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COMPREHENSIVE HYDROLOGICAL STUDY OF NARMADA RIVER BASIN ESTIMATION OF HYDROLOGICAL SOIL PROPERTIES OF NARSINGPUR DISTRICT

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PREFACE

Selection of the optimum drainage plan and the design and construction of adequate and successful drainage facilities depend upon the reliability and adequacy of the basic drainage data. The basic data must provide the knowledge of soil texture, saturated hydraulic conductivity of the soil and topography of the area under consideration.

Texture of the soil is an important property specially in the design of sub surface drainage system because it is a soil characteristic which has a general relationship with hydraulic conductivity and water retention. It is difficult to measure the saturated hydraulic conductivity of the soil in the fields when water table is present at large depth. If the soil classification of the area is available than the saturated hydraulic conductivity can be determined by the Johnson's curves. In this study the field measurement of in situ saturated hydraulic conductivity was carried out by using the Guelph Permeameter. The Guelph Permeameter is a very useful and reliable equipment for the measurement of insitu saturated hydraulic conductivity of the soil when water table is at shallow depth or at large depth. In this report hydrological soil properties of doab between Sher river and left bank canal of Bargi project such as texture, soil moisture characteristics curve, and saturated hydraulic conductivity have been determined in situ and are reported here. This report is prepared by Sri S. L. Srivastava, RA . Dr. B. Soni, Head, Drainage Division. The field work has been carried out by Sri S.L.Srivastava, R.A, Shri Dhanpal Singh and Sri Dinesh Kumar attached to Soil Water Laboratory.

(S. M. Seth)
Director

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Abstract

This study deals with the estimation of hydrological soil parameters of the doab between Sher and Barau river and Bargi left bank canal falling in Narsingpur district of M.P..The soil properties to be determined are Soil Texture, Sat. Hydraulic conductivity using Guelph permeameter (for in situ measurement) and from Johnsons graph, Matric flux potential, Alpha parameter and Soil moisture characteristic curves.

Based upon the soil classification of Soil Survey Department of Govt. of M. P., a base map for soil classification was prepared and at twelve locations disturbed soil sampling and insitu measurement of Saturated conductivity was performed. The soil samples were brought to the Soil Water Laboratory of the Institute and the textural analysis of all the samples was carried out and is presented here. The matric flux potential , alpha parameter and saturated hydraulic conductivity as given by Johnsons graph were also determined and are presented here.

1.0 INTRODUCTION

Narsingpur district is located in the Jabalpur division of Madhya pradesh. Narsingpur city is about 100 kms away from Jabalpur city. This area comes under the command area of Bargi irrigation project. which is a multipurpose project. The Bargi dam is constructed on river Narmada. The area for the present study selected is the doab of river Sher, Barau and left bank canal of Bargi irrigation project (Fig.1).

1.1 Salient features of the Bargi Project:

The proposed Bargi Project in M.P. comprises of a dam about one mile long and 210 high across the river Narmada at Bargi near Jabalpur, and canal system to provide controlled irrigation to 6.6 lac. acres, a major portion of the area lies towards the south west and the remaining to the north-east of Narmada river. About 20,653 acres is under forest while the remaining area is under cultivation.

Whereas, the river discharge touches a peak point of about 4.19 lac cusecs during the monsoon season, it falls off very considerably during the summer months. Its catchment area up to the proposed dam site comprises of 5,600 square miles of partly hilly and partly forest covered land. The gross capacity of the proposed reservoir is 3.18 million acre feet of which 0.60 million acre feet will be allocated for dead storage.

It is proposed to take off canal system which would irrigate land on both sides of the river. It will irrigate area of 6,60,000 acres on both the banks of the river. The salient features of the project are given below:

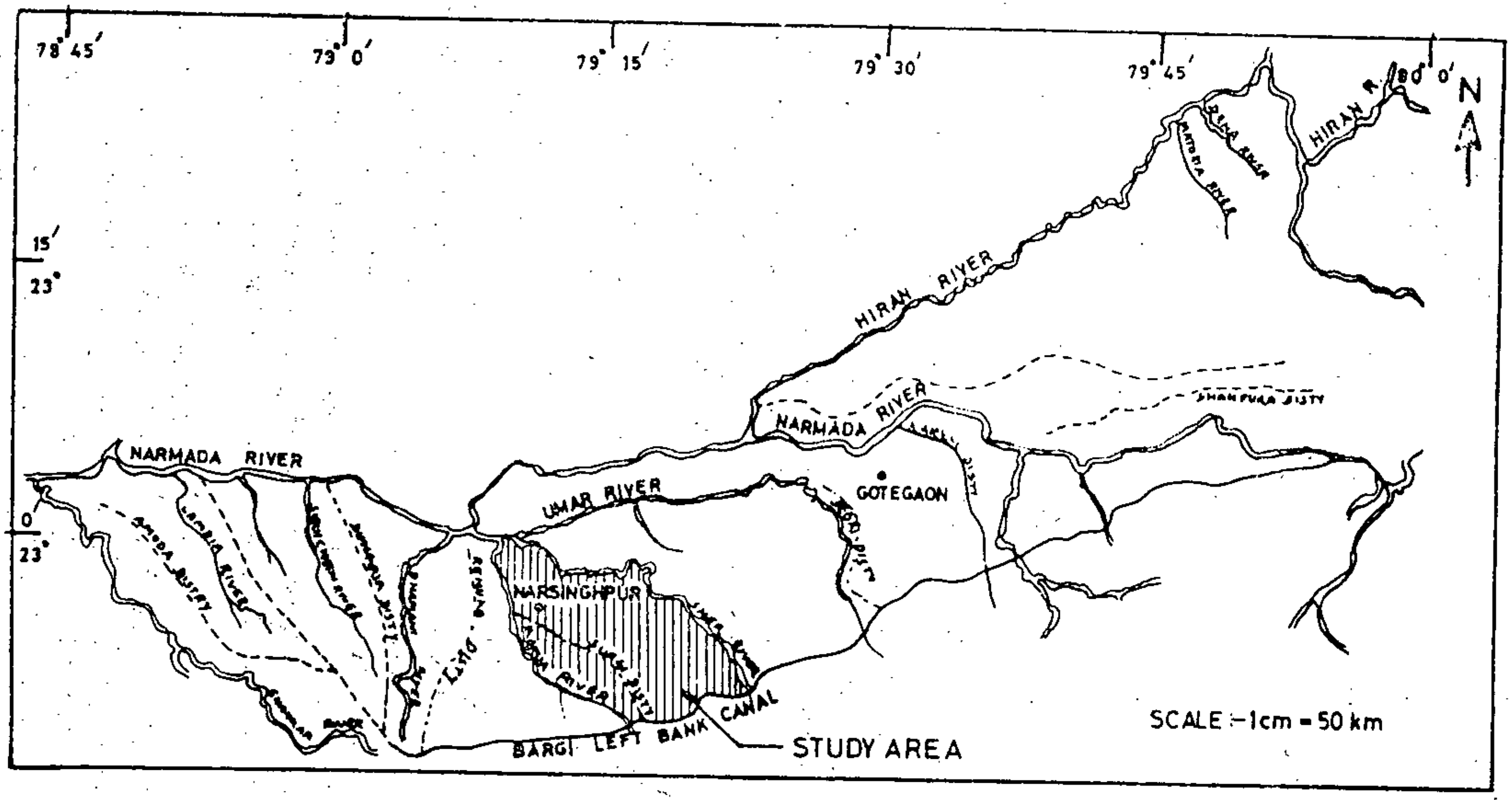


FIG.1 : BARGI LEFT BANK CANAL PROJECT

Location:

1.	State	Madhya Pradesh
2.	District	Dam - Jabalpur Command - Jabalpur & Narsinghpur District
3.	Latitude	22 - 56 - 30")
	Longitude	79 - 55 - 30") Toposheet No.55.
4.	River	Narmada
5.	Location	Dam site is near village Bijora 11.2 km (7 miles) east of village Bargi

Hydrology:

		C.G.S. (units)	F.P.S. (Units)
1.	Catchment area upto dam site.	14,556.05 sq.km.	5,620 sq.M.
2.	Maximum annual rainfall 1926 upto (Jamtara)	2,311 mm.	90.98 inches
3.	Minimum annual rainfall 1899 (upto Jamtara)	664 mm.	26.16 inches
4.	Average annual rainfall 1891-1967 (upto Jamtara)	1,448 mm.	57.01 inches
5.	Design flood	45,296 m^3/sec.	16,00,000 cusecs
6.	Actual observed maximum flood, at Jamtara (9-7-61)	11,876 m^3/sec.	4,19,500 cusecs
7.	Available runoff at Bargi (1891-1967) from computer series		

i) 50% dependability	0.895 mham.	7.250 M.A.F.
ii) 75% dependability	0.672 mham.	5.450 M.A.F.
iii) 90% dependability	0.471 mham.	3.880 M.A.F.

Canal System (Irrigation):

1.	Gross command area	3.21 lakh hac.	7.93 lakh acre
2.	Culturable area	2.98 lakh hac.	7.36 lakh acre
3.	Area to be irrigated	2.67 lakh hac.	6.60 lakh acre
4.	Annual irrigation	5.181 lakh hac.	12.80 lakh acre
	Left bank main canal	107.58 M^3/sec.	3,800 cusec
	Right bank main canal No.I	58.06 "	2,051 "
	Right bank main canal No.II	37.86 "	1,337 "

Length of Main Canal:

i.	Left bank main canal	135.06 km.	83.94 miles
ii.	Right bank main canal No. I	43.65 km.	27.13 miles
iii.	Right bank main canal No. II.	95.57 km.	59.40 miles

1.2 General description of the area:

1.2.1 Location & extent:

The area lies between E. longitudes 78 - 35' to 79 - 50' and N. latitudes 22 - 35' to 23 - 5' and includes Jabalpur district and Gadarawara and Narsinghpur tehsils of Narsinghpur district.

In the north, river Hiran limits the boundary of command area of Jabalpur district, while river Narmada limits the boundary for Narsingpur district. In the west, the extent of command area ends with Shakker river. In the south and west direction there is no prominent features to show the boundary of the area. However, proposed left bank canal will form the boundary in south. The area to be irrigated tehsilwise is shown in Table 1.

Table 1. Tehsilwise area to be irrigated from Bargi Project in Narsingpur district (acres)

District	Tehsil	Geographical area as per villagewise statistics	Cultivable area	
			Covered by Project	To be irrigated
Narsinghpur	Narsinghpur	3,05,653	2,45,743	2,21,166
	Gadarwara	1,24,680	1,01,144	91,033
	Total	4,30,333	3,46,887	3,12,199

1.2.2 Physiography & relief:

The elevation above mean sea level of the command area varies from 1027 to 1248 feet. The general topography of the area appears to be flat except in the vicinity of the rivers, where deep gullies and ravines have formed giving rise to undulating to rolling topography. As such the entire area is a broad plain of low relief, Local differences in elevation is small due to adoptions of Haveli system of cultivation, which has checked the erosion. In the plain area, the slope ranges from 0 to 3%, but in area having undulating topography the steeper slopes even up to 15% are noticed. The distribution of area under different slope class are as per Table 2.

Table 2: Distribution of area under different class

Slope class	Slope %	Area covered	Percentage
A	0 - 1 %	2,56,620	29.65
B	1 - 3 %	2,68,480	31.03
C	3 - 5 %	1,60,440	18.58
D	5 - 8 %	10,240	1.18
E	8 - 15 %	17,920	2.07
BC	1 - 5 %	64,000	7.39
CD	3 - 8 %	87,532	10.11
		8,65,232	100.01

1.2.3 Rivers, major streams & drainage:

The area is provided with a number of rivers and major streams. The main river of the area is Narmada, it covers whole of the area starting from village Ghughri in Jabalpur tahsil to village shakalpur in Gadarwara tahsil. The depth of Narmada in various localities varies from 40 to 100 feet. The river Narmada flows from south to north from village Ghughuri to Gwarighat and than onward, it flows east to west. The other major tributaries are Sher and Sakko both flow south-east to north-west and merge with Narmada at Sagon Ghat and Sokalpur respectively. There are number of minor tributaries namely Bururewa, Umar, Sikhchain, Shanker nala, Singri, Sitarewa and Machhavai in Narsinghpur district

In this way district is having a net work of drainage, which drain excess water of the area successfully and finally into the river Narmada. On an average after every 10 miles one or the other major or minor streams are present for the drainage. These streams and rivers are quite deep and do not silt up like those in alluvium tracts, where the natural drains have chocked up and have blocked the drainage system. Hence due to net work of drainage and their position in the landscape the command area is well drained. The natural drainage follows the general slope of the land. The rainfall of Narsingpur varies from 45" to 50", but even there is no problem of water stagnation or upward movement of salts.

1.2.4 Geology:

Soils of whole of the Bargi Project in Jabalpur and Narsingpur district have been derived from trap rook but with regard to soils only Deccan trap is important one which has given rise to Characteristic colour and properties to the soils of the area. Deccan trap is the great formation of horizontally bedded basaltic lavas that occupies a large portion of the western part of India.

In Narsingpur district quite a large area of the district is covered by the Deccan trap. Fresh trappen exposures are seen in the south-east and north of the district while the central part is occupied by the older alluvium and flat land composed of dark grayish brown, dark brown with small area under yellowish brown colour.

1.2.5 Climate:

The tract enjoys a sub-tropical climate. The annual rainfall of Narsinghpur district varies from 45" to 50", most of it precipitate during monsoon season i.e. end of June to end of September. The summer temperature goes as high as 45° C. The extremes of cold and heat are experienced during winter and summer respectively.

2.0 Methodology

2.1 Particle Size Distribution

2.1.1 Soil Texture

Soil texture is a term which refers to the size range of the particles present in the soil mass. The diameter of the particles present in the soil sample makes the soil to be coarse, medium and fine. Table 3 gives the textural class names of soils as per particle diameter. The traditional method of characterising particle sizes in the soils is to devide the particle sizes into gravel, sand, silt and clay. The soil texture is actually determined by separating these fractions and measuring their proportion which is called the mechanical analysis. The soil texture triangle is then used to convert quantitative data from detailed gradation analysis of separates less than 2 mm in diameter to textural class names of soils. Soil texture is especially important in sub surface drainage as it has a direct relationship with hydraulic conductivity and water retention (David 1982).

Tab 3: Textural classification as per particle Diameter

Material	Diameter
Stones	>10 inches
Cobbles	10 - 3 inches
Coarse gravel	3 - 0.5 inches
Fine gravel	0.5 - 2 mm
Very coarse sand	2 - 1 mm
Coarse sand	1 - 0.5 mm
Medium sand	0.5 - 0.25 mm
Fine sand	0.25 - 0.1 mm
Very fine sand	0.1 - 0.05 mm
Silt	0.005 - 0.002 mm
Clay	<0.002 mm

In a particle size distribution curve,the y-axis or the ordinate in the graph indicates the percentage of soil particles having the diameter finer than indicated on X-axis. Chart are also available in literature showing the percentages of clay, silt and sand in the basic soil textural classes. The triangle of particle size distribution is given in Fig. 2 (drainage manual USDA).

2.1.2 Soil Moisture Tension and PF values

The moisture contained in the pore spaces of a soil mass is subjected to the capillary forces. This capillary force causes a negative soil moisture tension, which is also called suction. The suction is expressed as the height of water column (h) that will rise from the water table against the force of gravity. This height is inversely proportional to the diameter of the pores. Therefore, $h = 0.3/d$, where d = equivalent pore diameter (EPD) of a cylindrical pore with the same capillary. The negative logarithm of soil moisture tension in centimeters of water is used to indicate the soil moisture tension. This negative log of soil moisture is referred to as pF. Table 4 shows the characteristic figures of capillary soil moisture.

2.1.3 Field Capacity

The water present in a saturated soil is allowed to drain out, the water quickly leaves the soil via largest pores and air is pulled into the soil. This movement of water is mainly due to the gravitational potential difference. When the rapidly moving water in the unsaturated soil ceases to move then the soil is said to be at Field capacity. Field capacity occurs when soil retains the maximum amount of water with little or no further loss of water by drainage or loss of gravitational water. A soil water

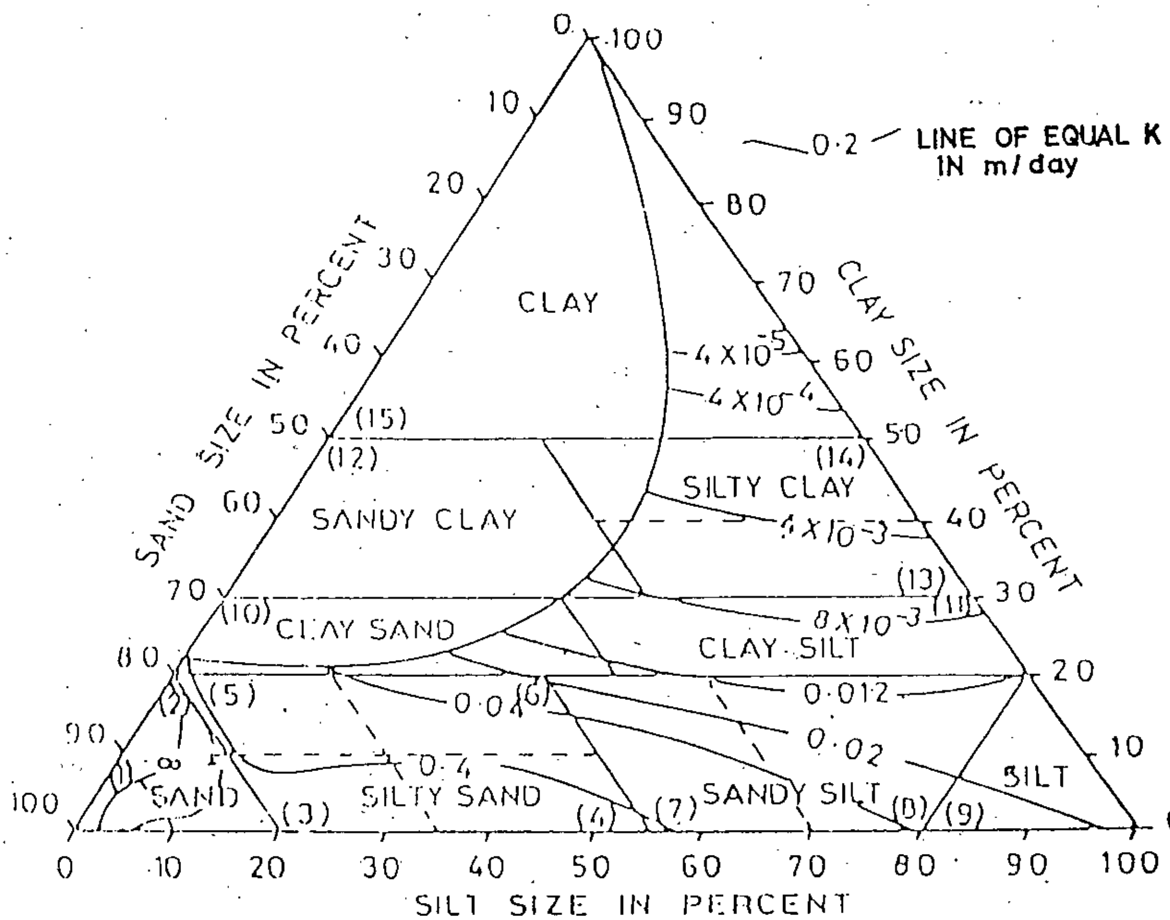


FIG. 2 : RELATION OF HYDRAULIC CONDUCTIVITY TO SAND, SILT AND CLAY PERCENTAGES

Tab 4: Characteristic figures of soil moisture and pF

Equivalent pore diameter (m)	SMT (cm)	pF value
3,000	1	0
1,200	2.5	0.4
1,000	3.0	0.5
300	10	1.0
30	100	2.0
20	150	2.20 FC
15	200	2.30
9	340	2.51 ME
3	1,000	3.00
0.3	10,000	4.00
0.2	15,000	4.18 WP
0.03	10^5	5.00
0.003	10^7	7.00 oven dry

FC = Field capacity, ME = Moisture Equivalent

WP = Wilting point

matrix potential of about -1/3 bars has been found to correspond to the field capacity. A bar is equal to 10^6 dynes. A dyne is equal to the force that imparts to a mass of 1 gram an acceleration of 1 cm/sec^2. A bar is also equal to 1,020 cm water column or 1,020 gm/cm^2.

2.1.4 Wilting Point

As soil becomes drier, the conductivity rapidly decreases and movement and uptake of water becomes slower. Therefore, if no additional water is added to the soil, the plant will absorb water slower than water is lost by transpiration. Thus a water deficit develops in the plant. This point is called wilting point. A soil water matrix potential of about -15 bars has been found to correspond to wilt point (Henry, 1984).

2.1.5 Available Water

The water present in the soil between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of -0.3 to -15.0 bars.

2.1.6 Effect of texture on Available water

The capacity of soil to hold water is related to surface area as well as pore space volume. Hence, water holding capacity is related to both structure and texture of the soil. In general fine textured soils have the maximum total water holding capacity, but maximum available water is held in medium-textured soils. Several researchers have indicated that available water in many soils is closely correlated with content of silt and very fine sand. It is well known that sandy soils are more droughty than clayey soils, because fine-textured soils are able to retain more available water. Also, there is a difference in the soil of soil-moisture characteristic curves of sand and clay. The flatness of the curve for fine sandy loam at water matrix potential is less than -4.0 bars which means that most of the available water in the sandy soils have a high potential. Therefore, plants can readily use this water in sandy soils. Since in clay or clay loam soils the water is available at lower potential therefore it can be rapidly used by the plants.

2.3 Sieve Analysis

In the Indian Standard (IS: 460-1962), the sieves are designated by the size of aperture in mm, whereas in BS (410-1962) and ASTM (E11-1961) standards, the sieve sizes are given in terms of the number of openings per inch. These are described in Report TR-82 by Dr.Seth, 1990. The mechanical analysis of soil is performed by sieve analysis and sedimentation analysis.

The soil sample for which the sieve analysis is to be carried out is first dried in the oven. Weigh the required quantity of soil sample and keep in 1000ml Beaker, soak it with water, paddle the sample throughly in water and transfer the slurry to the 0.075 m sieve and washing should be continued until water passing through the sieve is substantially cleaned so that silt and clay particles are seperated from sand and gravels fraction to collect the material passing through 0.075 mm (200 No.) sieve and material retained on it in seperat e containers and keep them in oven for drying. weight both group of soil retained and passed through 0.075 mm. sieve, and retained amount used for sieve analysis. The sieves used for fine sieve analysis are: 2mm, 600, 425, 300, 212, 150 and 75 micron. In order to carry out the sieve analysis the sieves are arranged in one over another in the lowering order of mash openings. The cover is placed on the top of assembly and a container is kept at bottom. The entire assembly is shaken by sieve shaker. Shaking of the sample is performed for nearly 10 minutes.

At the end the portion retained on each sieve is collected and weighted. The percentage of soil sample retained on each sieve on the basis of total weight of soil sample and the percentage of weight passing through each sieve was calculated (Bowles ,1986). The calculations were started with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

Percentage passing = Percentage arriving - percentage retained

2.4 Wet Mechanical analysis

The soil fraction which is finer than 75 micron size is used for sedimentation analysis. This analysis is based on the stokes law which states that all other factors being constant the velocity at which grains settle out of suspension is dependent upon the weight, shape and size of grains. Assumptions are made for the analysis that the soil particles are spherical and all the particles have some specific gravity. This assumption leads to the fact that coarser particles settle more quickly than finer ones. The terminal velocity of a particle in suspension is given by following formula:

$$v = \frac{D^2}{18} \cdot \frac{\gamma_s - \gamma_w}{\eta} \quad \ldots\ldots(1)$$

where, v = Terminal velocity,
r = Radius of spherical particle (cm),
D = Diameter of particle (cm),
γ_s = density (unit wt.) of particles (g/cm^3),
γ_w = density of water/liquid (g/cm^3)
η = viscosity of water/liquid ($g\text{-}sec/cm^2$)
η = μ /g
μ = viscosity in absolute units of dynes-sec/sq.cm,
and g = acceleration due to gravity (cm/sec)

If water is used as a medium for suspension, $\gamma_s = G\gamma = G$ as $\gamma = 1$ g/cu.cm. Therefore from eq. (1)

$$v = \frac{G-1}{1800\eta} D^2 \quad \ldots\ldots(2)$$

At 20^{o}c viscosity of distilled water is approximately 0.01 poise. For G = 2.68, the equation (2) reduces to

$$v = 91.5\ D^2 \qquad (3)$$

Equation (3) is an approximate solution of stokes law and is used for estimation of diameter of soil particles (Seth, 1990).

2.5 Hydrometer Method

In the hydrometer analysis the weight Wd per ml of suspension is found by reading the density of soil suspension at a depth He at various time intervals. This height He goes on increasing as the particles settle with the increase in time interval. Therefore, it is necessary to calibrate the hydrometer and sedimentation jar before the start of the sedimentation test. This calibration will provide the relation between He and the density readings of the hydrometer.

2.5.1 Calibration of Hydrometer

The stem of the hydrometer has horizontal markings which gives the density of the soil suspension situated at the centre of the bulb at any time. For the sake of convenience the hydrometer readings are subtracted by one and the remainder is multiplied by one thousand to give a reduced reading indicated as Rh. Hydrometer readings increase in the downward direction towards hydrometer bulb. Referring to fig. 3 when hydrometer is immersed in the jar water level increases, the level aa rises to a1a1 and bb to b1b1. At this point time b1b1 corresponds to the centre of hydrometer at which density measurements are taken.

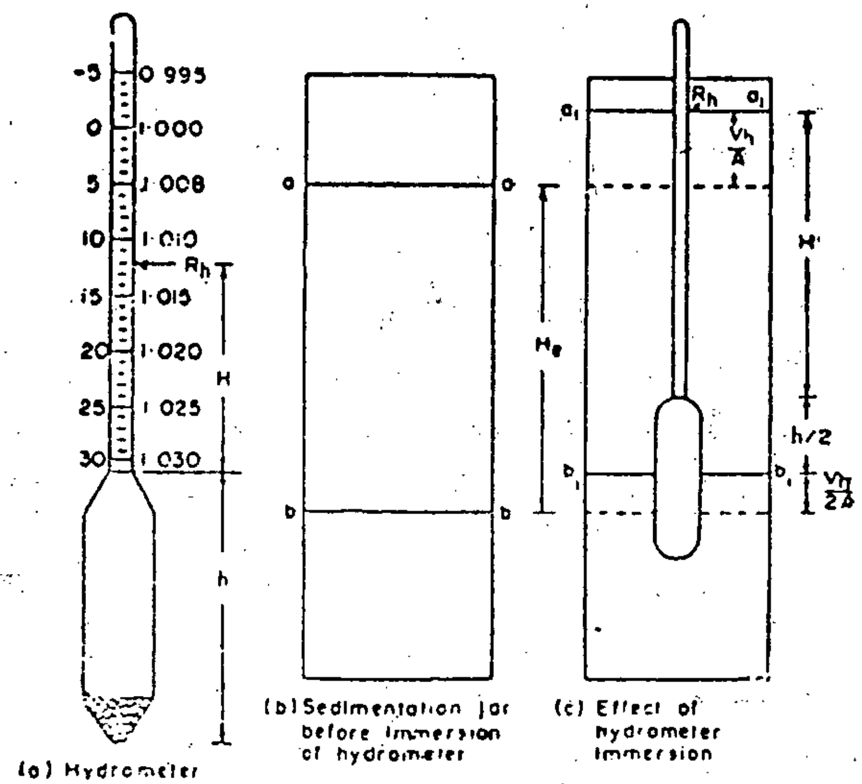


FIG. 3 : HYDROMETER ANALYSIS

$$He = (H + h/2 + Vh/2A) - Vh/A$$

$$He = H + 0.5(h - Vh/A)$$

Above equation have two variable He and H which depends upon the hydrometer reading (Rh). By selecting various hydrometer readings the depth H can be measured with the help of an scale and corresponding effective depths (He) can be found as Vh, A and h are constant for a given hydrometer.

2.5.2 Test procedure

2.5.2.1 Soil Suspension Preparation

About 24 to 60 gm of oven dried sample (depending upon the type of soil) is taken and is weighed accurately. The sample is placed in a beaker and distilled water is added to form a smooth thin paste. A deflocculating agent (e.g. sodium oxalate, sodium silicate and sodium polyphosphate compound such as tetra sodium petrophosphate, sodium hexametaphosphate (calgon) and sodium tripolyphosphate) is also added to get a proper dispersion of soil. IS:2720 (Part IV)-1965 recommends the use of dispersing solution containing 33 g of sodium hexametaphosphate and 7g of sodium carbonate in distilled water to make one litre of solution. 50 ml of this solution is added to beaker containing soil sample, this mixture is warmed gently for about 10 minutes. The contents are then transferred to the cup of mechanical mixture. The soil sample is stirred well for about 15 minutes and is then washed through 75 micron sieve using distilled water. Now the sample is ready for analysis and is transferred to measuring cylinder care should be taken that the volume of suspension should be 1000 ml for analysis.

The sedimentation jar is shaken vigorously and is kept verticle over solid bases. The hydrometer is inserted and readings are taken at definite time interval (1/2, 1, 2, 4, 8, 15, 30 mins and 1,2,4 hours etc.). To take reading, hydrometer is inserted 30 seconds before the given time interval so that it is stable at the time when reading is taken. The reading is taken for upper level of meniscus. A suitable meniscus correction is then applied to the hydrometer readings.

2.5.2.2 Correction for hydrometer reading

Hydrometers are generally calibrated at $27^{o}C$, if the temperature of soil suspension is not $27^{o}C$, a temperature correction (Ct) should be applied to the observed hydrometer reading. If temperature is more than $27^{o}C$ the reading of hydrometer will be less hence temperature correction will be positive and vice versa. Other corrections to be applied are meniscus correction and dispersing agent correction. As reading of hydrometer is taken at the top of meniscus, actual reading at water level is higher. Hence meniscus correction (Cm) is always positive. It is found by immersing the hydrometer in clean water. The dispersing agent correction (Cd) is always negative as it increases the density of water.

Therefore corrected hydrometer reading

$$R = Rn + Cm \pm Ct - Cd$$

where, Rn = observed hydrometer reading at the top of meniscus

Cm, Ct and Cd can be combined into C which is called composite correction.

$$R = Rn + C$$

2.5.2.3 Determination of composite correction

To calculate 'C' an identical cylinder with 1000 ml capacity is taken and filled with distilled water and same quantity of dispersing agent as is used in sedimentation analysis. The temperature of both cylinders being same the hydrometer is immersed in this comparison cylinder. The reading of hydrometer is taken at the top of meniscus. The negative of this reading so obtained gives the composite correction. Composite correction is found before the test and also at time interval more than 30 minutes.

2.5.2.4. Computation of D and N

The observed hydrometer readings were corrected suitably as per the calculated meniscus and temperature corrections and from the corrected hydrometer reading the He was calculated for the corresponding time and Rh. The particle size diameter was calculated by

$$D = 10^{-5} M (He/t)^{0.5} \quad \ldots\ldots(4)$$

The over all percentage finer was calculated as below

$$N = N' \frac{W1}{W} \quad \ldots\ldots(5)$$

where, $N' = \frac{100\ G}{Wd\ (G - 1)}$

N = over all percentage finer,

N' = percentage finer based on Wd,

G = specific gravity of soil particles,

Wd = weight per ml of suspension, and

W = total dry weight of soil

t = time to fall through a height He

The grain size was plotted against percentage finer on semi log paper and are given in Figs. 16 to 26 for all the samples.

2.6 Measurement of Field Saturated Hydraulic Conductivity by Guelph Permeameter

Hydraulic conductivity is the measure of the ability of a soil to conduct water under a unit hydraulic gradient. Field saturated hydraulic conductivity (Kfs) refer to the saturated hydraulic conductivity of soil containing entrapped air. Field saturated hydraulic conductivity is more appropriate than the truely saturated hydraulic conductivity for unsaturated zone investigations because by definition, positive pressure heads do not persist in unsaturated conditions long enough for entrapped air to dissolve. In the presence of the water table, the auger hole method is a simple and reliable technique for measuring saturated hydraulic conductivity in relatively uniform soils. However this method cannot be used if the water table is not present in the region of interest. The methods for measuring hydraulic conductivity in the absence of the water table are more complicated. The shallow well permeameter method, also known as the dry auger hole method and the bore hole permeameter method are the techniques for measuring hydraulic conductivity. Hydraulic conductivity decreases as the soil water suction increases. This relationship is called the conductivity pressure head relationship. The Guelph permeameter is used to determine Kfs for a particular soil. Once the soil water suction is measured, the hydraulic conductivity (K) at that soil water suction (φ) can be readily estimated by relatioship

$$K = Kfs(e^{\alpha * \varphi}) \quad (6)$$

where

α = Alpha is a parameter indicating slope of the curve relating natural log of K to φ

φ = Soil water suction in cm of water

e = 2.71828 (base of natural logrithm)

Kfs = Saturated hydraulic conductivity of the soil

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

$$\phi_m = 0.0572 * X * R1 - 0.0237 * X * R2 \qquad (7)$$

Alpha parameter (α) is the slope of the curve relating the natural log of hydraulic conductivity (K) to soil water suction in per cm expressed by following relationship

$$\alpha = Kfs / \phi_m \qquad (8)$$

2.6.1 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. The two models of Guelph Permeameter can be reffered in Shukla and Soni (1993).

(i) Tripod Assembly

(ii) Support Tubes and lower air tube fittings

(iii) Reservoir Assembly

(iv) Well Head Scale and upper air tube fittings

(v) Auxilliary tools

(i) Tripod Assembly:

The tripod assembly (Fig.4) consists of a tripod based with movable tripod rushing and three detachable tripod legs complete with end tips. The flexible tripod base has three leg sockets into which the tripod legs are inserted. 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 (Fig. 5) over the well hole and transports water from the reservoir to the water outlet. The water outlet tip serves as a base for the permeameter and disperses the energy of the out flowing 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.

(iii) Reservoir Assembly:

The reservoir assembly (Fig.6) provides a means of storing

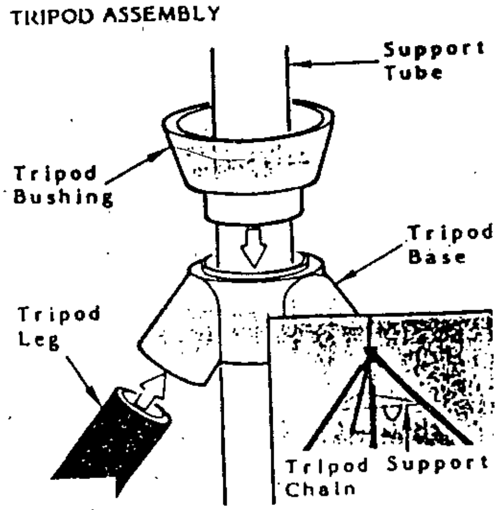


FIG. 4 : TRIPOD ASSEMBLY SHOWING THE TRIPOD BASE ARRANGEMENT

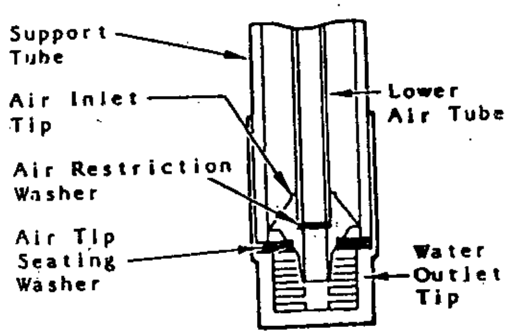


FIG. 5 : SUPPORT TUBE AND AIR TUBE FITTINGS

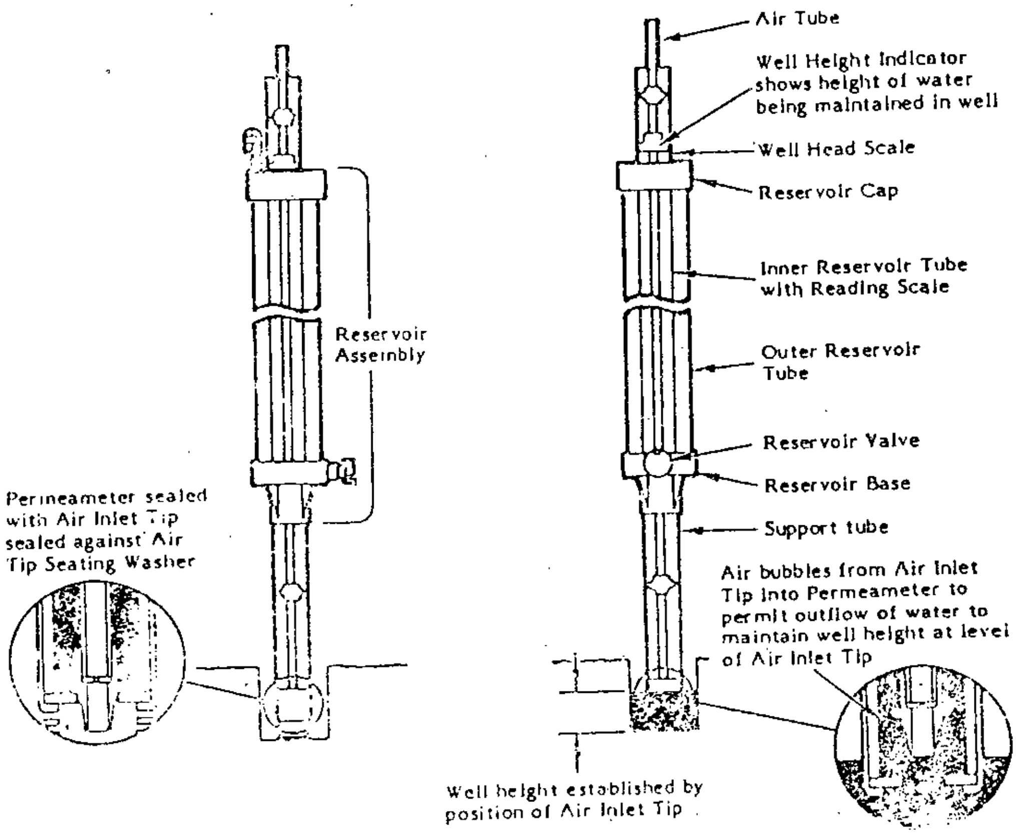


FIG. 6 : DETAILS OF RESERVOIR ASSEMBLY A) closed or sealed state with air inlet tip sealed against air tip washer B) when air tube is uplifted permitting of flow of water

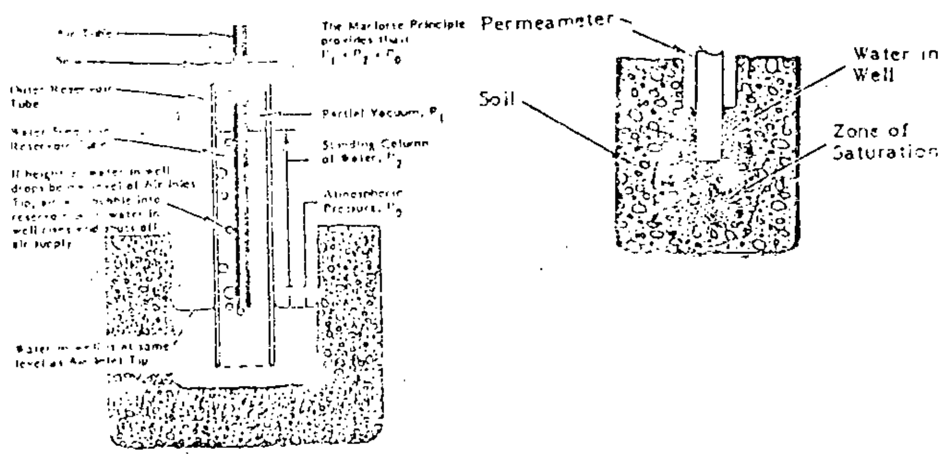


FIG. 7 : PERMEAMETER IN OPERATION A) equilibrium is established B) a view of bulb in zone of saturation

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 Guelph permeameter shows the closed or sealed state with air inlet tip sealed against air tip seating washer. When air tube is uplifted, 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 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 peep brush, a vacuum hand pump for pulling a vacuum in the reservoir and a collapsible water container for carrying water to the field. The well peep brush meant for removing any smear layer that exists in the auger ed well hole that may create a barrier to the natural flow of water out of the well into surrounding soil.

2.6.2 Procedure

The Guelph permeameter method (Reynold et.al. 1985) measures the steady state liquid recharge necessary to maintain a constant depth of liquid in an uncaged cylindrical well 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. The reduced pressure in the air above the water in the reservoir together with the pressure of the water column extending from the surface of the well to the surface of the water in the reservoir which is always equal to the atmospheric pressure. (Fig.7)

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. 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 and head of water in the well (Shukla and Soni, 1993).

2.6.3 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. The brief flow chart is shown in Fig.8.

2.6.4 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 than be excavated using the sizing auger to produce a debris free well hole of uniform geometry.

In the moist soils or in medium to fine textured soils, the process of angering 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 removed. The well peep brush is designed to use in the standard 6 cm diameter well hole.

2.6.5 Permeameter Placement

Tripod is centered over the well hole and slowly the permeameter is lowered 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 rushing alone provides the functions of centering and stabilizing the permeameter (Fig.9). After the permeameter is placed, it can be easily filled with water. The following standard procedure should be followed for making measurements.

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

(hi) Establish a 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.

(iii) 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.

(iv) 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 fall 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

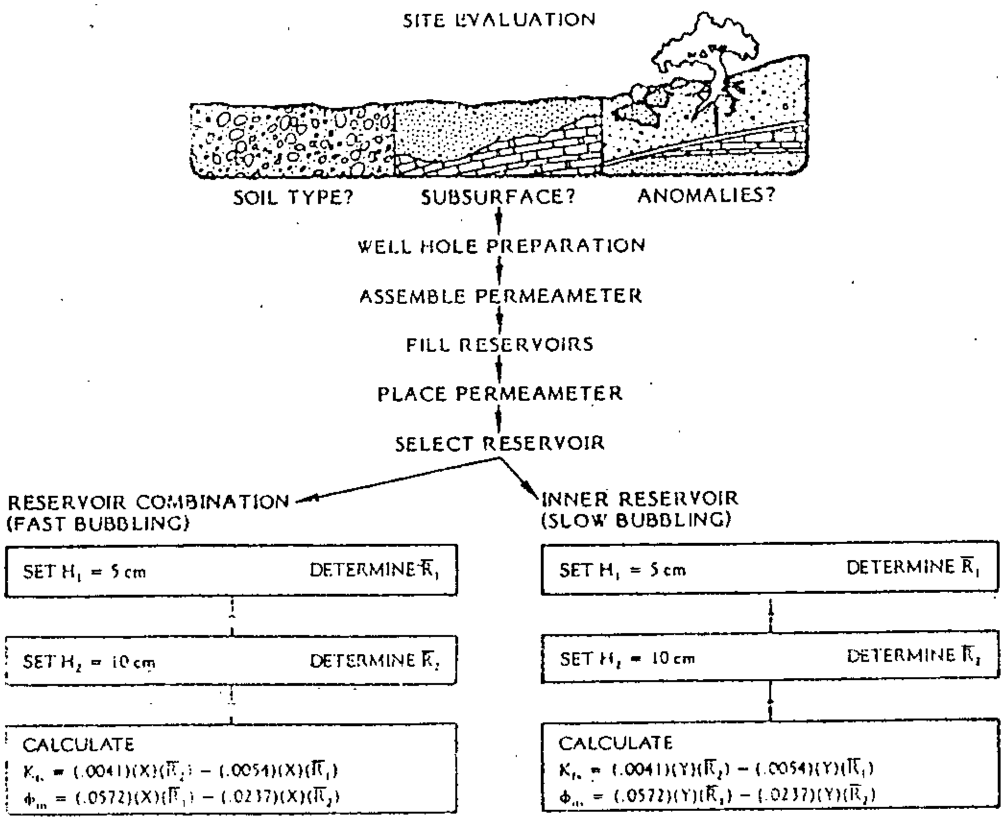


FIG. 8 : FLOW CHART OF PROCEDURE FOR Kfs MEASURE MENT USING THE GUELPH PERMEAMETER

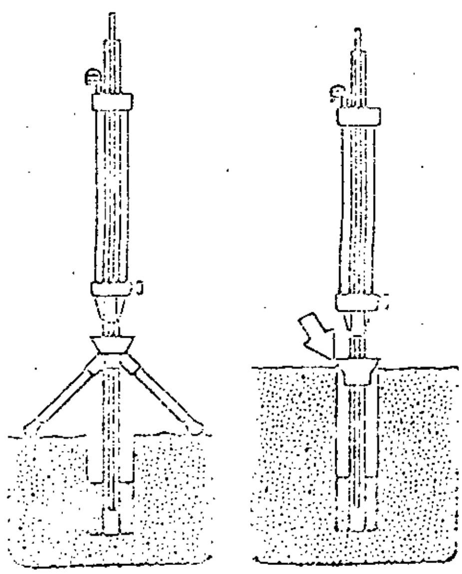


FIG. 9 : PLACEMENT OF PERMEAMETER IN WELL HOLE

"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.

(v) 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.

(vi) The field saturated hydraulic conductivity, Ks can be calculated using the following equation:

Ks = 0.0041*X*R2 - 0.0054*X*R1 ....(9)

where,

X = Reservoir constant, equal to 35.19 where reservoir combination is used and 2.16 when only inner reservoir is used

R2 = Steady rate of fall of water in the reservoir for a head of 10 cm.

R1 = Steady rate of fall of water in the reservoir for a well head of 5 cm.

2.7 Pressure Plate Apparatus

This is a standard method for obtaining the soil moisture retention curve. Pressure plate apparatus (Fig.10) 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

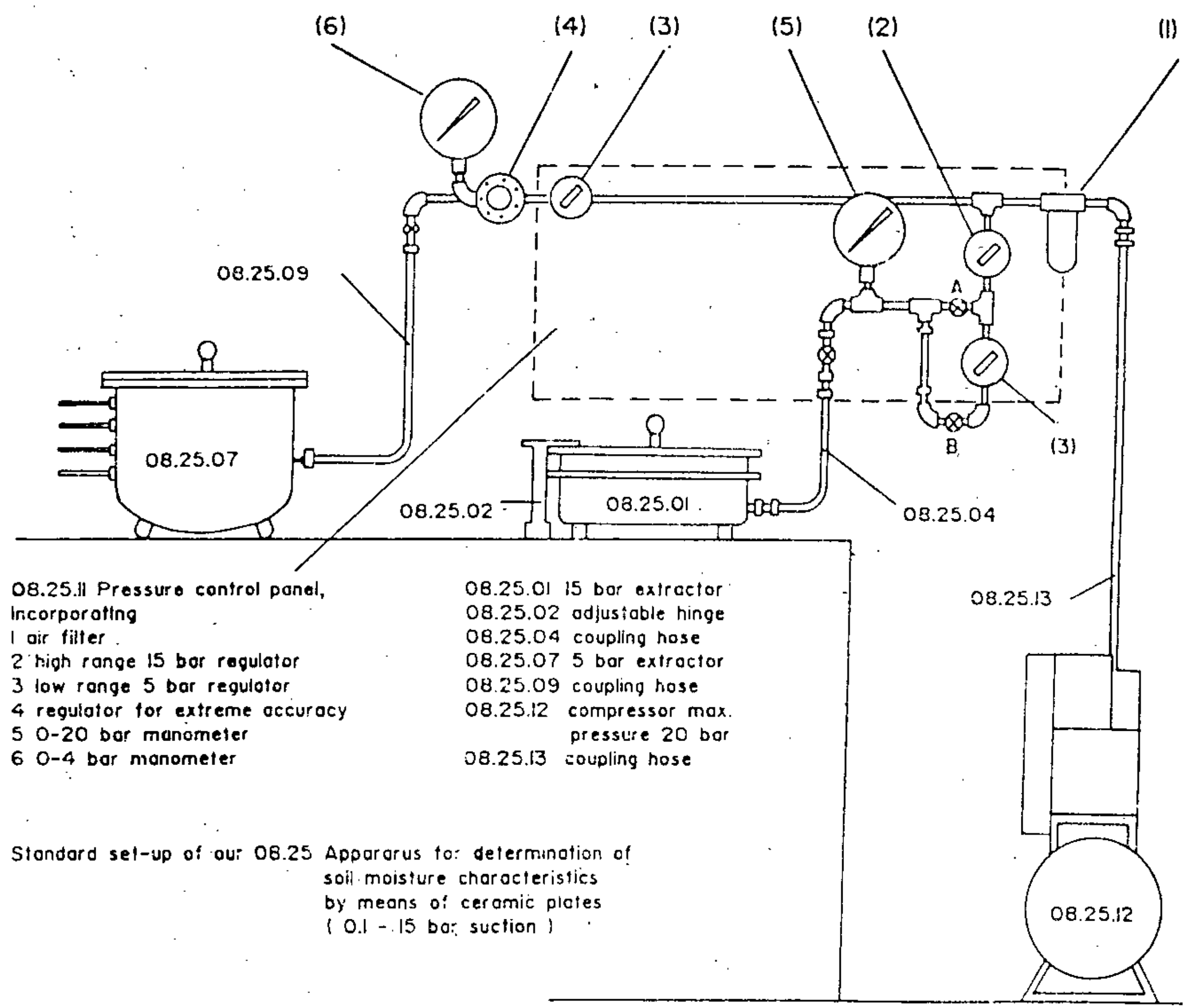
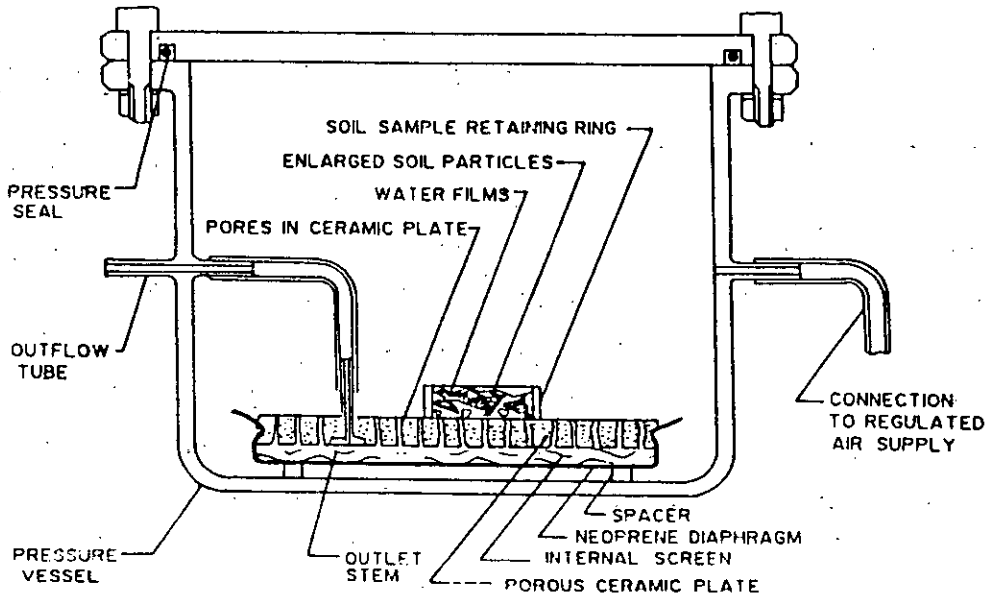


FIG. 10 : STANDARD SET UP OF PRESSURE PLATE APPARATUS

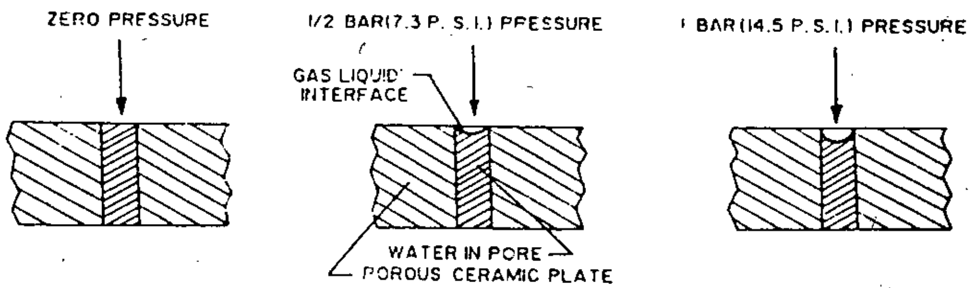
through the membrane outlet. Soil water will flow out from the soil sample until the metric potential of the unsaturated flow is same as the applied air pressure. The air pressure is t hen, released and the moisture content of the soil is gravimetrically determined.

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.11. 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



CROSS SECTION CERAMIC PRESSURE PLATE CELL AND SOIL SAMPLE, IN EXTRACTOR



CHANGES IN RADIUS OF CURVATURE OF GAS LIQUID INTERFACE WITH PRESSURE

FIG.11 : SELECTION VIEW OF CERAMIC PRESSURE PLATE CELL

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 1/1 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.

3.0 Procedure

3.1 Soil Sampling

The pilot area as shown in Fig.12 & 13 was selected for the estimation of soil hydrolytic properties of the area. The soil sampling was carried out from this area. Samples have been collected from 12 different sites at 21 points as indicated in the Fig. 12 & 13. Samples are collected for Grain size distribution and soil moisture retention curve analysis. Measurement of field saturated hydraulic conductivity was also carried out at 21 points of 12 different sites by Guelph Permeameter using Tripod assembly and without Tripod assembly as shown in Fig. 14 & 15 respectively.

3.2 Grain Size Analysis

1. Oven dried sample weighing 500 gm was taken and soaked with water.
2. This sample was washed through no. 200 sieve. The washing was carried out carefully using distilled water.
3. Two group of soils, one passing through the sieve and another retained on the sieve were collected separately.
4. Both the groups of soil were then oven dried. The group retained on sieve was subjected to sieve analysis and the group passing through the sieve was subjected to sedimentation analysis.

A. Sieve Analysis

1. Oven dried soil sample retained on no.200 sieve was taken for the sieve analysis.
2. The sample was sieved through a set of sieves i.e. 4, 10, 14, 20, 40, 60, 70, 200 no. sieves. The sieving was performed

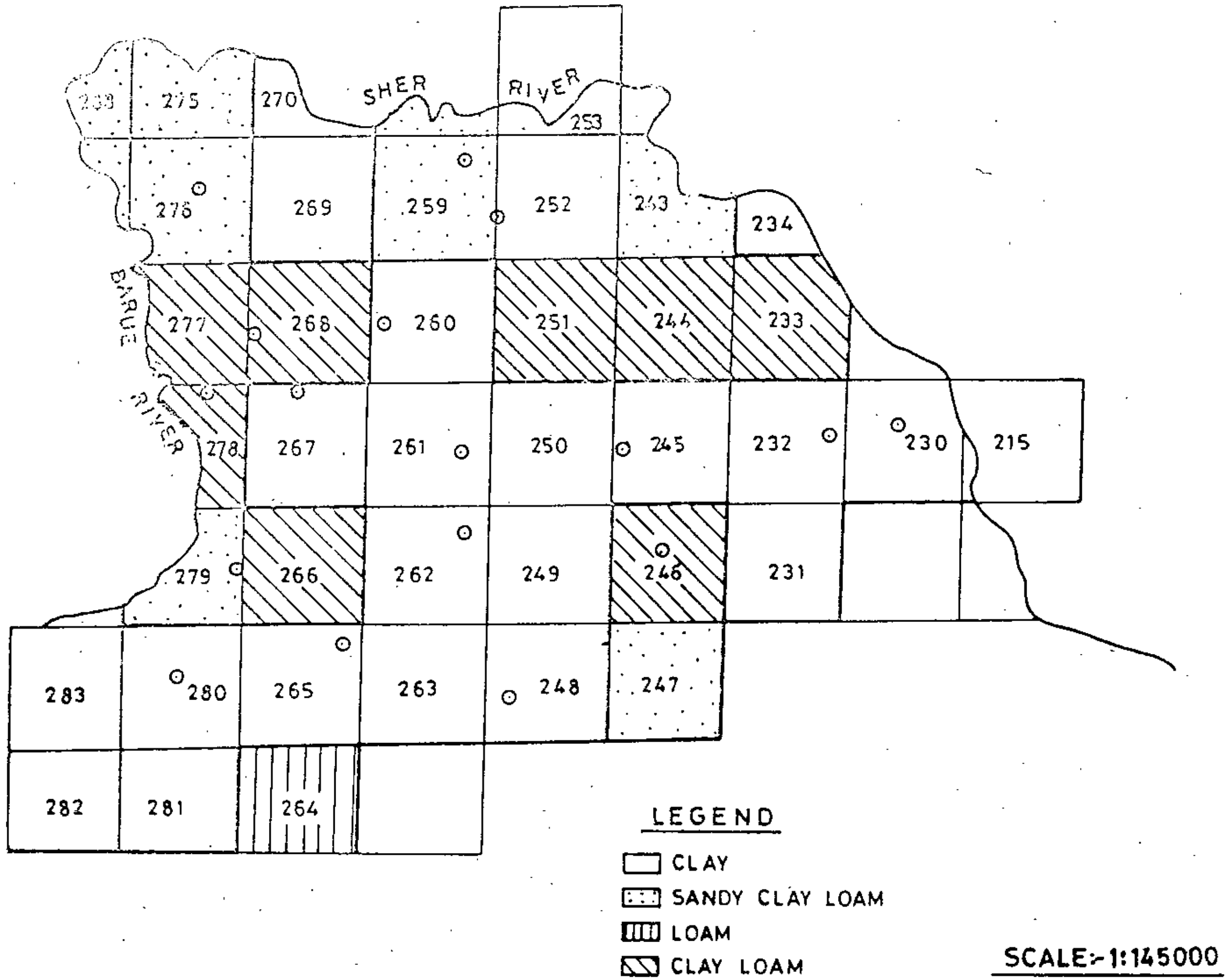


FIG.12- LOCATION OF TEST POINTS WITH GRID NO AND SOIL TYPE IN STUDY AREA

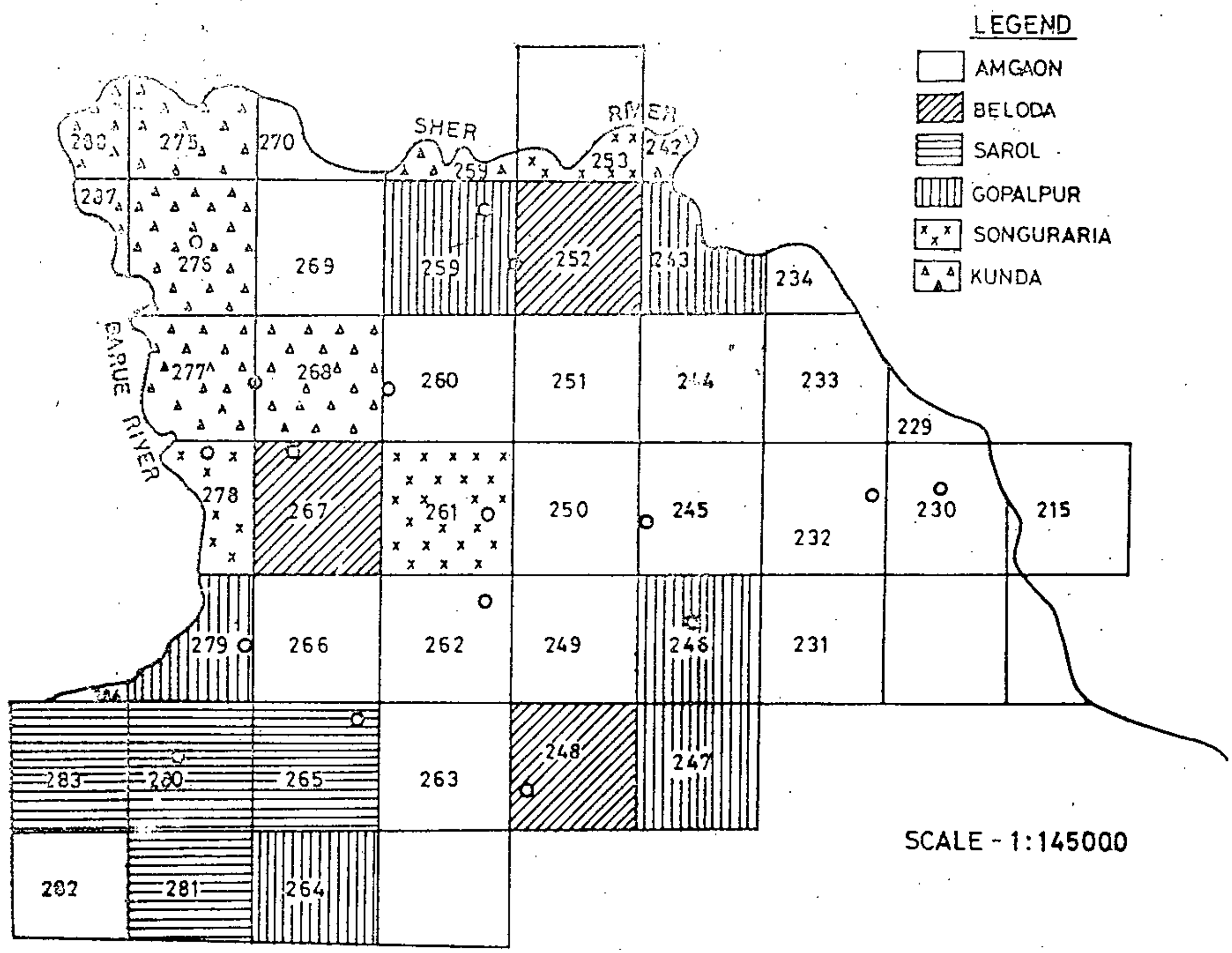


FIG.13-LOCATION OF TEST POINTS WITH GRID NO AND SOIL SERIES IN STUDY AREA

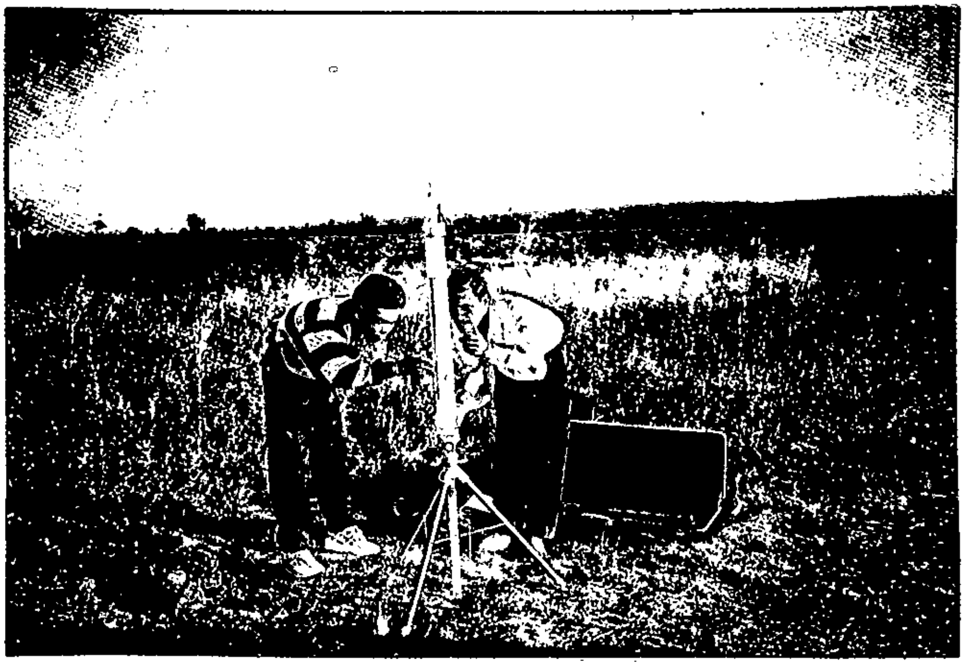


Fig.14 Experiment by Guelph Permeameter using tripod assembly in Narsinghpur district

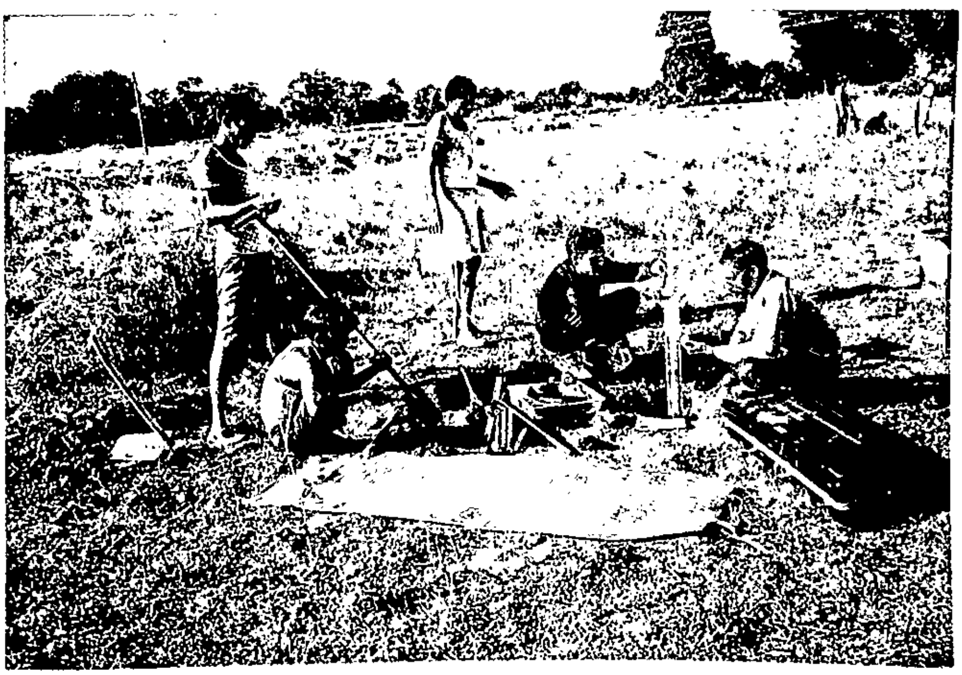


Fig.15 Experiment by Guelph Permeameter without tripod assembly in Narsinghput district

with mechanical sieve shaker for 10 to 15 minutes.

3. The stack of sieves were removed from sieve shaker and weight of material retained on each sieve was computed. The percentage of total soil sample retained on each sieve was also calculated.

4. The percentage of weight passing through each sieve was calculated. The calculation was started with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

   Percentage passing = Percentage arriving - percentage retained

5. A plot on semilogrithmic paper of grain size versus percent passing was plotted (Figs. 16 to 36).

B. Hydrometer Analysis

1. The soil group passing through the sieve no.200 was oven dried and 50 gm of the sample was taken for hydrometer analysis.

2. The soil sample (50 gm) was soaked with 100 ml of sodium hexametaphosphate solution for 24 hours.

3. All the contents were transferred into the mixer cup and suitable quantity of water was added. The mixing was carried out for 2 to 3 minutes. The mixture was then carefully transferred to the sedimentation cylinder.

4. The cylinder of soil suspension was covered with rubber stopper and the suspension was carefully agitated for one minute. The jar was placed constant temp. both and the cap was removed. The hydrometer and thermometer were then inserred in the controlled jar and readings of hydrometer were taken out 0.5, 1,2,4,8,15,30,60,120, 240 and 1440 minutes.

Fig.16 Grain Size Distribution Curve
Chilly Chand Khurd (10 - 35 cm)

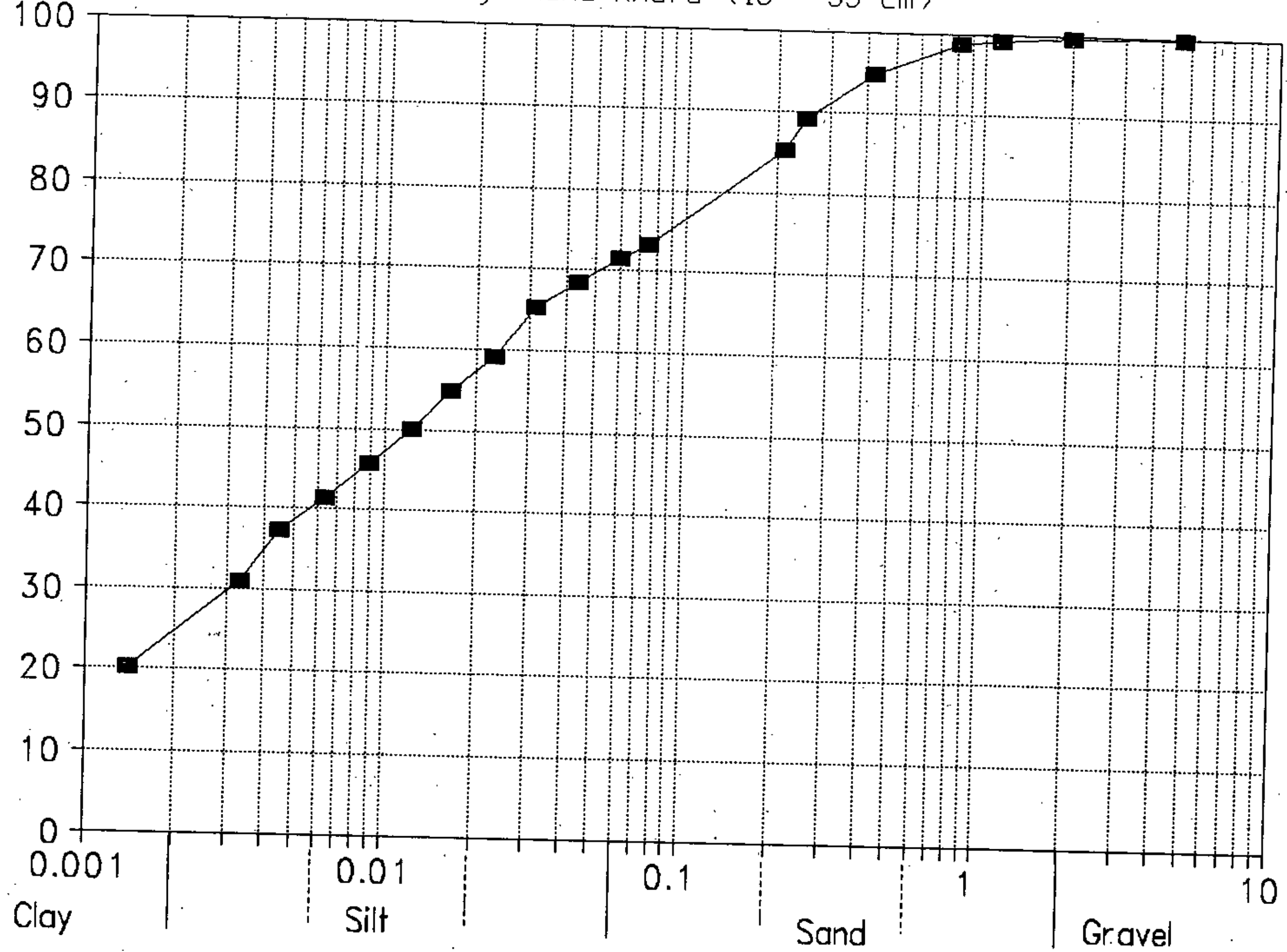


Fig.17 Grain Size Distribution Curve
Chilly Chand Khurd (90 - 130 cm)

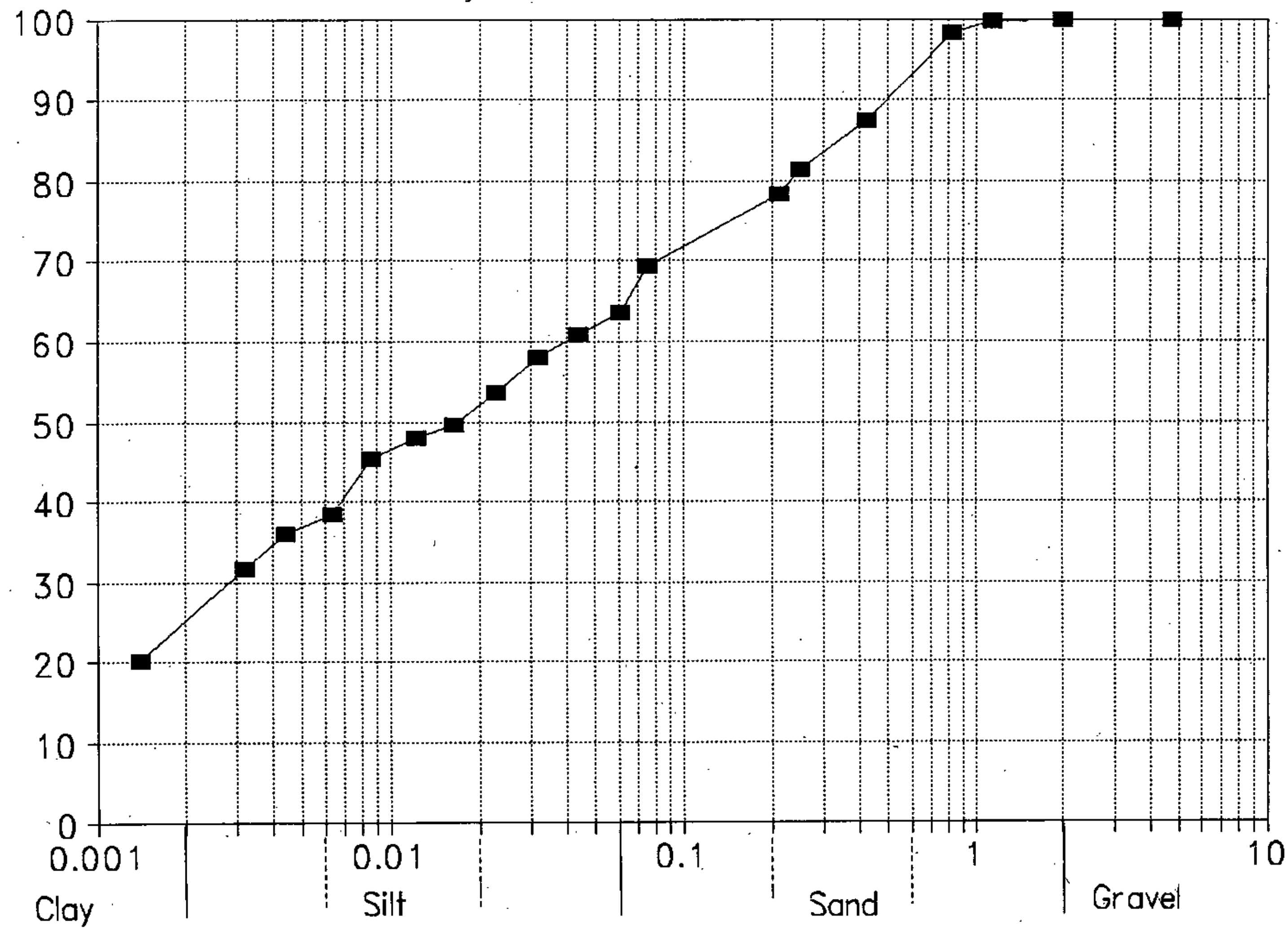


Fig.18 Grain Size Distribution Curve
Karahiya Khera (20 - 50 cm)

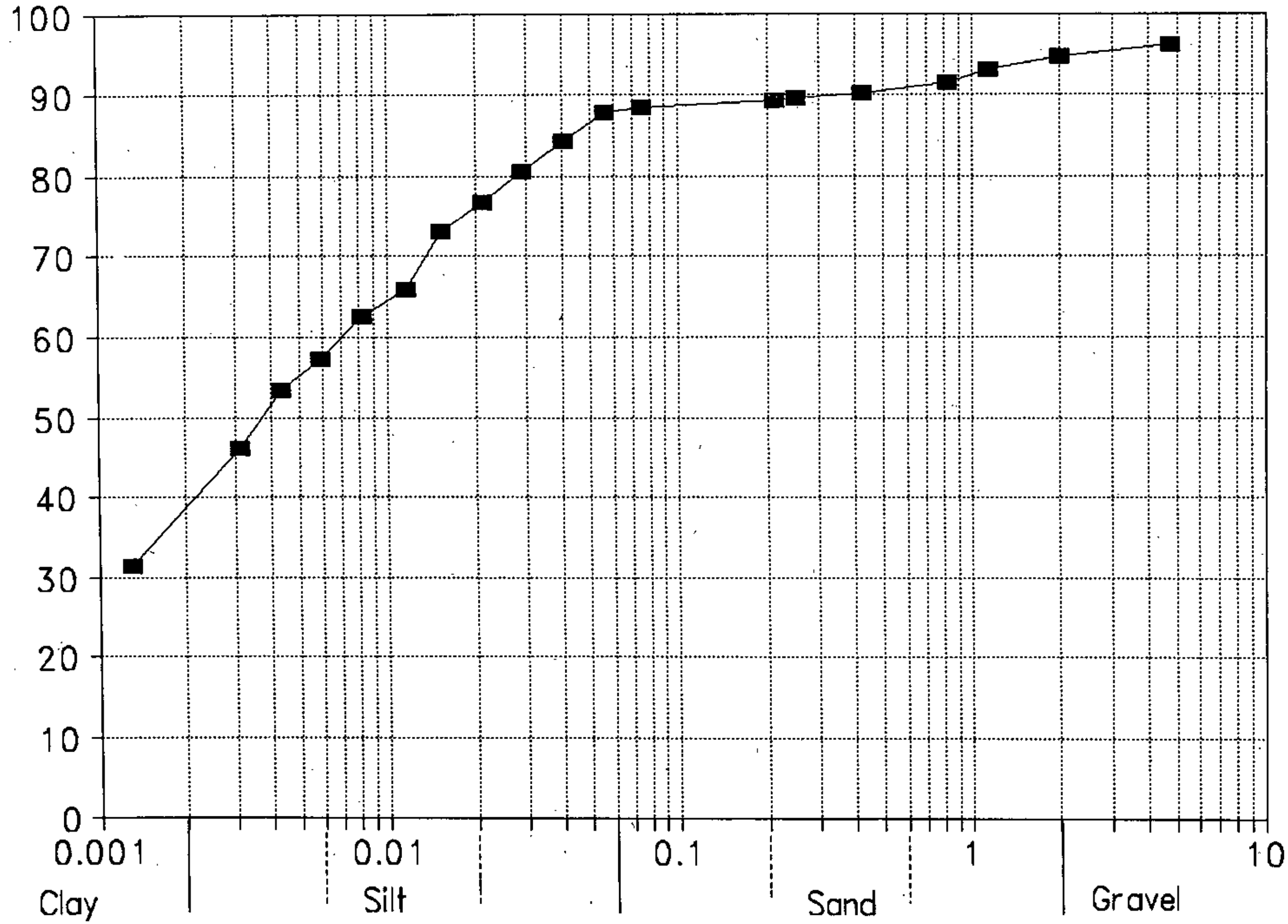


Fig.19 Grain Size Distribution Curve
Karahiya Khera (90 - 130 cm)

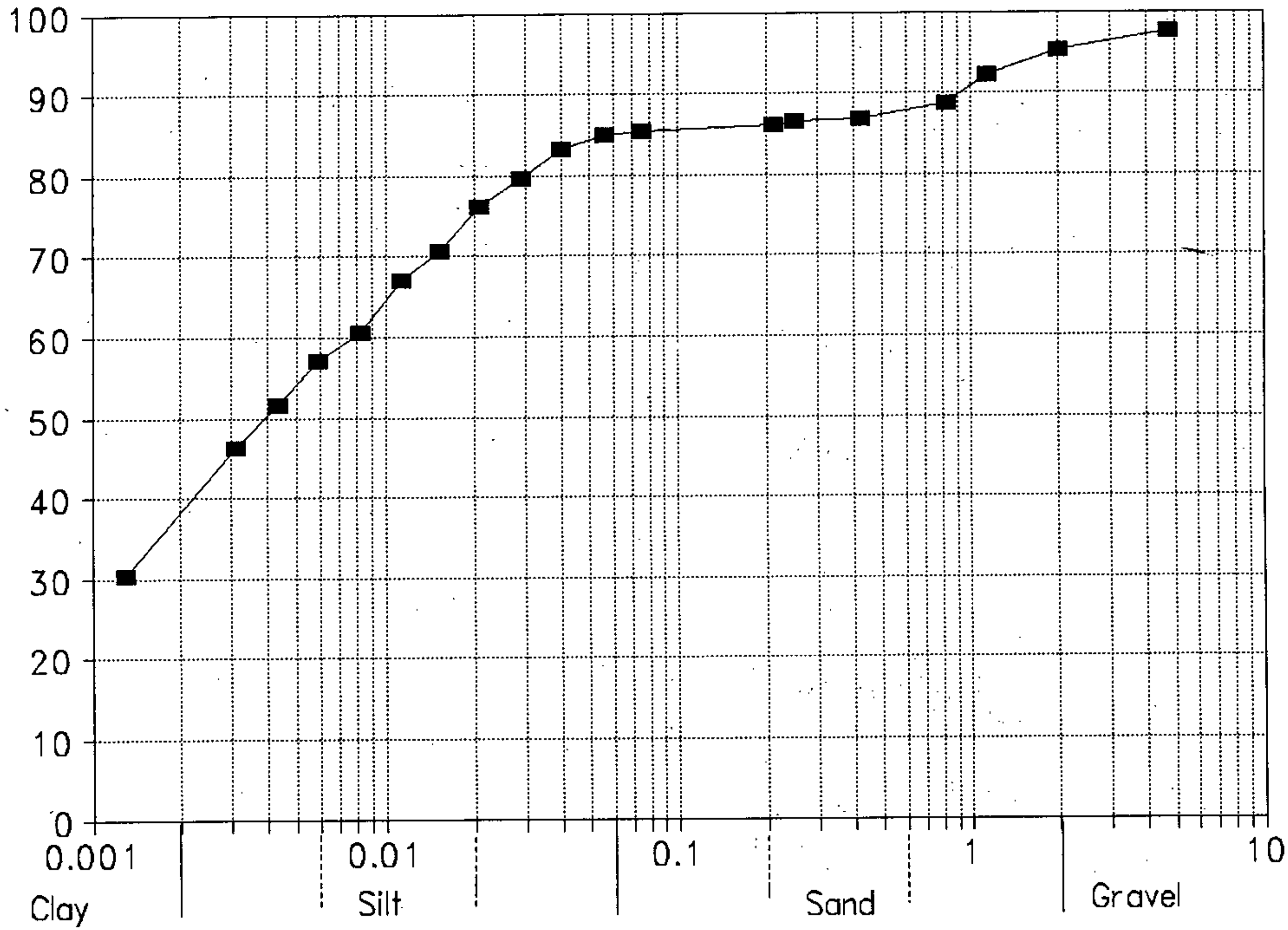


Fig.20. Grain Size Distribution Curve
Khameria (25 - 50 cm)

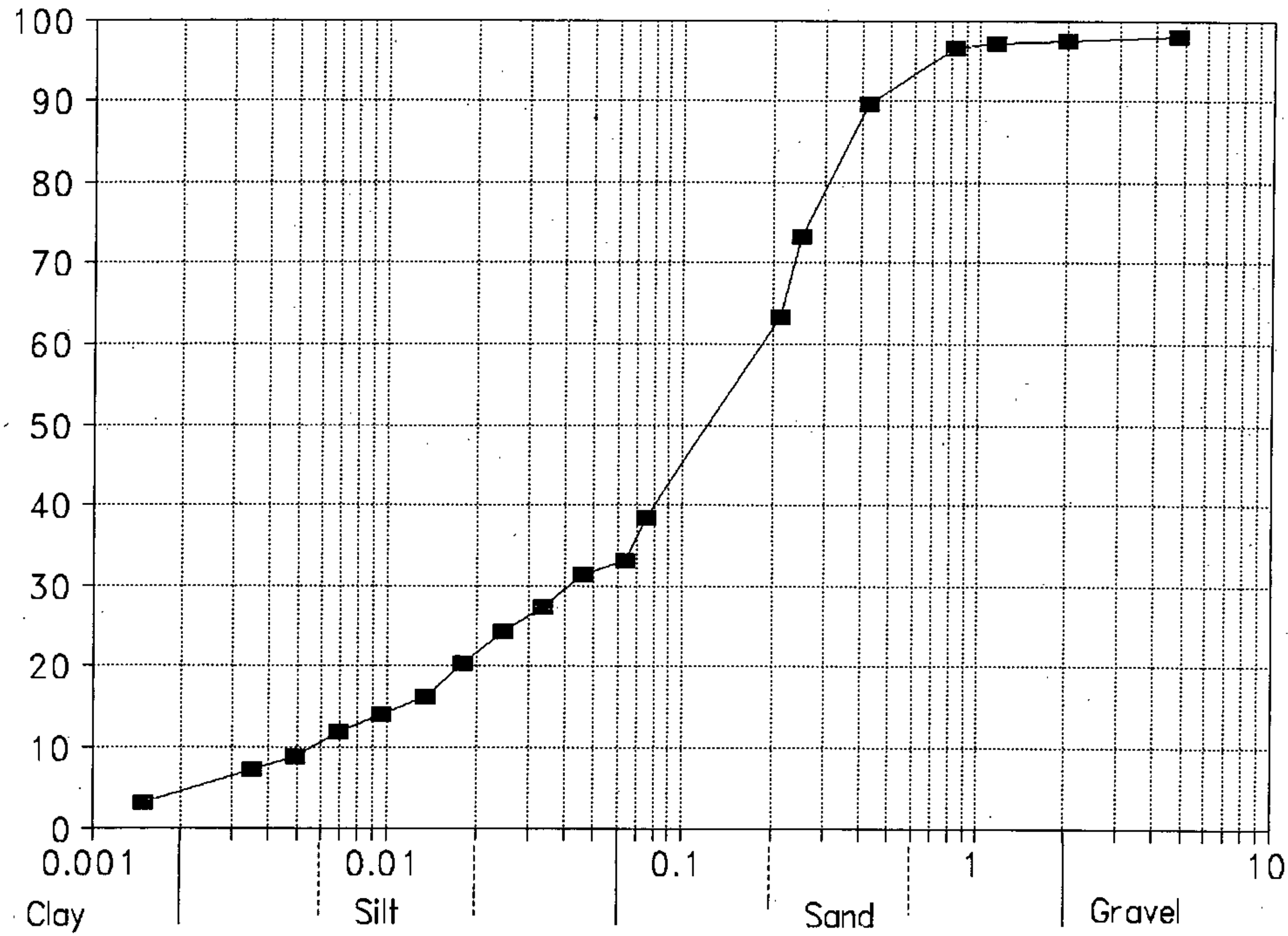


Fig.21 Grain Size Distribution Curve
Devari Kala (25 - 50 cm)

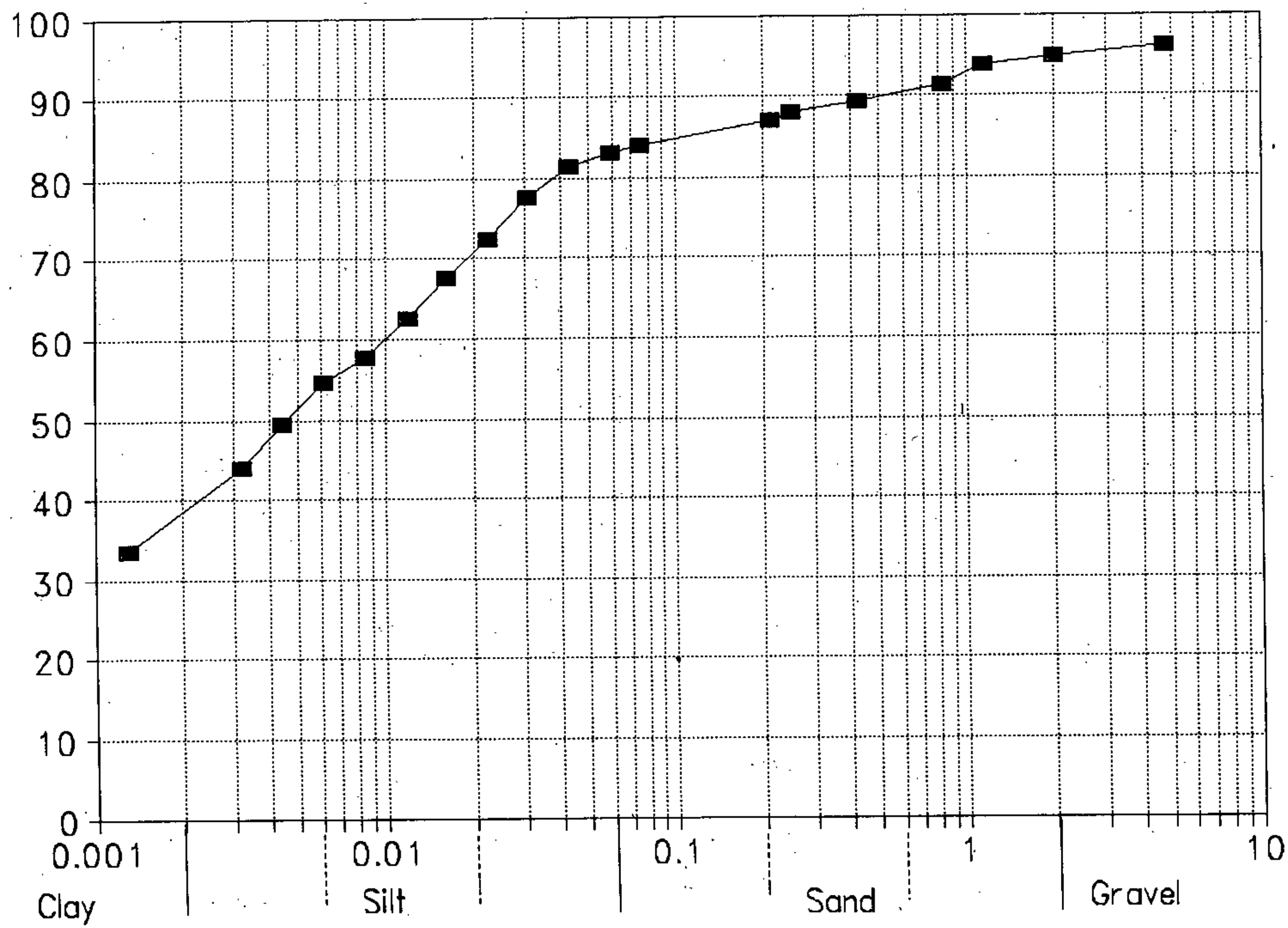


Fig.22 Grain Size Distribution Curve
Kukwara (25- 50 cm)

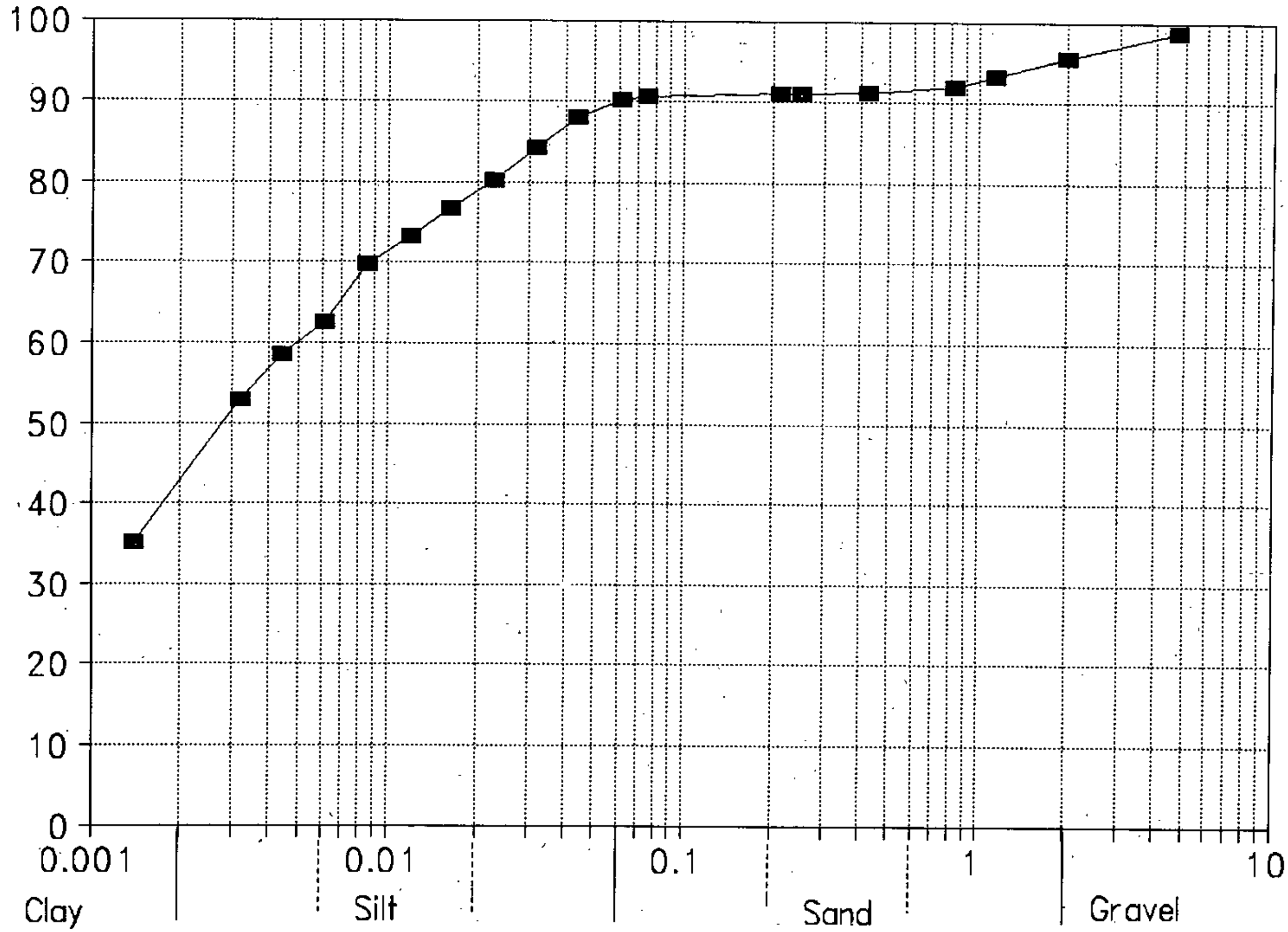


Fig.23 Grain Size Distribution Curve
Kukwara (90 - 130 cm)

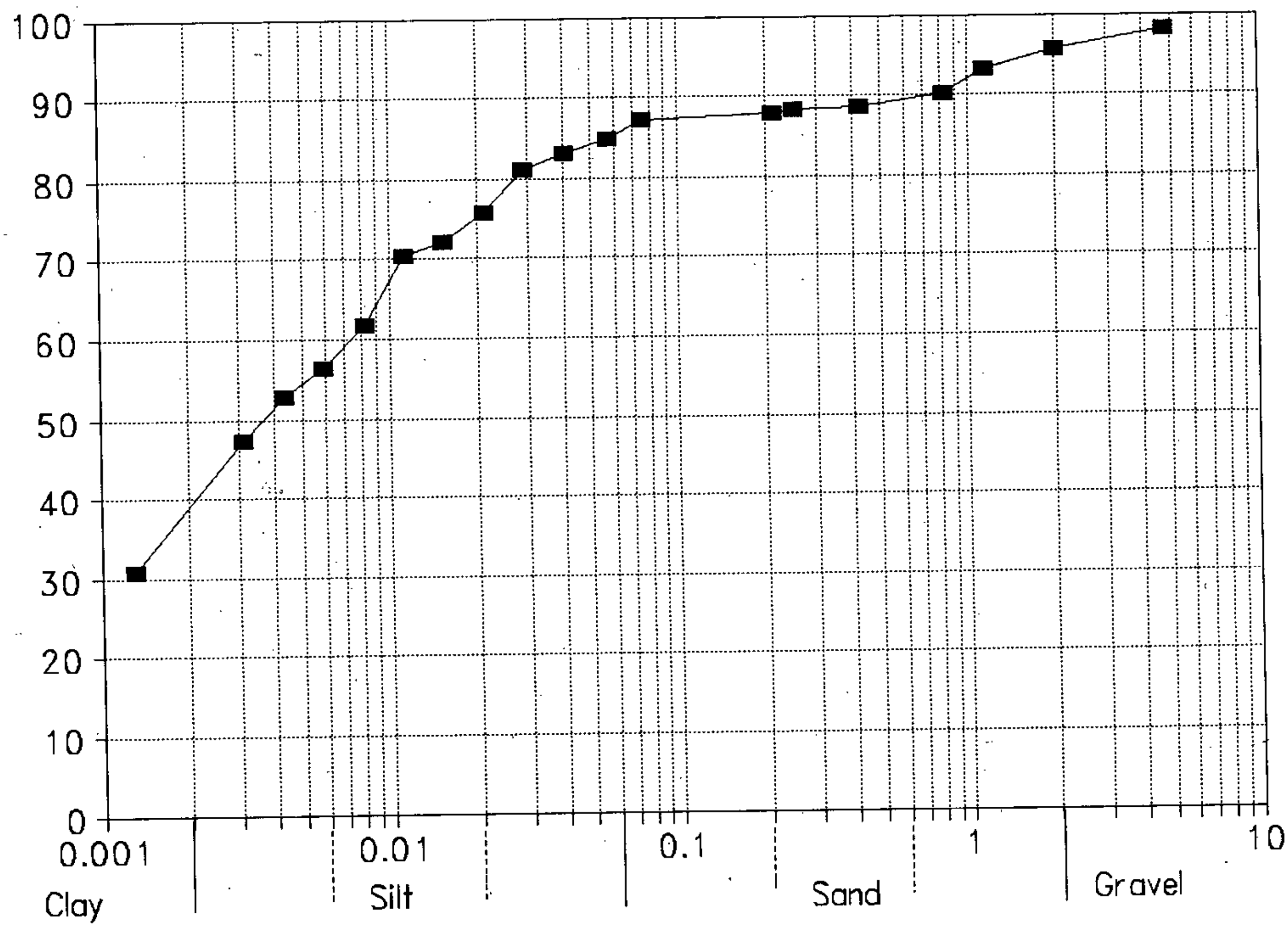


Fig.24 Grain Size Distribution Curve
Niwari (25 - 50 cm)

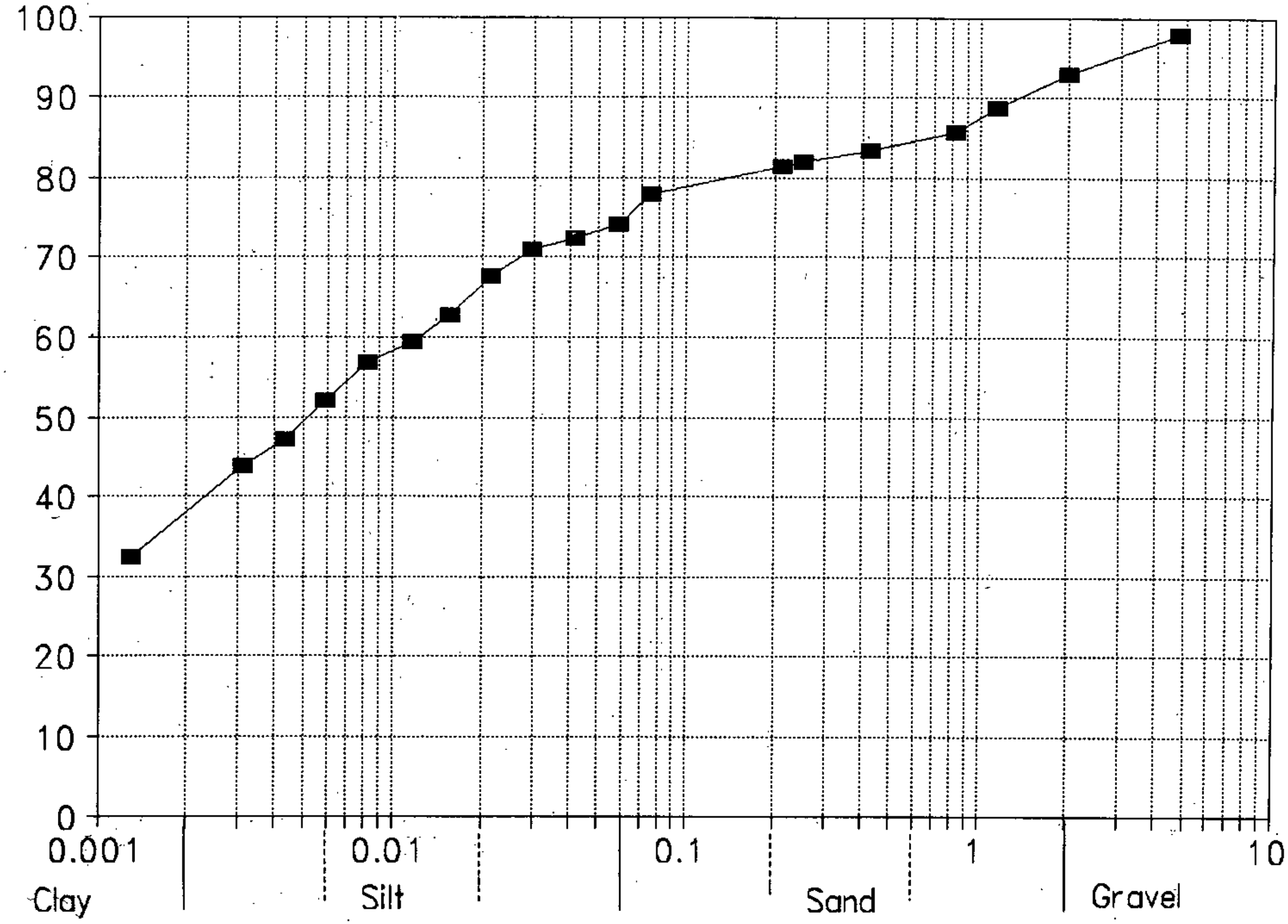


Fig.25 Grain Size Distribution Curve
Niwari (90 - 130 cm)

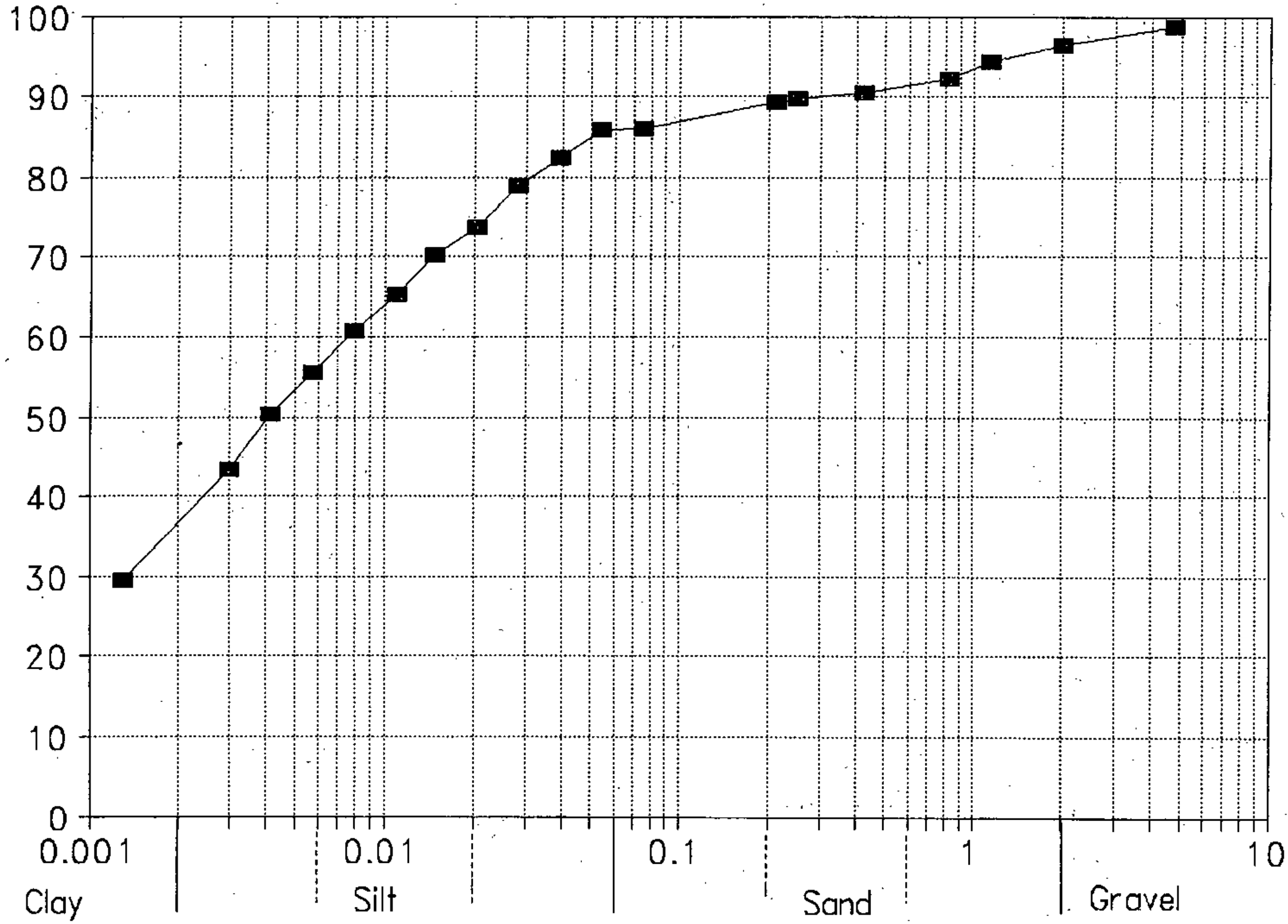


Fig.26 Grain Size Distribution Curve
Muriya (25 - 50 cm)

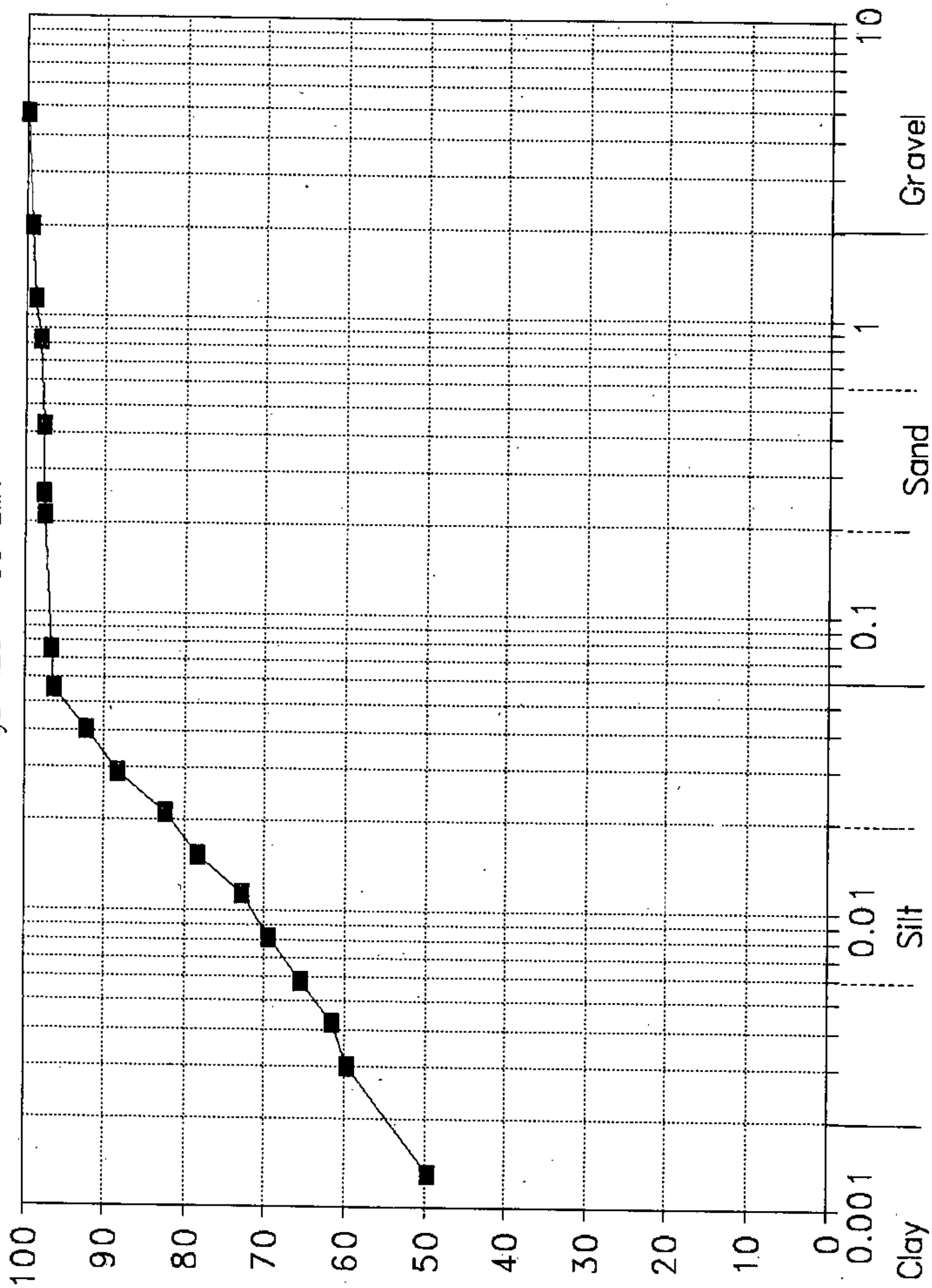


Fig.27 Grain Size Distribution Curve
Muriya (100 - 120 cm)

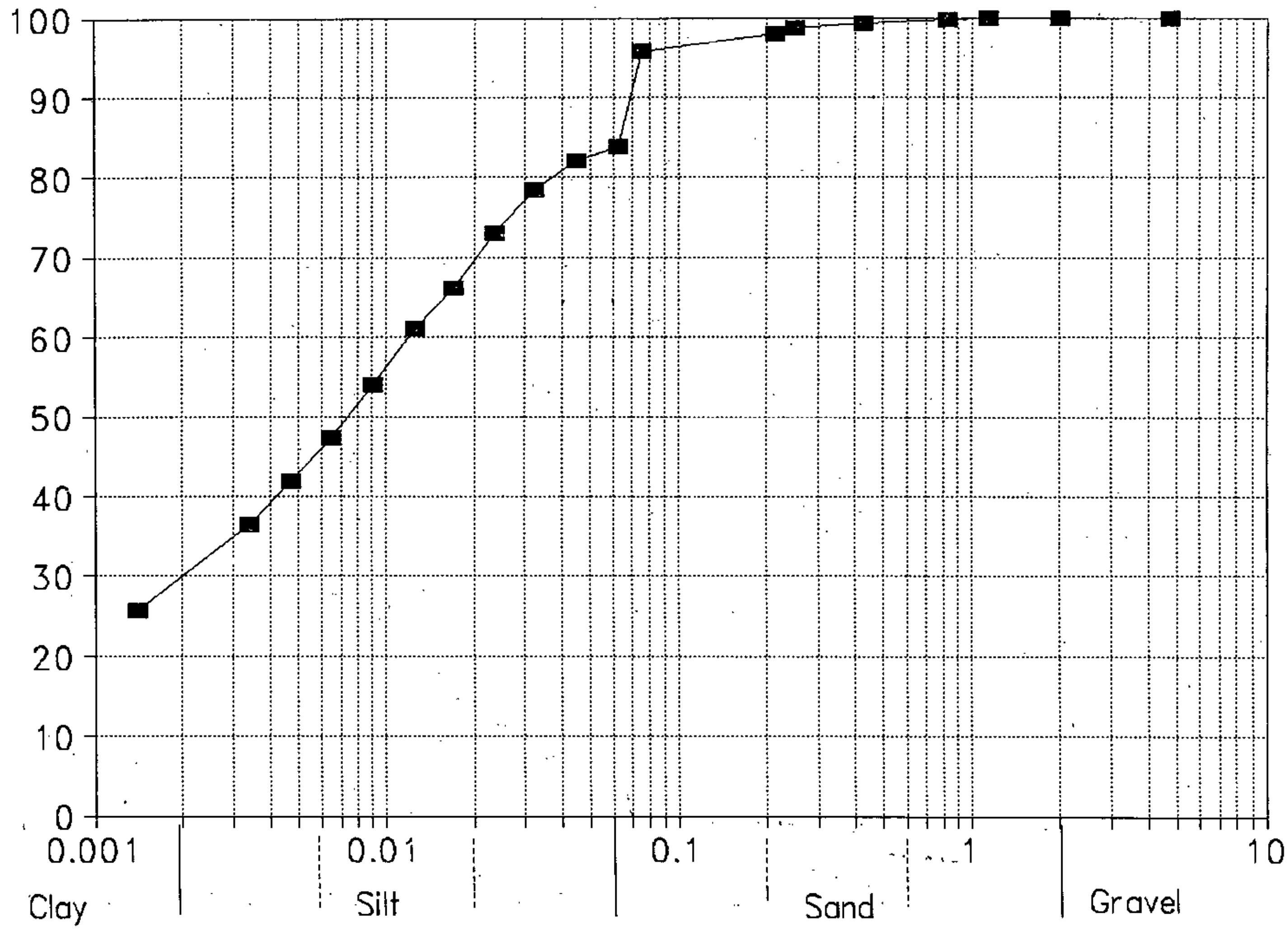


Fig.28 Grain Size Distribution Curve
Shyam Khera (20 - 40 cm)

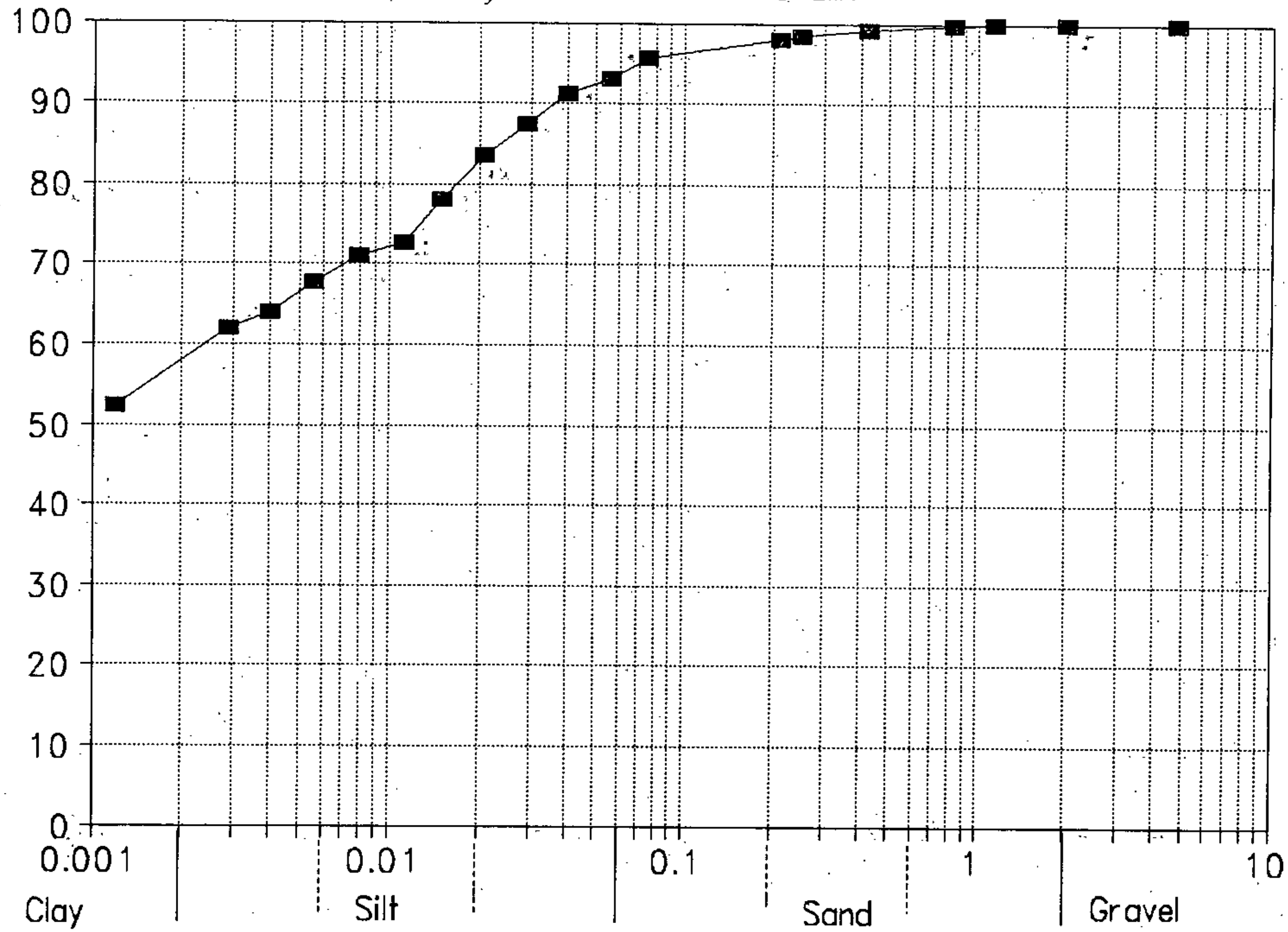


Fig.29 Grain Size Distribution Curve
Shyam Khera (90 - 120 cm)

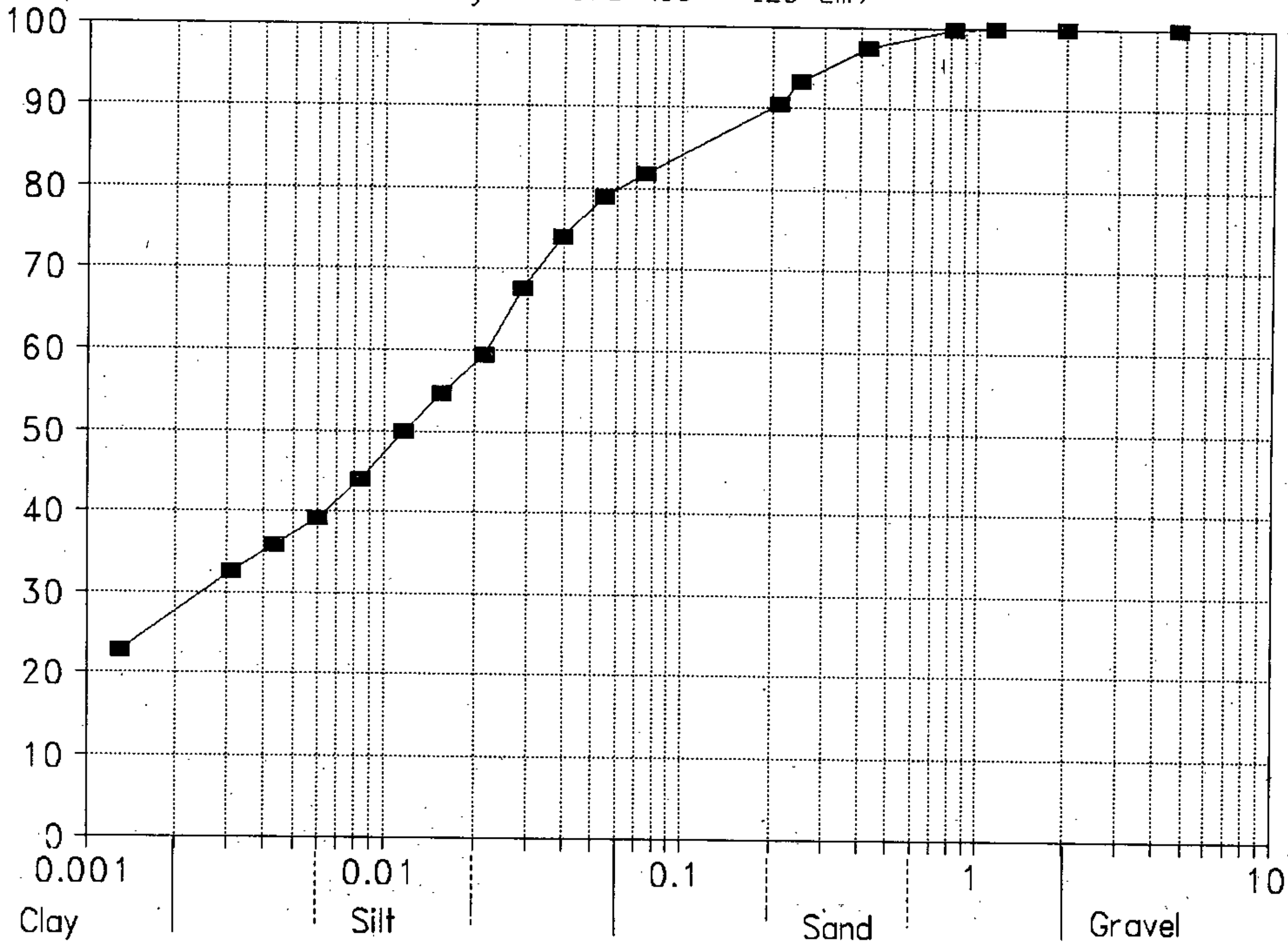


Fig.30 Grain Size Distribution Curve
Kandhrapur (20 - 50 cm)

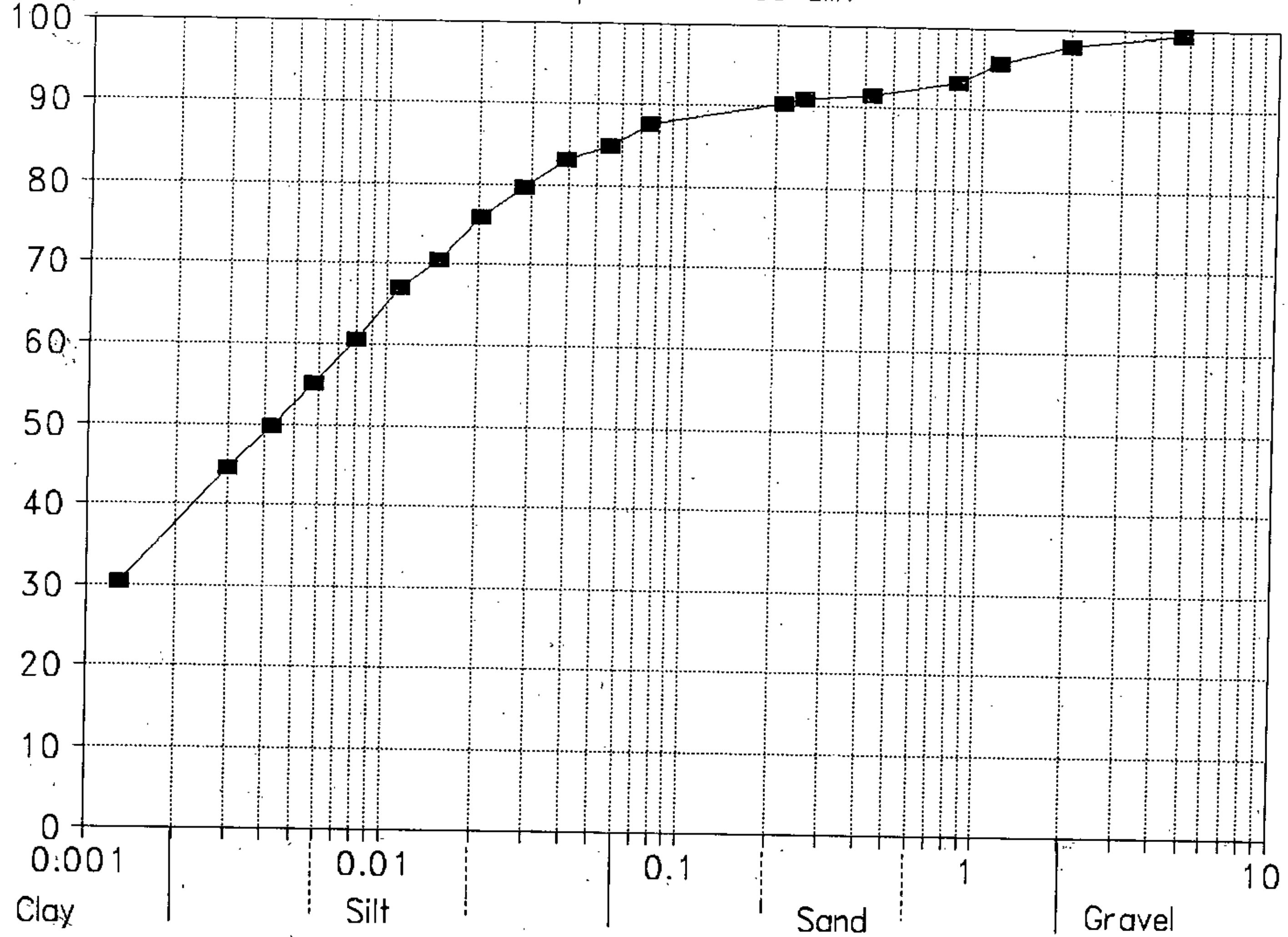


Fig.31 Grain Size Distribution Curve
Kadhrapur (100 - 130 cm)

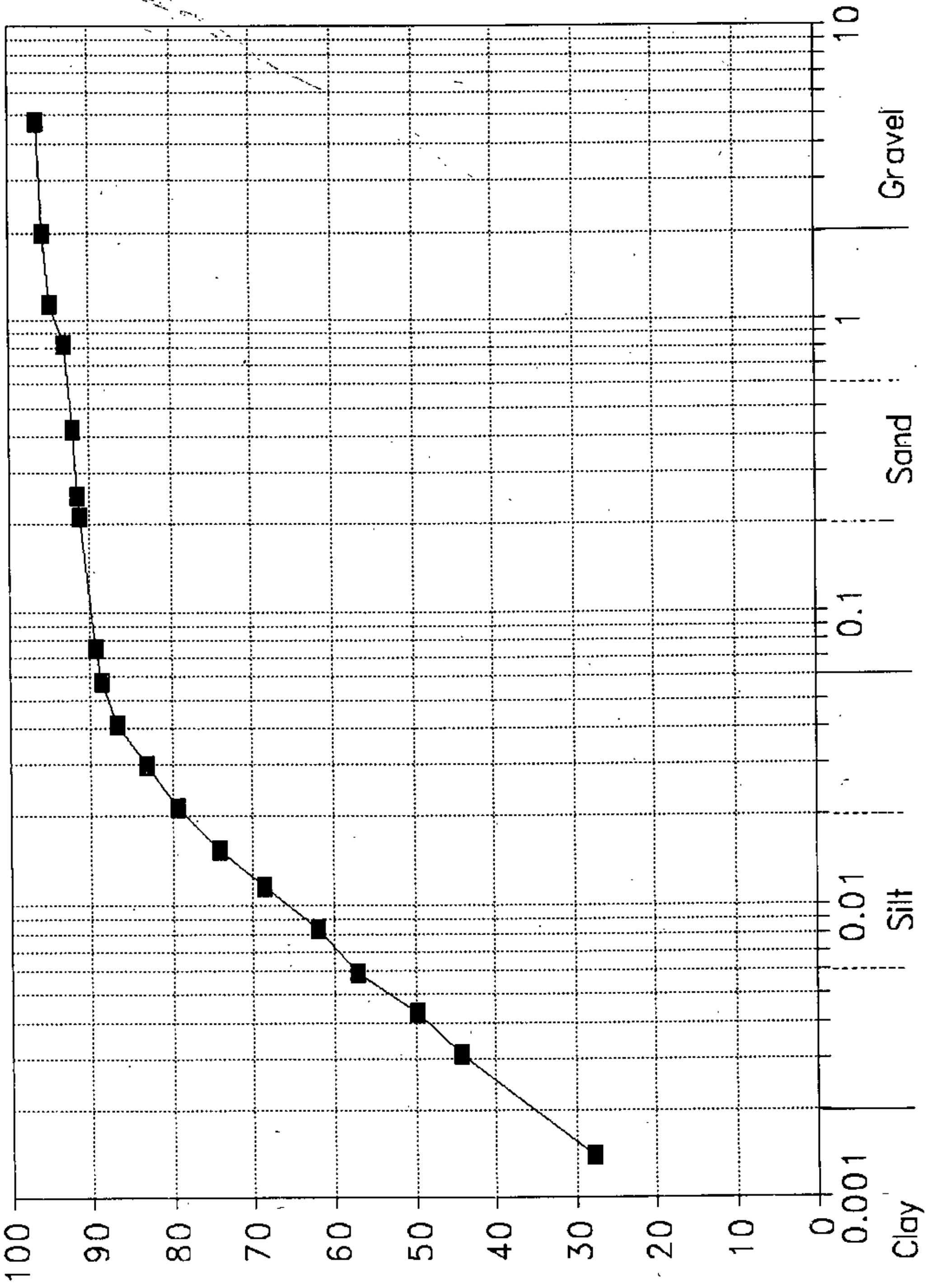


Fig.32 Grain Size Distribution Curve
Lokipar (20 - 50 cm)

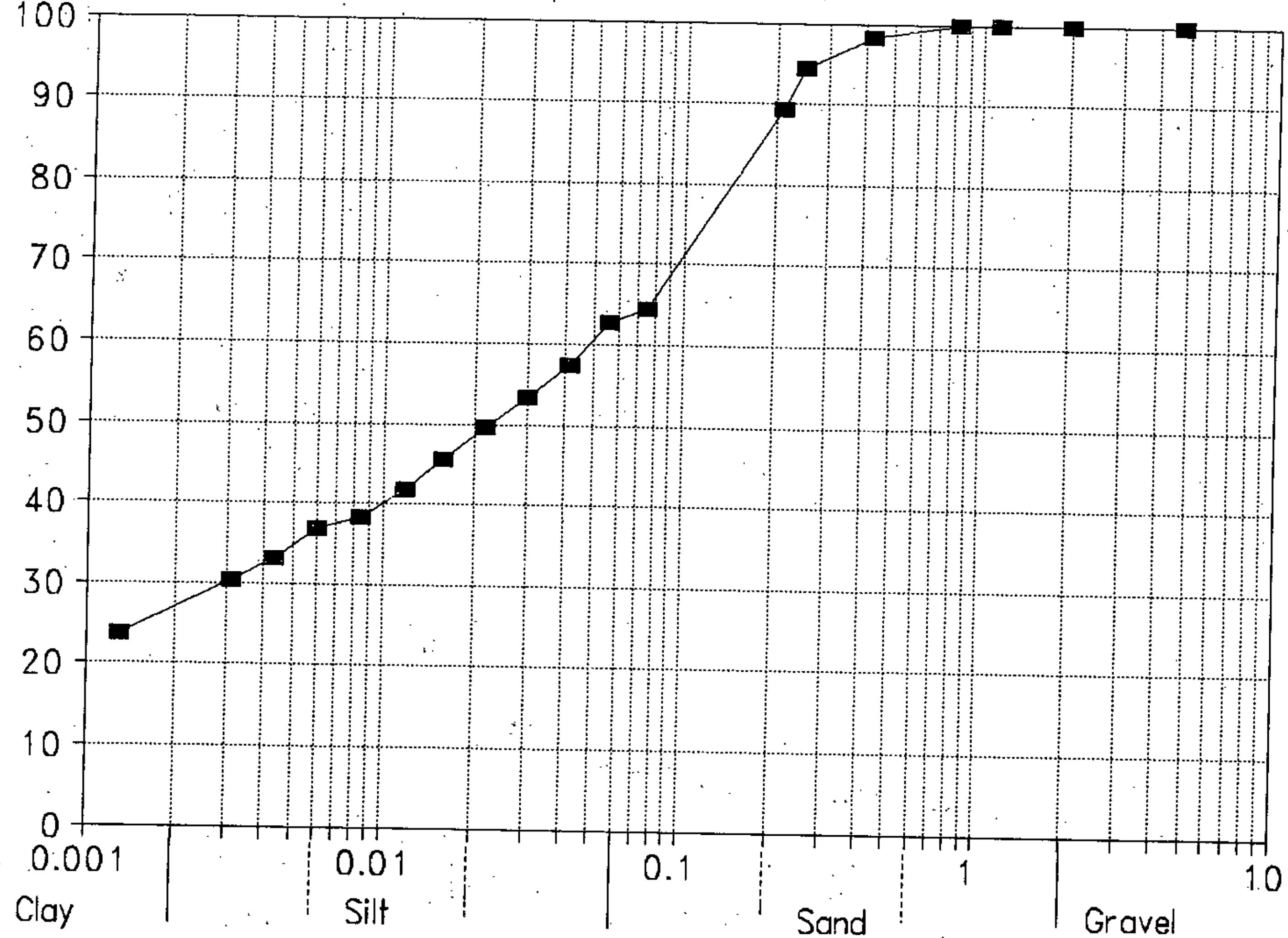


Fig.33 Grain Size Distribution Curve
Lokipar (120 - 150 cm)

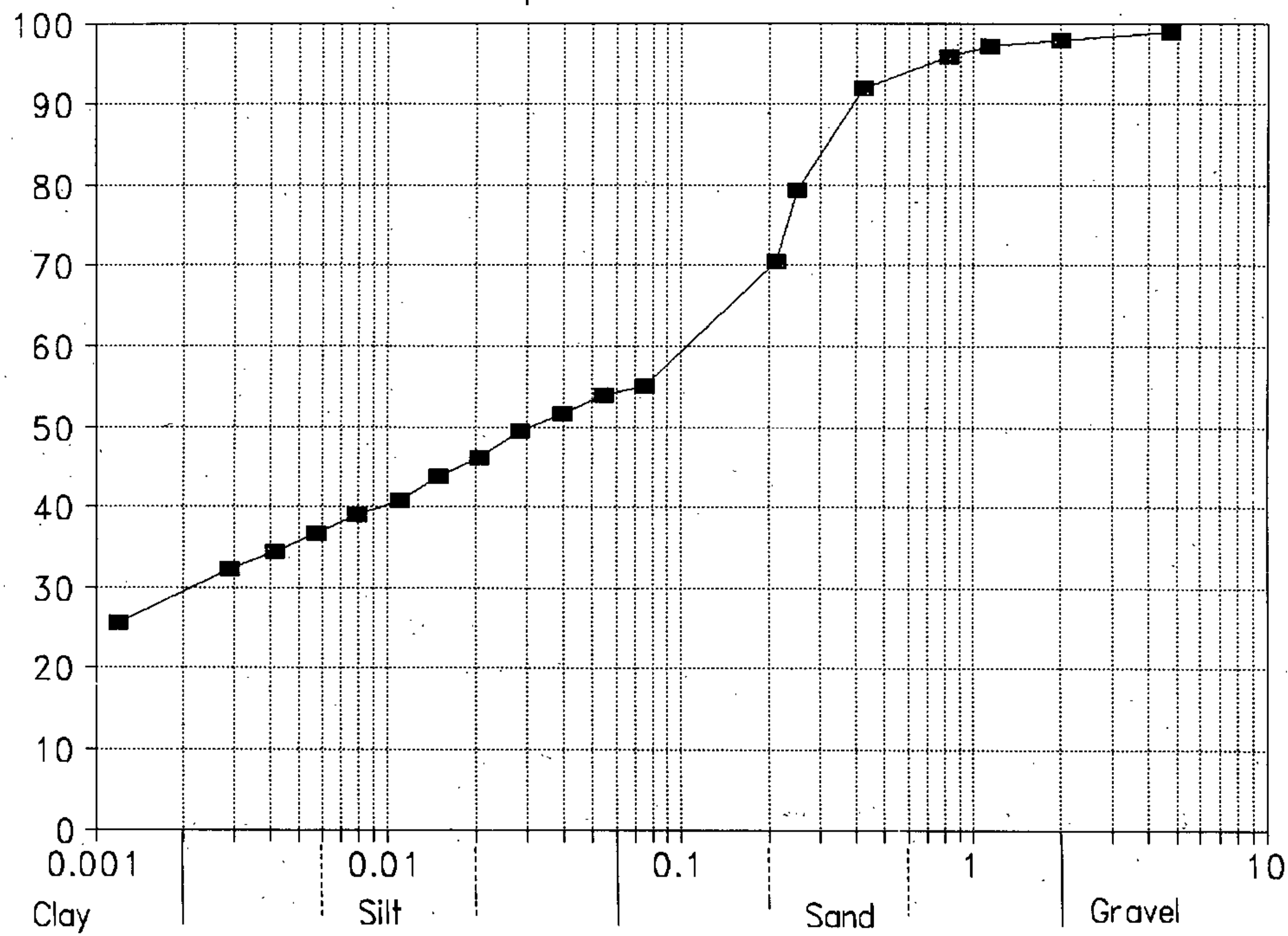


Fig.34 Grain Size Distribution Curve
Dhrughat (15 - 50 cm)

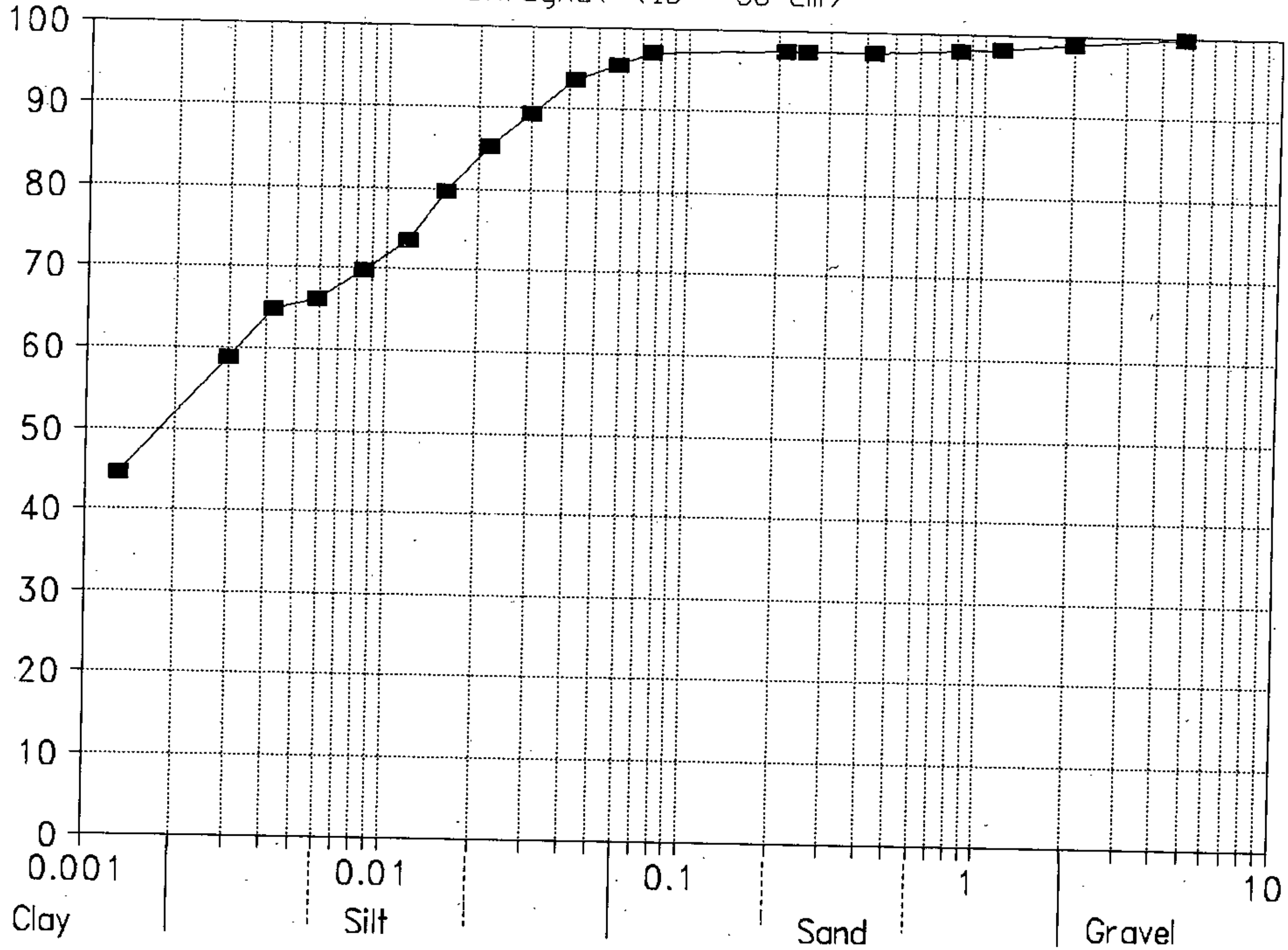


Fig.35 Grain Size Distribution Curve
Dhrughat (100 - 130 cm)

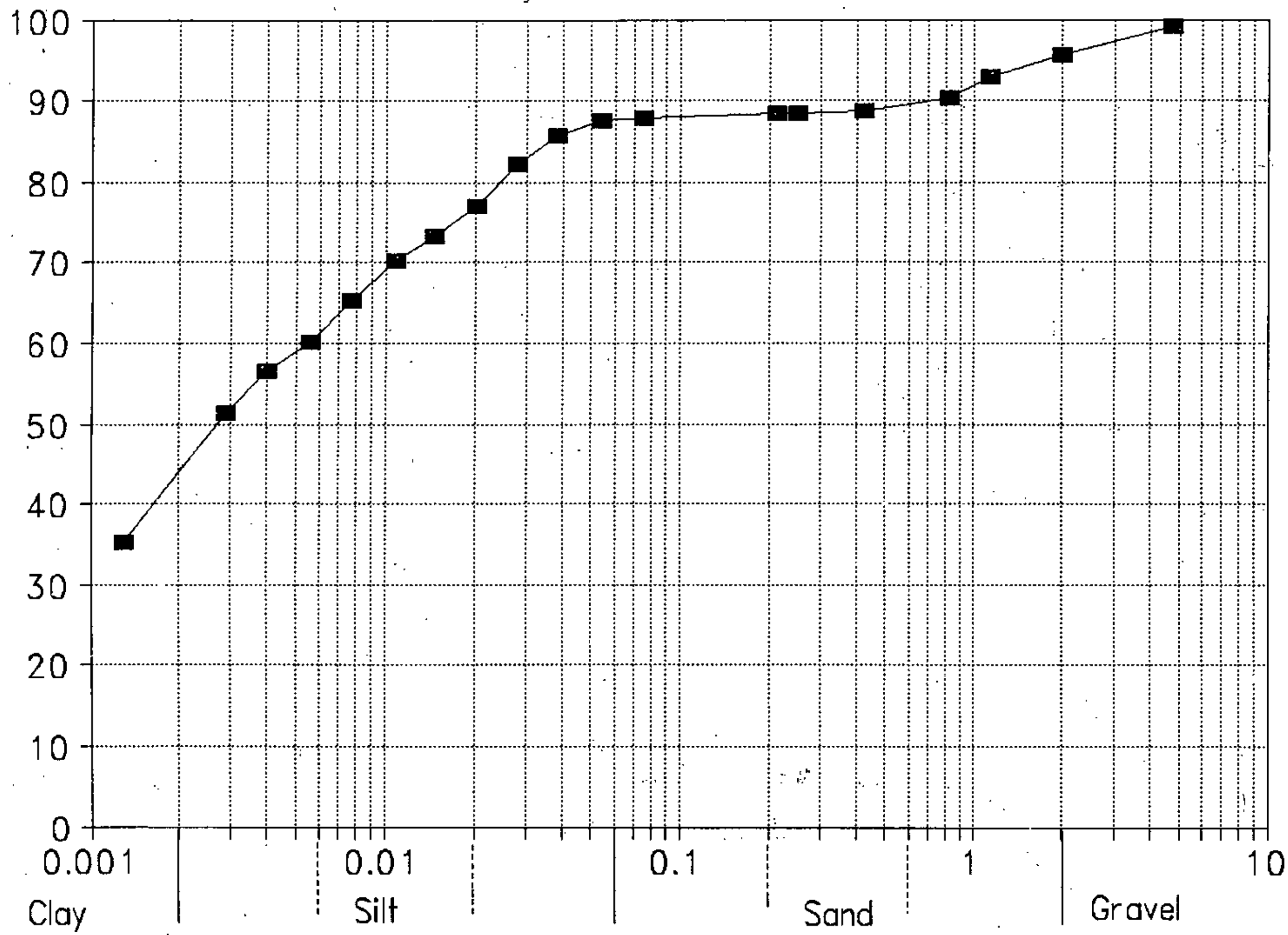
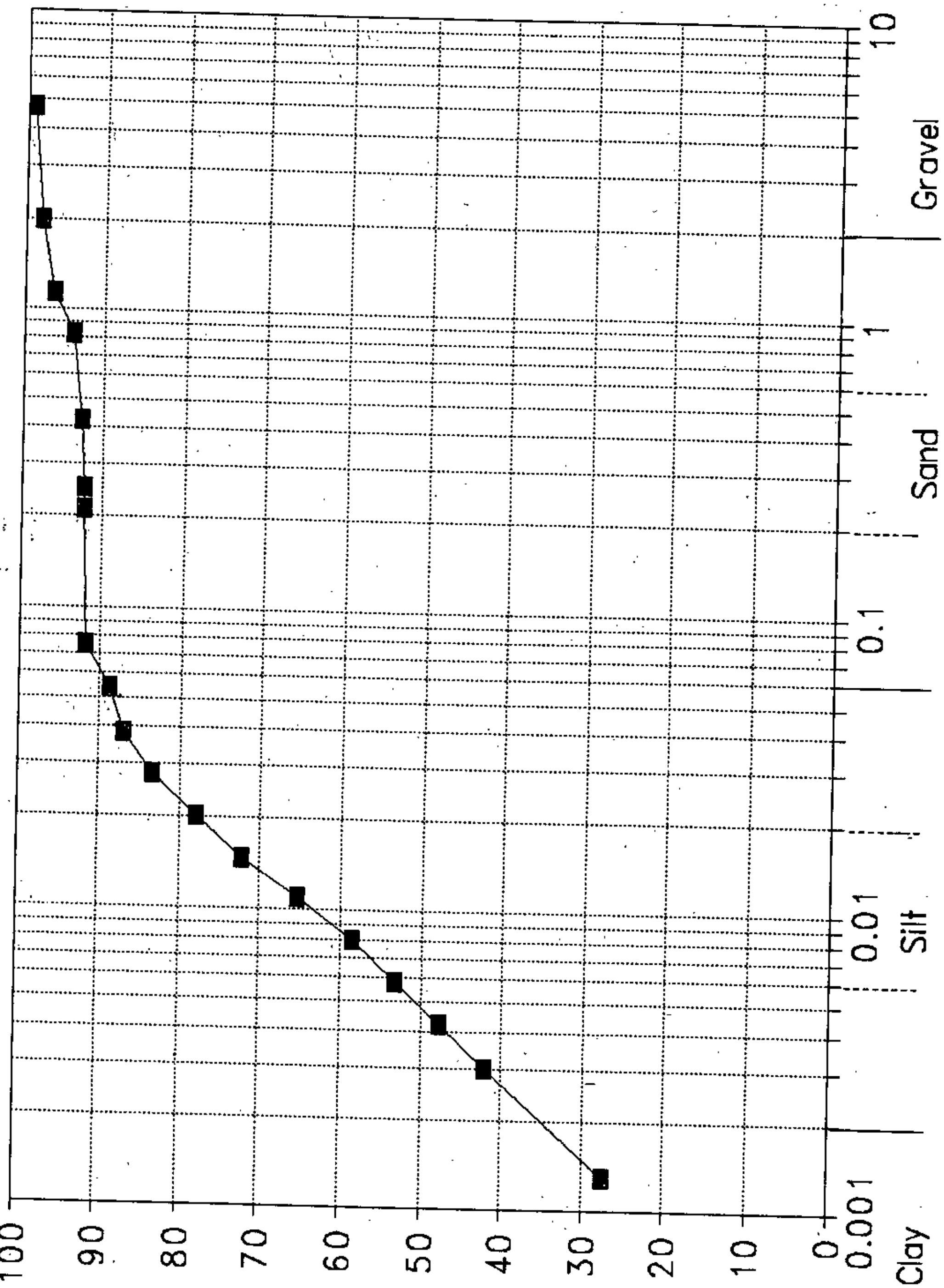


Fig.36 Grain Size Distribution Curve
Didwara (25 - 50 cm)



5. The temperature of suspension was also recorded to the accuracy of 1^{o}C for each hydrometer reading.
6. Between the hydrometer readings, hydrometer was placed in another jar containing 100 ml of dispersive agent and 900ml of water and placed at the same temperature as other jar. The reading of hydrometer was calculated to find out the hydrometer corrections.
7. The diameter and the percentage finer with respect to each elapsed time interval was calculated. The grain size was plotted against percentage finer on semi log paper (Fig.16 to 36). On the basis of grain size sand, silt, clay percentage are given in Tab. 5.

3.3 Procedure for measurement of field saturated hydraulic conductivity-

1. A well hole was prepared at the site with the help of soil auger and sizing auger. The hole was dug with the help of soil auger to a depth 15 cm less than the desired for final well depth. The 15 cm was dug with the help of sizing auger to produce a debris free well hole of uniform geometry of via 6 cm and bottom flat.
2. Tripod was centered over the well hole and permeameter was lowered so that the support tube entered into the well hole.
3. After the permeameter is placed, it is filled with water. Verification was then made for ensuring that both the reservoirs were connected.
4. The air inlet tip was slowly raised to establish the 5 cm well head height (H1).

Table 5: Textural Classification of Soil of Study Area

S.No.	Location	Grid No.	Depth (Cm)	Gravel %	Sand %	Silt %	Clay %	Type of Soil
1.	N,1,1 Chillychan Khurd	246	10-35	0.50	27.00	15.50	57.00	Medium clay
2.	N,1,2 -do-	246	90-130	0.00	37.00	10.50	52.00	Light clay
3.	N,2,1 Karahiyakhera	260	20-50	5.30	6.50	12.20	76.00	Heavy clay
4.	N,2,2 Karahiyakhera	260	90-130	4.70	10.00	10.25	75.00	Heavy clay
5.	N,3,1 Khameria	259	25-30	2.60	64.65	10.75	22.00	Sandy clay loam
6.	N,4,1 Devarikala	278	25-50	5.20	11.30	13.50	70.00	Medium clay
7.	N,5,1 Kukwara	267	90-130	4.20	5.60	11.00	79.00	Heavy clay
8.	N,5,2 Kukwara	267	90-130	4.20	9.30	11.00	75.00	Heavy clay
9.	N,6,1 Newark	280	25-50	7.00	17.50	9.50	66.00	Medium clay
10.	N.6,2 Niwari	280	90-130	3.50	10.60	12.90	73.00	Heavy clay
11.	N,7,1 Maria	245	25-50	0.80	2.80	14.90	81.50	Heavy clay
12.	N,7,2 Maria	245	100-120	0.10	16.90	13.00	70.00	Medium clay
13.	N,8,1 Shyamkhera	230	20-40	0.10	5.40	11.50	83.00	Heavy clay
14.	N,8,2 Shyamkhera	230	90-120	0.10	19.90	22.00	58.00	Medium clay
15.	N,9,1 Kandhrapur	279	20-50	2.10	11.67	10.73	75.50	Heavy clay

S.No.	Location	Grid No.	Depth (Cm)	Gravel %	Sand %	Silt %	Clay %	Type of Soil
16.	N,9,2 Kandhrapur	279	100-130	4.20	6.90	9.90	79.00	Heavy clay
17.	N,10,1 Lokipar	262	20-50	0.10	36.31	14.59	49.00	Light clay
18.	N,10,2 Lokipar	262	120-150	2.20	43.25	8.55	46.00	Light clay
19.	N,11,1 Dhrughat	261	15-50	1.10	2.60	11.30	85.00	Heavy clay
20.	N,11,2 Dhrughat	261	100-130	4.20	8.10	11.20	76.50	Heavy clay
21.	N,12,1 Didwara	260	25-50	2.20	7.70	12.60	77.50	Heavy clay

5. The rate of fall of the water in the reservoir was measured at a regular time interval. The difference in readings at consecutive time interval divided by the time interval gave the rate of fall of water level, R1 in the reservoir.
6. The rate of fall of water in the reservoir was continuously monitored until it was almost same for three consecutive intervals. This rate of fall of water is called R1 and is defined as steady state rate of fall.
7. A 10 cm well head height (H2) was established and the rate of fall of water, R2, in the reservoir was obtained for stable value of R2.
8. The field saturated hydraulic conductivity (Ks) was then calculated using following equation (9) (Tab 6).
9. The metric flux potential (ϕ_m) and alpha (α) were calculated using equation (7) and (8) respectively (Tab 7).

3.4 Soil Moisture Retention

Soil samples were prepared after drying light hammering and passing through 2.0mm sieve. The passing soils from 2.0mm sieve were used for determining soil moisture retention by applying 0.10, 0.33, 0.50, 0.70, 1.00, 3.00, 5.00, 10.00, 15.00 bars respectively.

Pressure plate apparatus (Soil Moisture Corporation Co. USA) was used to test the soil moisture retention behavior of the soil samples. Each of these samples were tested against 0.10, 0.33, 0.50 and 1.0 bar, by one bar pressure plate. Where as 3 bar by 3 bar plate and 5 bar by 5 bar plate as well as 10 bar and 15 bar with 15 bar pressure plate and following procedure should be followed for measurement.

Tab.6: Saturated Hydraulic Conductivity by Guelph Permeameter & Johnson Graph

S.No.	Location of Test	Saturated Hydraulic Conductivity		Water Table
		By Guelph (m/day)	By Johnson's Graph (m/day)	
1.	N 11 Chillychan Khurda (25 cm)	0.0370 -	$4x10^{-4}$	2.50
2.	N 12 Chillychan Khurda	-	$4x10^{-3}$	-
3.	N 21 Karahiya Khera (30 cm)	N.F.	$4x10^{-4}$	6.40
4.	N 22 Karahiya Khera	-	$4x10^{-8}$	-
5.	N 31 Khameria 35 cm	0.96336	$2x10^{-2}$	4.20
6.	N 41 Devarikala (35 cm)	0.003625	$4x10^{-6}$	2.20
7.	N 51 Kukwara (30 cm)	0.001987	$4x10^{-8}$	7.70
8.	N 52 Kukwara	- -	$4x10^{-8}$	-
9.	N 61 Niwari (28 cm)	N.F -	$4x10^{-6}$	4.80
10.	N 62 Niwari	- -	$4x10^{-8}$	-
11.	N 71 Muria (28 cm)	0.09050 -	$4x10^{-8}$	4.90

S.No.	Location of Test	Saturated Hydraulic Conductivity		Water Table
		By Guelph (m/day)	By Johnson's Graph (m/day)	
12.	N 72 Muria	-	4×10^{-6}	-
13.	N 81 Shyamkhera	0.00885	4×10^{-8}	24.60
14.	N 82 Shyamkhera	N.F.	4×10^{-7}	-
15.	N 91 Kandhrapur	0.20270	4×10^{-8}	2.25
16.	N 92 Kandhrapur	-	4×10^{-8}	-
17.	N 10,1 Lokipar	1.11500	4×10^{-3}	4.20
18.	N 10,2 Lokipar (130 cm)	0.031100	4×10^{-3}	7.10
19.	N 11,1 Dhrughat	0.04950	4×10^{-8}	-
20.	N 11,2 Dhrughat	-	4×10^{-8}	-
21.	N 12.1 Didwara (30 cm)	0.07158	4×10^{-8}	4.50

Table. 7: Saturated Hydraulic Conductivity (Kfs) Matric flux potential (m) and Alpha values ( ) for soil of study area

S.No.	Location	Saturated Hydraulic Conductivity Kfs (m/day)	Matric flux Potential ( ) m^2 day	Alpha (per m)
1.	N 11 Chilly Chan Khurda	0.0370	0.0012954	28.5626
2.	N 31 Chilly Chan Khurda	0.96336	0.082400	11.69126
3.	N 41 Chilly Chan Khurda	0.003625	0.0005955	6.0888
4.	N 51 Chilly Chan Khurda	0.001987	0.000101439	19.588126
5.	N 71 Chilly Chan Khurda	0.09050	(*)0.000382579	*236.5524
6.	N 81 Chilly Chan Khurda	0.00885	0.000778386	11.36968
7.	N 91 Chilly Chan Khurda	0.202700	0.00283295	71.55085
8.	N 10,1 Chilly Chan Khurda	1.11500	0.0381408	29.23378
9.	N 10,2 Chilly Chan Khurda	0.031100	0.00896967	3.46724
10.	N 11,1 Chilly Chan Khurda	0.04950	(*)0.000639636	(*)77.38776
11.	N 12,1 Chilly Chan Khurda	0.07158	0.001470968	48.6618

(*) Negative Values

Table 8: Soil Moisture Characteristic Data of Narsinghpur of Narmada Basin

Location	Soil moisture at different bar									Available Moisture
	0.10	0.33	0.50	0.70	1.00	3.00	5.00	10.00	15.00	*
N11-	39.07	38.01	35.80	33.11	32.02	29.43	24.63	21.09	21.09	16.92
N12-	31.17	22.86	22.02	21.69	19.99	16.01	14.29	12.92	12.06	10.80
N21-	45.05	38.27	36.85	34.66	33.34	26.69	25.96	24.68	19.47	18.80
N22-	40.35	32.51	31.55	30.87	30.37	24.77	22.02	20.63	17.79	14.72
N31-	26.55	24.99	22.59	21.79	20.52	15.23	13.53	12.57	10.30	14.69
N41-	40.20	32.72	30.24	28.51	27.49	23.04	21.13	19.46	16.73	15.99
N51-	48.34	40.78	37.51	35.08	32.89	26.24	25.82	24.16	19.68	21.10
N52-	42.90	36.53	34.24	33.17	29.85	25.83	23.72	21.62	17.54	18.99
N61-	35.68	32.88	30.14	25.64	23.23	21.14	18.34	16.74	14.42	18 46
N62-	35.21	30.61	28.46	27.27	24.79	22.30	21.20	19.32	17.14	13.47
N71-	38.06	37.01	35.65	34.20	30.81	27.06	23.42	21.73	20.56	16.45

N72-	39.03	37.95	34.72	32.28	30.54	25.15	24.56	23.39	19.53	18.42
N81-	45.91	42.22	41.50	40.44	38.02	33.60	29.83	27.07	21.71	20.51
N82-	46.06	39.57	34.53	33.74	32.47	27.05	22.74	21.06	18.60	20.97
N91-	37.88	28.97	28.56	27.40	26.08	24.15	20.90	19.67	16.21	12.76
N92-	39.77	34.20	32.16	31.60	27.23	24.83	21.17	20.07	10.77	23.43
N10,1-	32.36	25.43	22.09	20.08	18.66	16.42	14.35	12.89	11.59	13.84
N10,2-	32.36	24.09	22.33	20.92	18.53	15.25	13.25	12.76	11.41	12.68
N11.1-	46.17	40.34	38.53	37.15	35.20	29.25	25.40	23.39	21.83	18.51
N11,2-	44.51	43.33	39.47	36.04	34.91	29.45	23.14	22.69	17.61	25.72
N12.1-	38.01	35.80	34.11	32.02	29.43	24.63	21.97	21.09	16.87	18.93

(i) First saturated the pressure plates and then prepared soil sample placed on plate in three separate rings and soaked with water for complete saturation.

(ii) Saturated plate containing soil samples placed in pressure chambers and applied desired pressure till reaching equilibrium.

(iii) Samples taken out from the pressure chambers and weighed on the high precision micro balance to record the moist weight of the samples.

(iv) These weighed samples placed in the oven at 105°C-110°C till weight became constant on drying. The dry weight was recorded by weighing and moisture by weight was determined from the moist and dry weight of the sample.

Measurement of moisture of all soil samples of 12 sites at 21 points were carried out and results are given in the Table 8 . Soil moisture retention curves are also plotted and are shown in Fig. 37 to 57 respectively.

Fig.37 Soil Moisture Characteristic Curve
Site: Chilly Chand Khurd (10–35 cm)

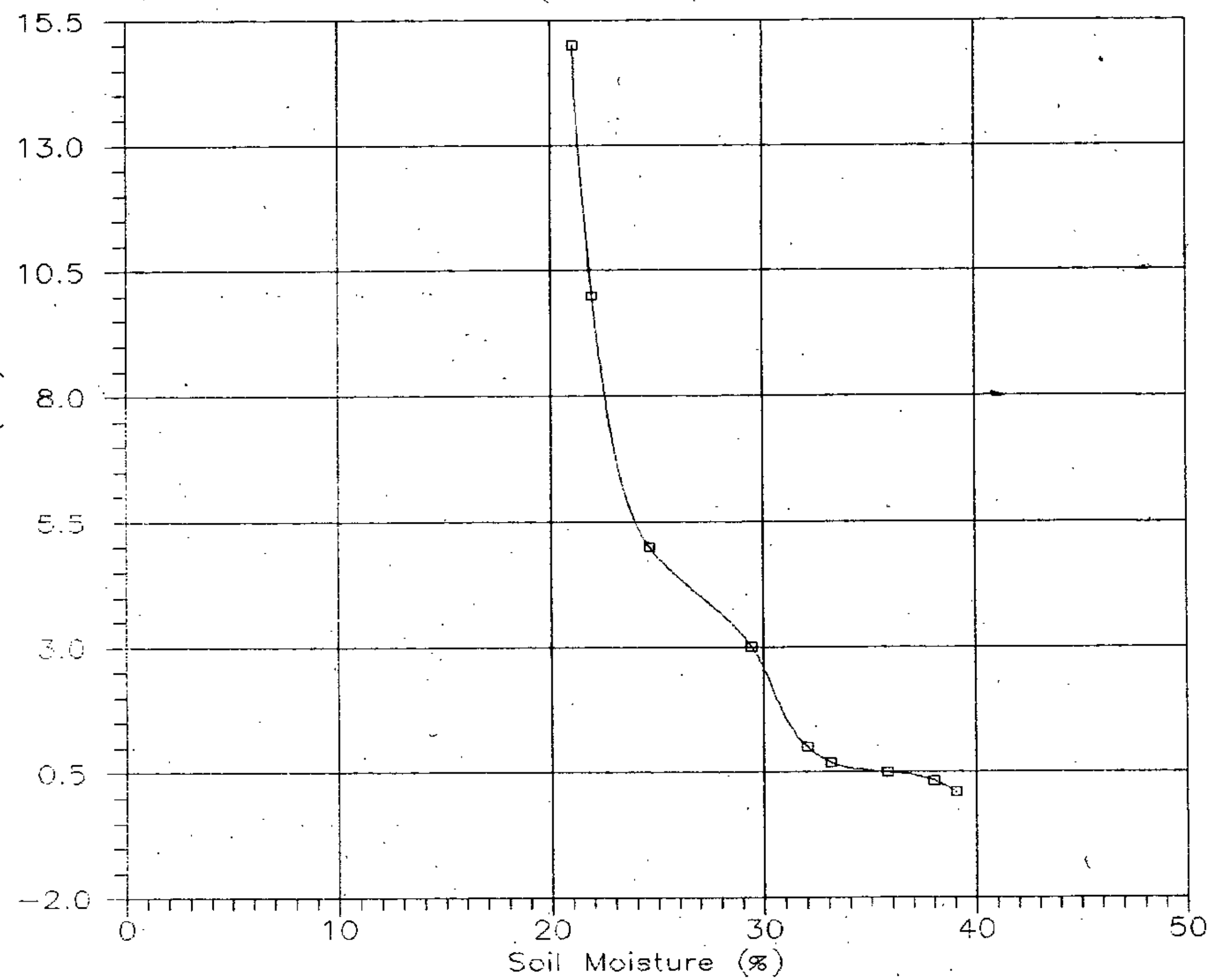


Fig.38 Soil Moisture Characteristic Curve
Site: Chilly Chcnd Khurd (90–130 cm)

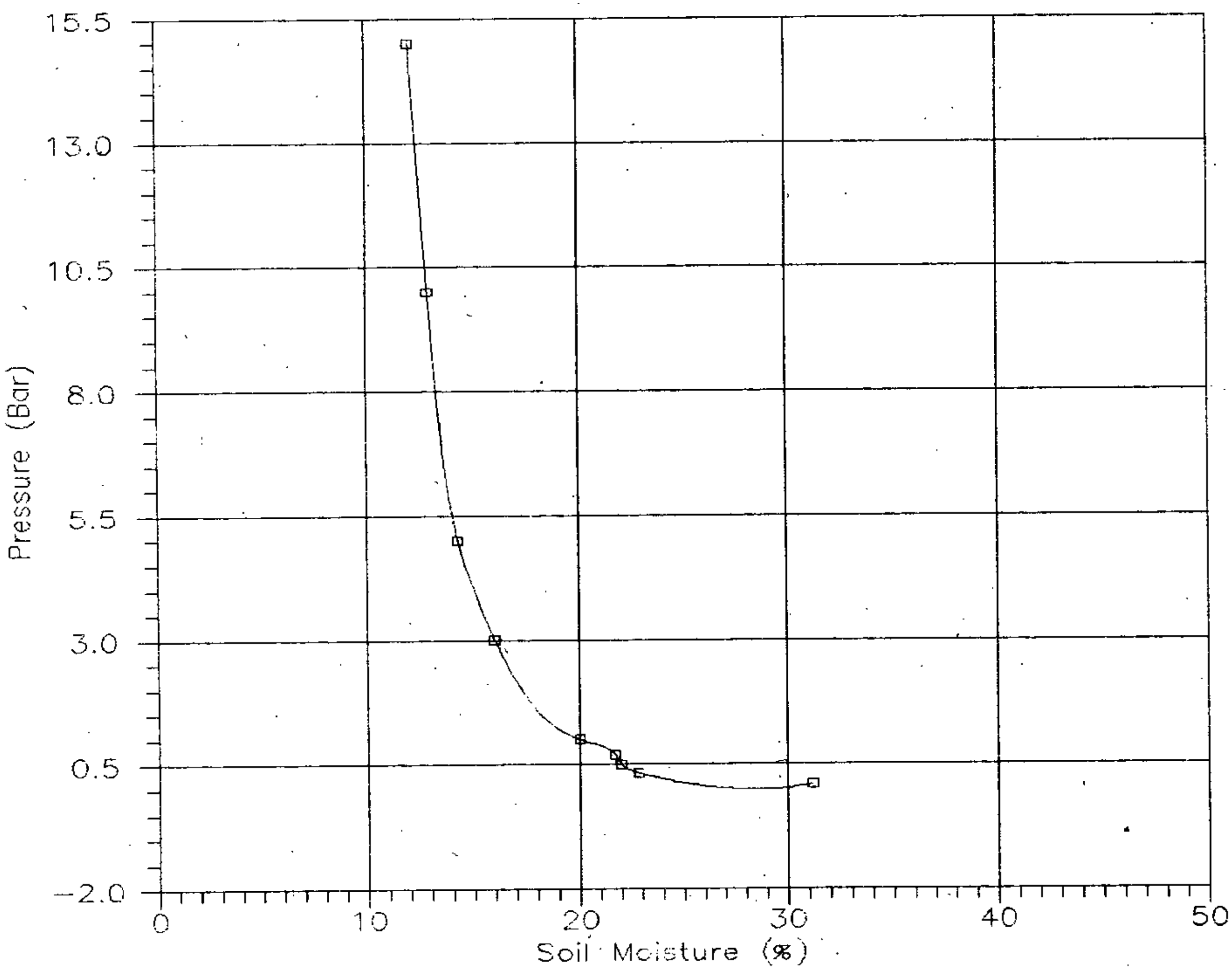


Fig. 39 Soil Moisture Characteristic Curve
Site: Karahiya Khera (20–50 cm)

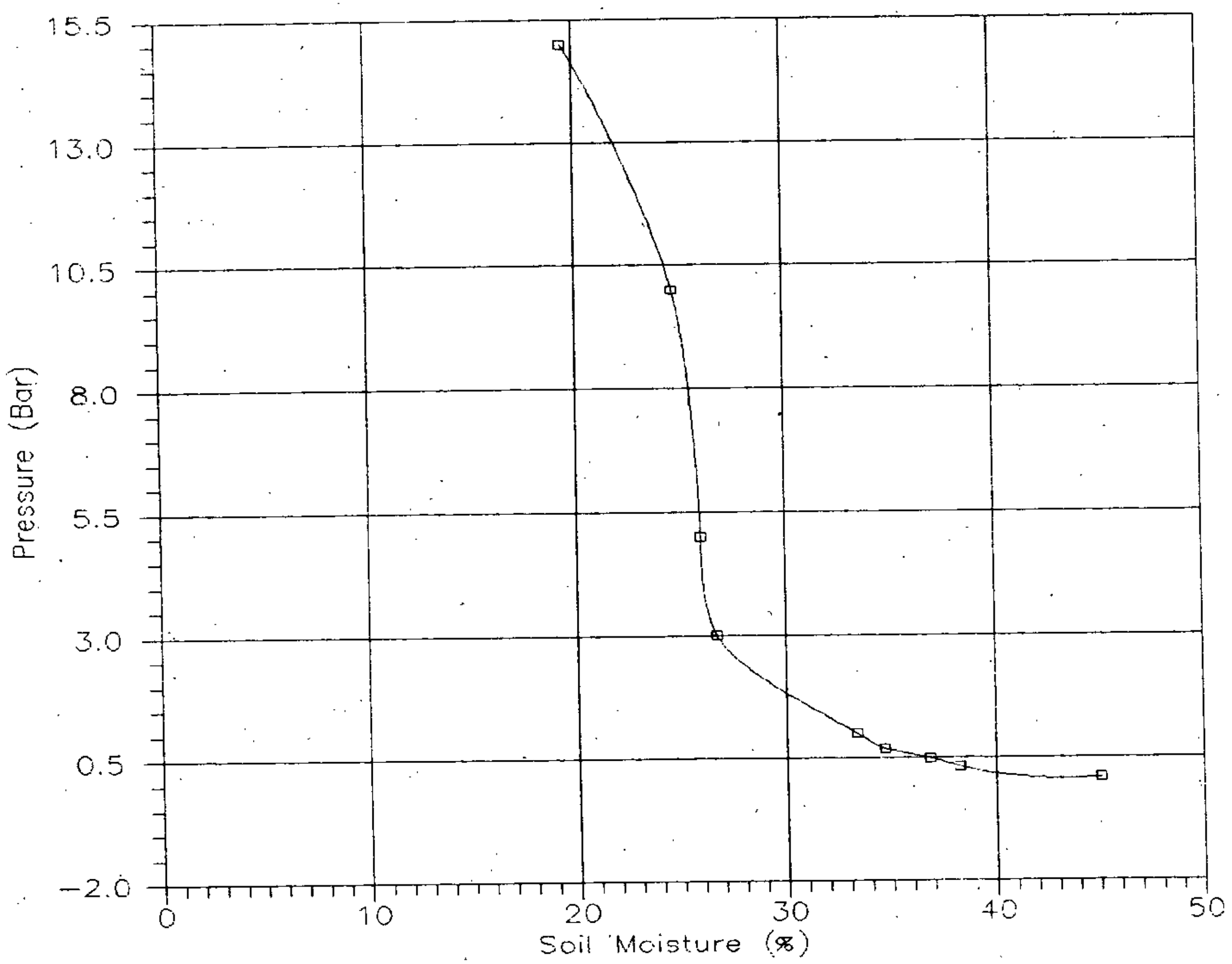


Fig. 40 Soil Moisture Characteristic Curve
Site: Karahiya Khera (90–130 cm)

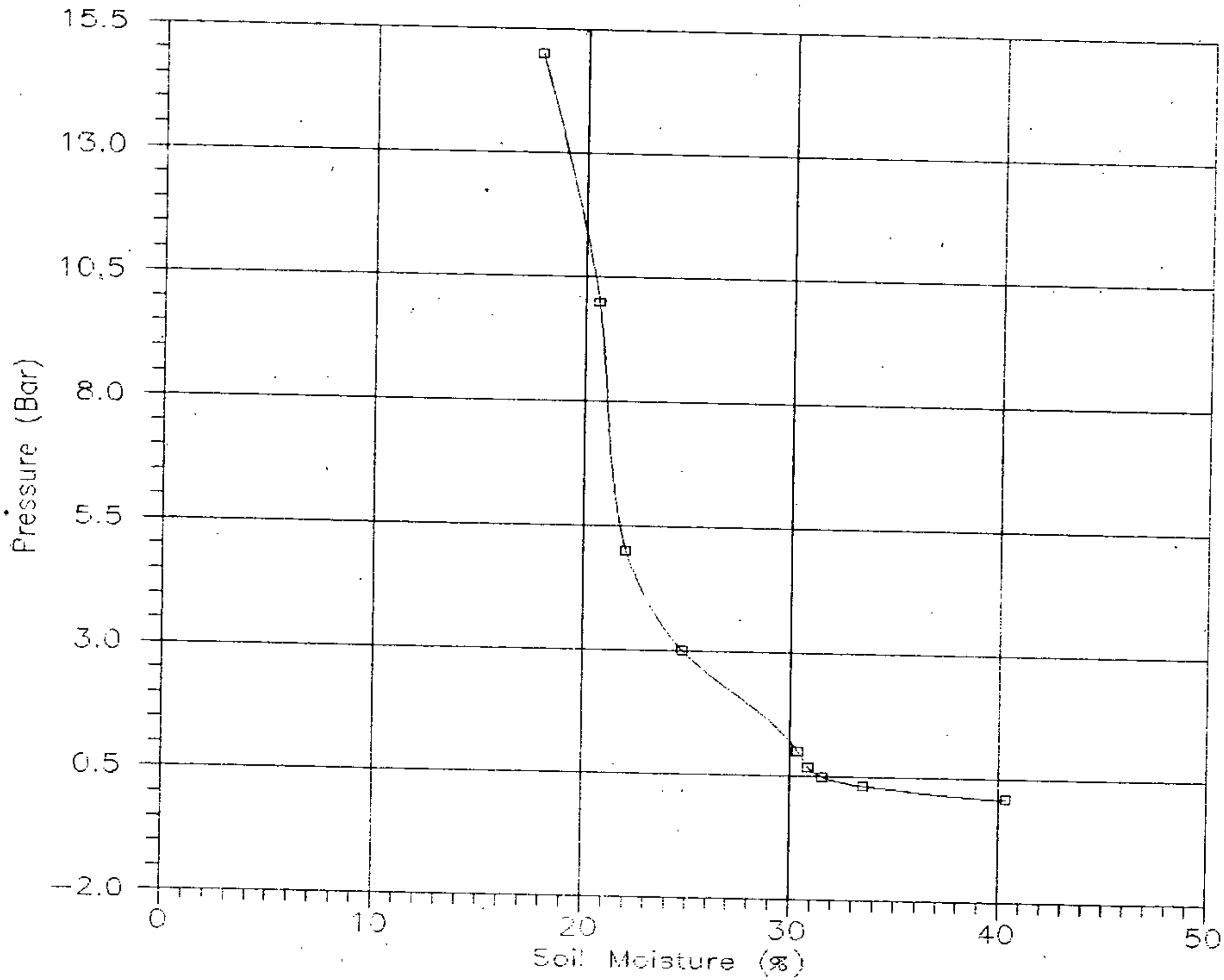


Fig.41 Soil Moisture Characteristic Curve
Site: Khameria (25–50 cm)

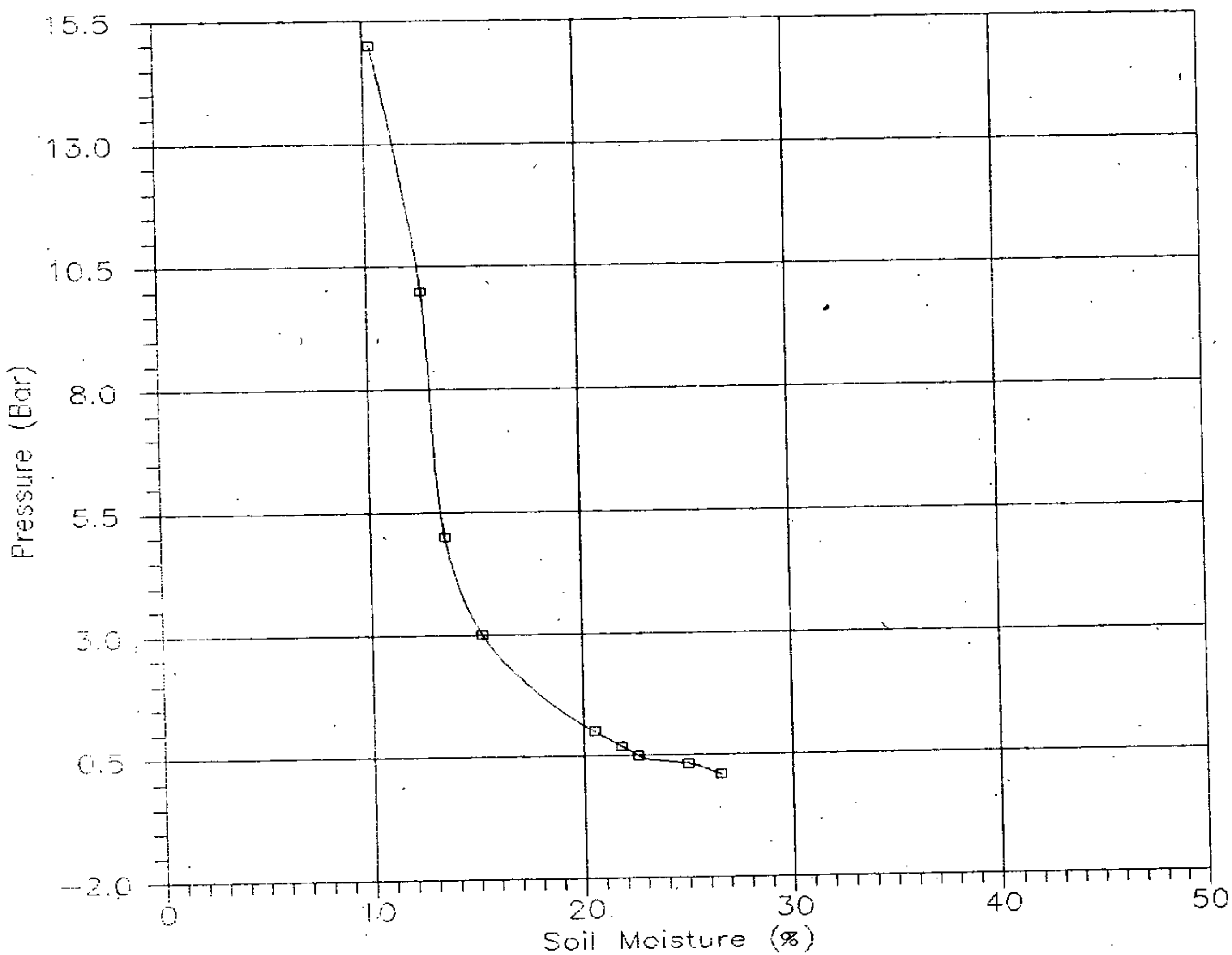


Fig. 42 Soil Moisture Characteristic Curve
Site: Devari Kalan (25–50 cm)

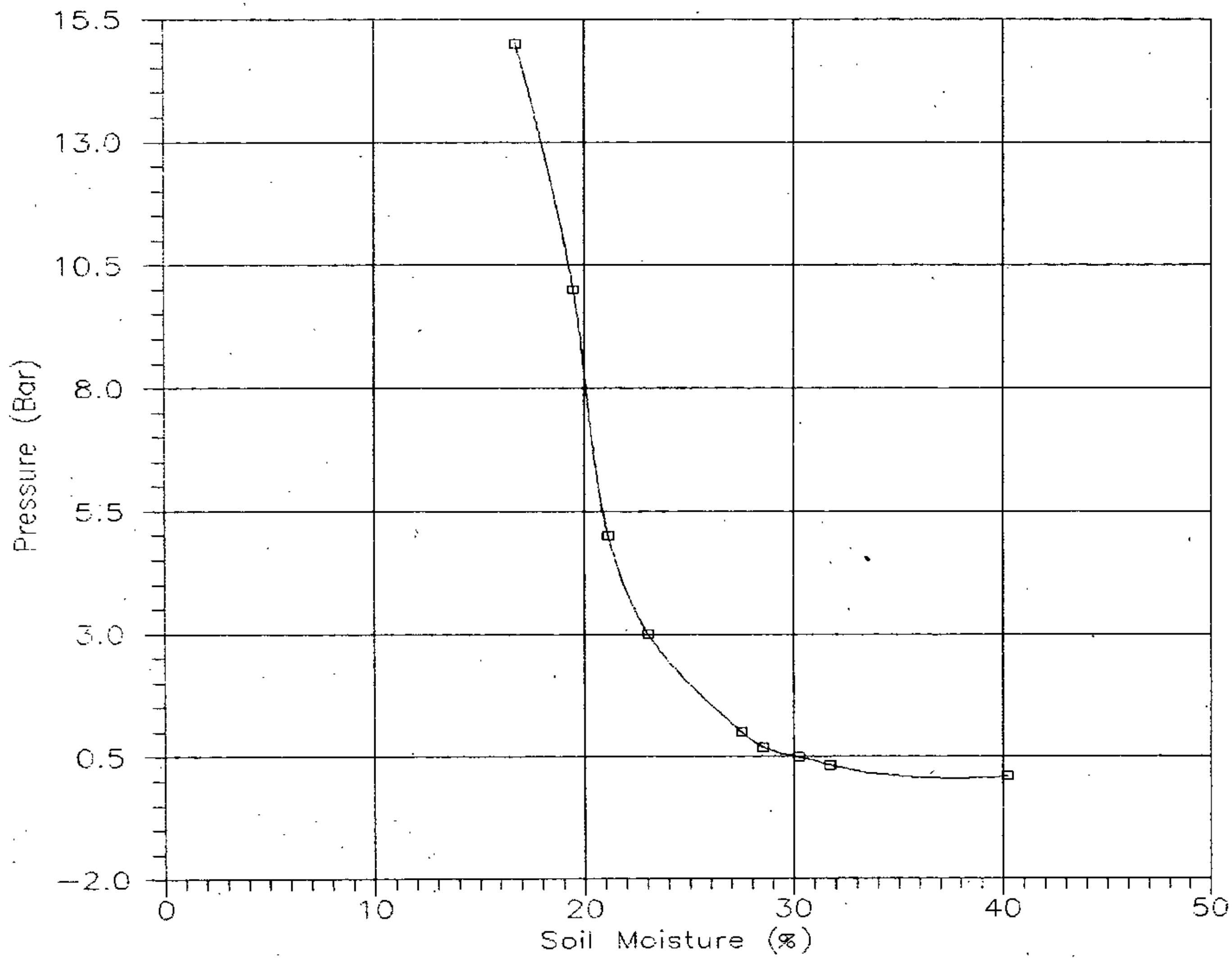


Fig 43 Soil Moisture Characteristic Curve
Site: Kukwara (25-50 cm)

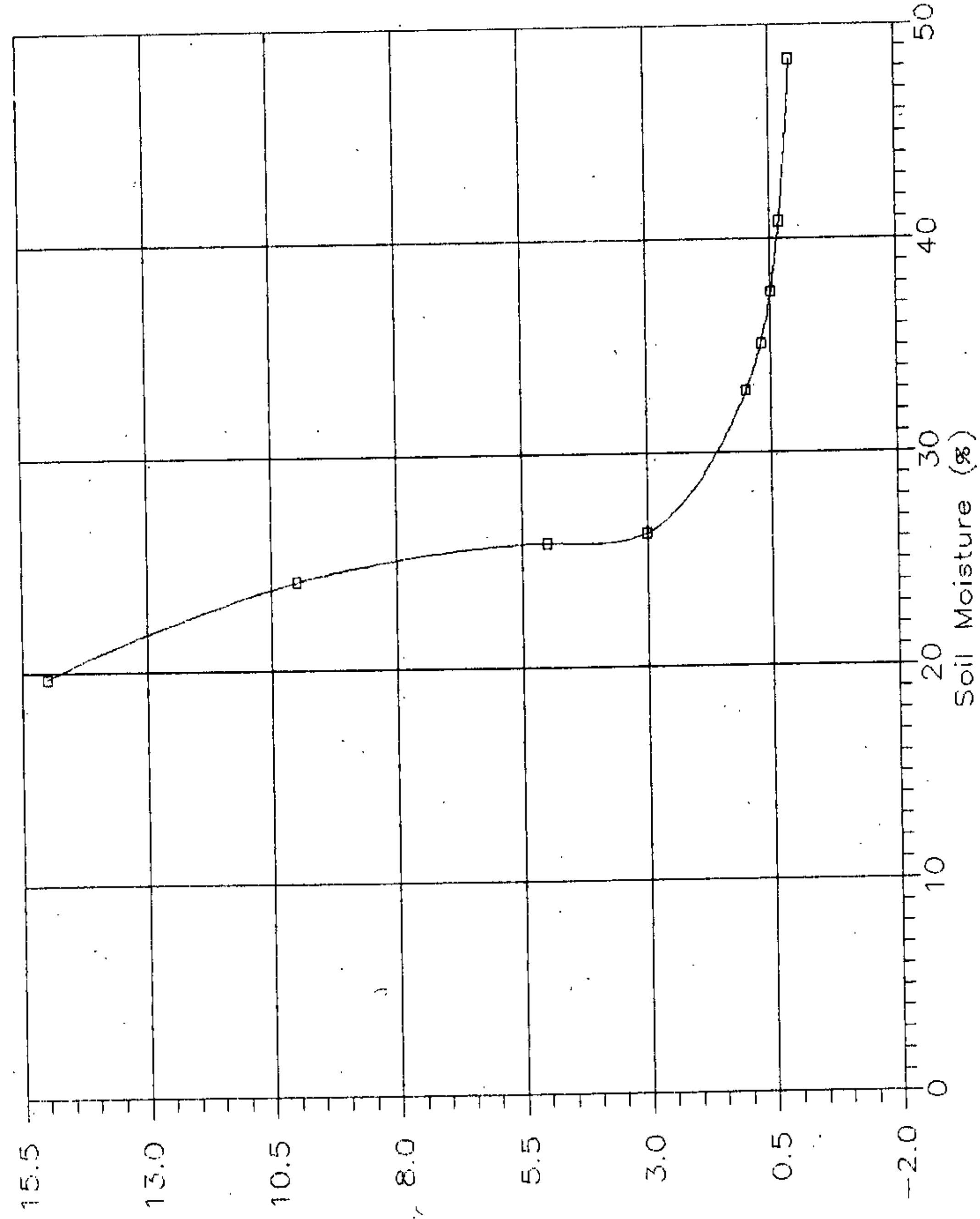


Fig.44 Soil Moisture Characteristic Curve
Site: Kukwara (90–130 cm)

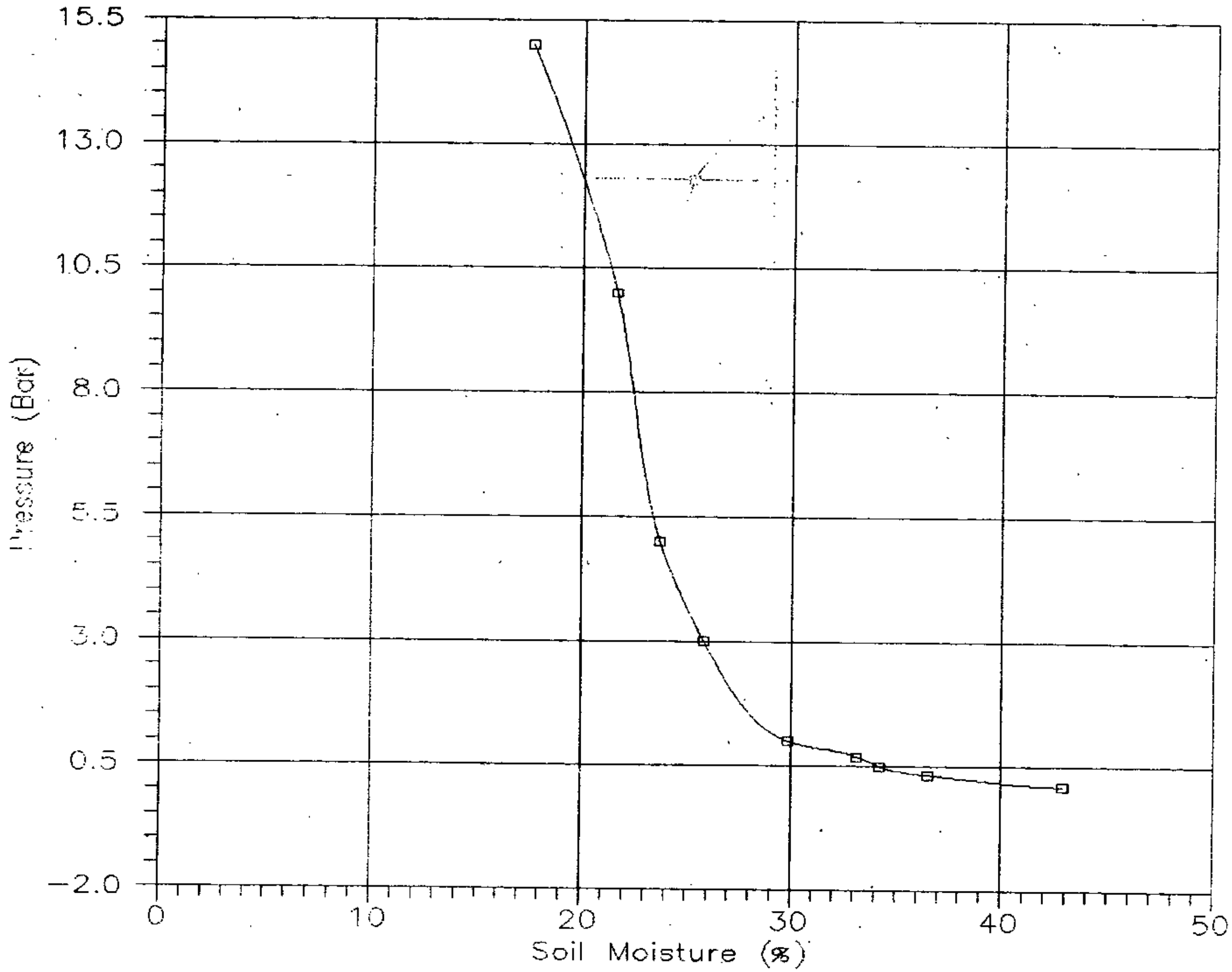


Fig. 45 Soil Moisture Characteristic Curve
Site: Niwari (25–50 cm)

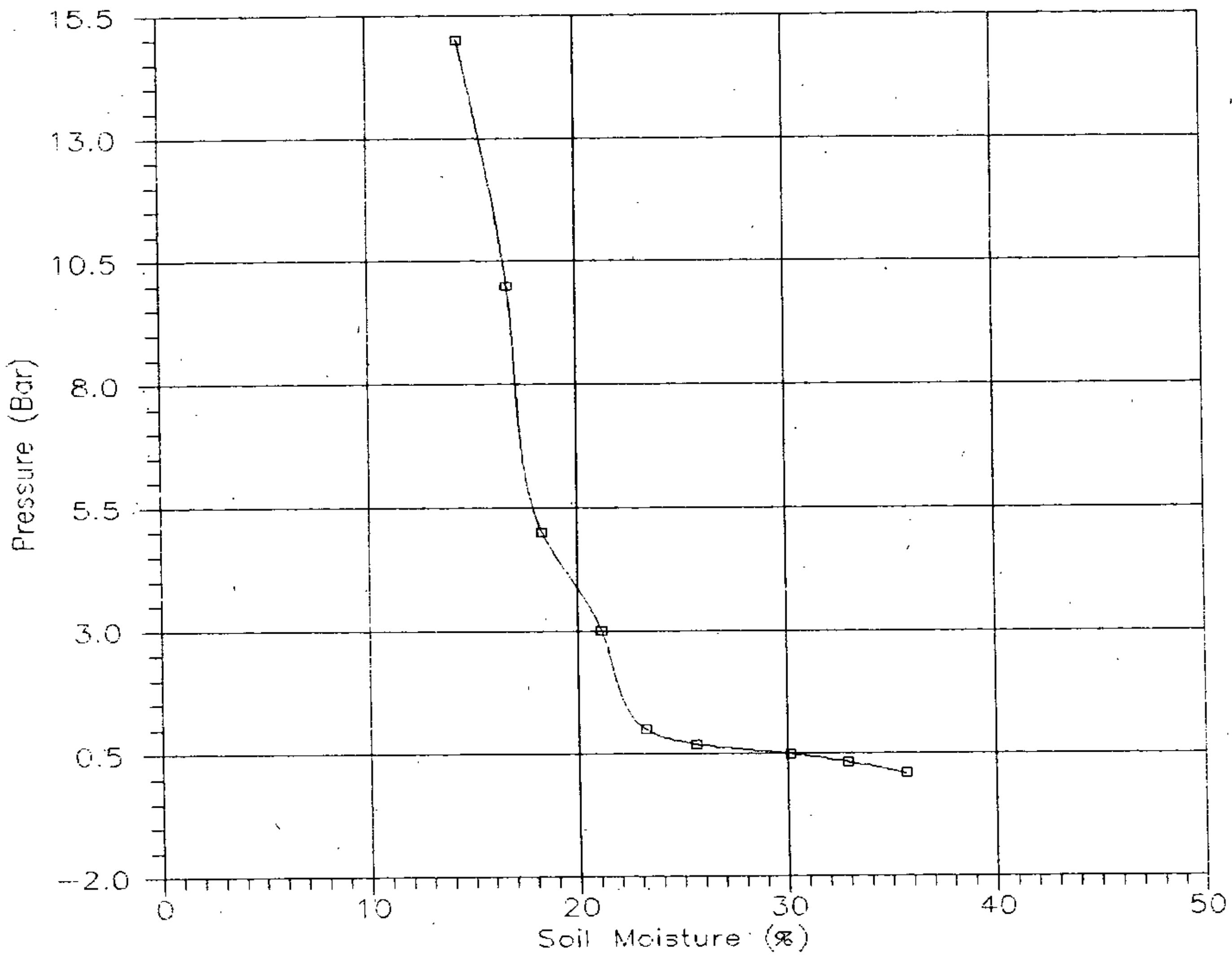


Fig. 46 Soil Moisture Characteristic Curve
Site: Niwari (90–130 cm)

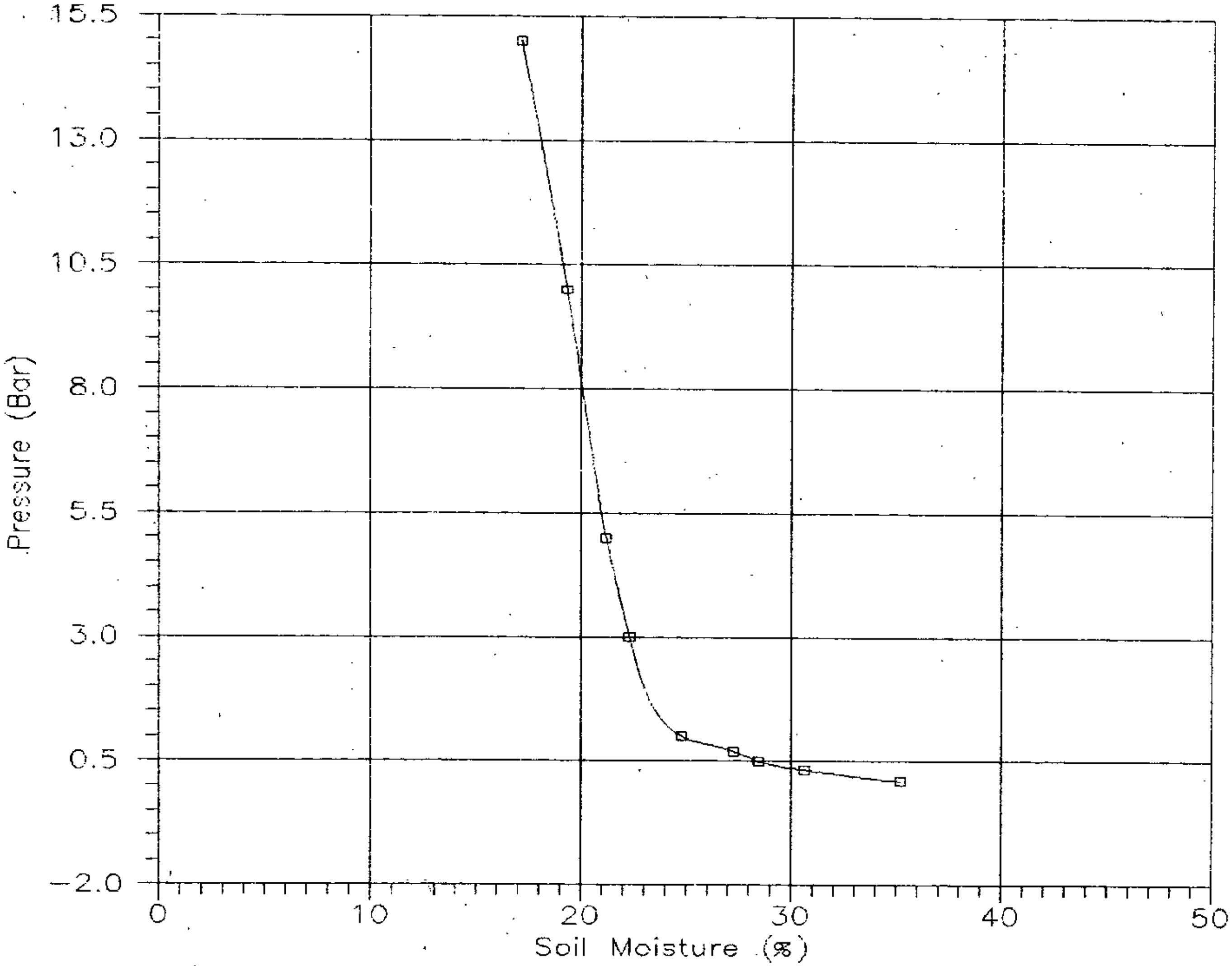


Fig.47 Soil Moisture Characteristic Curve
Site: Muria (25–50 cm)

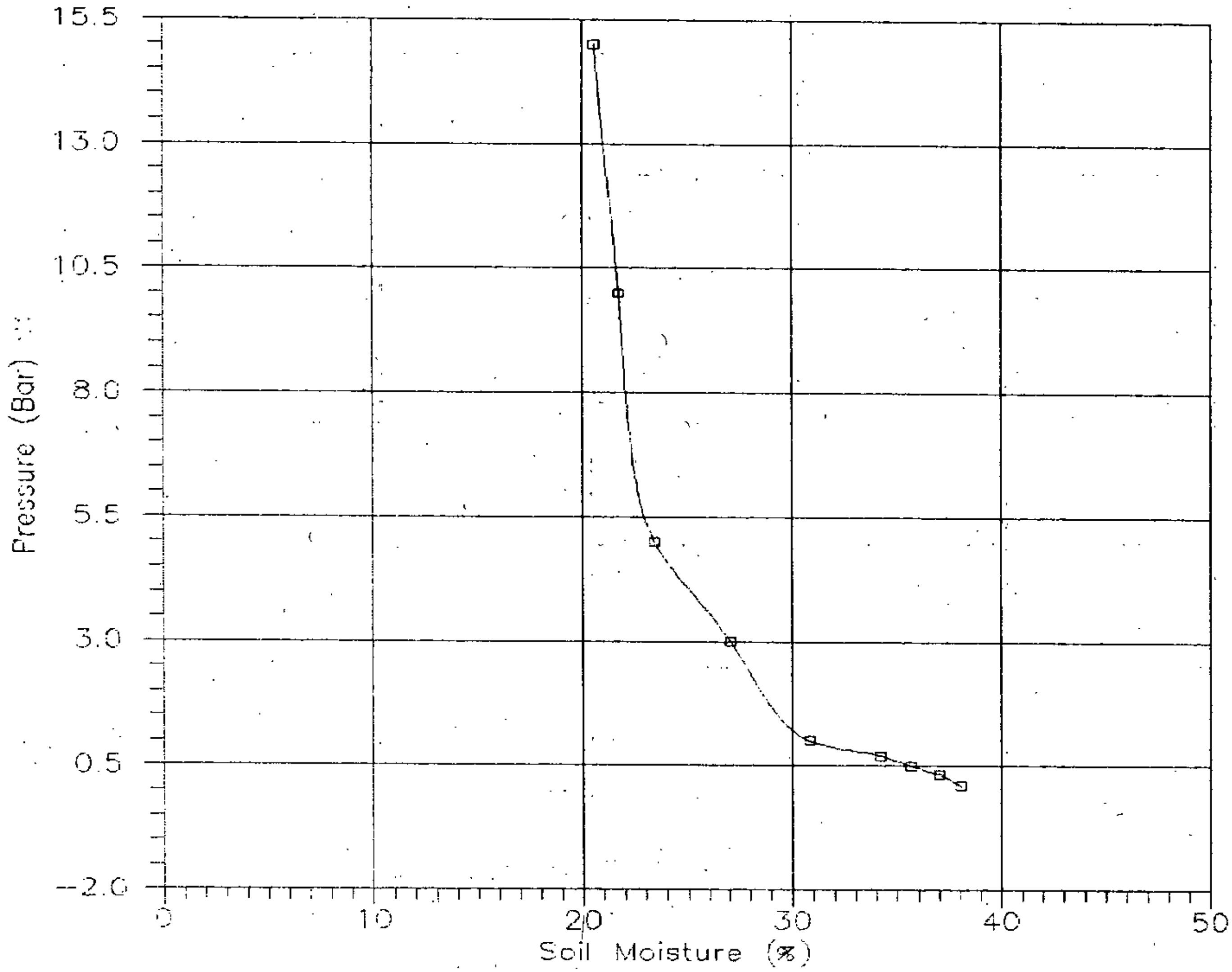


Fig.48 Soil Moisture Characteristic Curve
Site: Muria (100–120 cm)

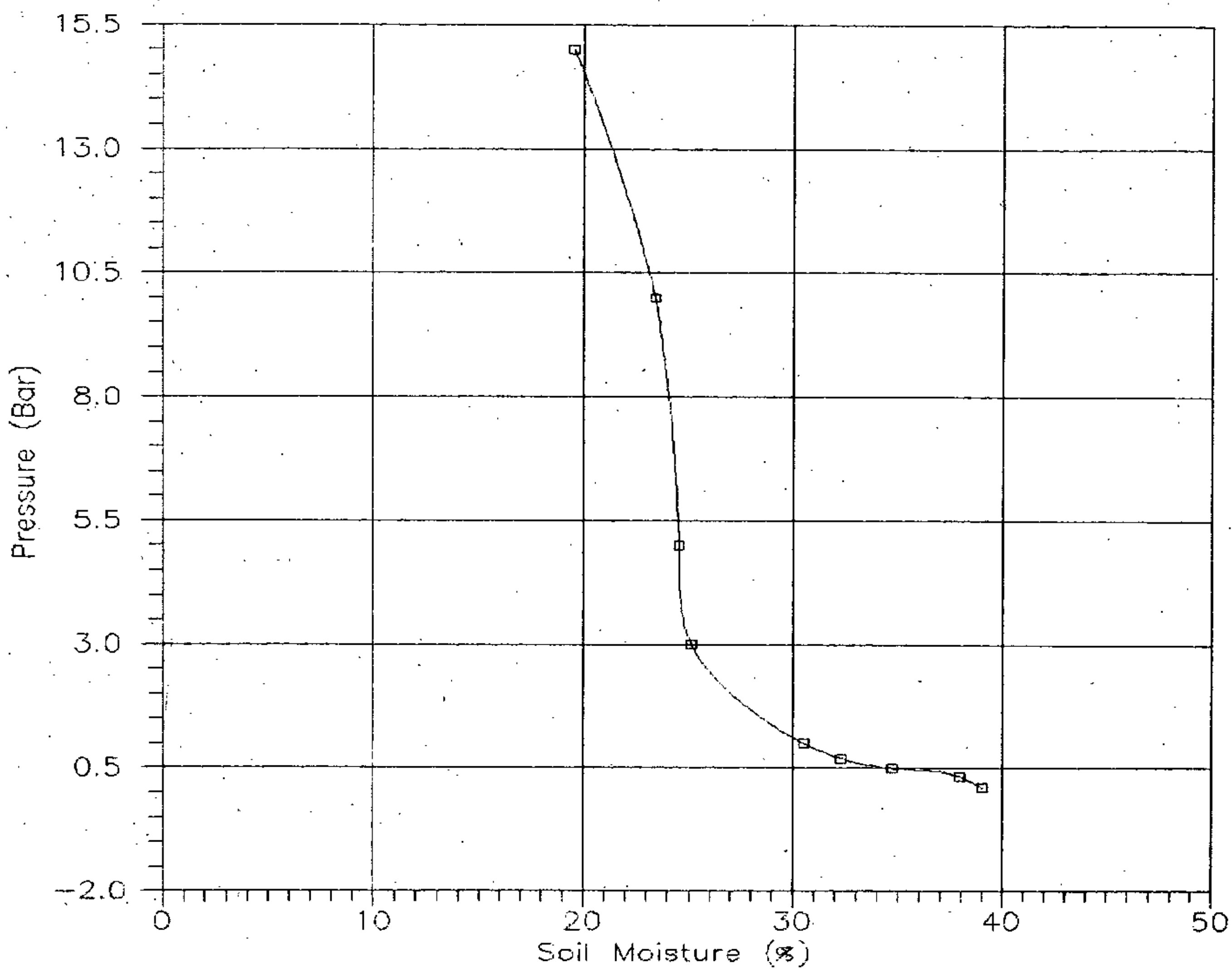


Fig.49 Soil Moisture Characteristic Curve
Site: Shyam Khera (20–40 cm)

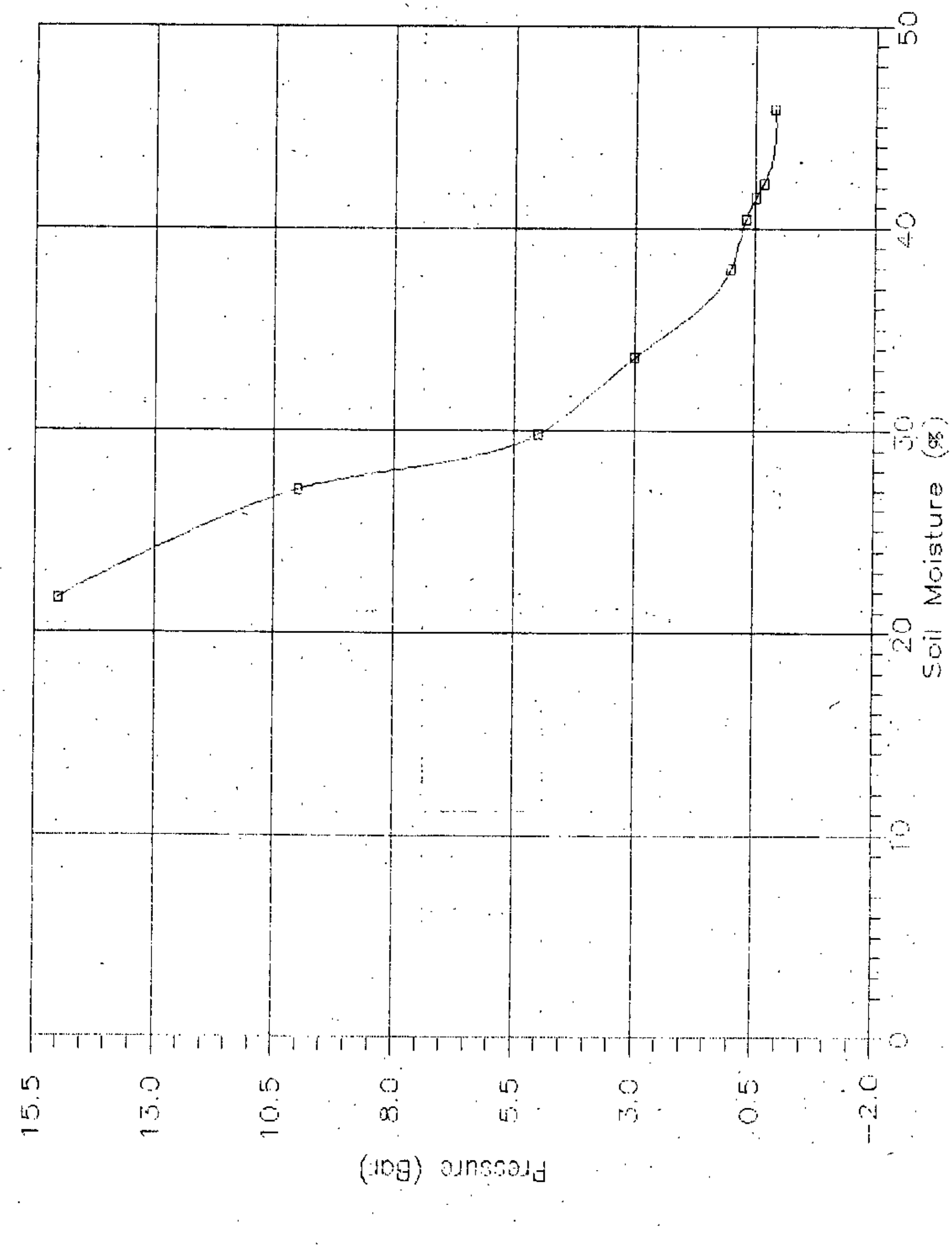


Fig.50 Soil Moisture Characteristic Curve
Site: Shyam Khera (90–120 cm)

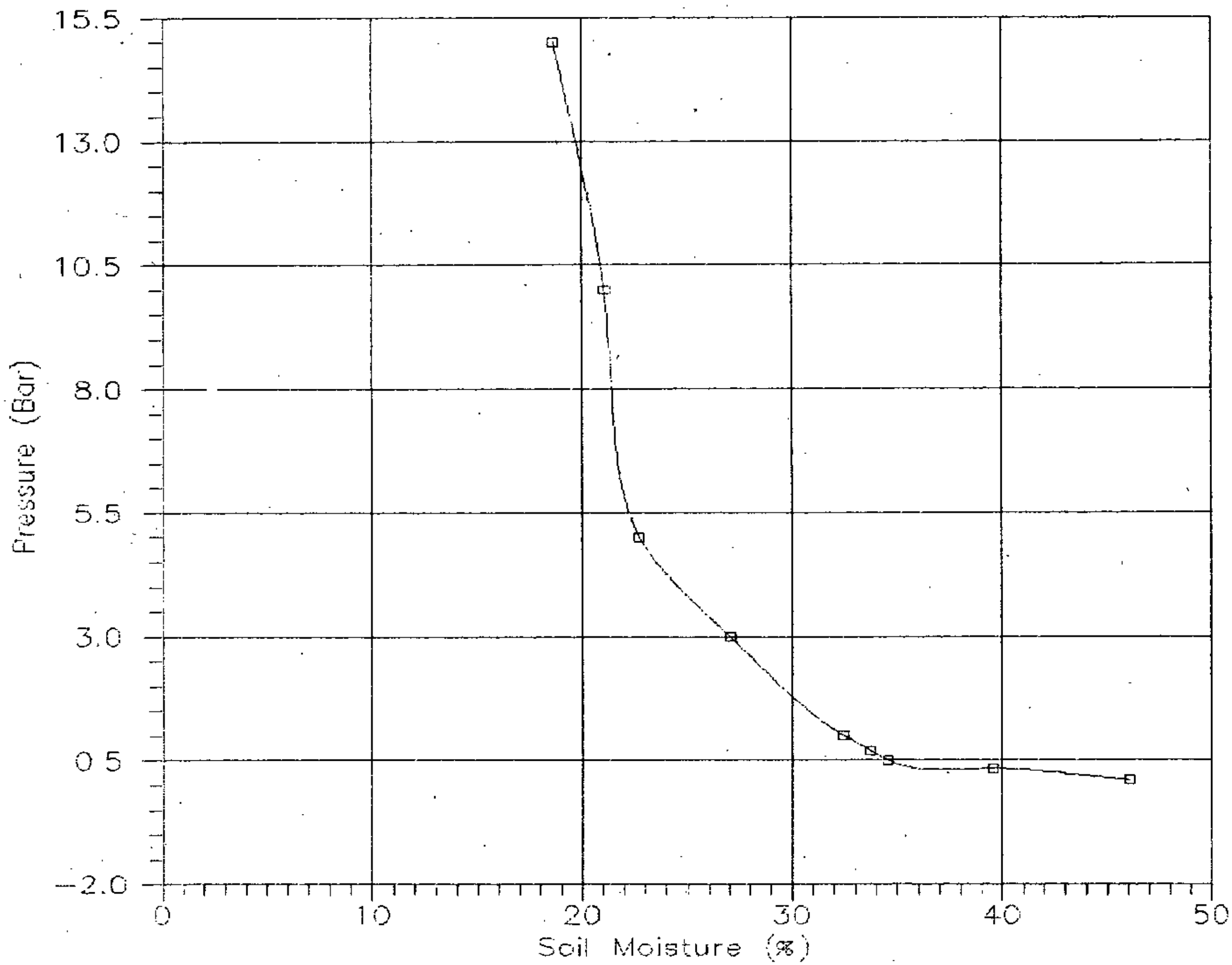


Fig. 51 Soil Moisture Characteristic Curve
Site: Kandharapur (20–50 cm)

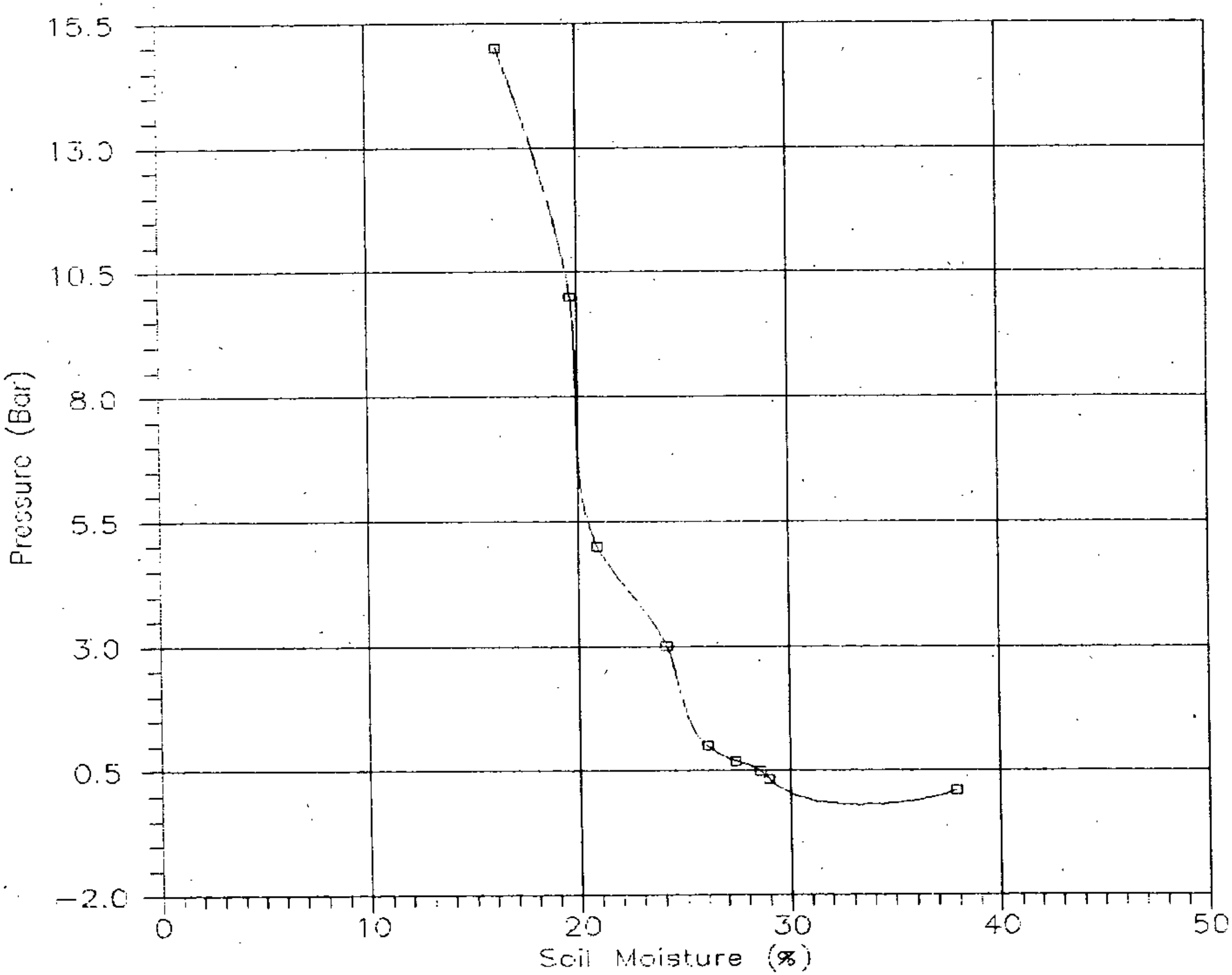


Fig.52 Soil Moisture Characteristic Curve
Site: Kandharapur (100–130 cm)

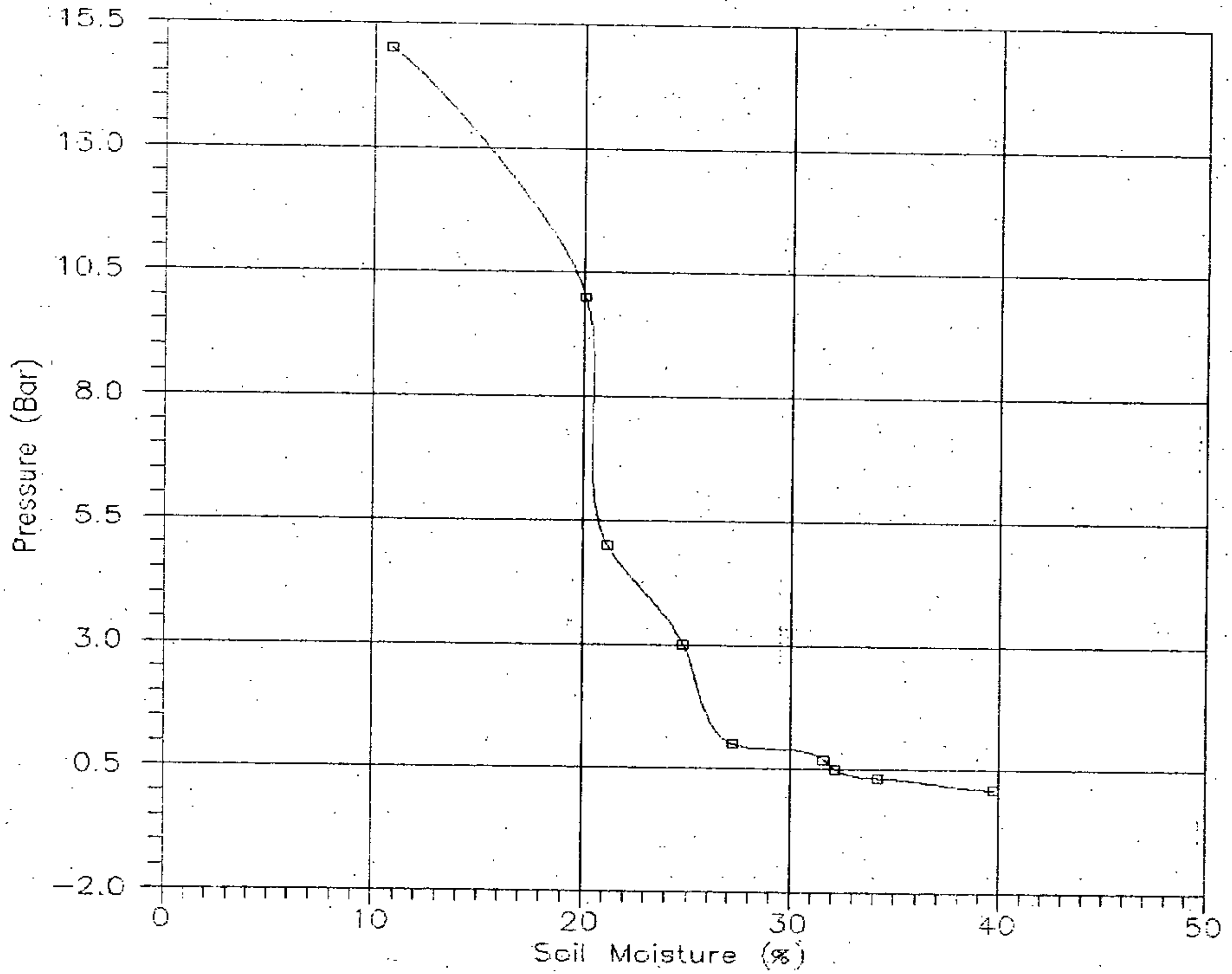


Fig. 53 Soil Moisture Characteristic Curve
Site: Lokipar (20–50 cm)

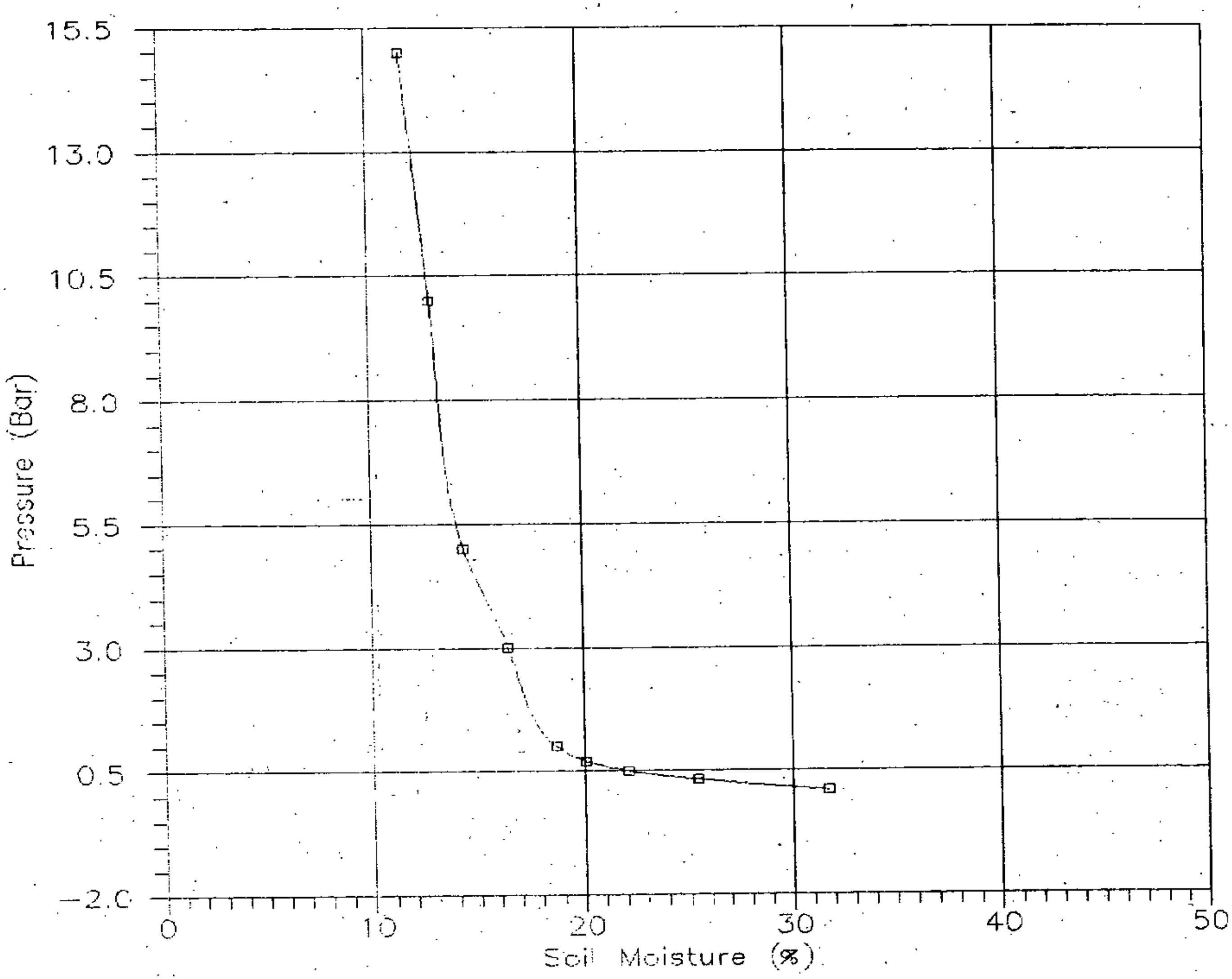


Fig. 54 Soil Moisture Characteristic Curve
Site: Lokipar (120–150 cm)

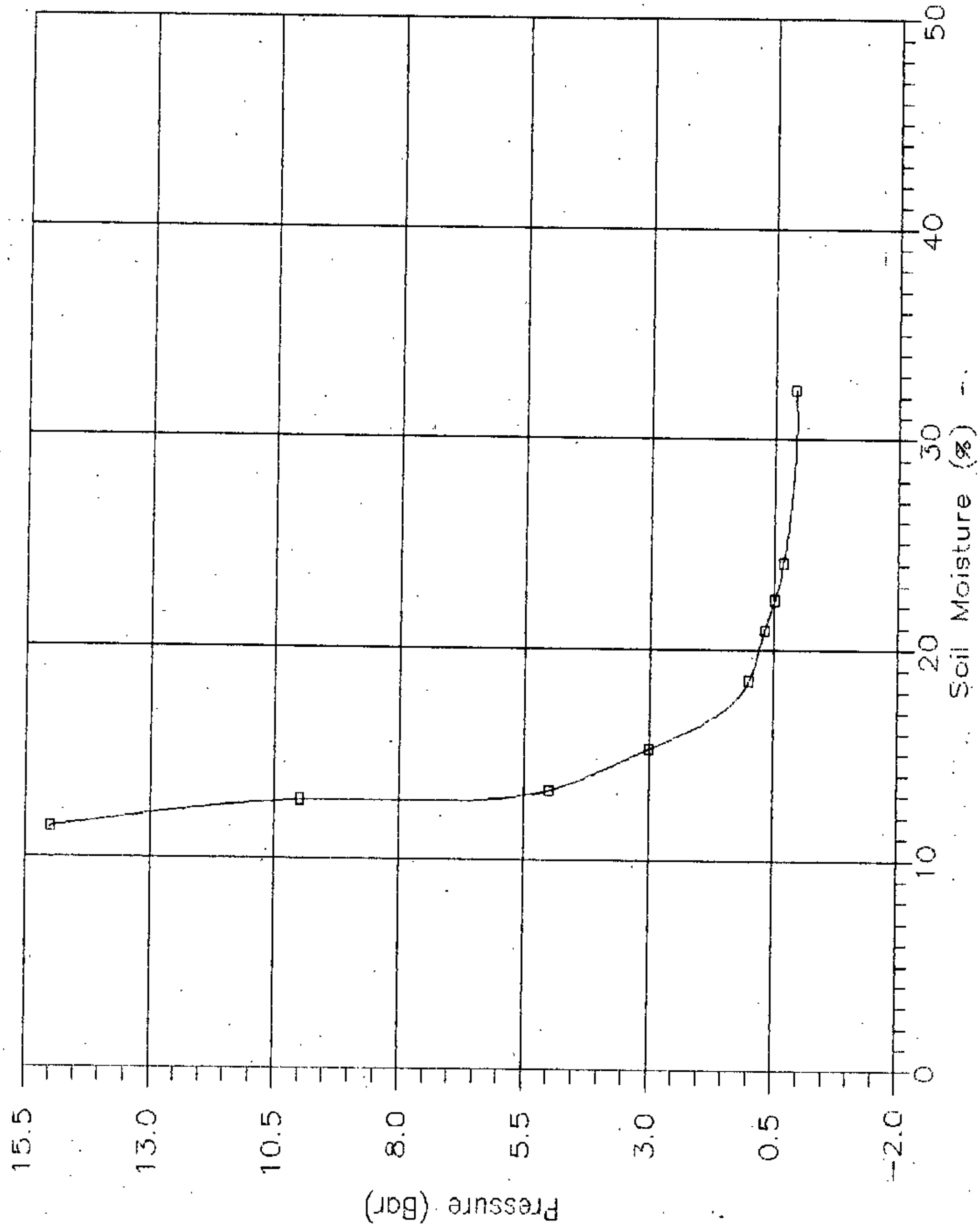


Fig.55 Soil Moisture Characteristic Curve
Site: Dhrughat (15–50 cm)

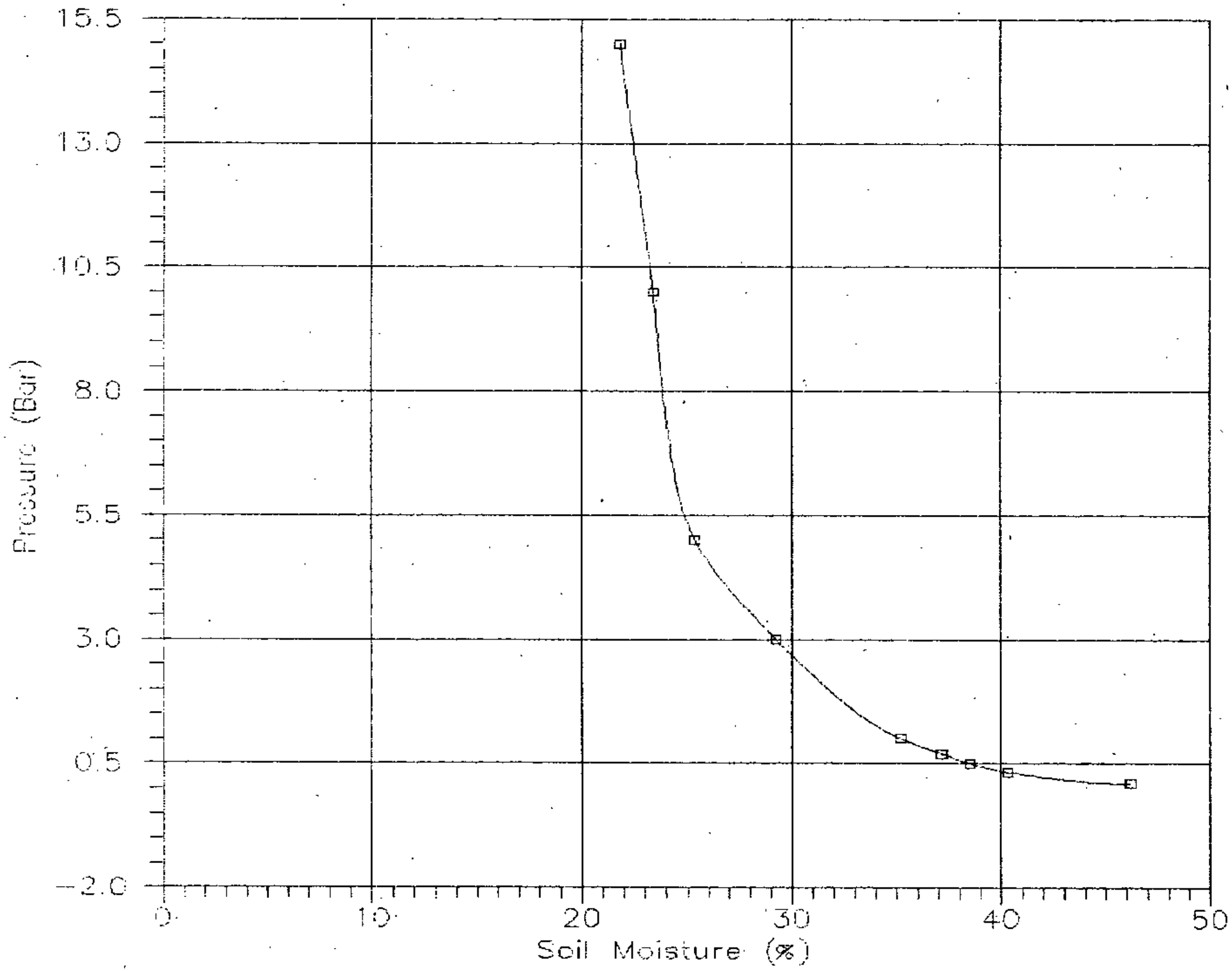


Fig.56 Soil Moisture Characteristic Curve
Site: Dhrughat (100–130 cm)

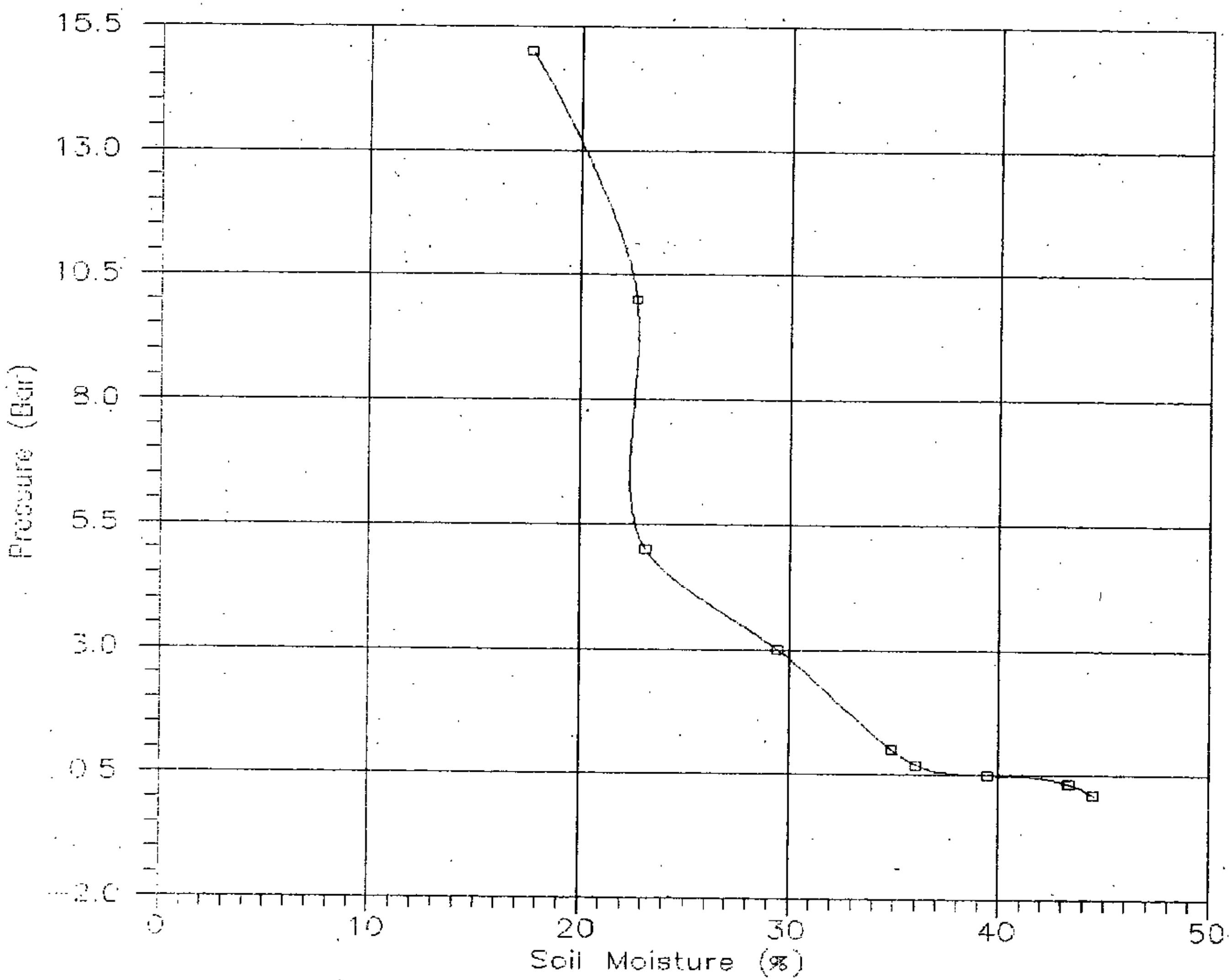
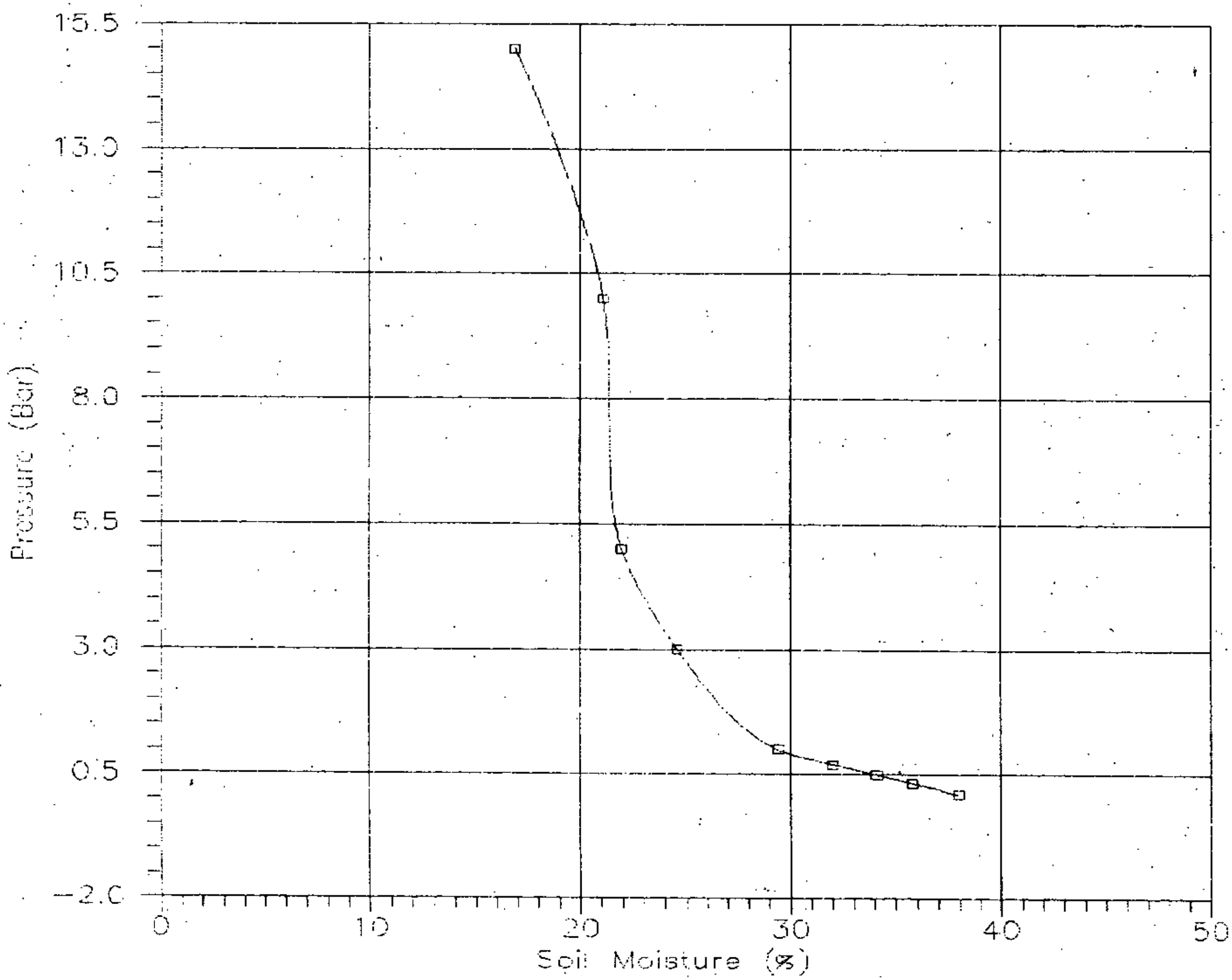


Fig.57 Soil Moisture Characteristic Curve
Site: Didwara (25–50 cm)



4.0 Result And Discussion

The particle size analysis of the soil samples were carried out in the soil water laboratory of the Institute. The grain size distribution of the soil particles have been determined. From the particle size distribution curves the grain size distribution of the soil samples were estimated. Using soil triangle graph (Fig 2) the textural classification of the soil of study area was found and is given in Tab.6. The grain size distribution shows that in general sand content varies from 2.5% to 20% , except at location N31 were sand content is as high as 64.65%. Silt content is varies from 10 to 20 % and clay from 50 to 85 % except at location N31 were clay content is only 22 % (Tab.5). The particle size distribution curves are also prepared by plotting the grain size in millimeter and the percentage passing on a log normal scale for all the soil samples. These graphs are illustrated in Figs. from 16 to 36.

The saturated hydraulic conductivity of the soil samples measured by Guelph permeameter is given in Tab (6). The insitu values are varies from 0.002 to 0.09 m/day. But at location N 31 and N 10. the hydraulic conductivity is high respectively as 0.96 and 1.12 (m/day). At location N 51 the values of hydraulic conductivity obtained by Guelph permeameter was very low i.e. 0.001987 m/day. The depth of water table has been measured and it is observed that it varies from 2 to 8 meter except at location N81 where it is 25 meter deep.

The relationship between in-situ saturated hydraulic conductivity and texture has also been given by Johnson (1963). The hydraulic conductivity values obtained by Johnson's graph is given in Tab 6. The metric flux potential as calculated by equation (7) varies from 0.0001 to 0.08 m^2/day (Tab 7). The slope parameter alpha were calculated using equation (8) and varies from 3 to 236 per m (Tab 7). The soil moisture measurement carried out at Nine pressures are given in Tab. 8 the values of field capacity varies from 22% to 43% and wilting point varied from 10% to 26%. respectively. The available moisture that is useful to point varied from 10 to 25%. The soil moisture characteristic curves have been also plotted and are shown in Fig. 37 to 57 for different locations.

5.0 Conclusions

From this study, it is observed that the study area has predominant in clay. Soil survey organization of Govt. of M. P. has also showed that about 90 % of the area is containing mostly clay. Consequently the hydraulic conductivity and metric flux potential values are also low in accordance with the clay texture of the soil.

6.0 Suggestions for further research

1. The present study should be carried out on a smaller grid for better estimation of saturated hydraulic conductivity and soil moisture retention curves.

2. The field experiments should also be carried out on the basis of soil series given by Soil Survey office, Govt. of M.P. for soil texture analysis.

3. The ground water table should be measured regularly for estimation of water table fluctuation and determination of ground water flow.

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