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ESTIMATION OF HYDROLOGICAL SOIL PARAMETERS FOR MALAPRABHA AND GHATAPRABHA SUBBASINS

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PREFACE

Hydraulic conductivity and soil moisture are the two important components of hydrological cycle. These parameters are quite essential in the field of agriculture and hydrology for irrigation and drainage planning, ground water modelling, rainfall-runoff modelling and for water management studies. Soil moisture movement studies are very important for understanding the mechanism of recharge through the soil and to provide soil moisture storage data for the water balance study.

In the present study, various soil parameters considered are (i) measurement of field saturated hydraulic conductivity (ii) grain size distribution and (iii) soil moisture retention curves. The field tests were carried out at various locations depending upon the soil types in Malaprabha & Ghataprabha sub basins. Textural analysis and soil moisture content were determined in the laboratory of National Institute of Hydrology, Roorkee. The in-situ field saturated hydraulic conductivity was determined by Guelph permeameter at various locations in Malaprabha and Ghataprabha subbasins.

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1.0 INTRODUCTION

Hydrological soil parameters are essential for irrigation and drainage planning, rainfall-runoff modelling and ground water studies. The essential parameters in the unsaturated flow are hydraulic conductivity and soil water retention curves. The unsaturated zone is the stratum which extends from the soil surface to the first water bearing horizon. This zone will be concentionally referred to as the "Soil The upper part of the unsaturated zone, which is the tilled soil, is referred as the "Solum". Moisture in the unsaturated zone may be found in different form and state. The complex of phenomena is related to the behaviour of this moisture referred to as the moisture regime of the unsaturated zone. These phenomena include:

i) an interchange of moisture between the unsaturated zone and atmosphere, ground waters and vegetation.

ii) a transfer of liquid moisture and vapour

iii) a retention of moisture in the unsaturated zone.

iv) an alteration in the physical state of moisture in the unsaturated zone.

Moisture in the unsaturated zone is present in the pore space. This includes pores of different size and shape. An essential characteristics of the pore space is the high value of the specific surface of the surrounding particles, which ranges from 10^{-2} m^2/gr for coarse textured soils and up to 10^2 m^2/gr. $(1<n<10)$ for fine textured soils.

Although knowledge of soil hydrology is very important in the development of techniques to increase production without jeopardizing conservation of the elements that make up the water balance of the soil, the most important one is water storage in the aeration zone, since it determines fertility and productivity. For this reason many theoretical and empirical methods have been proposed in past years to estimate the water balance in the soil, as well as methods and devices to ascertain variations in time and space.

In order to standardise measuring units in the appraisal of the water balance, it is customary to express the quantity of moisture contained in the soil using same units employed to measure rainfall and evaporation i.e. thickness of the sheet of water in mm, cm or inches. However, the conversion of soil moisture content values measured in relation to dry weight to the equivalents in relation to natural volume as required for this purpose, present difficulties in practice and it is necessary to determine this possible consequences. We believe that all hydrological studies on soil should be preceded by a determination as accurate as possible of the hydrological constants, which will later serve as points of reference for their balance.

Most of the process involving soil-water interactions in the field, and particularly the flow of water in the rooting zone of most crop plants, occur while the soil is in an unsaturated condition. Unsaturated flow processes are in general complicated and difficult to describe quantitatively, since they often entail changes in the state and content of soil water during flow, such changes involve complex relations among the variable soil wetness, suction and conductivity, whose interactions may be forth complicated by hysterises. The formulation and solution of unsaturated flow problems very often require the use of indirect methods of analysis, based on approximation or numerical techniques. For this reason the development of vigorous theoretical and experimental methods for tracing these problems was rather late in coming. The recent studies indicated, a gravelly or sandy soil with large pores can have a conductivity much greater than a clay soil with narrow pores though the total porosity of a clay is generally greater that that of a sandy soil. Cracks, warm holes, and decayed root channels are present in the field and may affect flow in different ways, depending on the direction and condition of the flow process. If the pressure head is positive, these passages will run full of water and contribute to be observed flux and measured conductivity if the pressure head in the water is negative that is, if soil water is under suction, large cavities will generally be drained and fail to transmit water.

In many soils, the hydraulic conductivity does not in fact remain constant. Because of various chemical, physical and biological processes, the hydraulic conductivity may change as water permeates and flows in a soil. Changes occurring in the composition of the exchangeable in complex as when the water extending the soil has a different composition or concentration of solutes than the original soil solution, can greatly change the hydraulic conductivity and it decreases with decreasing concentration of electrolytic solutes due to swelling and dispersion phenomena, which are also affected by the species of cation present. Detachment and migration of clay particles during prolonged flow may result in the clogging of pores.

Thus variation of 20% may be considered negligible whilst one of 200 or 300% would be highly significant. The determination of hydraulic conductivity in the laboratory is likely to produce results differing from those obtained in the field. This is due to the small volume of the samples and the comparatively short duration of the tests.

It is understood from the above discussion that hydraulic conductivity and soil moisture characteristics have numerous applications in the field of hydrology. Therefore it is essential to find out these parameters which will aid in water balance and other related studies. The present study has been conducted in the Malaprabha & Ghataprabha command areas using advanced techniques for measurement of field saturated hydraulic conductivity.

The various soil parameters considered in the present study are i) Saturated Hydraulic conductivity, (ii) Determination of soil moisture retention curves and (iii) Particle size analysis.

i) Saturated Hydraulic Conductivity:

Hydraulic conductivity is defined by Darcy's law and is expressed in terms of velocity, and is similar to the coefficient of permeability. Since, the aquifer may for a structural reasons have a preferred direction of flow, the hydraulic conductivity may also have a directional variation. It is dependent also upon porosity, grain size and the specific surface of the grains. The standard unit is given in terms of metres/sec(m/s) at a temperature of 20 C. Accurate estimate of hydraulic conductivity require temperatures to be considered because it is influenced by viscosity which in turn is influenced by temperature. For example a fall in temperature from 25o to 5C can lower the hydraulic conductivity by 40%.

Under natural condition the variation in hydraulic conductivity is large, ranging from 10^{-3} m/s for coarse sand down to 10^{-8} m/s or even 10^{-12} m/s for clay. However, samples taken from the same source can show large differences and the extent to which the hydraulic conductivity varies is more significant than its precise value become one of the most important and active topics of research in soil physics, and this research has resulted in significant theoretical and practical advances. Saturated hydraulic conductivity refers to the hydraulic conductivity of soil containing entrapped air.

ii) Particle Size Analysis:

The particle size analysis is used to determine the relative proportion of the different grain sizes that make up a given soil mass.

Empirical evidence and intensive reasoning indicate that conductivity increases with increasing particle size. It was generally found that hydraulic conductivity is proportional to the second power of particle size ($K \propto \phi^2$) where ϕ is particle diameter. If ϕ changes 10 times, hydraulic conductivity will change 100 times. Later on researchers replaced the particle diameter with the effective diameter, because the diameter of soil particles is not uniform. Small particles mixed into a soil will decrease its hydraulic conductivity. The expected relation between hydraulic conductivity and porosity is not always seen, especially in volcanic ash soil. Pore size as well as total porosity is an important factor determining hydraulic conductivity. The hydraulic conductivity is obviously affected by structure as well as by texture, being greater if the soil is highly porous, fractured, or aggregated than if it is highly compacted and dense. Hydraulic conductivity depends not only on total porosity, but also and primarily on the sizes of the conducting pores.

iii) Soil Moisture Characteristics:

This third important factor is soil moisture characteristics. In the recent years it is understood that the measurement of soil moisture content is important not only in the field of agriculture for planning irrigation regimes, yield estimation and erosion forecasting, but also in the field of hydrology for infiltration and drainage studies, groundwater recharge measurements and water balance studies. The moisture content of the surface layers is important for partitioning of rainfall into runoff and infiltration components.

pF of soils: Scholfield (1935) suggested the use of the logarithm of soil moisture tension and gave the symbol pF to this logarithm which is an exponential expression of a free energy differences (based on the height of a water column above free water level in cm). The pF function, analogous to the acidity-alkalinity scale pH, is defined as the logarithm to the base 10 of the numerical value of the negative pressure of the soil moisture expressed in cm of water.

$$pF = \log_{10} h$$

h = soil moisture tension in cm of water

If the osmotic tension is negligible, i.e. at low salt concentration, the pF of the soil moisture may nearly equal the logarithm of the capillary tension expressed in cm of water Soil moisture tension is a measure of the tenacity with which water is retained in the soil and shows the force per unit area that must be exerted to remove water from a soil. The tenacity is measured in terms of the potential energy of water in the soil measured, usually with respect to free water. It is usually expressed in atmosphere, the average air pressure at sea level. The other pressure units like cm of water or mm of mercury are also often used (1 atmosphere = 1036 cm of water or 76.39 cm of mercury). It is also some times expressed in bars (1 bar = 10^6 $dynes/cm^2$ = 1023 cm of water column).

Soil moisture tension is brought about at the smaller dimensions by surface tension (capillarity), and at the higher dimensions by adhesion. Buckingham (1907) introduced the concept of capillary potential to define the energy with which water is held by soil. This term, however does not apply over the entire moisture range. In a wet soil, as long as there is a continuous column of water, it might be called 'hydrostatic potential', in the intermediate range the term 'capillary potential

Older literature mentions the 'moisture equivalent' as being an indication for field capacity. The 'moisture equivalent is defined as the weight percentage of water retained by a previously saturated sample of soil of 1 cm thickness after it has been subjected to a centrifugal force of 1000 times gravity of 30 minutes and should also correspond with a moisture tension of about 1/3 atmosphere. However, all these definitions are misleading The 'practically ceased drainage' concept may only hold for a homogenous sandy profile having a good water transmitting properties. The attempts to correlate field capacity with a particular moisture tension ignore the fact that, in a soil profile, the moisture condition is not only dependent on the water retaining forces but also on the water transmitting properties over the whole soil profile.

If there is no influence of ground water, field capacity is assumed to be roughly approached by a tension of 100 to 200 cm of water (pF 2.0 to 2.3). With a shallow water table, the tension at field capacity equals the height above that table, i.e. the groundwater table at 80 cm, field capacity at the soil surface is equal to 80 cm tension, on pF=1.9. Heterogeneity of the soil profile, impeding layers fluctuating ground water levels complicate the determination of field capacity.

From literature it appears that the field capacity ranges from about 50 to 500 cm (pF = 0.7 - 2.7). In the following we take pF 2 as the field capacity point. It is considered as the upper limit of the amount of water available for plants.

The air content at field capacity, called aeration porosity, is important for the diffusion of oxygen to the roots. Generally, if the aeration porosity amounts to 10 or 15 vol % or more aeration is satisfactory for plant growth. In drainage practice, the aeration porosity is often termed as drainable pore space or as effective porosity. Its value is about the same as the so called as the storage coefficient

Wilting point:

Permanent wilting point is defined as the soil moisture condition at which the leaves undergo a permanent reduction of the water content (wilting) because of the deficient supply of soil water, a condition from which the leaves do not recover in an approximately saturated atmosphere overnight. The permanent wilting point is not a constant as it is influenced by the conditions in the plant tissues.

The variation in soil water pressure head at wilting point approximates - 10000- 20000 cm. For many practical purposes the mean value of -50,000 cm (pF 4.2) can be regarded as the lower limit of the soil water i.e. available for the plants.

Oven dry point:

When soil is dried in an oven at 105 C one assumes that no water is left in the soil. Generally this point is reached at pF=7.

Available water:

The amount of water held by a soil between field capacity (pF=2.0) and wilting point (pF=4.2) is defined as the amount of water totally available for the plants. Above field capacity and below wilting point, water is not available for the plants. The availability is not the same over the whole range indicated. An increase in desication of the soil the availability for the plants decreases progressively. Therefore, inorder to get optimum plant production, it is better not to allow the soil to dry out until wilting point. The admissible pressure head at which the soil water begins to limit the plant growth is roughly about -400 to -1000 cm (pF 2.6 to pF 3.0). In practice, it implies that the drought limit is reached when a fraction of 0.4 to 0.6 of the total amount of the water available in the root is used. This amount of water is often referred to as the readily available soil water.

In the last twenty years, much attention has been paid to the process of water entry into the soil (infiltration) which is considered as an important part of the hydrologic cycle, with many practical implications in irrigation, soil erosion and soil conservation. Nevertheless, results concerning the soil properties affecting the infiltration rate and means of estimating it are not yet conclusive.

Number of scientists and engineers tried to establish a relationship connecting infiltration, soil moisture and particle size. The methods of determining the infiltration rate and the factors affecting it were recently reviewed by Parr and Bertrand (1960). Using synthese of many experimental results, Free and Palmer (1940), Krimgold and Beenhouwer (1954), Mech (1960), Grin and Nazarov (1965) tried to get average values of the infiltration rate for various soils, crop setc. The conclusion derived by Free and Palmer was that, though it may be possible in the future, the correlation of the parameters of the infiltration curve with the properties of the soil cannot yet be achieved. Baver (1956), discussing the numerous factors affecting the infiltration rate, considered the non-capillary porosity (which is affected by soil texture, structure, volume changes etc.), moisture content and the affect of the entrapped air.

The affect of the soil moisture content antecedent to the determination has to be taken into consideration as one of the main factors hindering the elucidation of the relationship between infiltration and soil properties. Most people, (Ayers and Wikramanayake, 1958), Kulintchenko (1959), Konovalov and Popov (1961) observe a decrease in infiltration rate accompanying increase in moisture content. In some of our earlier researches (Obrejanu et.al, 1964), it was concluded that on similar soils, the infiltration rate was much greater when determined in spring on moist soils than in summer or autumn on dry soils. This conclusion was checked by Motoc, (1965) who noticed a good positive correlation between infiltration rate and soil moisture content. She suggested that the opposite opinions cited in the literature where due to the way in which the experiments were done; for, in most of the works reported by various authors, the infiltration rate determination were carried out during short time interval, on the same piece of land, artificial moistening of the soil is being used inorder to get the required different moisture content. On the contrary, Sagi, in his experiment allowed the soil to dry naturally to get the required different moisture content; Owing to this longer lapses of time were needed.

Clarification of the effect of antecedent moisture content of the soil on infiltration rate and the mathematical relationships involved will enable also a clarification of the relationships between infiltration and other soil properties.

In recent years studies have carried out to understand the infiltration and soil moisture characteristics. Feddes et al (1978), Hayhoe & Dejong (1982) and Idike et al (1982) have developed numerical models for predicting soil water content with depth. Many problems related to the infiltration of water into soil have been done by various researchers Bouwer (1964), (1978), Bruce and Whisler (1973), Jensen (1973), Hillel and Gardner (1970), Jain and Murthy (1985) and Mehta (1989). Sikka and Mishra (1986) has attempted soil moisture simulation approach to analyse drought frequency, severity and duration for a particular crop in a given watershed.

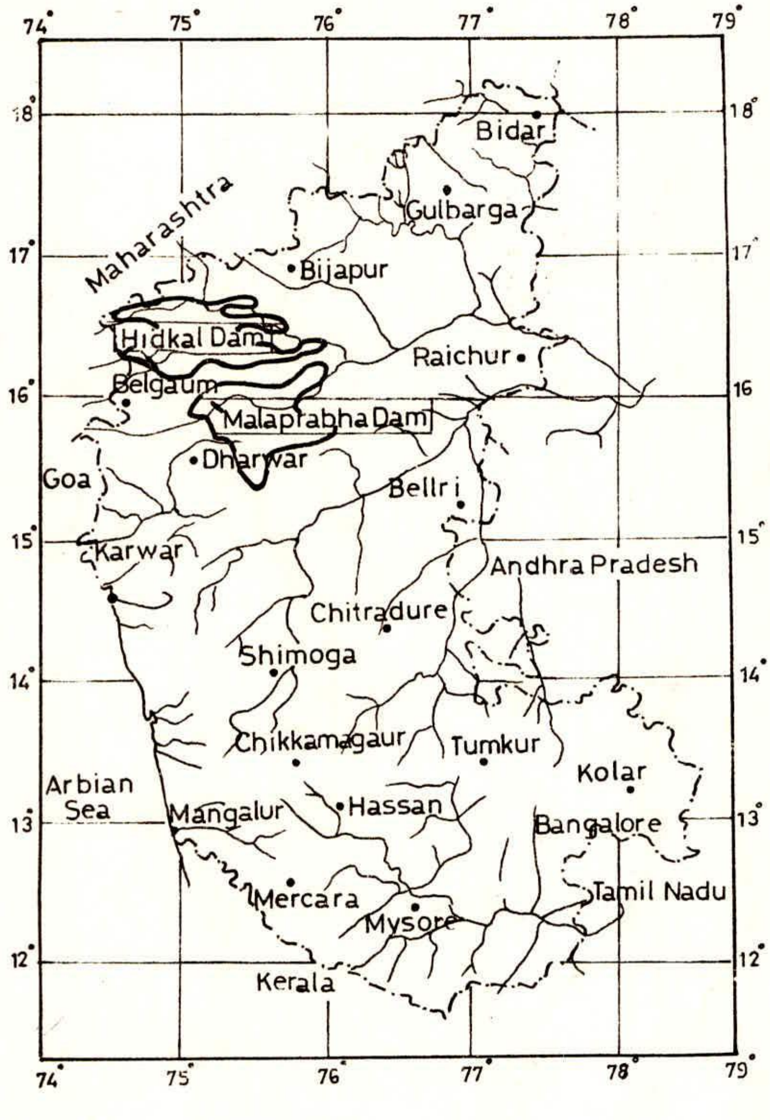
2.0 STUDY AREA

The present study has been carried out in the Malaprabha and Ghataprabha command areas of the hard rock region (Fig.1 & 2). Few tests were also conducted in the catchment areas of the Malaprabha and Ghataprabha reservoirs. The Malaprabha river is one of the main tributaries of the river Krishna. It has its source in the western ghats at an altitude of 792 m about 36 km SW of Belgaum district in Karnataka state. It travels a distance of 306 km in Belgaum and Dharwar districts before joining river Krishna at Kapil sangam.

The sub basin has a wide range of temperature variations. Excluding the hill stations the temperature varies between 6.7 C to 41.7 C. In general the climate of the sub-basin is dry except in monsoon months. The mean relative humidity is high during the southwest monsoon season and comparatively low during the nonmonsoon period. The sub-basin is covered by different types of soils namely medium black soil, deep black soil, mixed red and black soil. In these soils a variety of crops like jowar, wheat, millets, cotton, groundnut, paddy, tobacco, maize, sugarcane etc. are grown. The total culturable area is about 11.3% of the total area. A vast area of the sub basin is under forest cover. The experiments have been conducted mainly in the command area which lies between 15 24'02" to 16 36'09" N latitudes and 74 26'43" E to 56 33' longitude. The Malaprabha reservoir is located at Naviluteerth in Soundatti taluk to impound 1377 MCM. The Malaprabha project envisages irrigation of 2.17 lakh hectares covering Belgaum, Bijapur and Dharwad districts.

The Ghataprabha river is one of the right bank tributary of the river Krishna in its upper reaches. The river originates

FIG.1. INDEX MAP OF KARNATAKA



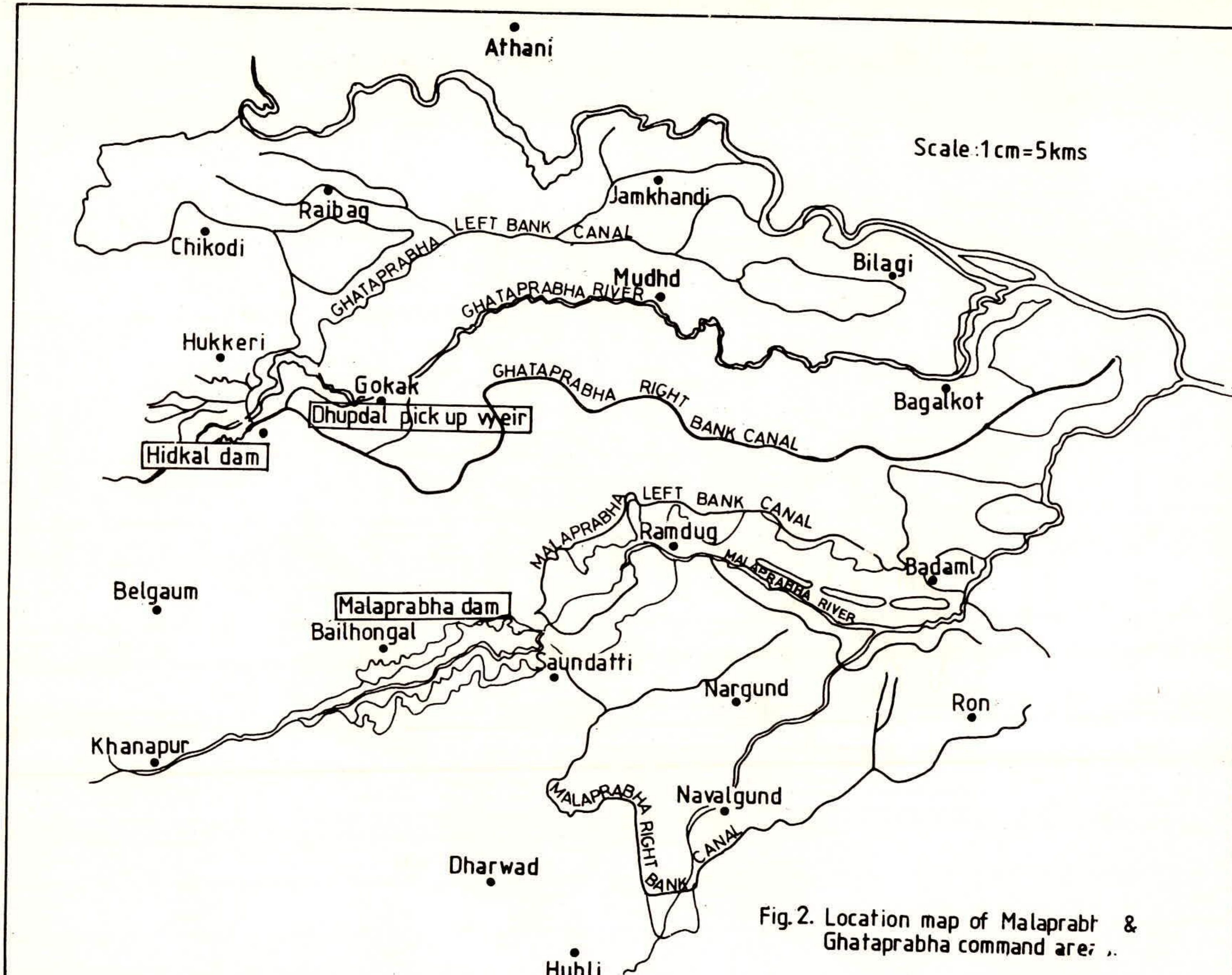


Fig. 2. Location map of Malaprabt & Ghataprabha command are; .

Fig. 3 Important Soil Type in Malprabha & Ghatprabha basins. Variation of Field Saturated Hydraulic Conductivity (cm/sec) in Malprabha and Ghatprabha basine.

from the western ghats in Maharashtra at an altitude of 884 m flows westwards for about 60 km through the Ratnagiri and Kolhapur districts of Maharashtra. In Karnataka the river flows for about 216 km through Belgaum district past Bagalkot. After a run of 283 km the river joins the Krishna on the right at Kudalisangam at an elevation of 500 m about 16 km from Almatti.

To harness the waters of the Ghataprabha river a dam is constructed at Hidkal, Hukkeri taluk of Belgaum district to impound 2202 MCM of water. The Ghataprabha command area lies between 16 0'8" to 16 88'09" N latitudes and 74 26'43" to 75 56'33" E longitudes. The project is envisaged to irrigate 3.18 lakh hectares of land in Belgaum and Bijapur districts.

The climate of the sub basin is marked by hot summer and mild winter. The monsoon sets in early June and continues to the end of the October. The winter is from November to mid February and the summer is from mid February to the end of May. December and April are the coldest and hottest months respectively. Humidity is low in dry weather being around 45% and in the monson it is as high as 91%. The sub basin experiences only the south west monsoon and the period generally from June to October. July being the rainiest month. The daily rainfall data, mean, maximum and minimum for the year. 1988-89 of various locations at Malaprabha & Ghataprabha basin are shown in Table 1 - Table 7. From the tables, it is observed that rainfall pattern is not uniform at all locations in the Malaprabha and Ghataprabha subbasin. The important soil types observed are medium black soils, Deep black soil, mixed red soil and lateritic soils as shown in Figure 3.

Table 1 : DAILY RAINFALL (mm) DATA

(a) STATION: BELGAUM YEAR: 1988–89

MONTH DATE	JUN	JUL	AUG	SEP	OCT.	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	10.0	10.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	2.4	36.2	5.2	3.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
3	00.0	3.5	78.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	1.0	27.4	00.0	3.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0
5	00.0	00.0	42.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	11.6	4.6	7.4	00.0	12.0	00.0	00.0	00.0	00.0	00.0	00.0	8.0
7	13.0	00.0	12.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	18.0
8	36.0	00.0	1.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	1.2	00.0	17.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	4.0	00.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	2.0	00.0	3.0	18.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	0.2	00.0	1.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	11.0	5.0	00.0	00.0	00.0	00.0	8.6	00.0	00.0	00.0	00.0	00.0
14	7.0	26.6	00.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
15	4.0	22.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0
16	4.0	64.4	2.4	3.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	00.0	52.4	27.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
18	00.0	73.0	10.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	12.0
19	00.0	46.0	3.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
20	00.0	36.6	0.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	00.0	5.8	6.0	12.0	00.0	00.0	00.0	00.0	00.0	00.0	27.0	00.0
22	4.0	6.0	5.0	18.3	00.0	00.0	00.0	00.0	00.0	22.0	00.0	00.0
23	4.5	25.2	0.8	16.5	00.0	00.0	00.0	00.0	00.0	00.0	6.0	00.0
24	9.8	2.0	1.5	12.6	00.0	00.0	00.0	00.0	00.0	25.0	14.5	00.0
25	7.0	1.2	4.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
26	6.9	6.8	00.0	11.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	13.0	17.2	00.0	2.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
28	7.5	20.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
29	10.8	22.0	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
30	3.0	2.2	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		6.0	00.0		00.0		00.0	00.0		00.0		00.0
TOTAL	160.5	452.1	300.05	114.3	18.5	00.0	8.6	00.0	00.0	49.0	47.5	38.0
MEAN	5.4	14.6	9.7	3.8	0.6	0.0	0.0	0.3	0.0	1.6	1.6	1.2
MAX	36.0	73.0	78.2	18.3	12.0	0.0	8.6	0.0	0.0	25.0	27.0	18.0
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2 : DAILY RAINFALL (mm) DATA
(b) STATION: HIDKAL DAM YEAR: 1988-89

MONTH DATE	JUN	JUL	AUG	SEP	OCT.	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	00.0	10.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	2.0	4.8	41.8	35.0	00.0	00.0	00.0	00.0	00.0	1.2	00.0
3	00.0	0.2	23.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	3.8	8.6	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0
5	00.0	00.0	1.66	00.0	8.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	27.6	00.0	1.8	00.0	1.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0
7	3.2	0.4	12.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	9.8
8	11.8	00.0	0.8	00.0	0.8	00.0	00.0	00.0	00.0	00.0	00.0	2.6
9	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	0.2	00.0	5.6	00.0	00.0	00.0	00.0	00.0	00.0	0.4	00.0	00.0
11	00.0	00.0	00.0	16.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	0.2	00.0	00.0	1.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	3.8	00.0	00.0	00.0	00.0	00.0	19.8	00.0	00.0	00.0	00.0	00.0
14	0.6	11.8	00.0	37.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
15	0.2	1.4	00.0	1.2	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0
16	00.0	9.0	1.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	00.0	8.4	42.6	11.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
18	00.0	23.0	6.0	1.0	00.0	00.0	00.0	00.0	00.0	00.0	4.2	24.2
19	00.0	23.8	0.6	20.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	0.6
20	00.0	3.8	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	0.2	1.6	00.0	2.6	00.0	00.0	00.0	00.0	00.0	00.0	11.2	00.0
22	00.0	16.4	1.0	8.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
23	00.0	0.8	0.6	4.4	00.0	00.0	00.0	00.0	00.0	00.0	15.0	00.0
24	3.8	9.6	0.2	1.0	00.0	00.0	00.0	00.0	00.0	00.0	4.8	00.0
25	2.0	2.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	1.8	00.0	00.0
26	4.8	13.6	00.0	28.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	1.8	8.6	00.0	14.4	00.0	00.0	00.0	00.0	00.0	0.8	00.0	00.0
28	0.6	1.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
29	6.6	1.8	0.4	00.0	00.0	00.0	00.0	00.0		1.8	00.0	00.0
30	00.0	0.4	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		1.2	1.0		00.0		00.0	00.0		00.0		00.0
TOTAL	67.4	141.8	107.85	207.6	46.0	00.0	19.8	00.0	00.0	6.8	36.4	37.2
MEAN	2.3	4.6	3.5	6.9	1.5	0.0	0.6	0.0	0.0	0.2	1.2	1.2
MAX	27.6	23.8	42.6	37.2	35.0	0.0	19.8	0.0	0.0	2.0	15.0	24.2
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3: DAILY RAINFALL (mm) DATA
(c) STATION: RAIBAG YEAR: 1988-89

MONTH DATE	JUN	JUL	AUG	SEP	OCT.	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	10.0	3.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	00.0	6.0	102.0	12.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
3	00.0	00.0	82.0	9.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	1.0	5.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
5	00.0	00.0	6.0	3.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	19.2	10.0	00.0	8.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	15.0
7	2.0	00.0	6.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
8	13.0	00.0	1.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	00.0	00.0	1.2	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	00.0	17.0	22.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	00.0	00.0	00.0	12.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	00.0	10.9	8.2	33.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	4.0	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0	00.0	00.0	00.0
14	00.0	5.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
15	3.0	1.5	00.0	30.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
16	00.0	5.0	3.4	22.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	00.0	13.0	9.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	3.6
18	00.0	3.5	26.0	78.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
19	00.0	10.9	00.0	14.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
20	00.0	3.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	4.0
21	00.0	1.0	00.0	0.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
22	00.0	3.5	00.0	4.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
23	00.0	00.0	12.0	4.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
24	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
25	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
26	00.0	5.0	00.0	36.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	4.2	3.0	3.6	00.0	00.0	00.0	00.0	00.0	00.0	29.0	00.0	00.0
28	00.0	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
29	00.8	6.0	7.8	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
30	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		00.0	4.5		00.0		00.0	00.0		00.0		00.0
TOTAL	45.4	99.0	199.95	371.1	12.0	00.0	2.0	00.0	00.0	29.0	00.0	22.6
MEAN	1.5	3.2	6.5	12.4	0.4	0.0	0.1	0.0	0.0	0.9	0.0	0.7
MAX	19.2	35.0	82.0	102.0	12.0	0.0	8.6	0.0	0.0	29.0	0.0	15.0
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4: DAILY RAINFALL DATA (mm)
(a) DISTRICT: BELGAUM
STATION : BIDI YEAR: 1988-89

MONTH DATE	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	7.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	3.4	17.3	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
3	00.0	00.0	76.6	35.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	93.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	3.1	00.0
5	00.0	00.0	14.4	10.4	3.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	00.0	00.0	6.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
7	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
8	20.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	6.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	4.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	00.0	00.0	12.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	34.0	14.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
14	2.4	18.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	11.4	00.0
15	3.8	35.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0
16	4.0	59.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	2.1
17	00.0	34.6	41.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
18	00.0	93.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	6.4
19	00.0	37.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
20	00.0	16.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	3.6	2.6	00.0	19.+	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
22	10.4	4.6	00.0	18.4	00.0	00.0	00.0	00.0	00.0	8.2	00.0	00.0
23	4.2	14.0	00.0	7.6	00.0	00.0	00.0	00.0	00.0	0.5	8.2	00.0
24	2.3	6.4	00.0	21.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
25	9.0	4.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
26	2.0	5.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	1.2	16.8	00.0	11.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
28	4.0	6.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
29	00.0	4.2	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
30	00.0	31.0	00.0	18.2	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		6.2	00.0		00.0		00.0	00.0		00.0		00.0
TOTAL	111.1	415.0	268.9	142.0	3.6	00.0	00.0	00.0	00.0	00.0	22.7	8.5
MEAN	3.7	13.4	8.7	4.7	0.1	00.0	00.0	00.0	00.0	00.0	0.7	0.3
MAX	34.0	93.4	93.6	35.6	3.6	00.0	00.0	00.0	00.0	00.0	11.4	6.4
MIN	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0

Table 5: DAILY RAINFALL (mm) DATA
DISTRICT: BELGAUM
STATION: RAMDURG YEAR: 1988-89

MONTII DATE	JUN	JUL	AUG	SEP	OCT.	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	00.0	19.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	00.0	2.0	34.0	13.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
3	00.0	00.0	10.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	4.0	00.0	12.0	00.0	00.0	00.0	00.0	00.0	00.0	3.0
5	00.0	00.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	00.0	00.0	00.0	00.0	20.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
7	47.0	00.0	4.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
8	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	00.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	00.0	00.0	30.0	1.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	00.0	00.0	00.8	5.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	17.2	00.0	00.0	00.0	00.0	00.0	7.0	00.0	00.0	00.0	00.0	00.0
14	00.0	12.0	00.0	6.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
15	00.0	00.0	00.0	7.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
16	00.0	6.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	00.0	5.0	9.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	5.0
18	00.0	11.6	2.0	5.0	00.0	00.0	00.0	00.0	00.0	00.0	3.0	13.0
19	00.0	00.0	00.0	6.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
20	00.0	10.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	2.0	00.0	00.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	4.0	00.0
22	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
23	00.0	1.0	2.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
24	4.4	1.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
25	00.0	00.0	00.0	1.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
26	3.0	2.4	00.0	49.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	1.0	1.0	7.9	7.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
28	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0
29	2.0	3.0	22.4	2.0	00.0	00.0	00.0	00.0		3.0	00.0	00.0
30	00.0	00.0	6.0	3.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		00.0	3.0		00.0		00.0	00.0		00.0		00.0
TOTAL	78.6	55.6	104.1	147.0	47.2	00.0	7.0	00.0	00.0	5.0	7.0	21.0
MEAN	2.6	1.8	3.4	4.9	1.5	00.0	0.2	00.0	00.0	0.2	0.2	0.7
MAX	47.0	12.0	30.0	49.0	20.0	00.0	7.0	00.0	00.0	3.0	4.0	13.0
MIN	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0

Table 6: DAILY RAINFALL (mm) DATA
(c) DISTRICT: BIJAPUR
STATION: BADAMI YEAR: 1988-89

MONTH DATE	JUN	JUL	AUG	SEP	OCT.	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	4.6	18.7	0.8	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	12.8	1.2	29.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
3	00.0	1.5	15.7	24.1	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	17.8	5.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	0.6
5	00.0	3.2	00.0	00.0	3.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	3.4	2.2	00.0	1.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
7	9.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	0.2
8	00.0	12.3	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	00.0	1.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	00.0	10.0	12.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	00.0	1.6	2.9	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	00.0	1.6	00.0	00.0	00.0	00.0	00.0	00.0	C0.0	00.0	00.0	00.0
13	0.4	1.4	00.0	00.0	00.0	00.0	11.2	00.0	00.0	00.0	00.0	00.0
14	00.0	8.3	00.0	8.6	00.0	00.0	9.6	00.0	00.0	00.0	00.0	00.0
15	00.0	00.0	00.0	10.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
16	00.0	3.0	0.2	0.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	0.3	10.0	16.4	6.1	00.0	00.0	00.0	00.0	00.0	00.0	00.0	9.9
18	00.0	2.1	1.5	34.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	18.3
19	00.0	00.0	2.8	4.7	00.0	00.0	00.0	00.0	00.0	00.0	00.0	7.4
20	00.0	00.0	00.0	0.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	9.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	1.8	00.0
22	1.8	00.0	00.0	3.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
23	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	11.2	00.0
24	13.9	6.0	00.0	3.8	00.0	00.0	00.0	00.0	00.0	6.2	00.0	00.0
25	00.0	00.0	00.0	0.2	00.0	00.0	00.0	00.0	00.0	5.6	00.0	00.0
26	3.0	4.0	11.0	5.3	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	0.8	0.8	7.0	29.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
28	5.6	4.8	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
29	3.6	4.3	12.0	0.2	00.0	00.0	00.0	00.0		2.0	00.0	00.0
30	00.0	0.6	11.8	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		00.0	6.8		00.0		00.0	00.0		00.0		00.0
TOTAL	50.8	91.7	124.1	184.1	4.4	00.0	20.8	00.0	00.0	13.8	13.0	36.4
MEAN	1.7	2.9	4.0	6.1	0.1	00.0	0.7	00.0	00.0	0.5	0.4	1.2
MAX	13.9	12.8	17.8	34.2	3.6	00.0	11.2	00.0	00.0	6.2	11.2	18.3
MIN	0C.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0

Table 7: DAILY RAINFALL (mm) DATA
(d) STATION: MUDHOL YEAR: 1988-89

MONTH DATE	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	00.0	00.0	00.0	11.5	4.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
2	00.0	3.0	0.5	11.0	3.8	00.0	00.0	00.0	00.0	00.0	00.0	0.5
3	00.0	0.2	38.0	18.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
4	00.0	00.0	0.5	8.1	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
5	00.0	2.0	00.0	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
6	61.0	0.5	0.4	21.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	2.5
7	9.0	00.0	12.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
8	29.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
9	00.0	0.7	00.0	1.2	0.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0
10	00.0	7.0	5.0	2.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
11	00.0	6.0	1.0	0.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
12	00.0	17.0	00.8	0.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
13	00.0	0.2	00.0	00.0	00.0	00.0	28.0	00.0	00.0	00.0	00.0	00.0
14	0.4	0.2	00.0	00.0	00.0	00.0	3.0	00.0	00.0	00.0	00.0	00.0
15	00.0	00.0	00.0	9.6	00.0	00.0	00.0	00.0	00.0	2.0	00.0	00.0
16	00.0	8.0	2.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
17	00.0	2.2	3.5	0.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	1.2
18	00.0	8.4	13.0	1.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	25.6
19	00.0	0.5	00.0	3.4	00.0	00.0	00.0	00.0	00.0	00.0	00.0	6.8
20	1.2	2.0	0.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
21	00.0	00.0	00.0	0.5	00.0	00.0	00.0	00.0	00.0	00.0	27.0	00.0
22	1.5	0.6	00.0	00.0	00.0	00.0	00.0	00.0	00.0	8.2	00.0	00.0
23	00.0	2.4	2.0	1.0	00.0	00.0	00.0	00.0	00.0	0.5	6.0	00.0
24	1.0	0.4	00.0	1.4	00.0	00.0	00.0	00.0	00.0	00.0	14.5	00.0
25	4.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
26	4.8	3.8	0.4	6.5	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
27	10.0	00.0	0.4	00.0	00.0	00.0	00.0	00.0	00.0	0.5	00.0	00.0
28	0.2	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	1.0	00.0	00.0
29	00.0	15.0	13.8	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
30	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0		00.0	00.0	00.0
31		00.0	2.8		00.0		00.0	00.0		00.0		00.0
TOTAL	122.7	80.1	96.45	98.9	8.3	00.0	31.0	00.0	00.0	10.2	00.0	36.6
MEAN	4.1	2.6	3.1	3.3	0.3	0.0	1.0	0.0	0.0	0.3	0.0	1.2
MAX	61.0	17.0	38.0	21.2	4.0	0.0	28.0	0.0	0.0	8.2	0.0	25.6
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.0 METHODOLOGY

Various methods have been developed for the determination of in-situ saturated hydraulic conductivity. However, when a water table is present the most commonly used method are auger hole technique. In the absence of water table, Guelph permeameter is used for measurement of field saturated hydraulic conductivity. Grain size analysis is generally done by sieve shakers and hydrometers, ceramic pressure plates apparatus are commonly used for obtaining soil moisture retention curve.

3.1 Guelph Permeameter Apparatus

The Guelph Permeameter is essentially an "in hole" Mariotte bottle constructed of concentric transparent plastic tubes. The apparatus comprises the following sections:

- i) Tripod Assembly
- ii) Support Tubes and lower air tube fittings
- iii) Reservoir Assembly
- iv) Well Head Scale and upper air tube fittings
- v) Auxiliary tools

i) Tripod Assembly:

The tripod assembly consists of a tripod based with movable tripod bushing and three detachable tripod legs complete with end tips. The flexible tripod base has three leg sockets into which the tripod legs are inserted (Fig.4). Tripod chain is used for firm placement and support of tripod legs.

ii) Support Tube and Lower Air tube fittings:

These are the fittings which conduct water from the reservoir assembly into the well hole and provide the means for establishing and maintaining a constant head in the well hole. The support tube supports the reservoir assembly over the well hole and transports water from the reservoir to the water outlet.

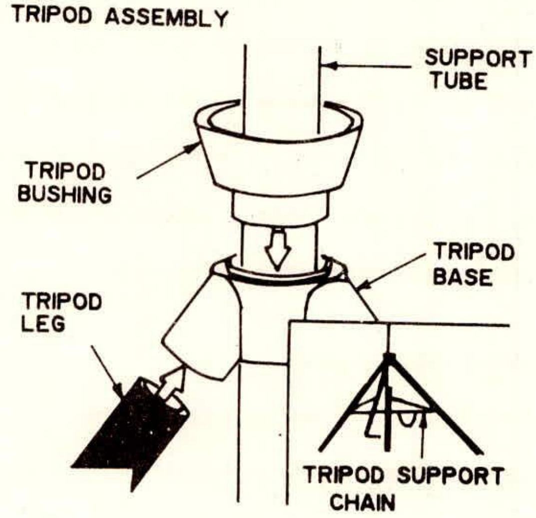


FIG. 4 TRIPOD ASSEMBLY SHOWING THE ARRANGEMENT OF TRIPOD BASE TRIPOD BUSHING AND DETECHABLE TRIPOD LEGS

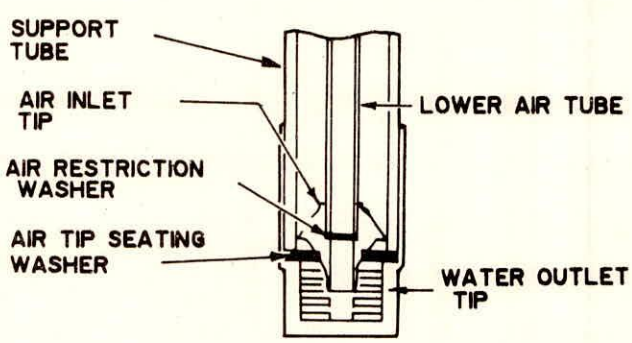


FIG. 5 SUPPORT TUBE AND AIR TUBE FITTINGS

The water outlet tip serves as a base for the permeameter and disperses the energy of the outflowing water through the ribbed vents at the bottom to the tip to minimize erosion of the soil in the well hole. The air tip seating washer rests on the inside step of the water outlet tip and is the seat for the Air Inlet tip when the air inlet is fully seated against the air tip seating washer, air cannot move up through the support tube and there is no flow of water out of the reservoir. The air inlet tip is connected to the bottom of the lower air tube and is used to regulate the well head height. The air restriction washer is located inside the air inlet tip and regulates air flow to provide a constant, non fluctuating head in the well. The details of support tube and air tube fittings are shown in Fig.5.

iii) Reservoir Assembly:

The reservoir assembly provides a means of storing water and measuring the outflow rate while the Guelph Permeameter is in use. It consists of inner reservoir tube, outer reservoir tube, reservoir valve, base and reservoir cap. For studies in very low permeability soils, for example clay soil, use of the inner reservoir alone is required to provide adequate outflow rate. When working in moderate to high permeable soils, for example sands and loamy soils, the reservoir combination is used. The inner reservoir tube is graduated in centimeters for measuring the rate of fall of water out of the reservoir in both situations. The details of the reservoir assemble is snown in Fig.6. The Guelph permeameter (Fig.6A) shows the closed or sealed state with air inlet tip sealed against air tip seating washer. When air tube is uplifted (Fig.6B), with accompanying air inlet tip and well height indicator, water flows from the reservoir down the inside of the support tube through the water outlet tip and into the well. The water height in the well is established by the height of the air inlet tip. This water height in the well can be set and read using well height indicator in conjunction with the well head scale.

The reservoir base includes the reservoir valve. The base connects and seats the inner and outer reservoir tubes to the support tube. Water flow is controlled by the position of the reservoir valve. When the valve position is up, both reservoirs supply water to the well hole. When it is pointing straight down, only the inner reservoir supplies water to the well hole. The reservoir cap provides an airtight cover for the top of the reservoir, the seal of the air tube and the supports the well head scale. The middle air tube is located inside the inner reservoir tube. Two ports are located in the reservoir cap namely Fill port and Fill plug. The vacuum port consists of an Access tube, Neoprene tube and clamping ring. The vacuum port facilitates pulling a vacuum when the reservoirs are not initially completely filled.

iv) Well Head Scale and Upper Air Tube Fittings:

The upper air tube is connected to be Middle air tube with an air tube coupling. It serves as an extension to facilitate setting the well head after the well head scale is put in place.

v) Auxiliary Tools

The Guelph permeameter kit includes a soil auger for excavating a well, a sizing auger, a well prep brush, a vacuum hand pump for pulling a vacuum in the reservoir and a collapsible

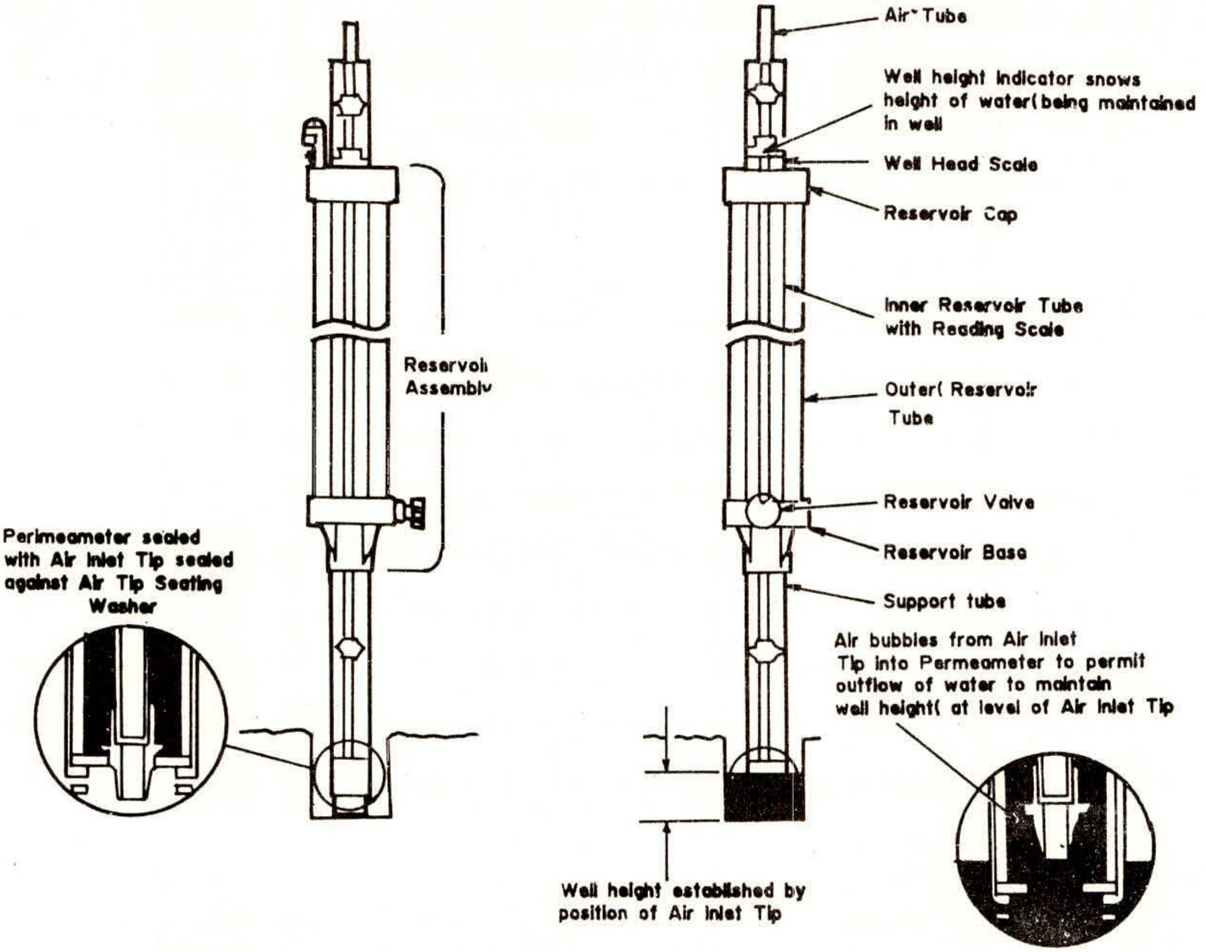
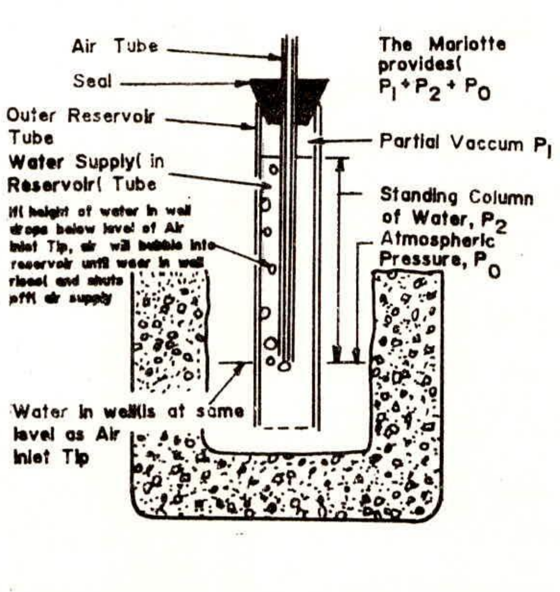


FIG.6- Details of reservoir assembly (A) closed or sealed state with air inlet tip sealed against air tip washer (B) when air tube is uplift permitting of flow of water.



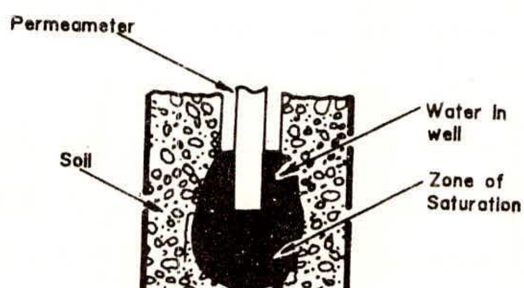


Fig.7- Permeameter in operation (A) Equilibrium is established
(B) A view of bulb in zone of saturation

water container for carrying water to the field. The well prep brush meant for removing any smear layer that exists in the augured well hole that may create a barrier to the natural flow of water out of the well into surrounding soil.

3.1.3 Theory

The Guelph permeameter method (Reynold et.al. 1985) measure the steady state liquid recharge Q. necessary to maintain a constant depth of liquid H in an uncased cylindrical well of radius 'a' finished above the water table. Constant head level in the well hole is established and maintained by regulating the level of the bottom of the air tube which is located in the centre of the permeameter. As the water level in the reservoir falls, a vacuum is created in the air space above water. When the permeameter is operating, an equilibrium is established as shown in Fig.7A.

When a constant well height of water is established in a cored hole in a soil, a bulb of saturated soil with specific dimension is rather quickly established as shown in Fig.7B. The bulb is very stable and its shape depends on the type of soil, the radius of the well and the head of water in the well. The shape of the bulb is numerically described by the C factor used in the calculations. Once the bulb shape is established, the outflow of water from the well reaches a steady state flow rate which can be measured. The rate of this constant outflow of water, together with the diameter of the well and height of water in the well can be used to determine the field saturated hydraulic conductivity of the soil.

The Richard analysis of steady state discharge from a cylindrical well in unsaturated soil, as measured by the Guelph permeameter technique accounts for all the forces that contribute to three dimensional flow of water into soils, the hydraulic push of water into soil, the gravitational pull of liquid out through bottom of the well and the capillary pull of water out of the well into the surrounding soil. The Richard analysis is the basis for the calculation of field saturated hydraulic conductivity. The C factor is a numerically derived shape factor which is dependent on the well radius 'a' and head 'H' of water in the well. The flow chart of procedure for measurement of saturated hydraulic conductivity is shown in Fig.8.

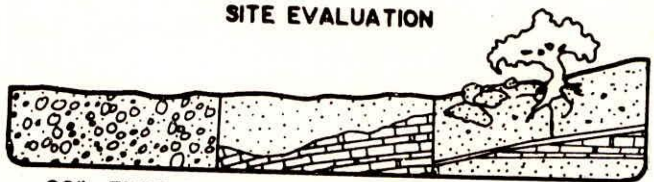
3.1.2 Procedures for Field Use

Before making a measurement with the Guelph permeameter in the field, it is necessary to perform a site and soil evaluation, prepare a well hole, assemble the permeameter, fill the reservoirs, and place the permeameter in the well hole.

3.1.3 Well preparation

The instruments needed for excavating and preparing a well bore hole are soil auger and sizing auger. The soil auger and sizing auger. The soil auger is used to remove bulk amounts of soil and rock. The sizing auger is used as a finishing tool to produce a proper sized well hole of uniform geometry and to clean debris off the bottom of the well hole. The sizing auger is designed to produce a hole that is uniformly 6 cm in diameter with a flat bottom. Generally, the procedure is to use the soil auger to excavate the well hole down to a depth 15 cm less than that desired for the final well hole. The last 15 cm can then be

SITE EVALUATION



SOIL TYPE ? SUB SURFACE ? ANOMALIES ?

WELL HOLE PREPARATION

ASSEMBLE PERMEAMETER

FILL RESERVOIRS

PLACE PERMEAMETER

SELECT RESERVOIR

RESERVOIR COMBINATION (FAST BUBBLING)

SET H_1 = 5 cm DETERMINE $\bar{R}_1$

SET H_2 = 10 cm DETERMINE $\bar{R}_2$

CALCULATE

$K_R = (.0041)(X)(\bar{R}_2) - (.0054)(X)(\bar{R}_1)$

$\phi m = (.0572)(X)(\bar{R}_1) - (.0237)(X)(\bar{R}_2)$

INNER RESERVOIR (SLOW BUBBLING)

SET H_1 = 5 cm DETERMINE $\bar{R}_1$

SET H_2 = 10 cm DETERMINE $\bar{R}_2$

CALCULATE

$K_R = (.0041)(Y)(\bar{R}_2) - (.0054)(Y)(\bar{R}_1)$

$\phi_m = (.0572)(Y)(\bar{R}_1) - (.0237)(Y)(\bar{R}_2)$

FIG. 8 FLOW CHART OF PROCEDURE FOR STANDARDIZED METHOD OF MEASUREMENT USING THE GUELPH PERMEAMETER

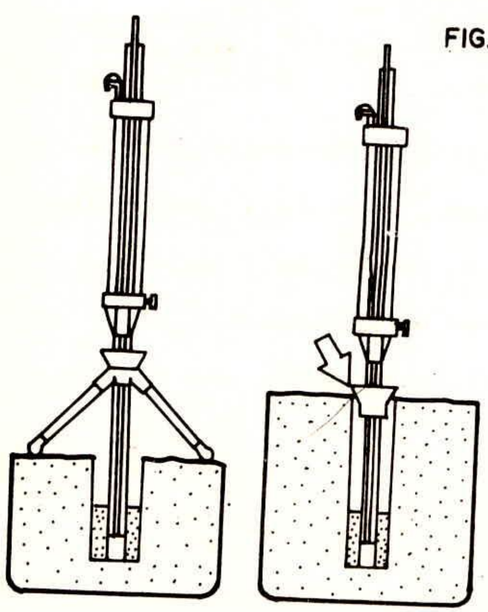


FIG. 9 PLACEMENT OF PERMEAMETER IN WELL HOLE

excavated using sizing . ıger to produce a debris free well hole of uniform ɔometry.

In the moist soils or in medium to fine textured soils, the process of auguring a hole may create a smear layer which can block the natural flow of water out of the well into the surrounding soil. In order to obtain reliable and representative results using the Guelph Permeameter, the smear layer must be remove. The well prep brush is designed to use in the standard 6 cm diameter well hole.

3.1.4 Permeameter Placement

Simply centre the Tripod over the well hole (as shown in Fig.9) and slowly lower the permeameter so that the support tube enters into the well hole. The tripod is used to support the permeameter in well down to approximately 38 cm in depth. For use in wells deeper that 38 cm, the tripod bushing alone provides the functions of centering and stablizing the permeameter. After the permeameter is placed, it can be easily filled with water. The following standard procedure should be followed for making measurements.

a) Verify that both the reservoirs are connected. The reservoirs are connected when the notch on the reservoir valve is pointing up.

b) Established 5 cm well Head Height (H1). Slowly raise the air inlet tip to establish the 5 cm well head height. Raising the air tube too quickly can cause turbulence and erosion in the well.

c) Observe the rate of fall of the water level in the reservoir. If it is too slow, then turn the reservoir valve so that the notch is pointing down. Water will then be supplied, only from the small diameter inner reservoir which will result in a much greater drop in water level between readings.

d) Measure permeameter outflow. This is indicated by the rate of fall of water in the reservoir. Readings should be made at regular time intervals, usually 2 minute intervals are used. The difference of readings at consecutive interval divided by the time interval equals the rate of fail of water, R1 in the reservoir. Continue monitoring the rate of fall of water in the reservoir until the rate of fall does not significantly change in three consecutive time intervals. This rate is called R1 and is defined as the "Steady state rate of fall" of water in the reservoir at height H1 which is the first well height established and is always 5cm in the standardized procedure.

e). Establish 10 cm Well head height (H2). Slowly raise the air inlet tip to establish the second well head height of 10 cm. Monitor the rate of fall of water, R2, in the reservoir until a stable value of R2 is measured.

f) The field saturated hydraulic conductivity, Kfs can be calculated using the following equation:

$$Kfs = 0.0041 \times R2 - 0.0054 \times R1$$

where,

x = reservoir constant, equal to 35.19 when reservoir combination is used, and 2.16 when inner reservoir is used

R2 = Steady, rate of fall of water in the reservoir when second head H2 equal to 10 cm of water is established.

R1 = Steady rate of fall of water in the reservoir when the first head H1 equal to 5 cm of water is established.

Kfs = field saturated Hydraulic conductivity in cm/sec.

3.2 Particle Size Analysis:

The various size groups of mineral particles in a soil are called separtes. These are generally clustered together as secondary particle or aggregates. For quantitative determination of particle sizes they have to be separated from one another by physical and chemical processes. Therefore the particle size analysis is essential to determine the relative proportion of the different grain sizes that make up a given soil mass. Obviously to have significance the sample must be statistically representative of the soil mass. Actually it is not possible to determine the individual soil sizes the test can only bracket the various ranges of sizes.

For determination of percentage particle size of various soil groups samples were collected from different locations in Malaprabha and Ghataprabha sub basins. The disturbed samples were oven dried. Since the soil in this area consist of both coarse and finer grains sieve analysis as well as hydrometer analysis were used. The samples were collected from 20-40 cm depth. 500 gm of oven dried soil sample was washed through 75 micron size sieve. The material retained on the sieve (75 micron) was used for sieve analysis after oven drying. The sieve analysis by arranging the various sieves one over the others and was shaked in a sieve shaking machine. The proportion of soil samples retained on each sieve was weighed and the percentage was calculated on the basis of the total weight of the dried soil samples (500 gm) taken. The material passing through 75 micron sieve size was used for hydrometer analysis by 152 H hydrometer.

3.2.1 Sieve Analysis

The complete particle size analysis of soil involves two main processes (1) dispersion or the separation of soil mass into its components or primary particles and stabilising the suspension and, (2) Fractination or the grading of different particle size groups or soil separates.

Dispersion: The first step for dispersion of soil mass is the soaking and mechanical trituration, removal of soluble electrolytes and divalent exchangeable cations, calcium-magnesium carbonates are removed by treating and washing with dilute hydrochloric acid. Organic matter may be removed by the treatment of hydrogen peroxide. The removal of electrolytes can be achieved by dissolution and leaching with dilute acids.

Fractination: After the complete dispersion of soil sample, the next step in the particle size distribution analysis grading of the particles into a number of size groups in order to know the percentage distribution of these groups of various sizes in the soil mass. Any process, that is used to separate the primary particles into various size groups is referred to as the Fractination. The coarser particles are fractionated into desired size groups through direct sieving and the finger particles are quantitatively determined by centrifugation.

Sieving: Sieving is the oldest and most widely used method for particles larger than 0.05mm size. . The standard test sieve consists of a woven wire screen with square apertures mounted in a shallow frame. The sieve shaker comprises of (1) Set of sieves: 4.75mm, 2.00mm, 1.40mm, 825 micron, 425 micron, 250 micron, 212 micron, 75 micron, (ii) thermostatically controlled oven (iii) Mortar and Pestle (iv) Physical balance sensitive to 0.1 gm (v) Mechanical sieve shaker (vi) Sieve brushes.

In direct sieving the dispersed soil suspension is passed through a nest of sieves of different sizes. The particles of different sizes are separated and retained on different sieves. Suitability of the method is restricted to coarse fractions only. The diameter of the sieve opening gives the diameter of a spherical particle which would just pass through the sieve aperture. The sieve analysis is carried out as follows: (1) Take the representative sample of soil collected from the field may be dried at 100-105 C in an oven for about 24 hrs. (2) Weigh the required quantity of dried soil keep it in a 1000 ml beaker and soak it with water. (3) Paddle the sample thoroughly in water and transfer the slurry to the 0.075 mm sieve and washing should be continued until the water passing through the sieve is substantially cleaned, so that the silt and clay particles are separated from sands and gravels fractioned to collect the material passing through 0.075 mm sieve (200) and the material retained on it in separate containers and keep them in oven for drying. (4) Weight both the group of soils retained and passed through 0.075 mm sieve and the retained amount of soil will be used for the sieve analysis and passed amount of soil will be used for hydrometer analysis, (5) Sieve the dried amount of soil retained on 0.075mm sieve through the set of sieves kept for the purpose. If the mechanical sieve shaker is not available then the process may be done by manually for about 10 minutes, (6) Remove the stack of sieves from the shaker and obtain the weight of material remaining on each sieve and compute the percent retained on each sieve by dividing the weight retained on each sieve by the original sample weight, (7) Compute the percent passing (or percent finer) by starting with 100% and substracting the percent retained on each sieve as cumulative procedure, (8) Make a semilogarithmic plot of grain size versus percent finer. Using the graph for this experiment and grain size curve can be completed by hydrometer analysis results.

Hydrometer Analysis: This method was introduced by G. Bouyoucos in 1927 and is applicable for determining the size distribution of particles having diameter less than 0.074 mm. The coarser particles bigger than this size are determined by direct sieving. The method of analysis is based upon the extended principle of hydrometer used in measuring the specific gravity of fluids. The varying specific gravity of well dispersed soil suspension as the particle settle or determined at different time intervals and thus the particle size distribution is known.

The method consists in determining (i) concentration of the particles at certain level of suspension column and (ii) the size of particles at the same level. Such pair of information for different time intervals provide various points for particle size distribution curve and thus gives the relative distribution of different soil separates. The procedure involves following steps. (1) Take passed amount of soil through 0.075 mm sieve and again

3.3 The leaching period

The leaching period prior to the transplanting of rice was 61 days only (15 Nov. 1970 - 15 Jan. 1971). In total 22, 100 m^3 of irrigation water was given in 4 applications of which 6,170 m^3 were stored in the soil profile down to 2.0 m in order to bring the soil to field capacity. The remainder part either percolated through the soil profile or evaporated at the soil surface. No rainfall was recorded during the leaching period. The discharge of the tile drainage system totaled 8,500 m^3 of water and the EC of the drainage water was 33 dS/m at 25 C (=22.0 grams of salt per liter).

It should be noted that there is a basic recharge to the drainage system, caused by upward seepage from deeper strata. This upward seepage is independent of the excess of irrigation water percolating through the soil profile. The seepage water has an EC of 10 dS/m at 25 C. The total basic recharge for the 4.9 ha plot amounts to 0.6 l/sec.

Table 6 : Mineralogical composition of the clay fraction (in percentage)

Depth in cm	Amorfic	Na-Ca (feld-spars)	Quartz	Kaolinite	Illite	Montmorillonite
0-10	9	5	6	15	35*	30
20-40	8	5	10	12	29*	36
120-160	10	5	6	10	19*	50

* partially (less than 50%)
random - interstratisfied illite - Montmorillonite

3.3.1 The first rice crop

From the 15th of January to the 1st of July, 1971 (167 days) a rice crop was grown. The yield obtained, 580 kg/ha, was very low, mainly due to high salinity at the moment of transplanting (Table 7). In total 57,700 m^3 of irrigation water was applied and a rainfall of 50 mm measured.

The change in soil moisture content in the soil profile can be considered zero, because the soil was wetted prior to transplanting time. The tile drainage system discharged 27,785 m^3 and the average EC of the drain water was 30 dS/m at 25 C (=19.9 grams of salt per liter). Surface drainage was considered necessary in case water pounded in the rice fields attained an EC oven dry at the temperature of 110 + or − 5OC. Weigh the 50gm of each soil and place the soil in 250 ml beaker. Mix the 125 ml of sodium hexa meta phosphate solution (40 gm/litre) and stir the beaker so the soil is thoroughly wetted. Allowed to soak about 16 hrs for clay soils and for sandy soils respectively.

(2) Transfer the soaked mixture in malt mixer (stirring apparatus) and washing any residue from the beaker into the mixer cup and add the tap water so that the cup is more than half full. Stir for a period of 1 minute.

(3) Immediately after dispersion transfer the soil water slurry into the glass sedimentation cylinder being very careful not to loose any material and add tap water and the total volume is 1000 ml. Be sure the tap water temperature is adjusted so that the sedimentation and control cylinder are at the same temperature. Control cylinders are used for composite correction.

(4) Cap the cylinder of soil suspension with rubber stopper and carefully agitate for about 1 minute. Set the jar down and remove the stopper and start the stop watch. About 20 second before reading the time, insert the hydrometer and take a reading at elapsed time 0.5, 1,2,4 minutes and also take the thermometer reading. Take also the temperature and meniscus reading on the hydrometer of the control jar for composite correction.

When placing the hydrometer in the suspension, avoid unnecessary agitation by proceeding slowly so that about 10 seconds are required for the operation. While taking reading with hydrometer, due to some foam formation in soil suspension, clarity is not there. It is proper to add two drops of Ethyl alcohol so that the foam formation will not be there and accurate reading of hydrometer will be recorded.

(5) Replace the stopper, reagitate the suspension and take another set of 0.5, 1,2,4 minutes readings. Repeat as necessary until the two sets of readings that agree within 1 unit of each other for both readings. If jar bath is used once more agitate the suspension and place it in the jar bath along with the control jar and take additional reading at elapsed time of 8, 15, 30, 60 minutes and 2,4,8 and 24 hrs. After the end of 4 hrs the reading should be taken once or twice within 24 hrs. Record the temperature of soil water suspension to the nearest 1 C for each hydrometer reading. Between hydrometer reading store the hydrometer and thermometer after washing in the control cylinder and jar (which should be at the same temperature).

The soils are classified on the basis of the mass ratios of the three fractions. Soils with different proportions of sand, silt and clay are assigned to different classes as shown in fig.10 (U.S. Dept. of Agri.)

3.3 Pressure Plate Apparatus

This is a standard method for obtaining the soil moisture retention curve. Pressure plate apparatus consists of a pressure chamber in which a saturated soil sample is placed on a porous ceramic plate through which the soil solution passes but no soil particle or air can pass. The soil solution which passes through the membrane is in contact with atmospheric pressure. As soon as the air pressure inside the chambers are raised above the atmospheric it takes excess water from the soil out of the chamber through the membrane outlet. Soil water will flow out from the soil sample until the metric potential of the unsaturated flow is same as the applied air pressure. The air

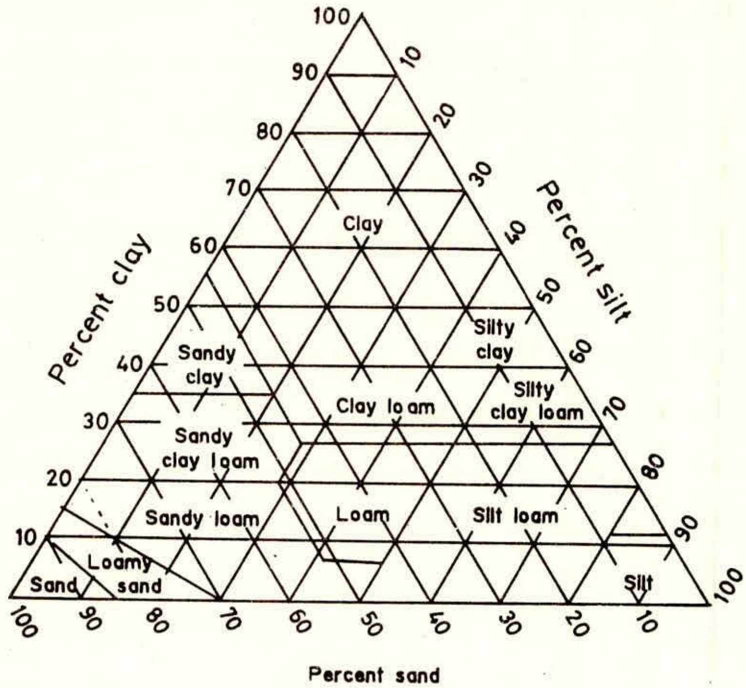


FIG.10- TRIANGLE OF SOIL TEXTURES FOR DESCRIBING VARIOUS COMBINATIONS OF SAND, SILT, AND CLAY (AFTER SOIL AND SURVEY STAFF)

pressure is then released and the moisture content of the soil is gravimetrically determined.

During a run, soil moisture will flow from around from each of the soil particle and out through the ceramic plate until such time as the effective curvature of the water film through out the soil are the same as at the pores in the plates. When this occurs an equilibrium is reached and the flow of moisture ceases. When air pressure in the chamber is increased, flow of water from the samples starts again and continue until a new equilibrium is reached. A source of regulated gas pressure is required for all extraction work. Compressed air from a compressor is the most efficient source of supply.

The ceramic plates are available in different range. Each ceramic pressure plate cell consists of a porous ceramic plate, covered on one side by a thin neoprene diaphragm sealed to the edges of the ceramic plate. An internal screen between the plate and diaphragm provides a passage for flow of water. An outlet stem running through the plates connects this passage to an outflow tube fitting which to the atmosphere outside of the extractor. Cross section view of ceramic pressure plate cell and soil sample is shown in Fig.9. To use the ceramic pressure plate cell, one or more soil samples are placed on the porous ceramic surface held in place by retaining rings of appropriate height. The soil samples together with the porous ceramic plate are then saturated with water. This is usually done by allowing an excess of water to stand on the surface of the cell for several hours. When the saturation is complete, the cell can be mounted into the pressure vessel. Air pressure is used to effect extraction of moisture from the soil samples under controlled conditions. The

1 bar ceramic plates are ideal for the routine determination of the 1/10 bar and 1/3 bar range of the soil suction. The 3 bar pressure plate cells are used in the range of 0-3 bars. The 15 bar ceramic cells are commonly used for measurement of soil moisture suction in the range of 5-15 bars of soil suction.

The moisture retention curve of a soil sample can generally be determined by equilibrating a soil sample at a succession is known tension value and each time determining the amount of moisture. The graph is plotted between the tension and corresponding soil moisture value to obtain the soil moisture retention curve. Different types of soil yields different retention curves.

4.0 RESULTS & DISCUSSIONS

4.1 Particle size distribution

The field tests were carried out in several locations in the Malaprabha and Ghataprabha basins. For determination of percentage particle size of various soil groups, samples were collected from various locations in Malaprabha & Ghataprabha basins. The disturbed samples were oven dried. Since the soil in this area consists of both coarse and fine grains, sieve analysis as well as hydrometer analysis were used. The samples were collected from 20 to 40 cm depth. 500 gm of oven dried soil sample was washed through 75 micron size sieve. The material retained on the sieve (+75 micron) were used for sieve analysis after oven drying. The proportion of soil samples retained on each sieve was weighed and the percentage was calculated on the basis of total weight of dried soil samples (i.e. 500 gm) taken. The material passing through 75 micron sieve size was used for hydrometer analysis by 152 H hydrometer. The percentage of Gravel, sand, silt and clay are shown in Table 8.

In generally, the particle size analysis will provide information regarding the diameter of the largest grains in the assemblage, and the grading pattern, i.e. whether the soil is composed of distinct groups of particles or in other words it may provide the sorting of soil particles, i.e. whether soil particles are poorly sorted, moderately sorted or well sorted and it is also possible to assess the length of transportation. The particle size distribution curve drawn between the grain size and cumulative percentages (in semi-logarithmic graph) are essential for knowing the sorting and to know the distance transported. This curve can also be differentiated graphically to yield a

Table 8 : Results of Sieve & hydrometer analysis of different soil samples

Locations	% of Gravel	% of Sand	% of Silt	% of Clay
Hidkal Dam	12.50	72.50	6.20	8.80
Belgaum	5.00	18.43	29.57	47.00
Ramdurg	0.60	53.40	14.50	31.50
Raibag	22.60	18.34	37.31	21.75
Jam Khandi	2.70	30.62	11.68	55.00
Mudhol	4.50	51.65	26.35	17.50
B D Tank	8.10	44.40	21.25	26.25
Badami	0.20	88.77	3.03	8.00

frequency distribution curve for grain sizes, with a peak indicating the most prevalent grain size. A general particle distribution curve representing different type of soils are shown in figure 11.

The particle size analysis of the Malaprabha region shows that, sand is the predominating constituent at Asoga, Ramdurg and Badami (Fig.12, 13 & 14). It is also evident that the grain size distribution in these regions follow a good sorting trend. The sample at Badami is comparatively well sorted due to its higher sand content.

The curve (Fig. 15) drawn for Bidi shows that the soil is mainly composed of sand with an admixture of silt and clay. The percentage of silt and clay comprises more than 50%. The grain size analysis of Ron, (Fig.16) shows that the clay is the most predominating constituent followed by sand and silt. The sorting of the particles are comparatively poorer.

The particle size distribution curve drawn for different soil types in the Ghataprabha command area are shown in figure and compared with the typical curves available. The fig. 17 & 18, the grain size distribution curve drawn for Hidkal and Mudhol follows a similar trend showing a higher percentage of sand. The curve also indicate a good sorting nature of the soil particles.

The curves (Fig. 19, 20 & 21), i.e of Gokak, Jamkhandi, Bagalkot follows the trend of clay particles as shown in typical diagram (Fig.11). A decrease in sorting nature can be clearly observed from the curve. The curve observed for Raibag (Fig.22) is a typical curve showing a loamy soil. It shows a somewhat equal mixing of all grain sizes. The curve (Fig.23) drawn for Belgaum shows the clayey nature of the soil sample with a poorer sorting. The details of percentage finer particles and their variation according to sieves for various location at Malaprabha and Ghataprabha basins are shown in Table 9 & Table 21.

4.2 Soil Moisture Retention Curves

In order to evaluate completely the condition of water in soil, one must know the energy of the water, the amount of water in the soil and how these conditions varies in space and time. The plant response to the water appears to be more closely related to the water potential, although the velocity of movement of water to the absorbing root is an important consideration. The movement rate is strongly related to the potential. There is a relation between the amount of water in a soil and the potential energy of the water in the soil system.

When the pressure head of the soil changes the water content of the soil which change. The graph representing the relationship between the pressure head and water content is

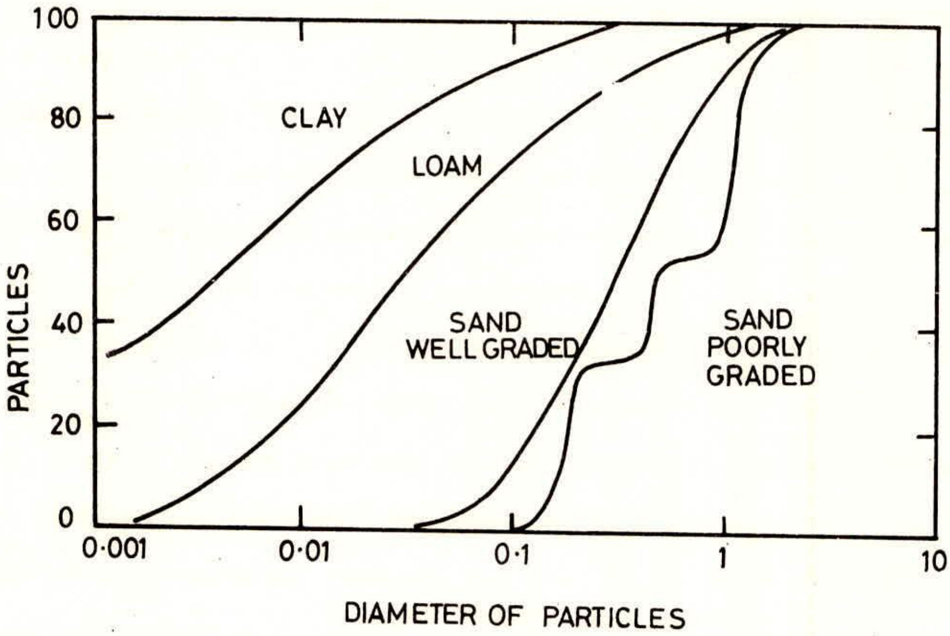
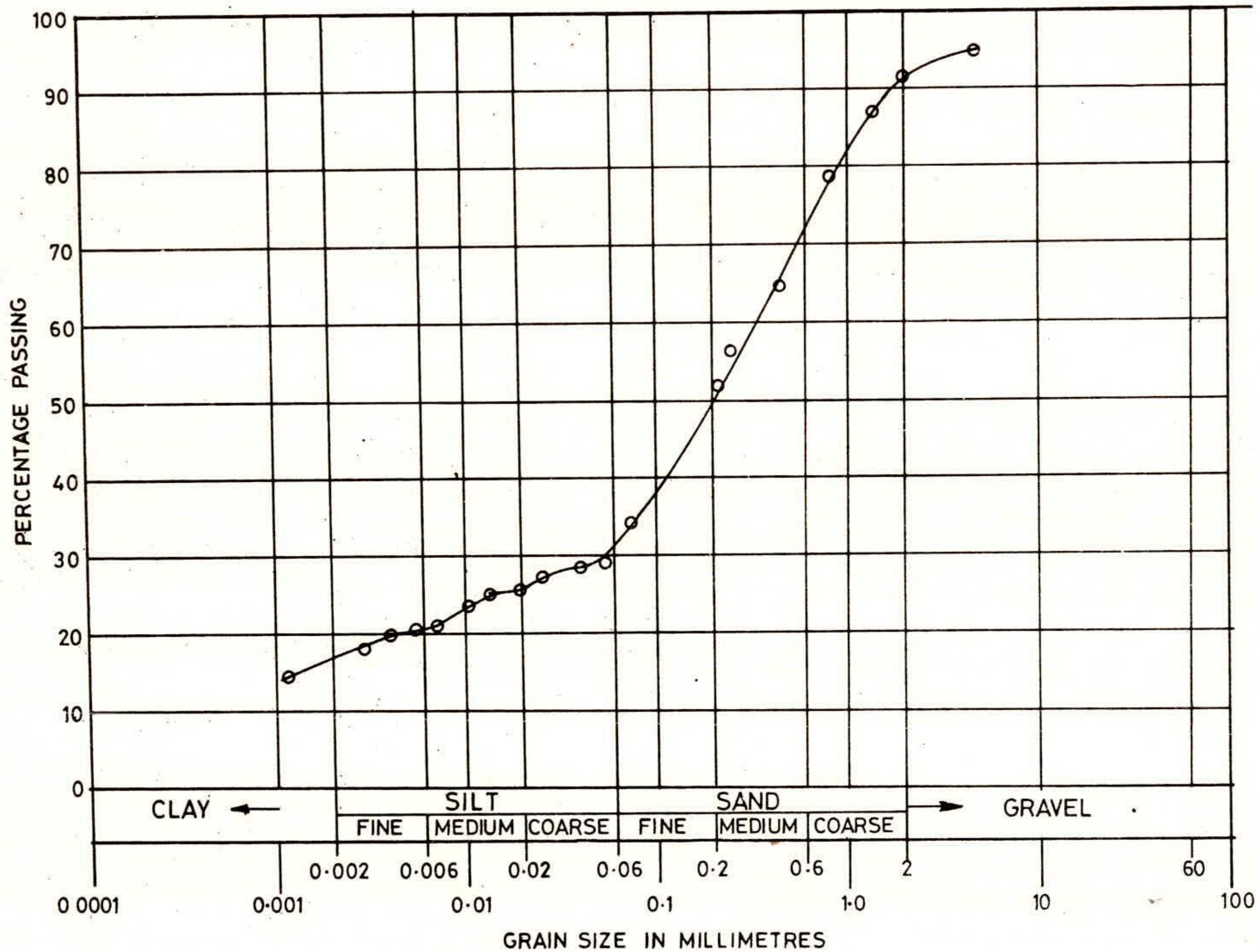


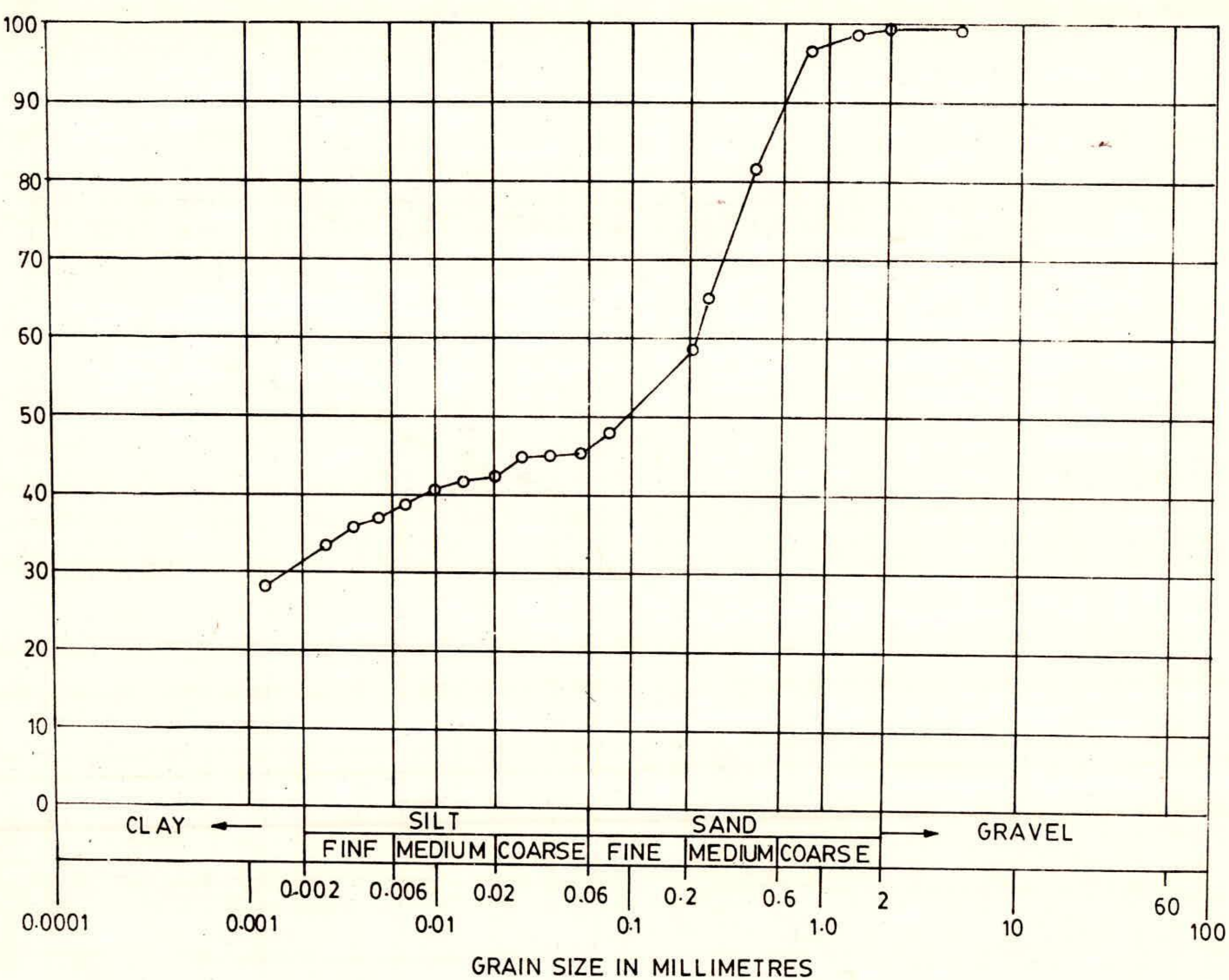
FIG. 11 - PARTICLE SIZE DISTRIBUTIONS CURVES FOR VARIOUS TYPES OF SOIL MATERIAL (SCHEMATIC)



ASOGA

GRAVEL = 3.8
SAND = 61.2
SILT = 19.75
CLAY = 15.25

Fig.12 Grain size distribution at ASOGA



RAMDURG

GRAVEL = 0.6
SAND = 53.4
SILT = 14.5
CLAY = 31.5

Fig.13 Grain size distribution at RAMDURG

BADAMI

GRAVEL = 0.20%
SAND = 88.77%
SILT = 3.03%
CLAY = 8.00%

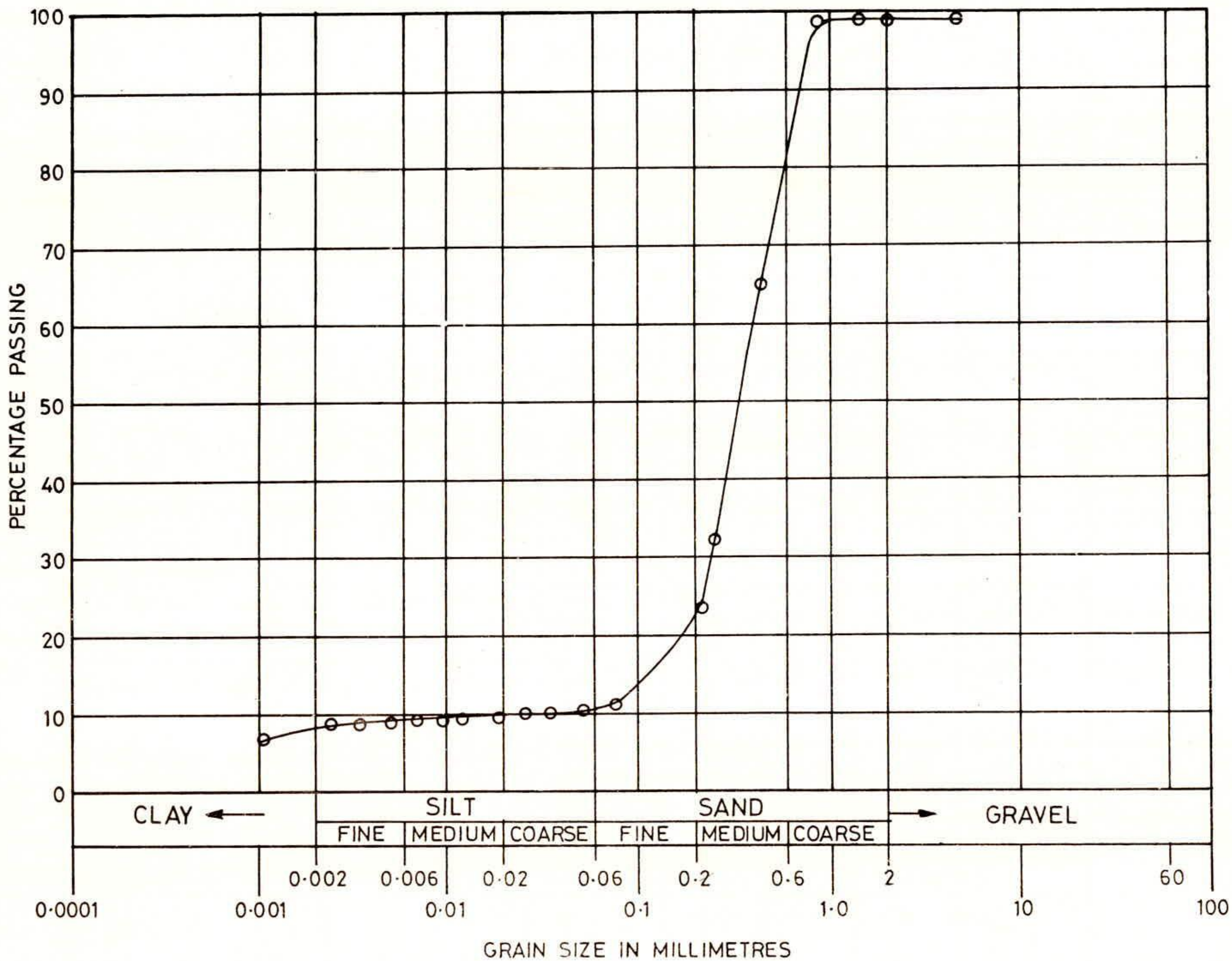


Fig.14 Grain size distribution at BADAMI

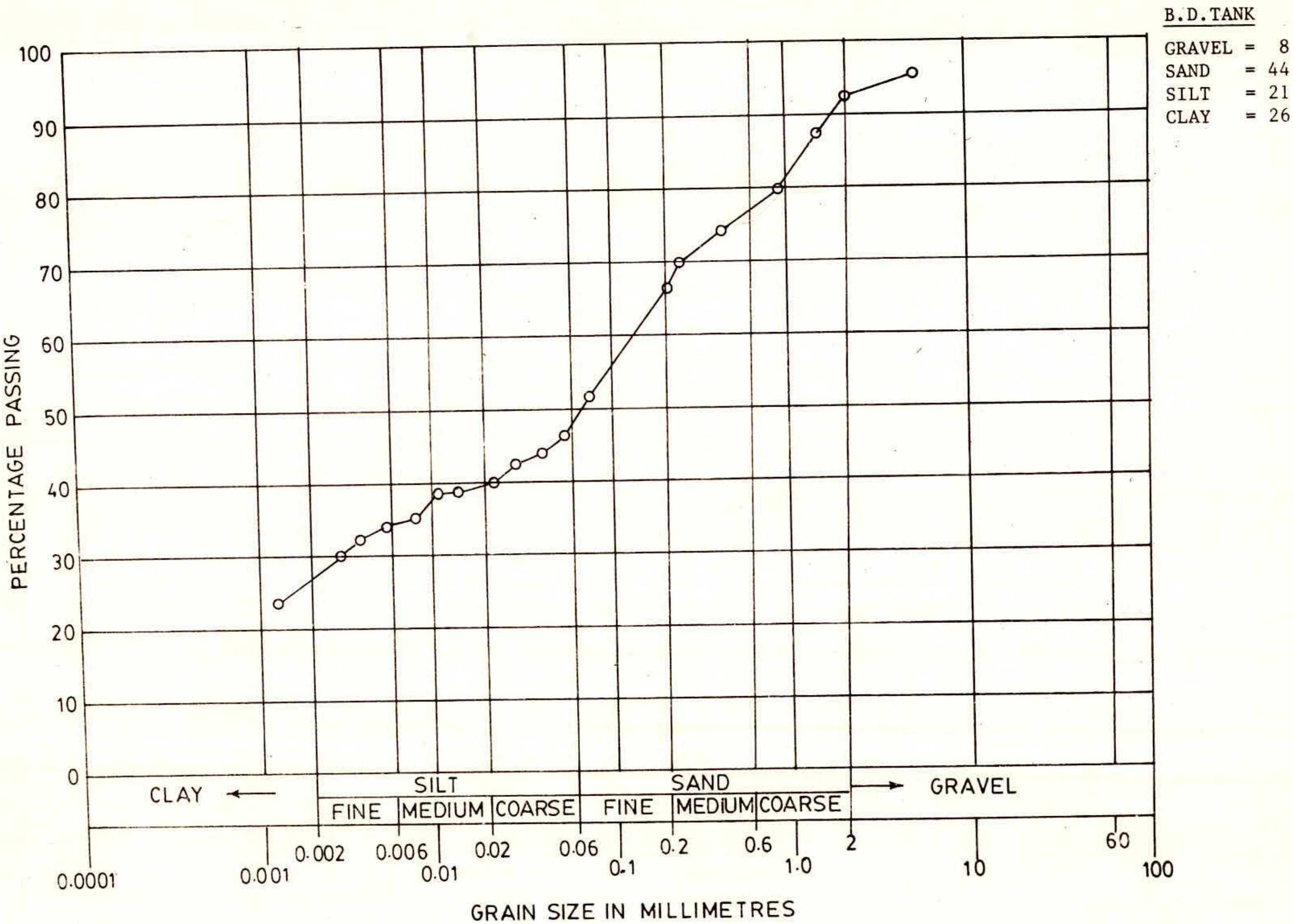
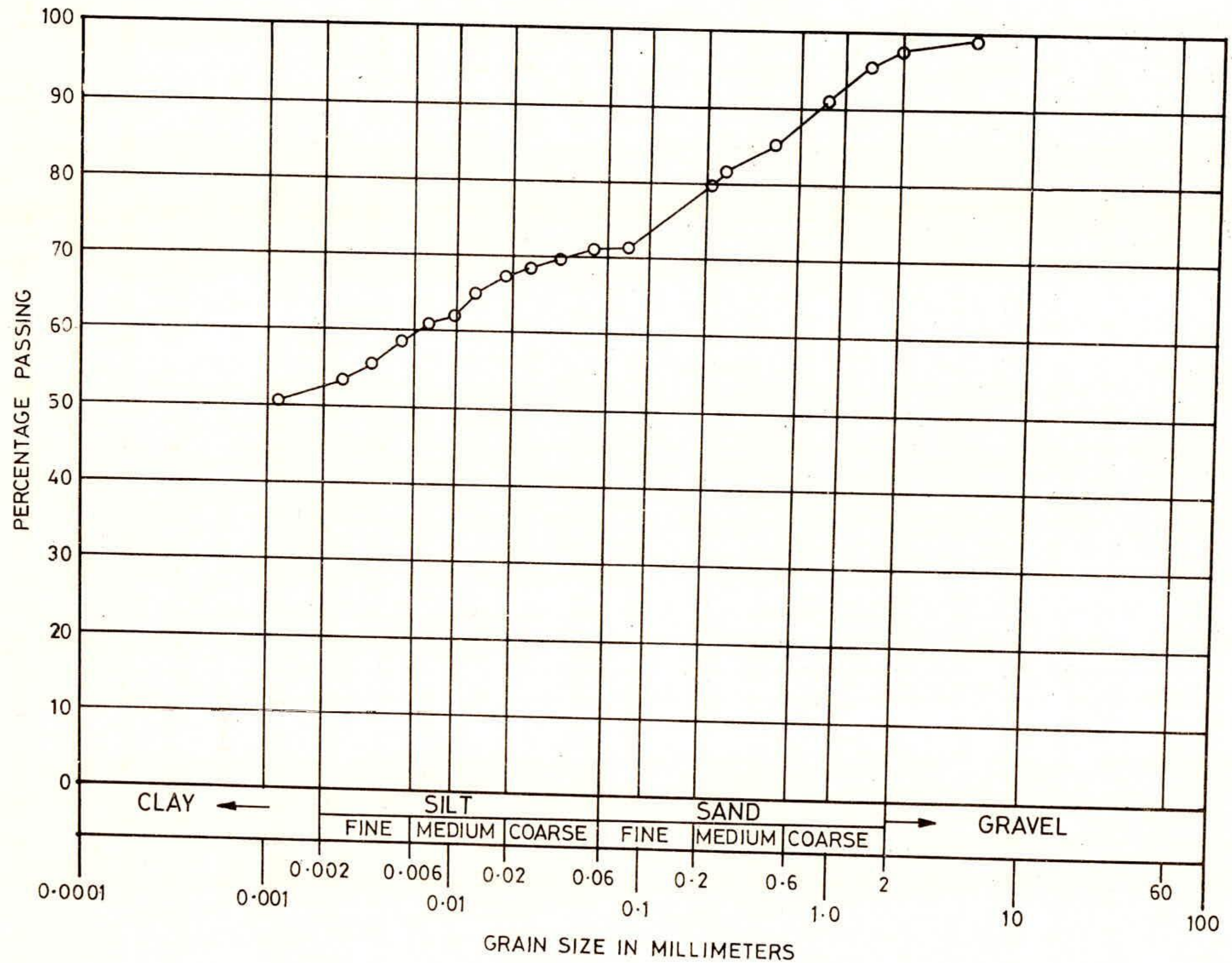


Fig.15 Grain size distribution at B.D.TANK



RON

GRAVEL = 2.70
SAND = 26.92
SILT = 18.38
CLAY = 52.00

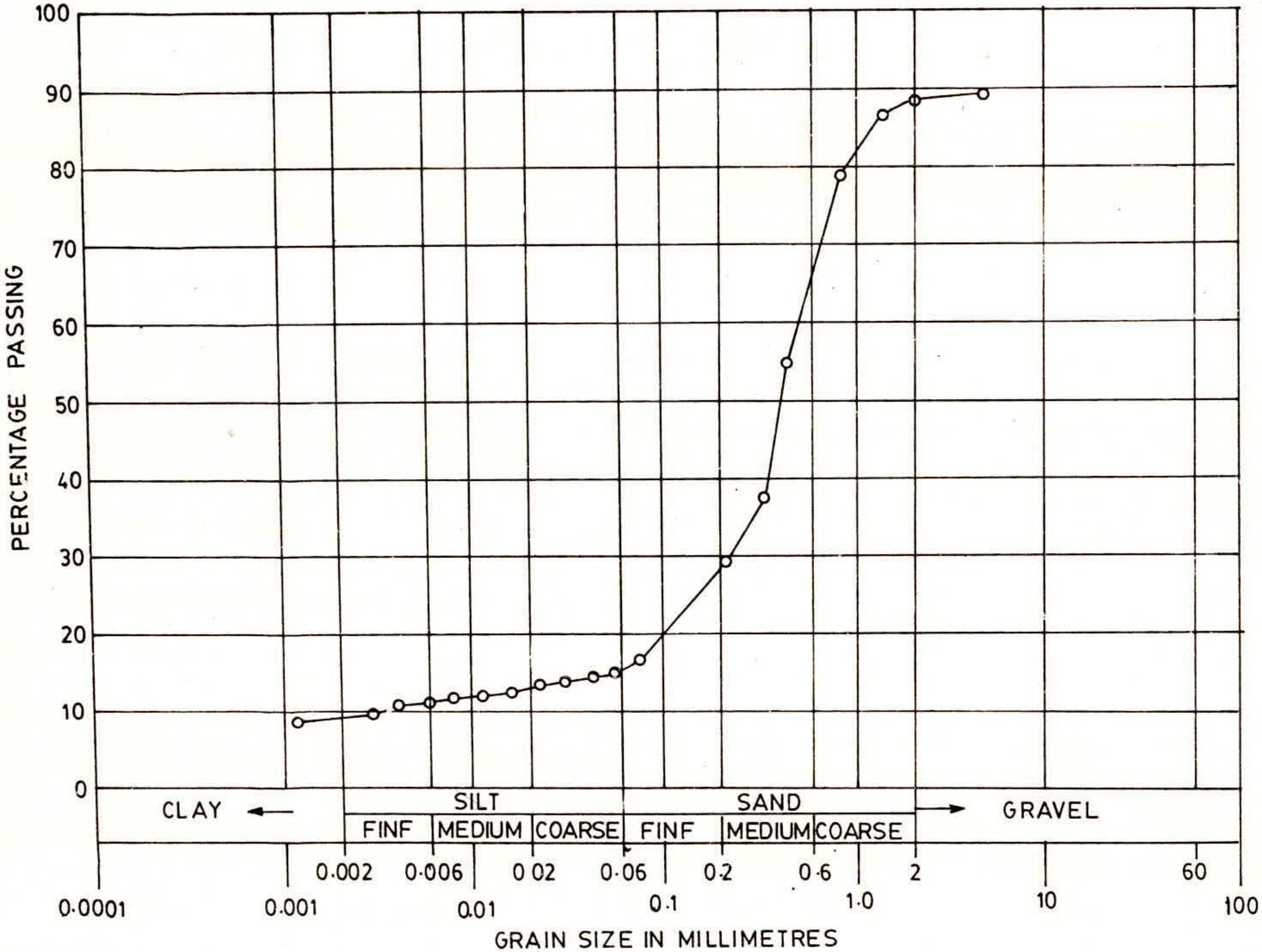
soil types in the Ghataprabha command area are shown in figure and compared with the typical curves available. The fig. 17 & 18, the grain size distribution curve drawn for Hidkal and Mudhol follows a similar trend showing a higher percentage of sand. The curve also indicate a good sorting nature of the soil particles.

The curves (Fig. 19, 20 & 21), i.e of Gokak, Jamkhandi, Bagalkot follows the trend of clay particles as shown in typical diagram (Fig.11). A decrease in sorting nature can be clearly observed from the curve. The curve observed for Raibag (Fig.22) is a typical curve showing a loamy soil. It shows a somewhat equal mixing of all grain sizes. The curve (Fig.23) drawn for Belgaum shows the clayey nature of the soil sample with a poorer sorting. The details of percentage finer particles and their variation according to sieves for various location at Malaprabha and Ghataprabha basins are shown in Table 9 Table 21.

Soil Moisture Retention Curves

In order to evaluate completely the condition of water in soil, one must know the energy of the water, the amount of water in the soil and how these conditions varies in space and time. The plant response to the water appears to be more closely related to the water potential, although the velocity of movement of water to the absorbing root is an imoortant consideration. The movement rate is strongly related to the potential. There is a relation between the amount of water in a soil and the potential energy of the water in the soil system.

When the pressure head of the soil changes the water content of the soil which change. The graph representing the relationship between the pressure head and water content is



HIDKAL DAM

GRAVEL = 12.5
SAND = 72.5
SILT = 6.2
CLAY = 8.8

Fig.17 Grain size distribution at HIDKAL DAM

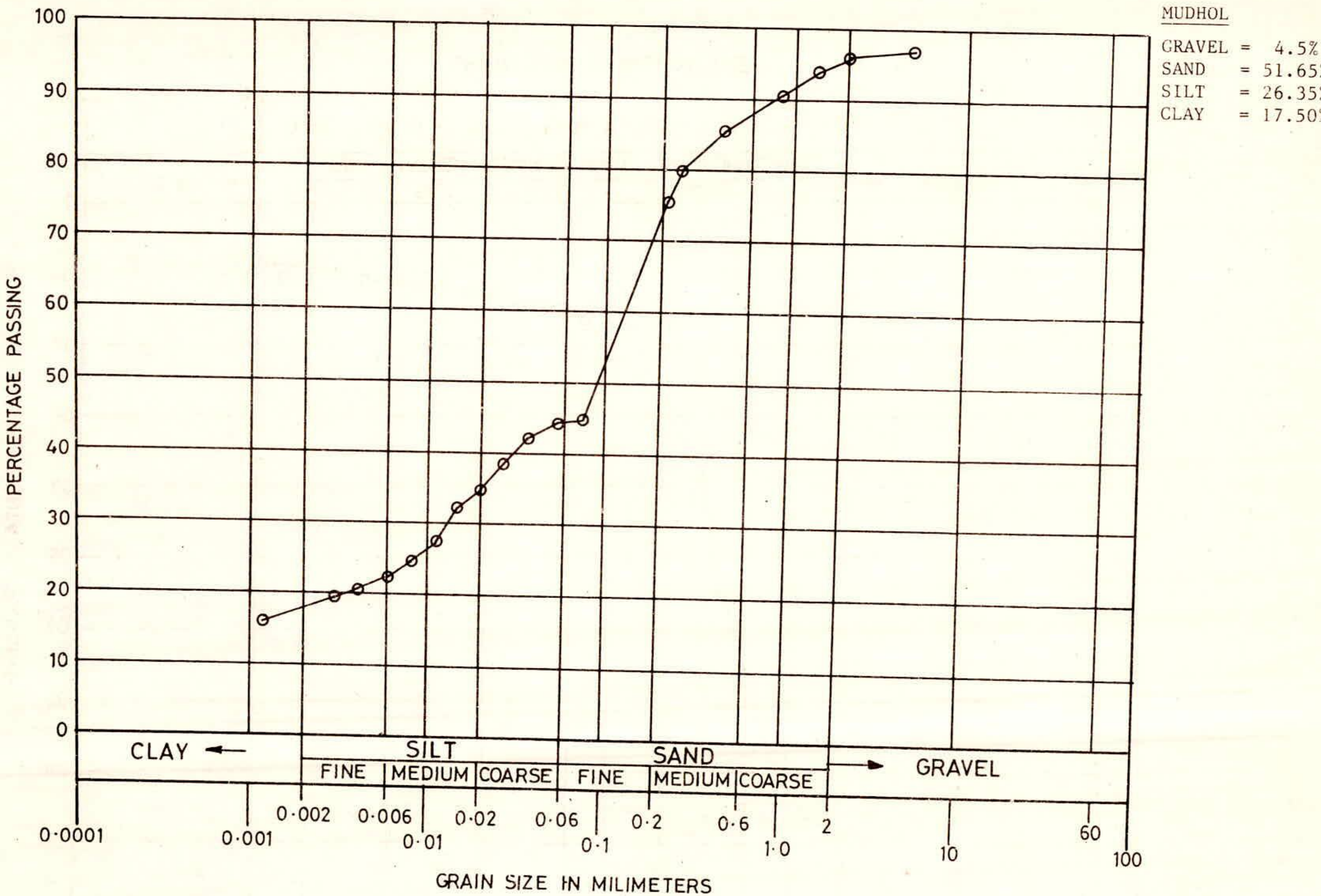


Fig.18 Grain size distribution at MUDHOL

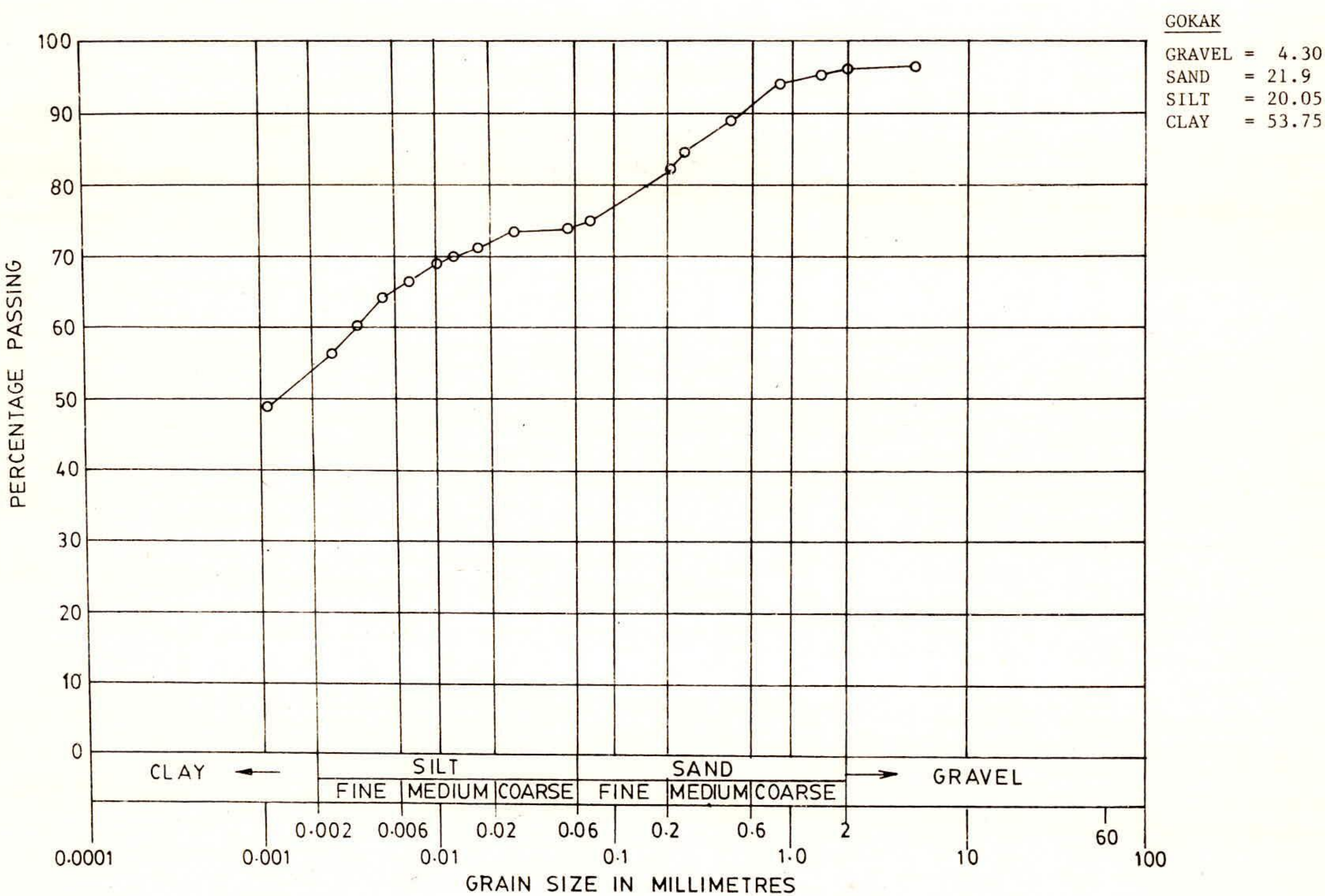
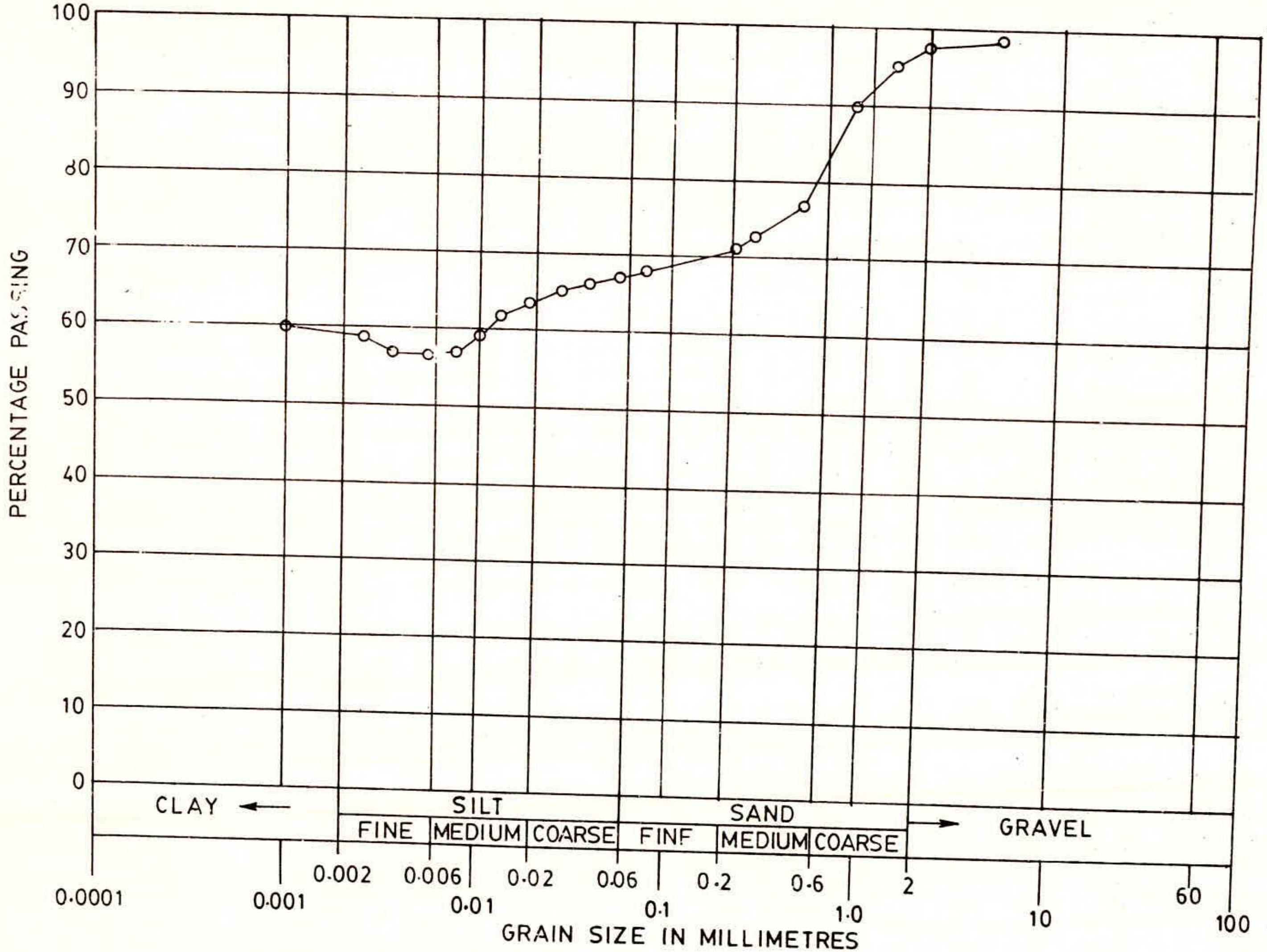


Fig.19 Grain size distribution at GOKAK



JAMKANDI

GRAVEL = 2.7%
SAND = 30.62%
SILT = 11.68%
CLAY = 55.0%

Fig.20 Grain size distribution at JAMKANDI

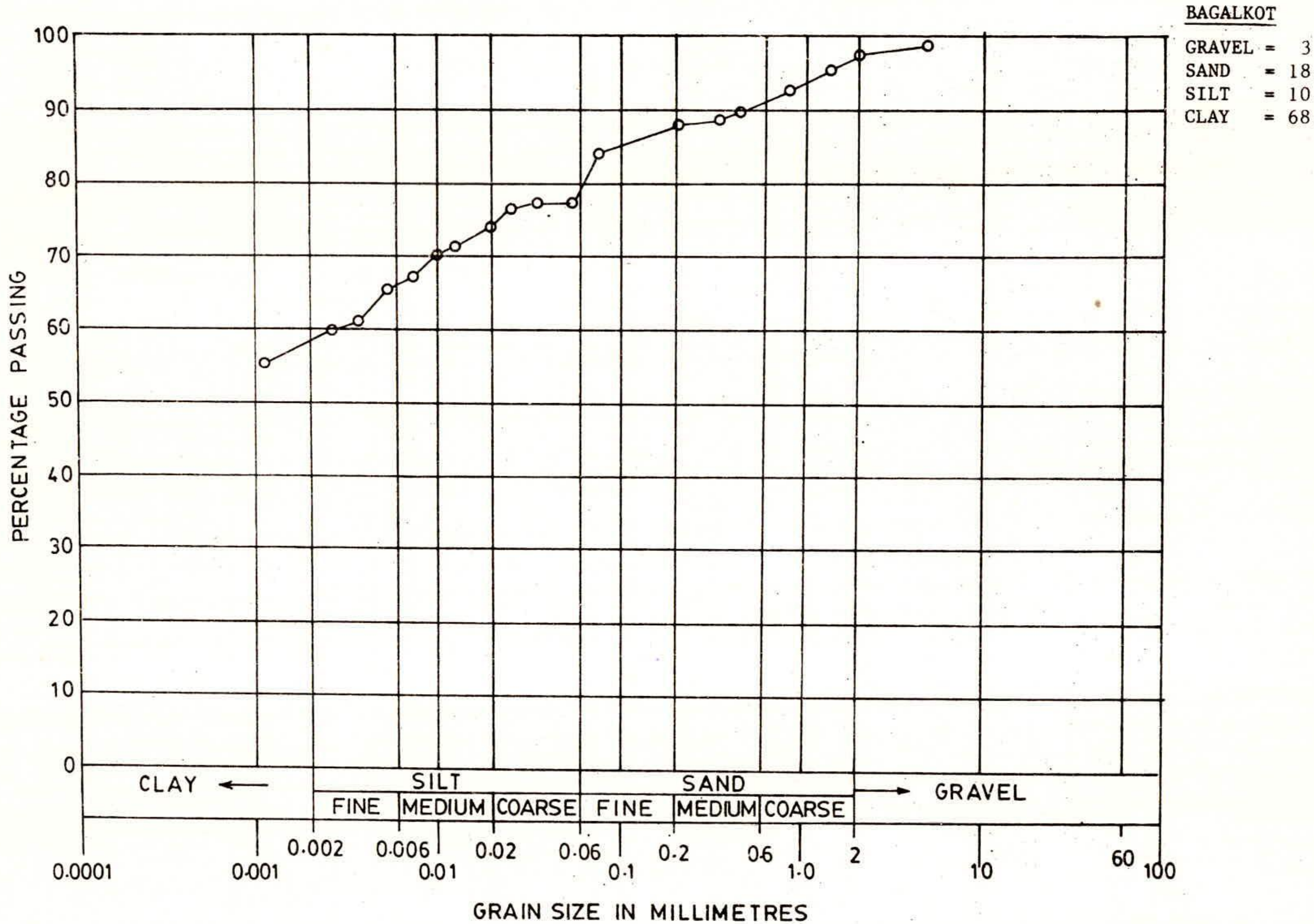


Fig.21 Grain size distribution at BAGALKOT

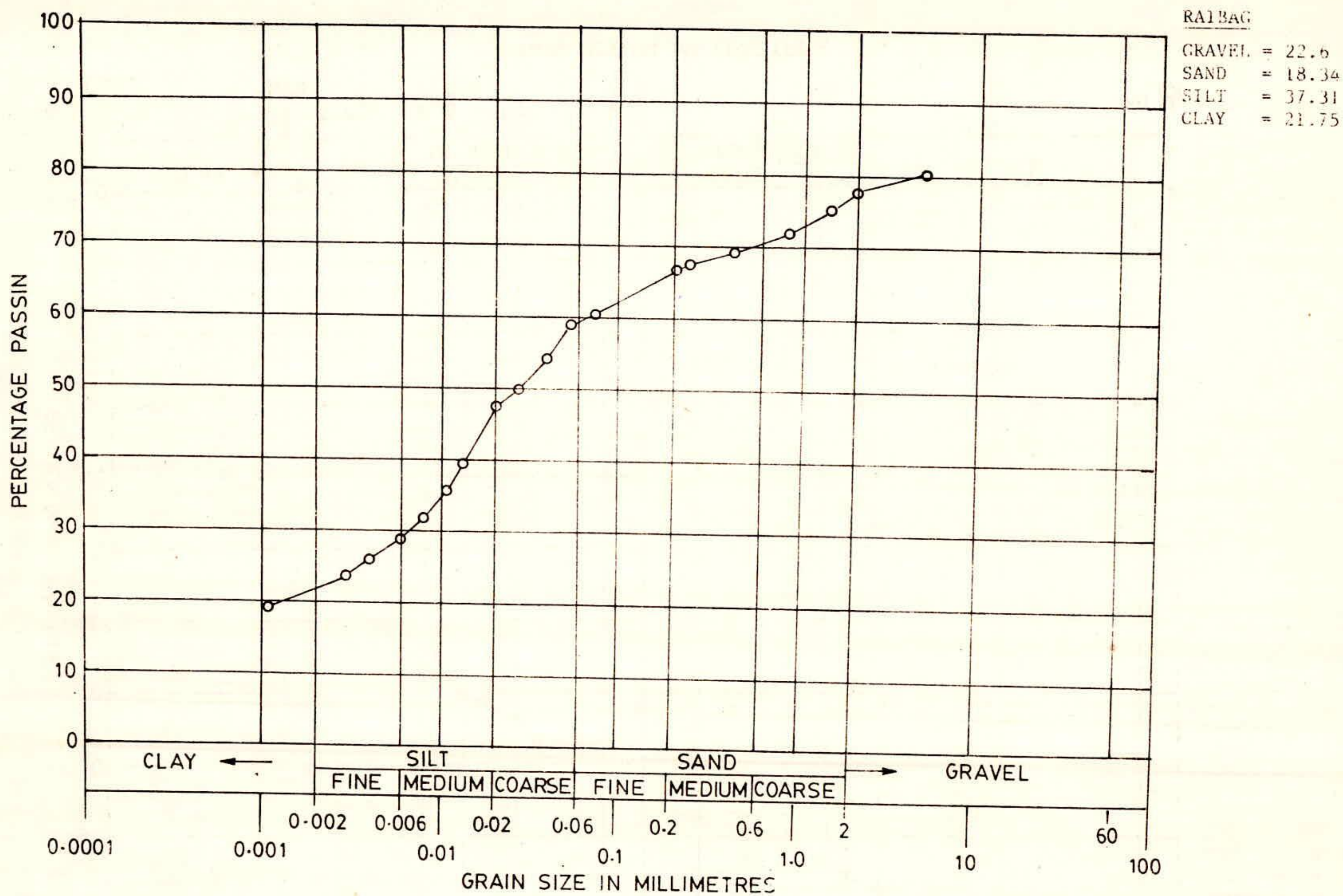
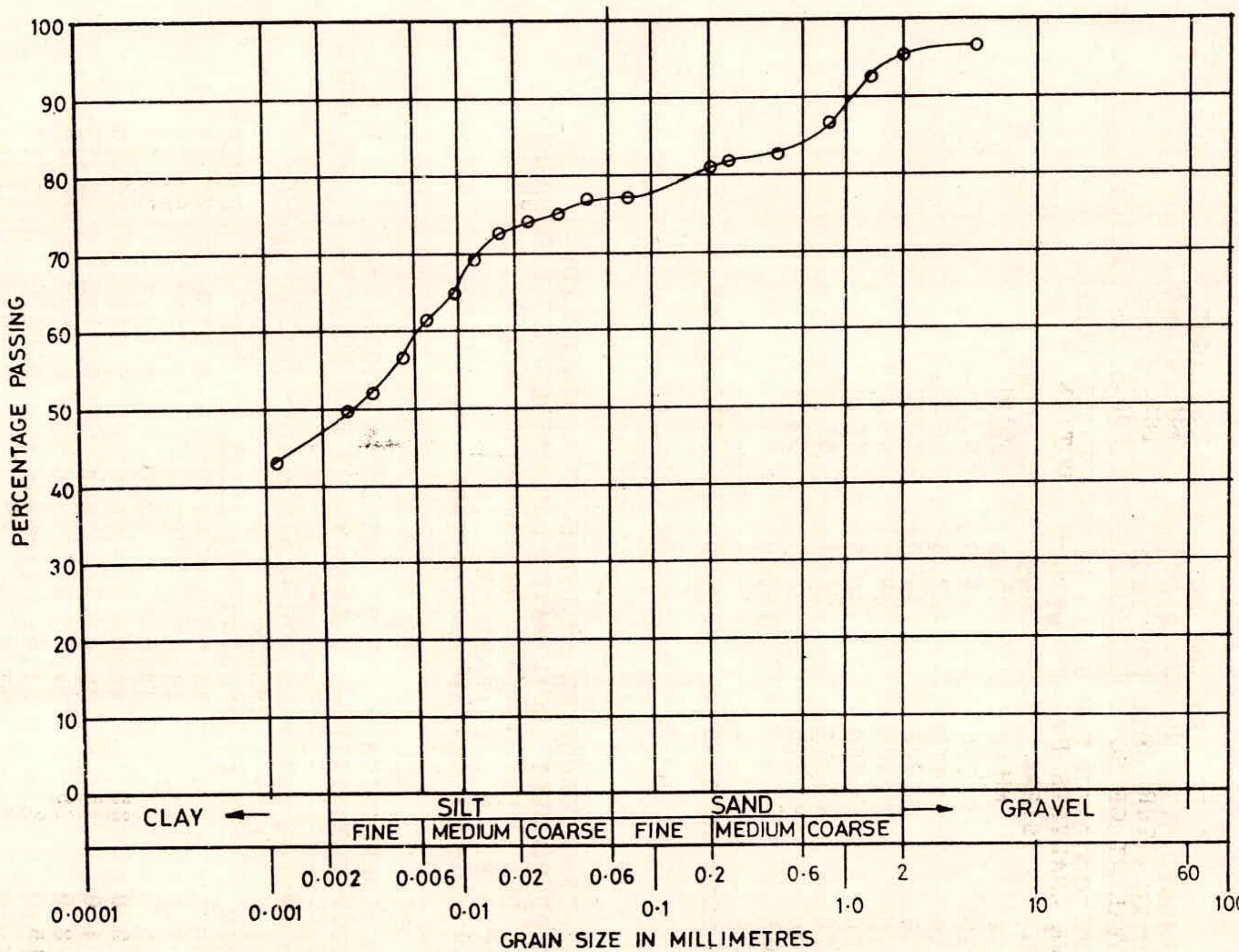


Fig.22 Grain size distribution at RAIBAG



BELGAUM

GRAVEL = 5.0%
SAND = 18.43%
SILT = 29.57%
CLAY = 47.0%

Fig.23 Grain size distribution at BELGAUM

Table 9: Grain size distribution of Asoga Soil

PROJECT: GRAIN SIZE DISTRIBUTION OF ASOGA(K.PUR)
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRPTION: DARK RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: FEBRAURY 28TH 1992

WT DRY SOIL = 336.1GMS
WT WASHED THRU NO 200 SIEVE = 163.9 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	28.3	94.3
#10	2.000	15.9	91.2
#14	1.400	22.8	86.6
#20	0.825	44.3	77.7
#40	0.425	68.9	64.0
#60	0.250	40.3	55.9
#70	0.212	21.4	51.6
#200	0.075	94.3	32.8
PAN		163.9	

SUM SOIL WEIGHTS = 500.0 (336.1 GMS)

PROJECT: HYDROMETER ANALYSIS OF ASOGA(KH.PUR)
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DARK RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 6TH,1992

ZERO CORRECTION = 3.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.65 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	25.	45.5	87.6	0.0536	28.71
1.0	25.	44.5	85.6	0.0382	28.05
2.0	25.	43.0	82.6	0.0274	27.07
4.0	25.	40.0	76.6	0.0199	25.10
8.0	25.	38.0	72.6	0.0143	23.79
15.0	25.	36.0	68.6	0.0106	22.48
30.0	25.	34.0	64.6	0.0076	21.17
60.0	25.	33.0	62.6	0.0054	20.52
120.0	26.	31.0	59.3	0.0039	19.43
240.0	26.	28.0	53.3	0.0028	17.47
1440.0	25.	24.0	44.6	0.0012	14.62

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 10: Grain size distribution of Bidi Tank

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF B.D.TANK
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: FEBRAURY 25TH, 1992

WT DRY SOIL = 245.7GMS
WT WASHED THRU NO 200 SIEVE = 254.3 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	24.7	95.1
#10	2.000	15.7	91.9
#14	1.400	24.1	87.1
#20	0.825	40.4	79.0
#40	0.425	28.3	73.4
#60	0.250	23.0	68.8
#70	0.212	16.4	65.5
#200	0.075	73.1	50.9
PAN		254.3	

SUM SOIL WEIGHTS = 500.00 (245.7 GMS)

PROJECT: HYDROMETER ANALYSIS OF B.D.TANK
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 11TH,1992

ZERO CORRECTION = 5.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.52 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	21.	48.0	89.2	0.0571	45.36
1.0	21.	46.0	85.1	0.0412	43.26
2.0	21.	45.0	83.0	0.0294	42.21
4.0	21.	42.0	76.8	0.0214	39.06
8.0	21.	41.5	75.8	0.0152	38.54
15.0	21.	41.0	74.7	0.0111	38.01
30.0	21.	38.0	68.5	0.0081	34.86
60.0	21.	36.0	64.4	0.0058	32.76
120.0	22.	35.0	62.8	0.0041	31.92
240.0	22.	32.5	57.6	0.0029	29.30
1440.0	21.	27.0	45.8	0.0013	23.31

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 11: Grain size distribution of Belgaum

PROJECT: GRAIN SIZE DISTRIBUTION OF BELGAUM
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRPTION: DARK RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: FEBRAURY 28TH 1992

WT DRY SOIL	=	116.2GMS
WT WASHED THRU NO 200 SIEVE	=	383.8 GMS
TOTAL WT OF SOIL FOR TEST	=	500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	18.3	96.3
#10	2.000	6.9	95.0
#14	1.400	14.8	92.0
#20	0.825	30.4	85.9
#40	0.425	20.2	81.9
#60	0.250	5.5	80.8
#70	0.212	2.9	80.2
#200	0.075	17.1	76.8
PAN		383.8	

SUM SOIL WEIGHTS = 500.0 (116.2 GMS)

PROJECT: HYDROMETER ANALYSIS OF BELGAUM
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DARK RADISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 3RD,1992

ZERO CORRECTION = 6.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.70 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	25.	55.0	99.5	0.0478	76.35
1.0	25.	54.0	97.5	0.0342	74.84
2.0	25.	53.0	95.5	0.0244	73.32
4.0	25.	52.0	93.5	0.0175	71.80
8.0	25.	49.5	88.6	0.0127	68.01
15.0	25.	47.0	83.7	0.0095	64.21
30.0	25.	45.0	79.7	0.0068	61.17
60.0	25.	41.5	72.8	0.0050	55.86
120.0	26.	38.5	67.5	0.0036	51.84
240.0	26.	37.0	64.6	0.0026	49.56
1440.0	25.	33.0	56.0	0.0011	42.96

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 12: Grain size distribution of Bagalkot

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF BAGALKOT
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: VERY DARK GRAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 3RD. 1992

WT DRY SOIL = 84.8GMS
WT WASHED THRU NO 200 SIEVE = 415.2 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	9.8	98.1
#10	2.000	5.1	97.0
#14	1.400	10.6	94.9
#20	0.825	13.8	92.2
#40	0.425	12.8	89.6
#60	0.250	7.8	88.0
#70	0.212	4.1	87.2
#200	0.075	20.9	83.0
PAN		415.2	

SUM SOIL WEIGHTS = 500.0 (84.8 GMS)

PROJECT: HYDROMETER ANALYSIS OF BAGALKOT
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: VERY DARK GRAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 10TH.1992

ZERO CORRECTION = 5.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.63 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	20.	51.0	92.4	0.0541	76.74
1.0	20.	51.0	92.4	0.0383	76.74
2.0	20.	50.5	91.4	0.0272	75.91
4.0	20.	49.0	88.4	0.0195	73.41
8.0	20.	48.0	86.4	0.0140	71.74
15.0	20.	47.0	84.4	0.0103	70.07
30.0	20.	45.0	80.4	0.0074	66.73
60.0	20.	44.0	78.4	0.0053	65.07
120.0	20.	41.5	73.3	0.0038	60.89
240.0	20.	40.5	71.3	0.0027	59.23
1440.0	20.	38.0	66.3	0.0011	55.06

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 13: Grain size distribution of Gokak Soil

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF GOKAK
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: VERY DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 3RD, 1992

WT DRY SOIL = 129.7GMS
WT WASHED THRU NO 200 SIEVE = 370.3 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	20.0	96.0
#10	2.000	1.6	95.7
#14	1.400	3.7	94.9
#20	0.825	9.5	93.0
#40	0.425	25.7	87.9
#60	0.250	22.3	83.4
#70	0.212	12.4	81.0
#200	0.075	34.5	74.1
PAN		370.3	

SUM SOIL WEIGHTS = 500.0 (129.7 GMS)

PROJECT: HYDROMETER ANALYSIS OF GOKAK
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: VERY DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 10TH,1992

ZERO CORRECTION = 6.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.60 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	20.	55.0	99.1	0.0523	73.43
1.0	20.	55.0	99.1	0.0370	73.43
2.0	20.	54.5	98.1	0.0263	72.68
4.0	20.	53.0	95.1	0.0189	70.43
8.0	20.	52.0	93.1	0.0135	68.94
15.0	20.	51.5	92.1	0.0099	68.19
30.0	20.	50.0	89.0	0.0071	65.94
60.0	20.	48.5	86.0	0.0051	63.69
120.0	20.	46.0	80.9	0.0037	59.94
240.0	20.	43.5	75.9	0.0027	56.20
1440.0	20.	38.5	65.8	0.0011	48.70

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 14: Grain size distribution of Hidkal Dam Site

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF HIDKAL DAM
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: DARK BROWN CLAY
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 5TH, 1992

WT DRY SOIL = 419.1GMS
WT WASHED THRU NO 200 SIEVE = 80.9 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	56.7	88.7
#10	2.000	5.6	87.5
#14	1.400	6.9	86.1
#20	0.825	40.5	78.0
#40	0.425	117.3	54.6
#60	0.250	88.3	36.9
#70	0.212	42.2	28.5
#200	0.075	61.5	16.2
PAN		80.9	

SUM SOIL WEIGHTS = 500.0 (419.1 GMS)

PROJECT: HYDROMETER ANALYSIS OF HIDKAL DAM
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DARK BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 3RD,1992

ZERO CORRECTION = 5.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.45 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	21.	48.0	90.9	0.0584	14.71
1.0	21.	46.0	86.7	0.0421	14.03
2.0	21.	44.0	82.5	0.0304	13.34
4.0	21	43.0	80.4	0.0217	13.00
8.0	21	41.0	76.2	0.0156	12.32
15.0	21	39.0	72.0	0.0116	11.64
30.0	21	38.0	69.9	0.0083	11.30
60.0	21	36.0	65.6	0.0059	10.62
120.0	22	35.5	65.0	0.0042	10.52
240.0	22	33.0	59.8	0.0030	9.67
1440.0	21	28.0	48.8	0.0013	7.90

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 15: Grain size distribution of Jamkhandi Soil

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF JAMKANDI
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: VERY DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 3RD, 1992

WT DRY SOIL =	166.ØGMS
WT WASHED THRU NO 2ØØ SIEVE =	334.Ø GMS
TOTAL WT OF SOIL FOR TEST =	5ØØ.Ø GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.75Ø	6.Ø	98.8
#1Ø	2.ØØØ	7.4	97.3
#14	1.4ØØ	13.4	94.6
#2Ø	Ø.825	28.1	89.Ø
#4Ø	Ø.425	63.5	76.3
#6Ø	Ø.25Ø	2Ø.5	72.2
#7Ø	Ø.212	6.4	7Ø.9
#2ØØ	Ø.Ø75	2Ø.6	66.8
PAN		334.Ø	

SUM SOIL WEIGHTS = 5ØØ.Ø (166.Ø GMS)

PROJECT: HYDROMETER ANALYSIS OF JAMKANDI
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: VERY DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 1ØTH,1992

ZERO CORRECTION = 6.Ø MENISCUS CORRECTION = 1.Ø
SPECIFIC GRAVITY = 2.58 WT OF DRY SOIL WS = 5Ø.ØØGMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
Ø.5	2Ø.	55.Ø	99.6	Ø.Ø526	66.56
1.Ø	2Ø.	54.Ø	97.6	Ø.Ø376	65.2Ø
2.Ø	2Ø.	53.Ø	95.6	Ø.Ø269	63.84
4.Ø	2Ø.	52.Ø	93.5	Ø.Ø192	62.48
8.Ø	2Ø.	51.Ø	91.5	Ø.Ø137	61.13
15.Ø	2Ø.	49.Ø	87.4	Ø.Ø1Ø2	58.41
3Ø.Ø	2Ø.	47.5	84.4	Ø.ØØ74	56.37
6Ø.Ø	2Ø.	47.5	84.4	Ø.ØØ52	56.37
12Ø.Ø	2Ø	47.5	84.4	Ø.ØØ37	56.37
24Ø.Ø	2Ø.	48.5	86.4	Ø.ØØ26	57.73
144Ø.Ø	2Ø.	5Ø.Ø	89.5	Ø.ØØ1Ø	59.77

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 16: Grain size distribution of Ramdurg Soil

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF RAMDURG
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: DUSKY RED SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: FEBRAURY 25TH, 1992

WT DRY SOIL = 263.4GMS
WT WASHED THRU NO 200 SIEVE = 236.6 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	2.4	99.5
#10	2.000	0.8	99.4
#14	1.400	2.6	98.8
#20	0.825	16.1	95.6
#40	0.425	71.0	81.4
#60	0.250	84.2	64.6
#70	0.212	32.1	58.2
#200	0.075	54.3	47.3
PAN		236.6	

SUM SOIL WEIGHTS = 500.0 (263.4 GMS)

PROJECT: HYDROMETER ANALYSIS OF RAMDURGE
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DUSKY RED SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 11TH,1992

ZERO CORRECTION = 5.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.62 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	21.	52.0	95.1	0.0531	44.98
1.0	21.	51.5	94.0	0.0377	44.50
2.0	21.	51.0	93.0	0.0268	44.02
4.0	21.	49.0	89.0	0.0194	42.12
8.0	21.	48.0	87.0	0.0138	41.16
15.0	21.	47.0	85.0	0.0102	40.21
30.0	21.	45.0	81.0	0.0073	38.31
60.0	21.	43.0	76.9	0.0053	36.40
120.0	22.	41.5	74.3	0.0037	35.16
240.0	22.	39.0	69.3	0.0027	32.78
1440.0	21.	34.0	58.8	0.0012	27.82

'ERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 17: Grain size distribution of Raibag Soil

PROJECT: GRAIN SIZE DISTRIBUTION TEST OF RAIBAG
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 5TH, 1992

WT DRY SOIL = 200.4GMS
WT WASHED THRU NO 200 SIEVE = 299.6 GMS
TOTAL WT OF SOIL FOR TEST = 500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	100.7	79.9
#10	2.000	12.5	77.4
#14	1.400	14.9	74.4
#20	0.825	15.8	71.2
#40	0.425	13.8	68.4
#60	0.250	7.4	67.0
#70	0.212	3.8	66.2
#200	0.075	31.3	59.9
PAN		299.6	

SUM SOIL WEIGHTS = 500.00 (200.4 GMS)

PROJECT: HYDROMETER ANALYSIS OF RAIBAG
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DARK GRAYISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 10TH,1992

ZERO CORRECTION = 6.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.60 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	20.	54.0	97.1	0.0529	58.21
1.0	20.	50.0	89.0	0.0390	53.36
2.0	20.	47.0	83.0	0.0284	49.72
4.0	20.	45.0	78.9	0.0205	47.29
8.0	20.	38.5	65.8	0.0154	39.41
15.0	20.	35.0	58.7	0.0115	35.17
30.0	20.	32.0	52.6	0.0083	31.53
60.0	20.	29.0	46.5	0.0060	27.89
120.0	20.	27.0	42.5	0.0043	25.47
240.0	20.	25.0	38.4	0.0031	23.04
1440.0	20.	22.0	32.4	0.0013	19.40

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 18: Grain size distribution of Ron Soil

PROJECT: GRAIN SIZE DISTRIBUTION OF RON
LOC.OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRPTION: VERY DARK GRAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: FEBRAURY 28TH 1992

WT DRY SOIL =	147.1GMS
WT WASHED THRU NO 200 SIEVE =	352.9 GMS
TOTAL WT OF SOIL FOR TEST =	500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	9.9	98.0
#10	2.000	3.8	97.3
#14	1.400	11.5	95.0
#20	0.825	23.7	90.2
#40	0.425	29.3	84.4
#60	0.250	18.5	80.7
#70	0.212	9.4	78.8
#200	0.075	41.0	70.5
PAN		352.9	

SUM SOIL WEIGHTS = 500.0 (147.1 GMS)

PROJECT: HYDROMETER ANALYSIS OF RON
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: VERY DARK GRAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 3RD,1992

ZERO CORRECTION = 6.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.60 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	25.	54.0	99.8	0.0498	70.25
1.0	25.	53.5	98.7	0.0354	69.53
2.0	25.	52.5	96.7	0.0253	68.11
4.0	25.	51.5	94.7	0.0181	66.68
8.0	25.	50.0	91.7	0.0130	64.55
15.0	25.	48.0	87.6	0.0097	61.70
30.0	25.	47.0	85.6	0.0069	60.27
60.0	25.	45.5	82.6	0.0050	58.13
120.0	26.	43.0	78.2	0.0036	55.07
240.0	26.	41.5	75.2	0.0025	52.93
1440.0	25.	40.0	71.4	0.0011	50.30

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 19: Grain size distribution of Badami Soil

PROJECT: GRAIN SIZE DISTRIBUTION OF BADAMI
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRPTION: DARK RED SANDY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 1ST 1992

WT DRY SOIL	=	443.ØGMS
WT WASHED THRU NO 2ØØ SIEVE	=	57.Ø GMS
TOTAL WT OF SOIL FOR TEST	=	5ØØ.Ø GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.75Ø	Ø.5	99.9
#1Ø	2.ØØØ	Ø.3	99.8
#14	1.4ØØ	Ø.3	99.8
#2Ø	Ø.825	4.1	99.Ø
#4Ø	Ø.425	169.8	65.Ø
#6Ø	Ø.25Ø	163.1	32.4
#7Ø	Ø.212	44.7	23.4
#2ØØ	Ø.Ø75	6Ø.2	11.4
PAN		57.Ø	

SUM SOIL WEIGHTS = 5ØØ.Ø (443.Ø GMS)

PROJECT: HYDROMETER ANALYSIS OF BADAMI
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: DARK RED SANDY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 6TH,1992

ZERO CORRECTION = 3.Ø MENISCUS CORRECTION = 1.Ø
SPECIFIC GRAVITY = 2.7Ø WT OF DRY SOIL WS = 5Ø.ØØGMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
Ø.5	25.	49.Ø	93.5	Ø.051Ø	1Ø.66
1.Ø	25.	48.Ø	91.6	Ø.0364	1Ø.43
2.Ø	25.	47.Ø	89.6	Ø.026Ø	1Ø.21
4.Ø	25.	46.Ø	87.6	Ø.Ø186	9.98
8.Ø	25.	45.Ø	85.6	Ø.Ø133	9.76
15.Ø	25.	44.5	84.6	Ø.ØØ97	9.64
3Ø.Ø	25.	43.5	82.7	Ø.ØØ69	9.42
6Ø.Ø	25.	43.Ø	81.7	Ø.ØØ49	9.3Ø
12Ø.Ø	26.	4Ø.Ø	76.4	Ø.ØØ35	8.71
24Ø.Ø	26.	38.Ø	72.5	Ø.ØØ25	8.26
144Ø.Ø	25.	34.Ø	63.9	Ø.ØØ11	7.28

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 20: Grain size distribution of Mudhol Soil

PROJECT: GRAIN SIZE DISTRIBUTION OF MUDHOL
LOC OF PROJECT: SOIL WATER LABORATORY (N.I.H. ROORKEE)
SOIL DESCRPTION: YELLOWISH BROWN
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: MARCH 5TH,1992

WT DRY SOIL =	278.7GMS
WT WASHED THRU NO 200 SIEVE =	221.3 GMS
TOTAL WT OF SOIL FOR TEST =	500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	18.2	96.4
#10	2.000	4.4	95.5
#14	1.400	10.2	93.4
#20	0.825	15.0	90.4
#40	0.425	27.1	85.0
#60	0.250	28.6	79.3
#70	0.212	21.5	75.0
#200	0.075	153.7	44.3
PAN		221.3	

SUM SOIL WEIGHTS = 500.0 (278.7 GMS)

PROJECT: HYDROMETER ANALYSIS OF MUDHOL
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: YELLOWISH BROWN SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 3RD,1992

ZERO CORRECTION = 6.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.50 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	25.	52.0	98.2	0.0526	43.44
1.0	25.	50.0	94.0	0.0380	41.60
2.0	25.	46.0	85.7	0.0280	37.93
4.0	25.	42.0	77.4	0.0205	34.26
8.0	25.	39.0	71.2	0.0149	31.50
15.0	25.	34.5	61.8	0.0113	27.37
30.0	25.	31.5	55.6	0.0082	24.61
60.0	25.	29.0	50.4	0.0059	22.32
120.0	26.	26.0	44.9	0.0042	19.88
240.0	26.	25.0	42.9	0.0030	18.96
1440.0	25.	21.5	34.9	0.0013	15.43

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

Table 21: **Grain size distribution of Nargund Soil**

PROJECT: GRAIN SIZE DISTRIBUTION OF NARGUND
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRPTION: VERY DARK GRAY CLAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 1ST 1992

WT DRY SOIL =	105.2GMS
WT WASHED THRU NO 200 SIEVE =	394.8 GMS
TOTAL WT OF SOIL FOR TEST =	500.0 GMS

SIEVE ANALYSIS FOR GRAIN DISTRIBUTION CURVE

SIEVE NO	SIEVE D MM	WT RET GMS	% FINER
# 4	4.750	4.6	99.1
#10	2.000	7.0	97.7
#14	1.400	11.1	95.5
#20	0.825	13.4	92.8
#40	0.425	12.9	90.2
#60	0.250	11.4	87.9
#70	0.212	9.5	86.0
#200	0.075	35.2	79.0
PAN		394.8	

SUM SOIL WEIGHTS = 500.0 (105.2 GMS)

PROJECT: HYDROMETER ANALYSIS OF NARGUND
LOC OF PROJECT: SOIL WATER LABORATORY(N.I.H.ROORKEE)
SOIL DESCRIPTION: VERY DARK GRAY SOIL
TESTED BY: S L SRIVASTAVA
DATE OF TESTING: APRIL 6TH,1992

ZERO CORRECTION = 5.0 MENISCUS CORRECTION = 1.0
SPECIFIC GRAVITY = 2.68 WT OF DRY SOIL WS = 50.00GMS

HYDROMETER ANALYSIS FOR GRAIN DISTRIBUTION CURVE

ELAP T MIN	TEMP DEG C	HYDROM READING	% FINER	DIAM MM	%FINERT
0.5	25.	54.0	99.9	0.0486	78.89
1.0	25.	52.8	97.5	0.0349	77.01
2.0	25.	52.5	96.9	0.0247	76.54
4.0	25.	52.0	95.9	0.0176	75.76
8.0	25.	51.0	94.0	0.0126	74.19
15.0	25.	49.0	90.0	0.0094	71.05
30.0	25.	47.5	87.0	0.0067	68.70
60.0	25.	47.0	86.0	0.0048	67.91
120.0	26.	45.0	82.7	0.0034	65.33
240.0	26.	44.0	80.7	0.0024	63.76
1440.0	25.	42.0	76.1	0.0010	60.07

DISPERSING AGENT = SODIUM HEXA METAPHOSPHATE

generally referred as the soil moisture retention curve or soil moisture characteristics curve. Pressure plate apparatus (ceramic plates) has been used for the determination soil moisture characteristics curve. Pressure plat apparatus (ceramic plates has been used for the determination soil moisture characteristics curve. A typical soil moisture characteristic curve is shown in figure 24. The curve for the clay shows that the moisture is released in fairly even increments as tension increases. The curve for the sand shows a proportionally greater release of moisture at low tension than the curve for the clay. Curve for the loam is intermediate in shape. A typical soil retention curve for different type of soil is shown in fig. 24.

From the present study based on the soil moisture retention curve drawn for the soil samples of the Malaprabha command area (including parts of catchment) indicates that there are mainly three types of soils, (i) loamy sands (ii) sandy clay loams (iii) clays. Table 22 shows the soil moisture content at various pressures.

Loamy sands are found in the upper reaches of the catchment, i.e. at Asoga in Khanapur taluk of Belgaum district (Fig.25). The textural analysis of the soil samples indicates a very high percentage of (61.2%) of sands with intermittent silts (13.75%) and clays (16.25%). The percentage of gravel is found to be 8.8%. The wilting point observed for this soil is 7.64% and the field capacity is found to be 22.46%.

Sandy clay loams are found in downstream of Asoga, and it extends through Bidi upto Ramdurg (Fig.26 & 27). In this region, the percentage of clay is very less. It varies between 26.25% to 31.5%. The percentage of sand is comparatively high (44.4% to

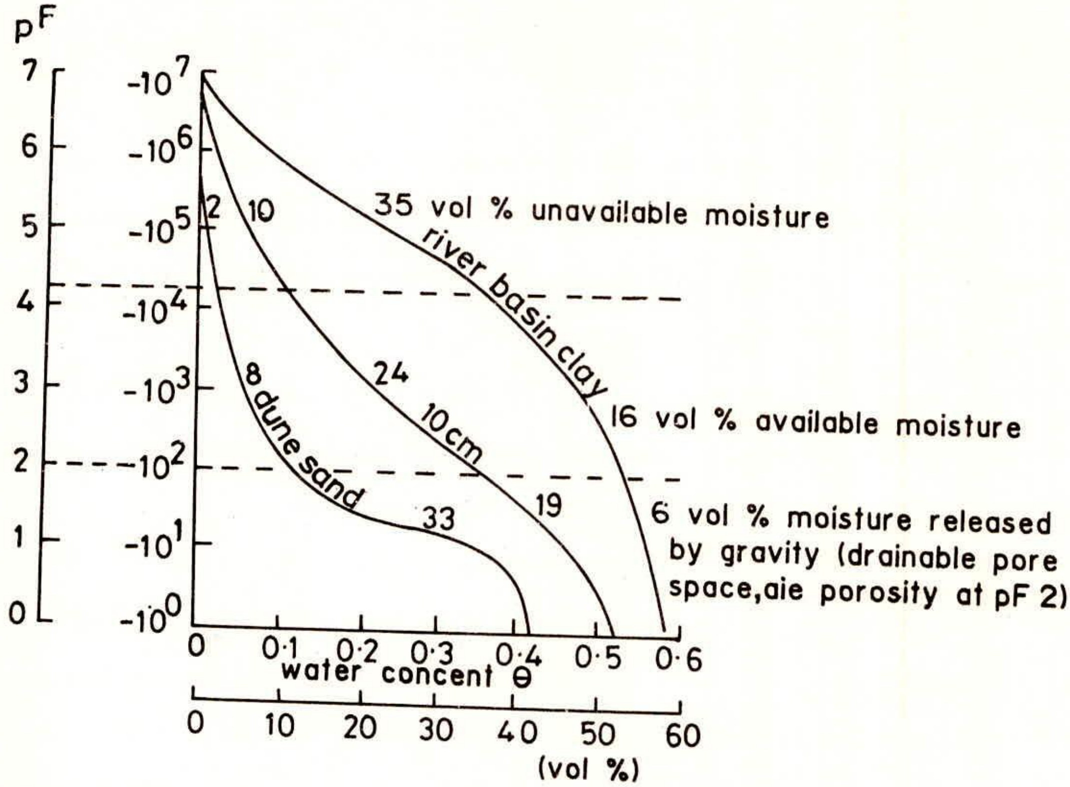


FIG. 24 EXAMPLES OF SOIL MOISTURE RETENTION OR pF-CURVES OF THREE SOIL TYPES WITH SOME SPECIFIC CONCEPTS

Table 22

Soil moisture, characteristics curve of Malaprabha & Ghataprabha basins

	Soil moisture at different pressure (Bar)								
Location	0.10	0.33	0.50	0.70	1.00	3.00	5.00	10.00	15.00
Asoga (Khanapur)	22.46	14.03	11.05	11.79	10.14	9.26	8.63	7.64	7.73
B.D. Tank	28.26	20.66	20.02	19.37	17.33	16.06	15.09	14.21	13.53
Bagalkot	54.22	45.44	39.23	36.46	34.42	34.09	30.73	23.60	21.55
Belgaum	37.48	29.43	25.91	26.57	24.42	23.65	23.65	19.59	22.27
Gokak	48.90	40.39	35.26	36.84	30.94	28.67	28.67	23.16	21.13
HIDKAL DAM	13.36	7.93	6.42	6.14	5.95	5.28	5.28	3.99	4.20
Jamkandi	42.07	33.59	30.15	13.41	27.89	25.88	26.81	18.32	21.22
Ramdurg	27.17	18.54	16.40	16.61	14.31	13.41	14.07	10.25	11.05
Raibag	42.04	33.20	30.02	28.29	24.26	23.79	21.56	19.40	19.13
Ron	42.96	24.00	28.50	28.42	24.71	24.03	20.94	17.76	19.50

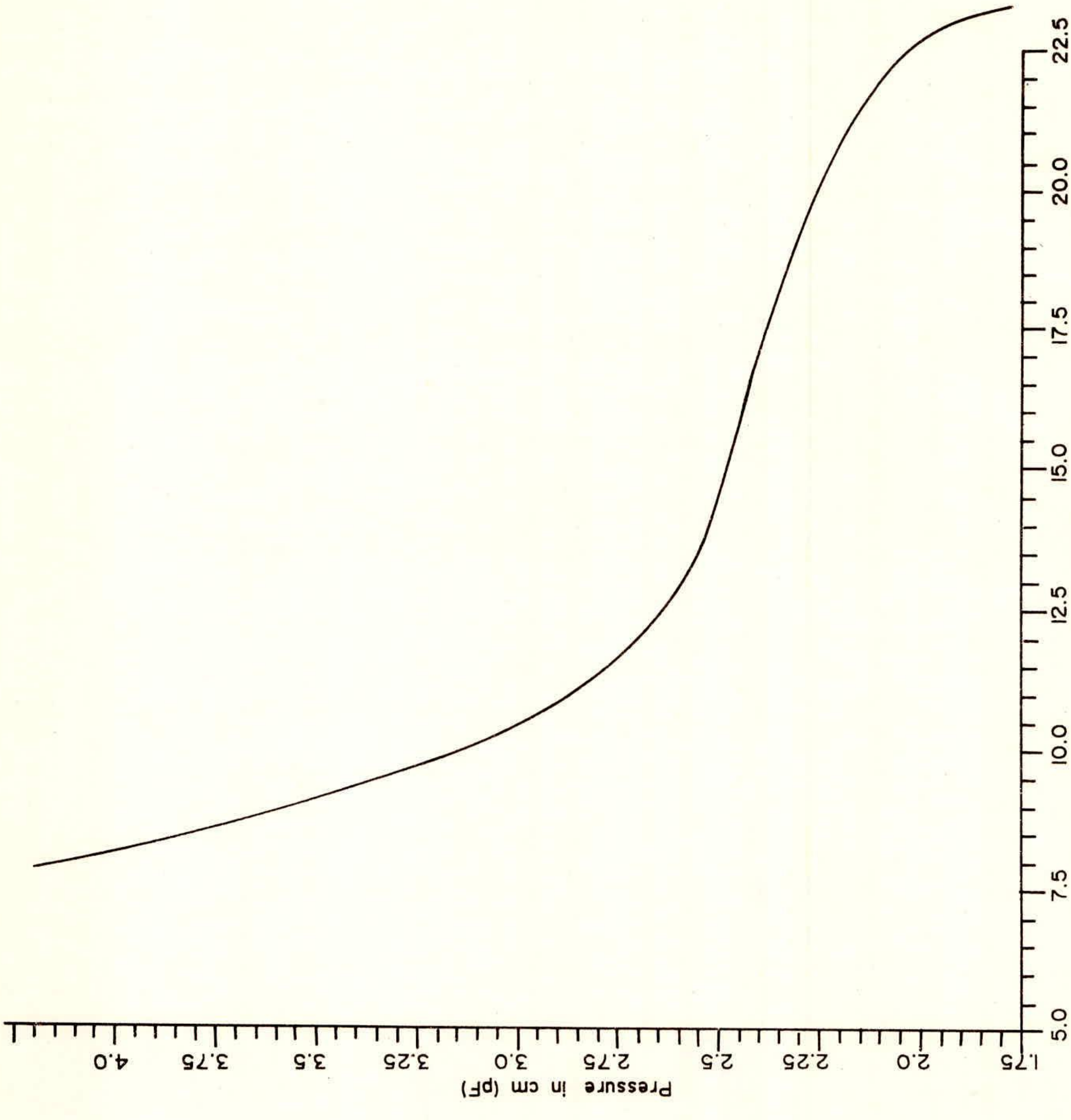


FIG.25: SOIL MOISTURE RETENTION CURVE DRAWN FOR SOIL SAMPLE OF ASOGA (LOAMY SAND)

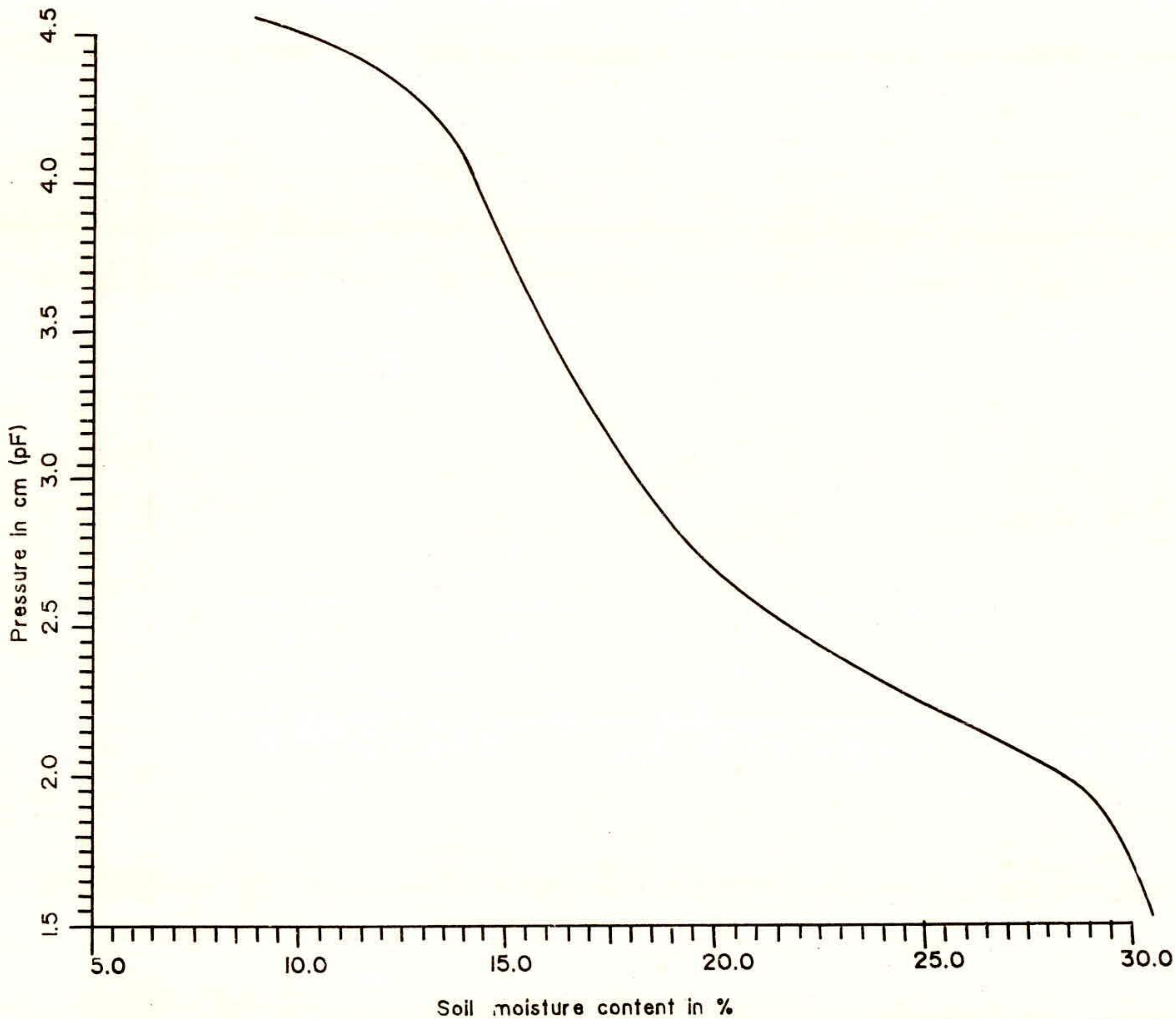


FIG.26: SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF BIDI TANK

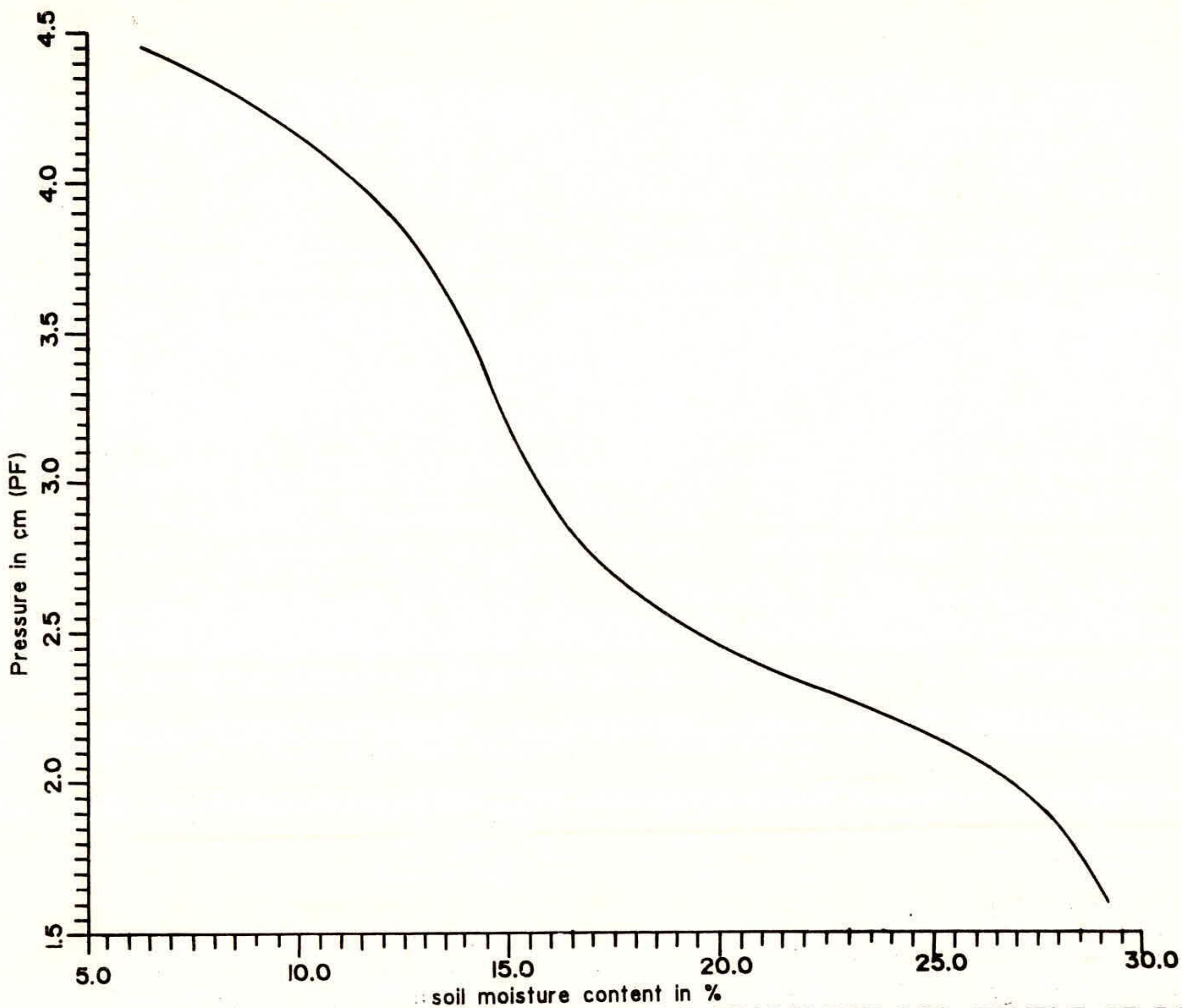


FIG. 27 SOIL MOISTURE RETENTION CURVE DRAWN FOR SOIL SAMPLE OF RAMDURG

53.4%) and silt content varies between 14.5% to 21.25%. The soil type observed at Belgaum (Fig. 28) also follows the same character as that of sandy clay loam, however the percentage of clays (47%) and silts (29.57%) are comparatively higher than that of the observed at Bidi and Ramdurg. The wilting point for this group of soils varies widely between 10.2% and 14.2%. The field capacity varies between 27.17% and 28.26%.

Clays: Clayey soils are distributed in the downstream region of Ramdurg. These are mainly distributed over Ron area, (Fig.29) here, the percentage of clay is comparatively more (52%). The wilting point observed for a clay samples 17.76% and the field capacity is measured as 42.96%.

The soil moisture characteristics curve (Fig. 30 to 34) of the Ghataprabha command area shows three distinct group of soils, i.e. (1) sandy loams, (ii) clays and (iii) loamy soils.

Sandy loamy soils are distributed near the Hidkal dam area (Fig. 30). Here, the percentage of clay is very less (8.8%) and sand content is very high (72.5%). The wilting point observed is very minimum (3.99%). The field capacity is comparatively very less (13.36%).

Clay distribution is very common in the command area. Gokak, Jamkhandi and Bagalkot regions shows high percentages of clay (Fig. 31, 32 & 33). The maximum percentage of clay is found at Bagalkot (58%). In general, the percentage of clay increases towards the downstream region (53.75% to 58%). The wilting point varies between 18.32% and 23.6% depending upon the clay content. However, variation in wilting point may be brought by the intermixing of silt and sand particles. Similar variation in field capacity is also observed. Maximum field capacity (54.22%)

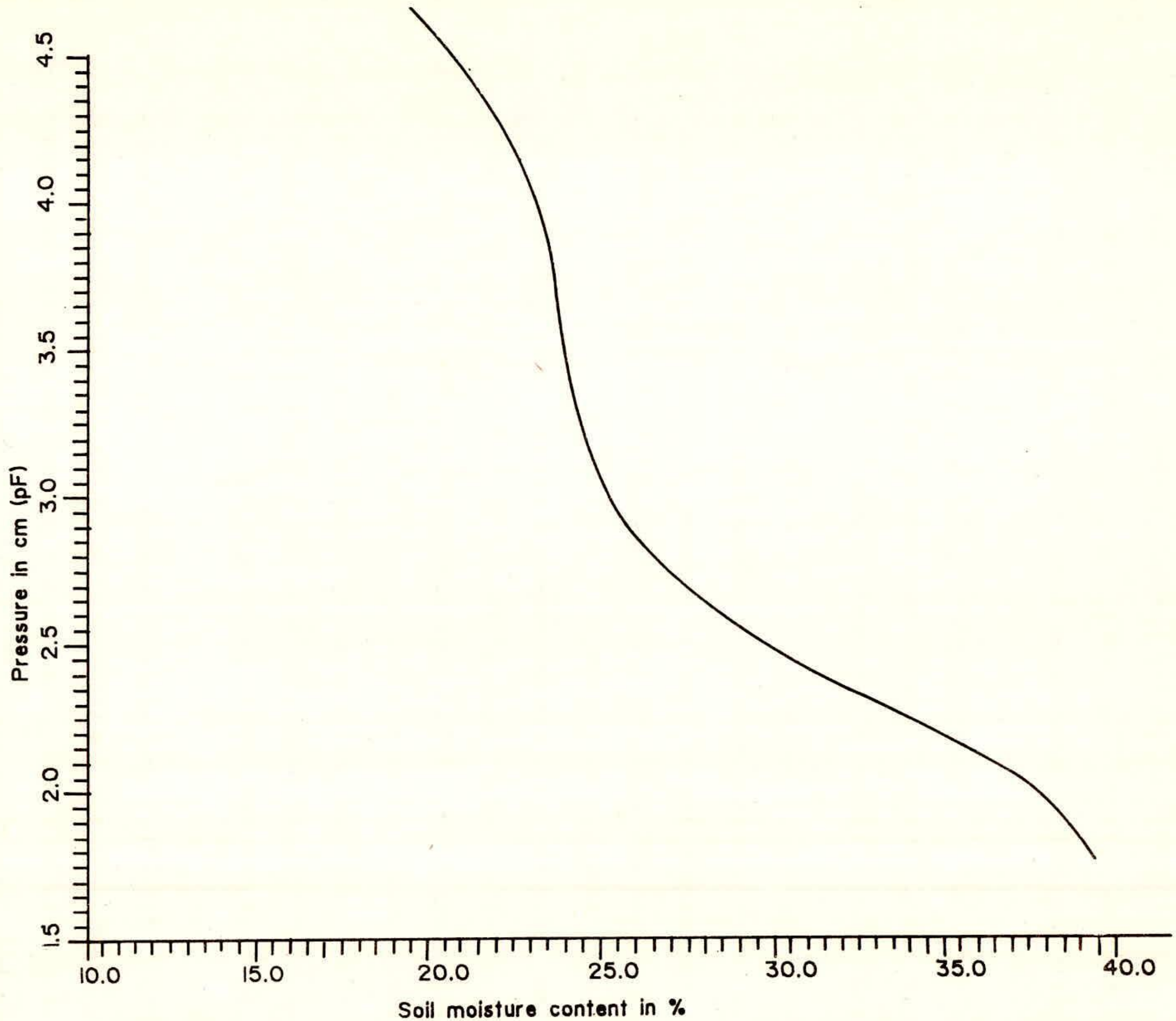


FIG.28: SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF BELGAUM

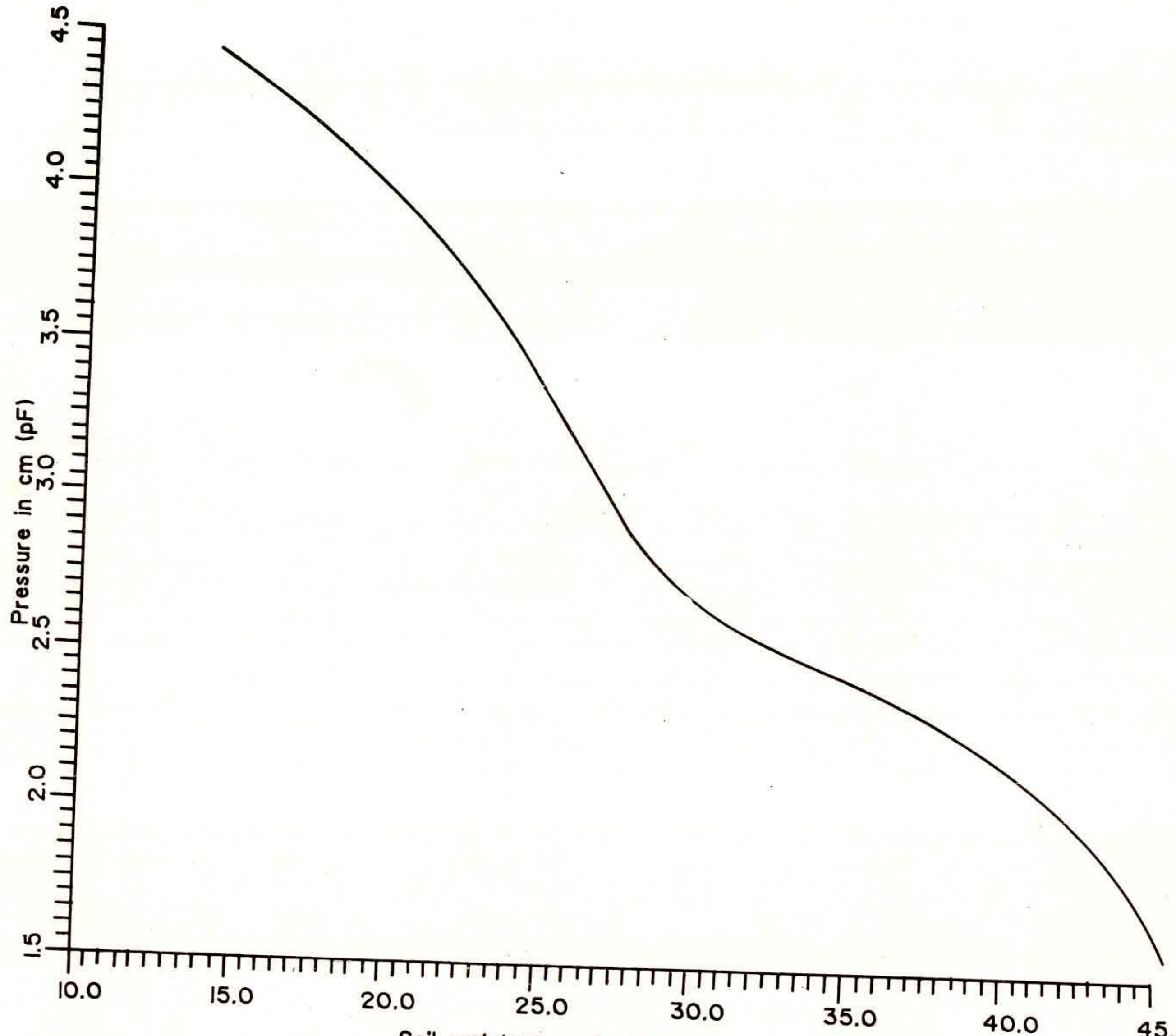
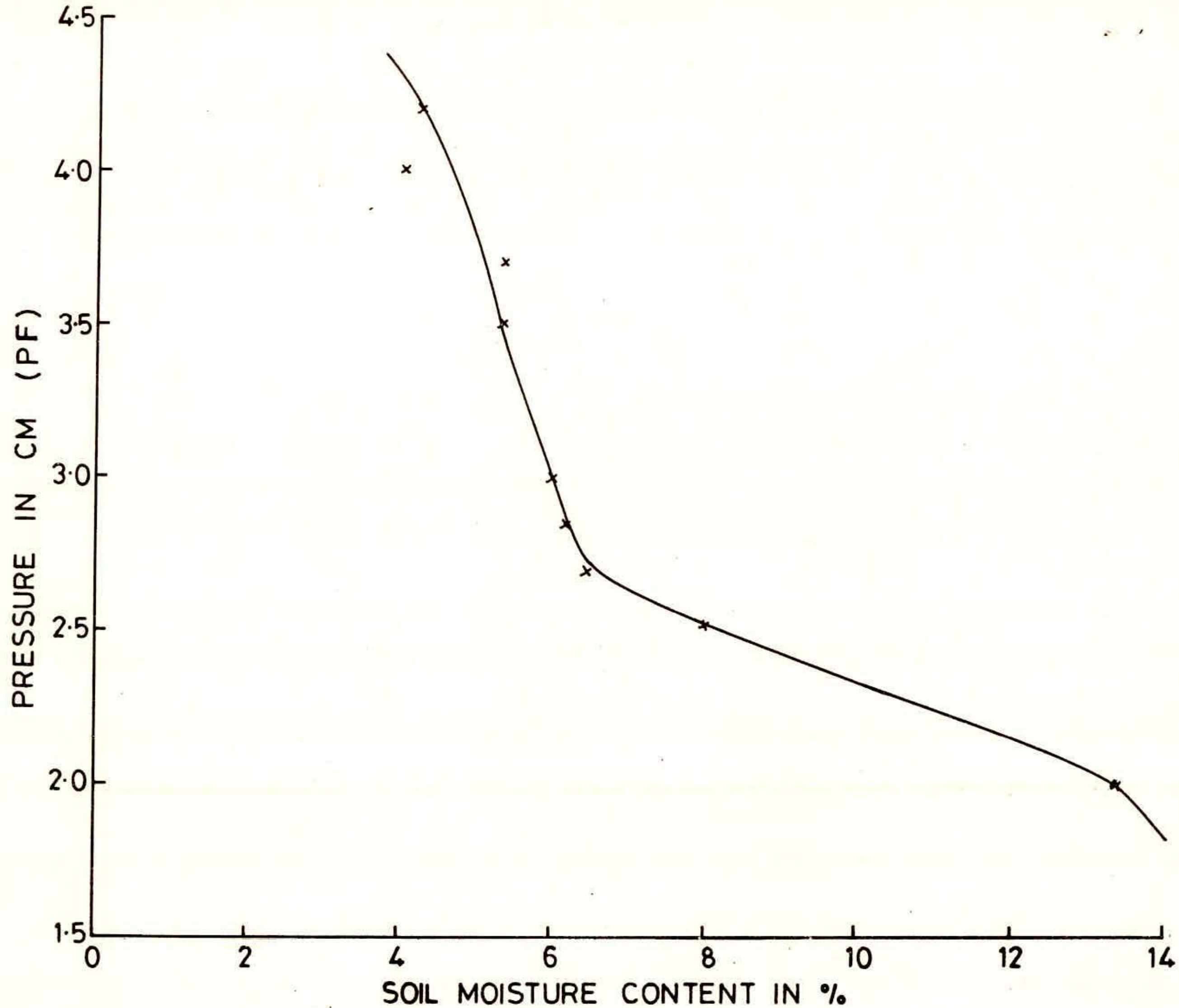


FIG.29: SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF RON


PRESSURE IN CM (PF)
4·5
4·0
3·5
3·0
2·5
2·0
1·5
0
2
4
6
8
10
12
14
SOIL MOISTURE CONTENT IN %

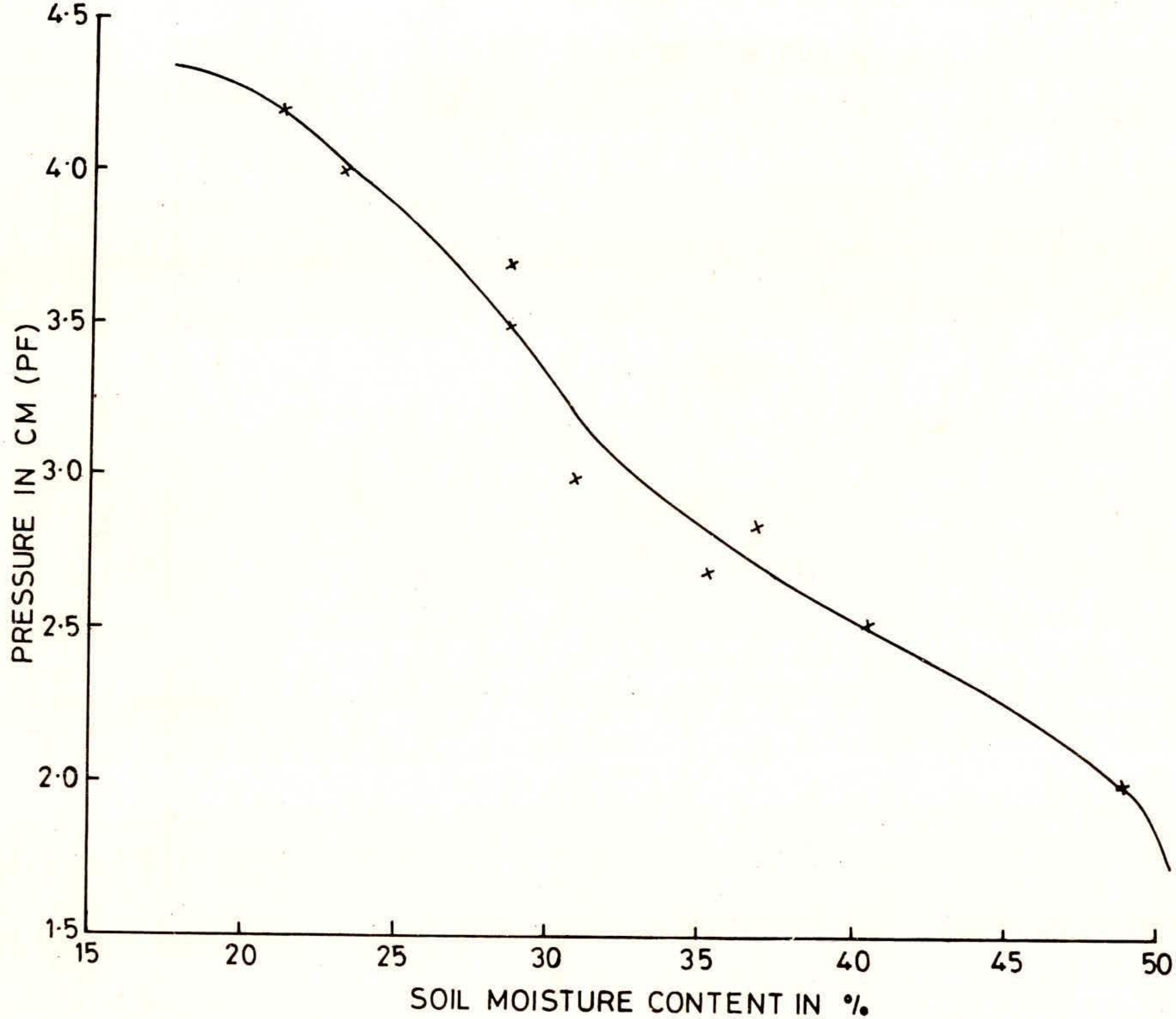


FIG. 31 SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF GOKAK

FIG. 30 SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF HIDKAL

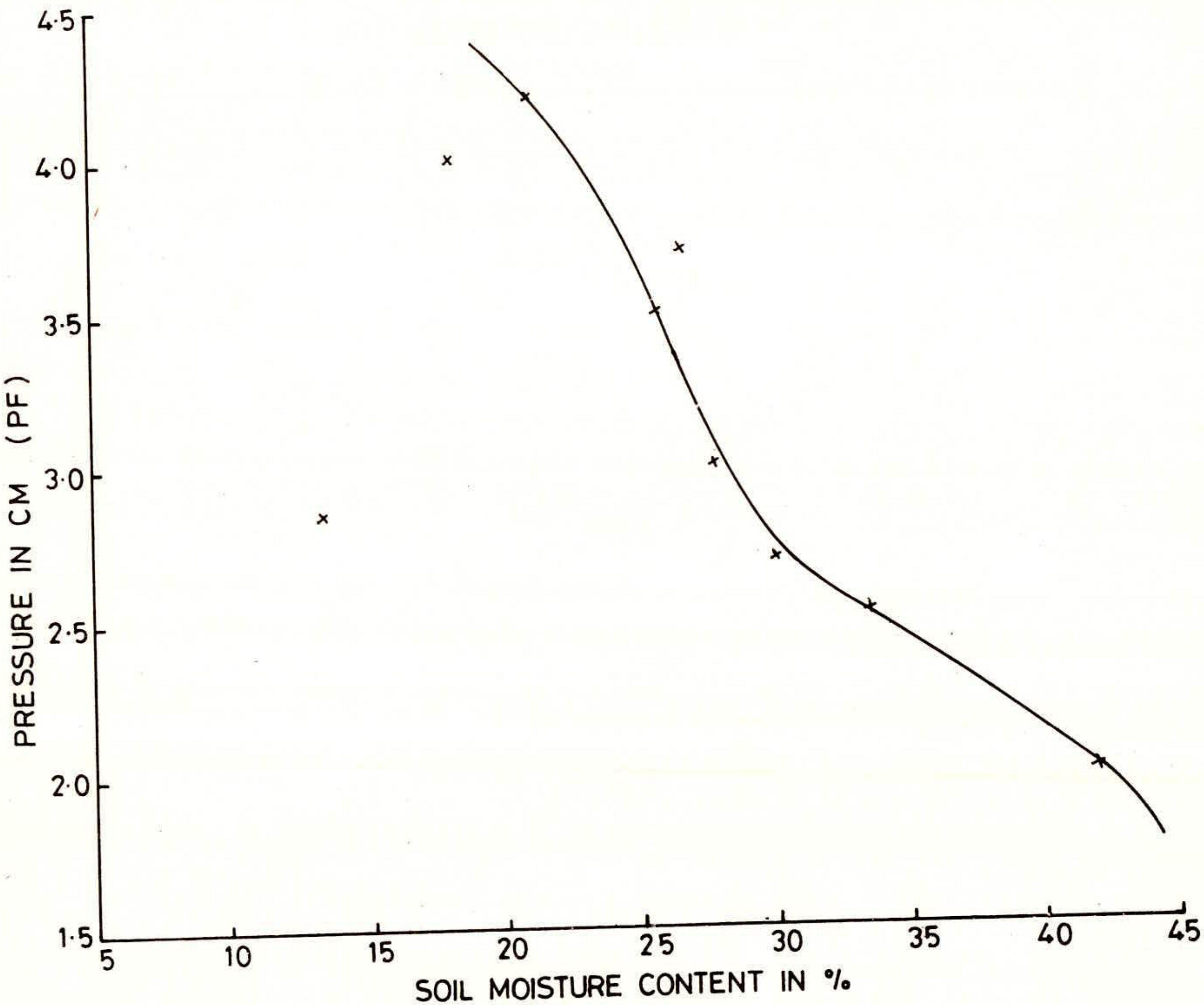


FIG. 32 SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF JAMKHANDI

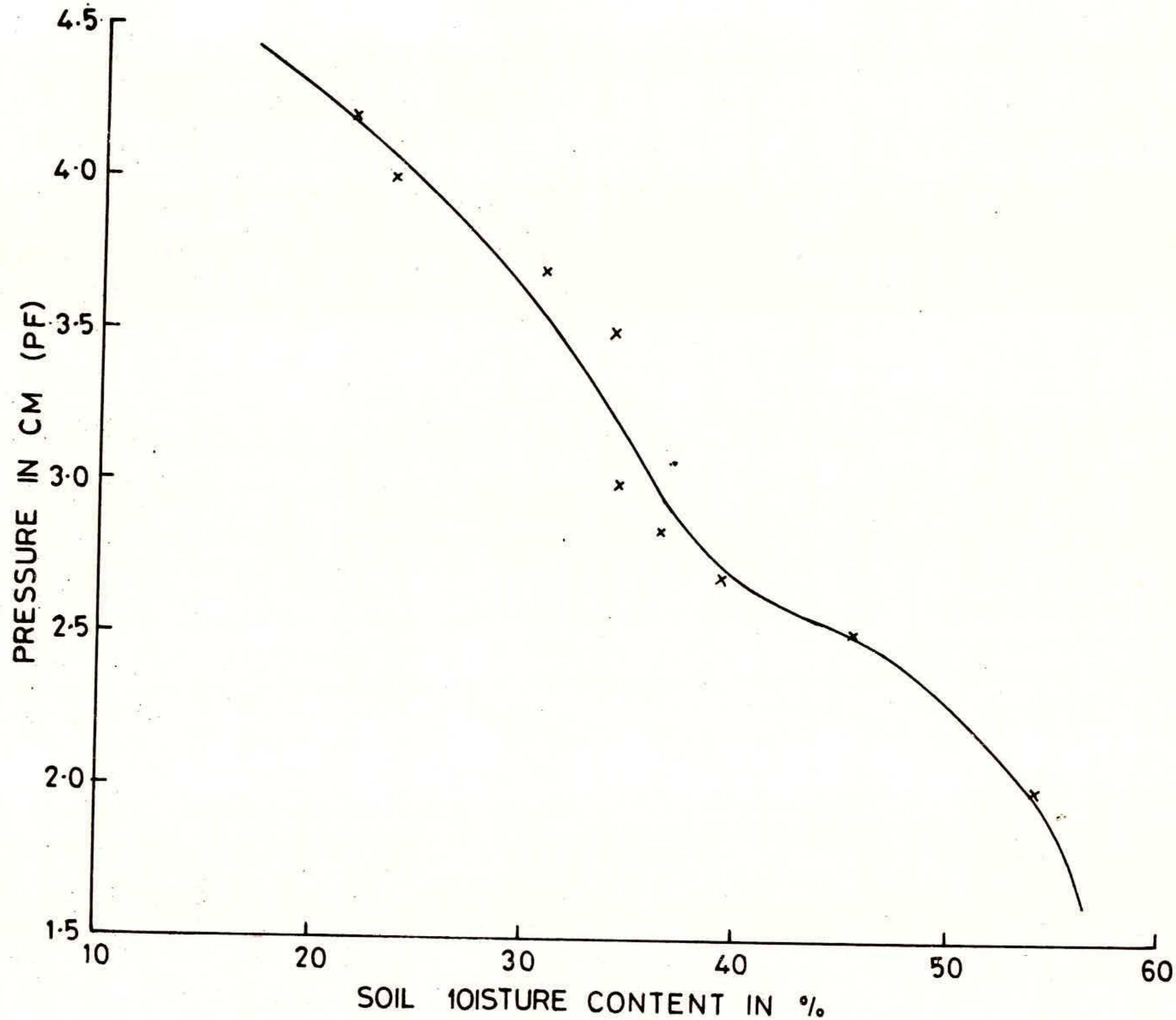


FIG. 33 SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF BAGALKOT

is determined at Bagalkot.

The third category of soil found are loamy soils. This type of soil is identified at Raibag (Fig. 34). Here, the percentage of gravel (22.6%) and silt (37.31%) are comparatively high when compared to other type of soils. The wilting point of the soil is 19.4% and the field capacity is measured as 42.04%.

4.3 Soil and Infiltration

Infiltration tests conducted in the representative basin of Malaprabha and Ghataprabha catchments indicates, in addition to the soil texture, land use pattern and geomorphological characteristics play a significant control over the infiltration rate. The infiltration rates observed in Malaprabha representative basin for different type of soils based on texture are summarised below.

(i) Light loam soil: The average rate of infiltration stands at 3.8 cm/hr and it varies between 3 cm/hr under barren condition and 5.1 cm/hr under forest land.

(ii) The medium loam shows an infiltration rate of 2.3 cm/hr and it varies between 1.2 cm/hr and 3.3 cm/hr under varying land use and topographic conditions.

(iii) Heavy loam: The rate of infiltration varies between 0.9 cm/hr and 3.6 cm/hr and the average is 2.2 cm/hr.

(iv) Clayey soils shows minimum infiltration, i.e. 1.8 cm/hr and it varies between 1.2 cm/hr and 2.4 cm/hr depending upon the land use pattern and geomorphology.

In the Ghataprabha representative basin the infiltration rate is found to be very high. Here, in the light loam soils the infiltration rate is 6.6 cm/hr and varies between 4.8 cm/hr and

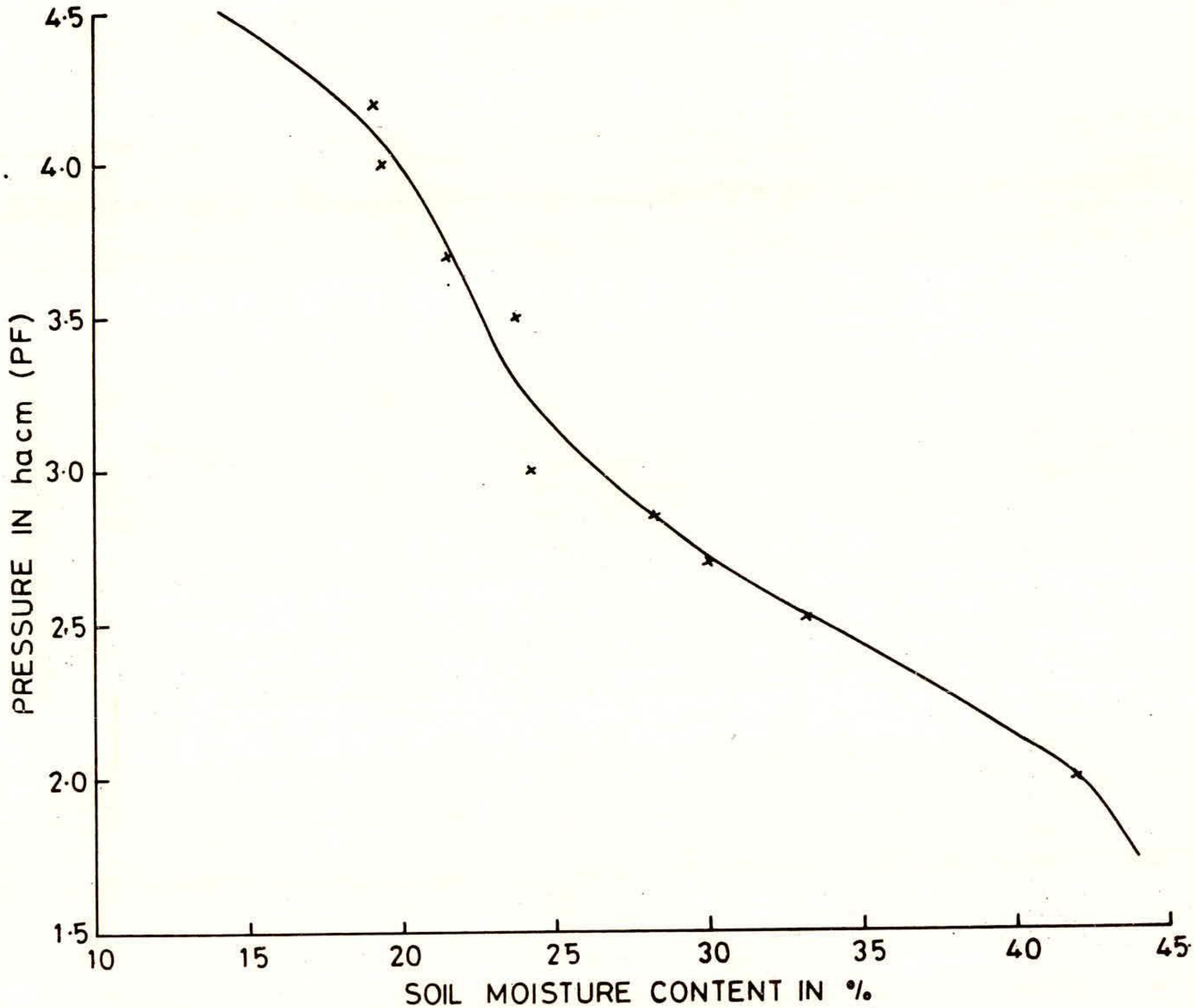


FIG. 34 SOIL MOISTURE RETENTION CURVE FOR SOIL SAMPLE OF RAIBAG

8.4 cm/hr. In the medium loamy soils, the infiltration rate stands at 6.3 cm/hr which varies between 2.1 cm/hr and 16.5 cm/hr depending upon land use pattern, topographic condition and soil characteristics. In heavy loam soils of the Ghataprabha representative basin, the average rate of infiltration is 4.8 cm/hr which varies between 0.9 cm/hr under agriculture land and 13.2 cm/hr under forest land.

In general, the rate of infiltration which is mainly a vertical downward flow depends mainly upon soil type, geology and geomorphology and land use pattern where as the hydraulic conductivity, depends upon soil texture, porosity and specific surface and composition of the soil particles.

4.4 The Saturated Hydraulic Conductivity

The hydraulic conductivity of a soil depends on various of physical parameters like porosity, particle size distribution, shape of particles and other related factors. In general, for consolidated porous media, the hydraulic conductivity varies with particle size. The clayey material exhibits low values of hydraulic conductivity, where as, sands and gravels display high values.

The value of field saturated hydraulic conductivity are shown in table 23. The variation observed is very significant. Minimum values are observed at Bidi tank (0.025×10^{-4} cm/sec) and at Raibag (0.106×10^{-4} cm/sec). Soil types found in these region are sandy clay loams, loamy sands and clays. Maximum rate is observed at Badami (45.25×10^{-4} cm/sec) where loamy sands are predominating. The higher value of hydraulic conductivity is attributed to the high percentage of sand particles (88.77%).

Table 23: Field Saturated Hydraulic Conductivity (cm/sec).

S.No.	Locations	Kfs cm/sec
1.	Badami	45.25×10^{-4}
2.	Ramdurg	3.62×10^{-4}
3.	Belgaum	2.46×10^{-4}
4.	Hidkal Dam	2.37×10^{-4}
5.	Mudhol	0.484×10^{-4}
6.	Jamkandi	0.438×10^{-4}
7.	Raibag	0.106×10^{-4}
8.	B D Tank	0.025×10^{-4}

This result clearly indicates that the varying distribution of silt and clay particles play a major role in determining the hydraulic conductivity.

5.0 CONCLUSION

Estimation of Hydrological soil parameters are essential for irrigation and drainage planning, rainfall runoff modelling and for ground water balance studies. The various parameters considered in this study are (i) field saturated hydraulic conductivity, variation with particle size analysis and soil moisture retention curves. Soil texture, infiltration rate and hydraulic conductivity are essential for hydrological soil classification. From the present study, the following points were observed.

1) Saturated Hydraulic conductivity shows a wide variation in the Malaprabha command area (0.025×10^{-4} cm/sec to 45.25×10^{-4} cm/sec.). The major soil types found in the Malaprabha command area sandy clay loams.

2) In the Ghataprabha command area the saturated hydraulic conductivity shows a minor variation i.e. 0.106×10^{-4} cm/sec to 2.37 cm/sec. The clays are the dominating soil types distributed over larger areas of the command area.

It is better to conduct few more tests in different type of soils to derive at a general conclusion. It is also necessary to determine the soil moisture contents at closer intervals to get a smoothened retention curve.

ACKNOWLEDGEMENT:

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