CS(AR) 6/96-97

INFILTRATION STUDIES IN SHER-UMAR RIVER DOAB IN NARMADA BASIN

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INDIA
1996-97

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1.0 INTRODUCTION

Infiltration is an important component of the hydrologic cycle and is defined as the process of entry of water through the soil surface. Earlier, the term infiltration was used to denote the difference between rainfall and runoff in small areas. Hydrological importance of the infiltration process is to be seen from the fact that it marks the transition from fast moving surface water to slow moving soil moisture and groundwater.

Infiltration process is responsible for modifying precipitation and converting it to runoff and additions to soil moisture storage. The infiltration and other processes are inter-related through a common dependence on soil moisture conditions. Thus, simulation of any hydrological system cannot be achieved without taking into account the infiltration process.

Generally, infiltration has a high initial rate that diminishes during continued rainfall to a nearly constant lower rate. The rate at which water enters into the soil at a given moment is known as the '**Infiltration rate**'. Infiltration rate is of great interest to the hydrologists and water resources engineers, as it influences many of the hydrological parameters, such as, surface runoff, soil moisture, evaporation and evapotranspiration, groundwater recharge and spring flow rates. It is also of interest to the agriculturists, conservationist and environmentalists. The knowledge of infiltration properties can help agriculturists in developing integrated crop, soil and water management plan including adoption of proper irrigation methods and irrigation schedule. The conservationist and environmentalist can derive the information on soil erosion (as runoff depends on infiltration) and in turn the sedimentation rate in reservoirs using the infiltration data.

Infiltration studies are mainly addressed to variety of applications for managing water resources. The design of methods for estimation for flood mitigation and erosion control are often based on estimates of peak discharge derived from prediction of infiltration rate. Water conservation procedures require computation of cumulative infiltration to produce estimates of runoff yield. Similarly, in exploiting water resources for plant growth from rainfall or irrigation, an assessment of cumulative infiltration becomes necessary for calculation of an optimal level of productivity. This assessment embodies efficient water use and maintains an acceptable level of erosion control.

Quantitatively, infiltration rate is defined as the volume of water passing into the soil per unit time and has the dimension of velocity (L/T). This rate depends on a number of factors viz. physio-chemical properties of the soil, vegetation and landuse pattern, rainfall intensity and duration, and surface slope. Besides these factors, the depth to groundwater, climate and man's activity also affects the process of infiltration.

Under special circumstances wherein the rainfall exceeds the ability of the soil to absorb water, infiltration proceeds at a maximal rate called as soil's **'Infiltration capacity'** (Horton, 1940).

Keeping in view the importance of infiltration studies, infiltration studies have been initiated in the Bargi Left Bank Canal Command area. In the year 1996-97 infiltration tests were conducted in the Sher - Umar doab falling under the command area of Bargi Left Bank canal in Narsinghpur district of Madhaya Pradesh.

2.0 STUDY AREA

The Bargi multi-purpose project, renamed as Rani Avanti Bai Sagar Project, is one of the major river valley project on Narmada river by the Govt. of Madhya Pradesh as a part of the Narmada Valley Development Plan. On completion of the project, irrigation facilities will be available for 157,000 hectares in Jabalpur and Narsinghpur districts through Left Bank Canal system and 46,000 hectares in Jabalpur district through Right Bank Canal system.

The study area is a part of the Left Bank Canal Command of Bargi Multi-purpose Project. The canal is 132.2 kilometer long and has a discharge capacity of 124.65 cumecs. This canal has Culturable Command Area of 95,000 hectares

2.1 LOCATION

The study area is a part of Narsinghpur tehsil of Narsimhapur District, Madhya Pradesh and occupies the central part of Bargi Dam Command area in Narmada river basin (Fig. 1). The area lies between latitudes 22^0 53′ N to 23^0 03′ N and longitudes 79^0 10′ E to 79^0 32′ E and falls under Survey of India toposheets no. 55M/4, 55M/8 and 55M/9. The area is bound by the Sher river in west, by the Umar river in east and north, and by the Bargi Left Bank Canal in South (under construction). This is one of the most fertile and populus part of Narsinghpur.

The study area lies in the East of Narsinghpur town and is traversed by State Highway No. 22 from Jabalpur to Hoshangabad. The main broadgauge railway line from Hawrah to Bombay also passes though the study area.

2.2 PHYSIOGRAPHY

The study area occupies a part of the southern part of the Narmada Valley which is most fertile and populus part of Narsinghpur district. The general level of the study area lies between 338m to 360m above MSL. 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. At few places, gravel mounds are also present.

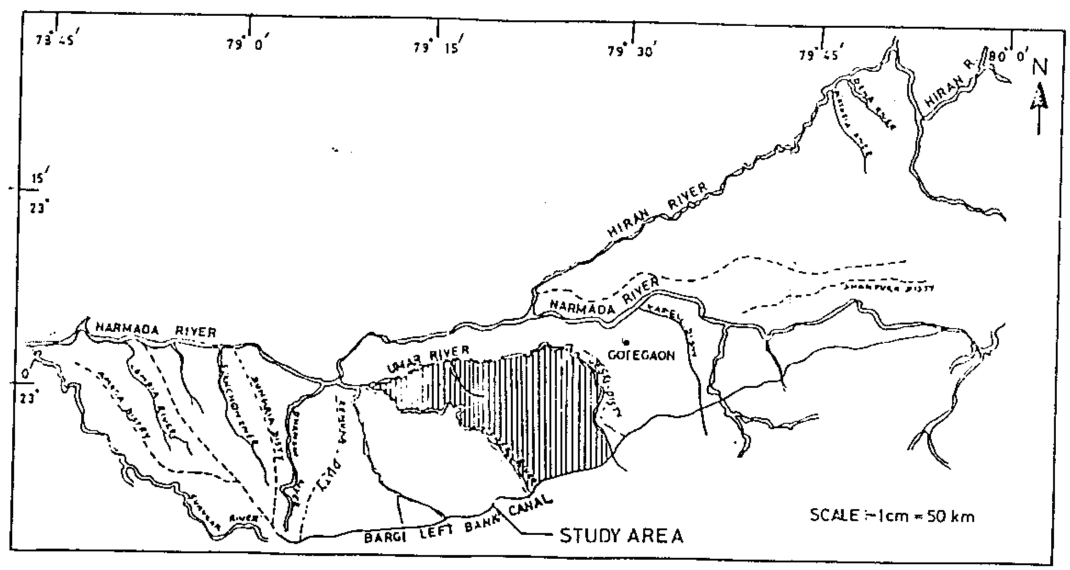

FIG.1 : Location map of the Sher-Umar river doab.

The general slope of the area is towards north and northwest. In the plain areas, the slope is upto 3 %, whereas in the undulating areas the slope is upto 15 %. The drainage pattern in the area is dendritic type. Small rivulets are confined to the southern and northern part of the study area (FIG.2). In southern area, the drainage is mainly in the hilly area and in the northern part it is along the two major rivers, i.e., Sher and Umar. The landscape of the area is such that most of the surplus rain water drains through rivers and streams, but poor to moderate drainage conditions occur in the flat areas creating drainage problem in the central part of the doab.

2.3 CLIMATE

The study area falls in sub-zone-2c based on hydrometeorological classification of the country (Kaushal & Chaudhary, 1975; WAPCOS, 1986). The climate in the region is sub-tropical.

The rainy season extends from June to October under the influence of south-west monsoon. Normally the rainfall ceases by the end of September, but in quite a large number of years, the area receives good rainfall during October. The area also receives some rainfall during January and February. There is considerable variation in rainfall from year to year. As per the rainfall data of Narsinghpur meterological station, annual rainfall varied from 563.3 mm (1965) to 1893.6 mm (1977), with average annual rainfall of 1162 mm (1965-89). Mean monthly rainfall of Narsinghpur meteorological station is given in TABLE-1.

The temperature in the area varies from 45^0 C in summers to 2^0 C in the winters. The temperature begins to rise rapidly from March till May, which is generally the hottest month of the year. With the onset of the monsoon in the second week of June, there is an appreciable drop in the day temperature. From mid-November onwards, both day and night temperature decreases rapidly. December and January are the coldest months of the year.

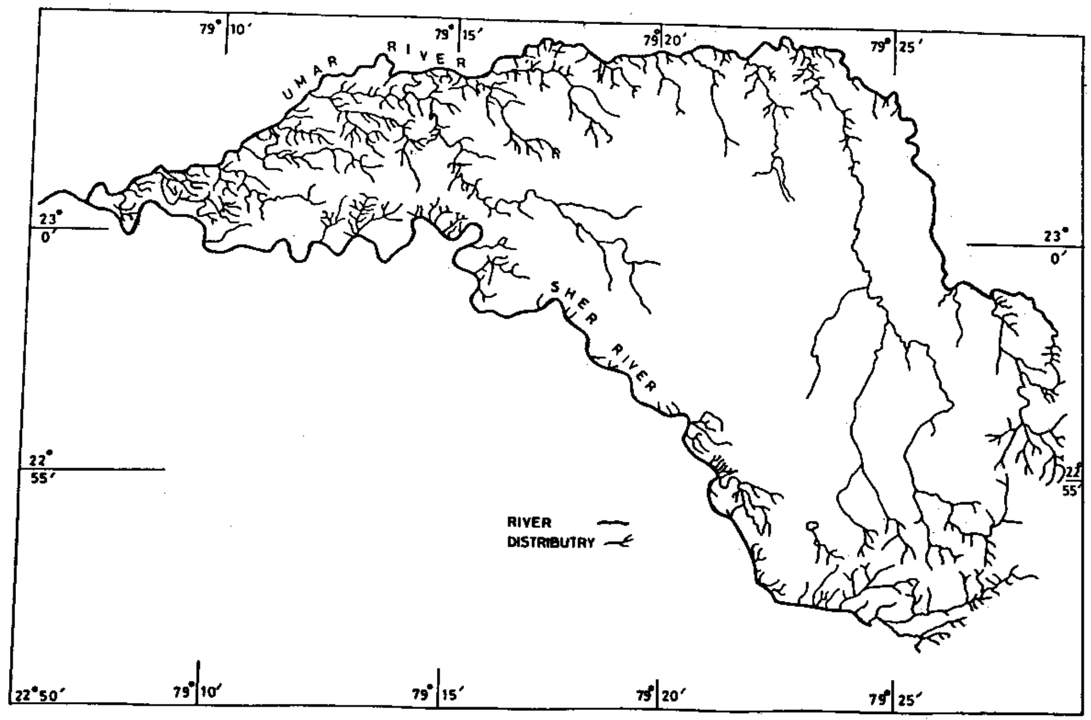

FIG. 2 : Drainage map of the Sher-Umar river doab.

Table-1 : Mean monthly rainfall at Narsinghpur meterological station for the period 1965-89.

Sl. No.	Month	Mean monthly rainfall (mm)	Year 1989
1.	January	18.74	0.00
2.	February	19.40	0.00
3.	March	10.36	38.00
4.	April	1.68	0.00
5.	May	7.05	0.00
6.	June	166.70	231.80
7.	July	314.95	93.40
8.	August	422.50	603.60
9.	September	155.58	120.80
10.	October	22.30	0.00
11.	November	11.30	0.00
12.	December	11.40	0.00
	TOTAL	1161.96	1087.60

2.4 SOILS

The soils of the area are alluvial in nature. The thickness of alluvium increases towards north. Rocks are exposed on the southern periphery of the study area. Kankars have been observed at a depth of 80 cm to 150 cm.

The top soils of the area are normally heavy and dark coloured and are derived from Deccan Trap rocks. The top black soil is variable in thickness with average thickness of about 1 meter with a maximum thickness of 9 meters. This soil is clayey in texture and has high moisture retaining capacity. The black soil is underlain by light textured yellow soil. This yellow soil has low water retaining capacity as compared to black soil.

In some places, the soils have been formed from sand stone parent material in which a lot of textural variation is found. It varies from sandy loam to clay. The soil crust is deep and has a fair amount of gravel or Kankar (impure form of nodular calcium carbonate) along the depth of profile.

The soil survey of the area had been carried out by Soil Survey Unit, Jabalpur under Department of Agriculture, Govt. of Madhya Pradesh. In study area, there are only three types of soil i.e. clay, clay loam, silty clay loam, in which clay and silty clay loam are predominant (FIG.3).

Towards the banks of river, the texture of the soil changes from heavier to lighter grade i,e from clay to clay loam, loam, sandy loam and finally sandy. The colour of the soil also changes from dark greyish brown to brown, yellowish brown and finally yellow grey.

2.5 GROUNDWATER

The entire study area is covered with alluvium of recent age. Alluvium consists mainly of clay and fine to medium grained sand. The thickness of alluvium varies from place to place ranging from 15 to 180m. Groundwater is mostly present under confined conditions and gives yield of 75-150 m^3/hr for 6m drawdown.

Water table is a guiding factor which controls the movement of water through soil, though by physical character, a soil may have different drainability.

2.6 AGRICULTURE AND IRRIGATION

The study area is normally agricultural area with no forest land. Forested area lies beyond Bargi canal in the south. The main crops grown in the area are Soyabean, Gram, Arhar, Masoor, Moong, Jwar, Wheat and Sugar Cane. In some low lying areas, rice is also cultivated. Fruit bearing trees are Mango and Jamun.

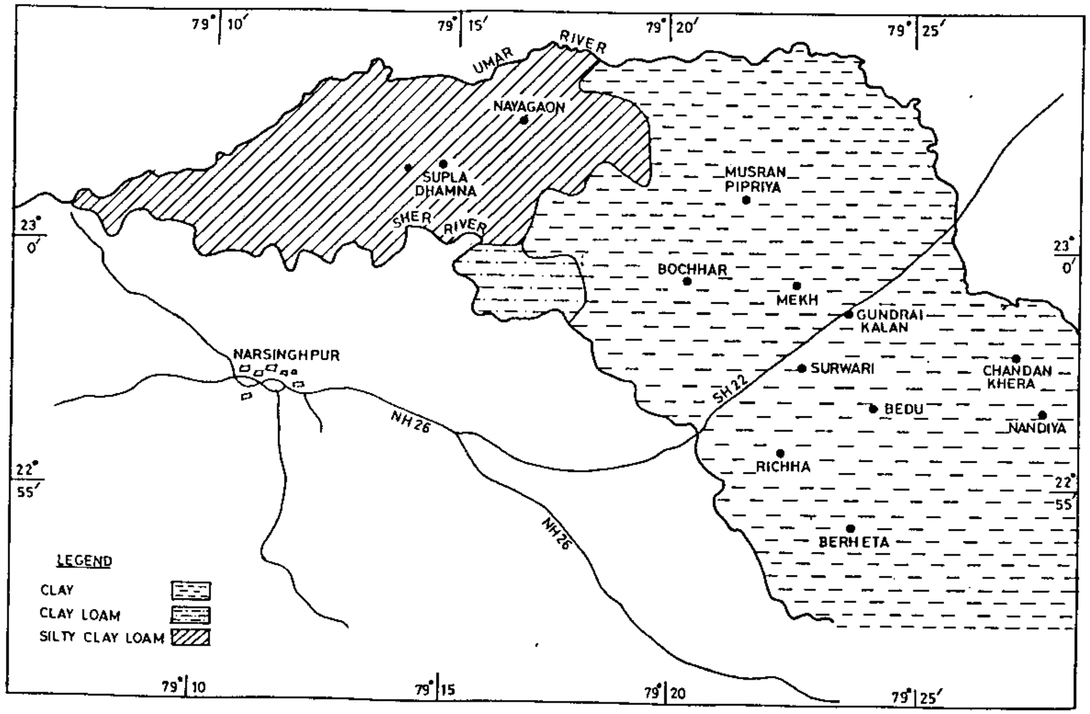

FIG. 3 : Soil type map of the Sher-Umar river doab

As the general topography of the area under study is somewhat irregular, soil is highly impermeable due to its high clay content, both surface/sub-surface method of irrigation are not efficient for the study area. Therefore, Sprinkler method of irrigation is in general practice to irrigate the fields located in the study area.

"The old Haveli" system of cultivation is practised in rabi. The preference to rabi cultivation is due to the high clay content of the soil which is difficult to work in rainy season. Broadly speaking, under Haveli system a large area is bunded and utilised for collecting rain water during the monsoon and is left fallow during Kharif season. The rain water stored as soil moisture helps to grow rabi crops

3.0 INFILTRATION PROCESS AND METHODS OF MEASUREMENT

Infiltration characteristics of a soil is an important parameter for hydrological modelling. It is essential to know the rates at which different soils will take in water under different conditions. Infiltration rates are affected by a number of factors of which soil moisture, soil texture and vegetal cover are most important. It is a basic parameter for developing an integrated crop, soil and water management plan. The knowledge of infiltration is of great importance to a hydrologist in estimating rate of runoff and peak flow with time, to a soil scientist / agronomist in estimating the availability of soil moisture, to irrigation and drainage engineer in planning and design of various water resources development projects.

3.1 FACTORS AFFECTING INFILTRATION RATE

Once the importance of study of infiltration rate has been established, it is useful to understand the effect of various soil and climatic factors on the infiltration rate. Some of the most common factors affecting infiltration rate are :

a. Soil properties (including structure, texture and distribution, porosity and compactness of soil grains),
b. Soil moisture,
c. Landuse characteristics,
d. Rainfall (duration and intensity),
e. Surface slope, and
f. Climate.

Effect of soil properties

Musgrave and Horton (1964) have shown that infiltration , characteristics are effected by grain size and grain size distribution in the soil. In sands the grains are relatively stable, while soils with appreciable amounts of clay may provide large pores but swells appreciably upon wetting. During a storm, sands may slowly rearrange themselves into a more dense mix than before, whereas in silts and clays the soil aggregates breaks due to the impact of raindrops, causing the clay and silt particles to flow at and penetrate previously existing pores, thus clogging them and greatly reducing infiltration.

Rauzi and Fly (1968) found that the unfavourable surface soil conditions markedly reduce water intake rates. They found that soils with compact or blocky clay sub soils and clay have low intake rates. Clay soils with good structure take water at rates three or four times that of dense clay soils with poor structure i.e. the degree of surface soil compactness is a major factor affecting infiltration rate.

Many experiment have shown that pore sizes and pore-size distribution are greatly affected by the content of organic matter because both the sizes and soil aggregates and their stability in water are related to the amount of soil organic matter. The addition of organic matter or its removal changes the prevailing permeability.

Effect of Soil Moisture

Horton studied the maximum and minimum infiltration rates of a soil. The maximum infiltration rate for a given soil occur at the beginning of the rain. He has indicated that the infiltration rate decreases rapidly because of changes in the structures of the surface soil and increase in soil moisture and then gradually approaches to a somewhat stable minimum. Powell and Beasley have reasoned that when the soil is dry the high initial infiltration rate is primarily the result of the filling of the pore spaces larger than the capillary size. Once these pores are filled, the infiltration is due to the advance of water by capillary potential.

Effect of land use

Musgrave and Horton have stated that vegetation is one of the most significant factors affecting infiltration of water. Vegetation protects the soil surface from rainfall impact. Massive plant root systems such as grass keeps the soil unconsolidated and porous. The organic matter from crops promotes a crumb structure and improves permeability. Forest litter, crop residues and other humus materials protect the soil surface.

The density of herbaceous vegetation is closely related to infiltration. Packer (1951) for instance found that the percent of the soil covered by living or dead plant parts was closely related to runoff and therefore to infiltration. Fibrous-rooted vegetation such as wheat grass has been found to be much more effective in controlling runoff than tap-rooted annual weeds (Lull 1964).

The great influence of vegetation cover on infiltration is further evidenced by the fact that bare-soil infiltration capacity can be increased 3 to 7.5 times with good permanent forest or grass cover, but little or no increase results with poor row crops (Jens and McPherson, 1964).

Effect of Rainfall

Linsley, Kohler and Paulhus(1949) have reported that rainfall intensity has little effect on the rate of infiltration when it exceeds the capacity rate. This agrees with the findings of Schreiber and Kineaid (1967), but disagrees with those of Fletcher (1960). Willis (1965) has found that the infiltration rate of a bare soil was reduced by an increase in Kinetic Energy of rainfall which is the function of the velocity of impact of raindrops and of the rainfall intensity. Local experiments on the variation of infiltration capacity with rainfall intensity showed predominant variation for bare soil, as noted by Horner and Jens (1942), and a lesser amount of variation for sodded areas.

Duley and Kelly (1939) found that when the rate application of water was sufficient to give runoff, a fairly definite amount of water entered the soil and any amount of application in excess of this intake appeared in the runoff. He observed that the rapid reduction in the rate of intake by cultivated soil, as rainfall continuously fell on the soil surface, was accompanied by the formation of a thin, compact layer at the soil surface, and that the water was able to pass this layer very slowly. He postulated that this thin, compact surface layer was apparently the result of severe structural disturbance due in part to the beating effects of the rain-drops, and in part, to an assorting action, as water flowed on the soil surface, fitting fine particles around the larger once to form a relatively impervious seal.

Green (1962) has also concluded that surface sealing diminishes the effect of antecedent moisture on infiltration because the hydraulic conductivity of immediate soil surface controls water flow into the soil and surface sealing does not allow suction gradients to control the rate of infiltration.

Effect of Soil Surface Slope

Duley and Kelley (1939) tested soils on different slopes and noted that there was a tendency for the amount of water intake to decrease slightly with increase in slope. The greatest intake was found on the greatest slope.

Effect of Climate

Frozen ground affects infiltration, if frozen when very dry, some soils are fluffed up and frost is discontinuous, as in the honey comb and stalactite types. A soil under this condition may be permeable as, or even more permeable than, frost-free soil. On the other hand, if the soil is frozen while saturated, concrete frost in the form of a very dense, nearly impermeable layer often results. Trimble et. al (1958) found that in the North East infiltration was zero on concrete frost in the open and forest area, but was not affected where soil was transversed by large holes in which water had not frozen.

3.2 INFILTRATION ESTIMATION AND MEASUREMENT TECHNIQUES

The three step sequence, i.e., surface entry, transmission and exhaustion of storage presents difficulties in the measurement of infiltration. For the most part, hydrologists determine the rate and amount of in-soak and attempt to correlate this with various combinations of soil, vegetation and antecedent soil moisture. There are two general approaches to determine the infiltration capacity of a soil cover and soil moisture complex. One of these is the analysis of hydrographs of runoff from natural rainfall on plots and watersheds. The other is the use of infiltrometers with artificial application of water to enclosed sample areas.

Maximum infiltration rates are measured in the field by applying water to the soil surface either by ponding or as natural or artificial rain at rates sufficient to cause some runoff. Maximum infiltration rates are very high in the beginning of water application, but diminishes in time to much lower, nearly constant values.

In India many type of infiltrometers (as discussed below) are used to determine the infiltration characteristics of the soils. Where infiltrometer data are not available, phi index or empirical formulae are used.

Infiltrometers can be grouped into two general groups; (i) Rainfall Simulators, with the water applied in the form and at the rate comparable with natural rainfall and (ii) Flooding type with the water applied in a thin sheet upon an enclosed area and usually in a manner to obtain a constant head. In India only flooding type infiltrometers are used, which may vary in size, in the quantity of water that is required, and in the methods of measuring the water. In flooding type too, mainly double ring infiltrometers are used, but some times single ring infiltrometers are also used.

Single Ring Infiltrometer

It consists of a metal cylinder which is driven into the soil to a short distance (nearly 15 cm). The time pattern of infiltration is obtained by monitoring the change in supply to the surface. Refinements to the technique involve the introduction of an outer ring as a buffer and devices for monitoring a constant head of supply

Changes in the supply are monitored by recording the water levels in the graduated column above the infiltrometer at selected times.

Double ring infiltrometer or Concentric Ring Infiltrometer

The most common type consists of two shallow concentric rings of sheet metal, usually ranging from 22.5 to 90 cm diameter are placed with their lower edges a few centimetres below the ground surface and with the upper portion projecting above (FIG.4) :

Water is now applied in both apartments 'a' and "b' and is always kept at same level in both. The function of the outer ring is to prevent the water within inner space from spreading over a larger area after penetrating below the bottom of the ring. From the rate at which water must be added to the inner ring in order to maintain a constant level, the infiltration capacity and its manner of variation are determined. A plot of infiltration rate in cm/hr v/s time is shown in FIG.4.

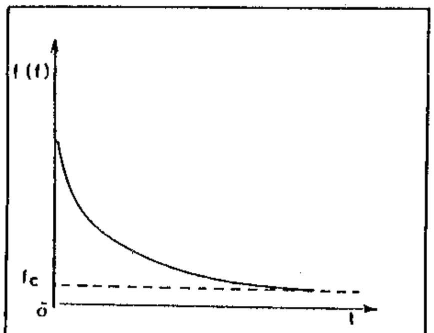

Fig. 1(a) - Typical Infiltration Curve.

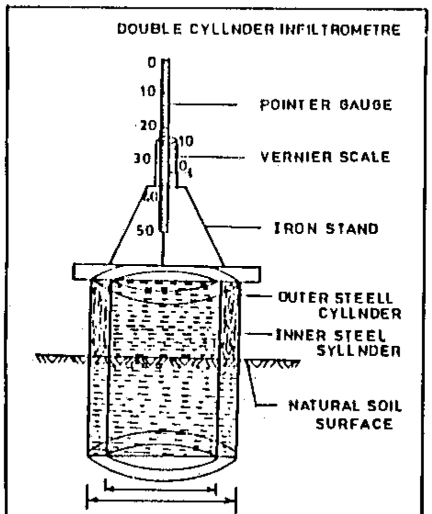

Fig. 1(b) Equipment Measuring Infiltration Rate

FIG.4 : Double Ring Infiltrometer

4.0 METHODOLOGY

Normally, three steps are involved in any field investigation, i.e., pre-field preparations, field investigations and post-field analysis.

4.1 PRE-FIELD PREPARATIONS

Reconnaissance soil survey of the Bargi Left Bank Canal Command area has been carried out by the Soil Survey Unit, Department of Agriculture, Government of Madhaya Pradesh. The soil texture map of the Narsinghpur District was collected from the Department of Agriculture, Narsinghpur (FIG.3). A base map, indicating road network of the area, was prepared using Survey of India toposheets. The soil texture map was transferred on the base map for location of test sites. The sites were tentatively chosen in such a way that different type of soils found in the area are covered and the sites are easily approachable. Twelve sites were identified for the infiltration tests, well distributed all over the area (FIG.5) and covering two soil types. The area covered by third soil type (clay loam) was small, hence no test could be conducted in that type.

4.2 FIELD INVESTIGATIONS

Field work was carried out during the first and last week of October, 1996. During the field work, infiltration tests were carried out at twelve locations and soil samples were collected for soil texture analysis. Information about groundwater level was also collected from local survey (Table-2).

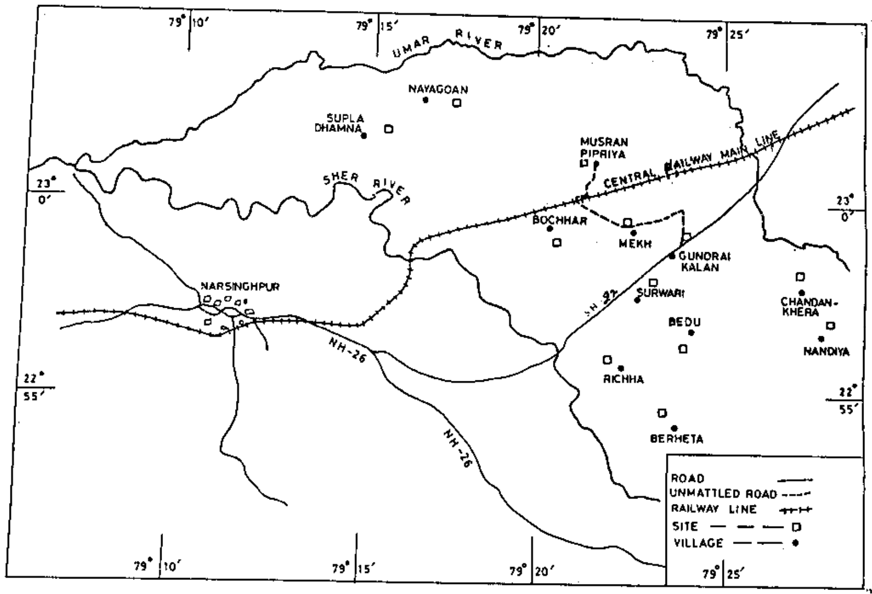

FIG.5 : Location of Infiltration test sites.

Table-2 : Groundwater table depth in Sher-Umar river doab in October 1996.

S.No.	Name of village	Depth to Water Table (m)
1.	Nayagaon	6.6
2.	Supla	6.8
3.	Bedu	9.6
4.	Gundrai Kalan	9.4
5.	Berheta	6.5
6.	Survari	7.8
7.	Bochhar	6.9
8.	Mekh	8.4
9.	Musran Piparia	9.2
10.	Pachauri (Nadiya)	1.3
11.	Chandankhera	7.4
12.	Richha	7.5

Infiltration tests were carried out using micro-processor based double ring infiltrometer. The inner and outer rings used for the test were of 22.5 cm and 35 cm diameter, respectively. The rings were inserted into the ground upto a depth of 25 - 30 cm. The tests were carried out using constant head method with a head of 10 cm. Each test was conducted for such a duration (2 to 4 hrs.) during which the infiltration rate became constant.

4.3 POST FIELD ANALYSIS

After the field work was over, the samples were brought to the National Institute of Hydrology, Roorkee for laboratory analysis, i.e. particle size analysis and Saturated hydraulic conductivity etc.

Textural analysis

The samples collected from the field were tested in the Soil Water Laboratory, National Institute of Hydrology, Roorkee, for the particle size distribution. Particle size distribution of the soils was by sieve and sedimentation analysis. Soil samples were washed with distilled water to remove the soluble salts. The washed samples were separated into two fractions i.e., +75 micron and -75 micron through wet sieving. Sieve analysis was performed for the fraction of soil retained on 75 micron sieve (+75 micron). The portion passing through the 75 micron sieve (-75 micron) was analysed by sedimentation analysis using hydrometers. The test results of the analysis are given in TABLE-3.

Table-3 : Paricle size distribution in soils of Sher-Umar river doab

S. No.	Name of village	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Texture
1.	Nayagaon	4.9	5.4	62.1	27.6	silty clay loam
2.	Supla	0.0	8.9	61.7	29.4	silty clay loam
3.	Bedu	0.5	13.9	37.7	47.9	clay
4.	Gundrai Kalan	2.4	16.4	20.3	60.9	clay
5.	Berheta	2.4	20.2	24.8	52.6	clay
6.	Survari	0.0	6.0	26.8	67.2	clay
7.	Bochhar	1.6	10.3	34.7	53.4	clay
8.	Mekh	1.0	14.0	21.8	63.2	clay
9.	Musran Piparia	0.0	12.5	19.3	68.2	clay
10.	Pachauri (Nadiya)	0.6	24.3	26.0	49.1	clay
1.	Chandankhera	0.4	4.6	22.7	72.3	clay
12.	Richha	0.0	12.8	12.3	74.9	clay

The Table-3 shows that the soils are mostly clayey in texture, except at two places were sand percentage is a bit higher.

Preparation of Infiltration map

Raw data obtained from the field was processed to find the infiltration capacity of the soils (TABLE-4). This soil infiltration capacity was transferred to soil series map of the area and infiltration capacity map was prepared (FIG.6).

Table-4 : Infiltration capacity of the soils of Sher-Umar river doab.

S.No.	Name of village	Infiltartion Capacity (cm/hr)
1.	Nayagaon	4.80
2.	Supla	2.40
3.	Bedu	0.40
4.	Gundrai Kalan	0.12
5.	Berheta	0.10
6.	Survari	0.60
7.	Bochhar	2.40
8.	Mekh	3.00
9.	Musran Piparia	0.24
10.	Pachauri (Nadiya)	2.40
11.	Chandankhera	0.20
12.	Richha	0.20

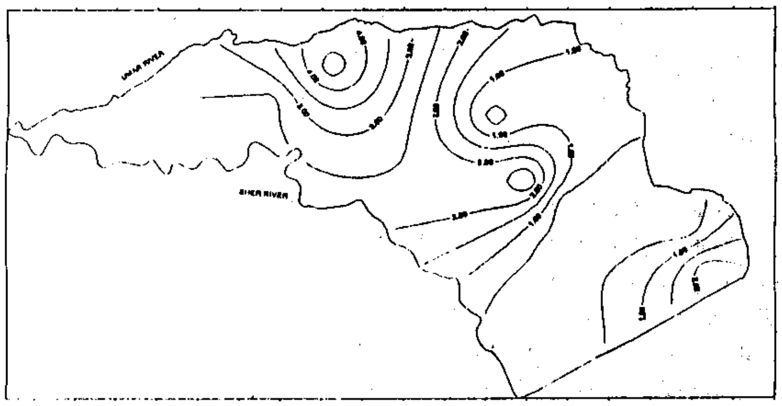

FIG.6 : Infiltration Map of the Sher-Umar Doab

5.0 RESULTS AND DISCUSSION

Infiltration tests were carried out at twelve locations in the Sher-Umar doab in Narmada basin during October, 1996 to assess the infiltration capacity of the soils in that area. Results of the infiltration tests are shown in FIG.7 to FIG.18.

The top soils of Sher-Umar doab area are mostly dark coloured and are clayey in texture. These soils normally form a layer of about 1-2 meter thickness. At few places, underlying coarse calcareous yellow coloured soil are also exposed. Black clayey soils have been derived from Deccan Trap rocks, which are abundant in the nearby areas. Both the black clayey soils and yellow calcareous soils have low infiltration rate, ranging from 0.1 cm/hr to 4.8 cm/hr. In the initial period of water application the infiltration rate is very high which reduces very rapidly with time.

Initial high infiltration rate may be because of the presence of cracks in the soils. As the time of water application increases, the infiltration rate reduces very quickly, may be. due to the presence of swelling clays. The soils derived from basic rocks (like Deccan Trap) generally contain clay minerals like montmorilonite. These clay minerals have the property of expanding in the presence of moisture. This expansion of minerals causes the reduction in pore space as well as the connectivity of pores and hence reduces the infiltration rate. The light coloured soils are rich in $CaCo_3$, as is evident from the presence of kankers in this layer of soils. The low rate infiltration rate may be due to cementation of mineral particles by the calcareous material present.

Till now, limited water is available for irrigation in the form of groundwater. There is no source of surface water except rain water. Therefore, agriculture in the area is mainly rainfed. In the irrigated field, water is applied through sprinklers, from the water derived from groundwater source. Ground water in the area is present mainly in confined conditions and very few dug wells are present.

During rainy season, in the areas having some slope, excess water runs away through small rivulets, but in flat areas or small/shallow depressions the water stands for long periods as the infiltration capacity of the soils is low. This renders the land waterlogged and thereby unusable for quit some time. Only way of removal of this water is through evaporation.

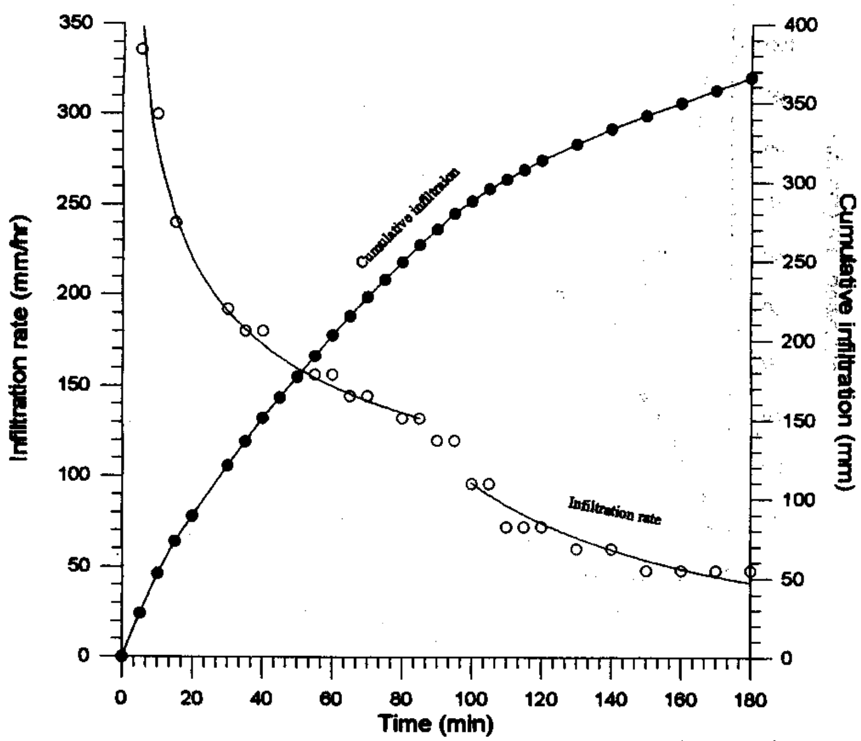

FIG.7 : Infiltration rate and Cumulative infiltration curves at Nayagaon.

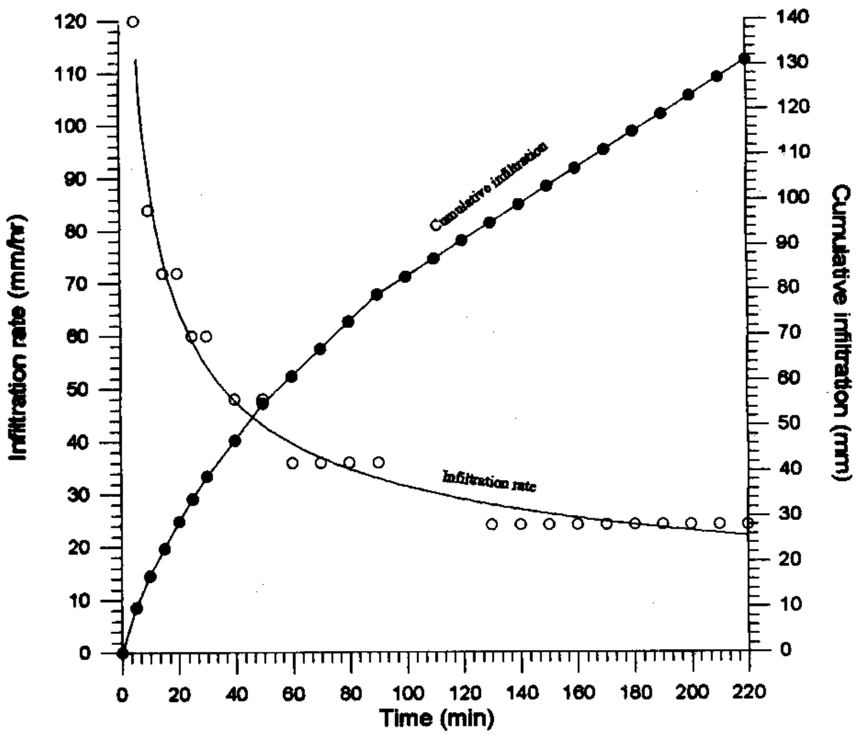

FIG. 8 : Infiltration rate and Cumulative infiltration curves at Supla.

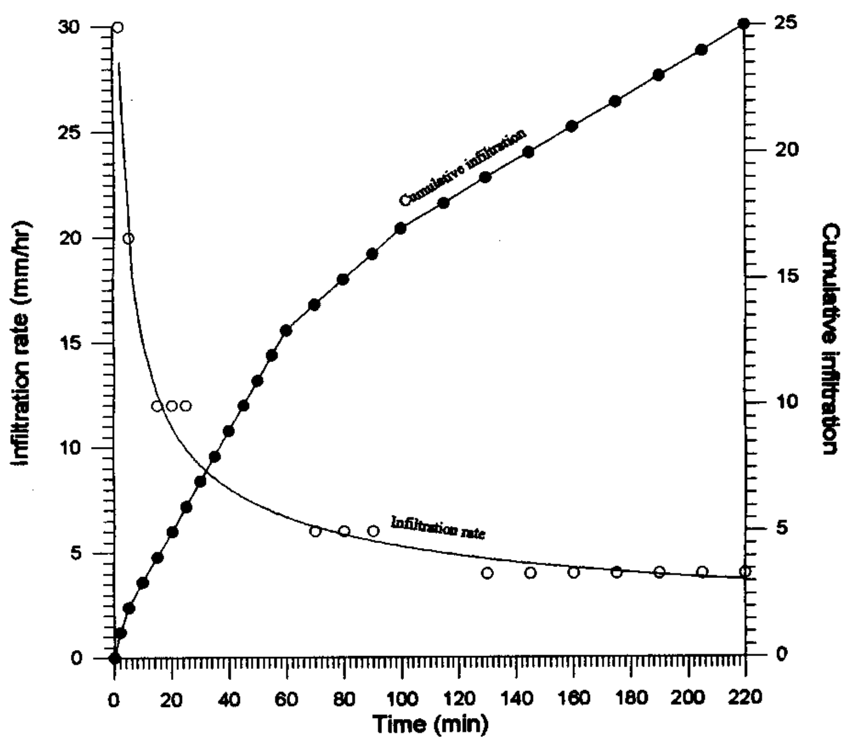

FIG. 9: Infiltration rate and Cumulative infiltration curves at Bedu.

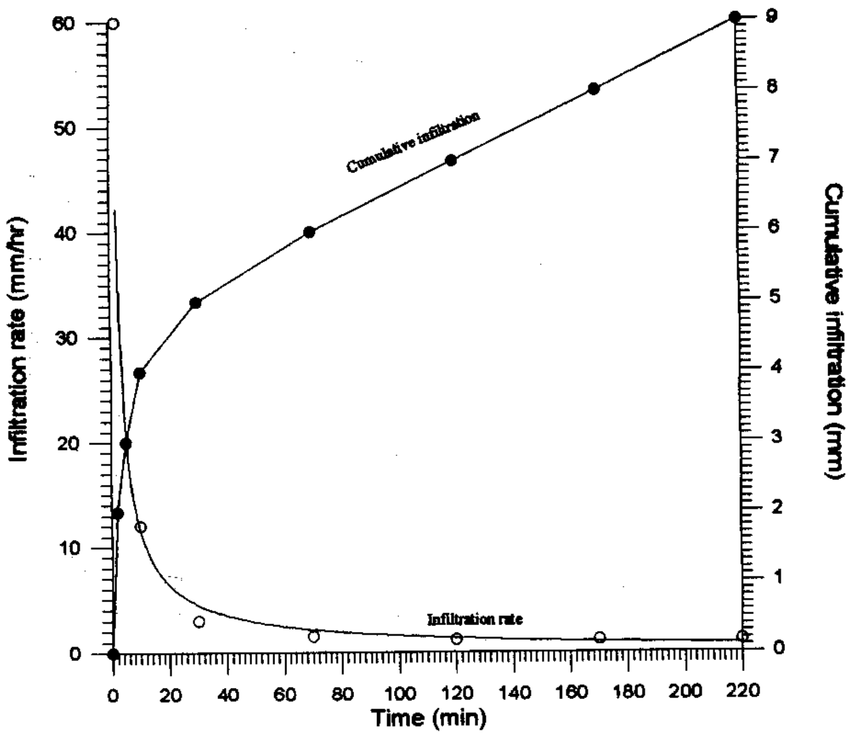

FIG.10 : Infiltration rate and Cumulative infiltration curves at Gundrai Kalan.

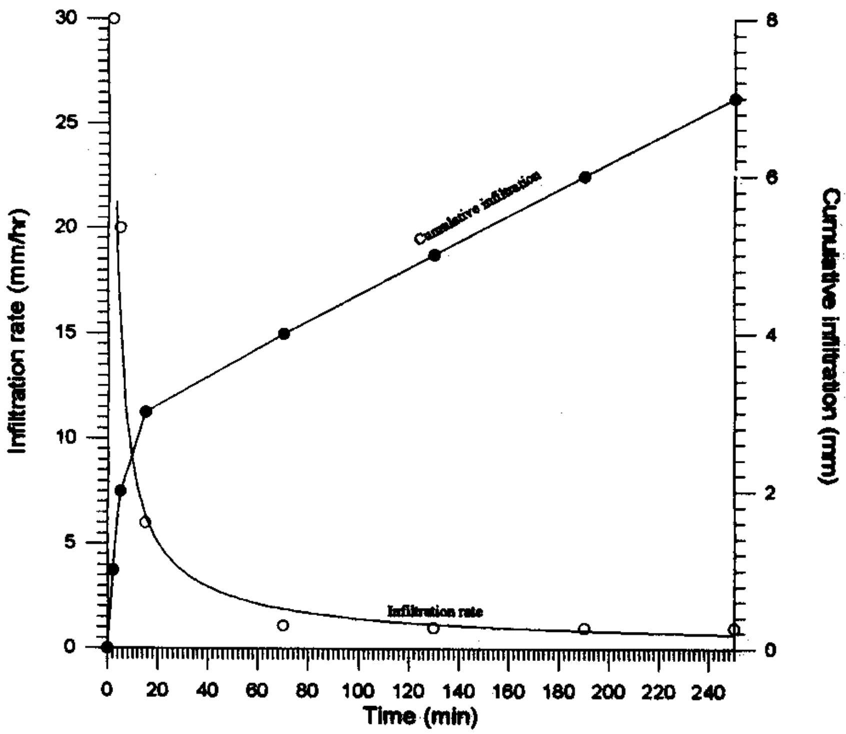

FIG.11 : Infiltration rate and Cumulative infiltration curves at Berheta.

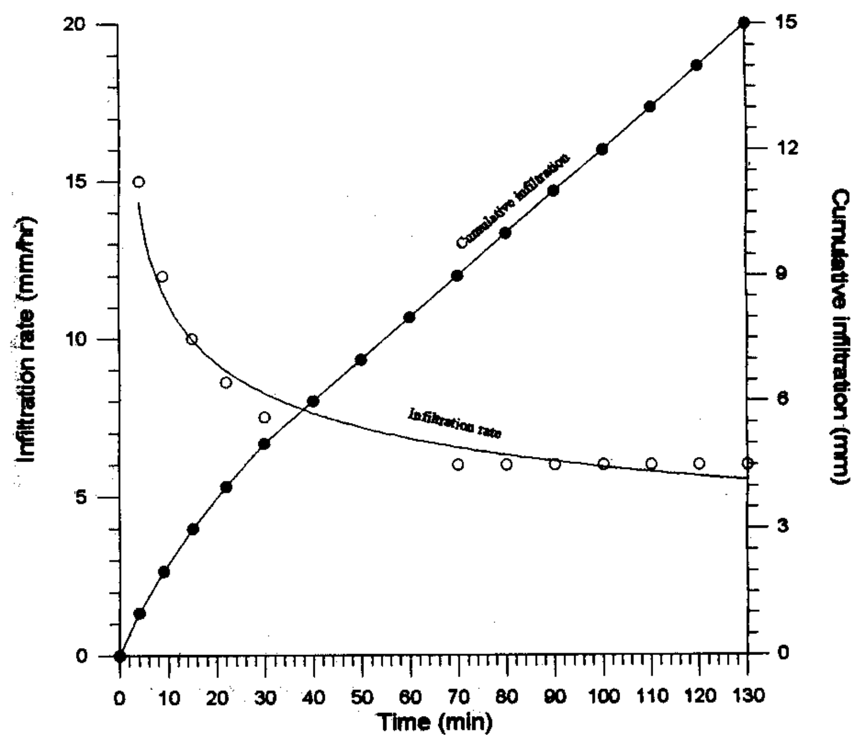

FIG.12 : Infiltration rate and Cumulative infiltration curves at Survari.

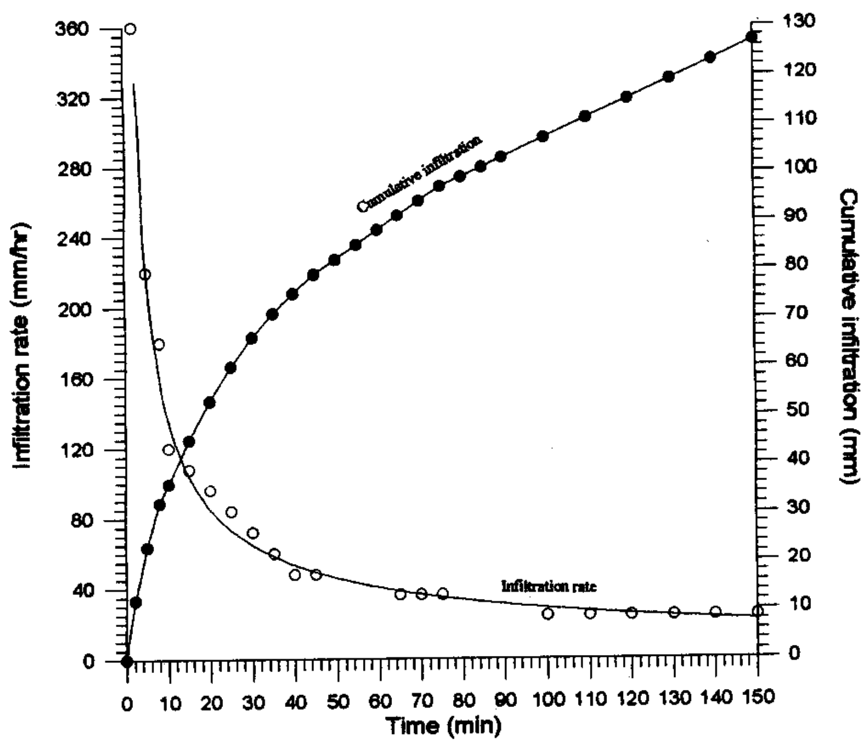

FIG.13 : Infiltration rate and Cumulative infiltration curves at Bochhar.

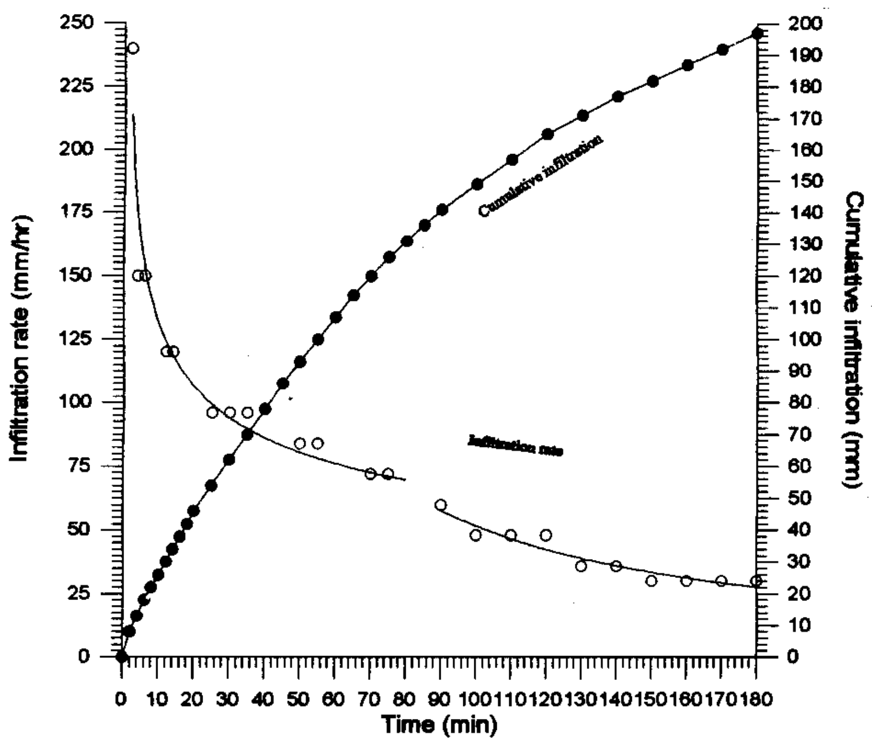

FIG.14 : Infiltration rate and Cumulative infiltration curves at Mekh.

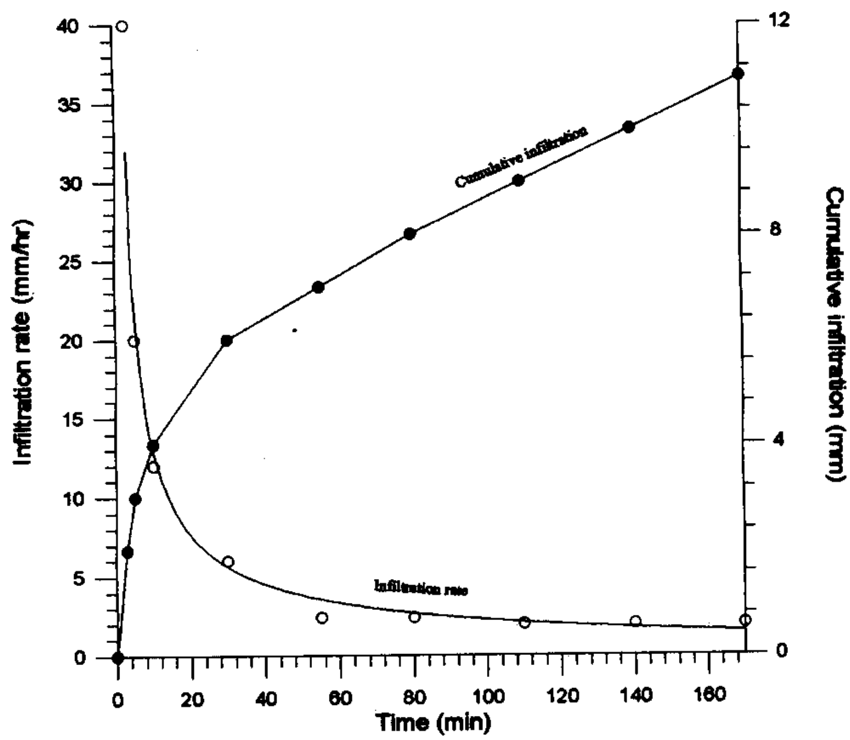

FIG.15 : Infiltration rate and Cumulative infiltration curves at Musran-Piparia.

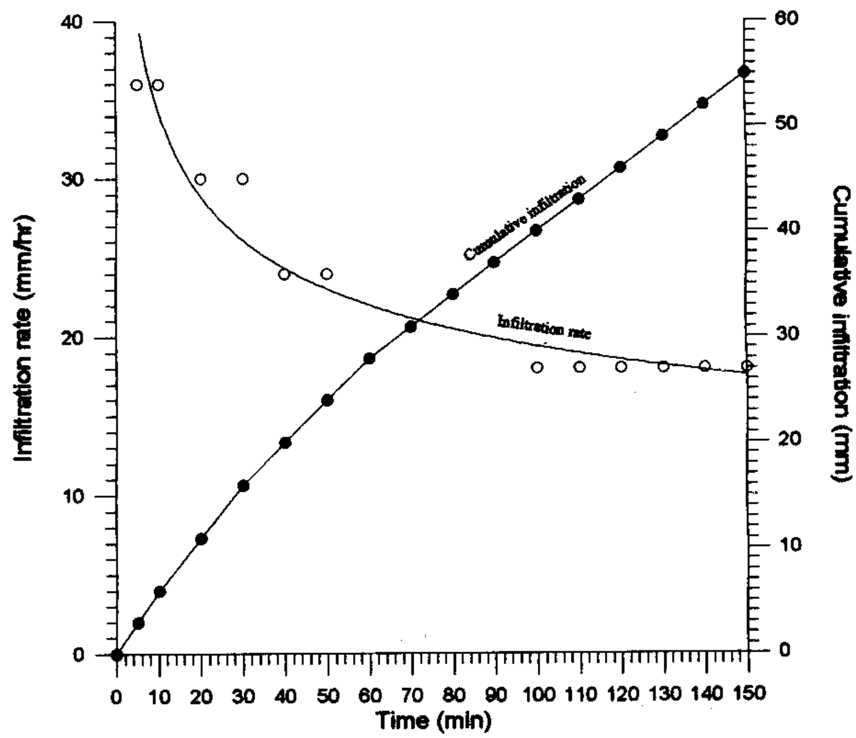

FIG.16 : Infiltration rate and Cumulative infiltration curves at Pachauri.

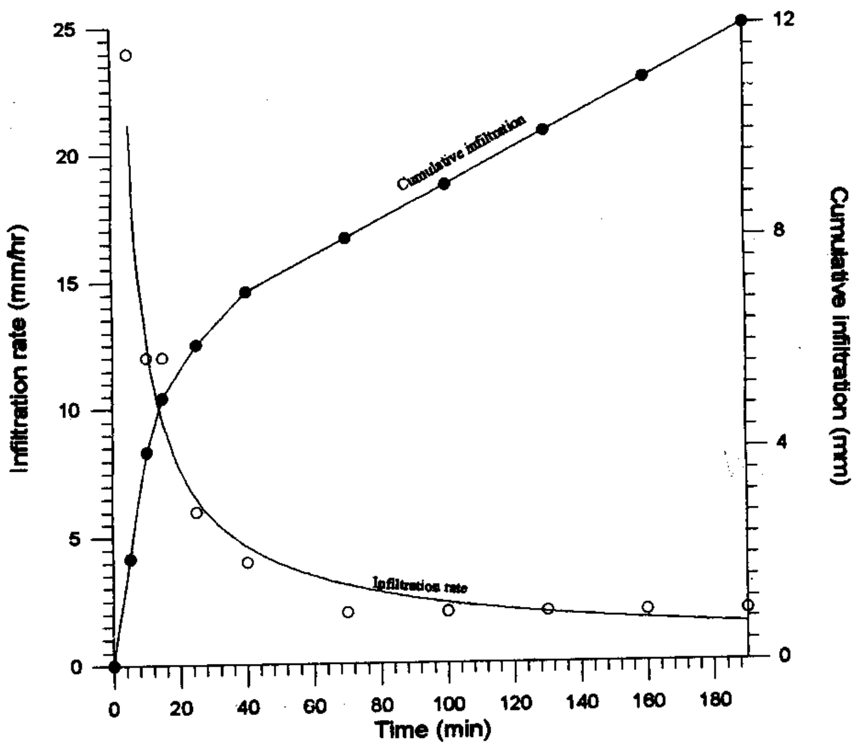

FIG. 17 : Infiltration rate and Cumulative infiltration curves at Chandankhera.

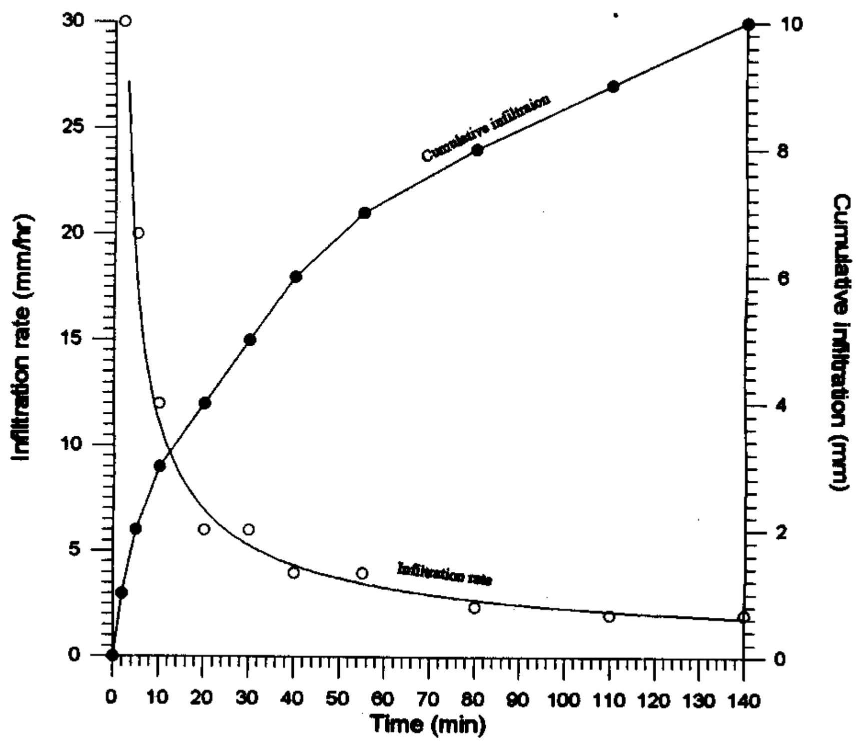

FIG. 18 : Infiltration rate and Cumulative infiltration curves at Richha.

When the Bargi Left Bank Canal will be complete then abundant water will be available for irrigation. For irrigation of land in this area, the water will have to be applied carefully. Excess water will have to be removed through drainage or the water will have to be applied through sprinklers. Otherwise waterlogging or salinisation may occur causing degradation of land.

6.0 CONCLUSIONS

Based on the infiltration tests carried out in the Sher-Umar doab, following conclusions can be derived :

- The soils present in the Sher-Umar doab are mainly black clayey soil (black cotton soils) with very low infiltration capacity ranging from 0.1cm/hr to 4.8cm/hr.

- The soils are not suitable for flooding method of irrigation. If this practice of irrigation is used (after the completion of the Bargi Left Bank Canal), then proper drainage should be provided .

- Excess irrigation with canal water may lead to waterlogging and salinisation.

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APPENDIX -I

Location	:	Village Nayagaon
Latitude	:	23^0 02′ 15″N
Longitude	:	79^0 17′ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	2-3 % towards west
Soil texture	:	Silty clay
Soil moisture	:	High
Water level	:	6.6 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	27th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
5	28	336
10	53	300
15	73	240
20	89	192
30	121	192
35	136	180
40	151	180
45	164	156
50	177	156
55	190	156
60	203	156
65	215	144
70	227	144
75	238	132
80	249	132
85	260	132
90	270	120
95	280	120

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
100	288	96
105	296	96
110	302	72
115	308	72
120	314	72
130	324	60
140	334	60
150	342	48
160	350	48
170	358	48
180	366	48

Location	:	Village Supla
Latitude	:	23° 00′ 02″N
Longitude	:	79° 14′ 30″E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	2-3 % towards west
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	6.8 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	27th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	
5	10	120
10	17	84
15	23	72
20	29	72
25	34	60
30	39	60
40	47	48
50	55	48
60	61	36
70	67	36
80	73	36
90	79	36
100	83	24
110	87	24
120	91	24
130	95	24
140	99	24
150	103	24

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
160	107	24
170	111	24
180	115	24
190	119	24
200	123	24
210	127	24
220	131	24

Location	:	Village Bedu
Latitude	:	22^0 56′ N
Longitude	:	79^0 24′ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	<1 %
Soil texture	:	Silty clay
Soil moisture	:	High
Water level	:	9.6 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	28th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
2	1	30
5	2	20
10	3	12
15	4	12
20	5	12
25	6	12
30	7	12
35	8	12
40	9	12
45	10	12
50	11	12
55	12	12
60	13	6
70	14	6
80	15	6
90	16	6
100	17	6
115	18	4

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
130	19	4
145	20	4
160	21	4
175	22	4
190	23	4
205	24	4
220	25	4

Location	:	Village Gundrai Kalan
Latitude	:	22^0 58′ N
Longitude	:	79^0 23′ 45″ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	<1 %
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	9.4 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	28th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
2	2	60
5	3	20
10	4	12
30	5	3
70	6	1.5
120	7	1.2
170	8	1.2
220	9	1.2

Location	:	Village Berheta
Latitude	:	22° 54′ N
Longitude	:	79° 23′ 30″ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	<1 %
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	6.5 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	29th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
2	1	30
5	2	20
15	3	6
70	4	1.1
130	5	1.0
190	6	1.0
250	7	1.0

Location	:	Village Survari
Latitude	:	22° 57′ N
Longitude	:	79° 22′ 30″ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	<1 %
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	7.8 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	29th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
4	1	15
9	2	12
15	3	10
22	4	8.6
30	5	7.5
40	6	6
50	7	6
60	8	6
70	9	6
80	10	6
90	11	6
100	12	6
110	13	6
120	14	6
130	15	6

Location	:	Village Bochhar
Latitude	:	22° 58′ 30″ N
Longitude	:	79° 20′ 15″ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	Flat
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	6.9 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	30th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
2	12	360
5	23	220
8	32	180
10	36	120
15	45	108
20	53	96
25	60	84
30	66	72
35	71	60
40	75	48
45	79	48
50	82	36
55	85	36
60	88	36
65	91	36
70	94	36
75	97	36
80	99	24

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
85	101	24
90	103	24
100	107	24
110	111	24
120	115	24
130	119	24
140	123	24
150	127	24
160	125	24

Location	:	Village Mekh
Latitude	:	22^0 58′ 30″ N
Longitude	:	79^0 22′ 30″E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	1-2 % towards west
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	8.4 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	30th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
2	8	240
4	13	150
6	18	150
8	22	120
10	26	120
12	30	120
14	34	120
16	38	120
18	42	120
20	46	120
25	54	96
30	62	96
35	70	96
40	78	96
45	86	96
50	93	84
55	100	84
60	107	84

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
65	114	84
70	120	72
75	126	72
80	131	60
85	136	60
90	141	60
100	149	48
110	157	48
120	165	48
130	171	36
140	177	36
150	182	30
160	187	30
170	192	30
180	197	30

Location	:	Village Musran-pipariya
Latitude	:	23^0 00′ 30″ N
Longitude	:	79^0 21′ 30″ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	Flat
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	9.2 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	31th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
3	2	40
5	3	20
10	4	12
20	5	6
30	6	6
55	7	2.4
80	8	2.4
110	9	2
140	10	2
170	11	2

Location	:	Vill. Pachauri (Panchayat - Nadiya)
Latitude	:	22^0 55′ 30″ N
Longitude	:	79^0 26′ 30″ E
Landuse	:	Agricultural barren land
Irrigation	:	Rainfed
Slope	:	Undulating
Soil texture	:	Clay
Soil moisture	:	Moderate
Water level	:	1.3 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	31st Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
5	3	36
10	6	36
20	11	30
30	16	30
40	20	24
50	24	24
60	28	24
70	31	18
80	34	18
90	37	18
100	40	18
110	43	18
120	46	18
130	49	18
140	52	18
150	55	18

Location	:	Vill. Chandankhera
Latitude	:	22^0 57′ N
Longitude	:	79^0 27′ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	Flat
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	7.4 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	31th Oct. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
5	2	24
10	4	24
15	5	12
25	6	6
40	7	4
70	8	2
100	9	2
130	10	2
160	11	2
190	12	2

Location	:	Vill. Richha
Latitude	:	22^0 55′ 15″ N
Longitude	:	79^0 22′ E
Landuse	:	Agricultural barren land
Irrigation	:	Sprinkler
Slope	:	Flat
Soil texture	:	Clay
Soil moisture	:	High
Water level	:	7.5 m
Last rainfall	:	23rd - 25th Oct. 1996
Date of test	:	1st Nov. 1996

Time (min)	Cummulative Infiltration (mm)	Infiltration rate (mm/hr)
0	0	-
5	2	24
10	4	24
15	5	12
30	6	4
50	7	2.4
80	8	2
110	9	2
140	10	2
170	11	2

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