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# HYDROLOGICAL SOIL CLASSIFICATION OF DUDHNAI SUB-BASIN : (ASSAM/MEGHALAYA PT-II)

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## ABSTRACT

*Hydrologic soil classification at Dudhnai sub-basin for an area of 476 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 various 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. Isoresistivity of the basin has been mapped for the available electric sounding data, at a depth of five meter and the results are interpreted for water bearing stratum of shallow sub surface. Soil water retention curves for different soil compositions have been analysed from the results of bar pressure plate and interpreted for the soil water retention characterstics. Statistical methods are applied after selecting three descriptive variables from the soil parameters to study the clusters and their deviation.*

*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.*

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## 1.0 INTRODUCTION :

Selection of the optimum drainage plan , design and construction of comprehensive drainage projects and water management works require basic soil data that must provide the knowledge of soil texture, structure, hydraulic conductivity, infiltration characteristics of the area under consideration etc. In any watershed soil characteristics play an important role in its surface runoff, soil moisture storage and deep percolation or infiltration. As a result basin response is affected by the characteristics of soils in the surface and sub-surface horizons.

Soils may be generally classified as coarse or fine , cohesive, or non cohesive, inorganic or organic, and so on. But these descriptions are general and cover a wide variety of soils in a group. A more meaningful grouping is therefore necessary to establish criterion in terms of measurable characteristics. Soil classification groups together soils of like characteristics and are designated by group name in order to simplify the procedure of identification. Such a grouping of soils, with the sole purpose of engineering application, is known as engineering soil classification. Prerequisite to the classification of soils is the concept that the soil mantle consists of natural geographic bodies with their own genesis. Such a concept became possible after the science of geology was born, even though the first theory of soil genesis as rock weathering was found inadequate later. Present systems of soil classifications reflect many more aspects of soil and theories of genesis in requirement of improved soil and water management practices.

Once the soil has been identified, its suitability for specific engineering use for planning any developmental activities in the field of agriculture, irrigation, forestry and general land use planning can be evaluated. Efforts were made during the 19th century to classify 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, Guelph 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. A report titled 'Hydrological Soil Classification of Dudhnai Sub-basin : Assam /Meghalaya' Pt-1 was completed during 1995-96 , which covered for half of the basin. In this report, besides covering the entire area some more works like statistical applications for classifying soils in clusters, soil water retention characterstics of distinct soil classes, principal component model and isoresistivity map of the basin has been added. The results of the study would be used in the subsequent hydrologic studies to model the basin.

## 2.0 METHODOLOGY :

### 2.1 General :

Hydrologic classification of soils considers soil particle size, shape, permeability, infiltration value and effective depth for grouping the soil into various classes. The detail procedure adopted for determining the various parameters used for this study are described in the subsequent section.

### 2.2 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.**

#### 2.2.1 Hydrologic Soil Groups:

<u>A: (low runoff potential)</u>

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.

<u>B: (moderately low runoff potential)</u>

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.

<u>C: (moderately high runoff potential)</u>

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.1**
**(Hydrologic Soil Classification Based On Soil Conservation Service)**

| Soil character -istics | HYDROLOGIC SOIL GROUP | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Effective depth, cm | > 100 | 51-100 | 26-50 | < 25 |
| Texture | SLS | 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 |
| Permeable-ity (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.1.** 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.

**2.2.2 Soil Texture :**

Soil texture is a term which refers to the size range of the particles present in the soil mass. The diameter of the particle present in the soil sample makes the soil to be coarse, medium and fine. **Table-2** gives the textural class names of the material larger than 2mm in diameter. The traditional method of characterizing particle sizes in the soils is to divide the particle sizes into gravel, sand, silt and clay. The soil texture is actually determined by separating these fractions and measuring their proportion which is called the mechanical analysis. The soil texture triangle is then used to convert quantitative data from detailed gradation analysis of separates less than 2 mm in diameter to textural class names of soils. Soil texture is especially important is sub surface drainage as it has a direct relationship with hydraulic conductivity and water retention (David 1982).

Table-2
(Textural classification As Per Particle Diameter)

| Material | Diameter |
|---|---|
| Stones | >10 inches |
| Cobbles | 10 - 3 inches |
| Coarse gravel | 3 - 0.5 inches |
| Fine gravel | 0.5 - 2 mm |
| Very coarse sand | 2 - 1 mm |
| Coarse sand | 1 - 0.5 mm |
| Medium sand | 0.5 - 0.25 mm |
| Fine sand | 0.25 - 0.1 mm |
| Very fine sand | 0.1 - 0.05 mm |
| Silty | 0.005 - 0.002 mm |
| Clay | Less than 0.002 mm. |

In a particle size distribution curve, the y-axis or the ordinate in the graph indicates the percentage of soil particles having the diameter finer than indicated on X-axis. Charts are also available in literature showing the percentages of clay, silt and sand in the basic soil textural classes. 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.

**2.2.3 Soil Structure And Composition :**

Formation of the soil aggregate is the result of deposition of soil solids in suspension, in air or water (sediments). The soil solids so deposited are arranged in random networks forming aggregates Soil structure refers to the arrangement of particles in the soil framework. Soil structure governs the moisture and air regimes in the soil. Field identification of soils is carried out by the Visual Examination to group the soil as single grained, granular, crumb, subgranular blocky, columnar, strong angular, blocky prismatic, strong platy compact massive

**2.2.4 Effective Soil Depth:**

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.3.**

**Table.3**
**(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***

In the present study the results of *Electrical Resistivity Investigations* obtained by C.G.W.B for E.Garo Hills & districts of Goalapara are used to identify and estimate alluvium thickness in case of some stations in the basin. For rest of the stations visual inspection of proximity digs and trenches were made during the field study to identify the top soil layer. The top soil layer were measured using tape for atleast three such different locations to get an idea about the thickness of the effective depth of the layer. The results obtained by the above methods are used to classify the basin into various groups.

2.2.5 **Infiltration:**

The rate of infiltration process determines how much water will enter the root zone and how much, if any, will runoff. Different types of soils allow water to infiltrate at different rates. For example , rain falling on a gravelly or a sandy soil will rapidly infiltrate and, provided the phreatic surface is below the ground surface, even heavy rain will not produce surface runoff. Nassif and Wilson[1] have reported in detail about the relationship of infiltration capacity as a function of both soil type and cover.

In the present study a double ring infiltrometer is used to measure infiltration rate over a period. The rings are flooded with water to a depth of 75 mm over the surface and continually filled to maintain this depth, the inflow to the central tube being measured. The infiltration rate is related to the time elapsed in a graph, which is used for determining the initial and final infiltration rate. The initial value indicates the infiltration rate at incipient moisture condition in the soil and the final value indicates the saturated infiltration rate. The above parameters are used to classify the soils on basis of their infiltrability. The results are further used to calculate the Soil Index (Discussed in detail in later part of the chapter) for the catchment

2.2.6 **Hydraulic Conductivity :**

Hydraulic conductivity is the measure of ability of a soil to conduct water under unit hydraulic head. Field saturated hydraulic conductivity ($K_s$) refers to the saturated hydraulic conductivity of soil containing entrapped air is more appropriate than the truly saturated hydraulic conductivity for unsaturated zone investigations because by definition, positive pressure heads do not persist in unsaturated conditions long enough for entrapped air to dissolve. In the presence of the water table, the auger hole method is a simple and reliable technique for measuring saturated hydraulic conductivity in relatively uniform soils.

The Guelph permeameter is used to determine $K_s$ for a particular soil. Once the soil water suction is measured, the hydraulic conductivity (k) for that soil at that soil water suction () can be readily estimated by the relationship

$K = f(e, \ )$ ........................................(1)

Guelph permeameter can measure matrix flux potential ( ) which is the measure of a soil's ability to pull water by capillary force through a unit cross sectional area in a unit time. The matric flux potential ( ) in sq.cm/sec is given by following relationship

$= 0.0572 * X * R1 - 0.0237 * X * R2$ ................(2)

where R1 and R2 are the Guelph permeameter constants and X is the constant fall of head of water in the permeameter tube.

The values of hydraulic conductivity and flux potential as obtained by Guelph permeameter for representive sites in the basin are used to classify the soils in respect to their runoff potentialities as high, medium or low. The relative classes of soil conductivity and their run-off potentials are shown in the **Table.** below:

Table.4
(Conductivity and Runoff potential)

| Conductivity 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 |

**2.3 Soil Classification On Basis Of Consistency Indices :**

Soil indices define the consistency of soils in various phases of state. Plasticity characteristics are due to presence of clay and silt in the soil. These indices correlate many soil properties of clays and the silts and gives an idea of their mineral composition. The plastic limit and liquid limit are useful in selection of soils to be used for different engineering applications.

Liquidity Index indicates the degree of degree of plasticity of the soil is relat ed to water content as per following relation,

$$I_t = \frac{W_n - W_p}{I_p} \qquad \text{..............................(3)}$$

where, $W_v$ and $W_p$ are natural water content and water content at plastic limit.

$I_p$ is the plasticity index.

Consistency Index is a measure of sensitivity of the soil is defined by he follo ing relation,

$$I_c = \frac{W_l - W_n}{I_p} \qquad \text{..............................(4)}$$

where $W_l$ is the water content at liquid limit.

The laboratory test consists of preparing a thread of moist soil by rolling it on a glass or mica plate with the palm, to a size of about 3mm diameter. Soil passing 0.425 mm sieve was selected for this test. Water content of the crumbled thread is the plastic limit. Standard Casagrande Method is used to determine the liquid limit of the soil.

**2.4 Soil Classification On the Basis Of Soil Moisture Retention 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 :

$- P = 2\ \tau\ \cos\theta / r$....................................(5)

$- P = 2\ \tau / r$ (angle of contact, $\theta = 0$)...(6)

Where P = Suction
$\tau$ = Surface tension in dynes/cm
r = Pore radius in cm
$\theta$ = 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 available. This characteristic curve differs with different basic soil properties. 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 . But, in the higher suction range (> 1 bar) the moisture retention is due mainly to the adsorption phenomena which is function of soil texture.

**2.5 Isoresistivity Map Of The Basin :**

In the present study, vertical electrical soundings (VES) data from a part of Dudhnai area have been used for the computation of true and average resistivity at various are presented in the form of iso-resistivity and average resistivity contour maps.

The data were collected by Central Ground Water Board ,N E Region, Guwahaty in parts of E. Garo hills and Goalapara district of Assam using Schlumberger configuration with maximum electrode configuration (AB/2) 250m. The location of these soundings are shown on the Dudhnai basin map(**Fig.1** ). The x- axis represents 90°40'56" to 93°45'18" E longitude and y-axis represents $25^{O}$ 30'25" to 26° 50' 35" N latitude, both converted in decimals. The same x and y-axis are

**Table-5**
**(Standard Reference Table For Interpreting Sounding Data)**

| Lithology | Resisitivity |
|---|---|
| i.Unsaturated formation | > 60 Ohm-m |
| ii.Fully saturated sand with fresh water | 40 to 60 Ohm-m |
| iii.Fully saturated sand with saline water | 10 to 40 Ohm-m |
| iv.Saturated with saline water and high clay content | 3 to 10 Ohm-m |

used in contour maps in subsequent figures in order to facilitate in identification of particular location on the maps. Each vertical electrical sounding data set is interpreted in terms of true resistivities and thicknesses of subsurface layers (i.e. p and h) using the standard **Table-5** refereed below These resistivities and thicknesses are used to compute average resistivities at 5m depth. These values are used to prepare iso-resistivity contour maps for the study area.

## 2.7 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.

## 3.0 Statistical Methods In Soil Classification:

Statistics computes descriptive statistics and t tests. Descriptive statistics are numerical summaries of data that reveals a unique piece of information about a variable. Data from the normal distribution can be completely described using the mean and standard deviation and for data that do not follow the normal distribution, other descriptive statistics are appropriate. Statistics that do not depend on the type of distribution include: range, minimum, maximum, midrange,quartiles, and percentiles.

In the statistical method of soil classification, it is observed that the soils (mainly soil profiles) fall into natural clusters or group which can then be ordered into a classification. Although little work has been done towards development of a coordinate classification scheme, however, some of the statistical methods described can be effectively used for classifying soils assuming that soil characterstics vary in a way to form a continnum in the whole population of soil. A method is suggested by which soils can be classified using a set of well separated centroids and classes formed on the basis of the general affinity of real soils to the centroid.

### 3.1 T-test :

T-test computes three types of t tests for comparing means. In t- tests, data are often described in terms of a typical experiment, where "measurements" are made on "subjects". The specific procedure depends on the type of t test required to be performed. Three types of t tests that are available are as follows:

1.The two-sample t test (independent t test) compares the means of two groups of cases,

2.The paired comparison t test (dependent t test) compares the means of two variables for a single group (the matched pairs t test is a variation of the paired t test),

3.The one-sample t test compares the mean of one variable with a known or hypothesized value.

Two-sample (independent): One or more quantitative variables is selected and one grouping variable that has only two values & separate t test is performed for each quantitative variable.

Paired comparison (Dependent): At least two quantitative variables is selected and the hypothesized or known value as a new variable is choosed along with the quantitative variable to be tested.

**3.2 Cluster Analysis:**

Cluster analysis is a multivariate procedure that detects natural groupings in data. Data "objects" are classified into groups, according to their similarity. SYSTAT provides two methods of clustering:

1.Hierarchical, tree, or linkage methods

2.The K-means splitting method, which is not necessarily hierarchical.

In tree or linkage method distances are computed with pairwise deletion of missing values, so that missing values are excluded from all computations. Profiles that are missing all their values are as far apart as possible. Join produces a tree that displays hierarchical clusters, where clusters successively contain other clusters. Each tree branch reaches one object. The most similar objects are located closest to each other. Objects may be:

1.Cases (rows)

2.Variables (columns)

3.Individual entries in the data matrix: cross-sections of a case and variable (matrix)

Matrix, under Join, clusters rows (cases) and columns (variables) and produces a shaded display of the original data matrix. Different symbols represent the magnitude of matrix values. SYSTAT chooses the number of symbols, this works well when the data fall into easily separable groups. If data are uniformly distributed, it may be required to control the number of symbols used. Missing data are displayed in the matrix as question marks . A SYSTAT file is used containing a Rectangular, SSCP, Covariance, Correlation, Similarity or Dissimilarity matrix. By Groups... allows to analyze subgroups of data, but only with Rectangular matrices. Quantitative variables are to be clustered, if variables are not selected, all numeric variables are used.

Distance metrics for computing dissimilarity between objects include:

a.Euclidian Normalized Euclidian distance Gamma (1 - Goodman-Kruskal gamma coefficient).

b.Pearson (1-Pearson product-moment correlation) Percentage of discrepant values.

Kmeans splits a set of cases into a selected number of groups by maximizing between-cluster variation relative to within-cluster variation. It produces clusters that are not necessarily hierarchical. Kmeans works on rectangular files only and clusters cases only. If one wants cluster variables, the file has to be transposed first. One must decide in advance how many clusters is required. Kmeans is like a multivariate analysis of variance in which the groups are not known in advance. The output includes MANOVA statistics, which should be interpreted with caution.

**3.2.1 Cluster Analysis Of Soil :**

In this method grouping of soils is accomplished by numerical method on basis of theii charcterstics , i.e texture, structure, soil profile etc. Groupings are done using the following general procedure : First, data for a number of units such as soil profiles are assembled including a sizable number of selected variable properties for each unit. The data are commonly arranged into a matrix consisting of soils by columns and soil properties in rows. Next an overall estimate of resemblance is obtained between pairs of soils by some mathematical function of all differences between the values for each property of the two soils. After numerical estimate of the resemblance between all pairs of soils are obtained, the matrix is subjected to sorting strategy which forms groups of similar soils. The nature of groups formed and their relationships can be presented in various ways like recorded matrices, ordination or simple tables.

### 3.3 Ordination Of Soils :

Another approach to the examination of taxonomic structure is through ordination, which is normally used when the distribution of individuals tends to continuous rather than in distinct clusters. Two kinds of ordination has been used in soil studies such as Q-type and R-type ordination. Q-type ordination helps in analysis of objects operating on a similarity matrix and examines the distribution of objects to find the dimensions along which the objects are distributed. These dimensions are formed by clusters of covarient variables. R-type ordination starts by extracting the eigenvalues and eigen vectors of the correlation matrix, and than discarding the less important of these.

#### 3.3.1 Common Factor Model :

Factor analytic methods decompose a correlation or covariance matrix into linear components (factors) that explain linear relationships among the variables. With a rectangular data set, factor computes a correlation or covariance matrix before factoring. Missing values are handled with pairwise or listwise deletion. One may use factor to compute principal components, then use MGLH to regress variables onto the components.

The common factor model describes observed variables as a function of unobserved factors. It expresses variation within observed variables as common variation among factors and specific variation among random errors. The fundamental factor equation is:

Observed covariances = Factor covariances + Error covariances

The covariances in this equation are usually expressed in matrix form. Factors are estimated iteratively until communalities, which are the diagonal values of the hypothetical factor covariance matrix, are indistinguishable from the diagonal of the modified observed covariance matrix. To estimate initial communalities, SYSTAT uses the squared multiple correlations or the maximum absolute correlations. Select the quantitative variables to factor. If you don't select variables, all numeric variables are used.

Equamax maximize simultaneously the variance of loadings across rows and down through columns of the component loadings matrix

Varimax maximize the variance of loadings down through columns of the component loadings matrix

Quartimax maximize the variance of loadings across rows of the component loadings matrix

Eigenvalue to be retained in order to limit the number of factors

* Pairwise deletion : Uses pairwise deletion when values are missing.
* Plot factors : Plot all possible pairs of factor loading
* Sort loadings : Make high loadings adjacent and list from highest to lowest in matrix.

**3.3.2 Principal Components Model :**

Principal components computes component lines that summarize associations among variables. Each component line is perpendicular, or "orthogonal," to the others in the component space, and each accounts for a maximum portion of the available variance. Some researchers want to know the relation between original values and the components. Covariances of the original variables with their components are called component loadings. The signs of the loadings are arbitrary. First the quantitative variables required is selected and if no variables are selected, all numeric variables will be chosen.

## 4.0 RESULTS AND ANALYSIS :

Soil classifications based on hydrologic soil properties soil indices, Soil-water retention characterstic and that by National Board of Soil Survey & Land Use (NBSS & LU) are analysed here in this section. Thirty one locations are selected for collection of field samples over the whole of basin are shown in **Fig.1.** On the basis of data ascertained from field & laboratory experiments, the interpretaion has been made to classify soils of Dudhnai sub-basin into different soil groups. The isoresistivity contour map for the basin is derived for interpreting the saturated alluvium layer. Soil-water retention tests carried out for twelve representative locations is discussed for deriving a representing relattionship between moisture tension and moisture content.

### 4.1 Classification Based on Hydrological Soil Properties :

The soil parameters used for hydrologic grouping of soils 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 effective depth are determined for the represented sites 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 given in **Table-6.**

#### 4.1.2 Classification Based on Soil Texture of Dudhnai :

From the particle size distribution the grain size distribution of the soil samples was found out. Using soil triangle, the textural classification of the study area was found and is given in **Table-7.**On the basis of texture various soils in the basin has been classified **(Fig.2).**

#### 4.1.3 Classification Based on Soil Structure of Dudhnai:

The arrangement of soil particles in the soil is refered to as structure of a particular soil and this governs the moisture and air regimes in the soil. The structure is classified to various nomeclature as discussed in Ch-2 of the report

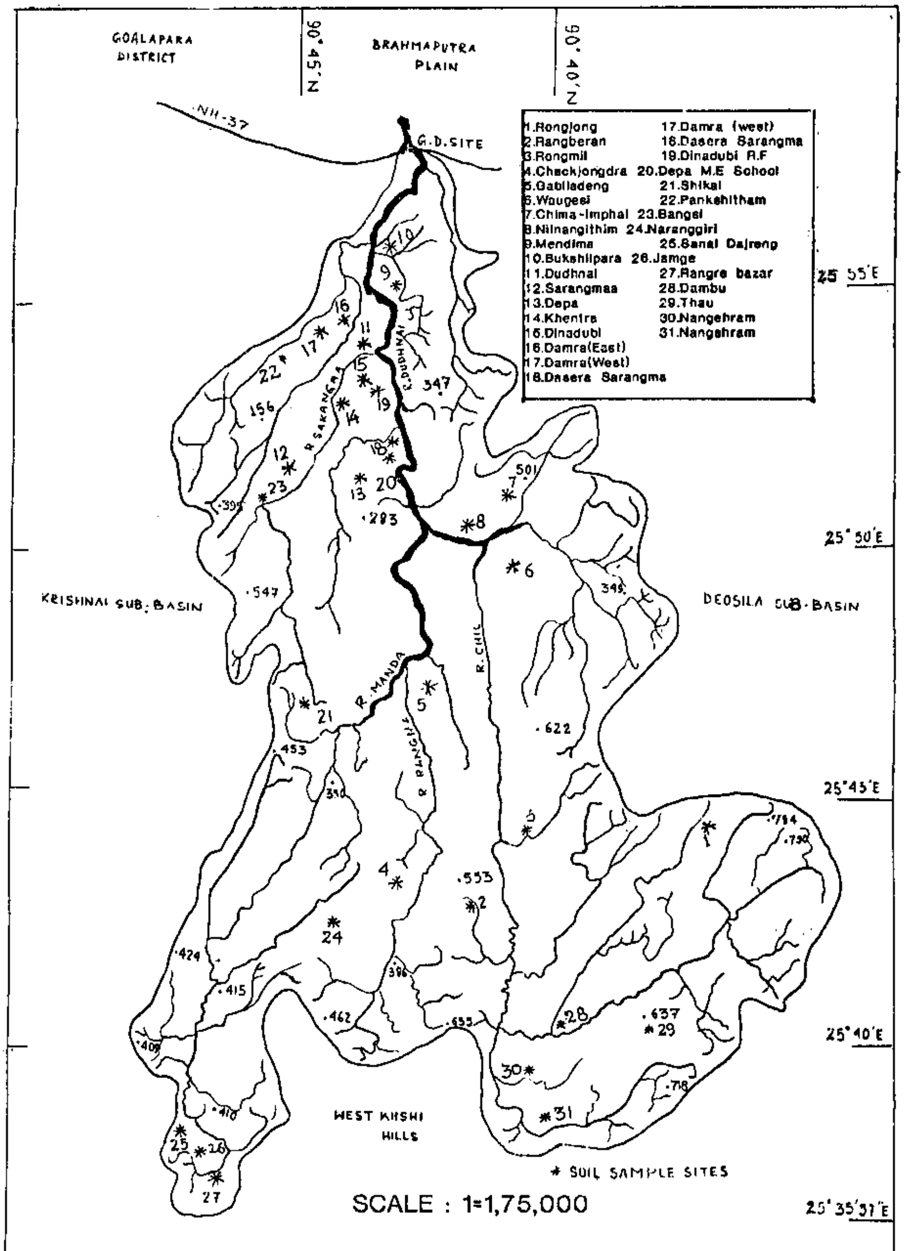



**Fig.1 INDEX MAP OF DUDHNAI SUB-BASIN**

**Table-6**

(Classification Based On Effective Depth Of Soil)

| Sl No Site | Effective Depth Of Soil in M. | Class | Runoff potential |
|---|---|---|---|
| 1. Rong Jong | 16.5 | d5 | Low |
| 2. Rongberan | 0.40 | d4 | Moderately low |
| 3. Rongmil | 0.40 | d4 | Moderately low |
| 4. Chakjongdra | ** | ** | ** |
| 5. Gabliadeng | ** | ** | ** |
| 6. Waugesi | 0.40 | d4 | Moderately low |
| 7. Chima-Imphal | 0.40 | d4 | Moderately low |
| 8. Nilnangithim | ** | ** | ** |
| 9. Mendima | 7.60 | d5 | Low |
| 10.Bukshilpara | 6.00 | d5 | Low |
| 11.Dudhnai | 3.00 | d5 | Low |
| 12.Sarangma | 0.60 | d4 | Moderately low |
| 13.Depa | >1 | d5 | Low |
| 14.Khentra | >1 | d5 | Low |
| 15.Dinadubi | 0.60 | d4 | Moderately low |
| 16.Damra(E) | >1 | d5 | Low |
| 17.Damra(W) | >1 | d5 | Low |
| 18.Desera Sarangma | >1 | d5 | Low |
| 19.Dinadubu R.F | 7.40 | d5 | Low |
| 20.Depa M E School | >1 | d5 | Low |
| 21.Shikal | 0.42 | d4 | Moderately low |
| 22.Pankshitham | 0.60 | d4 | Moderately low |
| 23.Bangsi | 0.60 | d4 | Moderately low |
| 24.Naranggiri | 0.60 | d4 | Moderately low |
| 25.Sanal Dajrang | 0.60 | d4 | Moderately low |
| 26.Jamge | 0.60 | d4 | Moderately low |
| 27.Rangre Bazar | 0.60 | d4 | Moderately low |
| 28.Dambu | 0.60 | d4 | Moderately low |
| 29.Thau | 0.60 | d4 | Moderately low |
| 30.Nangehram | 0.60 | d4 | Moderately low |
| 31.Nangshram | 0.60 | d4 | Moderately low |

*** Data not available*

## Table-7

(Classification Of Soils Of Dudhnai Based On Texture)

| Sl No Site | Qualifying texture Class | Runoff potential |
|---|---|---|
| 1. Rong Jong | Loamy sand, Well graded | Low |
| 2. Rongberan | Silty sand, Uniformly graded | Moderately high |
| 3. Rongmil | Loamy sand, Medium graded | Low |
| 4. Chakjongdra | Silty sand, Uniformly graded | Moderately high |
| 5. Gabliadeng | Silty sand, Uniformly graded | Moderately high |
| 6. Gandual | Loamy sand, Uniformly graded | Low |
| 7. Chima-Imphal | Loamy sand, Well graded | Low |
| 8. Nilnangithim | Silty sand, Uniformly graded | Moderately high |
| 9. Mendima | Loamy sand, Medium graded | Low |
| 10.Bukshilpara | Loamy sand, Well graded | Low |
| 11.Dudhnai | Silty sand, Uniformly graded | Moderately high |
| 12.Sarangma | Loamy sand, Medium graded | Low |
| 13.Depa | Loamy sand, Medium graded | Low |
| 14.Khentra | Sandy loam, Well graded | Low to moderately low |
| 15.Dinadubi | Sandy loam, Well graded | Low to moderately low |
| 16.Damra(E) | Loamy sand, Medium graded | Low |
| 17.Damra(W) | Loamy sand, Medium graded | Low |
| 18.Dasera Sarangma | Loamy sand, Medium graded | Low |
| 19.Dinadubu R.F | Sandy loam, Well graded | Low to moderately low |
| 20.Depa M E School | Loamy sand, Medium graded | Low |
| 21.Shikal | Sandy loam, Well graded | Low to moderately low |
| 22.Pankshitham | Sandy loam, Well graded | Low to moderately low |
| 23.Bangsi | Sandy loam, Well graded | Low to moderately low |
| 24.Naranggiri | Sandy loam, Well graded | Low to moderately low |
| 25.Sanal Dajrang | Sandy loam, Well graded | Low to moderately low |
| 26.Jamge | Clayie, Medium graded | Low |
| 27.Rangre Bazar | Sandy loam, Well graded | Low to moderately low |
| 28.Dambu | Loamy sand, Medium graded | Low |
| 29.Thau | Silty loam, Well graded | Low |
| 30.Nangehram | Sandy loam, Well graded | Low to moderately low |
| 31.Nangshram | Sandy loam, Well graded | Low to moderately low |

**Table-8**

(Classification Based On Soil Structure)

| Sl No Site | Soil Structure | Runoff potential |
|---|---|---|
| 1. Rong Jong | Strong angular, Blocky prismatic | Moderately high to high |
| 2. Rongberan | Single grained | Low |
| 3. Rongmil | Strong angular, Blocky prismatic | Moderately high to high |
| 4. Chakjongdra | Silty sand, Uniformly graded | Moderately high |
| 5. Gabliadeng | Strong angular, Blocky prismatic | Moderately high to high |
| 6. Gandual | Strong platy, Compact massive | High |
| 7. Chima-Imphal | Strong angular, Blocky prismatic | Moderately high to high |
| 8. Nilnangithim | Strong angular, Blocky prismatic | Moderately high to high |
| 9. Mendima | Strong platy, Compact massive | High |
| 10.Bukshilpara | Strong platy, Compact massive | High |
| 11.Dudhnai | Strong platy, Compact massive | High |
| 12.Sarangma | Strong platy, Compact massive | High |
| 13.Depa | Strong platy, Compact massive | High |
| 14.Khentra | Strong platy, Compact massive | High |
| 15.Dinadubi | Strong angular, Blocky prismatic | Moderately high to high |
| 16.Damra(E) | Strong platy, Compact massive | High |
| 17.Damra(W) | Strong platy, Compact massive | High |
| 18.Dasera Sarangma | Strong platy, Compact massive | High |
| 19.Dinadubu R.F | Strong angular, Blocky prismatic | Moderately high to high |
| 20.Depa M E School | Single grained | Low |
| 21.Shikal | Sandy loam, Well graded | Low to moderately low |
| 22.Pankshitham | Subangular blocky, Colmunar | Mod. low to mod. high |
| 23.Bangsi | Granular crumb | Moderately low to low |
| 24.Naranggiri | Granular crumb | Moderately low to low |
| 25.Sanal Dajrang | Strong angular, Blocky prismatic | Moderately high to high |
| 26.Jamge | Strong angular, Blocky prismatic | Moderately high to high |
| 27.Rangre Bazar | Single grained | Low |
| 28.Dambu | Single grained | Low |
| 29.Thau | Single grained | Low |
| 30.Nangehram | Granular crumb | Moderately low to low |
| 31.Nangshram | Granular crumb | Moderately low to low |

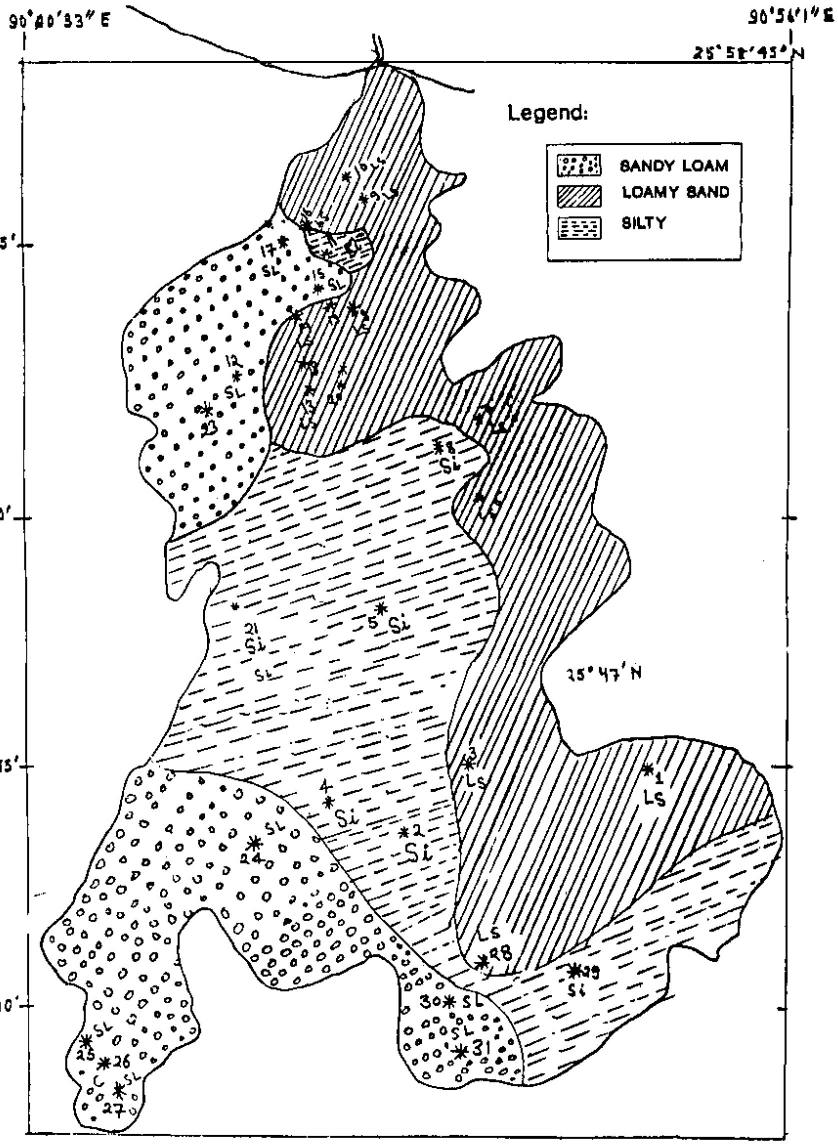



Fig.2 HYDROLOGIC SOIL CLASSIFICATION FOR DUDHNAI BASIN BASED ON TEXTURE AND STRUCTURE

## Table-9

(Infiltration Data For Dudhnai Basin)

| Sl No Site | Infiltration Rate in Cm/Hr. | | Runoff Potential |
|---|---|---|---|
| | Initial Rate | Final Rate | |
| 1. Rong Jong | 777.60 | 2.050 | Moderately high to high |
| 2. Ronberan | ** | ** | ** |
| 3. Rongmil | 2160.0 | 3.820 | Moderately high to high |
| 4. Chakjongdra | 878.40 | 0.730 | High |
| 5. Gabliadeng | 5400.0 | 2.200 | Moderately high to high |
| 6. Waugesi | ** | ** | ** |
| 7. Chima-Imphal | 1166.4 | 1.880 | Moderately high to high |
| 8. Nilnangithim | 705.60 | 1.710 | Moderately high to high |
| 9. Mendima | 1512.0 | 0.520 | High |
| 10.Bukshilpara | 835.20 | 0.580 | High |
| 11.Dudhnai | 921.60 | 0.540 | High |
| 12.Sarangma | 1310.4 | 0.900 | High |
| 13.Depa | 1051.2 | 0.510 | High |
| 14.Khentra | 662.40 | 0.450 | High |
| 15.Dinadubi | 864.00 | 0.510 | High |
| 16.Damra(E) | 489.60 | 0.450 | High |
| 17.Damra(W) | 676.80 | 0.530 | High |
| 18.Dasera Sarangma | 331.00 | 0.340 | High |
| 19.Dinadubu R.F | 259.20 | 1.810 | Moderately high to high |
| 20.Depa M E School | 953.60 | 0.320 | High |
| 21.Shikal | 1.600 | 0.100 | High |

**Table-10**

(Soil Classification Based On Permeability & Flux Potential)

| Sl No Site | Permeability Of Soil in cm/hr | Permeability Class | Runoff potential |
|---|---|---|---|
| 1. Rong Jong | 0.118** | Very slow | High |
| 2. Rongberan | 0.010* | Very slow | High |
| 3. Rongmil | 0.024* | Very slow | High |
| 4. Chakjongdra | 1.018 | Moderately slow | Moderately high |
| 5. Gabliadeng | 1.103 | Moderately slow | Moderately high |
| 6. Waugesi | 5.016 | Moderately rapid | Moderately low |
| 7. Chima-Imphal | 5.004 | Moderately rapid | Moderately low |
| 8. Nilnangithim | 0.713 | Moderately slow | Moderately high |
| 9. Mendima | 1.010 | Moderately slow | Moderately high |
| 10.Bukshilpara | 7,165 | Moderately rapid | Moderately low |
| 11.Dudhnai | 1.214 | Moderately slow | Moderately high |
| 12.Sarangma | 1.415** | Moderately slow | Moderately high |
| 13.Depa | 2.014 | Moderate | Mod. high to low |
| 14.Khentra | 0.018* | Very slow | High |
| 15.Dinadubi | 0.004* | Very slow | High |
| 16.Damra(E) | 0.210* | Slow | High |
| 17.Damra(W) | 0.210* | Slow | High |
| 18.Dasera Sarangma | 0.005* | Very slow | High |
| 19.Dinadubu R.F | 0.017* | Very slow | High |
| 20.Depa M E School | 1.723 | Moderately slow | Moderately high |
| 21.Shikal | 0.780** | Moderately slow | Moderately high |
| 22.Pankshitham | 7.500 | Moderately rapid | Moderately low |
| 23.Bangsi | 14.40 | Rapid | Low |
| 24.Naranggiri | 12.75 | Moderately rapid | Moderately low |
| 25.Sanal Dajrang | 2.400 | Moderate | Mod.high to low |
| 26.Jamge | 10.75 | Moderately rapid | Moderately low |
| 27.Rangre Bazar | 11.25 | Moderately rapid | Moderately low |
| 28.Dambu | 0.100 | Very slow | High |
| 29.Thau | Rapid | | |
| 30.Nangehram | Rapid | | |
| 31.Nangshram | Rapid | | |

** Runoff classification is based on the hydraulic conductivity as obtained from Guelph Permeameter results.*

***Runoff classification is based on the flux potential as obtained from Guelph Permeameter results.*

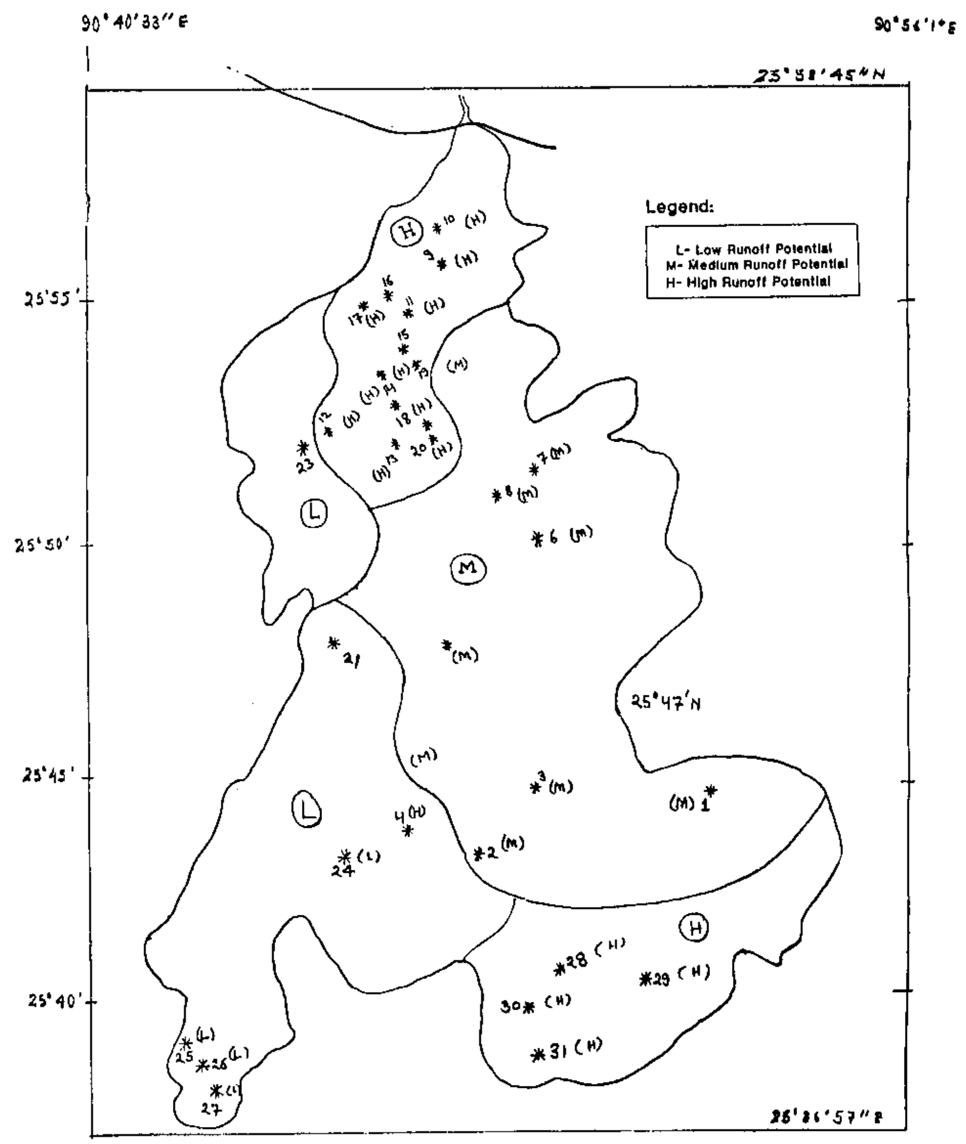



**Fig.3 HYDROLOGIC SOIL CLASSIFICATION FOR DUDHNAI BASIN BASED ON SOIL INFERTIBILITY AND PERMEABILITY**

on basis of visual inspection and are grouped as given in **Table-8.** Soil classification based on structure for the basin is shown in **Fig.2.**

**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 as per the method discussed earlier in the report. Initial infiltration rate at incipient moisture conditions and final infiltration rate at the represnted sites are considered for grouping the soils into various hydrlogical classes. The results are illustrated for all represeted sites in the **Table-9** and the soil classification for the basin on basis of infiltration results are shown in **Fig.3**

**4.1.5 Classification Based on Permeability Data of Dudhnai**

On the basis of governing criteria as already discussed in **clause 2.3.5** soils samples were tested for their permeability in the laboratory using ICW Permeameter. In persuance of the field tests measurement of hydraulic conductivity and flux potential was carrieid out at 50 cm layer at ten sites using Guelph Permeameter. The results are used for classification as per SCS criteria is shown **Table-10** and **Fig.3**

**4.2 Hydrologic Soil Classification based on SCS :**

The basin is divided into ten grids identified by numbers signifying X and Y coordinate numbers. Each grid is clssified into A, B, C and D on basis of soil groups of the sampling sites within the grid. SCS governed guidelines discussed in **clause 2.4.1** are used to identify the soil groupings of different stations. The results are presented in **Table-11** and **Fig.4..**

**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.

## Table-11

(Soil Classification Of Dudhnai Sub-basin Based On S.C.S)

| Site | Structure | Texture | Eff. Depth (cm.) | Permeability (Cm/Hr) | Soil Group |
|---|---|---|---|---|---|
| 1. Rong Jong | Strong angular | LS | 16.5 | 0.118 | D |
| 2. Rongberan | Single grained | Si | 0.40 | 0.010 | D |
| 3. Rongmil | Strong angular | LS | 0.40 | 0.024 | D |
| 4. Chakjongdra | Uniformly graded | Si | ** | 1.018 | C |
| 5. Gabliadeng | Strong angular | Si | ** | 1.103 | C |
| 6. Gandual | Strong platy | LS | 0.40 | 5.016 | B |
| 7. Chima-Imphal | Strong angular | LS | 0.40 | 5.004 | B |
| 8. Nilnangithim | Strong angular | Si | ** | 0.713 | D |
| 9. Mendima | Strong platy | LS | 7.60 | 1.010 | C |
| 10.Bukshilpara | Strong platy | LS | 6.00 | 7.165 | B |
| 11.Dudhnai | Strong platy | Si | 3.00 | 1.214 | C |
| 12.Sarangma | Strong platy | LS | 0.60 | 1.415 | C |
| 13.Depa | Strong platy | LS | >1 | 2.014 | C |
| 14.Khentra | Strong platy | SL | >1 | 0.018 | D |
| 15.Dinadubi | Strong angular | SL | 0.60 | 0.004 | D |
| 16.Damra(E) | Strong platy | LS | >1 | 0.210 | D |
| 17.Damra(W) | Strong platy | LS | >1 | 0.210 | D |
| 18.Desera Sarangma | Strong platy | LS | >1 | 0.005 | D |
| 19.Dinadubu R.F | Strong angular | SL | 7.40 | 0.017 | B |
| 20.Depa M E School | Single grained | LS | >1 | 1.723 | C |
| 21.Shikal | Well graded | SL | 0.42 | 0.780 | D |
| 22.Pankshitham | Subangular | SL | 0.60 | 7.500 | B |
| 23.Bangsi | Granular crumb | SL | 0.60 | 14.40 | A |
| 24.Naranggiri | Granular crumb | SL | 0.60 | 12.75 | A |
| 25.Sanal Dajrang | Strong angular | SL | 0.60 | 2.400 | B |
| 26.Jamge | Strong angular | Clay | 0.60 | 10.75 | B |
| 27.Rangre Bazar | Single grained | SL | 0.60 | 11.25 | B |
| 28.Dambu | Single grained | LS | 0.60 | 0.100 | D |
| 29.Thau | Single grained | SL | 0.60 | Rapid | A |
| 30.Nangehram | Granular crumb | SL | 0.60 | Rapid | A |
| 31.Nangshram | Granular crumb | SL | 0.60 | Rapid | A |

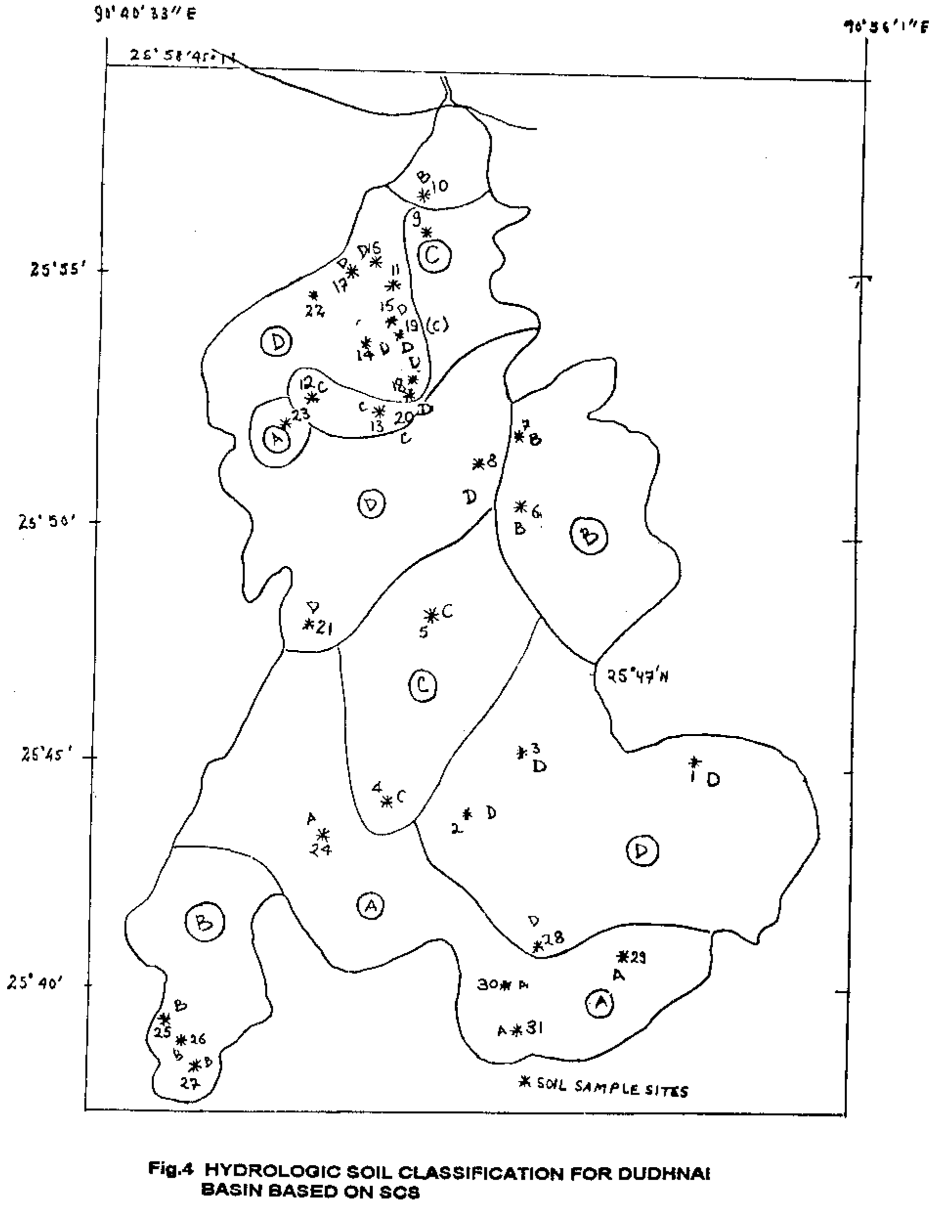


**Fig.4 HYDROLOGIC SOIL CLASSIFICATION FOR DUDHNAI BASIN BASED ON SCS**

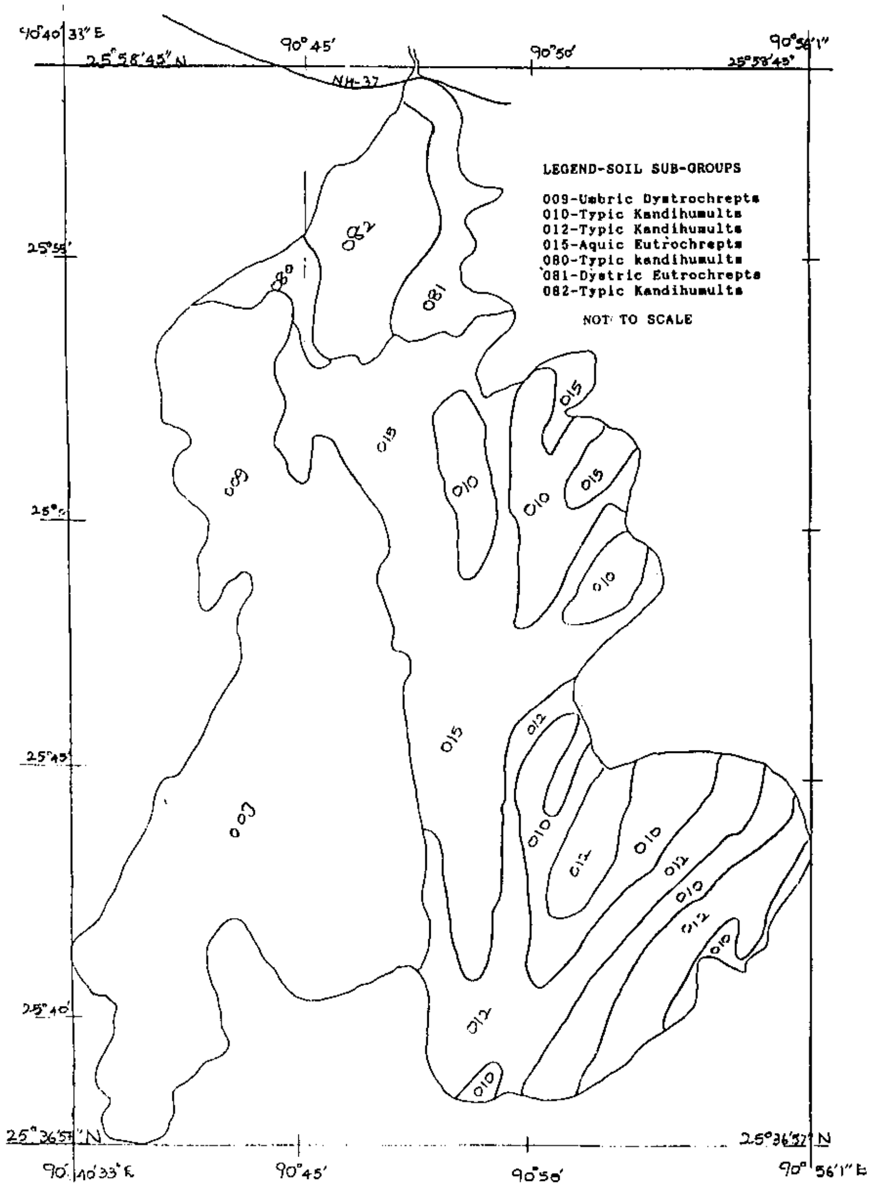



**Fig.5 SOIL RESOURCES INVENTORY.**
***Source : NBSS & LU***

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-12 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.5.

**Table-12**
**(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 |

With reference to these delineations marked in the soils are sub-grouped in terms of run-off potential and furnished in Table-13..

Table-13
(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 |

**4.4 Iso-Resistivity Map Of Dudhnai :**

The data of preliminary report on Vertical Electrical Soundings results of Goalapara and East Garo Hills published by North Eastern Regional Centre of

**Table-14**
**(Electro - Resistivity Data For Dudhnai Basin)**

| Sl No Site | Longitude | Latitude | Resistivity (Ohm - m) | Depth (m) |
|---|---|---|---|---|
| 1. Rong Jong | 90° 37' 00" | 25° 44' 50" | 46 | 3.8 |
| 2. Rongberan | 90° 42' 20" | 25° 42' 50" | 500 | 1.9 |
| 3. Rongmil | 90° 41' 20" | 25° 43' 00" | 500 | 1.9 |
| 4. Waugesi | 90° 41' 10" | 25° 41' 10" | 102 | 4.7 |
| 5. Chima-Imphal | 90° 41' 00" | 25° 51' 30" | 260 | 4.7 |
| 6. Nilnangithim | 90° 41' 10 | 25° 50' 10" | 260 | 4.7 |
| 7. Sarangma | 90° 45' 30 | 25° 52' 55" | 100 | 1.0 |
| 8. Depa | 90° 44' 00 | 25° 51' 50" | 100 | 1.0 |
| 9. Khentra | 90° 44' 45 | 25° 53' 10" | 45 | 1.0 |
| 10.Dinadubi | 90° 44' 00 | 25° 53' 50" | 45 | 1.0 |
| 11.Dinadubu R.F | 90° 44' 40 | 25° 53' 30" | 45 | 1.0 |
| 12.Shikal | 90° 45' 00 | 25° 47' 20" | 100 | 0.6 |
| 13.Bangsi | 90° 46' 00 | 25° 54' 10" | 92 | 1.3 |
| 14.Dambu | 90° 40' 10 | 25° 51' 55' | 54 | 2.2 |
| 15.Nangehram | 90° 41' 30 | 25° 40' 00" | 54 | 2.2 |
| 16.Nangshram | 90° 41' 55 | 25° 39' 00" | 170 | 7.0 |

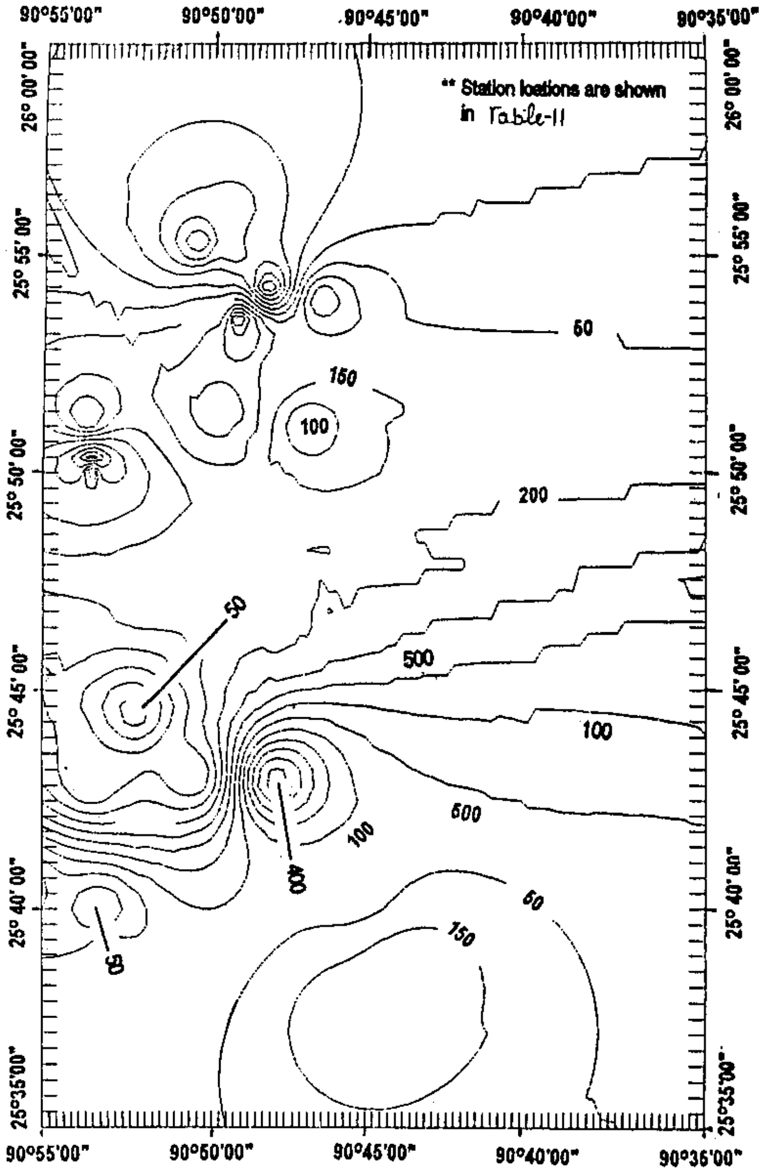
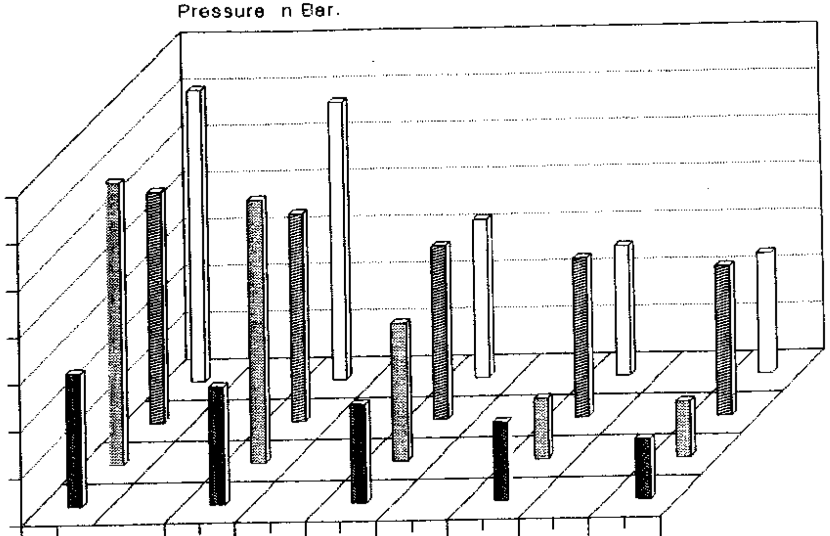



**Fig.6 ISORESISTIVITY MAP FOR 5 M. DEPTH IN DUDHNAI BASIN**

## Table-15

(Soil-Moisture Retention For Different Soils Of Dudhnai Sub-basin at Various Pressures)

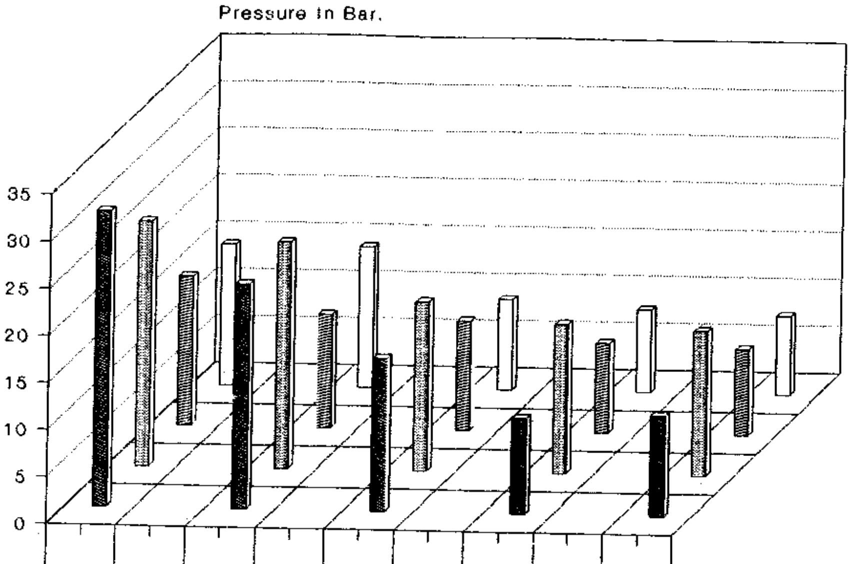
| Sl Site/Pressure in bar | 0.33 | 2.0 | 3.0 | 10.0 | 15.0 |
|---|---|---|---|---|---|
| | | | Soil Moisture in % | | |
| 1. Rong Jong | 14.12 | 12.55 | 10.47 | 8.330 | 6.330 |
| 2. Rongberan | 30.07 | 28.02 | 14.65 | 6.420 | 5.910 |
| 3. Rongmil | 24.67 | 22.09 | 18.46 | 16.92 | 15.89 |
| 4. Chakjongdra | 31.12 | 29.60 | 16.84 | 13.78 | 12.75 |
| 5. Gabliadeng | 31.47 | 23.85 | 16.24 | 10.15 | 10.65 |
| 6. Waugesi | 26.08 | 24.03 | 17.90 | 15.83 | 15.32 |
| 7.Sanal Dajrang | 15.58 | 12.05 | 11.62 | 9.500 | 9.100 |
| 8.Dambu | 14.93 | 14.91 | 9.600 | 8.760 | 8.350 |
| 9.Thau | 14.96 | 12.93 | 8.300 | 5.770 | 4.900 |
| 10.Nangehram | 22.67 | 22.27 | 12.67 | 10.92 | 10.48 |
| 11.Nangshram | 35.01 | 29.97 | 22.65 | 19.90 | 18.99 |
| 12.Bangsipal | 34.24 | 32.61 | 27.66 | 24.27 | 23.44 |




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Chak Jongdra | 31.12 | 29.6 | | 16 84 | | 13.78 | | 12.75 |
| Rongmil | 24.67 | 22 09 | | 18 46 | | 16.92 | | 15.89 |
| Rong Beran | 30.07 | 28 02 | | 14.65 | | 6.42 | | 5.91 |
| Rong Jong | 14.12 | 12.55 | | 10.47 | | 8.33 | | 6.33 |

Soil Moisture In %

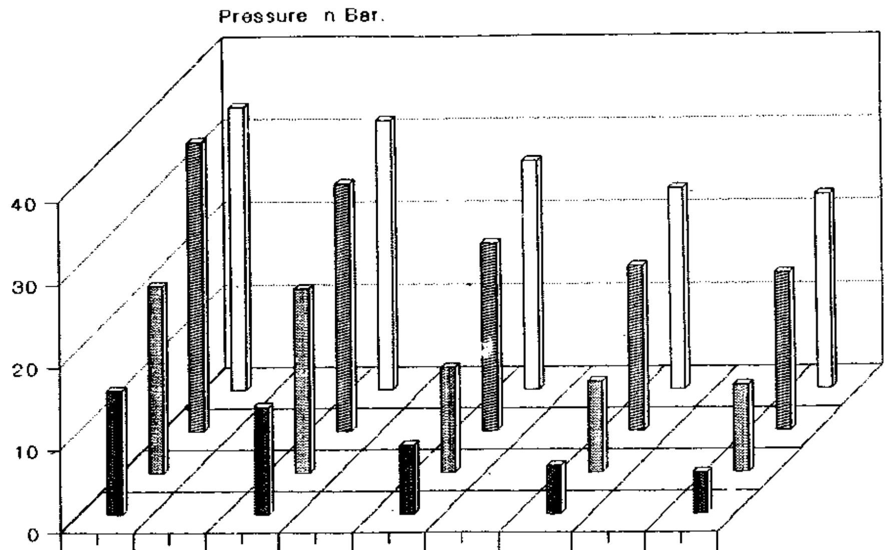
Fig.7 Soil Moisture Retention Curve.




| | | | | | |
|---|---|---|---|---|---|
| Dambu | 14.93 | 14.91 | 9.6 | 8.76 | 8.35 |
| Sanai Dajreng | 15.85 | 12.05 | 11.62 | 9.5 | 9.[illegible] |
| Waugesi | 26.06 | 24.03 | 17.95 | 15.83 | 15.32 |
| Gabliadeng | 31.47 | 23.85 | 16.24 | 10.15 | 10.65 |

Soil Moisture in %

Fig.8 Soil Moisture Retention Curves.




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Bangsipal | 34.24 | | 32.61 | | 27.66 | | 24.27 | | 23.44 |
| Nangshrsm | 35.01 | | 29.97 | | 22.65 | | 19.9 | | 18.99 |
| Nangehrsm | 22.61 | | 22.27 | | 12.67 | | 10.92 | | 10.48 |
| Thau | 14.96 | | 12.93 | | 8.3 | | 5.775 | | 4.9 |

Soil Moisture in %

Fig.9 Soil Moisture Retention Curves.

C.G.W.B is used for obtaining the isoresistivity map for the basin. Fourteen vertical electrical soundings data of schumberger configuration with maximum electrode expansion (AB/2) of 250 m collected from Dudhnai-area-Meghalaya & Assam are interpreted in terms of resistivities and thicknesses of various subsurface layers. Resistivity contour maps have been used to identify the unsaturated alluvium thickness. These resistivity variations of different sites are interpreted in terms of alluvium thickness and are shown in **Fig.6.** For the locations of stations **Table-14** is to be refered.

**4.5 Soil Water Retention Characterstics Of Soils In Dudhnai :**

In the tests carrieid out in the laboratory soil moisture at different values were determined as per the procedure discussed in **clause 2.4.** The soils used for the test were taken from samples earlier collected from twelve sites of the representative basin. These values broadly represent three groups of soil types viz, silty, sandy and clay. The graph plotted between the tension corresponding to soil moisture at equilibrium yields different retention curves. The soil water retention results are given in **Table-15** and curves for five different suctions are shown in **Fig.7,8 & 9.** The following are the broad observatins derived from the plot.

i. **Loamy sand** : The curve is relatively flat and soil have relatively low potential.

ii. **Silty sand** : The curve is steep indicating that most of the water in the soil have low potential, making it difficult for plants to use this water.

iii. **Sandy loam** : The curve is flat indicating that most of the water in the sandy soils have a high potential, making it easier for plants to readily use this water.

**4.6 Statistical Methods In Soil Classification:**

Data from the normal distribution can be completely described using the mean and standard deviation. For data that do not follow the normal distribution, other descriptive statistics are appropriate. Statistics that do not depend on the type of distribution include: range, minimum, maximum, midrange,quartiles,

## Table-16

(Soil Data Used For Cluster Analysis & Ordination)

| Sl No Site | Permeability (cm/hr) | % Sand | Void Ratio |
|---|---|---|---|
| 1. Rong Jong | 0.118** | 75.21 | .684 |
| 2. Rongberan | 0.010* | 87.55 | 1.02 |
| 3. Rongmil | 0.024* | 82.83 | .697 |
| 4. Chakjongdra | 1.018 | 88.01 | .571 |
| 5. Gabliadeng | 1.103 | 88.87 | 1.14 |
| 6. Waugesi | 5.016 | 0.000 | .662 |
| 7. Chima-imphal | 5.004 | 81.37 | 1.18 |
| 8. Nilnangithim | 0.713 | 90.77 | .710 |
| 9. Mendima | 1.010 | 83.75 | .571 |
| 10.Bukshilpara | 7.165 | 77.38 | .760 |
| 11.Dudhnai | 1.214 | 89.58 | .968 |
| 12.Sarangma | 1.415** | 83.16 | .203 |
| 13.Depa | 2.014 | 0.000 | .428 |
| 14.Khentra | 0.018* | 0.000 | .538 |
| 15.Dinadubi | 0.004* | 79.19 | .228 |
| 16.Damra(E) | 0.210* | 0.000 | .333 |
| 17.Damra(W) | 0.210* | 0.000 | .333 |
| 18.Dasera Sarangma | 0.005* | 73.25 | .542 |
| 19.Dinadubu R.F | 0.017* | 74.23 | .236 |
| 20.Depa M E School | 1.723 | 0.000 | .250 |
| 21.Shikal | 0.780** | 68.08 | .882 |
| 22.Pankshitham | 7.500 | 7.670 | .650 |
| 23.Bangsi | 14.40 | 15.33 | .354 |
| 24.Naranggiri | 12.75 | 0.000 | .463 |
| 25.Sanal Dajrang | 2.400 | 10.00 | .310 |
| 26.Jamge | 10.75 | 0.000 | .155 |
| 27.Rangre Bazar | 11.25 | 0.100 | .750 |
| 28.Dambu | 0.100 | 14.50 | .840 |
| 29.Thau | 17.76 | 25.67 | .756 |
| 30.Nangehram | 28.22 | 14.75 | .233 |
| 31.Nangshram | 12.33 | 7.500 | .143 |

** Runoff classification is based on the hydraulic conductivity as obtained from Guelph Permeameter results.*
***Runoff classification is based on the flux potential as obtained from Guelph Permeameter results.*

and percentiles.

As a first step for analysing soils with statistical applications three variabes are selected from the soil properties i.e percentage soils passing 75 microns sieve (S), void ratio of the soil (e) and permeability (k) (refer Table-16).In making the selection of variables it is assumed that soil characterstics vary in a way to form a continnum the whole population of soil. Simple stastics shows the following results :-

Table-17
(Descriptive Statistics)

Total Observations: 31

| | K | S | E |
|---|---|---|---|
| N OF CASES | 31 | 31 | 31 |
| MINIMUM | 0.004 | 0.000 | 0.143 |
| MAXIMUM | 28.220 | 90.770 | 1.180 |
| RANGE | 28.216 | 90.770 | 1.037 |
| MEAN | 4.718 | 42.540 | 0.567 |
| VARIANCE | 45.481 | 1528.219 | 0.086 |
| STANDARD DEV | 6.744 | 39.092 | 0.294 |
| STD. ERROR | 1.211 | 7.021 | 0.053 |
| SKEWNESS(G1) | 1.788 | 0.048 | 0.344 |
| KURTOSIS(G2) | 2.990 | -1.880 | -0.797 |
| SUM | 146.251 | 1318.750 | 17.590 |
| C.V. | 1.429 | 0.919 | 0.518 |
| MEDIAN | 1.214 | 25.670 | 0.571 |

## Cluster Analysis

Software SYSTAT is used for clustering the soils into distinct clusters on the basis of the descriptive variables S, e and k. The results are shown below

Table-18
(Summary Statistics For 2 Clusters)

| VARIABLE | BETWEEN SS | DF | WITHIN SS | DF | F-RATIO | PROB |
|---|---|---|---|---|---|---|
| K | 338.161 | 1 | 1026.274 | 29 | 9.556 | 0.004 |
| S | 44222.981 | 1 | 1623.578 | 29 | 789.901 | 0.000 |
| E | 0.457 | 1 | 2.132 | 29 | 6.216 | 0.019 |

*CLUSTER NUMBER: 1*

| Case | Distance | Variable | Minimum | Mean | Maximum | St.Dev. |
|---|---|---|---|---|---|---|
| 6 | 3.83 | K | 0.02 | 7.92 | 28.22 | 7.78 |
| 13 | 4.85 | S | 0.00 | 5.97 | 25.67 | 7.77 |
| 14 | 5.72 | E | 0.14 | 0.45 | 0.84 | 0.22 |
| 16 | 5.63 | | | | | |
| 17 | 5.63 | | | | | |
| 20 | 4.97 | | | | | |
| 22 | 1.02 | | | | | |
| 23 | 6.57 | | | | | |
| 24 | 4.44 | | | | | |
| 25 | 3.94 | | | | | |
| 26 | 3.82 | | | | | |
| 27 | 3.90 | | | | | |
| 28 | 6.68 | | | | | |
| 29 | 12.72 | | | | | |
| 30 | 12.77 | | | | | |
| 31 | 2.70 | | | | | |

*CLUSTER NUMBER: 2*

| Case | Distsnce : | Variable | Minimum | Mean | Maximum | St.Dev. |
|---|---|---|---|---|---|---|
| 1 | 3.72 ¦ | K | 0.00 | 1.31 | 7.16 | 1.98 |
| 2 | 3.55 ¦ | S | 68.08 | 81.55 | 90.77 | 6.62 |
| 3 | 1.05 ¦ | E | 0.20 | 0.69 | 1.18 | 0.30 |
| 4 | 3.73 ¦ | | | | | |
| 5 | 4.24 ¦ | | | | | |
| 7 | 2.16 ¦ | | | | | |
| 8 | 5.33 ¦ | | | | | |
| 9 | 1.28 ¦ | | | | | |
| 10 | 4.15 ¦ | | | | | |
| 11 | 4.64 ¦ | | | | | |
| 12 | 0.97 ¦ | | | | | |
| 15 | 1.58 ¦ | | | | | |
| 18 | 4.85 ¦ | | | | | |
| 19 | 4.30 ¦ | | | | | |
| 21 | 7.78 ¦ | | | | | |

It is observed from the results that the first cluster having sixteen members have low value of standard deviation i.e 0.22 to 7.78 for cluster 1 and 0.30 to 6.62 for cluster 2. The distance of the centroids of cluster 1 from mean varies between 1.02 to 12.77 and for the second cluster the value ranges from 0.97 to 7.78.

***Ordination Of Soils :***

Taxonomic structure of the soil groups are done throug ordination, which is normally used when the distribution of individuals tends to continuous rather than in distinct clusters. Two kinds of ordination has been used in soil studies such as Q-type and R-type ordination. Q-type ordination helps in analysis of objects operating on a similarity matrix and examines the distribution of objects to find the dimensions along which the objects are distributed. These dimensions are formed by clusters of covarient variables. R-type ordination sn sn sn starts by extracting the eigenvalues and eigen vectors of the corelation matrix, and than discarding the less important of these.

Common Factor Model describes observed variables as a function of unobserved factors. It expresses variation within observed variables as common variation among factors and specific variation among random errors. The fundamental factor equation is:

Observed covariances = Factor covariances + Error covariances

To estimate initial communalities, SYSTAT uses the squared multiple correlations or the maximum absolute correlations. Select the quantitative variables to factor. Using correlations gives equal influence to each variable in the matrix. Using covariances gives variables influence in proportion to their variances. The results obtained after running SYSTAT are briefly shown in the following section.

**Latent Roots (Eigenvalues)**

| 1 | 2 | 3 |
|---|---|---|
| 1.744 | 0.780 | 0.476 |

**Component Loadings**

| | 1 | 2 | 3 |
|---|---|---|---|
| S | 0.849 | 0.030 | 0.528 |
| E | 0.729 | 0.593 | -0.341 |
| K | -0.701 | 0.654 | 0.285 |

Variance Explained By Components

| 1 | 2 | 3 |
|---|---|---|
| 1.744 | 0.780 | 0.476 |

Percent Of Total Variance Explained

| 1 | 2 | 3 |
|---|---|---|
| 58.128 | 26.004 | 15.867 |

Rotated Loadings

| | 1 | 2 | 3 |
|---|---|---|---|
| E | 0.971 | 0.091 | 0.221 |
| K | -0.090 | -0.975 | -0.203 |
| S | 0.235 | 0.217 | 0.948 |

Variance Explained By Rotated Components

| 1 | 2 | 3 |
|---|---|---|
| 1.006 | 1.006 | 0.988 |

Percent Of Total Variance Explained

| 1 | 2 | 3 |
|---|---|---|
| 33.531 | 33.541 | 32.928 |

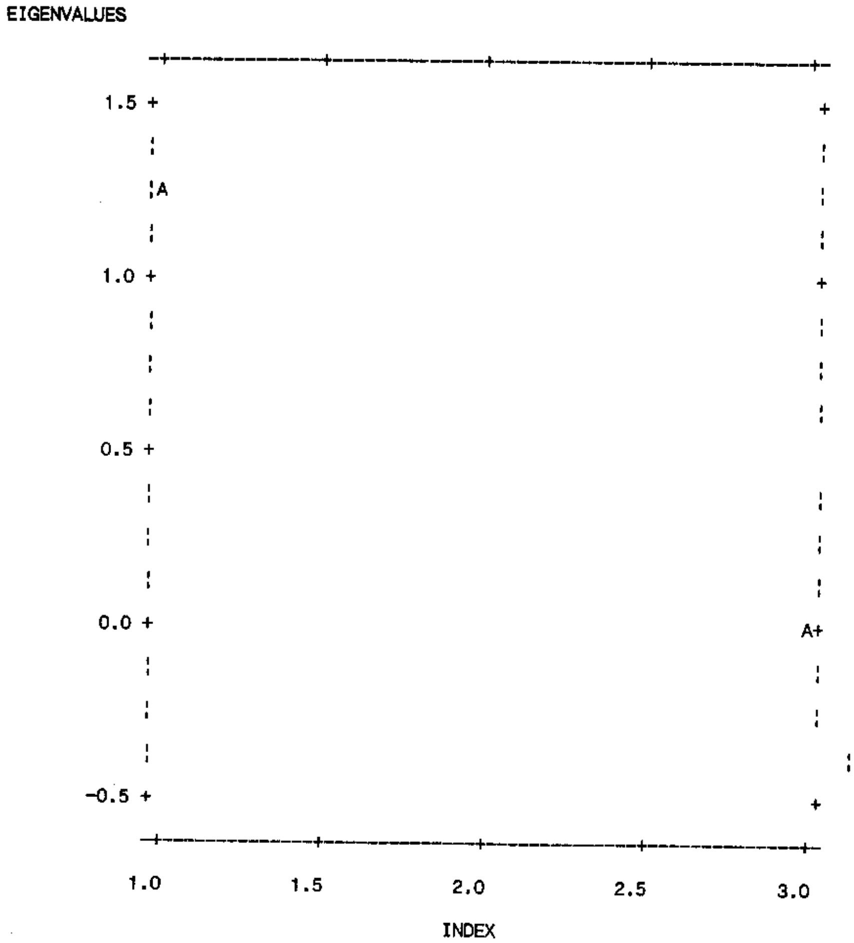



Fig.10 FACTOR SCREE PLOT

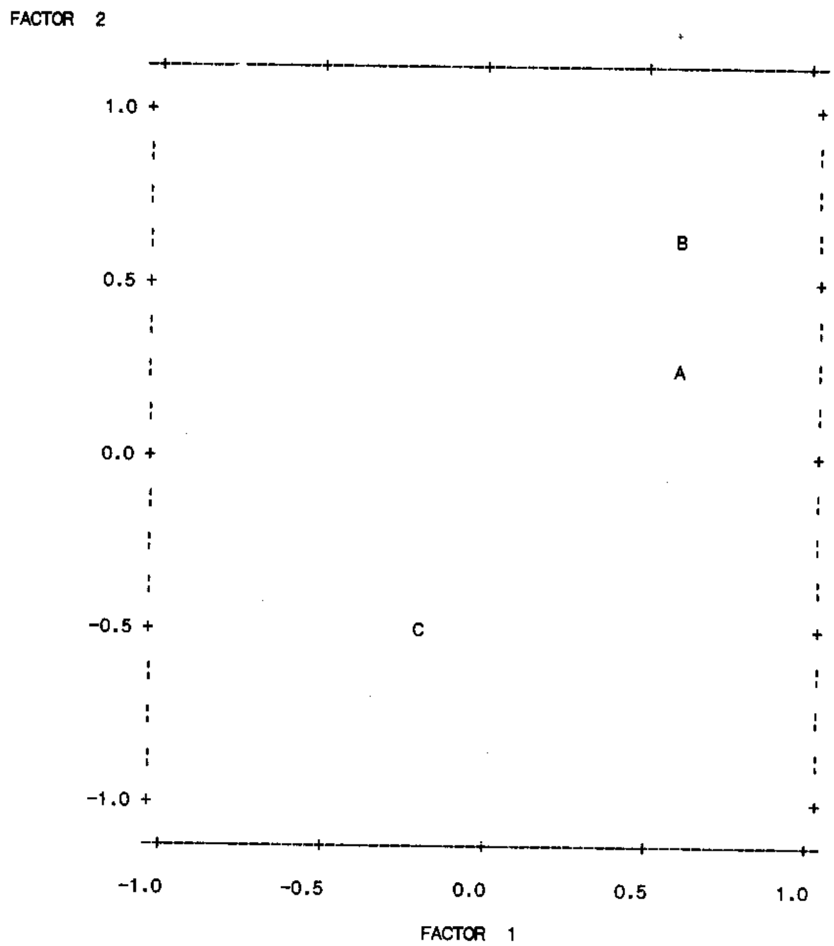



Fig.11 FACTOR LOADING PLOTS

## 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. In this report soils are classified to different groups as per SCS and the classification by National Bureau Of Soil Survey & Land Use have been incorporated for comparison and use. The soil variables like permeability (K), void ratio (e) and soil percentage passing 75 microns (S) are used for cluster analysis and basic ststistics. The following are the broad conclusions derived from the analysis :

1. Two soils representing samples of thirty one number of sites in the basin falls into two major clusters of sixteen and fifteen respectivily.

2. The centroids of the clusters vary in a range of 1 to 12.

3. The centroids have a low standard deviation, indicating the homogeneity of the clusters.

4. Percentage soil passing 75 micron size sieve (S) has a high standard deviation and variance but the other two variables e & k have a low value of variance.

5.Skewness of K is more indicating nonsymmetry distribution of the variable.

6. Percent of total variance explained by ordination using SYSTAT was same for all variables at 30.

7. Factor loadings are plotted.

From the experiments conducted for twelve samples tested in bar pressure plate apparatus, soil water retention curves were drawn and the following inferences are drawn ;

1. For loamy sand the curve is relatively flat and soil have relatively low potential.

2. For silty sand the curve is steep indicating that most of the water in the soil have low potential, making it difficult for plants to use this water.

3. For sandy loam the curve is flat indicating that most of the water in the sandy soils have a high potential, making it easier for plants to readily use this water.

From the electro resistivity data of Central Ground Water Board for part of the basin, an attempt was made to plot the iso-resistivity curve. Though the data were inadequate to infer about the water stratum in subsurface, however, they were made use to arrive at effective depth of the top soil stratum.

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 the 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.

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