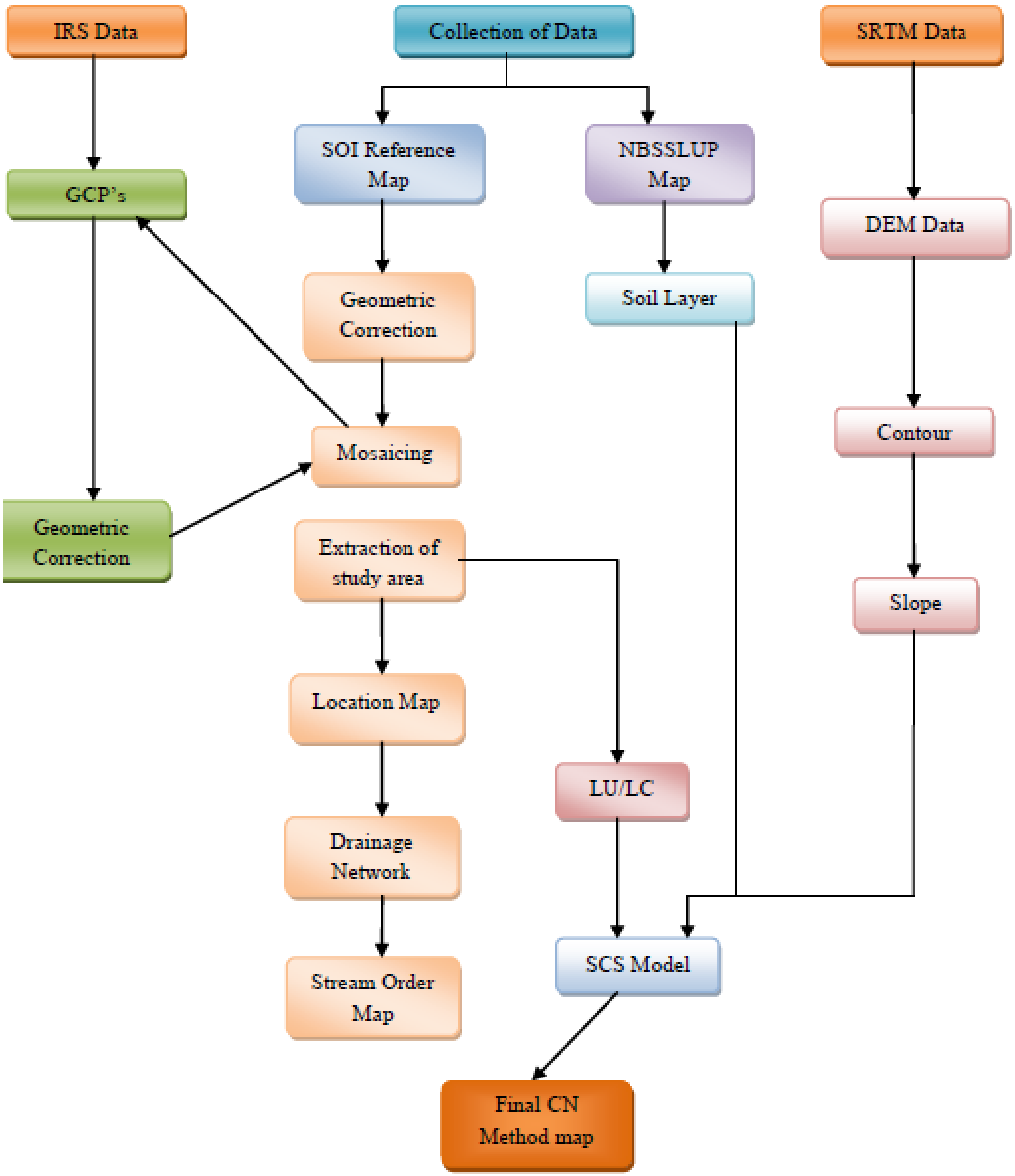


Fig 2

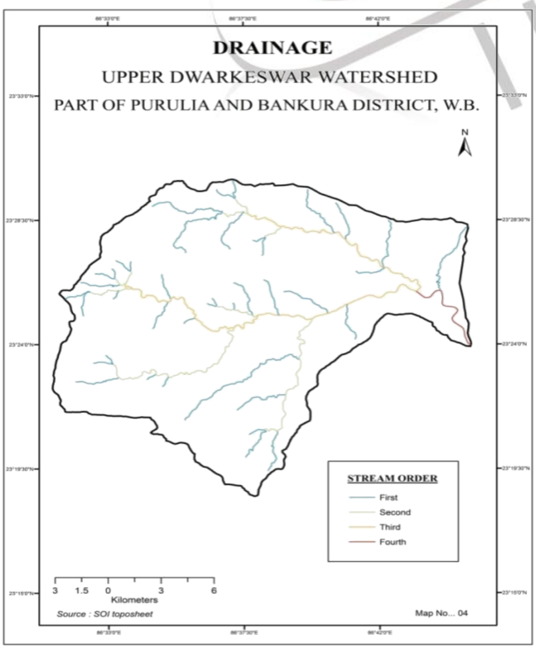


Fig 3: River & Streams map of the area

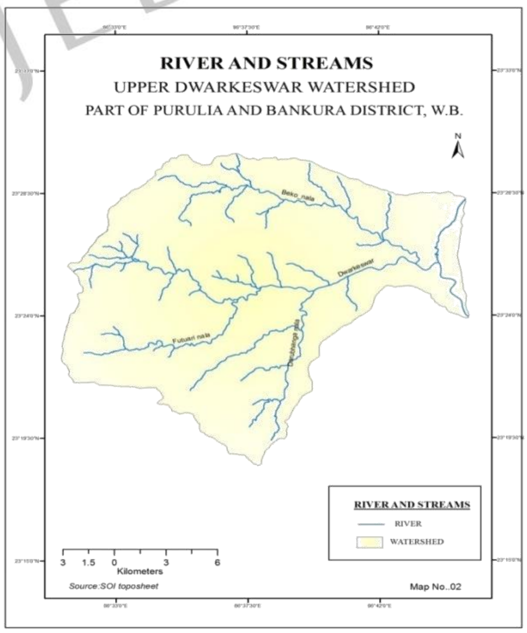


Fig 4: Drainage map of the area

Drainage & Watershed Delineation:

The drainage layers was digitized using Arc Info tools from FCC of LISS-III data and then Updated using the Resources at (LISS-III) data because of the high spatial resolution data with multispectral bands, and a substantial increase in the number of drainages compared to the LISS-III data (Smith et.al., 2012). All drainage layers mainly 1st order streams will be validated to the SRTM DEM data. To generate the DEM layer which is better interpreted to drainage behavior and its patterns through visualization viewer (Figure6) and also validated the SOI reference maps of 1:50000 scale. The stream ordering was given to each stream is Using Arc Info software by following Strahler (1952) Stream ordering technique. Stream order is a measure of the position of streams in the hierarchy of the tributaries, the first order stream which have no tributaries. Stream ordering technique is determination hierarchical position of a stream with in a drainage basin (Table: 1).

Table1: Stream Ordering

Stream Nos	Orders	Stream Nos	Orders
1+1	2	3+2	3
2+1	2	3+1	3
2+2	3	3+3	4

The drainage pattern shaped the origin for separated into riverbanks, sub-watershed and micro-watershed. The texture of drainage pattern and its density not only define a geomorphic region but also indicate its cycle of erosion. The properties and pattern of a drainage basin are dependent upon a number of classes i.e. nature, distribution, features. The quantitative features of the drainage basin and its stream channel can be divided into linear aspect, aerial aspect and shape parameters.

Runoff Estimation Method Using CN method:

The SCS curve number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. As typically utilized with the assumption of average appropriately analyzed to study the moisture condition of each micro-watershed. SCS (Soil Conservation Service) is to be used with GIS to estimate the runoff from each Micro-Watershed (Pramod et.al, 2001). The CN method is also known as hydrological soil cover complex method. It is widely used for runoff estimation of Micro-Watershed. SCS CN model carried on some parameters namely hydrological soil groups, daily rainfall data, land use/land cover features. Soil Conservation Service (USDA, 1985) Curve Number method is a well accept tool in hydrology, which uses a land condition factor called the Curve Number. This curve number is taken based some important properties of catchments namely soil type, land use, surface condition, and antecedent moisture conditions, and also some desirable curve number in suitable land use/land cover features of Indian conditions. Soil Conservation Service Runoff Curve Number is a quantitative descriptor of the land use/land cover, soil complex characteristics of watershed and its computed direct runoff through an empirical relation that requires the rainfall and watershed co-efficient namely runoff curve number (Sachin, 2005). The SCS Curve Number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. The volume of runoff is expressed as:

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

Where: VR = Runoff (runoff excess) in cm, P= Precipitation in cm, S= Maximum potential abstraction after the runoff begins.

Data Used & Methodology:

The SCS curve number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. As typically utilized with the assumption of average appropriately analyzed to study the moisture condition of each micro-watershed. SCS (Soil Conservation Service) is to be used with GIS to estimate the runoff from each Micro-Watershed. The CN method is also known as hydrological soil cover complex method. It is widely used for runoff estimation of Micro-Watershed.

Table2: Input data

Data Type	Details	Source
SOI REF map	1:50,000	Survey of India
Soil map	1:5,00,000	NBSS LUP
Satellite data	LISS III	NRSC
Rainfall Data	2008,2009,2010	Metrological Department

Results & Discussion:

Land Use & Land Cover Classification:

A NDVI (Normalized Difference Vegetation Index) index was performed to derive the class in the forest area and water-bodies. As all the LISS III scenes were acquired in the different time interval hence, each was separately used for NDVI and then desired classes were sliced while clubbing other classes. Final NDVI map was overlaid on the classified image to represent the classes which were not considered during the supervised classification. A supervised classification technique was adopted with maximum likelihood algorithm. Due care was taken in generating the signature sets for the desired classes and where validated with the error of omission and error of commission. Wherever, overlapping of signatures was found, new sets of signatures were generated to improve the classification of LISS –IV image. Basic visual and digital interpretation parameters were followed like; tone, texture, shape, size, pattern, location and association for the recognition of objects and their tonal boundaries. Further refinement was carried out in the classified image with filtering and recoding of few classes. The final classified output image was assigned 7 classes (Table 3). Validation was performed with respect to SOI reference maps and other collateral data. Overall good accuracy of 90 95 % was achieved (Figure - 6).

Landuse type	Dwarkeswar Watershed (Area in km^2)
Dense Forest	83.175723
Open Forest	31.513316
Open Scrub	1.113532
Waterbody	32.363069
Settlement	42.911002
Stonywaste	15.822738
Agriculture	89.613577

Table-3 Distribution of various classes of land use in the watershed

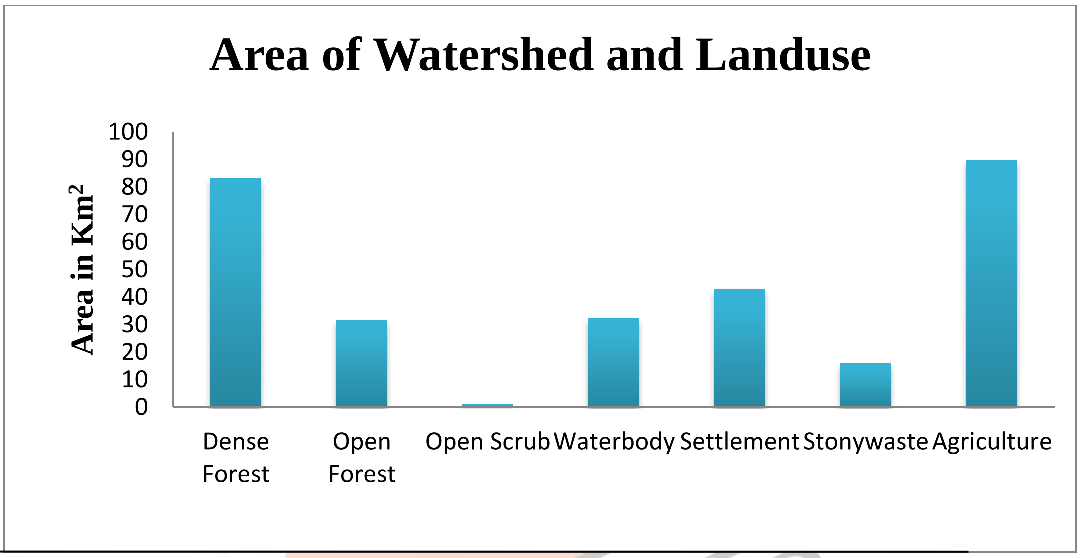


Fig 5: Showing graph Distribution of various classes of land use in the watershed

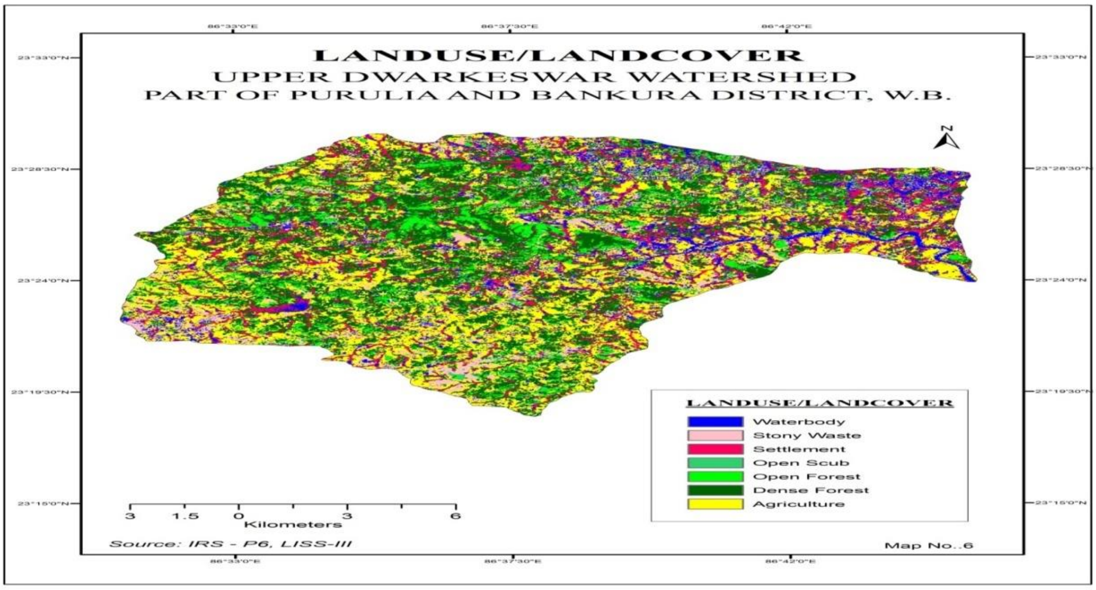


Fig 6: Land use/Land cover map of the study area

Defining Hydrological Soil Groups:
A soil and its moisture condition are very important in runoff estimation and universal soil loss model for prioritization of micro watershed and water resource management and land resource management. Soil properties influence the relationship between

rainfall and runoff by affecting the rate of infiltration. NRCS divides soils into four hydrologic soil groups based on infiltration rates (Groups A, B.C and D). The hydrologic groups can be derived by soil texture and soil taxonomic conditions.

Group A: Well drained
Group B: Moderate to well drain
Group C: Poor to Moderate drained
Group D: Poorly drained

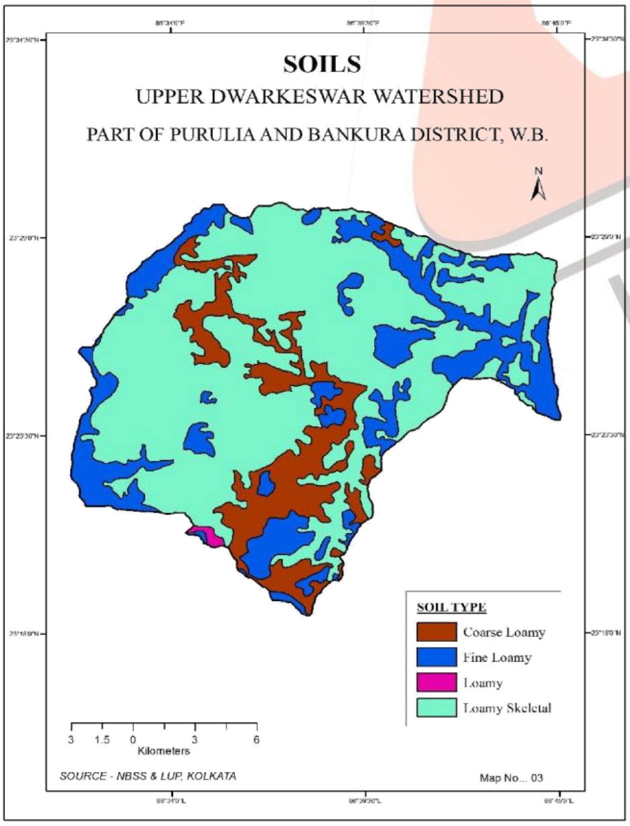
Group A: Group A soils have a low runoff potential due to high infiltration rates even when saturated (High capacity (>7.62 mm). It consists of deep, well to excessively well drained sands or gravels. Specific to loam-clay texture soils. 0.30 in/hr to 0.45 in/hr or 7.6 mm/hr to 11.4 mm/hr). These soils primarily consist of deep sands, deep loess, and aggregated silts.

Group B: Group B soils have a moderately low runoff potential due to moderate infiltration rates when saturated (Medium capacity (3.81-7.62 mm). This characterizes the loamy and loamy Sandy texture soils.
0.15 in/hr to 0.30 in/hr or 3.8 mm/hr to 7.6 mm/hr). These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures (shallow loess, sandy loam).

Group C: Group C soils have a moderately high runoff potential due to slow infiltration rates (Low capacity (1.27-3.81 mm). Specific to loam-clay texture soils 0.05 In/hr to 0.5 in/hr or 1.3 mm/hr to 3.8 mm/hr if saturated). These soils primarily consist of soils in which a layer near the surface impedes the downward movement of water or soils with moderately fine to fine texture such as clay loams, shallow sandy loams, soils low in organic content, and soils usually high in clay.

Group D: Group D soils have a high runoff potential due to very slow infiltration rates (Very low capacity (0-1.27 mm). Specific to loam-clay and clay-loamy texture(USDA-NRCS, 1986). less than 0.05 in./hr or 1.3 mm/hr if saturated). These soils primarily consist of clays with high swelling potential, soils with permanently high water tables, soils with a clay pan or clay layer at or near the surface, shallow soils over nearly impervious parent material such as soils that swell significantly when wet or heavy plastic clays or certain saline soils.

The soil map of the study area was digitally converted and geo-referenced with respect to study area. Different soil groups were derived in GIS environment and later they were merged in 4 classes (A, B, C and D) according to their taxonomy and hydrological parameters, land use classes. Fig 7 and 8.



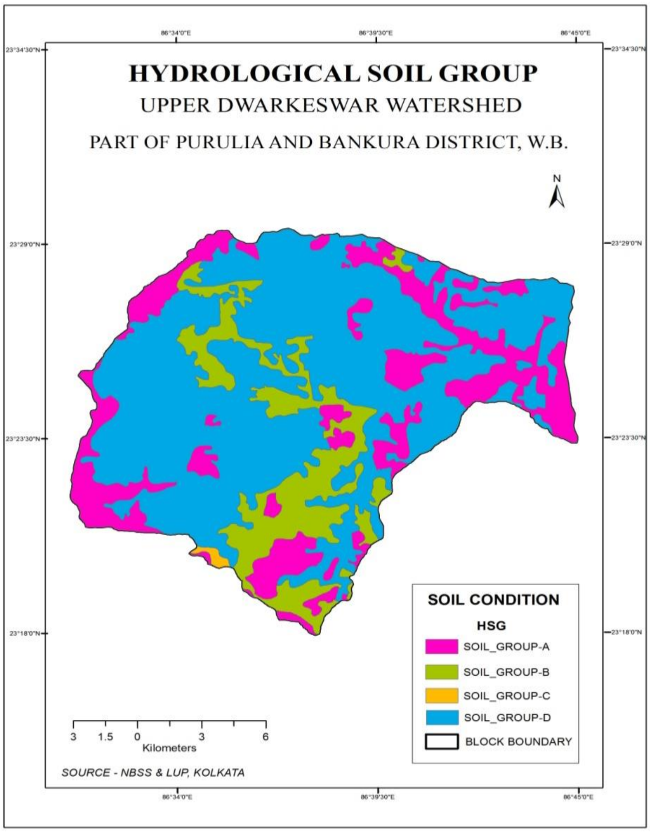


Fig 7: HSG map of the Study area

Fig 8: Soil map of the area

Antecedent moisture condition:

Water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff. AMC is an indicator of watershed wetness and availability of soil moisture storage during the rain. The soil conservation service developed three antecedent soil moisture conditions and named as AMC-I, AMC-II, AMC-III. Table 4 gives seasonal rainfall and dormant rainfall limits, soil conditions for these three antecedent soil moisture conditions. The AMC condition I curve number is dry condition in can be denoted to CN-I, AMC condition II curve number is normal condition in can be denoted to CN-II, AMC condition III curve number is dry condition in can be denoted to CN-III, AMC depends the submission of previous five days rainfall then apply the which storm date goes to condition I, II, III. The average curve number Antecedent moisture condition II approaches to: (USDA, 1985) The CN values were documented for the case of AMCII. The each micro-watershed computed curve number of Indian conditions suitable land use/land cover and analyzed curve number is derived Table 5. The Antecedent moisture condition I &III, adjust the CN-II from the following equation 2 & 3, expressed as:
CN depends on previous (antecedent) rainfall

- Dry conditions, AMC (I)
- Normal or average conditions, AMC (II)
- Wet conditions, AMC (III)

The Empirical Equation is as follows:

$$CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)}$$

$$CN(III) - \frac{23CN(II)}{10 + 0.13CN(II)}$$

Antecedent Condition	Description	Growing Season	Dormant Season
AMC - I DRY	soils are dry but not to the wilting point, and when satisfactory plowing	Less than 1.4 in. or 35 mm	Less than 0.05 in. or 12 mm
AMC II Average	The average case for annual floods	1.4 in. to 2 in. or 35 to 53 mm	0.5 to 1 in. or 12 to 28 mm
AMC III WET	When a heavy rainfall, or light rainfall and low temperatures	Over 2 in. or 53mm	Over 1 in. or 28 mm

Table 4: Antecedent Moisture Conditions for determining the value of CN

2.2.6 Estimation of S:
The parameter S depends upon characteristics of the Soil-Vegetation-Land (SVL) complex and antecedent soil moisture condition in a watershed. S is related to the curve number. The Soil Conservation Service expressed S as:

$$S = \left(\frac{2540}{CN}\right) - 25.4$$

The equation 4 is valid only for otherwise volume of runoff **VR = 0** where **P** is rainfall and **S** is watershed storage. If **P** is greater than **0.2S** than calculate the volume of runoff of each micro-watershed otherwise the volume of runoff is always zero.

Runoff Estimation:
Using the hydrological soil groups A, B, C and D, land use classes to create the curve number. Based on the land use classes and hydrological groups and CN are using in above equation-1, the composite and average curve number was found. This composite CN is the value of AMC-II, Using this CN is above equation 2 & 3 then determine the CN from AMC-II and AMC-III. The values of curve number for the all three antecedent moisture condition are listed in Table-5. $V_R = \frac{(P-0.3S)^2}{(P+0.7S)}$
To calculate the runoff estimation of each watershed by applying the hydrological equation. The equation depends on the one variable P and one parameter S. where P is the value of rainfall and S is the Watershed storage.

Sl No.	Landuse	Soil type	CN value
1	waterbody	Fine Loamy	100
2	Dense Forest	Coarse Loamy	60
3	Open Forest	Loamy	66

4	Open Scrub	Loamy Skeletal	56
5	Agriculture		74
6	Settlement		65
7	Stony Waste		86

Table 5: CN values for AMC II conditi

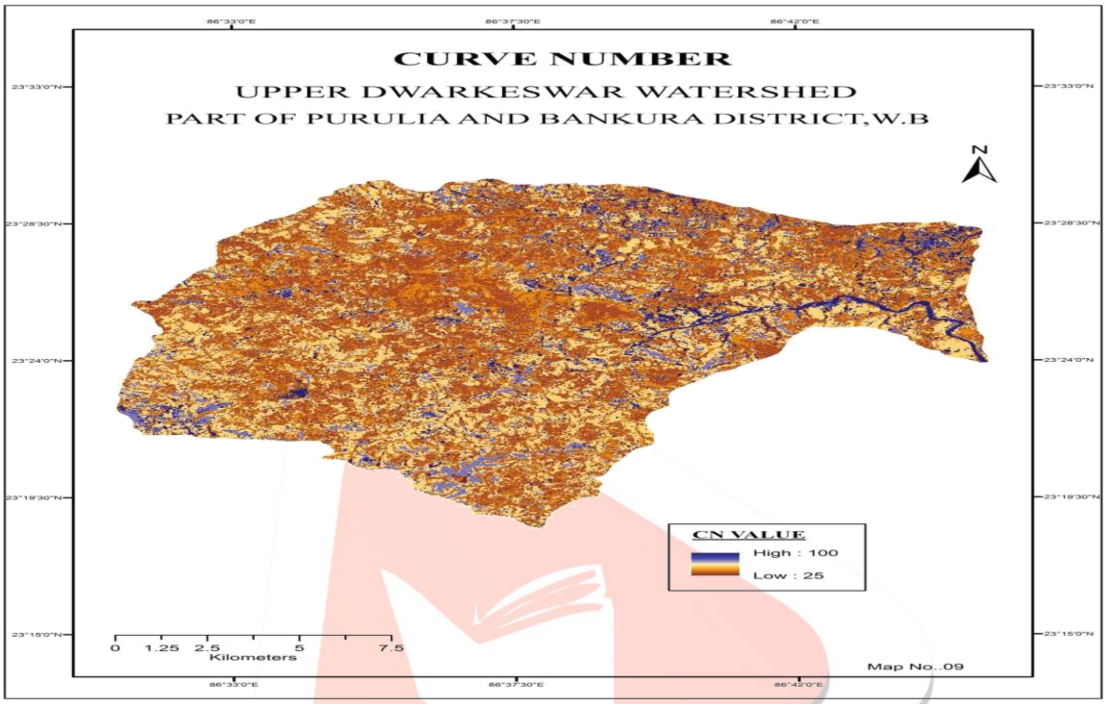


Fig 9: Curve number map of the study area

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Date	2008 Discharge In Cumecs	2009 Discharge In Cumecs	2010 Discharge In Cumecs
1	15.29	41.22	Nil
2	15.29	29.84	Nil
3	15.29	21.1	Nil
4	7.42	16.44	Nil
5	7.42	25.6	Nil
6	7.42	128.57	Nil
7	Nil	H-Flood	Nil
8	Nil	284.36	Nil
9	Nil	29.44	10.47
10	Nil	21.7	7.42
11	Nil	20.11	Nil
12	Nil	18.33	Nil
13	Nil	13.41	31.79
14	Nil	10.97	57.71
15	7.42	10.97	21.1
16	7.42	10.97	13.8
17	Nil	10.97	10.97
18	7.42	10.97	10.97
19	10.97	10.97	10.97
20	18.1	10.97	10.97
21	15.19	7.42	10.97
22	23.14	Nil	10.97
23	45.74	Nil	10.97
24	45.74	Nil	10.97
25	30.83	Nil	10.97
26	22.53	Nil	10.97
27	15.19	Nil	7.42
28	10.97	Nil	7.42
29	10.97	Nil	Nil
30	10.97	Nil	Nil
Total	350.73	733.89	266.83
Average	11.314	23.674	8.607