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Hydraulic Performance of Deep Horizontal Tile Drainage System

by

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Abstract ; *The hydraulic performance of deep tile drainage system was evaluated in saline rising water table area. The tiles were laid at a depth of 2.5 m below land surface with 24, 48 and 72 m spacings. The q vs n relationship showed curvilinear trend indicating the contribution of flow mainly from top layers and the existence of impermeable layer almost at the tile level. The variation of quality of drainage affluent was also in conformity with the above observations. The hydraulic conductivity varied between 0.3 to 0.9 m day*$^{-1}$. ***The optimum tile spacing for existing hydrogeological condition was 60-70 m.***

Introduction

In irrigated areas, the seepage from main irrigation distribution system and deep percolation losses due to faulty on-farm water management practices, result in the rise of water table. The problem of rise of water table further gets accentuated due to impeded natural drainage. In the arid and semi-arid regions, ground waters are often rich in soluble salts. The rising water table bring along these salts and when it attains the critical [depth, the loss through capillary rise pushes them to the surface. Evaporation from soil surface and plant water uptake, leaves the soluble salts in the profile resulting in their gradual accumulation in the root zone such that, in course of time, the soils become salinized. In the initial years, the crop yields may be only marginally reduced but are seriously affected in the subsequent years and such lands may have to be abondened because salts render them completely unproductive. Haryana state has a significant share of problem. The state faces this problem of water table rise in more than 2.8 million ha out of its 3.8 million ha arable land. The area under the influence of water table rise is largely underlain by brackish and saline groundwater, an annual supply of about 1.05 million ha m of irrigation water from the various canal systems bring nearly 2 million tonnes of salts to the soils thereby adding substantially to the existing salinity problem. At present approximately 0.5 million ha area is affected by salinity and the area is increasing year after year. Increasing pressure on land resources due to growing demand for food and food products require that area affected with this problem are reclaimed to make them productive. In most irrigated lands in the semi-arid and arid regions, artificial drainage is indispensable for overcoming and avoiding the problem of water logging and salinity.

The research farm of Harayana Agrilcultural University situated in Inland Drainage basin started receiving irrigation water from Bhakra canal system during 1964-65. The canal water allowance was 0.6 cumec per 1000 ha at the distributory head with irrigation intensity of 62 percent at the farmer's fields. A network of observation wells was set up at the farm and adjoining areas to monitor the fluctuation of water table depth and groundwater quality. It showed that during last two decades water table came up at the rate of 60 cm per year (Kumar, et al, 1982) and on an average water table rose from 16.0 m during 1967 to 1.5 m during 1988, (Anonymous, 1988). The water table almost came on the surface during rainy seasons in the area adjoining Farm Minor. The groundwater quality varied from 2 to 30 dS/m. The water quality of shallow tube-wells (about 30-40 m deep) installed during 1966-70 has appreciably deteriorated due to inharent salts in the soil profile and leaching of salts along with the deep percolation losses from irrigation water and subsequent mixing with the groundwater. The pumped water quality trom these tubewells has deteriorated from 4-7 dS/m to 6-16 dS/m rendering most of the tubewell's water unfit for irrigation under existing shallow water table conditions. The studies have shown that in order to prevent secondary salinization, the water table should be maintained at a depth of about 75cm below the maximum height of capillary rise. The maximum height of capillary rise from constant water table for different soils of Haryana has been observed as 62.5-77.5 cm in sands, 117.0-148.4 cm in loamy sands, 155.7-174.5 cm in sandy loam and 127.5-154.1 cm in clay loam (Malik and Kumar, 1983). Therefore in order to minimize secondary salinization, the water table for sandy loam soil should be maintained below 2.25 m. Thus any drainage system in the existing hydrogeological condition where no drainage outlet is available should attempt to maintain the water table below 2 m. The experience of deep subsurface horizontal tile drainage in India is very little, therefore, a pilot project was undertaken to study the hydraulic performance of this system and to resolve the issues such as depth and spacing of drains, drainage material, filter etc.

Back Ground

A horizontal tile drainage system was installed in 10.5 ha. area of vegetable research farm afflicted with very high salinity (2-40 dS/m ECe) and shallow water table conditions ($<$1m). The project area had sandy loam soils with percentage of sand varying between 55-60, the average field capacity and bulk density being 29.5 percent and 1.4 gm/cc respectively. The hydraulic conductivity in the area ranged between 0.2-0.6 m/day and depth of impermeable layer between 12-16 m. The designed tile spacing with 2.5m depth, was estimated to be 43 m (Hooghoudt's formula) taking the drainage coefficient as 2 mm. The SW (Stone ware) pipes of 10cm diameter and 30 cm length were laid at a depth of 2.5 m with a gradient of 1 in 300 with three different spacings 24, 48 and 72 m (Fig. 1). P gravel (2-3 mm diameter) of 10 cm thickness was provided all around the pipe which was covered with Hasen's cloth, before back filling. For collectors, 15 cm diameter RCC pipes were used with sealed collar joints. The inspection chambers were provided for each lateral to facilitate cleaning and recording of data. The observation wells were also installed to monitor water table changes and groundwater quality. A separate sumpwell (open from bottom) ot 5m diameter was provided for each segment to collect the drainage affluent from all the laterals. This sump well also acted as skimming well to drain the areas in the vicinity of the well. The drainage water is collected in the sump well and subsequently pumped into the existing irrigation channels for use at the downstream end either in conjunction with canal water or as such depending on canal running or closure. The water level in the sumpwell is always maintained below collector pipe to avoid backflow by resorting to regular pumping. The effect of drainage on soil

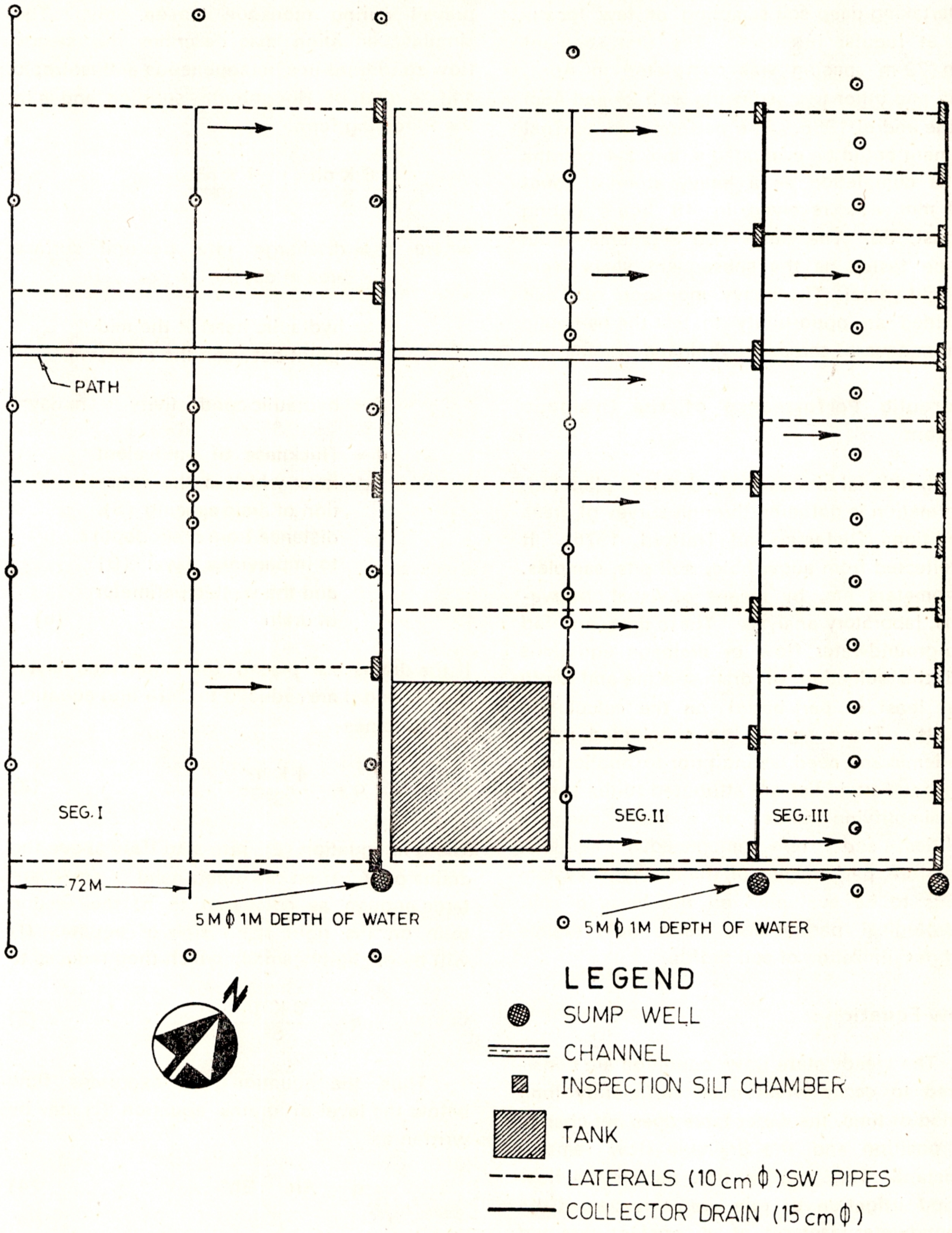

Fig. 1. : Layout of tile Drainage System at Vegetabie Farm H.A.U. HISAR

salinity, crop performance was monitored by undertaking deep soil sampling at few locations at regular intervals. The first segment with 72 m spacing was completed in April, 1985 and other two segments with 24 and 48m by the end of 1986. The performance of first segment could be evaluated within 3-4 months of its completion as a heavy storm of about 200 mm was received in 48 hours during August, 85. The other two segments could not be tested as the subsequent years were drought years. The heavy monsoon of 1988 provided an opportunity to test the hydraulic performance of the entire drainage system.

Hydraulic Performance of the Drainage System :

In rational approach to drainage planning, information is gathered through survey of areas conditions (Dieleman and Trafford, 1976). It is collected from auger hole, soil pits, samples, piezometers etc, by means of visual observations, laboratory analysis. These data are fed into groundwater flow or drainage equations and the selection of drain spacing and depth is at least in part-based on the calculation results. These results are considered rather academic and need testing prior to application. These uncertainities are attributed to the use of oversimplifying model of a very complex realities and non-homogeneous aquifers. Therefore, performance of the drainage system needs to be evaluated on the basis of soil-hydrological parameters, water table regime and desalinization of soil profile.

Flow Equation :

The steady state flow condition are considered to occur when over sufficiently long period of time, the water table does not change its position and the drainage flow remains constant. This implies that during the flow period irrigation or rain water recharges the groundwater reservoir at a constant rate and is equal to drain outflow for a sufficient time span. Such a situation in the area is likely to prevail during monsoon season only. The simplest equation that describes the steady flow conditions in a homogeneous and isotropic soil is that of Hooghoudt's solution and is in the following form,

$$q = \frac{8\,K\,dh}{S^2} + \frac{4\,K\,h^2}{S^2} \qquad (1)$$

where q = discharge rate per/unit surface area m day^{-1}

h = hydraulic head at the mid point between the drain, m

K = hydraulic conductivity m day^{-1}

d = Thickness of equivalent layer which is the function of drain spacing (S), distance from drain depth to impervious layer (D) and the wetted perimeter of drain (u)

If the drains are placed on impervious layer, then D and d are reduced to zero and equation (1), becomes

$$q = \frac{4\,K\,h^2}{S^2} \qquad (2)$$

The q in equation (2) refers to flow above the drains only. If on the other hand D and d are large enough as compared to h, the second term on the right hand side of equation (I) will be negligibly small, which then reduces to

$$q = \frac{8\,K\,dh}{S^2} \qquad (3)$$

Thus, the equation (3) expresses flow below the level of drains equation (I) may be written as

$$q = Ah + Bh^2 \qquad (4)$$

$$\text{or} \quad \frac{q}{h} = A + Bh \qquad (5)$$

where $A = \frac{8Kd}{S^2}$, $B = \frac{4K}{S^2}$

System Testing :

The discharge measurement from each tile was made three times a during period of high discharge following recharge i.e. 2 - 3 days after heavy rains during Sept. 24, 1988. During periods of distinct decreases in discharge rate, the frequency of measurement was decreased to two times a day. Following constant outflow, the measurements were taken only once a day. For water table heights, the observations were recorded at least four times a day during periods of high water table elevation at uniform time interval. Thereafter the frequency of recording was reduced to once a day following constant discharge. The observed discharge rate from each tile was converted into m day^{-1} and the water table depths were converted into hydraulic head in m. Figs. 2. 3, 4 show the plot of q VS h and q/h VS h for segment I, II and III respectively for a selected tile in each segment. In all the figures the relationship between q and h was curvilinear indicating that the flow above the tile level is quite significant. To facilitate the interpretation of results, d/h VS h was plotted which yielded straight line as indicated by equation 4. The hydraulic conductivity was determined by using equation (5),

$$B = \frac{4K}{S^2} = \tan \text{ i.e. the slope of the line}$$

The value of KD was determined by $A = \frac{8Kd}{S^2}$, where A is intercept of the line. The results indicated the spatial variability of hydraulic conductivity. It varied between

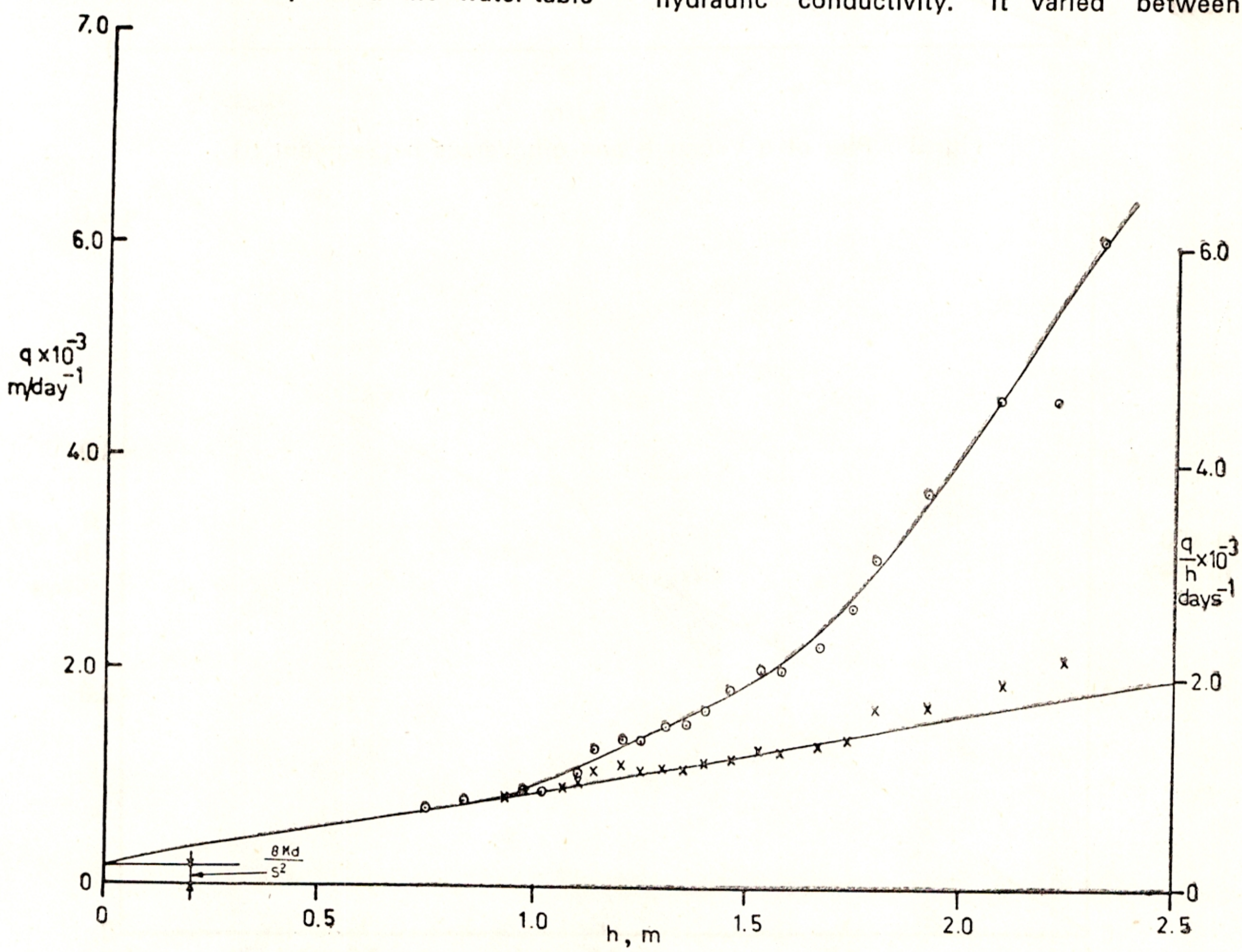

Fig. 2 : Plot of q Versus h and q/h Versus h (Segment I)

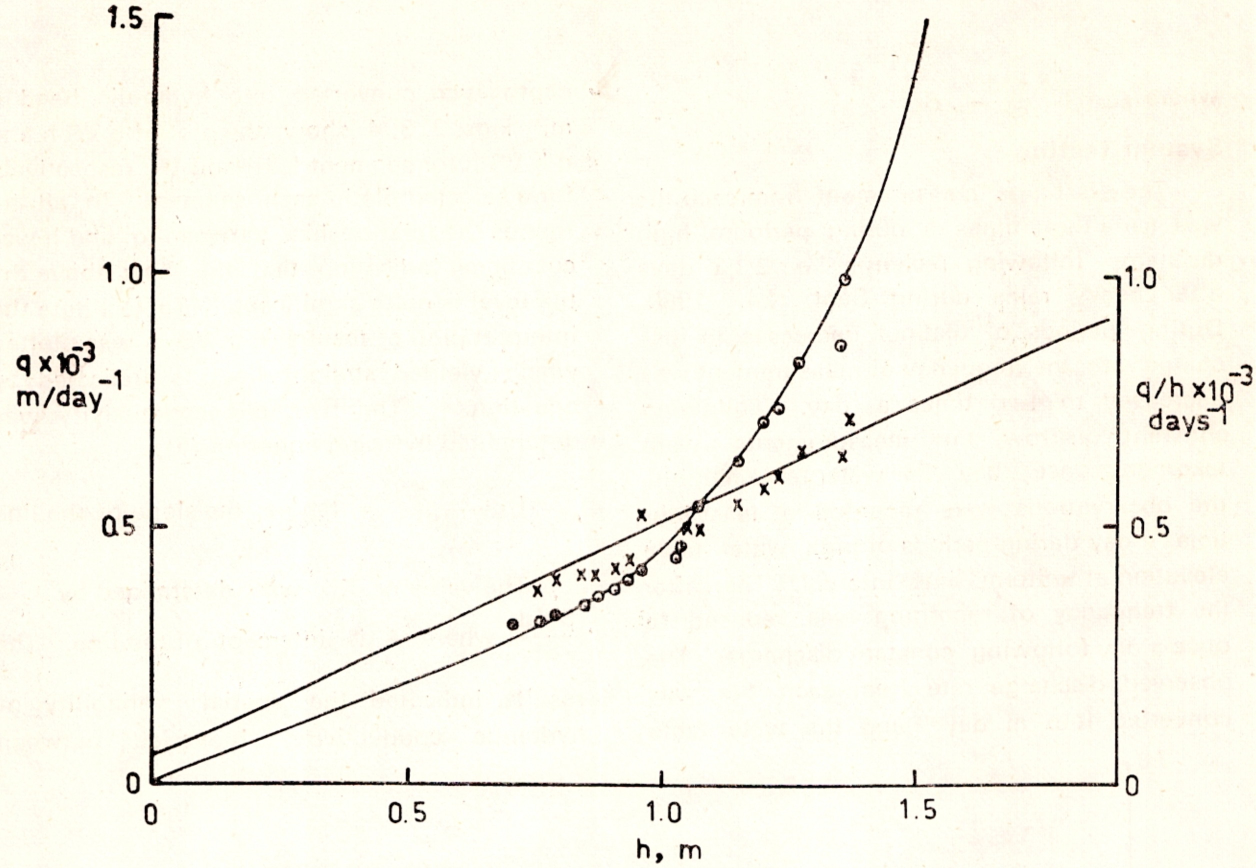

Fig. 3 : Plot of q Versus h and q/h Versus h (Segment II)

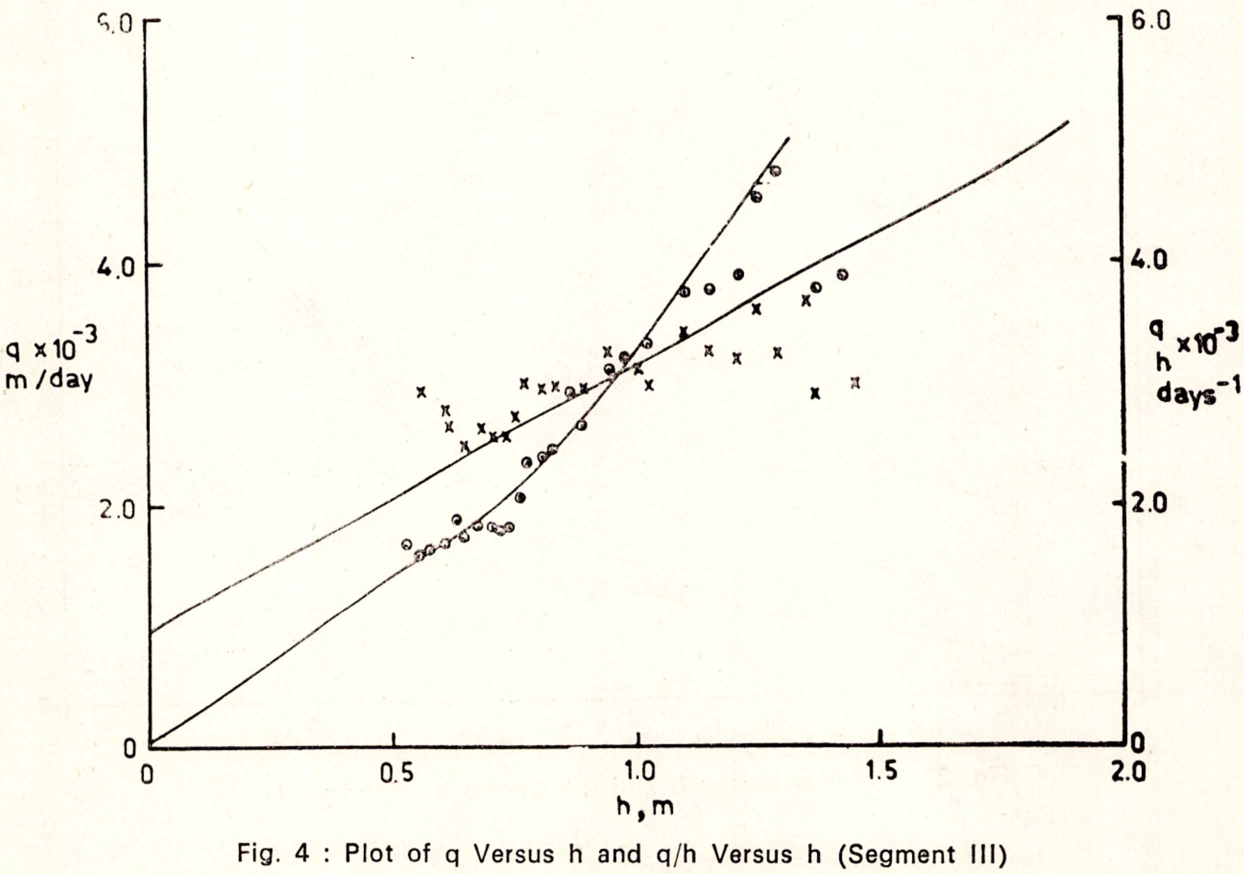

Fig. 4 : Plot of q Versus h and q/h Versus h (Segment III)

0.23 to 0.93 m day^{-1}. The equivalent depth d in all the three cases was almost negligible indicating that tiles almost rested on the impervious layer, and most of the flow took place from above the tiles. This is further supported by the fact that the quality of drainage water affluent marginally increased (Fig. 5). Had the impervious layer been deep

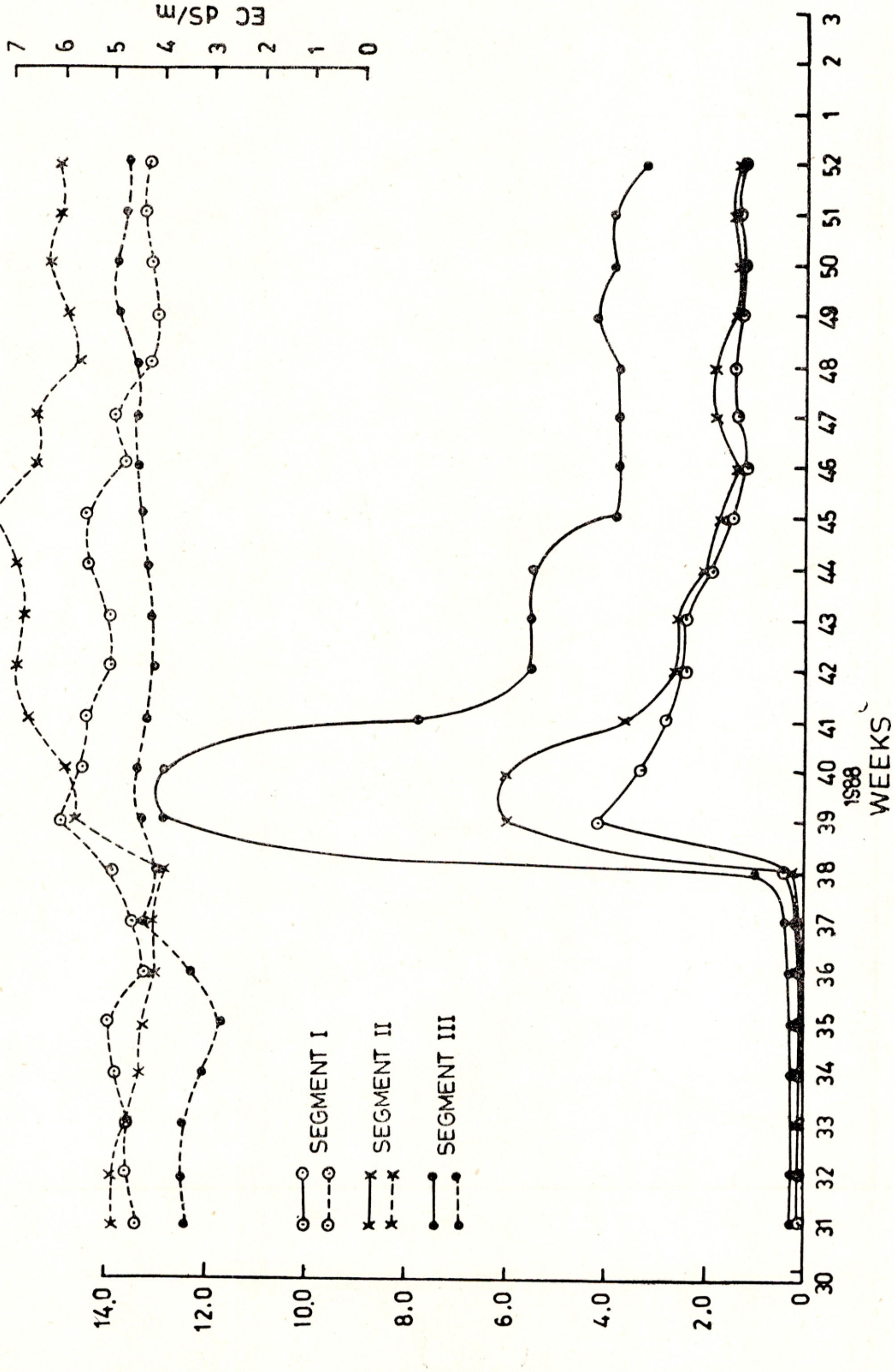

Fig. 5 : Variation of Drainage Coefficient and Drainage Water Quality with time

enough, the deeper soil column would have contributed as most of the flow would have taken place in that situation from below the tiles and thereby resulting in higher salinity of drainage affluent. Fig. 6 shows the variation of soil salinity with dcpth at one of the test points. In the beginning (August, 86), the soil salinity was quite high particularls in the top layers which registered a sharp decline over the years. By August, 1988, before the

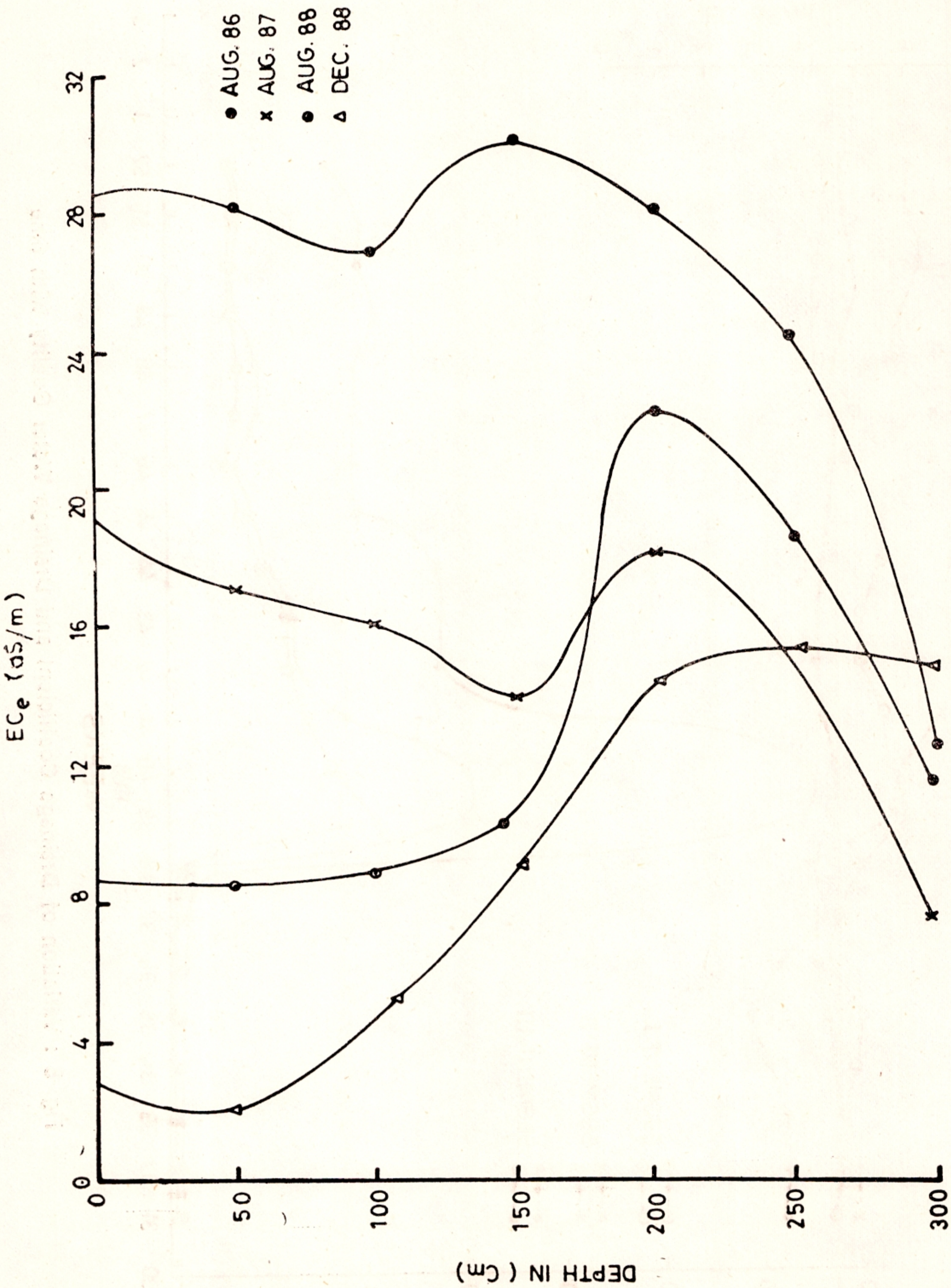

Fig. 6 : Soil Salinity Profiles Test Location (T_4)

onset of heavy monsoon, the salinity in the top layers was nearly 9 dS/m which declined sharply to less than 3 dS/m with salinity increasing in the bottom layers. It further establishes the existence of impervious layer close to the tile level. Though, for design, the impervious layer (thick clay layer) was assumed to exist at 12 - 16 m based on the litholog of the tubewell existing in the area, but the testing of the system reveoled that relatively less impervious layer of small thickness close to the title level acted as impermeable layer,

Effect of spacing on Drainage Coefficient and water table depth :

Fig. 5 shows the variation of drainage coefficient with time during 1988. Before the occurence of heavy storm of 200 m in hours, the drainage coefficient in all the segments was less than 0.5 mm which shot up to 13 mm in segment III followed by 6 mm and 4 mm in segment II and segment I respectively. The drainage coefficient, thereafter, declined abruptly in all the segments maintaining the same trend

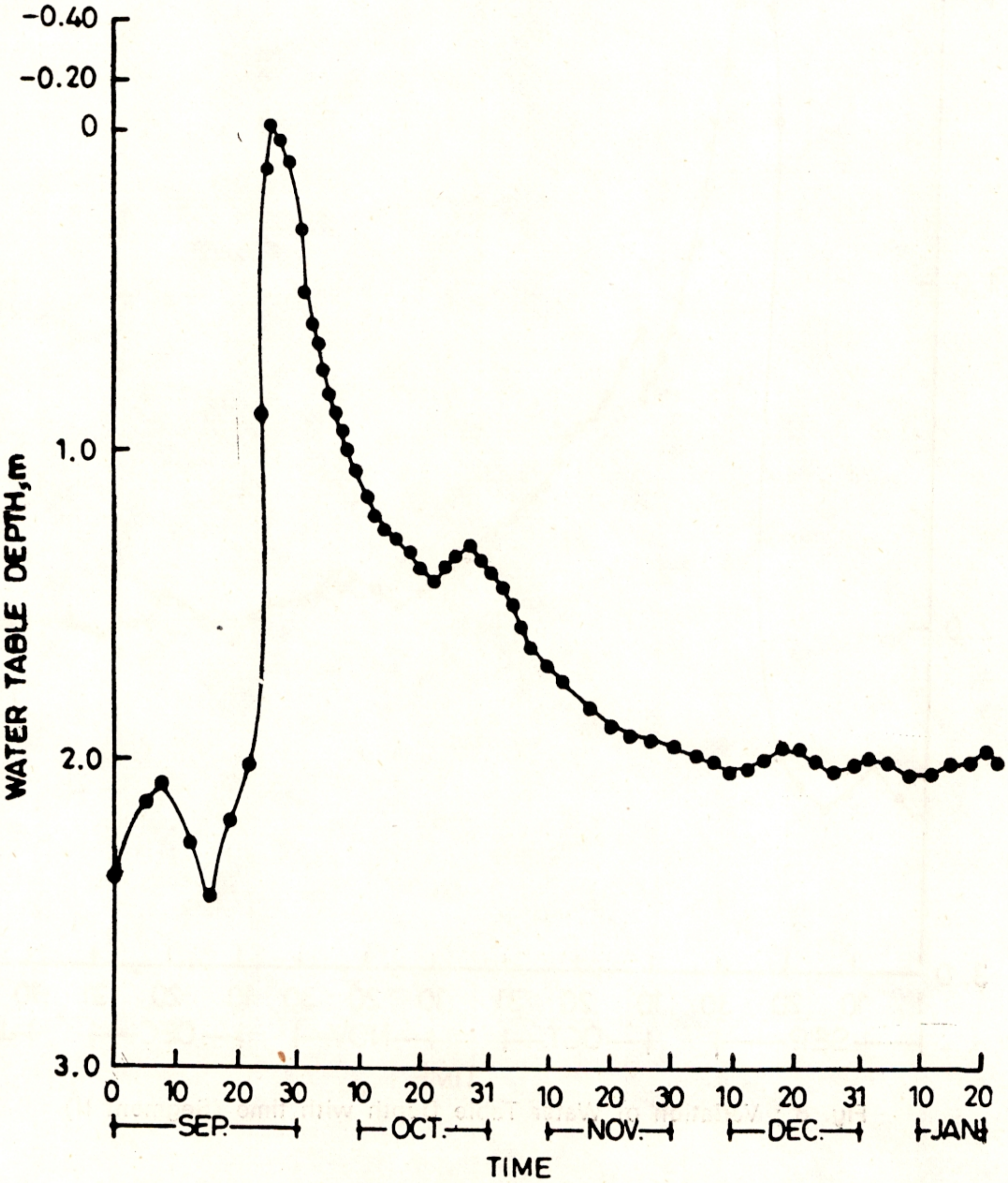

Fig. 7 : Variation of Water Table Depth with Time (Segment I)

The variation of water tabie depths as observed in the centre of two tile lines during monsoon of 1988 in all the segments are shown in Fig. 7, 8, 9. As is clear from these figures, the water table was close to tile level which came up as a result of heavy storm, it got depressed to 0.8 m, 0.9 m, 1.0 m within a week (Ist week of October) in segment I, II, III, respectively. In segment I and II, it further declined to 1.4 and 1.5 m by third week of October where as in segment III it got depressed to **2** m by 2nd week of October. It clearly indicates that hydraulically 24 m tile spacing performed more efficiently as compared to other two spacings. The tile spacing of 48 and 72 m performed almost similarly with respect to depressing of water table within a reasonable period which for most of the crops was safe. The cost of laying tiles at 24 m spacing was much higher, therefore, under the existing conditions of pilot area 60 - 70 m spacing appears to be optimum.

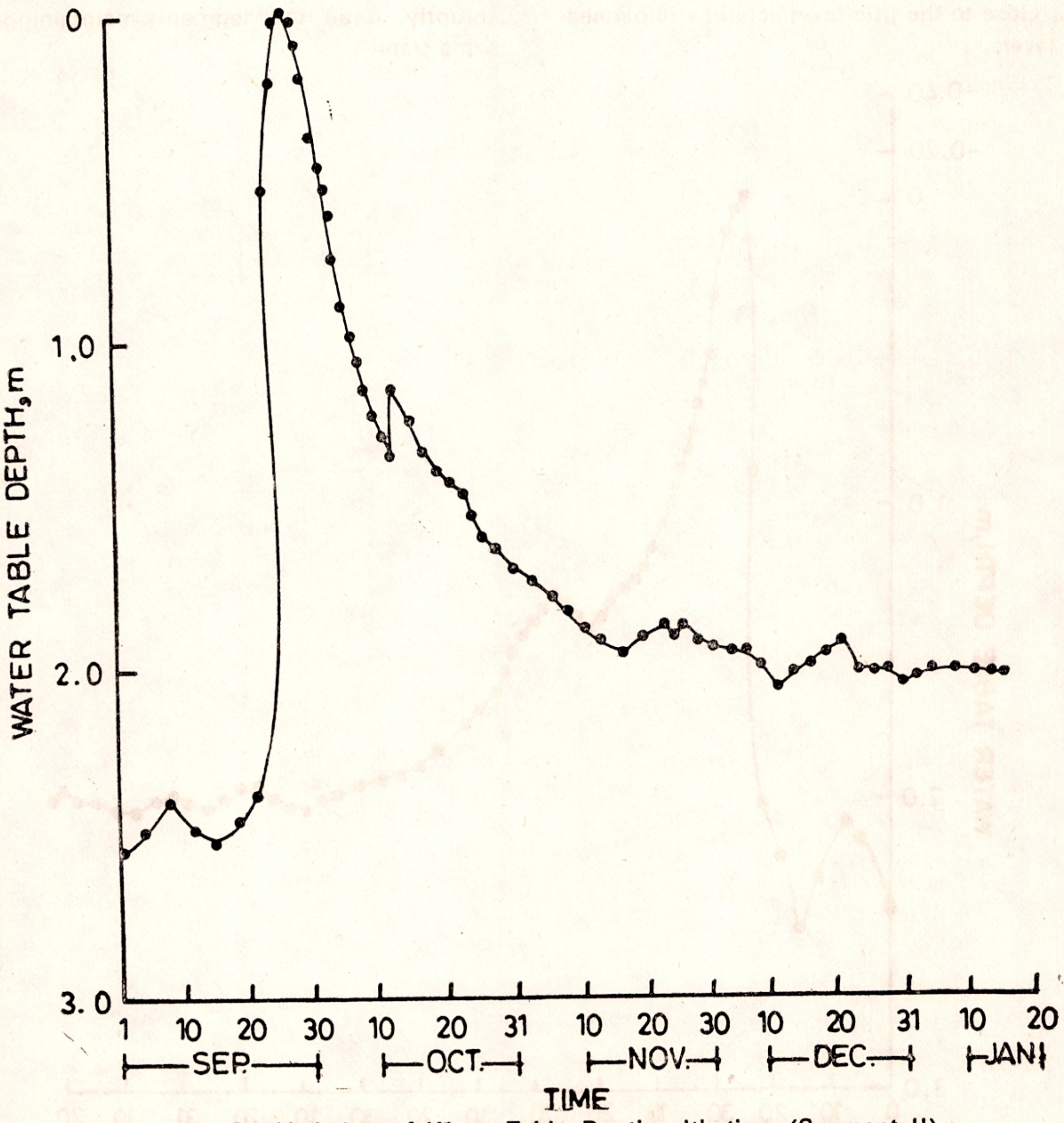

Fig. 8 : Variation of Water Table Depth with time (Segment II)

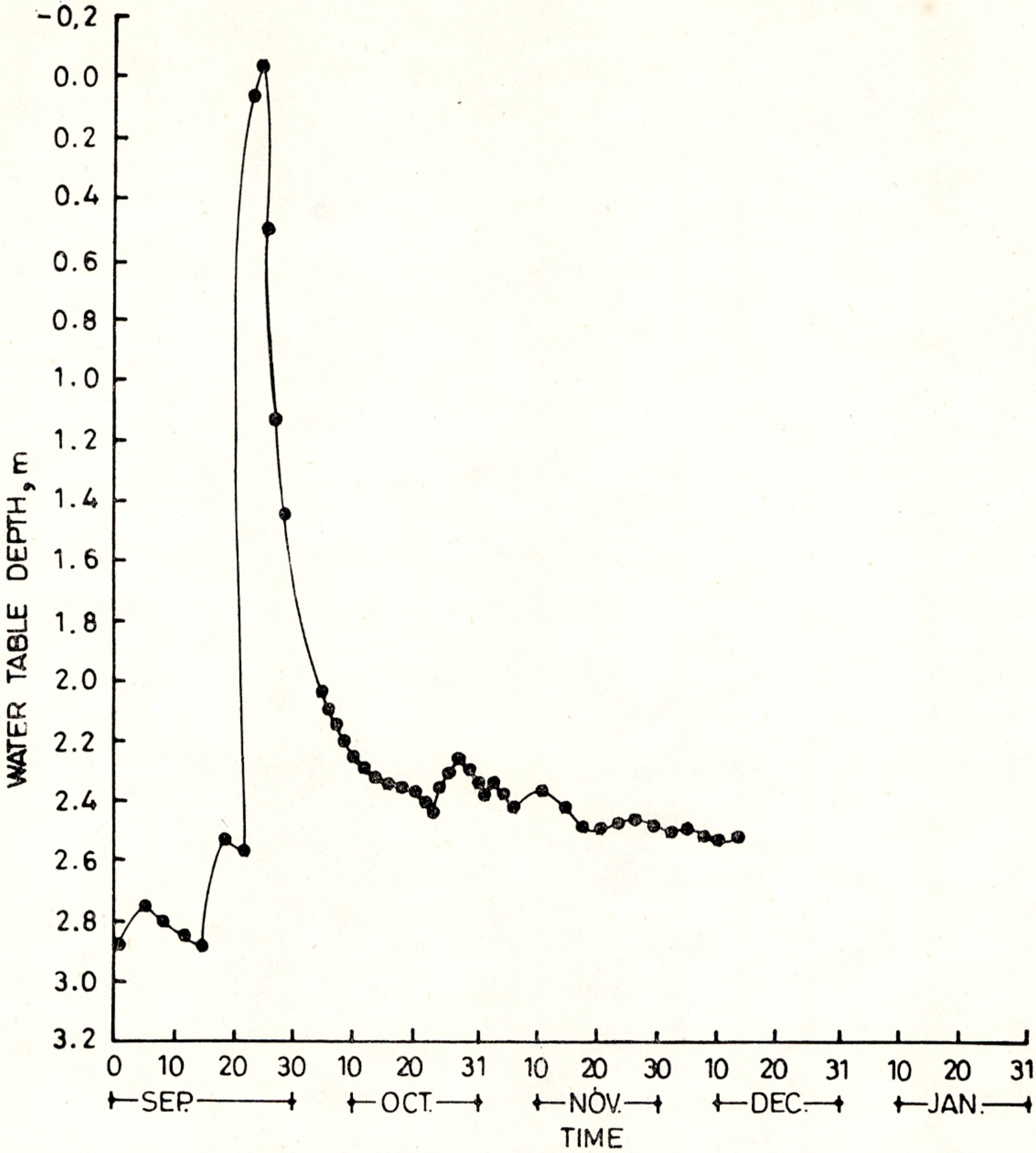

Fig. 9 : Variation of Water Table Depth with time (Segment III)

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