CS(AR)-220

HYDROLOGICAL SOIL CLASSIFICATION OF DUDHNAI SUB-BASIN : ASSAM/MEGHALAYA PART-I

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667
1995-96

PREFACE

One of the primary concerns while undertaking hydrological studies in a basin, is the knowledge of its soil-water relationships. The capability of the soil to transmit water both laterally & vertically is a function of its different properties like hydraulic conductivity, effective depth of saturated zone and other interrelated characteristics like density, particle size, grain distribution, texture, structure and so on. Soils at site are heterogeneous and to understand the spatial extent of water movement or retention through it for water balance estimations or watershed management practices, it is essential to classify the soils depending upon its properties. For soil and water management, soil classification provides information on soil suitability for irrigated agriculture run-off potential, erodability, degradability, water-logging etc.

Like all other north east hilly regions detailed soil survey at Dudhnai basin has not yet been done due to hilly terrain, poor communication & inaccessibilities. Based on the broad information available elsewhere and number of field investigations in the lower part of the basin, the soils have been studied and attempt has been made to classify it into different hydrological groups. The study was undertaken as one of the requirements for long term representative basin studies at Dudhnai on the recommendation of the Regional Coordination Committee of the regional centre. The results should be useful for future hydrological studies in the area.

The report has been prepared by B C Patwary, P K Bhunya, and V S Jeykanthan with assistance from C S Chauhan, under the guidance of Dr K K S Bhatia, Sc'F'& Coordinator.

(S M Seth)
DIRECTOR

LIST OF FIGURES

ABSTRACT

Hydrologic soil classification at Dudhnai sub-basin for an area of about 250 sq km has been made based on the regional information collected from various agencies supplemented by own field & laboratory experiments on the soil samples collected from time to time. In requirement of var ious soil classification systems, soil properties together with other information have been studied and grouped into different classes as a reference base for future hydrological studies of the basin.

Soils are generally heterogeneous and anisotropic i.e. having unequal physical properties along different axes. This results nonuniform field conditions. Then the soil properties at places undergo considerable changes with time. This calls for systematic monitoring of soil parameters for its effective management. The present work has also the scope for further improvement by incorporating more and more future investigations in the basin which has been selected for long term representative basin studies.

the soils of a few states. With the setting-up of National Land Resources Commission at the Centre and Landuse Boards in the States, works for preparing soil resources maps for different regions are going on to provide rational approach for land use planning. For a few States of India, Agricultural Atlas have also been prepared by certain agencies for visual presentation of data on agricultural sectors. For the states of the north-east India, no such Atlas has so far been prepared.

The Dudhnai sub-catchment of about 500 km^2 on the south bank of the river Brahmaputra has been selected for long term representative basin studies. Under this broad objective, North Eastern Regional Centre undertook field investigations in the basin. Point infiltration tests, Guelf Permeameter tests for hydraulic conductivity & flux potential etc. were conducted at various locations in respect of different land uses. Soil samples were also collected from test sites and tested in laboratory to relate the results to soil types. The results of the study would be used in the subsequent hydrologic studies to model the basin. However, due to inaccessibility of the upland about 50 percent of the basin area has been covered in the report.

2.0 REVIEW :

2.1 General :

Soils can be classified employing various methods that are in use in different parts of the world. The engineer classifies soil on the basis of those characteristics which determine how a soil will behave as an engineering construction material. Hydrologic classification of soils considers soil particle size, shape, density and consistency among other characteristics for grouping the soil into various classes. The hydrologist is concerned with the surface and subsurface percolation of water through soil and the effects of forces of nature on them. The systems of soil classification differs from country to country and all the systems have a number of common points in the method of classification.

2.2 Systems of Soil Classification :

The first systematic soil survey was launched in 1899 in the United States before any method for classification of soils was developed. The early system of soil classification was a direct reflection of the prevailing concept of soil as the weathered mantle of rock. The system was followed in United States with little change for about 30 years . Despite this frame of reference for the classification of soils, however , attention was given to soil profile characteristics that were not directly related to weathering or to source rocks. Those characteristics were being introduced as series criteria within the first 10 years of the century , well before a different approach had been proposed (Simonson,1964).

The important soil classification systems can be divided into two categories. The first category is based on grain size of the soils and is essentially useful for classifying soils in which single grain properties are of importance, such as cohesionless soils e.g. gravels and sands. The other category is one which is more general in nature and is employed for classification of both the coarse as well as fine grained soils. These systems are based both on structure and texture of the soil.

2.2.1 Soil Structure And Composition :

The original parent material of soil which is the solid rock of the earth's outer skin on weathering and erosion breaks down the surface layers of the solid geological strata and remains as deposits of unconsolidated material. Thus a soil may be a direct product of underlying weathered rocks or may be formed from loose deposits unrelated to the solid rocks below. Soil depths and their composition can therefore be variable along the subsurface. The top layer is the organic material derived from living plants and other organisms. An idealized section through a typical sequence of soil layers is shown in **Fig.1**. Layers of vegetation litter and partly decomposed debris lie on the surface above what is termed the *A* horizon, a layer generally friable and rich in humus. The *B* horizon is mainly composed of well weathered parent material with its structure modified by its root and living creatures such as earthworms. The *C* horizon is a unconsolidated rock material containing wide range of particle and stone sizes. The thickness of soil layers depends upon their location relative to the geological structure and the geomorphology of surface features.

2.2.2 Particle Size Classification :

This system classifies soils on the basis of their grain size. Accordingly soils are termed as gravel, sand, loamy sand, silt, silty loam, clay, sandy clay loam, clayey fine etc depending on their grain size. Sieving and sedimentation analysis are used to determine grain sizes of soils.

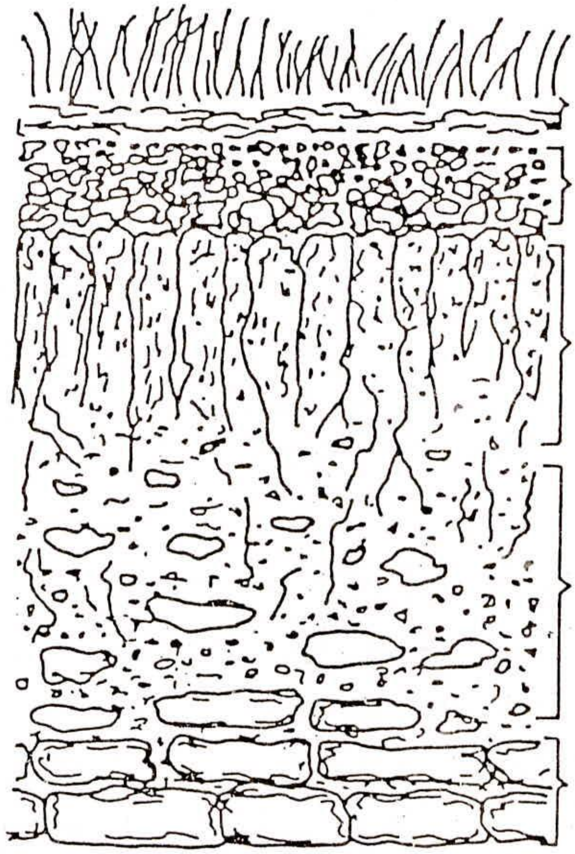

FIG.1 Idealised Soil Section of Soil Profile

In Sieve test gravel fraction of the soil is removed by sieving on the 2.00 mm sieve. The sample of soil which passes 2.00 mm sieve are dried and then shaken through a series of sieves ranging from coarse to fine and the amount (% of sample dry weight) retained on each sieve is weighed and recorded.

Sedimentation test is conducted for the finer fractions of the soil which passes the 75 micron sieve. Then this soil is shaken up in a test tube with water and allowed to settle. Different proportions of finer material can be seen at the top of the test tube and coarseness of grain size increases towards bottom of the test tube. Particle size is determined by observing the rate at which the grains settle through a liquid. Hydrometer or a pipette is used to determine this. As discussed above soils are grouped according to their grain size and many of them are in use. The important and commonly used particle size classifications are as follows.

i) Highway Research Board (HRB) Classification:

Highway research board classification system, also known as Public Road Administration (PRA) classification system is based on both the particle size composition as well as the plasticity of the soil. The classification was extensively revised in 1945,1949and in 1966. It has also been designated as American Association of State Highway Officials (AASHO) classification. According to the revised system, soils are classified into seven groups, designated as *A-1*, *A-2...A-7* as shown in **Table.1**. Group *A-1* is divided into two sub-groups and *A-2* is divided into four sub-groups.

The Group Index(GI) is determined from the following equation,

$$GI= (F-35)[0.2+0.005(LL-40)] + 0.01(F-15)(PI-10)$$

where, F= That portion of percentage passing US.no.74 micron expressed as a positive whole number.

General Classification	Granular Material (35 per cent or less Passing No. 74μ)*							Silt-Clay Materials (More than 35 per cent Passing No. 74μ)*			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis, per cent passing											
2.00 mm*	50 max										
420 μ*	30 max	50 max	51 min								
74 μ*	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 420 μ*											
Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of significant constituent materials	Stone fragments — gravel and Sand		Fine sand	Silty or clayey gravel and sand				Silty Soils		Clayey Soils	
General rating as subgrade	Excellent to good							Fair to poor			

Classification procedure: With required test data in mind, proceed from left to right in chart; correct group will be found by process of elimination. The first group from the left consistent with test data is the correct classification. The A-7 group is subdivided into A-7-5 or A-7-6 depending on the plastic limit. For P.L. < 30, classification is A-7-6; for P.L. ≥ 30, A-7-5.

N. P. denotes, non-plastic.

**Old members corresponding to new designation are 74 μ → no. 200, no. 420 μ → no. 40, 2.00mm → no. 10.*

Table 1 HRB-Classification of Soils and Soil Aggregate Mixtures

LL= Liquid limit

PL= Plasticity index

Classification procedure: With required test data available, proceed from left to right on the chart and elimination process is used to find out the correct group. The first group from left into which the test data will fit is the correct classification.

The group index is always reported to the nearest whole number unless its calculated value is negative. In that case, it is reported to be zero. The group index is appended to the group and subgroup classification. For example, a clay soil having a group index of 22 may be classified A-7-6 (22).

ii) Unified Soil Classification System:

A.Casagrande in 1942 developed a soil classification system for the United States Crops of Engineers which was termed as Airfield Classification (A.C) System, popularly known as "Arthur Casagrande"classification system. After some modifications U.S. Bureau of Reclamation adopted this system in 1946. Airfield Classification system was renamed as Unified Soil Classification System after once again it was revised in 1952,with A.Casagrande acting as consultant. In 1969 the unified system was adopted by the 'American Society for Testing Materials' as a standard method for classification of soils for engineering purposes. The system is based on both grain size and plasticity properties of the soil and is therefore applicable to any use is shown in **Table.2**.

According to this system the coarse grained soils are classified by their grain size and fine grained soils are classified according to their indices. The names and symbols used to distinguish between the typical and boundary soil groups are as follows.

Soil Components:

TABLE 2. U.S. Bureau of Reclamation-General Land Classifications

	Class 1 arable	*Class 2, arable*	*Class 3 arable*
Texture	Sandy loam to friable clay loam	Loamy sand to very permeable clay	Loamy sand to permeable clay
Depth to sand or gravel	90 cm plus or free working fine sandy loam or heavier, or 105 cm of sandy loam	60 cm plus or free working fine sandy loam or heavier. or 75-50 cm in sandy loam	45 cm plus or free working fine sandy loam or heavier, or 60—90 cm of lighter soil
Depth to impermeable shale or raw soil	150 cm plus or 115 cm with 150cm of gravel over impervious material, or sandy loam throughout	120 cm plus or with 15 cm of gravel over impervious material, or loamy sand throughout	105 cm plus or 90cm with 15cm of gravel over impervious material, or loamy sand throughout
Depth to penetrable lime zone	45 cm with 150 cm penetrable	35 cm with 120 cm penetrable	25 cm with 90 cm penetrable
Alkalinity at equilibrium*	Exchangeable sodium generally less than 15% for all land classes, butmay be higher or lower depending on the type of clay minerals		
Salinity at equilibrium*	Electrical conductivity of saturation extract less than 4 millimhos per cm	Electrical conductivity of saturation extract less than 8 millimhos per cm	Electrical conductivity of saturation extract less than 12 millimohs per cm
Slopes	Smooth slopes up to 4% with large areas in same plane	Smooth slopes up to 8% in large areas in the same plane, or rougher slopes less than 4% in general gradient	Smooth slopes up to 12% in large areas in the same plane or rougher slopes less than 8% in general gradient
Surface	Requires little levelling and no heavy grading	Moderate grading required, but in amounts found feasible in comparable areas	Heavy and expensive grading required in spots. but in amouns found feasible in comparable irrigated areas
Cover (rocks and vegetation)	Insufficient to affect productivity, or clearing cost small	Sufficient to reduced productivity and interfere with farming; clearing possible at moderate cost	Requires expansive but feaseible clearing
Drainage	No drainage requirement expected	Some drainage expected, but at reasonable cost	Considerable drainage required. Considered expensive but feasibie

Class 4, limited arable

Includes irrigable lands which are adaptable to a narrow range of crops

Class 5. nonarable

Includes lands which require additional studies to determine their irrigability and lands reclassified as temporarily non-productive pending construction of corrective works and reclamation through application of these works

Class 6, nonarable

Includes lands which do not meet the minimum requirements and small areas of arable land lying within larger bodies of nonarable land

*Equilibrium conditions based on projected use of a specific irrigation water supply.

Gravel-G, Sand-S, Silt-M, Clay-C, Organic-O, Peat-Pt.

Gradations: Well graded-W, Poorly graded-P

Liquid limits: High liquid limit-H, Low liquid limit- L

These are combined to form the group symbols which correspond to the names of typical soils in **Table.3** which is self explanatory and deserves careful study. The plasticity chart **Fig.2.** gives the relationship of Attenberg limits of the various fine grained soils of the system. If all the particles of a soil represent fairly well it is said to be well graded soil and a soil is poorly graded if there is excess or deficiency of certain sizes. To determine the soil as well graded or poorly graded, its coefficient of uniformity and coefficient of curvature are to be calculated, which are explained as follows.

Co-efficient of Uniformity $U = D_{60}/D_{10}$

Co-efficient of Curvature $C_c = (D_{30})^2/D_{10} X D_{60}$

For a well graded soil co-efficient of curvature must be between 1 and 3 and the co-efficient of uniformity must be greater than 4 for gravels and 6 for sands.

The system has the following advantages:

i) The classification is based on physical properties inherent in the soil and the soil behavior. It may be used for classifying soils for all varieties of engineering problems.

ii) The system defines 15 soil groups each of which has distinct engineering properties. Soils having properties common to two groups can be defined as border line cases.

iii) The system incorporates field identification and basis of classification in laboratory or field is simple.

iii) M.I.T classification proposed by Massachusetts Institute of Technology:

M.I.T. Classification divides the soils into various main

Table.3.UNIFIED SOIL CLASSIFICATION
INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)				GROUP SYMBOLS
COARSE GRAINED SOILS More than half of material is larger than No 200 sieve size	GRAVELS More than half material is larger than NO 4 sieve size	CLEAN GRAVELS (Little or no fines)	Wide Range in grain size and substantial amounts of all intermediate sizes missing.	GW
			Predominantly on size or a range of sizes with some intermediate sizes missing.	GP
		GRAVELS WITH FILES (Appreciable amount of fines)	Non plastic fines (for identification procedures see ML below)	GM
			Plastic fines (for identification procedure see CL below)	GC
	SANDS More than half of coarse fraction is smaller than NO 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particles sizes.	SW
			Predominantly one size or a range ofsizes with some intermediate sizes missing.	SP
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM
			Plastic fines (for identification procedures see CL below)	SC

GW - Well graded grovel-sand mixtures, little or no fines
GM - Silty gravels, poorly graded gravel-sand silt mixtures
SW - Well graded sands, gravelly sands, little or no fines
SM - Silty sands, poorly graded sand silt mixtures
GP - Poorly graded gravels, gravel-sand mixtures little or no fines
GC - Clayey gravels, poorly graded gravel sand clay mixtures
SP - Poorly graded sands, gravelly sands, little or no fines
SC - Clayey sands, poorly graded sand clay mixtures.

(contd.)

Table:3 Contd.

IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE					
FINE GRAINED SOILS More than half at material is smaller than No 200 sieve size (The No 200 sieve size about the smallest particle visible to the naked eye)		DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILUTENESS (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY PLASTIC LIMIT)	
	SILTS AND CLAYS Liquid limit less than 50	None to slight	Quick to slow	None	ML
		Medium to high	None to very slow	Medium	CL
		Slight to medium	Slow	Slight	OL
	SILTS AND CLAYS Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	MH
		High to very high	None	High	CH
		Medium to high	None to very slow	Slight to medium	OH
HIGHLY ORGANIC SOILS		Readily identified colour,odour,spongy, feel and frequently by fibrous texture			Pt

ML - Inorganic silts and very fine sands, rock flour silty or clayey fine sands with slight plasticity.

OL - Organic silts and organic silt-clays of low plasticity

CH - Inorganic clays of high plasticity, fat clays

OH - Organic clays of medium to high plasticity

CL - Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, clean clays.

MH - Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts

Pt - Peat and other highly organic soils

Contd.

Table :3 Contd.

<table>
<tr><th colspan="3">LABORATORY CLASSIFICATION CRITERIA</th></tr>
<tr><td rowspan="7">Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No 200 sieve size) coarse grained soils classified as follows

Less than 5 % — GW. GP. SW. SP
More than 12 % — GM. GC. SW. SC
5 % to 12 % — Borderline cases requiring use of dual symbols</td><td colspan="2">$C_w = \frac{D_{60}}{D_{10}}$ Greater than 4

$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3</td></tr>
<tr><td colspan="2">Not meeting all gradation measurement for GW</td></tr>
<tr><td>Atterberg limits above 'A' with Pt less than 4</td><td>Above 'A' line with Pt between 4 and 7 are borderline cases requiring use of dual symbols</td></tr>
<tr><td colspan="2">$C_w = \frac{D_{60}}{D_{10}}$ greater than 6

$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3</td></tr>
<tr><td colspan="2">Not meeting all gradation requirements for SW</td></tr>
<tr><td>Atterberg limits below 'A' line or Pt less than 4</td><td rowspan="2">Above 'A' line with Pt between 4 and 7 are borderline cases requiring use of dual symbols</td></tr>
<tr><td>Atterberg limits above 'A' line with Pt greater than 7</td></tr>
</table>

Contd.

Table:3 Contd.

INFORMATION REQUIRED FOR DESCRIBING SOILS

Give typical name, indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition with hardness of the coarse grains, local or geologic name and other permanent descriptive information,and symbol in parenthesis.

For undisturbed soils add information on stratification degree of compactness cementation, moisture conditions and drainage characteristics.

EXAMPLE :-

Silty sand, gravelly about 20 % hard, regular gravel particles 1 in maximum size; rounded and sub-angular sand grains coarse to fine, about 15 % nonplastic fines with low dry strength, well compacted and moist in place, alluvial sand; (SM)

Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odor if any; local or geologic name and other pertinent descriptive information, and symbol a parenthesis.

For undisturbed soils add information a structure, stratification, consistency on undisturbed and remolded states, moisture and drainage conditions.

EXAMPLE :-

Clay silt, brown, slightly plastic; percentage of fine sand numerous vertical root holes firm dry in place, losses, (ML)

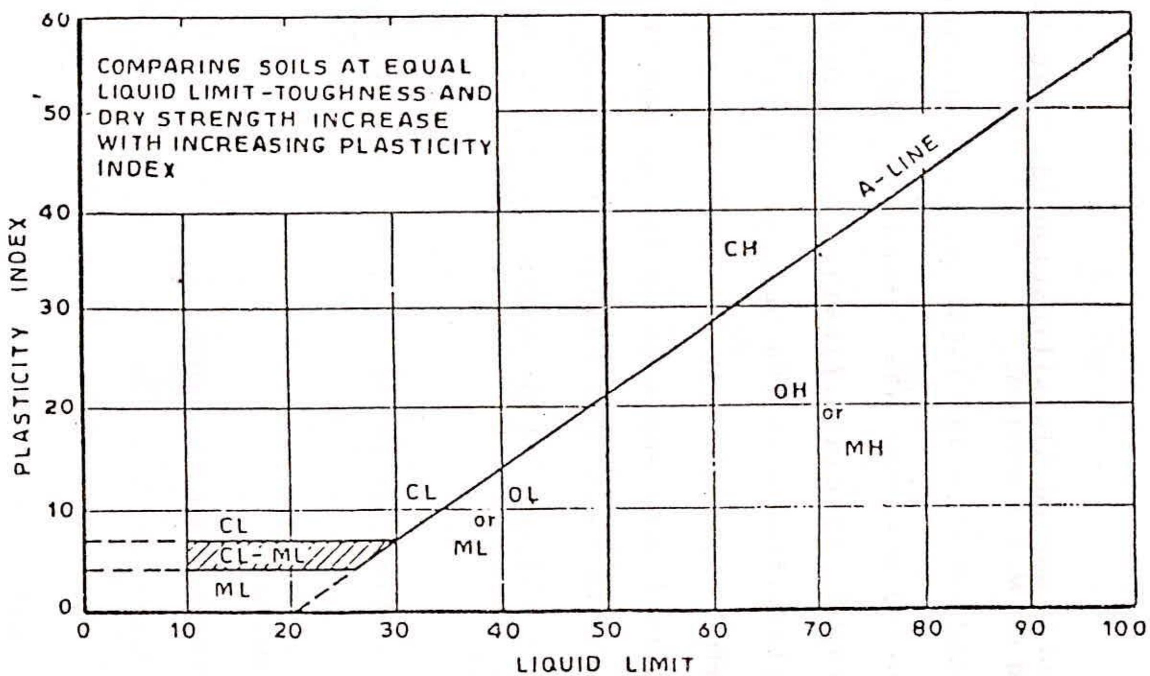

FIG.2 Plasticity chart

groups as sand, silt and clay and further subgroups them as coarse,medium and fine on basis of standard grain size intervals as given in the following chart,

Coarse Sand	2.0 mm-0.6	mm
Medium Sand	0.6 mm-0.2	mm
Fine Sand	0.2 mm-0.06	mm
Coarse silt	0.06 mm-0.02	mm
Medium Silt	0.02 mm-0.006	mm
Fine Silt	0.006 mm-0.002	mm
Clay	<0.002	mm

iv) Indian Standard Classification (IS:1948-1970) based on M.I.T system:

The Indian Standard (IS:1498-1959) on classification of soils for general engineering purposes was issued in 1959. It was revised in 1970 (IS:1498-1970). IS classification is given **Table.4.** Fine grained soils are classified with the help of plasticity chart as in **Fig.2.** In IS system of classification soils are classified into three ranges of liquid limit, where as in the system of unified soil classification there is only two ranges of liquid limit. It is recommended that on all important projects soils be classified according to IS:1498.

Field identification soils is carried out by the following tests.

i) Visual Examination

ii) Wet and Manipulated Strength

The following tests are carried out only for the fine grained soils.

iii) Toughness Test

iv) Dilatancy Test

v) Dry Strength

2.3 Soil Classification based on Hydrologic Soil Properties :

Hydrologic soil classification is essential for the evaluation

TABLE 2.9 SOIL CLASSIFICATION (INCLUDING FIELD IDENTIFICATION AND DESCRIPTION)

Division	*Sub-Division*		*Group Letter Symbol*	*Hatching*	*Mapping Colour*	*Typical Names*	*Field Identification Procedures (Excluding Particles Larger than 80 mm and Basing Fractions on Estimated Weights)*	*Information Required for Describing Soils*
1	2		3	4	5	6	7	8
Coarse-grained soils (more than half of material is larger than 75-micron IS Sieve size) The smallest particle visible to the naked eye	*Gravels* More than half of coarse fraction is larger than 4.75-mm IS Sieve size (For visual classification the 5-mm size may be used as equivalent to the 4.75-mm IS Sieve size)	Clean gravels (Little or no fines)	GW		Red	Well graded gravels, gravel-sand mixtures; little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	For undisturbed soils add information on stratification; degree of compactness, cementation, moisture conditions and drainage characteristics. Give typical name; indicate approximate percentages of sand and gravel; maximum size, angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. *Example* Silty sand, gravelly; about 20 percent hard angular gravel particles; 10 mm maximum size; rounded and subangular sand grains; about 15 percent non-plastic fines with low dry strength; well compacted and moist; inplace; alluvial sand (SM).
			GP		Red	Poorly graded gravels or gravel-sand mixtures; little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing	
		Gravels with fines (Appreciable amount of fines)	GM		Yellow	Silty gravels, poorly graded gravel-sand-silt mixtures	Non-plastic fines or fines with low plasticity (for identification procedures *see* ML and MI below)	
			GC		Yellow	Clayey gravels, poorly graded gravel-sand-clay mixtures	Plastic fines (for identification procedures, *see* CL and CI below)	
	Sands More than half of coarse fraction is smaller than 4.75-mm IS Sieve size (For visual classification the 5-mm size may be used as equivalent to the 4.75 mm IS size)	Clean sands (Little or no fines)	SW		Red	Well graded sands, gravelly sands; little or no fines	Wide range in grain size and substantial amounts of all intermediate particle sizes	
			SP		Red	Poorly graded sands or gravally-sands; little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing	
		Sands with fines (Appreciable amount of fines)	SM		Yellow	Silty sands, poorly graded sand-silt mixtures	Non-plastic fines or fines with low plasticity (for intermediate procedures, *see* ML and MI below)	
			SC		Yellow	Clayey sands, poorly graded sand-clay mixture	Plastic fines (for identification procedures, *see* CL and CI below)	

Division	*Sub-Division*	*Group Letter Symbol*	*Hatching*	*Mapping Colour*	*Typical Names*	*Identification Procedures (on Fraction Smaller than 425-Micron IS Sieve Size)* *Dry Strength*	*Dilatancy*	*Toughness*	*Information Required for Describing Soils*
Fine-grained soils (more than half of material is smaller than 75-micron IS Sieve size). The 75-micron IS Sieve size is about the smallest particle visible to the naked eye	Silts and clays with low compressibility and liquid limit less than 35	ML		Blue	Inorg. silts & very fine sands, rock flour silty, clayey fine sands & silts with none to low plasticity	None to low	Quick	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions. Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition; odour, if any; local or geologic name and other pertinent descriptive information and symbol in parentheses. *Example :* Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loses (ML)
		CL		Green	Inorg., gravelly, sandy, silty, lean clays of low plasti.	Medium	None to very slow	Medium	
		OL		Brown	Organic silts and organic silty clays of low plasticity	Low	Slow	Low	
	Silts and clays with medium compressibility and liquid limit greater than 35 & less than 50	MI		Blue	Inorg. silts, silty clayey fine sands, clayey silts of med. plasti.	Low	Quick to slow	None	
		CI		Green	Inorg., gravelly, sandy, silty, lean clays of med. plast.	Medium to high	None	Medium	
		OI		Brown	Organic silts and org. silty clays of medium plasticity	Low to medium	Slow	Low	
	Silts and clays with high compressibility and liquid limit greater than 50	MH		Blue	Inorganic silts of high compressibility, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Low to medium	Slow to None	Low to medium	
		CH		Green	Inorganic clays of high plasticity, fat clays	High to very high	None	High	
		OH		Brown	Organic clays of medium to high plasticity	Medium to high	None to very slow	Low to medium	
Highly Organic Soils		Pt		Orange	Peat & other highly organic soils with very high compressibility	Readily identified by colour, odour, spongy feel and frequently by fibrous texture			

NOTE — *Boundary classification :* Soil possessing characteristics of two groups are designated by combinations of group symbols, for example, GW-GC, Well-graded, gravel-sand mixture with clay binder.

of runoff. The main parameters used commonly in hydrologic soil classification are :

1. Effective soil depth,
2. Soil texture/average clay content in the surface and subsurface layers
3. Soil structure in the surface and subsurface layers
4. Infiltration rate, and
5. Soil permeability and drainability

2.3.1 Effective Soil Depth:

The depth of soil that can be effectively exploited by the plant roots is an important criterion in selecting land for irrigation. Effective depth includes the solum thickness plus adjusted or corrected thickness of the disintegrated and weathered permeable rock material where the soil rests on such a material. In case of soils with hard pan, the effective depth is the thickness of soil overlying such a layer. When the soils are laying over disintegrated and weathered rock material, the effective soil depth will consist of soil depth plus the percentage soil equivalent of the weathered substratum. The adjusted and corrected thickness for such a disintegrated layer can be calculated by multiplying thickness of this layer with the percent soil material contained in it. For example, if the disintegrated substratum is 50 cm thick and contains about 30 percent soil materials and this substratum is overlain by a soil solum of 30 cm., then the effective depth will be 30 + 15 = 45 cm. In case of soils with hard pans, indurated or permanently saturated moisture zone that prevents the entry of water through it, the effective depth signifies the thickness of the soil overlying such layer. The significance of effective soil depth to runoff potential is given in **Table.5**.

Table.5 Effective soil depth and runoff potential

Thickness(cm)	Soil depth class*	Runoff potential
Above 100	d5	Low
51 - 100	d4	Moderately low
26 - 50	d3	Moderately high
11 - 25	d2	High
0 - 10	d1	High

***As used by the All India Soil and Land Use Survey Organization**

2.3.2 Soil Texture/Average Clay Content:

Soil texture refers to relative proportion of various soil separates in a soil material and is related to soil water interrelationships. On the basis of relative proportion of this basic separates, as shown in **Table.6**, various soil textural groups are recognized. Clay, being the most active and reactive fraction, is used as a single factor index in deciding hydrologic group of a series. Clay content of the surface layer and the average clay content of the whole profile are considered for this purpose. In order to compute average clay content of the profile, the clay content of each of the soil horizon is multiplied by its respective thickness and the summation of these is divided by the total thickness of the profile.

Clay content of the surface layer is more important with respect to infiltration. The relationship between clay content, textural class and runoff potential are given in **Table.6**.

Table.6 Clay content and runoff potential

Clay content (%)	Qualifying Texture class	Runoff potential
0 - 8	Sand, loamy sand	Low
9 - 25	Sandy loam, silt	Low to moderately Low
26 - 40	Silt, sandy clay loam, clay loam, silty clay loam	Moderately high to high
> 41	Sandy clay,Silty clay,clay	High

2.3.3 Soil Structure:

Soil structure refers to the arrangement of soil particles in the soil profile. Soil structure governs the moisture and air regimes in the soil. The movement of water in the soil and its transmission is affected by soil structure and texture. The influence of structure on runoff potential is given in **Table.7**

Table-7 Soil structure and runoff potential

Soil structure	Runoff potential
1. Single grain	Low
2. Granular, Crumb	Moderately low to low
3. Subgranular blocky Columnar	Moderately low to moderately high
4. Strong angular blocky prismatic	Moderately high to high
5. Strong platy compact massive	High

2.3.4 Infiltration:

Infiltration is the term applied to the process of water entry into the soil, generally by downward flow through all part of the surface. The rate of this process determines how much water will enter the root zone and how much, if any, will runoff. The infiltration rate is defined per unit of soil surface area. The maximum rate at which the soil can absorb water through the soil surface is termed as infiltration capacity. This is a function of soil moisture condition. At saturation, infiltration capacity is minimum and is the characteristics of the soil i.e. texture, structure, organic matter content, type of clay mineral, antecedent soil moisture etc. The relationship between infiltration classes and runoff potential is given in **Table.8** as per the studies conducted by All India Soil and Land Use Survey Organization of Ministry of Agriculture.

Table.8 Infiltration rate and runoff potential

Infiltration Class	Basic Infiltration rate(cm/hr)	Runoff Potential
1. Very high	< 8.0	Low
2. High	5.01 - 8.0	Low to moderately low
3. Medium	3.11 - 5.0	Moderate low to moderately high
4. Low	1.60 - 3.1	Moderately high to high
5. Very low	< 1.6	High

2.3.5 Soil Permeability:

Soil permeability refers to the ease with which water can move in the soil profile. It is a measure of drainability of the soil in cm/hour or cm/day. Soil properties such as texture, structure, management practices, land cover, land use all control the total water intake in a soil profile at a given time. The relative classes of soil permeability and their run-off potentials are shown in the **Table.9** below:

Table.9 Permeability and Runoff potential

Permeability Class	Water intake rate, cm/hr.	Runoff Potential
Very slow	< 0.13	High
Slow	0.13 - 0.5	High
Moderately slow	0.51 - 2.0	Moderately high
Moderate	2.01 - 5.0	Moderately high to moderately low
Moderately rapid	5.01 -13.0	Moderately low
Rapid	13.01 -25.0	Low
Very rapid	>25.0	Low

2.4 Hydrologic Soil Groups Classification based on SCS:

Soil Conservation Service of the U.S Department of Agriculture has classified the soils into four hydrologic soil groups namely Group A,B,C and group D respectively in the increasing order of runoff potential. All the four groups alongwith their grouping criterion and descriptions are given in **Table.10.**

2.4.1 Hydrologic Soil Groups:

A: (low runoff potential)

These are soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep to very deep, well to excessively drained sands or gravels. These soils have a high rate of transmission throughout the profile and ground water table is usually below 5 meters.

B: (moderately low runoff potential)

These are soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission throughout the profile. The depth of ground water table is usually 3 to 5 meters or more.

C: (moderately high runoff potential)

These are soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine textures. These soils have a slow rate of water transmissions. The depth of water table is usually 1.5 to 3.0 meters or more.

D: (high runoff potential)

These are soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils (vertisols and vertic subgroups) with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a slow rate of water transmission.

Table.10
Hydrologic soil classification based on Soil Conservation Service

Soil characteristics	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Effective depth, cm	> 100	51-100	26-50	< 25
Texture	S,LS	SL,Sil,L	Si, SCL, CL, SiCL	SC,SiC,C
Clay percentage	0 - 8	9 - 25	26 - 40	> 40
Structure	Simple grained, granular crumb	Granular crumb, sub angular blocky	Sub angular blocky, columnar prismatic	Platy, massive
Infiltration rate (cm/hr)	> 8.0	5.1-8.0	1.6-5.0	< 1.6
Permeability (cm/hr)	high > 13	Mod.High 2.0-13.0	Mod. low to Mod.high 0.5-2.0	Low < 0.5

S-sand, LS-loamy Sand, SL-Sandy Loam, Sil-Silty Loam, L-Loam, Si-Silt,SCL-Sandy Clay Loam, CL-Clay Loam, SiC-Silty Clay, C-Clay,SiCL-Silty Clay Loam

The SCS soil group can be identified at a site using one of the three ways :

1. Soil Characteristics
2. Soil Survey, and
3. Minimum infiltration rate.

The soil characteristics associated with each group are presented in **Table.10**. Soil survey gives a detailed description of the soils at a given location. These surveys are usually the best means of identifying the soil group. Soil analysis can be used to predict the minimum infiltration rates, which can be used to classify the soil into various hydrologic soil groups. The SCS cover complex classification consists of three factors namely, land use, treatment or practice and hydrologic condition. There are approximately fifteen different land uses that are identified. for estimating curve number. Agriculture land use are often subdivided by treatment or practices, such as contoured or straight row. The hydrologic condition reflects the level of land management and it is classified into three classes, namely poor, fair and good.

The SCS developed an index which is termed as the runoff curve number (CN), to represent the combined hydrologic effect of soil, land use, agriculture land treatment classes, hydrologic condition and antecedent soil moisture. These factors can be assessed from soil surveys, site investigation, and land use maps.

2.5 Hydrologic Soil Grouping by All India Soil and Land Use Survey Organization :

All India Soil and Land Use survey Organization has been carrying out soil surveys since 1958 in various parts of Andhra Pradesh, Bihar, Gujarat, Himachal Pradesh, Madhya Pradesh, Maharashtra, Orissa, West Bengal. The surveys were done in the catchments of selected River Valley Projects namely, Sutlej, Chambal, Ramganga, Mayurakshe, Damodar Valley, Kangsabati. Machkund, Mahandi, Ghod, Dantiwada, Tungbhadra and Kunda. Some of the non-river valley project areas have also been surveyed. So far more than 12 million hectors area have been surveyed by this organization and about 4500 soil series have been recognized by them.

All India Soil and Land Use Survey Organization has also attempted the classification of the soil series into hydrologic soil groups. The important soil characteristics like effective depth, average clay in the profile, soil structure, infiltration rate, permeability were considered in soil classification.The important characteristics of these soil series, their hydrologic soil groups, area mapped under the soil series and their location with regard to state, district, river valley project or non-river valley project have been estimated and presented in the report published in 1984.

2.6 Irrigable Soil Classifications In India :

The soil is not only the live media which sustains crops but also a water reservoir of micro nature in comparison to the main irrigation reservoir. It has a live storage (field capacity moisture level) and dead storage (wilting moisture level). Therefore soil characteristics play a major role in irrigated agriculture. Efficiency of an irrigation system is greatly influenced by various soil constraints. The classification of various soil parameters and their various ranges to be considered are given in **Table.11 & 12.**

2.7 Irrigated Soil Classification in Colorado, U.S.A:

All major irrigated soils in the Colorado State are listed and assigned to a design group. Each design group is then listed with an assigned cylinder infiltrometer intake family and a brief general soil description. This description includes a depth range, a permeability range, nature of sub-stratum and available water holding capacity range, a surface texture and other pertinent data. The assigned intake families are based on ring infiltrometer data, which applies to borders or other controlled flooding methods where an entire surface is flooded.

The irrigated soils in Colorado are classified into 17 design groups according to cylinder infiltrometer intake families and available water holding capacities. The intake families represented in Colorado are : 0.1, 0.3, 0.5, 1.0, 1.5, 2.0 and 3.0. They are related to intake rates in inches per hour. The available water

TABLE-11

CONSTRAINTS OF SOIL EFFICIENCY

Soil properties	Irrigable soil class A	B	C	D	Non-irrigable soil class
Effective soil depth (useful to crops)	More than 90 cm	45-90 cm	22.5-45 cm	7.5-22.5 cm	Less than 7.5 cm
Texture of surface 30 cms	Sandy loam to clay loam inclusive	Loamy sand clay	Sand clay	Sand clay	Any texture
*Soil permeability of least permeable layers.	5.0-50 mm/hr	1.3-5 mm/hr. 50-130 mm/hr.	0.3-1.3 mm/hr 130-250 mm/hr	Less than 0.3 mm greater than 250 mm/hr.	Not applicable
Available water holding capacity depth of 90 cms.	12 cm or more	9-12 cm	6-9 cm	2-6 cm	Less than 2 cm
Coarse fragments (%) cobble sand stones -/75mm	Less than 5	5-15	15-35	35-65	More than 65
Gravel and Kankar -/723 to 75 mm	Less than 15	15-35	35-55	55-70	More than 70
Rock out crops distance apart in meters.	40	20	15	5	Less than 5

CONTD.

CONTD.

Soil properties	Irrigable soil class A	B	C	D	Non-irrigable soil class
**Salinity E.C. x 10^3 (in saturation est. or salinity in 1:2 dilutions.	Less than 4.0mm Mhos/cm	4.8 milli mhos/cm	8-12 milli mhos/cm	12-16 milli m.hos/cm	More than 16 m.Mhos.
Salt affected (visual) (% of area effected)	Less than 20%	Less than 20%	20-50%	20-50%	More than 50%
Severity of Alkali problem	E.S.P. less than 15%	E.S.P. less than 15%	E.S.P. more than 15%	E.S.P. more than 15%	E.S.P. more than 15%
Sub-soil or sub-strata drainage characteristics	Lower sub-soilisat least permeable or a permeable layer of at least 6" thickness occurs below the soil.		No moderately permeable sub-soil or other permeable layer of at least 6" thickness.		
Soil erosion status.	Effects of sheet and sill erosion are reflected in effective soil depth available moisture holding capacity and in some other factors shown above. Moderately or severaly gullied soils may be classified based on local experiments.				

* Soil permeablity as a criteria is not applicable to deep black soils because of their unique properties deep black soils (vertisols) which are inherently slowly permeable due to expanding 2:1 lathice type clay minerals do not qualify for irrigability soil class A. They would qualify for being placed in B, C & D class.

** The criteria for salinity and alkalinity refer to equilibrium conditions under irrigation with specified irrigation waters.

TABLE-12.

SPECIFICATIONS FOR LAND IRRIGABILITY CLASSES

Land Classification	Irrigable Land Class				Class Temporary non-irrigable unclassified further investigations needed	Class not suitable for irrigation includes lands which do not meet the minimum requirement for the other land classes are not suitable for irrigation or small isolated tracts (specifying size or distance from canal) not susceptible to delivery of irrigation water.
	Class 1	Class 2	Class 3	Class 4		
Sil Irrigatibilities Class	A	A to B	A to C	A to D		
	TOPOGRAPHY					
Slope	Less than 1%	1-3%	3-5%	5-10%		
Surface grading	No restriction	Moderate restrictions	Moderately severe restrictions	Service restrictions		
	Specifications to be developed locally					
	DRAINAGE					
Out-lets	Suitable outlets available	Suitable outlets available	Suitable outlets available	No drainage outlets available		
Surface	Less than Mtr. of shallow surface drains required per acre	Less than Mtrs. of shallow surface drains required per acre	Develop specification			

CONTD.

CONTD.

Sub-surface	No sub-surface drainage needed or land in within ...mtr/ of adquate drainage (Nalla or rivers)	No sub-surface drainage needed or land in within ...Mtr/ of adequate drainage ways (Nalla or river)	Sub-surface drainage needed specification to be developed run off drainage exceeds	No natural drainage outlets available cost of pump off drainage exceed ...Rs./hr	Note: With regard to items under topography (-) and drainage (2) and (3), the criteria will have to be worked out for each project on the basis of local conditions
Depth of water table	More than 5 Mtr.	3.0-5 Mtr.	1.5-3 Mtr.	1.5 Mtr. & below	

holding capacities are : very low (2 to 3 inches), low (3 to 6 inches), moderate (6 to 9 inches) and high (over 9 inches). The available water holding capacity is the amount of water stored in the soil profile, or the amount stored to a depth of 5 feet, whichever is appropriate.

The details of the various design group are :

Group 1: Deep and moderately deep, very slow or slowly permeable soils with moderate (5 to 7.5 inch.) water capacity. The surface texture is of clay, clay loams and loams. (Intake family 0.1)

Group 2Deep, very slowly permeable soils with low (2.5 - 5 inch.) water capacity with loamy sand surface textures. (intake family 0.1)

Group 3: Deep, very slowly permeable soils with high water capacity (> 7.5 inch) with surface textures of silty clays and clay loams. (Intake family 0.1)

Group 4: Deep and moderately deep slowly permeable soils with low (2.5 to 5 inch) water capacities and with surface texture of clay, clay loam, loam and sandy loam (Intake family 0.3)

Group 5: Deep, slowly permeable soils with high (> 7.5 inch) water capacity. Surface texture is of loam, silty clay loam, clay loam, sandy loam and loamy sand (Intake family 0.3)

Group 6: Shallow, moderately slowly permeable soils with very low (< 2.5 inch) watwater capacity. Surface textures is of silty clay, silty clay loam and loam. (Intake family 0.5)

Group 7: Deep and moderately deep, slowly permeable soils with moderate (5 - 7.5 inch) water capacity. Surface texture is of loam, sandy loam, clay loam and silty clay loam
(Intake family 0.5)

Group 8: Deep well drained soils with high (> 7.5 inch) water capacity with surface texture of loam, silt loam, clay loam, silty clay loam and gravelly clay loam.
(Intake family 1.0)

Group 9: Shallow soils with very low (< 2.5 inch) water capacity and loam surface texture (Intake family 1.0)

Group 10: Deep and moderately deep soils with low (2.5 - 5 inch) water capacity. Surface textures is of stony and cobble loams and clay loams (Intake family 1.0)

Group 11: Deep and moderately deep, moderately permeable soils with moderate (5 - 7.5 inch) water capacity. Surface soils range from clay loam to sandy loam (Intake family 1.0)

Group 12: Deep moderately permeable soils with high (> 7.5 inch) water capacity and surface soils varies from loam, clay loams, and sandy loam surface textures.(Intake family 1.0)

Group 13: Deep soils with moderately rapid permeability and low-(2.5 - 5 inch) water capacities. Surfaces textures is of cobbly and gravelly loams and sandy loams(Intake family 1.5)

Group 14: Deep soils with moderate (5.0 - 7.5 inch) water capacity. Surface texture range from loamy sands, sandy loams, sandy clay loams, and loams(Intake family 1.5)

Group 15: Deep and moderately deep soils with low (2.5 - 5.0 inch) water capacities. S. Surface texture is of loamy sands, sandy loams and gravelly sandy loams(Intake family 2.0)

Group 16: Deep soils with moderate (5 to 7.5 inch) available water capacity. Surface texture varies from loam, sandy loam to loamy sands(Intake family 2.0)

Group 17: Deep soils with low (2.5 - 5.0 inch) water capacities. Surface texture is of sands, loamy sands, gravelly loamy sands, and gravelly and cobbly sandy loam(Intake family 3.0)

2.8 Soil Classification On the Basis Of Soil Moisture Characteristics:

On release of water from a soil a certain bearing with the size and volume of water fills the pores. In sub-atmospheric water pressure (suction) conditions, no outflow may occur until the suction exceeds a critical value called "air-entry." In the beginning, larger pores empty the water, as suction increases, the smaller pores release water. This is well reflected in the capillary equation :

$$-P = 2\tau\cos\theta/r$$

$$-P = 2\tau/r \quad (\text{angle of contact, } \theta = 0)$$

Where P = Suction
τ = Surface tension in dynes/cm
r = Pore radius in cm
θ = Liquid-Solid contact angle in degree.

As the suction increases, the smaller pores of soil will be progressively emptying water. Thus, increasing suction is associated with decreasing soil water. The amount of water present (or metric suction at that level) in the soil at equilibrium is a function of the sizes and volumes of water filled pores. The graphical presentation of the relationship between metric suction and moisture content is termed as "soil-moisture characteristic curve." Typical curves to show this relationship in clayey and sandy soils are given in **Fig.3**. This characteristic curve differs with different basic soil properties. Some empirical equations have been proposed by different workers. Visser (9166) advanced the following equation:

$$m = a(f - \theta)^b/\theta^c \quad \text{where:}$$

m = metric suction
f = porosity
θ = volumetric wetness
a,b,c are constants which vary from 0 to 10, 0 to 3 and 0.4 to 0.6 respectively. Gardner et al (1970) proposed the following empirical relationship :

$$m = a\,\theta^{-b}$$

(b = 4.3 for sandy loam soil)

In the low suction range (0 to 1 bar), the amount of water retained by the soil depends mainly on the pore size distribution which is a function of the structure of the soil matrix (**Fig.4**). But, in the higher suction range (> 1 bar) the moisture retention is due mainly to the adsorption phenomena which is function of soil texture.

Rao and Ramacharlu (1959) presented the relationships between pF (suction) and volumetric moisture content for a number of Indian soils with different textures. There is a clear indication from the relationships shown in **Fig.5** that an increase in tension from zero to 1/3 atmosphere released more than 75 per cent of water in a light textured soil, but less than 50 per cent in a heavy textured soil. Water retention characteristics as studied by Ali et al (1966) for a few alluvial, black, laterite, mountain, forest desert and saline soils of India (**Table.13**) show that most of the water is released within 1 to 2 atmospheric tensions.

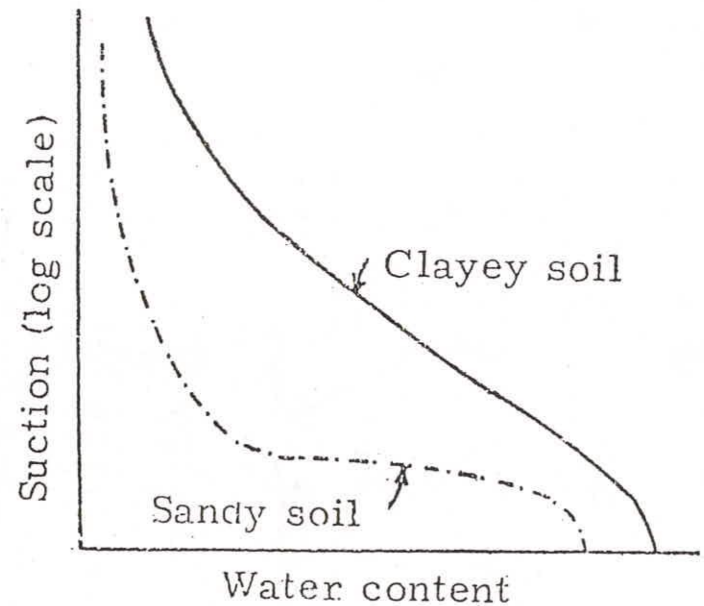

FIG.3 *Typical Soil Moisture Characteristics Curves*

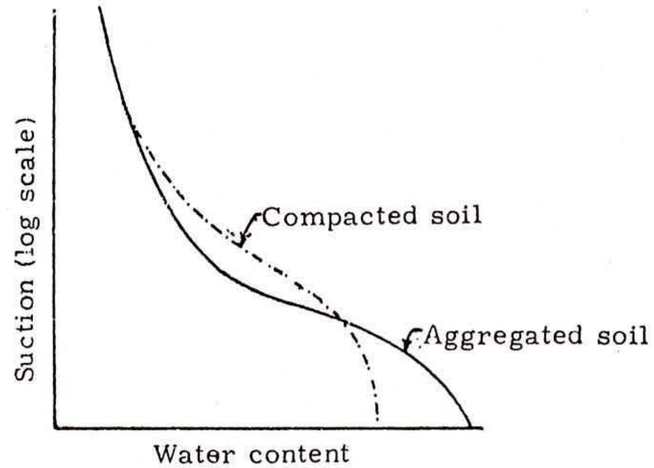

FIG.4 Moisture Content-Matric Suction Relationship

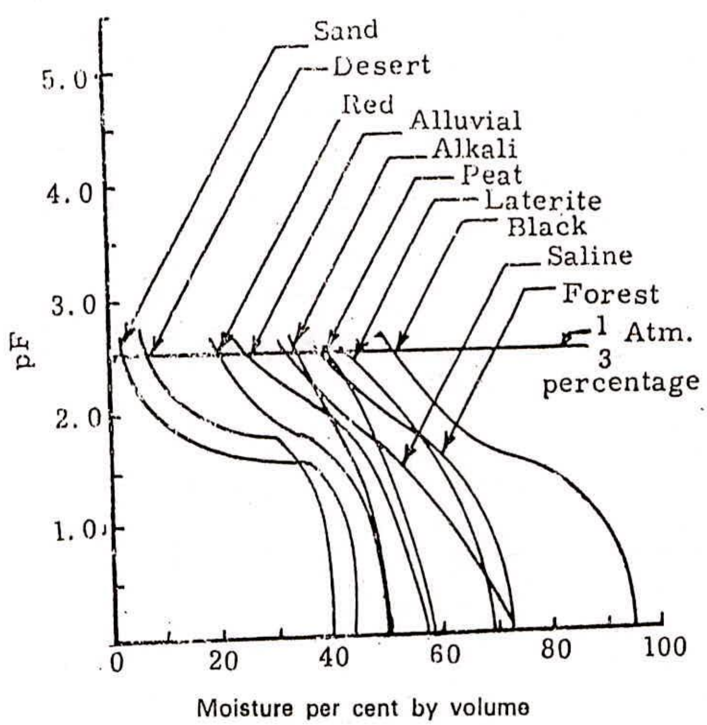

FIG.5 Soil Moisture Characteristic Curves of Indian Soils

Table.13 Moisture at various tensions in different soil types

Soil	Atmosphere				Available moisture in %
	0	1/10	1/3	15	
1	2	3	4	5	6
Alluvial					
Delhi	A 24.0	27.2	10.7	4.4	6.3
	B 37.4	29.7	17.7	7.7	10.0
Lucknow	A 47.0	42.1	29.2	8.1	21.1
	B 41.2	34.6	25.8	6.0	19.8
Chinsurah	A 54.1	48.2	36.7	19.0	17.7
	B 46.5	42.9	33.6	17.3	16.3
Burdwan	A 47.6	47.0	35.3	16.1	19.2
	B 55.6	41.8	32.2	17.0	15.3
Ludhiana	A 24.8	20.5	12.1	3.6	8.5
	B 25.7	21.9	11.3	3.7	7.6
Pusa	A 32.1	31.6	15.5	1.9	13.6
	B 36.6	34.9	23.8	2.8	21.0
Black					
Rajendranger	A 58.1	36.4	23.7	12.7	11.0
	B 54.5	34.4	23.2	12.0	11.2
Achalpur	A 60.0	48.1	38.0	15.8	22.2
	B 61.5	55.5	41.1	20.0	20.1
Tharsa	A 58.1	45.8	30.0	16.1	13.9
	B 54.5	40.5	28.3	16.2	12.1
Padegaon	A 83.8	68.3	43.5	25.7	16.8
	B 76.3	68.8	43.3	27.2	16.1
Nagpur	A 58.1	54.4	38.9	21.1	17.8
	B 54.5	51.3	34.8	20.5	14.3
Red					
Cheruvukomi-*mupalem	A 33.8	30.2	17.5	8.5	9.0
	B 41.4	34.9	23.0	12.3	10.7
Yemmiganur	A 34.5	31.4	19.8	8.2	11.6
	B 44.3	38.7	24.9	13.6	11.3

Contd.

Contd.

Hebbal	A	26.1	24.9	11.6	5.6	6.0
	B	29.3	62.2	12.8	7.8	5.0
Tolukhal	A	35.0	27.4	13.4	8.8	4.6
	B	35.6	25.8	16.8	11.6	5.2
Raichur	A	31.4	26.2	13.7	7.4	6.3
	B	32.2	24.3	14.0	7.5	6.5
Laterite and lateritic						
Midnapore	A	27.6	21.8	13.7	5.2	8.5
	B	37.2	27.9	18.2	9.1	9.1
Kuttapana	A	30.0	36.8	15.1	9.7	5.4
	B	43.0	33.8	25.6	19.9	5.7
Narkodu	A	51.6	43.2	22.2	16.9	5.3
	B	55.0	43.4	29.4	21.1	8.3
Bhata	A	43.0	35.2	26.5	13.1	13.4
	B	48.5	36.9	27.5	15.5	12.0
Suri	A	24.0	22.5	14.2	4.3	9.9
	B	23.0	20.5	13.3	4.4	8.9
Mountain and forest						
Bhowali	A	56.2	44.9	32.3	9.1	22.9
	B	50.3	36.4	27.2	10.4	16.8
Ootacamand	A	49.7	42.0	30.5	18.7	11.8
	B	45.2	34.9	26.7	17.3	9.4
Dehra Dun	A	41.3	37.0	29.1	8.4	20.7
	B	43.7	35.0	26.8	9.8	16.9
Desert						
Pali	A	40.1	29.8	19.3	8.0	11.0
	B	48.2	36.5	29.5	10.7	9.8
Beriganga	A	29.4	24.5	8.5	3.7	4.8
	B	24.4	20.8	6.0	2.7	3.3
Saline						
Sonapur	A	52.5	45.4	38.1	11.9	26.2
	B	57.9	42.1	36.3	13.2	23.1
Canning	A	55.6	54.2	41.9	15.5	26.4
	B	48.8	47.5	35.1	15.4	19.7

A and B represent surface (0-15 cm) and sub-surface (15-30 cm) samples, respectively.

3.0 STUDY AREA :

3.1 General: Soils of N.E.Region :

Soils of North Eastern Region have developed in situ on many types of rocks. The rocks comprise mainly of biotite-gneiss, tourmaline schist etc. The soils around Garo and Khasi hills have originated from quartzite and granites. Barail series, simsan formation (Garo Hills), Jaintia series, Disang series (ultrabsic in deep shades) occupy almost entire area of Manipur and Nagaland Western Jaintia Hills. Barail series and Simsang formation are predominantly shale and silt-stone with hands of weathered rather soft and micaceous medium grained yellowish gray rocks. Jaintia series and Disang series are represented by a monotonous sequence of gray shale with minor mud-stone, silt-stone and siliceous limestone. Manipur valley soils have developed from the transported material formed from shale and this is the reason why these soils are heavier in texture.

The soils of Assam have been derived from two major types of parent materials - residual and transported. The Assam plateau is mostly occupied by ferroginous red soils. The soils of the Northern part of the Brahmaputra valley are formed on the alluvium transport from the Assam Himalayas by the tributaries on the northern side of the Brahmaputra. But the alluvium brought down by the tributaries on the southern part of the river Brahmaputra forms the soils of the southern part of the Brahmaputra valley. The soils of the Barak valley are not very much different from those of the southern part of the Brahmaputra valley. Being formed from sandstone, shale and sandy shale of the surrounding hilly areas, the flat lands of this valley are deep and heavy.

Soils of the north eastern hilly regions have been classified into red loamy soils, red and yellow soils, lateritic soils, brown hill soils and old and new alluvial soils. The soils of this hilly region have not been surveyed thoroughly due to hilly terrain, poor communication and inaccessibilities and dense forest. Based on the available meager information, soils of the region can be broadly classified as shown in **Table.14.**

Table.14 Classification of soils of N.E.Region

Soil classification (Tradition or popular/ nomenclature)	Equivalent name according to the Approximation classification.
Red loamy soils	Paleustafs Rhodustalfs Haplustalfs
Red & yellow soils	Haplustalfs Ochraqualfs Rhodustulfs
Laterite soils	Plinthaqualfs
Brownhill soils (on Sandstone and shales)	Plinthustults Plaehumults

The hill soils are classified on the basis of topography and natural vegetation or major crops grown. These include non-laterite. red loam soils like ferroginous red soil, ferroginous gravelly soils, mixed red and black soils, forest soils and laterized red soils. According to the new classification these soils are included under Alfisol and Ultsol. The major groups in the Alluvium derived soils are Entisol, Inceptisol and Alfisol. Delineation of different soil groups for Assam where the study area partly lies is shown in Fig.6

3.1.1 Soils of Goalpara and East Garo Hills :

The soils of the Goalpara district have been grouped into old and new alluvium. The average nitrogen of few alluvial soil is 0.109%, P_2O_5 is 0.020 %, K_2O is 0.014%, pH is 6.6. Old soils are more acidic, the average pH is 4.9 in water extracts and 4.5 in KNO_3 extract. Goalpara soils vary from sands to loams. The content of P_2O_5 is fairly high in the majority of the soils but that of K_2O is

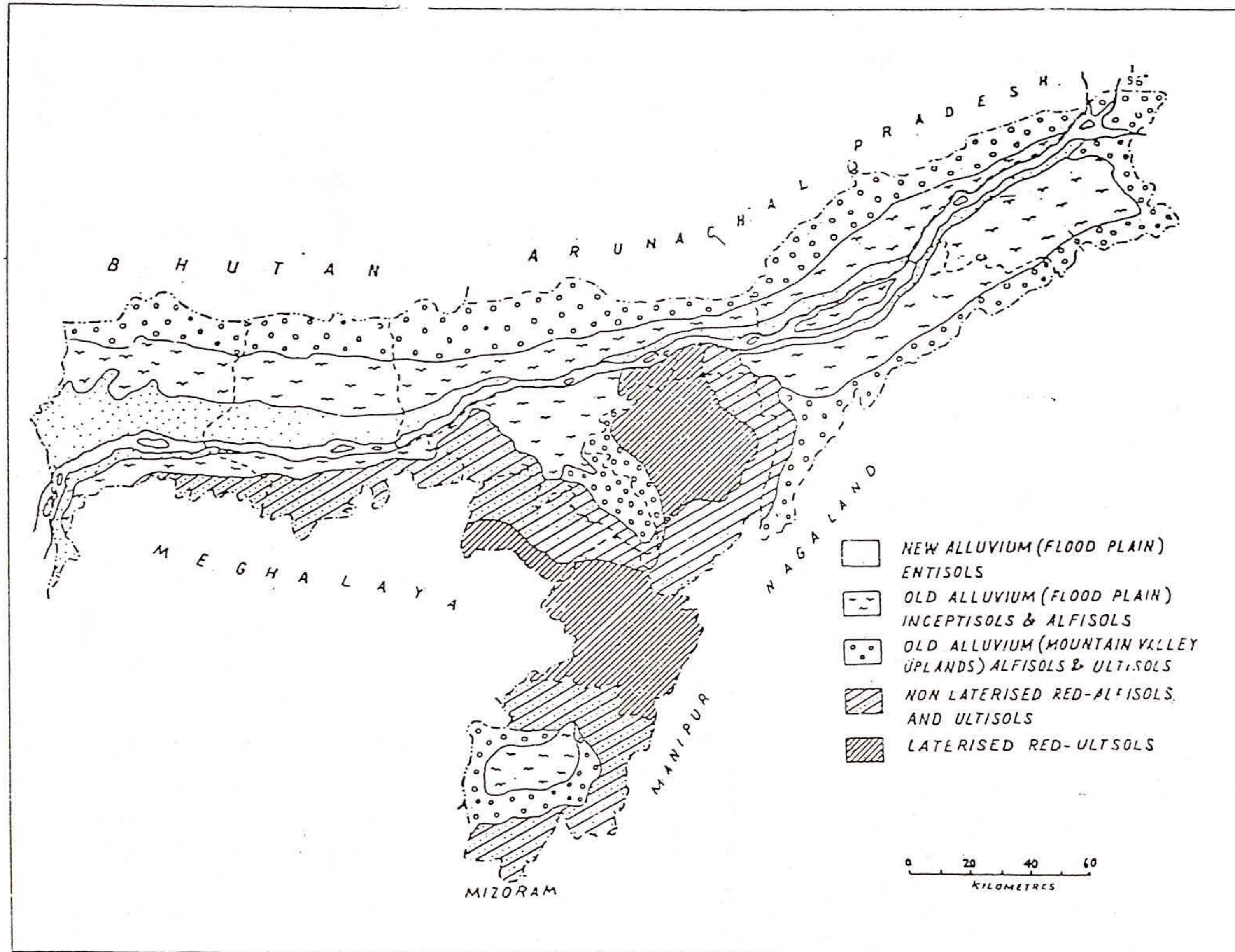

FIG.6 Soil Map of Assam

just sufficient. Nitrogen content is quite high, particularly in the surface soil.

The soil in the East Garo Hills is quite heavy clay and contains about 10 per cent organic matter. The nitrogen content is also high. The soils may be grouped in to hill soils and new alluvium is shown in **Fig.7**. Average nutrients status of the former (in per cent) is : N= 0.146, P_2O_5= 0.005, NO= 0.022. The value of pH is 4.9 in water extract and 4.5 in KNO_3 extract. The average value of nutrient status of new alluvial soil (in per cent) is : N= 0.08, P_2O_5= 0.055, K_2O= 0.10. The value of pH is 4.8 in water extract, and 4.8 in KNO_3 extract.

3.2 Dudhnai Sub-Basin:

The study area is the representative basin i.e. the Dudhnai sub-basin(**Fig.8**) on the south bank of the Brahmaputra. This sub-basin mostly lies in the district of East Garo Hills in Meghalaya and partly(towards out-fall) in the district of Goalpara, Assam. On the east lies the Deosila sub-basin and on the west is Krishnai sub-basin. On the North is the mighty Brahmaputra river where it outfalls and on the south west Khashi hill ranges limit the basin. The catchment area is about 510 Sq.Km. Basin elevation varies from 2100 metre to 2227 metre above mean sea level (m.s.l) and basin slope from south to north. 83% of sub-basin is within district of East Garo Hills in Meghalaya and 17% in Goalpara district of Assam. The study area is geographically located between 25^{o} 35' N and 26^{o} N latitude and 90^{o} 40' E and 90^{o} 55' E longitude. Dudhnai township at the basin mouth is situated at a distance of 60 Km. from Guwahati city. The outlet of the sub-basin is at Dudhnai with gauge discharge site at bridge site of NH-37 crossing. The basin is covered in four SOI maps of 1:50,000 scale as listed in **Table.15** below:

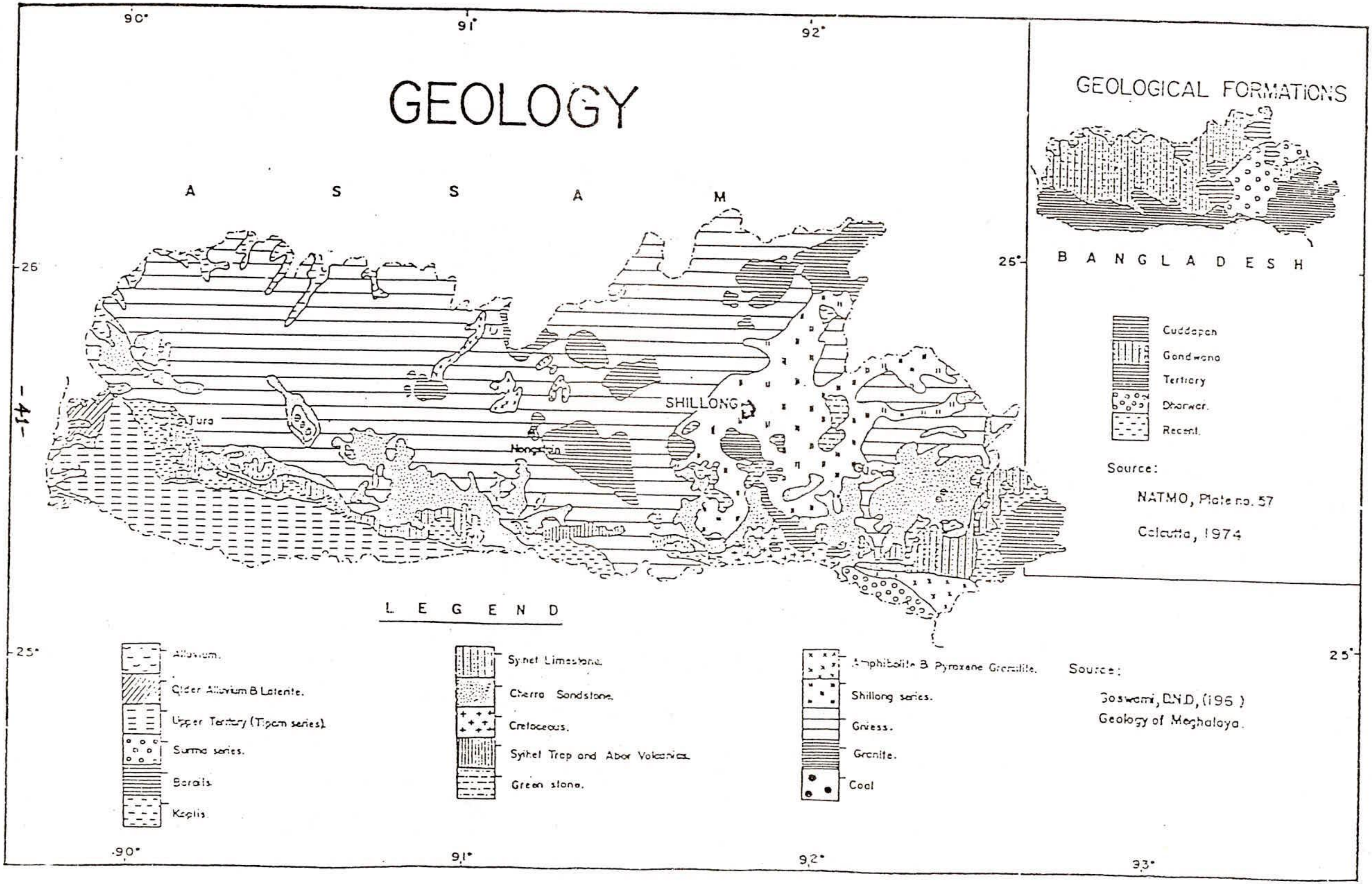

FIG.7 Geological Map of East Garo Hills

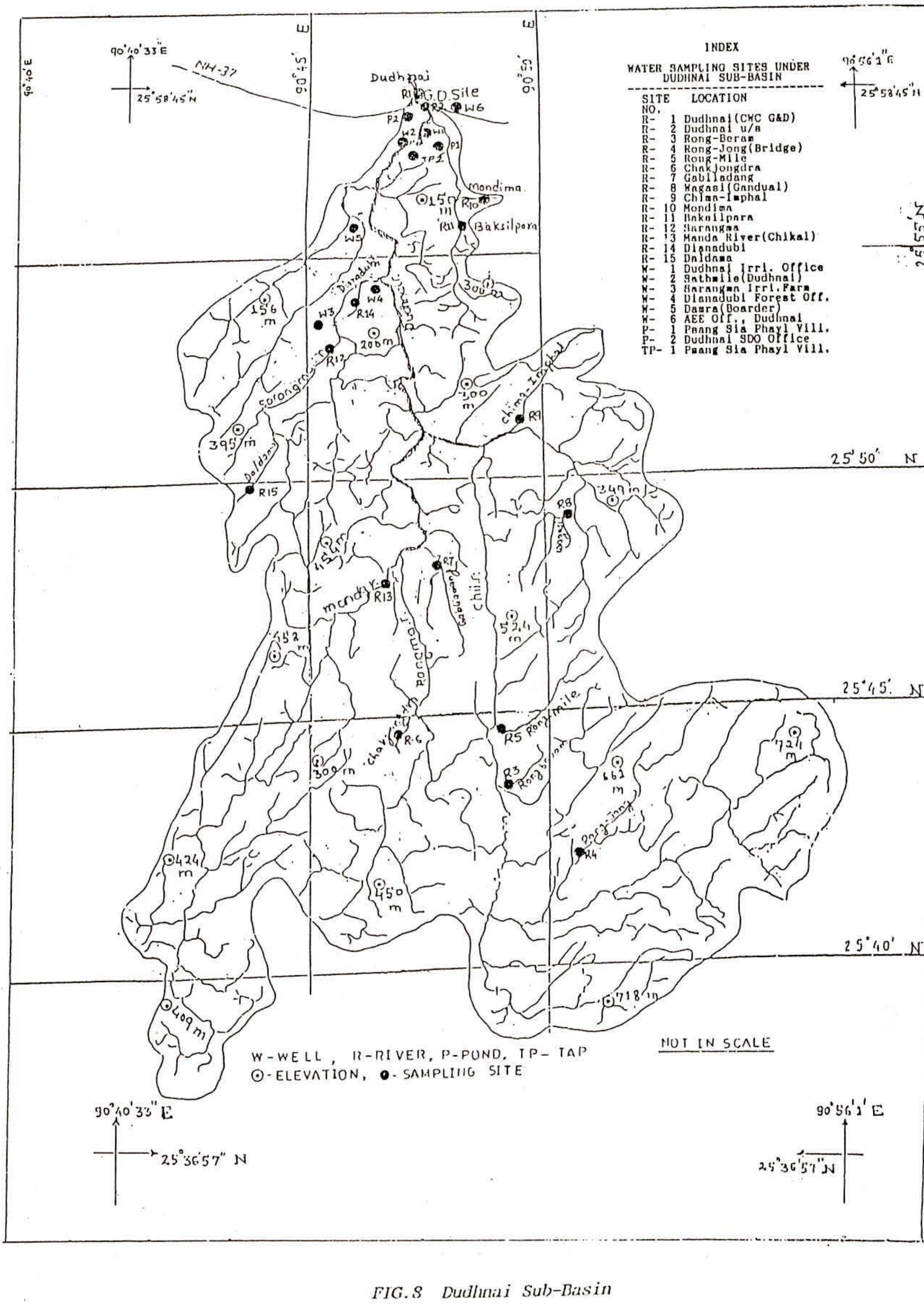

FIG.8 Dudhnai Sub-Basin

Table.15 :Details of Toposheets

Sl.No.	Sheet Reference Number	Scale	Year
1.	78K/9	1:50,000	1963-64
2.	78K/13	1:50,000	1963-64
3.	78K/14	1:50,000	1963-64
4.	78J/16	1:50,000	1963-64

Major part of the sub-basin is a hilly terrain with a few isolated V shaped valleys developed along the course of river with undulating topography. Geomorphologically the basin can be divided into three broad limits. The first one is hilly gneissic complex, the second one the foot hill zone consisting of unsorted mixture of boulders, clay and the third one i.e. flood plains is of alluvium deposits. The elevation of the basin decreases towards north.

While detailed soil investigations in the basin is in progress it has been reported that soil in the lower catchment is predominantly hard reddish clay to light yellowish & light grays felspar & Mica. The basin plains are mostly new alluvium as found in ri-arian areas. Soil in the upper catchment is sandy loam or silty mainly comprising of quartzite & laterite.

The hydrologic classification of soils in the basin has been attempted on the basis of soil properties, NBSS & LU Maps, data of electric sounding and Remote Sensing Imageries that were available for a part of the sub-basin (lower part of about 50% up to 25 Deg. 47 Min. North).

3.2.1 Dudhnai River System:

The river Dudhnai is one of the small south bank tributaries of the river Brahmaputra. It originates from the Northern slopes of the Garo Hill ranges of Meghalaya at latitude 25Deg.35Min.E at an elevation of around 400m. From here the river flows in the N.E.

direction by the name Manda for a distance of about 26 km till it is joined by the river Rongma -Chichra, a right bank tributary.

Depending on the topography, river gradient and bifurcation/confluence of important tributaries, the river Dudhnai can be divided into the following four reaches:

1. From its origin to the joining point of Chil.
2. From the joining point of Chil to Dianadubi at the Assam Meghalaya border.
3. From Dainabubi to its confluence with Krishnai near Domani.
4. From Domani to outfall into Brahmaputra.

3.2.2 Land Use and Land Cover:

To evaluate the landuse conditions of the study area, available of March season satellite imagery of IRS-1B, LISS-II, 09.03.1989 date have been interpreted in 1:50,000 scale. Interpretation has been carried out upto level II classification for the season.

From the satellite data different types of landuse with area and their hydrological conditions have been delineated for March season. Map in the **Fig.9** shows the landuse pattern of he study area.**Table.16** shows the aerial extent of landuse and hydrological condition delineated from satellite imagery (09-03-1989).

Table.16
Aerial Extent of Landuse And Hydrological Condition

Sl.No.	Level I	Level II Hydrological Condition	Area in Sq.Km.	% of Extent
1.	Built up	Rural	9.125	3.53
2.	Agriculture	Khariff	20.200	7.80
		Follow-1	21.420	8.29
3.	Forest	Deciduous dense	127.980	49.48

Contd.

Contd.

	Scrub	9.70	3.75
	Forest Plantation	13.65	5.28
	Forest blank	56.575	21.87
		258.650	100.00

The land utilization statistics of most of the basin areas for which information were available are as in **Table.17** below:

Table.17 : Land Uses from Topo-Sheets

Sl. No.	land use	Area in Goalpara Dist	Area in E/Garo Hill	Total
1.	Total area	9988 Ha.	37760Ha.	47748Ha.
2.	Forest	1739 Ha.	13883Ha.	15622Ha.
3.	Barren un- cultivable land	3296 Ha.	5288Ha.	8584Ha.
4.	Cultivable Waste	455 Ha.	10076Ha.	10531Ha.
5.	Fallow Land	210 Ha.	5079Ha.	5289Ha.
6.	Net area sown	4238 Ha.	3434Ha.	7672Ha.

3.2.3 Hydrometerology:

The 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 enjoys an average annual rainfall of 1817.20 mm. In this zone the bulk of the rainfall occurs during the month of May to September. Significant rainfall occurs in May and October too. The months from November to March are generally dry. Tropical storms and depressions affect the weather in this zone during the months from June and September.

Climatological situation prevailing in Dudhnai sub-basin in different parts of the year is predominantly characterized by four distinct seasons in a year:(i)Winter, (ii)Pre-Monsoon, (iii)Monsoon and (iv)Pcst Monsoon seasons.

The average annual rainfall over the whole catchment is around

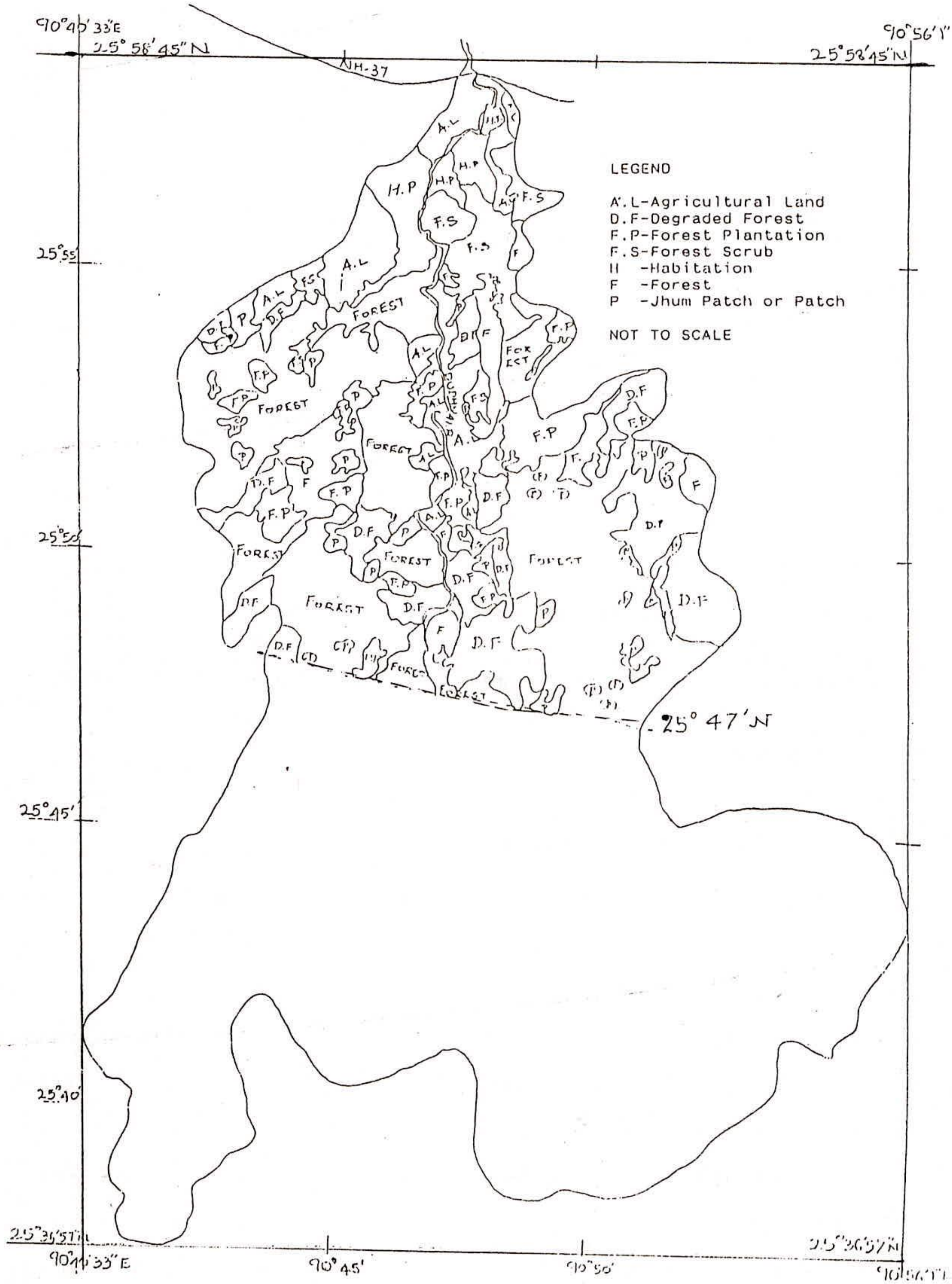

FIG.9 Landuse/Landcover Map of Part of Dudhnai Basin

1817 mm based on simple arithmetic average of three existing ordinary raingauge stations in the basin. It is seen that maximum rainfall occurs at Damra where the annual average accounts for being 2881 mm followed by 1326 mm and 1244 mm at Domoni and Dudhnoi respectively. Of the mean annual rainfall of 1817 mm the seasonal distribution is: monsoon (June to Sept.)-1173mm(64.55%), pre-monsoon(March to May)-474.60mm(26.12%), post monsoon (Oct.to Nov.)-140.86mm(07.75%) and winter season(Dec. to Feb.)-28.93mm(01.59%).

3.2.4 Agriculture :

Agriculture and forests are the mainstay of the people in the sub-basin. Rice is the principal crop. Other important crops grown are jute, wheat, sugarcane, mustard, pulses, millet, maize, sweet potato etc.

Shifting cultivation known as Jhum cultivation is the age old practice in the hilly region. Shifting cultivation degraded the vegetal cover of the area and washes down the rich top fertile soil cover rendering the surface area progressively infertile.

3.3 Soil Classification of the Sub-Basin:

Of interest to hydrology, the properties of soil which influence the runoff are effective depth, clay in the surface layer, average clay content in the profile, infiltration, permeability, soil texture etc. Detailed soil investigation results are not available for the sub-basin. However, there are some available regional information with other agencies such as the preliminary reports of deep tube well testing conducted by Department of Geology and Mining, Govt of Assam, report of electric sounding in E.Garo Hills by CGWB, soil maps of National Bureau of Soil Survey And Land Use Planning, Jorhat and so on. These information alone are not at all sufficient to classify its soils into different groups. Therefore, besides making use of the above extra-departmental reports, field investigations/experiments were also carried out from time to time, soils samples were collected and tested in the laboratory.

On the basis of these information soil has been classified under different systems of classifications and the results are presented in **Chapter 4.**

4.0 RESULTS AND ANALYSIS:

Different systems of soil classifications need different set of information. On the basis of available information and data ascertained from field & laboratory experiments attempt has been made to classify soils of Dudhnai sub-basin into different soil groups. However, present study covers about 50% of the basin area as delineated in Fig.9.

4.1 Classification Based on Hydrological Soil Properties :

Commonly used soil parameters for the purpose are effective soil depth, soil structure, texture, infiltration and permeability which are determined from field & laboratory tests.

4.1.1 Classification Based on Effective Soil Depth of Dudhnai:

The classifications of soils of the basin based on data of vertical electric sounding conducted by C.G.W.B , Basic Data Report on Dudhnoi deep tube well (Directorate of Geology and Mining, Govt of Assam) and field observation using Sample Ring Kit Auger are shown in **Table.18.**

Table.18: Classification Based on Effective Soil Depth

Name of the Place	Site No.	Effective Soil Depth(cm)	Class
Dinadubi*	1	60	d4
	2	90	d4
	3	185	d5
	4	140	d5
	5	140	d5
	6	170	d5
	7	64	d4
	8	450	d5
	9	175	d5
	10	470	d5
	11	130	d5
	12	170	d5
	13	115	d5
	14	740	d5
	15	650	d5
	16	470	d5
	17	380	d5

Contd.

Contd.

Rongjong*	1	680	d5
	2	565	d5
	3	310	d5
	4	78	d4
	5	76	d4
	6	380	d5
	7	70	d4
	8	580	d5
	9	1650	d5
	10	400	d5
	11	60	d4
	12	600	d5
	13	72	d4
	14	320	d5
	15	700	d5
	16	30	d4
	17	220	d5
Mendhipathar*	1	180	d5
	2	760	d5
	3	210	d5
	4	135	d5
	5	90	d4
	6	90	d4
	7	70	d4
	8	150	d5
	9	92	d4
	10	380	d5
	11	620	d5
	12	90	d4
	13	78	d4
	14	90	d4
	15	120	d5
	16	200	d5
	17	100	d4
	18	110	d5
	19	110	d5
	20	520	d5
	21	500	d5
	22	600	d5
	23	160	d5
	24	110	d5
Dudhnoi**		300	d5
Chikal***		42	d4
Dasera sarangma***		>100	d5
Khentra***		50	d4
Damra***		>100	d5

** Data of Electric sounding conducted in E.Garo Hills (CGWB) Fig.10 to Fig.13*

*** Data of Basic Report on Dudhnoi deep tube well (Directorate of Geology and Mining Department, Govt. of Assam)*

**** Observations at sites using Sample Ring Kit Auger*

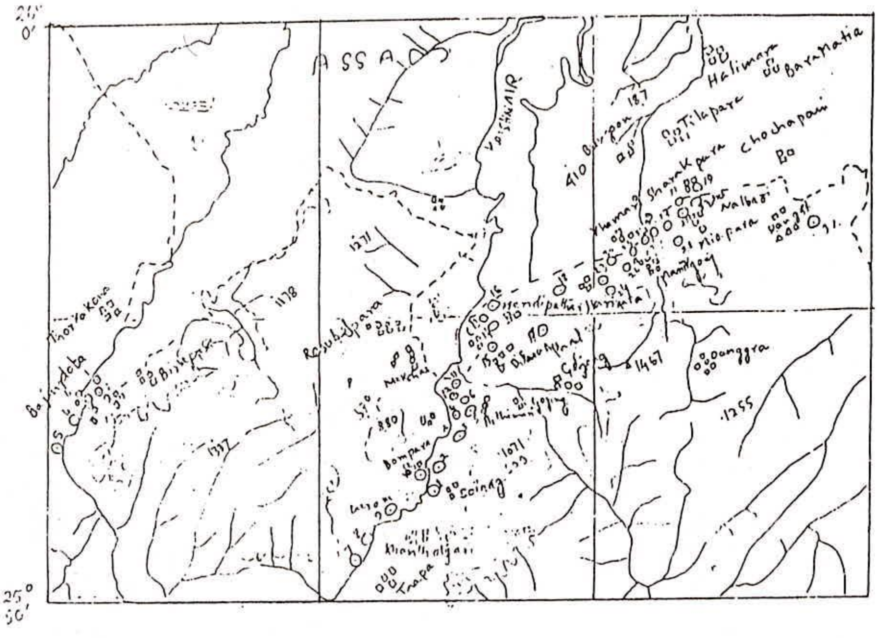

FIG. 10 Locations of Electric Soundings in Mendipathar

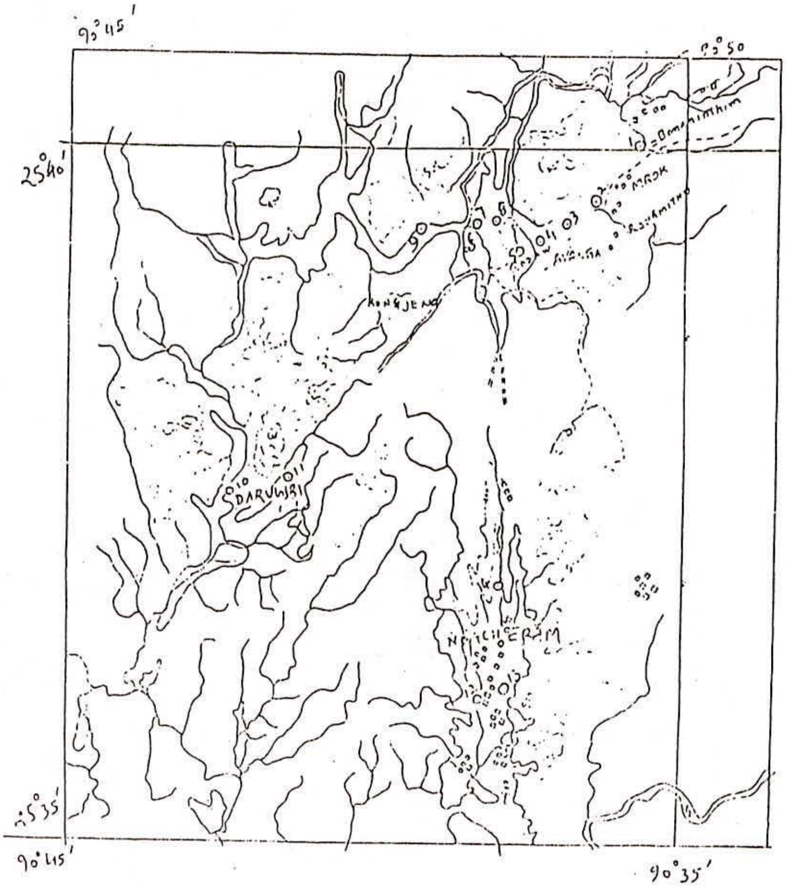

FIG. 11 Locations of Electric Soundings in Rongjong

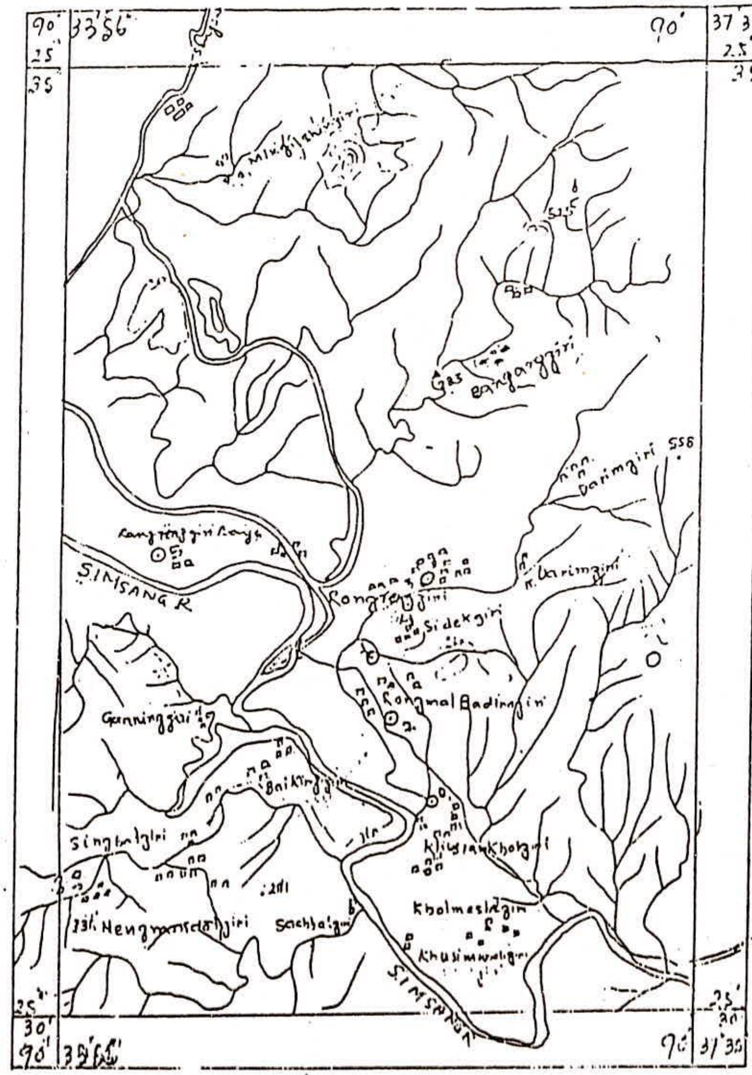

FIG.12 Locations of Electric Soundings in Williamnagar

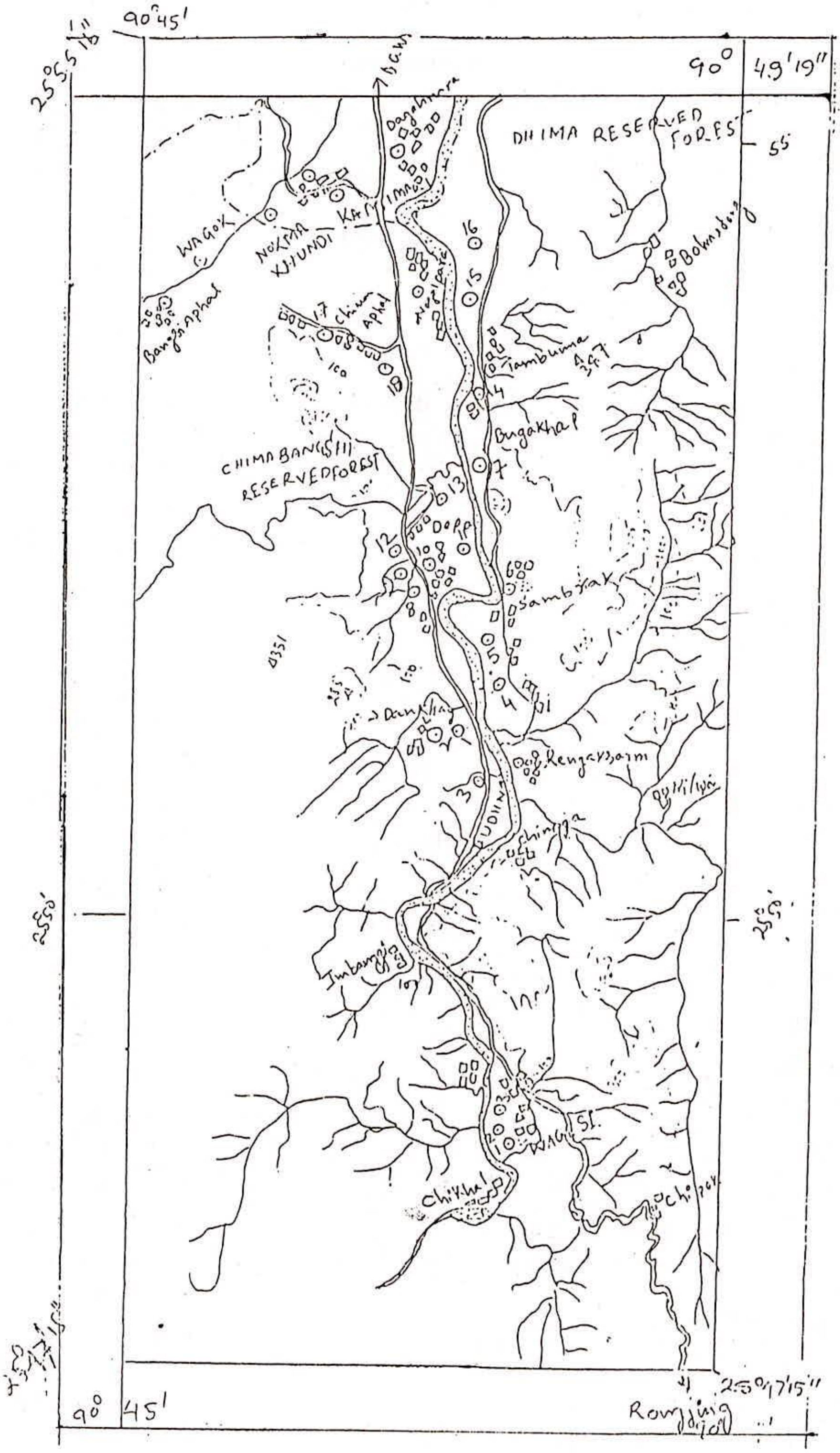

FIG. 13 Locations of Electric Soundings in Dinadubi

4.1.2 Classification Based on Soil Texture of Dudhnai

Soil texture refers to relative proportion of various soil separates in a soil material and is related to soil water interrelationships. On the basis of relative proportion of this basic separates, as shown in **Table.19**, various soils in the basin has been classified.**(Fig.14)**

Table.19
Classification of Soils of Dudhnai Based on Texture

Name of the site		Qualifying Texture Class	Runoff Potential
1	Rang Jong	Loamy Sand well graded	Low
2	Rangberan	Silty Sand uniformly graded	Moderately high
3	Rongmil	Loamy Sand Medium graded	Low
4	Chak Jongdna	Silty Sand uniformly graded	Moderately high
5	Gablianem	Silty Sand uniformly graded	Moderately High
6	Gandual	Loamy Sand uniformly graded	Low
7	Chima-Imphal	Loamy sand well graded	Low
8	Nilagithim	Silty Sand uniformly graded	Moderately high
9	Mandima	Loamy Sand medium graded	Low
10	Bukshirparh	Loamy Sand well graded	Low
11	Dudhnai	Silty Sand uiformly graded	Moderately high
12	Dianadubi	Sandy Loam well graded	Low to moderate -ly low

Contd.

Contd.

14	Sarangma Forest	Loamy Sand medium grade	Low
15	Chikal	Sandy Loam well graded	Low to moderate -ly low
16	Dasera Sarangma	Loamy Sand medium graded	Low
17	Forest Rest	Sandy Loam well graded	Low to moderate -ly low

4.1.3 Classification Based on Soil Structure of Dudhnai

Soil structure refers to the arrangement of soil particles in the soil profile. Soil structure governs the moisture and air regimes in the soil. The movement of water in the soil and its transmission is affected by soil structure and texture. The influence of structure on runoff potential is given in **Table.20**

Table.20 Classifications Based on Soil Structure

Sl.No	Name of the site	Soil Structure	Runoff Potential
1.	Chikal	Strong platy compact massive	High
2.	Dasera Sarangma	Strong platy compact massive	High
3.	Dasera Sarangma (Seed Farm)	Strong platy compact massive	High
4.	Dinadubi Forest Rest House(W)	Strong angular blocky prismatic	Moderately high to high
5.	Dinadubi Forest Rest House(E)	Strong angular blocky prismatic	Moderately high to high
6.	Rong Jong	Strong angular blocky prismatic	Moderately high to high
7.	Rongmill	Strong angular blocky prismatic	Moderately high to high
8.	Chakjongdra	Strong platy compact massive	High
9.	Gabliadeng	Strong angular blocky prismatic	Moderately high to high

Contd.

Contd.

10.	Gandual	Strong platy compact massive	High
11.	Chima-Imphal	Strong angular blocky prismatic	Moderately high to high
12.	Nilwagithim	Strong angular blocky prismatic	Moderately high to high
13.	Mendima	Strong platy compact massive	High
14.	Bukshilpara	Strong platy compact massive	High
15.	Dudhnai	Strong platy compact massive	High
16.	Sarangma	Strong platy compact massive	High
17.	Depa	Strong platy compact massive	High
18.	Khentra	Strong platy compact massive	High
19.	Dinadubi	Strong platy compact massive	High
20.	Damra(E)	Strong platy compact massive	High
21.	Damra(W)	Strong platy compact massive	High

4.1.4 Classification Based on Infiltration Data of Dudhnai

Infiltration tests at Dudhnai sub-basin were conducted with Double Ring Infiltrometer at 23 selected locations and infiltration curves for the areas were developed. On the basis of the results, classifications of soils(**Fig.15**) are made as below **Table.21**.

Table.21
Soil Classifications based on Infiltration Data of Dudhnai

Sl.No	Name of site	Infiltration Rate in cm/hr		Runoff Potential
		Initial rate	Final rate	
1.	Chikal	1.60	0.10	High
2.	Dasera Sarangma	*	0.78	High
3.	Dasera Sarangma (Seed Farm)	331.0	0.34	High
4.	Dinadubi Forest Rest House (W)	259.2	1.81	Moderately high to high

Contd.

Contd.

5.	Dinadubi Forest Rest House (E)	518.4	1.60	-do-
6.	Rong Jong	777.6	2.05	-do-
7.	Rongmill	2160.0	3.82	-do-
8.	Chakjongdra	878.4	0.73	High
9.	Gabliadeng	5400.0	2.20	Moderately high to high
10.	Gandual	950.4	0.66	High
11.	Chima-Imphal	1166.4	1.86	Moderately high to high
12.	Nilwagithim	705.6	1.71	-do-
13.	Mendima	1512.0	0.52	High
14.	Bukshilpara	835.2	0.58	High
15.	Dudhnai	921.6	0.54	High
16.	Sarangma	1310.4	0.90	High
17.	Depa	1051.2	0.51	High
18.	Khentra	662.4	0.45	High
19.	Dinadubi	864.0	0.51	High
20.	Damra(E)	489.6	0.45	High
21.	Damra(W)	676.8	0.53	High

4.1.5 Classification Based on Permeability Data of Dudhnai

In pursuance of the field programme,Guelph permeameter tests were conducted at ten different sites of the Dudhnai sub-basin where already infiltration test results and other soil data were available. The test results were used to calculate in-situ hydraulic conductivity and flux potential of the soil. All tests were conducted at a depth of 50 cm below ground level. On the basis of governing criteria as already discussed in **clause 2.3.5** soil classification is made as shown in **Table.22** below:

Table.22
Soil Classifications based on Hydraulic conductivity and Flux potential at Dudhnai sub-basin

Sl.	Name of the site	Hydraulic conductivity(k) cm/hr	Flux potential(o) sq cm/hr	Permeability rate cm/hr	Runoff Potential
1.	chikal Village	-0.0078	0.78	*	High
2.	Dasera sarangma	- 0.0615	1.415	*	High
3.	Dasera sarangma (forest site)	0.0053	0.153	Very slow	High
4.	Dianadubi forest rest house	0.0170	-0.160	Very slow	High
5.	Rongberan	0.0100	0.0346	Very slow	High
6.	Rongjong	-0.0046	0.118	*	High
7.	Rongmil	0.024	-0.050	Very slow	High
8.	Khentra	0.0175	-0.100	Very slow	High
9.	Dinadubi	0.0044	-0.025	Very slow	High
10.	Damra	0.210	-1.214	Slow	High

***** Negative K indicates heterogeneity in soil layer. Runoff classification is based on Flux Potential*

4.2 Hydrologic Soil Classification based on SCS

The soil characteristics associated with each group are presented in **Table-10**. On the basis of guide lines discussed in **clause 2.4.1** the results are presented in **Table.23 and Fig.16..**

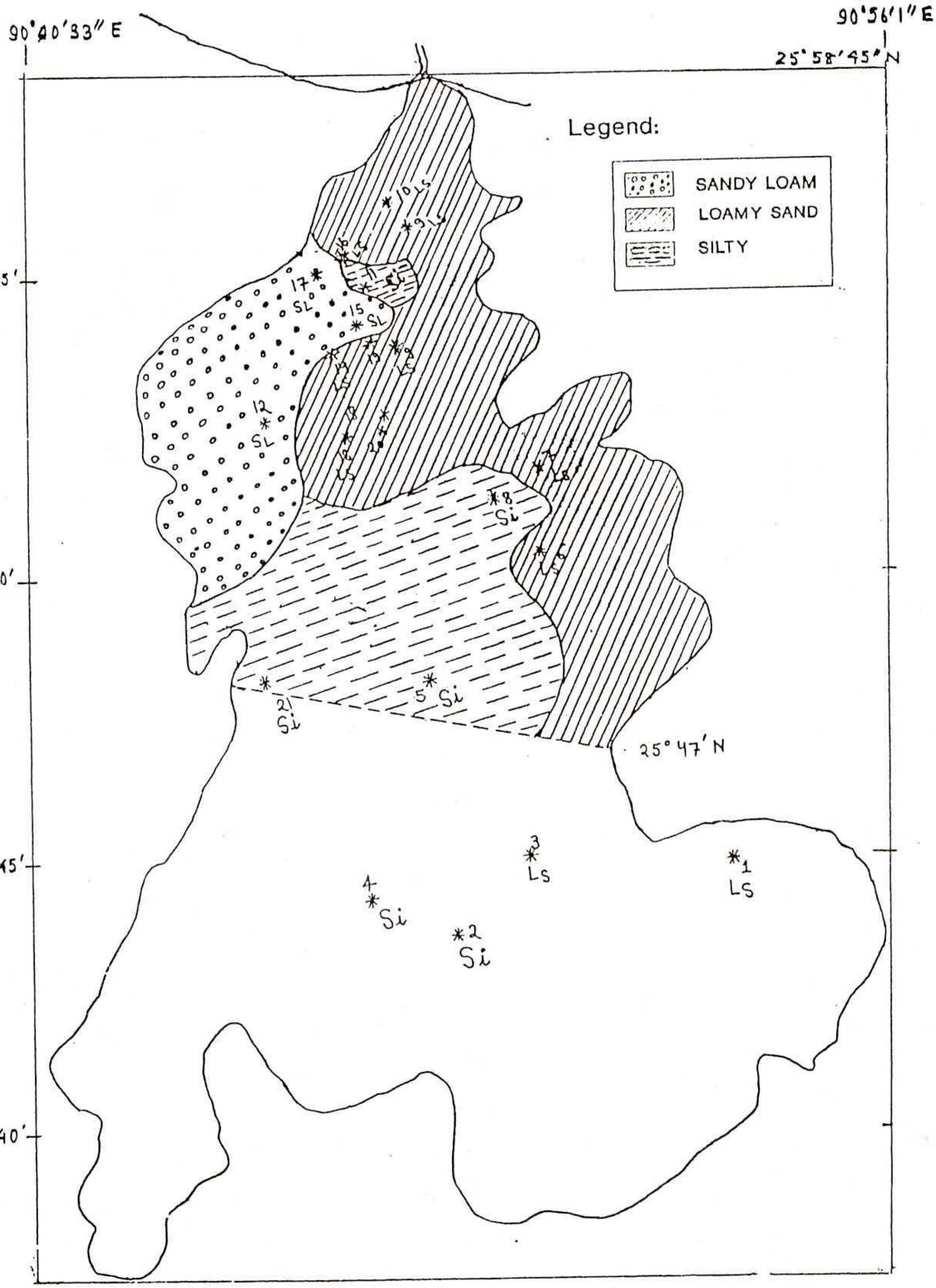

FIG. 14 Soil Classification based on Soil Texture/Structure

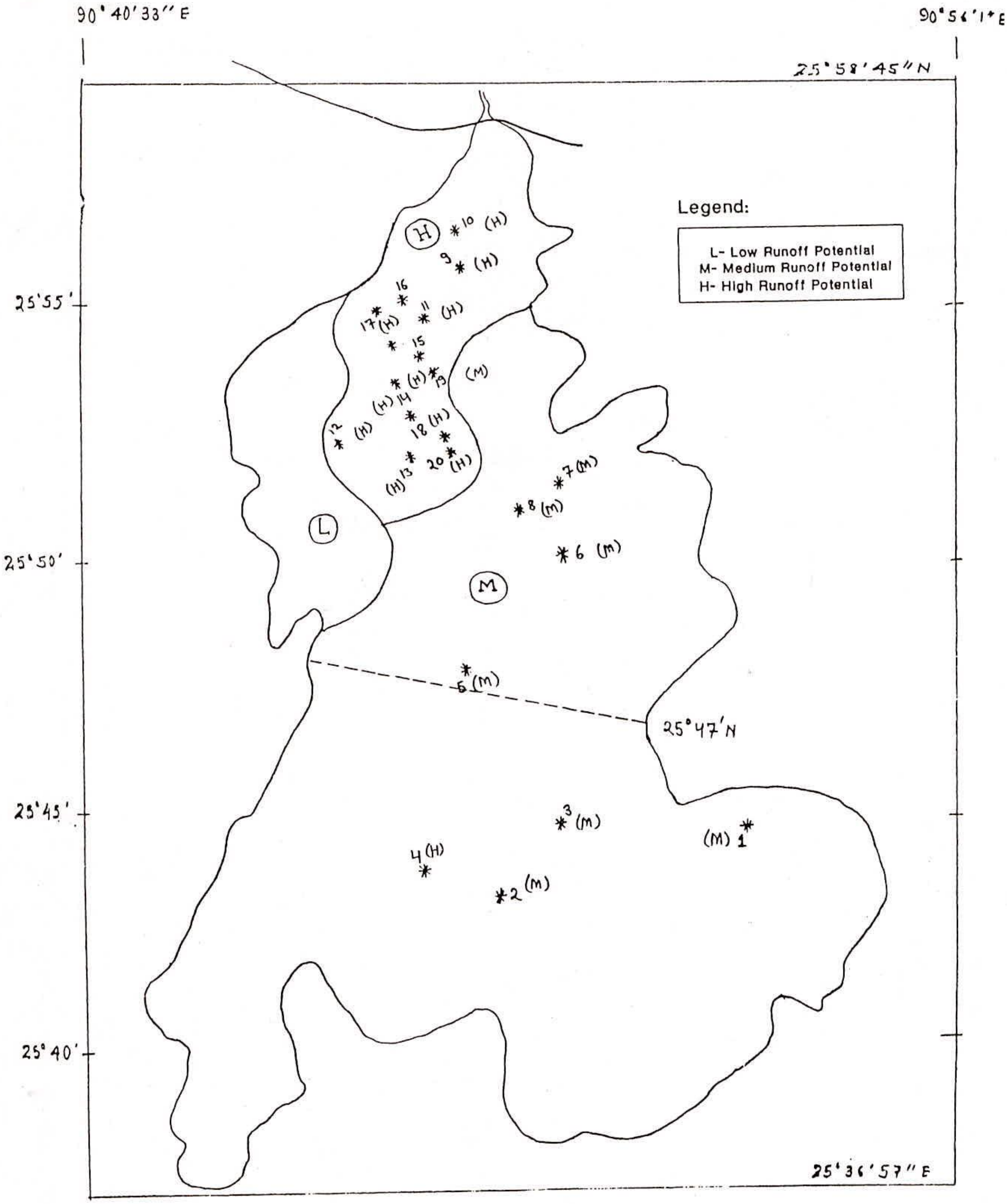

FIG. 15 Hydrologic Soil Classification based on Soil Infertibility and Permeability

Table.23
Soil Classifications of Dudhnai Sub-basin Based on S.C.S

Sl.	Site	Eff.depth (cm.)	Texture	Structure	Infiltrability (cm/hr)	Permeability (cm/hr)	Soil Group
1.	Shikal	42	SL	Strong platy compact massive	0.10	0.78***	D
2.	Dasera Sarangma	>100	LS	Strong platy compact massive	0.78	1.415*	D
3.	Dasera Sarangma(Forest Site)	>100	LS	Strong platy compact massive	0.34	0.0053	D
4.	Dinadubi	60-200	SL	Strong angular blocky	1.31	0.0170	C
5.	Khentra	<50	**	Strong platy compact massive	0.45	0.0175	D
6.	Dinadubi (Forest site)	200-380	SL	Strong angular blocky	1.60	0.0044	C
7.	Damra	>100	**	Strong platy compact massive	0.45	0.210	D
8.	Rongberan	*	Si,L	Strong platy compact massive	*	0.010	D
9.	Rongmil	*	LS	Strong angular blocky	3.82	0.024	C
10.	Rongjong	70-1650	LS	Strong angular blocky	2.057	0.118***	C

** Actual depth of soil layer not available (Approximated to the nearer station for arriving at soil group).*

*** Actual Texture not available (Approximated to the nearer station for arriving at soil group),*

**** The value indicates Flux Potential*

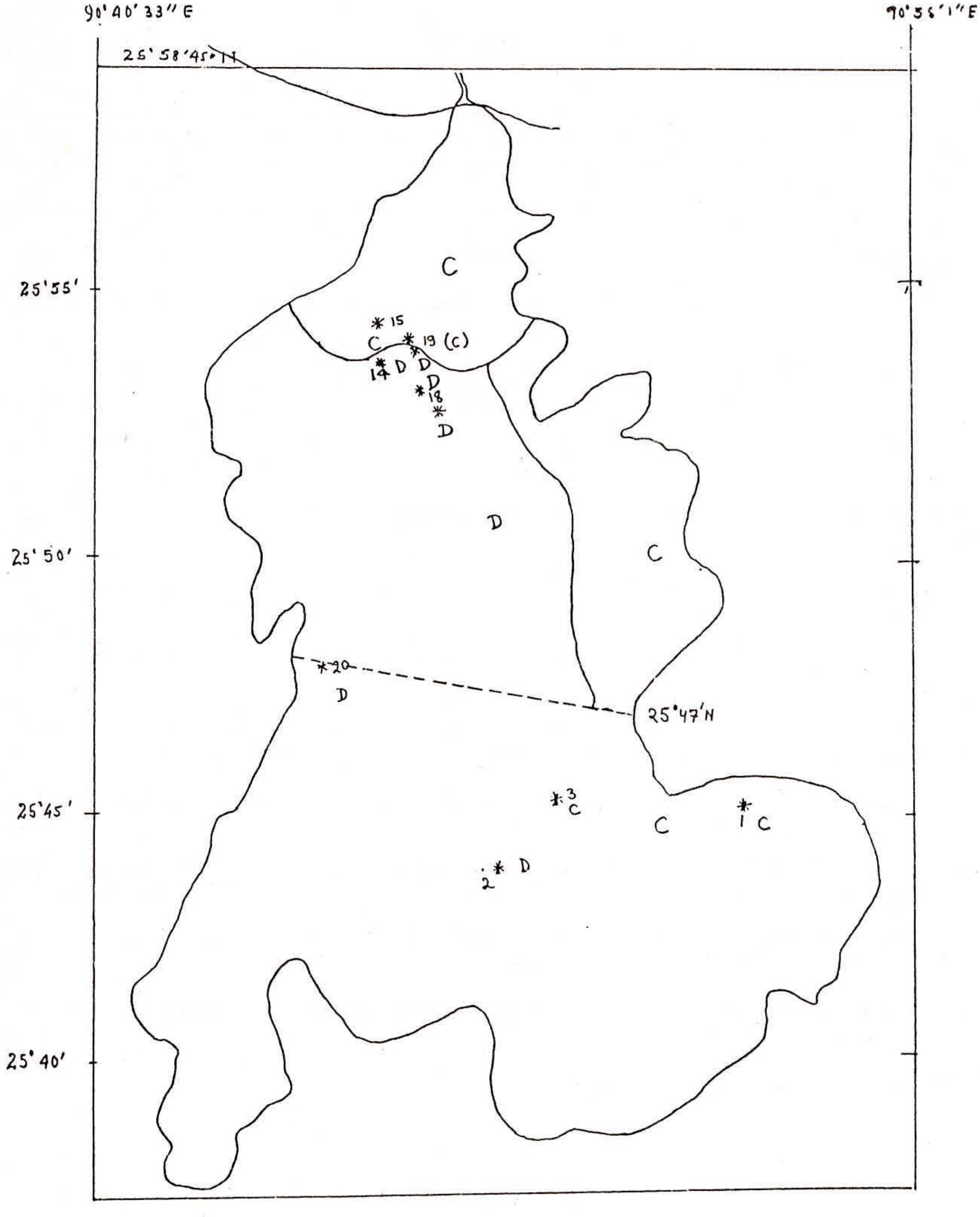

FIG.16 Hydrologic Soil Classification based on Soil SCS

4.3 Hydrologic Soil Grouping By NBSS & LU :

National Bureau of Soil Survey and Land Use Organisation has been carrying out soil surveys since 1958 in various states of the country. The surveys were done in the catchments of selected River Valley Projects. Including some of the non-river valley project areas also, so far more than 12 million hectares have been surveyed by this organisation and about 4500 soil series have been recognized by them.

The important soil characteristics like effective depth, average clay in the profile, soil structure, infiltration rate, permeability were considered in soil classification. The important characteristics of these soil series, their hydrologic soil groups, area mapped under river valley project or non-river valley project have been assessed and presented in the departmental publications of NBSS&LU.

Table.24 shows the distribution of hydrological soil group of study area as have been assessed by National bureau of Soil Survey and land use planning Regional centre, Jorhat (ICAR) in cooperation with Directorate of Agriculture, Govt. of Assam. Delineation of different soil groups have been projected in the basin map of Dudhnai in **Fig.17**.

Table.24 Distribution of Soil Group

Sl.No.	Hydrological Soil Group	Area Extended Sq.Km.	% of Extent
1.	B-Moderately low run-off potential	430.25	46.45
2.	C-Moderately low run-off potential	53.83	5.81
3.	D-High run-off potential	442.21	47.74
	Total	926.29	100.00

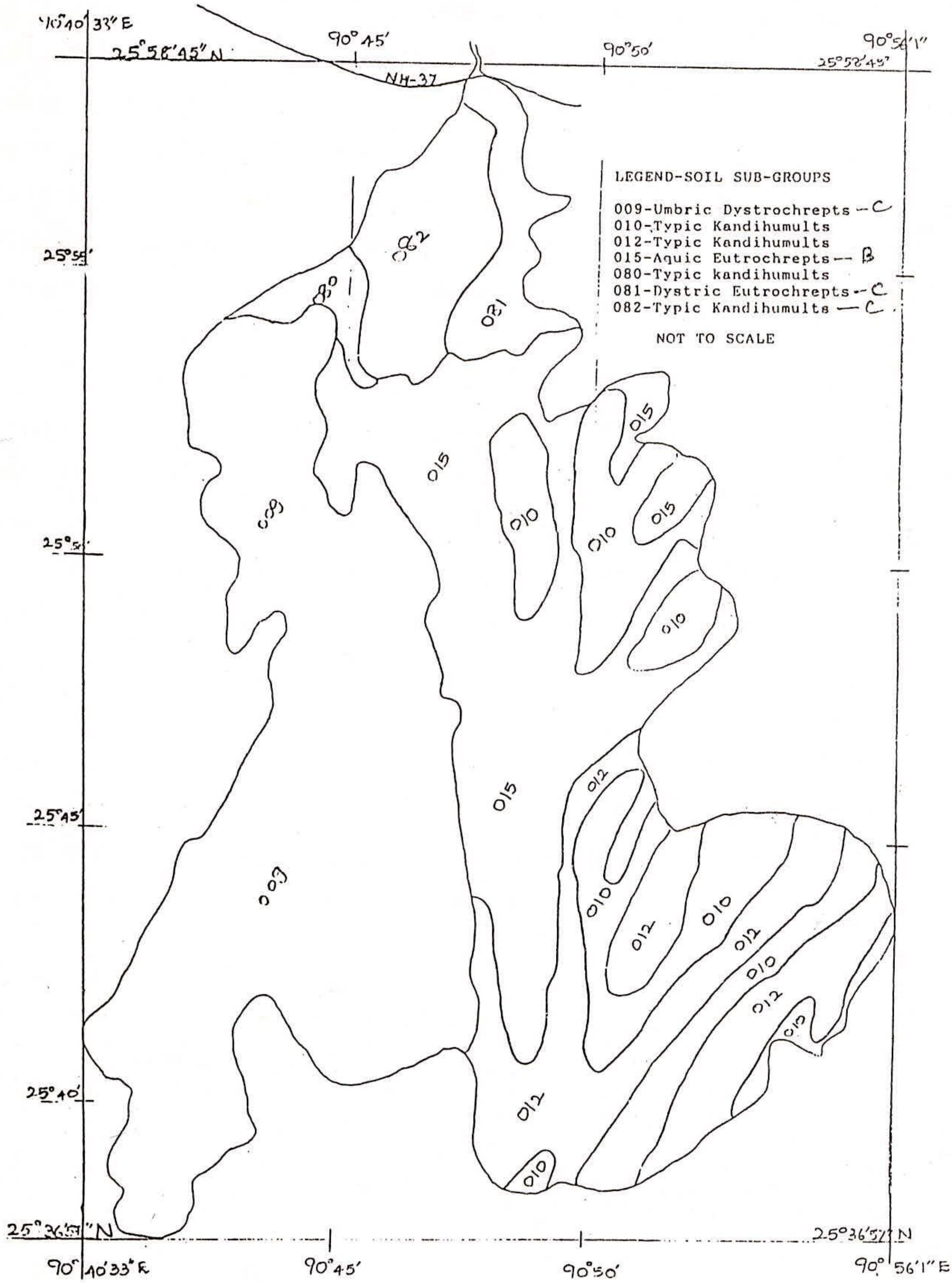

FIG. 17 Soil Resources Invantory Source: NBSS & LUP

With reference to these delineations marked in the soils are sub-grouped in terms of run-off potential and furnished in Table.25..

Table.25 Soil Sub-Groups and their Runoff Potential

Sl.No.	Soil Classification	Runoff Potential
1.	Typic Haplaquepts	C
2.	Acric Haplaquents	C
3.	Typic Udifluvents	B
5.	Aquie Udifluvent	B
6.	Acric Fluvaquents	B
7.	Typic Kandihumults	C

5.0 Concluding Remarks :

Soil classification needs knowledge of various soil properties and the extent to which the soil groups exist in a watershed. This necessitates mapping the basin after detailed soil survey. The monitoring of soil resources information is imperative, especially in areas where problems of degradation, such as rising ground water table resulting in development of soil salinity, sodicity, water-logging, erosion. etc. are encountered. Again, soil properties change with time because of various external influence upon it. Therefore, monitoring of the soils resource needs to be reviewed from time to time for scientific watershed management practices.

Many soil and landform attributes can be observed and classified. The choice depends upon the purpose for which classification is to be made. Generally, parameters which control or influence plant growth, such as soil texture, depth, profile development, drainability, soil infertability, and permeability are taken into consideration. These soil properties have also direct impact on the water balance or basin hydrological regime.

Different soil classification systems use a host of terminologies and there is need for standardization of the systems for ease of handling them and also to avoid confusion. Further, it has been difficult to ascertain the percentage contribution of the individual parameters of a system to the objectives.

The present work constitutes a component part of the overall long term representative basin studies of th the Dudhnai sub-basin. The information will be used in modelling the basin in the long run. However, with the progress of more investigations, there is scope of refinement and elaboration of the results.

REFERENCES :

1.Akroyed, T.N.W (1957)- Laboratory Testing in Soil Engineering.

2.Anonimous(1989-90)-"Role of Soils and Crops in Network Planning in the back ground paper of workshop on 'Net work Design on Water Management' organised at Guwahati by WAPCOS, MOWR & Irrigation Deptt., Assam. pp 98-102.

3.Baver, L.D (1956), "Soil Physics", Third Ed, John Willey.

4.Capper, P.H. Cassie, W.F & Gadds J.D (1966) Problems in Engineering soils, Spon Ltd. London.

5. Chow Ven Te, Handbook of Applied Hydrology, Mc Garo Hill Publications. pp.21/10 -14.

6.Dhruva Narayanan V.V.(1990)-Watershed Management. pp.2-31.

7.Drainage Manual(1978) A Water Resources Tech. publication, USBR. pp .15-27.

8.Dutta A.K. et al.(1981)-Soils of North Eastern Region, NBSS & LUP, Nagpur, Bulletin No.2.

9.Forth D. Henry, John W. Schafer, Soil Geography and Land Use, John Wiley & Sons.

10.Khanna P.N, Civil Engineers Hand Book(1988), Engineer's publishers, New Delhi. pp.6/4-17.

11.Kumar S.R. et al.(1995)- Infiltration Characteristics of Dudhnai Sub-Basin.

12.Patwary B.C. et al.(1994)- Hydrometeorological Aspects of Dudhnai sub-Basin.

13.Prasad R.N. & Munna Ram-Soils of North eastern Hill Region and their Management, pp.267-282.

14.Punima B.C., Soil Mechanics and Foundations engineering.

15.Rafael L. Brose, Hydrology- An introduction to Hydrologic Science, Auditor-Waseley Publication.

16.Rathore N.S., Natural Resources Base Development, Scientific Publishers, Jodhpur.

17.Raychandury S.P.(1966)- Land and Soil, Indian Book House, New Delhi. pp.75-92.

18.Raychandury S.P., R.R.Agarwal(1963),-Soils of India, Indian Council of Agricultural & Research, New Delhi. pp.22-35.

19.Sehgal J.L.(1994)-Soil Resources Mapping of Different States in India why & How ?, NBSS & LUP, ICAR, Nagpur.

20.Singh B., Shankar Prakash(1976), Soil Mechanics and Foundation Engg., Nemchand & Brons, Roorkee.pp.52-63.

21. Sony B. & G.C.Mishara(1984-85), Hydrologic Soil Classification, National Institute of Hydrology:RN-6, Roorkee. PP.3-12.

22. Soil Resources Mapping of Different States in India, Field Manual National Bureau of Soil Survey & Landuse Planning (1987), ICAR, Nagpur.

23. Varshoey S.C. Gupta, R.L.Gupta(1976)- Theory and design of Irrigation Structures Vol. I, Neemchand Brothers, Roorkee. pp.12-21.

24. Water Requirement & Irrigation Management of Crops in India(1977)- Water Technology Centre, IARI. Monograph No-4 (New Series), pp.20-25.

Director	*:Dr. S M Seth*
Co-ordinator	*:Dr. K K S Bhatia, Sc'F'*

Study Group:

B C Patwary	*:Scientist'E'*
P K Bhunya	*:Scientist'B'*
V S Jeykanthan	*:Scientist'B'*

Assistance

C S Chauhan	*:Technician*