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IMPLEMENTATION OF SCS MODEL IN DUDHNAI SUB-BASIN (ASSAM/MEGHALAYA)

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667
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PREFACE

In most of the river basins and sub-basins there exits long term rainfall data. But stream flow record particularly in subwatershed level is mostly inadequate. Therefore water resource managers always look for a suitable model capable of estimating runoff from rainfall data. Soil Conservation Service (SCS), USDA procedure which is the outcome of more than two decades studies of rainfall runoff relations has several advantages sensitive to changing landuse condition, applicable to different types of basins (small or large) and easy to understand.

Landuse/landcover one of the important parameter of the SCS model is accurately delineated using remote sensing with the advent of its synoptic view, repetitive coverage and reliability. Soil atlases available with the Soil Survey Organisations of the region has been used to derive the runoff potential of a particular soil. Antecedent moisture condition that affects the runoff is also taken into account in this method. The model was implemented in the representative basin Dudhnai in Assam and Meghalaya as a component part of its overall long term study.

The report has been prepared by V.S.Jeyakanthan, Sc.'B' and B.C.Patwary, Sc.'E' under the guidance of Dr.K.K.S.Bhatia, SC-'F' & Co-ordinater, NERC.

(S.M.SETH)
DIRECTOR

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ABSTRACT

In a predominantly agrarian country like India water is the most vital but limited natural resource for the survival of mankind. Therefore it has become necessary to estimate the amount of water that flows as runoff on the surface of the earth to be obtained from rainfall. To calculate the amount of runoff rainfall is an essential input. In many regions of the country rainfall records are available for fairly long period but runoff records are inadequate in most of the cases particularly on subwatershed level. Therefore runoff estimation using a suitable model that transforms the available rainfall into runoff forms an essential task in hydrological analysis.

Runoff depends on a multitude of climatic and physical characteristics such as landuse soil and moisture. For converting rainfall to runoff the model which incorporates these three important watershed characteristics is USDA (United States Department of Agriculture) Soil Conservation Service (SCS) method. Hence SCS method is chosen to estimate daily runoff in the present study.

The important constituents of the SCS model viz. landuse/landcover can be accurately delineated using remote sensing with the advent of its features of synoptic view repetitive coverage and reliability. Hydrological Soil condition representing the runoff potential of a particular soil is derived from the soil atlases available with the Soil Survey Organisation of the region. Antecedent moisture condition that alters the runoff volume has been taken account for in this study.

In this study the representative Dudhnai basin has been selected for implementing the model. Runoff volume has been estimated for all the nine subwatersheds of the study area. Four subwatersheds has been selected for water conservation measures.

1.0. INTRODUCTION

Runoff is one of the important hydrological processes which influence the various soil and water conservation and development programs in a watershed. Several attempts have been made in the past to estimate rainfall-runoff volume with the use of mathematical models. Most widely used and accepted methodology is the one which is developed by Soil Conservation Service (SCS). The SCS model also known as curve number approach has several advantages. It requires only a few and easily available parameters sensitive to changing landuse condition applicable to different types of basins (small or large) and easy to understand. The runoff estimated from SCS model primarily depends upon rainfall pattern, hydrological soil conditions, landuse pattern and antecedent moisture condition. The model computes the runoff which includes the surface runoff, subsurface flow and channel runoff in unknown proportions. Accuracy of the estimated runoff volume depends upon the precision of the model parameters calculated. Landuse information is the most dynamic phenomenon which changes from season to season in different agroclimatic regions. The information on changing landuse pattern can be best recorded from satellite platform with its synoptic view, repetitive coverage and reliableness. Hydrologic soil map shows the runoff potential or the infiltration capacity of a particular soil which is derived from the soil resources information collected from the soil survey organisations of the region or the country. The moisture or wetness condition of the soil which alters the amount of runoff collected is well taken care of and the model has capability to calculate the runoff on daily basis. On the basis of results arrived subwatersheds can be selected for conservation and development activities.

In this report SCS method is employed to the representative Dudhnai basin to compute daily runoff that is useful in watershed planning and management activites.

2.0 REVIEW

2.1 STUDIES USING SOIL CONSERVATION SERVICE METHOD

Anuthaman, (1981) made a study of curve numbers for different landuse in Bhavani basin using conventional technique. In the study he found that the runoff curve numbers with an initial abstraction of 0.55 for urban and rural land use and 0.28 for the forest is most suitable for predicting runoff of the Bhavani basin. Blanchand (1975) attempted to use remotely sensed data to directly estimate the curve numbers without using ancillary solid data. He collected LANDSAT data over several watersheds in Oklaoma during a full dry period was carried out. He related the measured curve numbers on these watershed to various LANDSAT band combinations and observed fairly good correlation. Slack and Welch and Cermak et al. conducted similar investigation using LANDSAT data.

Bonadelid et. al (1973) modified the curve number values to adopt it for use with U.S. Geological Survey Land use map series.

Hawkins examined the procedure established by USDA for the estimation of storm runoff volume as a function of storm volume and land condition and suggested some modification on it which makes the method realistic under certain conditions.

Tagan and Jackson attempted to evaluate the curve numbers for Anacastia river basin. They used 1:4,800 aerial photograph detailed soil map and field surveys to define the curve numbers of the watershed. Both high altitude colour infrared photographs and digital data were used to estimate land cover of the watershed. Both estimates were very close to the conventionally determined values. The SCS curve number estimation procedure had to be modified to make the land cover categories compatible with those that can be estimated using LANDSAT data.

Vanderspan, Bali J.S and Yadav Y.P,(1990) Ministry of Agriculture, Govt. of India suggested the various initial abstraction (Ia) to be used in the SCS rainfall runoff relationship for Indian conditions as.

Black Soils region AM II and III,	Ia = 0.1S
Black Soils region AMC I,	Ia = 0.3S
All other regions	Ia = 0.3S

where 'S' is the potential maximum retention.

Vellappan, R (1986) of Anna University had adopted the SCS method for runoff estimation from Kukalathorai watershed using remotely sensed data. He used aerial photos for the preparation of land use map and also prepared landuse map from satellite data using Multispectral Interactive Data Analysis System (MIDAS) and compared with that prepared from aerial photos. Soil map prepared by soil Survey and landuse organisation, Coimbatore has been used foe the preparation of hydrological soil map.

2.2 LANDUSE/LAND COVER MAPPING USING SATELLITE DATA

Aerial Photographs have been in use since the begining of 19th century for land use and land cover mapping. Development of colour and colour infrared films during 1940's further enhanced the capabilities of photo interpretation for such mapping. As a result of technological advancement concepts of multiband and multistage photography came into existance which resulted in a variety of data products and interpretation extracted from various types of data products using different interpretation procedures were entirely different from each other and hence had limited scope for its use in decision making and planning purposes.

In an effort to improve this situation, the US geological survey proposed a scheme of classifying land use data by means of remote sensing techniques (Anderson, 1971). The classification scheme was aimed to provide a logical framework for presenting land use and land cover information that could be derived from remote sensing techniques. The classification scheme consists of four level of categorization levels I and II of the system are to be used for land use mapping on a regional basis. The level I category can be identified using space imagery at scales of 1:1,000,000 to 1:250,000 with very little supplementary information. Level II can be most efficiently and economically acquired by high altitude aerial photography at scale of 1:80,000. Level III and IV are to be developed and utilized by local planners to meet their own specific requirement. Study of earth's resources using satellite data has been a matter of great interest since the launching of first US weather satellite like NIMBUS series in 1958. Since then there had been substantial contribution to this field from various parts of the world. Probably systematic efforts towards the use of satellite data for study of earth's resources began with the availability of orbital photographs from Gemini satellite series. By the end of the Gemini programme some 1100 usable colour photographs had been obtained. These pictures produced a number of interesting and unexpected discoveries.

The Apollo program was a further step forward in orbital photography. It was realised that only one film filter combination might not be sufficient if space photography had to be used efficiently. The need for multiband photography was greatly emphasized by Lowman (1969). Apollo-9 carried a multiband camera with four film filter combinations; panchromatic film with red and green filters block and white infrared film and colour infrared film. The bands covered were approximately those planned for the NASA earth Resources Technology satellite (LANDSAT). Colwell and his coworkers found that Apollo pictures were suitable for crop identification. Infrared colour pictures were found to be useful in estimating timber volume distribution (Aldrich, 1971). However, the discrimination capability has greatly enhanced after the introduction of multiband photograph landsat series of satellite was first launched in July 23, 1972 and so far five satellite have been launched. First three LANDSAT satellites have collected over 1 million images of earth's surfaces LANDSAT 4 & 5 have improved sensors, resolution and more sensitive ranges of band width

Indian Remote sensing Satellite (IRS-1A and IRS-1B) have been launched in 1987. These satellites have been specially tailored to the needs of water resources studies and related field. A comprehensive utilization program "IRS" - utilization program has been drawn up for the effective utilization of the huge amount of data which are already available from this satellite. Most application projects of IRS-utilization program have been launched keeping in view the characterizes of remotely sensed data, their potential in providing reliable, timely and comprehensive data base for National Resources Management System (NRMS). India took a major leap forward in the country satellite program when it joined the elite club nations having the capability to put 1000 Kg class of satellite into polar sunsynchronous orbit with the successful launching of its most powerful space rocket, the polar Satellite Launch Vehicle (PSLV) on October15,1994 - the IRS-P2 has been launched with the help of PSLV-D2 to achieve the multidisciplinary goals of water resources, drought monitoring forest volume study telecommunications etc.

2.3 VISUAL INTERPRETATION OF SATELLITE IMAGERY

Early experiments on the use of LANDSAT data for land use/vegetal cover mapping were mostly based on the methods of visual interpretation. Variation in tone, texture and shape form the basis for visual interpretation. Interpretation draws the boundaries of the features which appear similar in tone and texture on imagery. Names of the categories are assigned after interpretation using the available ground truth. In this process aerial photographs on black and white and colour infrared films available from conventional methods are frequently consulted

Krebs (1977) demonstrated advantages of false colour composites over single band black and white imagery. However, he suggested use of black and white imagery of some other date to detect the changes and improve classification accuracy. By this way he was able to achieve an accuracy of 90 percent in land cover mapping of Denali project area in Alaska, USA.

In land use mapping of Massachusetts Rhode Island and Connecticut, it was possible to identify land use categories derived on the basis of classification scheme suggested by U.S. Department of Interior. It was found that Woodlands were delineated most easily. Built up categories as a whole could be differentiated from non built up categories with relative ease. Agricultural areas could be effectively mapped using seasonal coverage. Marshyland and rock outcrops were very easily interpolated on colour composite (Leonard, 1975)

Limitations of the application of satellite to data to extract detailed information like species identification in forested areas, forest density determination etc have been discussed by Madhavan Unni (1978). He was able to decipher the differences in colour tones on false colour composites of two different seasons of the year and show the phonological changes that has occurred. The areas where January imagery has red tone but in March imagery had reduced or negligible red tone are deciduous forests which shed their leaves. Such comparison not only help in understanding the phonological behavior of forests over large areas but also help in differentiation and delineation of different broad types of forests such as evergreen from deciduous etc. (Madhavan Unni and Roy, 1979). To estimate the extent of forest cover and monitor the reduction in forested area, NRSA carried out visual interpretation of false colour composites and supporting material for the periods 1972-75 and 1980-82. It was found that in the 1972-75 total area under forest was 16.89% of the total geographical area which reduced to 14.105 in the period 1980-82. This reduction in forest cover amounts to a loss of more than 1 lakh Sq.Km forest area in the country during the period.

Land use survey of Idduki in Kerala has indicated that visual interpretation of false colour composites can be successfully used in mapping of Level -II categories of USGS classification scheme.However some difficulties were countered in forested areas due to shadow effects caused by undulating terrain (Space Application Centre and KSLUB, 1980). Visual interpretation of black and white imagery and false colour composites have been successfully used for preparation of land use and vegetal cover map at 1:25,000 scale with 10 categories of land use and vegetal cover in drought monitoring study of Dharwar, Belgaum and Bijapur districts of Karnataka. These maps were used to delineate irrigable and non-irrigable areas (NRSA, 1980). Sahai (1983) also reported the similar observation in land use mapping of Punchmahals district of Gujarat. They found that the crop inventory for major crops and their average estimates could be done in a shorter time than through conventional methods with fair accuracy .

Gautom (1983) pointed out that on false colour composite forested and cultivated areas were easily delineated due to their characteristic red to dark red and pink to light red tone and their patterns respectively. He also found that landsat imagery could be successfully used in the mapping of wet land and coastal saline land.

3.0 STUDY AREA

3.1 STUDY AREA AND LOCATION

The area selected for this study Dudhnai (Fig 3.1) is subbasin of Dudhnai Krishnai basin. Dudhnai river which divides the basin at the lower part into two half is south bank tributary of Brahmaputra. The sub-basin partly lies in the district of East Garo Hills in Meghalaya and partly in the district of Goalpara in Assam. On the east lies the Dsoila sub-basin and on the west it is Krishnai sub-basin. The catchment area is about 527.9 Sq. Km. 83% of sub-basin is in East Garo Hills in Meghalaya and 17% in Goalpara District of Assam. The study area is geographically located between 25° 35' N and 26° 0' N latitude and 90° 40' E and 90° 57' E longitude. Dudhnai is situated at a distance of 60 km from Guwahati city. The outlet of the sub-basin is at Dudhnai with gauge discharge site on NH-37.

The subbasin is a humid area with intense premonsoon and monsoon rainfall from May to October and relatively dry for the rest of the year. The deatils of the toposheet used in investigation are given in Table – 3.1.

TABLE - 3.1 DETAILS OF TOPOSHEETS

Sl.No.	Sheet Reference Number	Scale	Year
1.	78K/9	1:50,000	1963-64
2.	78K/10	1:50,000	1963-64
3.	78K/13	1:50,000	1963-64
4.	78K/14	1:50,000	1963-64

3.2 AGRICULTURE

Agriculture and forests are the mainly livelihood of the people in the sub-basin. Rice is the principal crop. Tea is grown on comparatively at higher land. Other important crops grown are Jute, Sugarcane, Mustered and Pulses. In the upper region forestry is also an occupation along

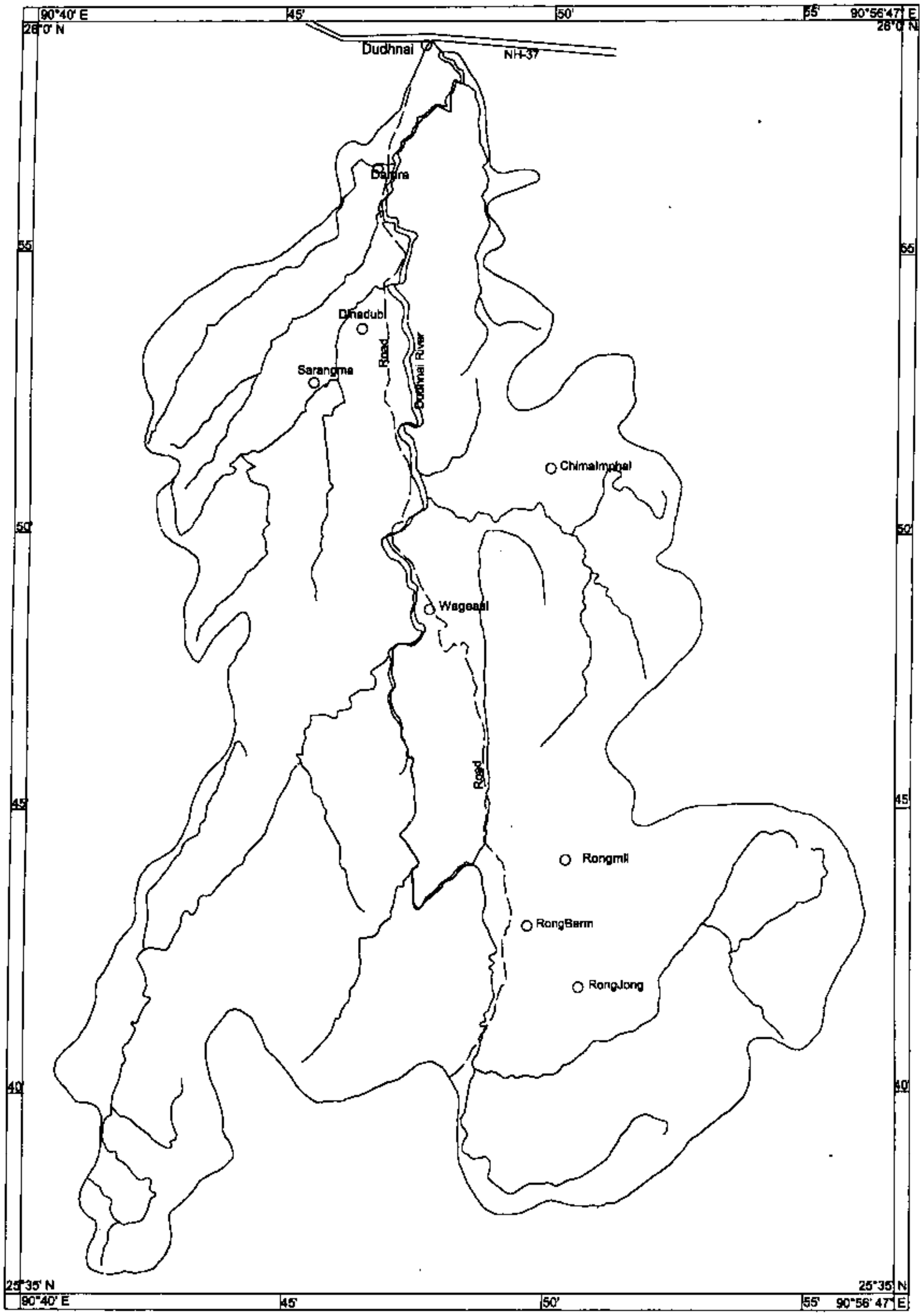

Fig.No.3.1 Study Area - Dudhnai Subbasin.

with agriculture. People are also trying to grow tea and coffee resorting to horticulture. Also experiments on growing cashewnut and rubber plantation have shown expecting results.

Shifting cultivation known as Jhum cultivation is being practiced in the hilly region since long this degraded the vegetal cover of the area and washes down the rich top fertile soil cover rendering the surface area progressively infertile. It is one of the principle cause of degrading the forests in this region.

3.3. SOILS

Soil in the lower catchment of Dudhnai sub-basin is predominantly hard reddish clay to light yellowish and light gray felspar and mica. The basin plains are mostly new alluvium as found in reparian areas. Soils in the upper catchment is sandy loam or silty mainly comprising of quartzite and laterite.

3.4 GEOLOGY

Geology of this area is such that cretaceous sandstone rocks lie on an irregular surface of Shillong quartzites and other metamorphic rocks. The basal bed is conglomerates embedded with sandstone followed by glyconitic sands carbonaceous sandstone which contains plant remains. In the Western part of the basin the lowest beds recently termed as tura stage includes sandstone and various out crops of thin coal occurring in and near the Garo hills.

3.5 HYDROMETEROLOGY

Dudhnai sub-basin falls within the climate zone-1 which comprises North and North east India and adjoining parts of Nepal, Bhutan, Bangladesh and North Burma. The sub-basin consists of three raingauge stations at Damra, Wageasi and Rongmil. The sub-basin enjoys an average annual rainfall of 1817.20 mm. In this zone the bulk of rainfall occurs during the month of May to September. The average annual temperature ranges between 29.50° C to 19.70° C. The temperature starts rising from the beginning of March and reaches maximum in July & August. Relative humidity in the rainy season (May to Sept.) is between 72% to 85%, in the non monsoon period (Feb. to April) it ranges between 50% to 75%.

3.6 SATELLITE DATA USED

The false colour composit (FCC) of IRS-1A,1B, LISS-II data generated on 1:50,000 scale were used for landuse classification. Details of satellite data product used is given in the Table 3.2.

TABLE – 3.2 DETAILS OF IRS - 1A,1B DATA PRODUCT USED

Sl.No.	Name of the Satellite	Date	Scale	Toposheet	Path & Row
1.	IRS – 1A	02.12.1989	1 : 50,000	78K/9	17 - 49
2.	IRS – 1A	02.12.1989	1 : 50,000	78K/10	17 - 50
3.	IRS – 1A	02.12.1989	1 : 50,000	78K/12	17 - 49
4.	IRS – 1A	02.12.1989	1 : 50,000	78K/13	17 - 49
5.	IRS – 1A	02.12.1989	1 : 50,000	78K/14	17 - 50
6.	IRS – 1B	06.03.1997	1 : 50,000	78K/9	17 - 49
7.	IRS – 1B	06.03.1997	1 : 50,000	78K/10	17 - 50
8.	IRS – 1B	06.03.1997	1 : 50,000	78K/12	17 - 49
9.	IRS – 1B	06.03.1997	1 : 50,000	78K/13	17 - 49
10.	IRS – 1B	06.03.1997	1 : 50,000	78K/14	17 - 50

4.0 METHODOLOGY

4.1 SCS METHOD AN OVERVIEW

The methodology established by Soil Conservation Services (SCS) United States Department of Agriculture (USDA) is applied in this study for the estimation of surface runoff volume. The method is widely adopted for estimation of runoff from rainfall depths and takes into account the important physical aspects of a basin on which runoff depends such as landuse, hydrological soil cover & antecedent moisture condition.

For a storm the relation between rainfall, runoff and retention can be expressed by an empirical relationship as

$$\frac{F}{S} = \frac{Q}{P} \tag{4.1}$$

where

F = Actual retention in mm
S = Potential maximum retention in mm
Q = Runoff in mm
P = Precipitation in mm ($P \geq Q$)

The potential maximum retention 'S' is a constant for a particular storm that can occur under the existing conditions of a basin. The variable actual retention F can be described as the difference between precipitation (P) and runoff (Q) which is written as follows:

$$F = (P - Q) \tag{4.2}$$

Eqn. (4.1) can therefore be rewritten as

$$\frac{(P - Q)}{S} = \frac{Q}{P} \tag{4.3}$$

Solving for Q produces the equation

$$Q = \frac{P^2}{P+S} \tag{4.4}$$

which is the rainfall runoff relation in which the initial abstraction is zero. If an initial abstraction (Ia) greater than zero is considered the amount of rainfall available for runoff is (P-Ia) instead of P. By substituting (P-Ia) for P in equation (4.1) the following equation is obtained.

$$\frac{F}{S} = \frac{Q}{(P-Ia)} \qquad (4.5)$$

in which case F < S and Q < (P-Ia). If so retention of a storm consists of Ia and the equation 4.2 can be rewritten as follows:

$$F = (P-Ia) - Q \qquad (4.6)$$

The following equation is obtained by substituting the value of F in equation (4.5)

$$\frac{(P-Ia)-Q}{S} = \frac{Q}{(P-Ia)} \qquad (4.7)$$

If the equation 4.7 is solved for Q the following equation is resulted.

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S} \qquad (4.8)$$

which is the rainfall runoff relation with the initial abstraction taken into account.

Initial abstraction consists mainly of interception infiltration surface storage all of which occur before runoff begins. To remove the necessity for estimating the variables in equation 4.8 the relation between Ia and S was developed by means of rainfall and runoff data from experimental watersheds. The empirical relationship for Indian condition is

$$Ia = 0.3S \qquad (4.9)$$

The following final rainfall runoff relation used in SCS of USDA is obtained by substituting 4.9 in 4.8.

$$Q = \frac{(P-0.3S)^2}{(P+0.7S)} \qquad (4.10)$$

The steps involved in estimation of runoff can be broadly grouped as follows and shown in Fig.4.1.

1. Rainfall data collection.
2. Estimating average depth of rainfall.
3. Deciding the Antecedent Moisture Condition (AMC)
4. Interpretation of satellite imagery.
5. Preparation of hydrological soil groups map.
6. Preparation of soil cover complex map.
7. Assigning the actual curve number values.
8. Calculation of potential maximum retention (S).
9. Calculation of daily runoff on sub watershed basis.
10. Calculation of runoff volume for each sub-watershed.

4.2 RAINFALL DATA COLLECTION

Analysis of rainfall runoff relation under this study requires daily rainfall data as a minimum requirement. If the raingauge stations located with in the catchment it would represent a better result in other case raingauge stations around the basin may also be used.

4.3 ESTIMATING AVERAGE DEPTH OF RAINFALL

Generally Thiessen polygon method is applied to estimate the average depth of rainfall. The polygons are formed by drawing perpendicular bisector of the lines joining nearby stations. The area of each polygons are determined and is used to calculate the daily rainfall value of the subwatershed. If a sub-watershed shares two polygons weighted average of the rainfall depth is calculated.

4.4 DECIDING THE ANTECEDENT MOISTURE CONDITION (AMC)

Antecedent moisture condition is 5 days moisture or wetness condition of the soil before occurrence of a storm. This is determined by the total rainfall in the 5 days period preceding a storm. To calculate the AMC of a particular day the cumulative rainfall values of the prior 5 days is calculated and decided with the help of the Table 4.1.

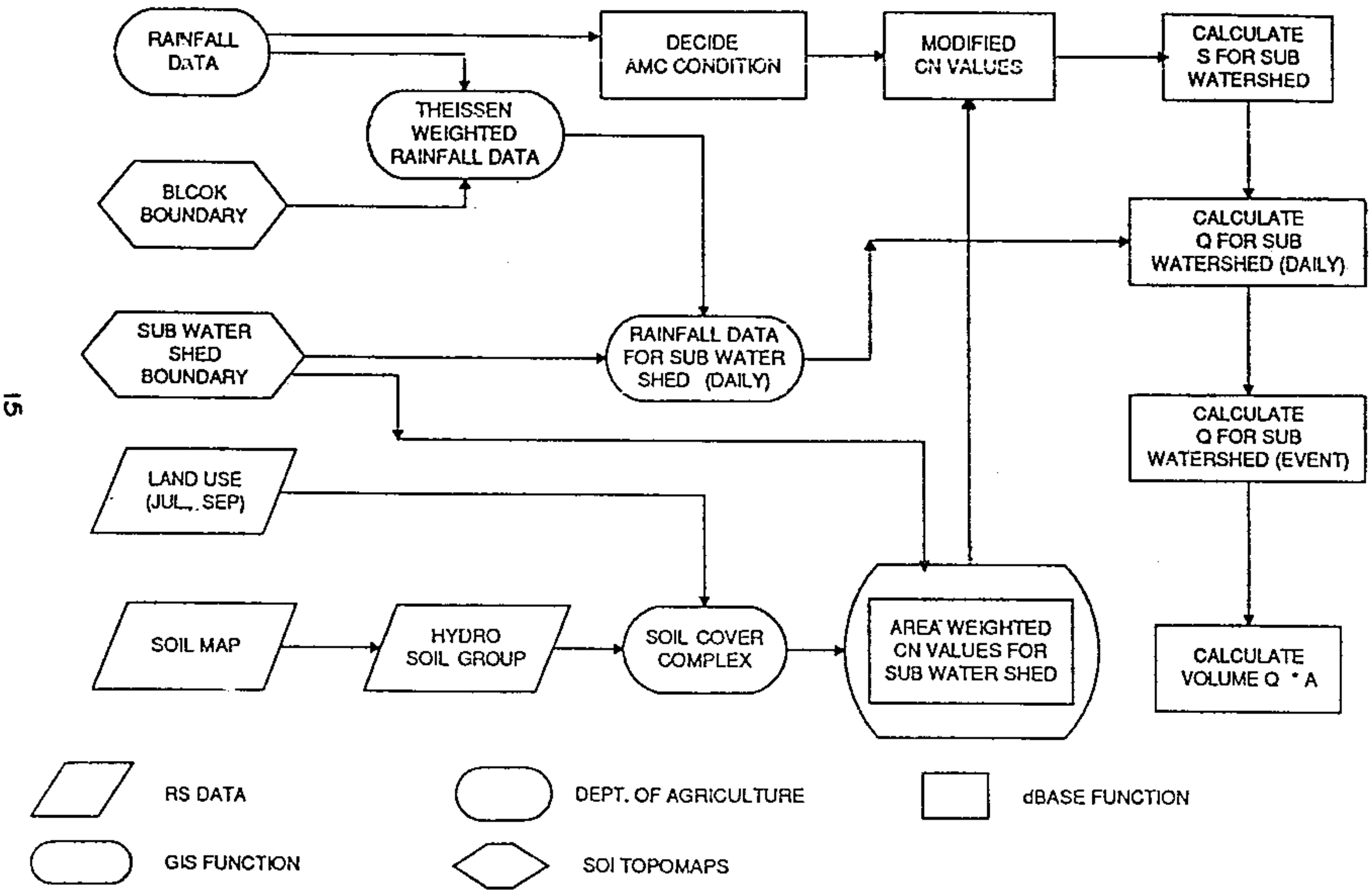

FIG. 11 FLOW CHART FOR THE ESTIMATION OF RUNOFF VOLUME BY SCS TECHNIQUE

TABLE - 4.1 LEVEL OF AMC

AMC GROUP	Total 5 days antecedent Rainfall (mm)	
	Dormant Season	Growing Season
I	< 12.7	< 35.6
II	12.7 – 27.9	35.6 – 53.3
III	> 27.9	> 53.3

4.5 INTERPRETATION OF SATELLITE DATA

Image interpretation is the art of examining the satellite data for the purpose of identifying the objects or surface features and studying their significance. Interpreters study remotely sensed data and attempts through the logical processes in deducing, identifying, classifying, measuring and evaluating the significance of physical and cultural objects, their pattern and special relationship. Image interpretation of the remotely sensed data can be attempted either by visual or digital technique of analysis. The purpose of applying either of the above two techniques is landuse/landcover identification and classification.

There are certain fundamental photo elements or image characteristics seen on image which aid in visual interpretation of the satellite imagery. Although there is a difference of opinion on the number of elements to be include a general consensus of them are as follows :

1.Tone or colour 2.Size 3.Shape 4.Texture 5.Pattern 6.Location

7.Association 8. Shadow.

Satellite imagery is the best medium available to obtain landuse/landcover classification in real time be the catchment small or large. Landuse which is one of the input in SCS model can be exactly determined using satellite technology with the advent of its unique characteristics of synoptic view repetitive coverage and reliability. Anderson's classification system for the remote sensing data has been used. Table 4.2 shows the part of the classification system adopted.

TABLE 4.2 PART OF LANDUSE/COVER CLASSIFICATION SYSTEM

LEVEL I	LEVEL II	LEVEL III
1. Built Up	1.1 Urban	2.1.1 Khariff 2.1.2 Rabi
2. Agriculture	2.1 Crop Land 2.2 Fallow	
3. Forest	3.1 Deciduous 3.2 Scrub Forest 3.3 Forest Blank 3.4 Forest Plantation	3.1.1 Dense 3.1.2 Open
4. Waste Land	4.1 Land with or without Scrub 4.2 Barren /Sheet Rocky	
5. Water Body	5.1 Lack /Reservoir	
6. Perennial Snow or Ice	6.1 Perennial Snow Field 6.2 Glaciers	

4.6 PREPARATION OF HYDROLOGIC SOIL GROUPS

Soil parameters influence the process of generation of runoff from rainfall and they must be considered in the methods of runoff estimation. The properties of soil which influence the runoff are clay in the surface layer, average clay content in the profile, infiltration, permanent soil texture etc. These soils data are to be determined from actual field investigation or to be obtained from various sources such as soil map prepared by National Bureau of Soil Survey (NBSS & LUP), State Agriculture Department, etc. On the basis of the information obtained soil has been classified (SCS,1956) into four hydrological soil groups A,B,C and D with their runoff potential.

4.7 PREPARATION OF SOIL COVER COMPLEX MAP

Soil cover complex map is prepared by integrating or overlaying hydrological soil map and landuse map. Polygons formed out this is assigned a curve number considering the average antecedent moisture condition (AMC - II). The sub watersheds which are having more than one cure number values are identified and assigned a single curve number for each sub watershed by calculating the weighted average of the curve numbers. This is a function of Geographic Information System (GIS) which can be applied using a computer software such as ILWIS, ARC/INFO, MAPINFO etc. to get the results of large basins in a short time.

4.8 ASSIGNING ACTUAL CURVE NUMBER VALUES

From the weighted average curve number (AMC-II) the curve number of the subwatershed is reassigned to a modified curve number and using the actual antecedent moisture condition (AMC I - III) of the watershed on daily rainfall basis.

4.9 CALCULATION OF POTENTIAL MAXIMUM RETENTION (S)

Potential maximum retention (S) is calculated on daily basis of a subwatershed by assigning the modified curve number value in the following formula :

$$S = \frac{25400}{MCN} - 254$$

Initial abstraction equals to 0.3 times of potential maximum retention. Naturally if a precipitation occurs less than 0.3 times of S, there would be no runoff. Hence runoff is calculated for a rainfall which equals to 0.3S and more than that.

4.10 CALCULATION OF RUNOFF

The value of S has been put into the following equation to get runoff on daily basis which is calculated in cm.

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

4.11 VOLUME OF RUNOFF

Volume of runoff of a subwatershed is calculated by multiplying surface runoff of and the area of the watershed.

5.0 RESULTS AND DISCUSSION

5.1 RAINFALL ANALYSIS

Daily rainfall data for the five years 1986 to 1991 (1989 not available) from three meteorological stations Damra, Wageasi and Rongmil which present inside the study area (Fig.5.2) are used for rainfall-runoff analysis. Wageasi is located at the center of the catchment. Damra and Rongmil are located at a distance of 25 k.m. North and 30 km South of Wageasi. These three rainfall station covers an area of about 78.77, 177.30 and 71.81 sq.km respectively. Table 5.1 and Fig.5.1 shows the rainfall in each sub watershed for five years.

TABLE – 5.1 RAINFALL (M) OF EACH SUBWATERSHED IN THE STUDY AREA

Year / Subwatershed No.	1986	1987	1988	1990	1991
SW1	2.03	1.90	2.12	2.43	2.42
SW2	2.07	1.83	2.46	3.11	1.73
SW3	2.15	1.67	3.14	4.45	4.71
SW4	2.20	1.57	3.58	5.34	5.71
SW5	2.06	1.83	2.42	3.03	3.10
SW6	2.07	2.42	3.43	4.29	4.71
SW7	1.87	3.69	3.22	2.73	3.23
SW8	1.72	4.69	3.04	1.50	2.06
SW9	1.72	4.69	3.04	1.50	2.06

5.2 SUBWATERSHED DELINEATION

Drainage and subwatershed boundary was delineated from four SOI 1:50,000 topographical maps with 20 metre contour interval and various bench mark points, depicted in the toposheets. Nine subwatersheds were delineated ranging from 15.55 sq.km to 132.22 sq.km. Extent of subwatersheds are shown in Table 5.2 and in Fig.5.2.

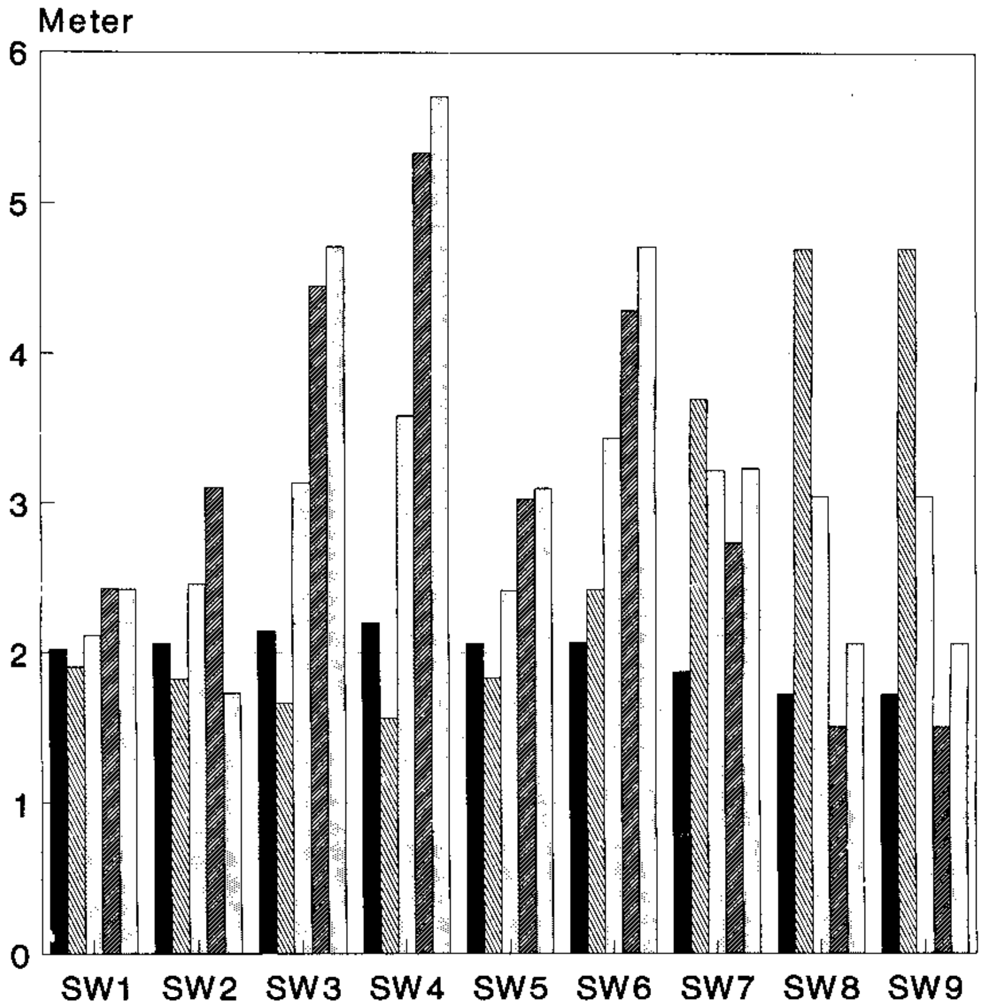

Fig.No.5.1 RAINFALL (M) OF SUBWATERSHEDS OF DUDHNAI SUBBASIN

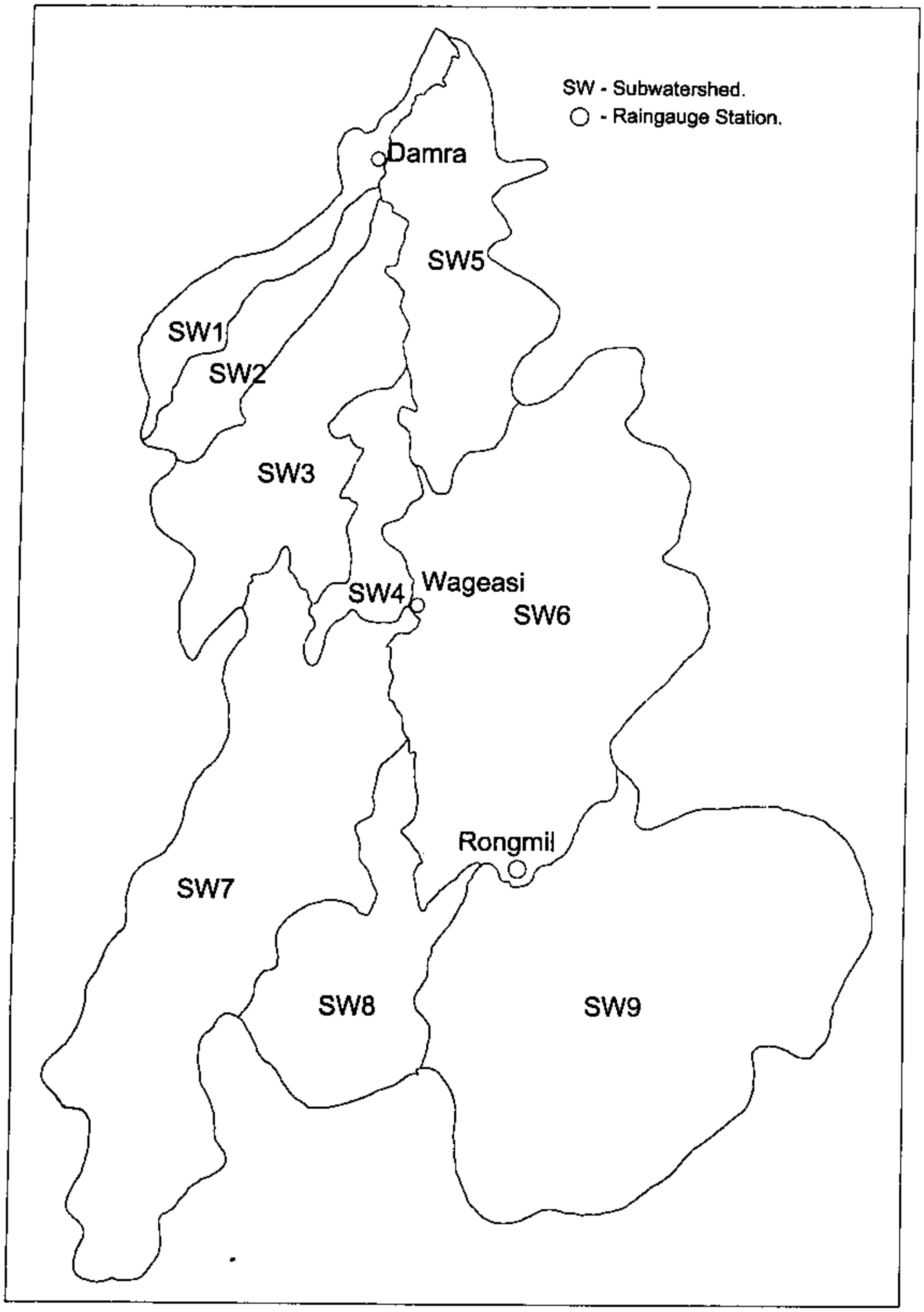

Fig.No.5.2 Subwatershed Distribution of Dudhnai.

TABLE – 5.2 EXTENT OF SUBWATERSHEDS IN THE STUDY AREA

Subwatershed No.	Area of subwatershed (sq.km)	% of Extent
SW1	16.93	3.20
SW2	15.89	3.00
SW3	47.72	9.04
SW4	15.55	2.95
SW5	44.15	8.36
SW6	113.26	21.46
SW7	104.07	19.71
SW8	38.08	7.22
SW9	132.22	25.05
Toatal	527.90	100.00

5.3 HYDROLOGICAL SOIL GROUP

Hydrological soil map (Fig.5.3) has been compiled with the help of soil resource information gathered from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) Regional centre, Jorhat in 1:250,000 scale. It has been enlarged to 1:50,000 scale using optical Reflecting Projector to suit with other existing maps. Table 5.3 gives the distribution of hydrological soil group in the study area.

TABLE – 5.3 DISTRIBUTION OF SOIL GROUP

Sl.No.	Hydrological Soil Group	Area covered Sq.km	% of Extent
1.	B-Moderately low runoff potential	102.00	19.32
2.	C-Moderately high runoff potential	425.90	80.68
	Total	527.90	100.00

Table 5.4 gives the soil subgroup and their runoff potential.

TABLE – 5.4 SOIL SUBGROUPS AND THEIR RUNOFF POTENTIAL

Sl.No	Soil Classification	Runoff Potential
1.	Umbic Dystrochrepts	C
2.	Typic Kandihumults	C
3.	Aquic Eutrochrepts	B
4.	Umbic Dystrochrepts	B

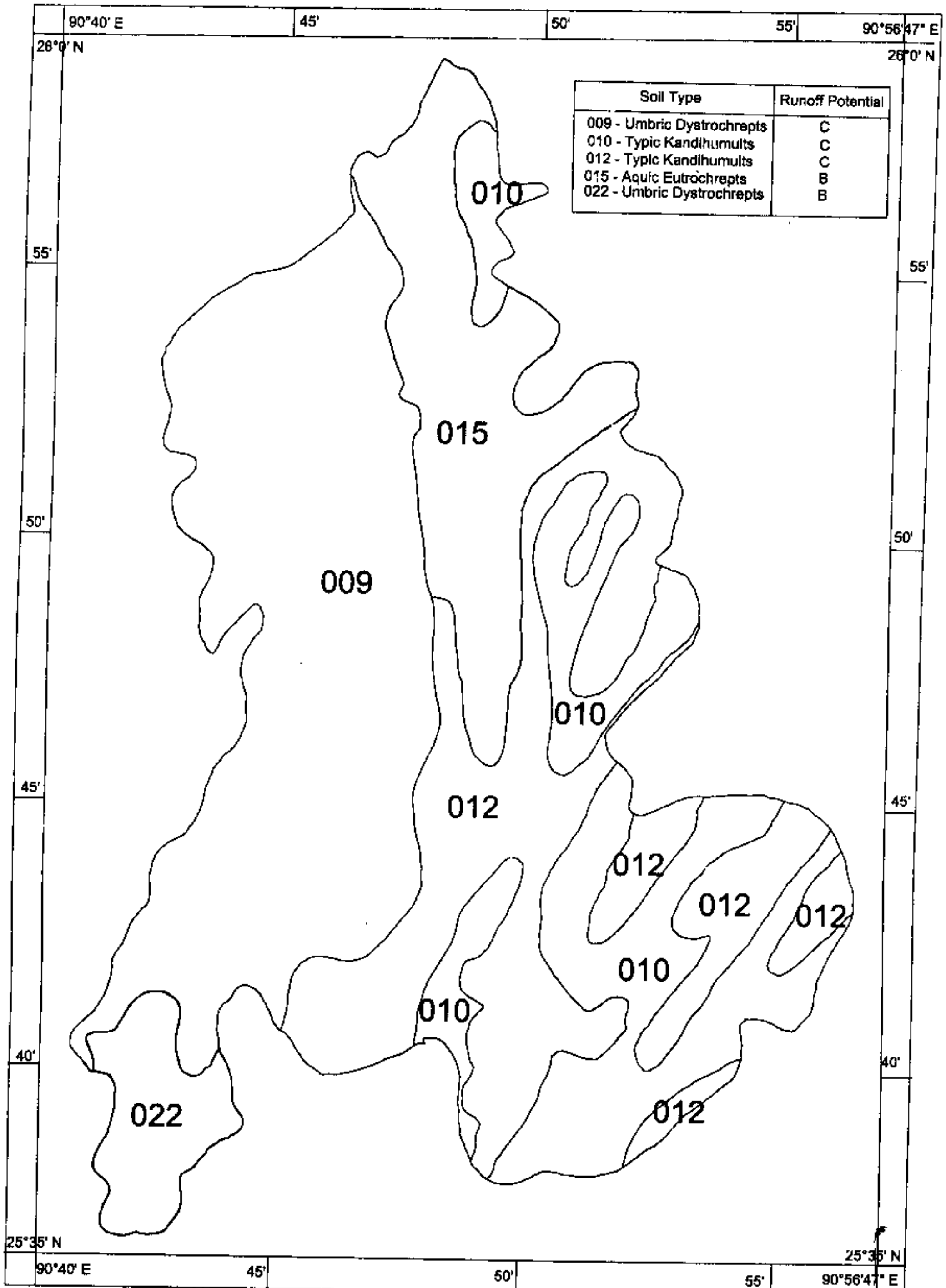

Fig No.5.3 Hydrologic Soil Groups Map of Dudhnai.

5.4 EVALUATION OF LANDUSE AND LANDCOVER

To evaluate the landuse conditions which is one of the major factors in estimating runoff 02.12.89 and 06.03.97 satellite imagery of IRS-IB, LISS-II data has been visually interpreted in 1:50,000 scale. Interpretation has been carried out upto level II classification.

5.4.1 Landuse – 1989

Different types of landuse with their respective area has been delineated for the year 1989 using 02.12.89 data. Fig. 5.4 and Table 5.5 shows the existing landuse pattern and aerial extent in the study area The study area was mostly covered by deciduous dense forest in 1989 comprising Teakwood and Bamboo. Comparatively less area (9.61 sq.km.) of fallow land arised due to shifting or Jhum cultivation conforms the practicing area of Jhum was less during this period.

5.4.2 Landuse - 1997

Aerial extent of landuse for the year 1997 is shown in Fig. 5.5 and Table 5.6. Comparison of two satellite data reveals that within a short period of seven years forest area has deduced to half and it was occupied by Jhum cultivation which augments surface runoff and erosional activities.

TABLE – 5.5 AERIAL EXTENT OF LANDUSE – 1989

Sl.No.	Level I	Level II	Area in Sq.km	% of Extent
1.	Build Up	Rural	3.20	0.61
2.	Forest	Deciduous Dense	501.90	95.07
		Fallow	9.61	1.82
3.	Water Body	Water logged Area	13.19	2.49
		Total	527.90	100.00

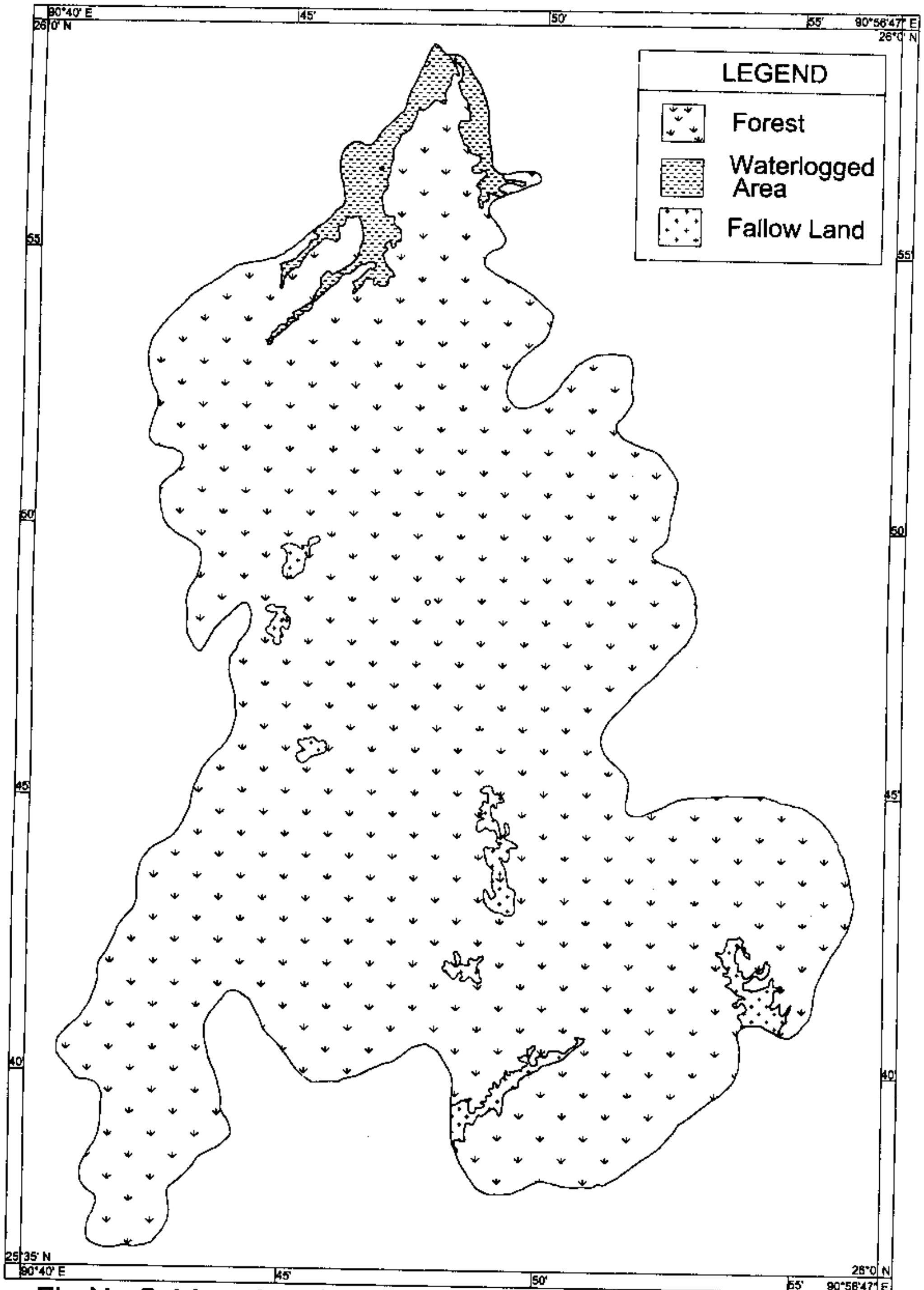

Fig.No.5.4 Landuse/Landcover of Dudhnai - December'89.

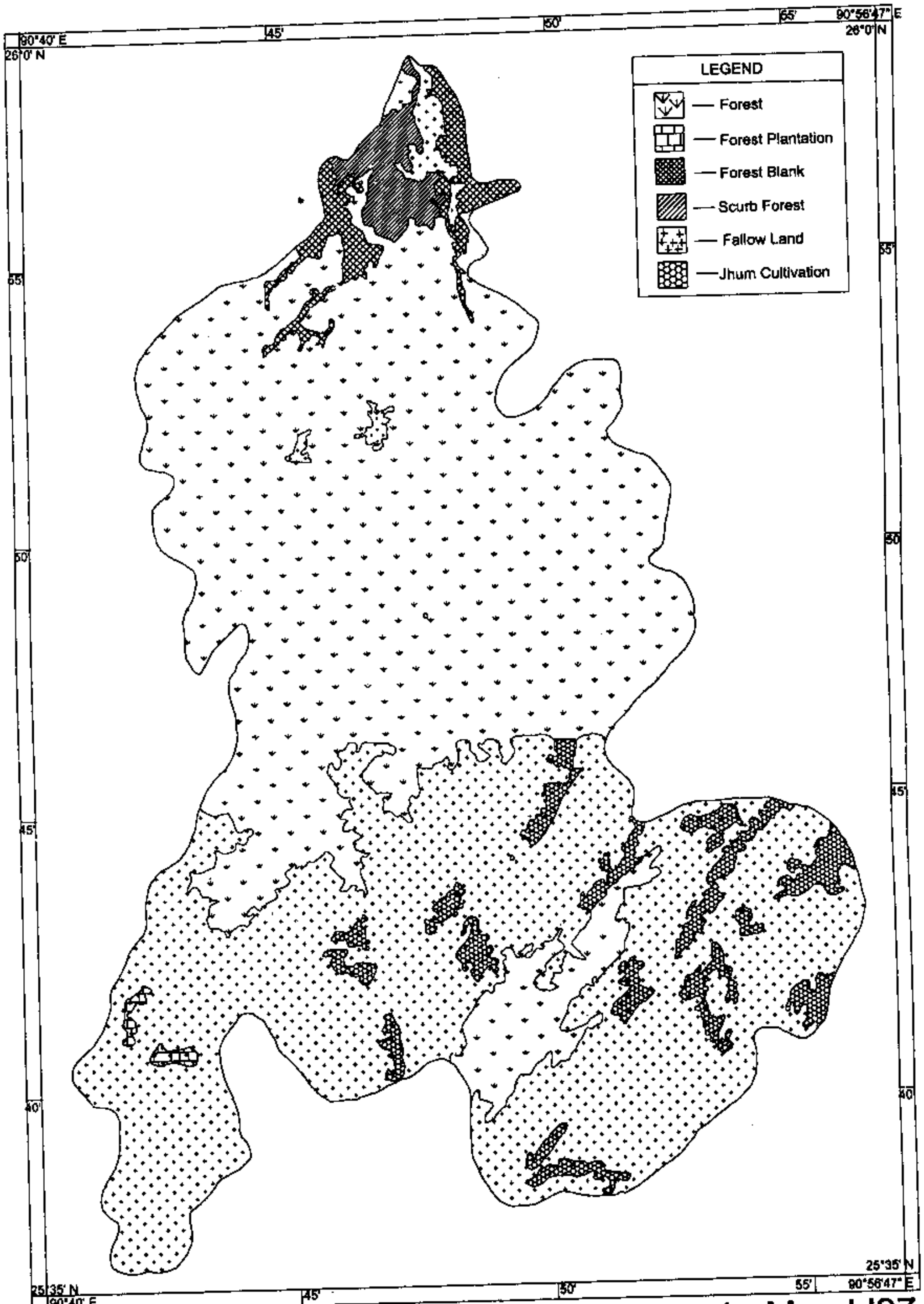

Fig.No.5.5 Landuse/Landcover of Dudhnai - March'97.

TABLE – 5.6 AERIAL EXTENT OF LANDUSE – 1997

Sl.No.	Level I	Level II	Area in Sq.km	% of Extent
1.	Build Up	Rural	5.23	0.99
2.	Agriculture	Jhum Cultivation	19.89	3.77
		Fallow	231.43	43.84
3.	Forest	Deciduous Dense	245.96	46.59
		Scrub	10.69	2.03
		Forest Plantation	5.52	1.05
		Forest Blank	9.21	1.75
		Total	527.90	100.00

5.5 CURVE NUMBER (CN)

Depicting Curve Numbers from the satellite data:

Delineated landuse map of the year 1989 has been superimposed with the hydrosoil map and all the polygons in the overlaid map has been given curve number by considering the average antecedent moisture (AMC-II) condition. Weighted curve number has been calculated for each subwatershed and thus fixing a single value of curve number to each sub-watershed of the study area. The same technique has been adopted to calculate the weighted curve number for the year 1997 landuse condition. Table 5.4 shows the average curve number (AMC - II) arrived for different landuse conditions present in the study area for the two different periods from the satellite data.

TABLE – 5.7 RUNOFF CURVE NUMBERS FOR DIFFERENT LANDUSE CONDITIONS DERIVED FROM THE SATELLITE DATA (AMC – II AND Ia = 0.3S)

			Curve Number for Hydrosoil Groups		
Sl.No.	Level I	Level II	B	C	D
1.	Built Up	Rural	86	91	93
2.	Agriculture	Jhum Cultivation	72	78	82
		Fallow	79	85	88
3.	Forest	Deciduous Dense	40	58	61
		Scrub	66	77	83
		Forest Plantation	44	60	64
		Forest Blank	66	77	83
4.	Water Body	Water logged Area/River	95	95	95

5.6 MODIFIED CURVE NUMBER (MCN):

Average curve number (AMC-II) has been modified using the actual antecedent moisture condition (AMC I -III) of each rainy day and the modified curve number (MCN).

5.7 POTENTIAL RETENTION (S)

Potential maximum retention (S) has been calculated for each rainy day using the following formula for all the five years (1986 - 91) and nine subwatersheds.

$$S = (25400/MCN) - 254$$

5.8 DAILY RUNOFF

Daily runoff has been calculated using the following equation for each sub watershed

$$Q = (P - 0.3S)^2/(P + 0.7S)$$

There would be no runoff if the initial abstraction is equal to 0.3 times of potential maximum retention hence the runoff is calculated for the precipitation which is more than 0.3S. Event (monthly, seasonally, yearly) based runoff can be obtained from the daily calculated runoff values. Rainfall Vs Unit runoff of all the nine subwatersheds of the study area for the five years are shown in Fig.5.6 to 5.10. Fig.5.11 shows only the resulted runoff of each subwatershed in five years.

4.9 RUNOFF VOLUME

Runoff volume of a subwatershed is obtained by multiplying the unit runoff of the subwatershed with its area which is shown in Table 5.8.

4.10 YIELD

Percentage yield of a watershed is calculated by dividing runoff of the watershed by its rainfall and multiplying with 100 which is calculated in Table 5.9.

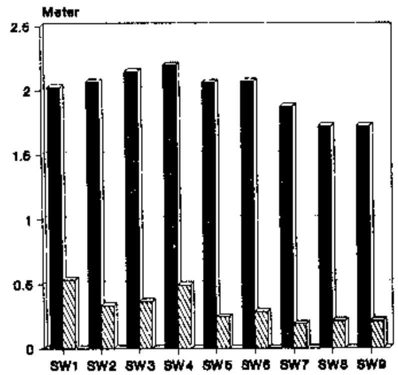

Fig.No.5.6 RUNOFF Vs RAINFALL FOR 1986.

RAINFALL'86 RUNOFF'86

SW - Subwatershed

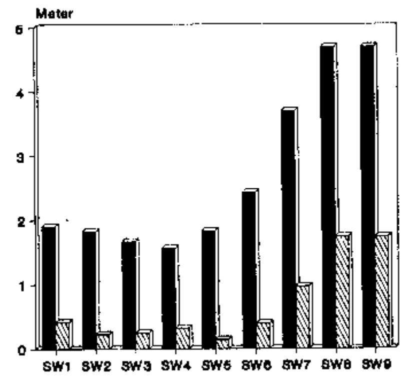

Fig.No.5.7 RUNOFF Vs RAINFALL FOR 1987.

RAINFALL'87 RUNOFF'87

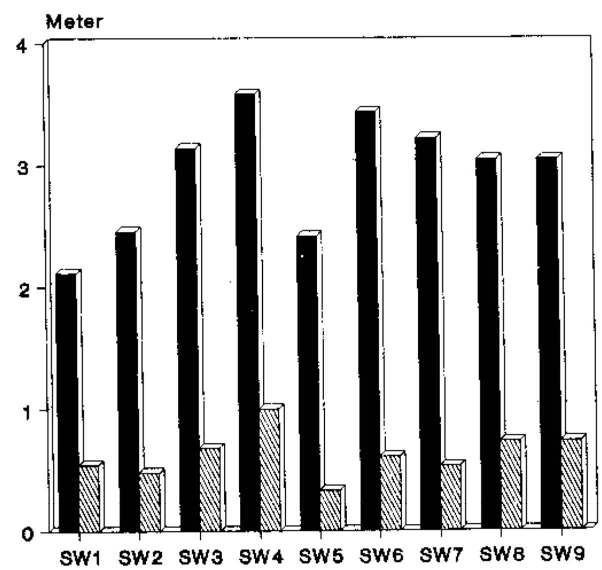

Fig.No.5.8 RUNOFF Vs RAINFALL FOR 1988.

RAINFALL'88 RUNOFF'88

SW - Subwatershed.

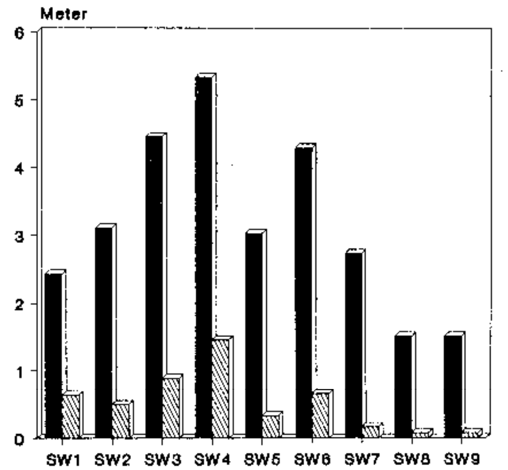

Fig.No.9 RUNOFF Vs RAINFALL FOR 1990.

RAINFALL'90 RUNOFF'90

SW - Subwatershed.

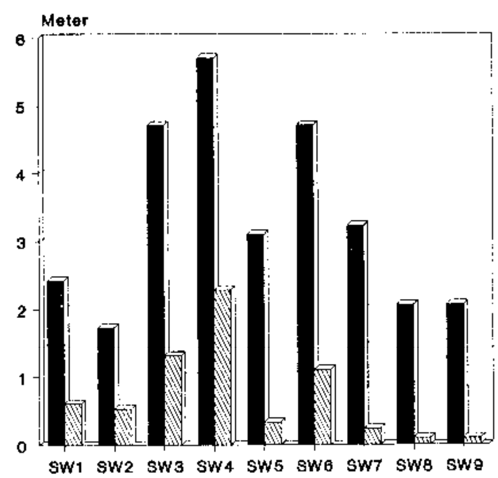

Fig.No.5.10 RUNOFF Vs RAINFALL FOR 91.

RAINFALL'91 RUNOFF'91

SW - Subwatershed.

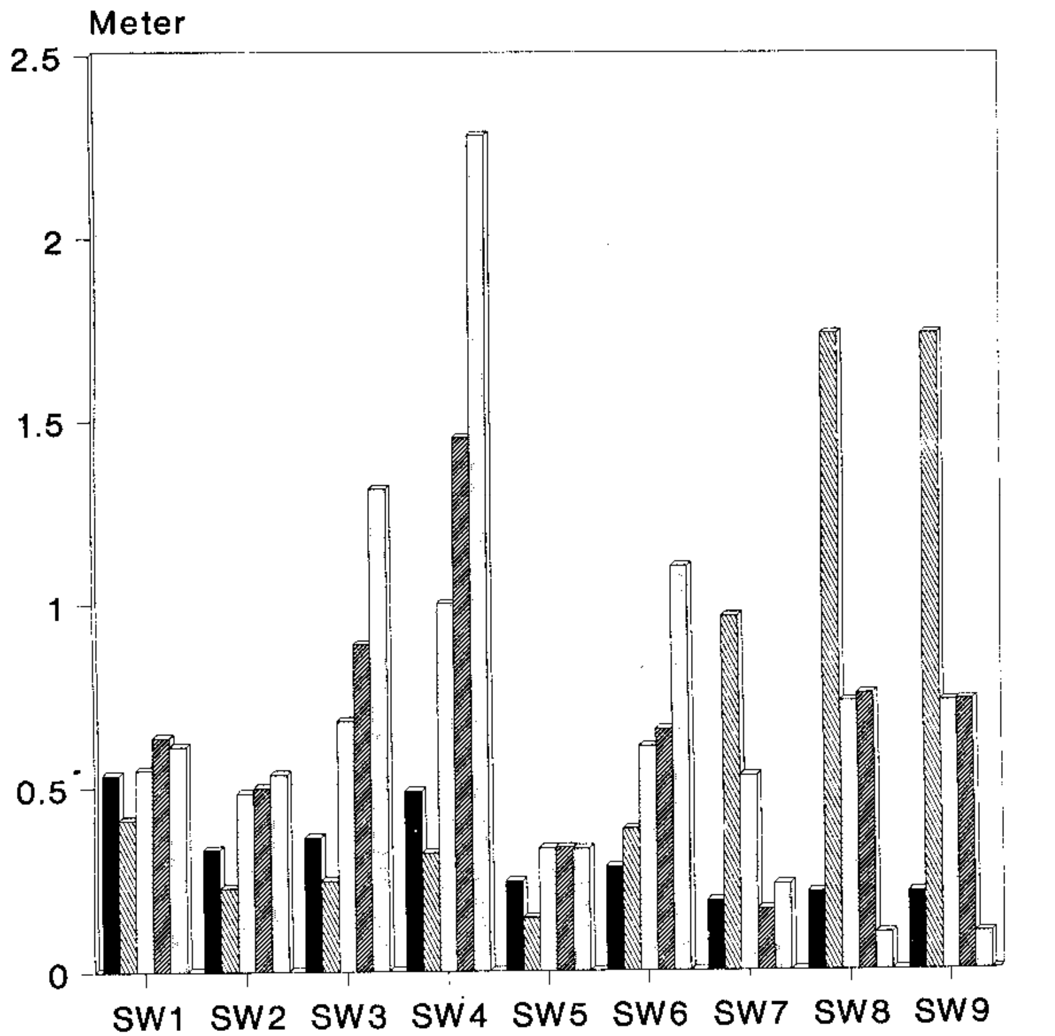

Fig.No.5.11 RUNOFF (M) OF SUBWATERSHEDS OF DUDHNAI SUBBASIN

SW - Subwatershed

TABLE - 5.8 RUNOFF VOLUME (Ham) OF THE SUB-WATERSHEDS OF DUDHNAI SUB-BASIN FROM 1986-91

Year		1986		1987		1988		1990		1991	
Subwatershed No.	Subw.shed Area(Ha)	Runoff in m	Runoff Vol.Ham	Runoff in m	Runoff Vol.Ham	Runoff in m	Runoff Vol.Ham	Runoff in m	Runoff Vol.Ham	Runoff in m	Runoff Vol.Ham
SW1	1693.00	0.54	906.02	0.41	697.72	0.55	929.67	0.64	1079.33	0.61	1037.44
SW2	1589.00	0.33	527.54	0.23	359.14	0.48	770.59	0.50	794.46	0.54	852.31
SW3	4772.00	0.36	1735.39	0.25	1174.27	0.68	3254.71	0.89	4252.16	1.32	6283.73
SW4	1555.00	0.49	762.66	0.32	500.93	1.00	1557.54	1.46	2263.31	2.28	3548.51
SW5	4415.00	0.24	1078.67	0.14	635.86	0.33	1476.29	0.34	1484.55	0.33	1467.27
SW6	11328.00	0.28	3212.78	0.39	4380.17	0.61	6922.79	0.66	7452.47	1.10	12493.97
SW7	10407.00	0.19	1966.77	0.97	10044.17	0.53	5523.34	0.17	1731.75	0.24	2453.44
SW8	3809.00	0.21	813.07	1.74	6628.58	0.73	2787.03	0.08	286.52	0.10	382.24
SW9	13222.00	0.21	2822.36	1.74	23009.46	0.73	9674.47	0.07	970.84	0.10	1326.84

Subwatershed in Hactare.
Runoff Vol. - Runoff Volume in
Hactare Meter.

TABLE 5.9 ANNUAL PERCENTAGE YIELD OF THE SUBWATERSHEDS IN DUDHNAI SUBBASIN.

Year	1986			1987			1988			1990			1991		
Wshed No.	R (cm)	P (cm)	% Yield	R (cm)	P (cm)	% Yield	R (cm)	P (cm)	% Yield	R (cm)	P (cm)	% Yield	R (cm)	P (cm)	% Yield
SW1	53.52	202.67	26.40	41.21	190.41	21.64	54.91	211.45	25.97	63.75	242.78	26.26	61.28	242.42	25.28
SW2	33.20	206.69	16.06	22.60	182.45	12.39	48.50	245.70	19.74	50.00	310.73	16.09	53.68	172.94	31.04
SW3	36.37	214.63	16.94	24.61	166.70	14.76	68.20	313.50	21.76	89.11	445.25	20.01	131.68	471.19	27.95
SW4	49.05	219.86	22.31	32.21	156.35	20.60	100.16	358.06	27.97	145.55	533.66	27.27	228.20	571.08	39.96
SW5	24.43	206.20	11.85	14.40	183.41	7.85	33.44	241.57	13.84	33.63	302.54	11.11	33.23	309.94	10.72
SW6	28.36	206.79	13.71	38.67	242.19	15.97	61.11	343.35	17.80	65.79	428.77	15.34	110.29	471.22	23.41
SW7	18.90	187.40	10.08	96.51	369.61	26.11	53.07	321.52	16.51	16.64	273.06	6.09	23.57	322.97	7.30
SW8	21.35	172.14	12.40	174.02	469.93	37.03	73.17	304.33	24.04	7.52	150.47	5.00	10.04	206.26	4.87
SW9	21.35	172.14	12.40	174.02	469.93	37.03	73.17	304.33	24.04	7.34	150.47	4.88	10.04	206.26	4.87

R - Runoff; P - Rainfall; % Yield = Runoff\Rainfall x 100.

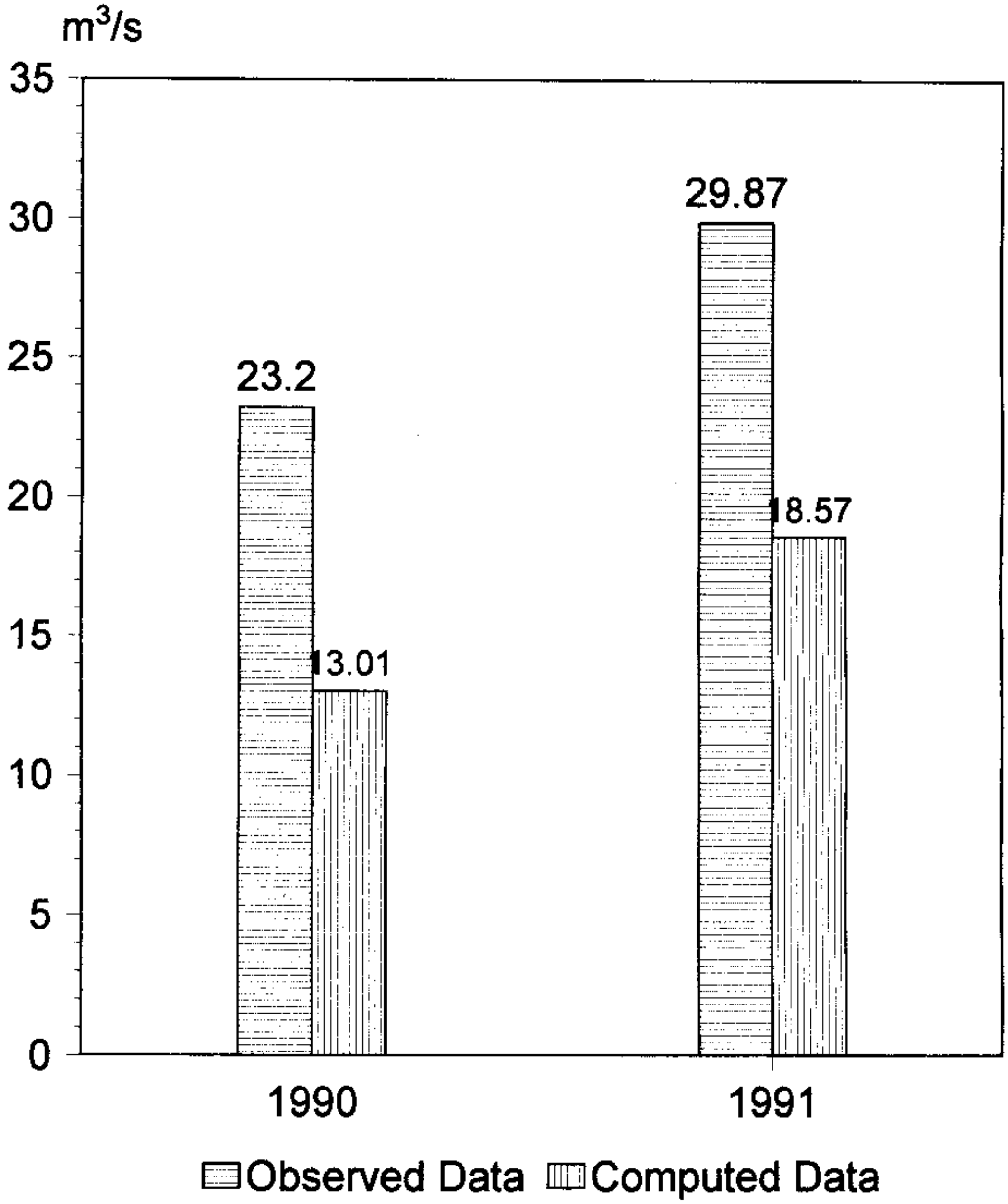

Fig.No. 5.12 Comparision of Observed and Computed data.

6.0 RECOMMENDATIONS

1. Yields of subwatershed number 3, 4 and 6 have comparatively high values so priority can be given to these sub watersheds for water conservation measures like construction of check dams, percolation ponds and farm ponds etc.
2. Analysis of slope and geomorphological conditions of the subwatershed may indicate exact location of water harvesting structures.
3. Sediment yield of a subwatershed can be determined by including erodability factor and shape factor with basic parameters of SCS method. It is proved the sensitive landuse can be determined in real time with the usage of satellite data.
4. The model can be further improved by incorporating evapotranspiration as a factor which is an important component of the long term hydrologic simulation while converting precipitation into runoff.
5. From the available runoff data collected concurrent period covers only 1990 & 1991. While comparing computed and observed data marked difference maximum upto 12.2 cumec (Annual average) is found. This may be because of ground water contribution from comparatively large adjacent hilly areas outside the basin divide.

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Director	:	Dr. S.M.Seth
Coordinator	:	Dr. K.K.S.Bhatia

Study Group:

V.S.Jeyakanthan, Sc-'B'
B.C.Patwary, Sc-'E'