A SUBSURFACE IRRIGATION EXPERIMENT ON A ST. SAMUEL SANDY LOAM SOIL

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ABSTRACT

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SUBSURFACE IRRIGATION IN A ST.SAMUEL SANDY-LOAM SOIL

Using a subsurface irrigation system, set up in the summer of 1983 in a modified subsurface drainage system, water table distributions were observed in eight irrigated plots and eight non-irrigated plots. The various components of the head loss in the system were isolated and their values calculated .

The total irrigation water input was measured and the effect of this input on the water table was observed.

It was found that the water table could be raised approximately 5-10 cm per day. The irrigation was far from ideal due to an inadequate water supply, nonetheless the overall yield from the irrigated plots was about twice that of the non-irrigated plots.

At the time of planning the experiment, it was thought that the water table should be within 60 cm from the soil surface, however the average depth obtained in this experiment was only approximately 75 cm, because of the inadequate water supply.

RESUME

Maîtrise Bernhard von Hoyningen Huene Génie Rural

IRRIGATION SOUTERRAINE D'UN SOL SABLONNEUX DE ST. SAMUEL

Un système d'irrigation souterraine a été installé pendant l'été 1983, en modifiant le système de drainage souterrain. Ceci a permis une observation de la distribution de la nappe phréatique, sur huit parcelles irriguées, et huit parcelles non-irriguées. Les différentes composantes, de la perte de charge dans le système, ont été isolées et leurs valeurs calculées.

L'intrant total d'eau pour l'irrigation a été mesuré et son effet sur la nappe phréatique a été observé.

Il a été constaté que la nappe phréatique pouvait être rehaussée de six à dix cm/jour, approximativement. Les conditions d'irrigation n'étaient pas idéales, de par le manque d'eau, toutefois, le rendement total des parcelles irriguées a été le double de celui des parcelles non-irriguées.

Au cours de la planification de l'expérience, il a été considéré que la nappe phréatique devait atteindre un niveau de 60 cm de la surface du sol, toutefois, en pratique, le niveau moyen obtenu a été de 75 cm approximativement, ceci étant dû à un approvisionnement insuffisant en eau.

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LIST OF SYMBOLS

Symbol		
A	=	area (l^2)
E	=	evapotranspiration rate (l/t)
H	=	height of water table above drain (l)
K	=	hydraulic conductivity (l/t)
L	=	length of drain (l)
Θ	=	volumetric water content
Q	=	discharge rate (l^3/t)
R	=	Reynolds number
S_e	=	slope of the energy grade line (l/l)
V	=	potential (F/l^2)
V	=	discharge velocity (l/t)
Y	=	vertical distance between water table and the impermeable layer (l)
d	=	pipe diameter (l)
d	=	equivalent depth (l)
h	=	head loss (l)
h	=	height (l)
h_r	=	hydraulic head at the ideal drain radius r (l)
h_s	=	hydraulic head at a radius r_s (l)
m	=	deflection of the water table at midspacing (l)
n	=	Manning's roughness coefficient
n_{CH}	=	number of flow channels
n_{PD}	=	number of potential drops
q	=	drainage coefficient (l/t)

Symbol

r_e = effective drain radius (l)

r_s = radius of the drain(l)

r = ideal drain radius(l)

s = drain spacing (l)

t = time (t)

v = flux (l/t)

v = kinematic viscocity (l^2/t)

x = horizontal coordinate (l)

y = horizontal/vertical coordinate (l)

z = vertical coordinate (l)

CHAPTER I

INTRODUCTION

1.1 General

Subsurface irrigation has been used in the Netherlands and Northern Germany for a number of decades. Ditches were built that could drain as well as irrigate the land. Today's method of subsurface irrigation no longer requires ditches but rather drainage tubes. The irrigation water is distributed in the fields via these tubes. The resulting water table distribution will be such that the water table is highest above the drain and lowest at midspacing.

In Quebec, large areas of land have been made more productive with the aid of drainage systems, since many fields were too wet to cultivate. However, certain fields with sandy soils, have a tendency to overdrain, due to the fact that the drainable porosities of these soils are relatively high. During dry summers, such as the summer of 1983, drought-like conditions occur on these soils, which in turn effect the yield negatively.

This research was done to see if a subsurface drainage system may be modified economically, such that it can be used for both, drainage and irrigation. The main factors are the availability of irrigation water and the optimum water table depth to obtain maximum yield. These two factors are interrelated, that is to say, the amount of water required depends on the water table depth and vice versa.

Since the water table distribution produced by this type of irrigation will not be even, due to the hydraulic head losses in the soil, a relatively flat topography is required to minimize the effect of this unevenness.

1.2 Objectives

The objectives of this study were:

1) To assess the feasability of converting a subsurface drainage system to a subsurface drainage/irrigation system in sandy soils.
2) To evaluate the water requirements of the experimental plots.
3) To evaluate the hydraulic head losses in a subirrigation system.
4) To observe the speed at which the water table may be raised by subsurface irrigation.
5) To determine whether the problem of poor water distribution during the first year of subirrigation was due to problems with the drainage pipes, which had been installed ten years earlier.

1.3 Scope

The results of this research would have been further enhanced by a comparative study of water table depth to crop yield, however neither time nor money was available for such an undertaking.

Furthermore, only one drain spacing was used, since further research of the effect of drain-spacing on the water table distribution was not possible due to financial and time constraints.

To obtain a more exact measure of evapotranspiration, it would have been necessary to evaluate the upward flux of water from the water table, but that would have included a study of unsaturated flow, which was considered beyond the scope of this research.

CHAPTER II

REVIEW OF LITERATURE

2.1 Historical Background

The term 'Subsurface Irrigation', also referred to as 'Subirrigation', is used here to signify the raising of the water table to supply the necessary moisture to plant roots. This practice is well known in both The Netherlands and Northern Germany, where the height of the water table was controlled by open ditches. These ditches, in turn, were connected to the rivers by means of sluices, which were built into the extensive dike system existing in these areas. Originally, the ditches were built for drainage purposes only, however due to improved drainage methods, the water table dropped sufficiently that irrigation became necessary on certain types of soil. According to Gwinner (1945), the summer of 1926 was so dry, that more dike sluices had to be installed in certain sections of the lower Weser river district in Northern Germany, to satisfy the irrigation demands. At high tide, the sluices were opened and water flowed into the ditches, as the tide retreated the sluices were closed again, leaving the water brought in by the tide in the ditches. The effect was that the water table rose in the fields.

The same system was used in The Netherlands, where subirrigation was also practiced extensively (Hooghoudt, 1952). Holland is a country, that due to its low elevation has had to design an extensive drainage system; consequently it has one of the most extensive subirrigation system in the world (Criddle and Kalisvaart, 1967).

The main problem however, seemed to be the lack of knowledge in the design of these systems, they seemed to just evolve as the need for them arose.

Renfro (1955) investigated the use of subirrigation and controlled drainage practiced in some regions of the United States. Controlled drainage may be considered to be a form of subirrigation, in as far as it employs a method of regulating the outflow of drainage water, thereby exerting some control over the depth of the water table. Since the use of subsurface drains has become quite popular, due to economic reasons, the regulation of the outflow from such a drainage system has become rather simple. A design of such a system is given by Doty <u>et al.</u> (1975).

One of the first to actually set up design standards were Fox <u>et al.</u> (1956). Later, Skaggs (1979) set up the design criteria that should be used, when a subsurface drainage system is also used as a subirrigation system. When the drain spacing is calculated, the following three points have to be kept in mind:

1) First of all, a drainage system should be designed, such that it can drain the fields in

a relatively short time, ie. the drain spacing should be such, that adequate drainage is provided in times of excess precipitation.

2) To include the subirrigation capacity in the system, the drain spacing should be such, that the water table may be raised in a short a period of time as possible.

3) The drain spacing has to allow the capability to achieve a steady state condition during high evapotranspiration periods.

After the drain spacing has been calculated for each of the above three cases, the smallest is then selected as the design drain spacing for such a system.

2.2 Water Table Depth

To be able to design a subirrigation system, one has to consider the role that the depth of the water table plays in the growth of the root system of plants.

2.2.a Effect of Water Table Depth on Yield

The optimum water table depth depends on both the type of crop grown, shallow to deep rooted plants, on the type of soil and, of course, the combination of the two. Furthermore, this optimum depth fluctuates from year to year, depending on the climatic factors, precipitation and potential evapotranspiration (Luthin et al., 1957). It was found that shallow rooting crops need a high water table and that the optimum level depend heavily on the soil type. At higher than optimum water tables, the plants will suffer, due to the lack of aeration, thereby restricting root growth, whereas at lower levels, yield decreases due to water deficiency. The approximate depth may be deduced by investigating the physical properties of the soil, such as capillary rise, water holding capacity etc. (van Schilfgaarde, 1974).

Several experiments have been conducted, showing the effects of a controlled water table. Blaauw (1938) (cited by Luthin et al., 1957), in his investigation of the relationship between water table height and yield of bulbs, found that the optimum water table depth was 50 cm in a coarse sand, whereas it was 60 cm in a fine sand. Since the sand contained little organic matter, low water retention capacity, a lowering of the water table by just 10 cm resulted in a significant decrease in yield. Doty *et al.* (1975), comparing controlled drainage and undrained experimental plots on sandy soils, showed that corn yields were increased if the water table was kept approximately 1 m from the soil surface. Similar results were reported by Follet *et al.* (1974) on sandy soils in North Dakota. Maximum yields of maize, sugar beet and alfalfa were obtained on these soils at water table depth of 70 cm.

Even though these results give the indication that the water table depth has a marked effect on crop yield, these results may not simply be transferred to other regions, since different soil properties and climatic factors may have a considerable effect on the results.

2.2.b Effect of the Water Table Depth on Soil Properties

One of the soil properties influenced the most by the water table is the level of aeration. Williamson and Kriz (1970) indicate, that two water table depth limits should be taken into consideration. First, the lower limit is that depth, that will still be able to supply the plant roots with sufficient moisture, ie. prevent soil moisture deficiency, and second, the upper limit, which permits the roots to have adequate aeration, since a too high a water table will choke off the plant roots.

Furthermore, Von Hoyningen Huene (1939) states that the leaching process is one of the most important soil altering factors and that, if not stopped either naturally or artificially, may lead to a total impoverishment of the soil. A controlled water table therefore, slows down this process. Water, as it infiltrates the soil, carries with it, the nutrients down to the lower horizons of the soil. As the water reaches lower levels, it's velocity decreases and the nutrients will be deposited at these levels. If the water table is sufficiently high, many of these nutrients will still be available to the plants. Furthermore, irrigation water supplied from below, does not take part in this leaching process.

According to the Soil Conservation Service of the U.S. Department of Agriculture (1973), drainage of organic soils contributes substantially to surface subsidence. Subsidence is caused by the oxidation of the organic particles by aerobic bacteria. A lowered water table allows air to enter the pores of the soil, which in turn helps the growth of these aerobic bacteria. Average subsidence in organic soils in Europe and the United States is around 25 mm per year. The degree of subsidence varies with the depth to which the soil is aerated, or in other words, with the depth of the water table.

From the above mentioned, it becomes clear that some form of water table control is not only beneficial but also advisable. For soils that have a tendency to overdrain, such as the sandy loam soil investigated in this research, some form of controlled drainage or subirrigation can prove to have a positive effect on both the yield and the soil properties.

2.2.C Theoretical Evaluation of the Optimum Water Table Depth

Aside from the above mentioned experimental determination of the optimum water table depth, it is possible to obtain this depth by applying the continuity equation and Darcy's law. Given the fact that, at optimum depth, the water table should supply enough moisture to the root zone, such that the consumptive use of the plants is met, one is able to calculate this depth by making the following assumptions and approximations:

1) At the optimum water table level, the upward flux is such that it equals the potential evapotranspiration.
2) Osmotic potential is assumed to be negligible.
3) Evapotranspiration is constant at a certain water table depth.
4) Hysteresis may be ignored by considering only monotonic changes of suction (increasing or decreasing).
5) Hydraulic conductivity in unsaturated soils is a function of water content only.

Since the upward movement of moisture from the water table is due to the difference in hydraulic potential, one may represent this potential difference by the following equation:

$$V(h) = V(g) + V(m) + V(o) + V(p)$$

where:

$V(h)$ = the hydraulic potential

$V(g)$ = the gravity potential

$V(m)$ = the matric potential

$V(o)$ = the osmotic potential (negligible)

$V(p)$ = the pressure potential (= 0 above W.T.)

This reduces to:

$$V(h) = V(g) + V(m) \qquad (1)$$

The continuity equation for the vertical flow of water (one dimension) is given by:

$$\partial\Theta/\partial t = - \partial v(z)/\partial z \qquad (2)$$

where:

Θ = volumetric water content

t = time

$v(z)$ = flux in the z-direction

Furthermore, Darcy's equation in one dimension is given by:

$$v(z) = - K(\Theta)(\partial h/\partial z + 1) \qquad (3)$$

where:

$v(z)$ = flux in the z-direction

Θ = the volumetric water content

K = the hydraulic conductivity

h = the suction in height of water

z = the vertical position measured downward from some reference point

Combining the continuity equation and Darcy's equation yields the following expression:

$$\partial\Theta/\partial t = \partial/\partial z(K\ \partial h/\partial z) - \partial K/\partial z \qquad (4)$$

An analytical solution for this equation is not available, however applying some of the assumptions mentioned previously, one may solve this equation. First, upward flux is equal to potential evapotranspiration, therefore there is no change in water content, i.e. equation (4) goes to zero. Second, h depends only on water content, since monotonic changes in suction are assumed. Therefore equation (4) reduces to:

$$\partial/\partial z(K\ \partial h/\partial z) - \partial K/\partial z = 0 \qquad (5)$$

This equation may be solved using numerical methods, however the relationship between suction and hydraulic conductivity and the boundary conditions need to be supplied.

The former is discussed in detail by Klute (1972). As far as the boundary conditions are concerned, both the upper and the lower need to be given. Whisler et al. (1968) points out that the maximum water uptake by the roots is at or near the lower section of the rooting zone. Skaggs (1979) states that the upper boundary may be taken to be the average root zone depth. The lower boundary is of course the water table. Therefore, one may conclude that the upper boundary and consequently, the effective depth, depends on the type of crop, or rather, the rooting depth of the crop.

From the preceding discussion, one may see that it is possible to calculate the optimum water table depth. However, since this depth depends on the evapotranspiration, which may, of course, vary considerably during the growing season, the optimum water table depth may be calculated by obtaining the maximum potential evapotranspiration from the weather data available.

2.3 Water Table Distribution

This next section deals with the water table distribution and furthermore with the flow of water beneath the water table. It is necessary to obtain an overall picture of saturated flow to be able to visualize the shape of the water table and the flow process involved during subirrigation.

2.3.a Shape of the Water Table during Subirrigation

Since the shape of the water table is a reversal of the drainage case, the drain spacing required for a combined system may be calculated using the same method, the Hooghoudt equation. Both Fox et al. (1956) and Skaggs (1979) developed equations for drain spacings in subirrigation, however both are in fact variations of the Hooghoudt equation.

Hooghoudt's equation for the drainage case is as follows:

$$s^2 = 4K/q(2dh + h^2) \qquad (6)$$

where:

s = the drain spacing (m)

K = the hydraulic conductivity (m/day)

q = the drainage coefficient (m/day)

d = equivalent depth (m)

h = the height of the water table above the drain height at midspacing (m)

This equation, however, may not be used in this form for subirrigation, since it assumes that the height of water above the drain itself is zero. Obviously, in subirrigation that is not true, furthermore, the drainage coefficient q needs to be replaced by the evapotranspiration rate. After making the necessary modifications to the formula, equation (6) is changed to the following:

$$s^2 = 4K/E(2m(H+d) - m^2) \qquad (7)$$

where:

s = the drain spacing (m)

K = the hydraulic conductivity (m/day)

E = the potential evapotranspiration rate (m/day)

d = the equivalent depth (m)

H = height of water table above drain (m)

m = deflection of water table at midspacing (m)

Figure 4 shows both cases, ie. drainage and subirrigation, together.

Since all the variables are known in equation (7), ie.

drain spacing, hydraulic conductivity, etc., m, the deflection of the water table at midspacing, may be calculated. It is therefore possible to calculate the shape of the water table using Hooghoudt's equation. Gallichand (1983) found that the Hooghoudt equation gave only an approximation of the experimentally observed m. However, it seems that these differences were mainly due to the fact, that the soil was not as uniform (homogeneous) as had been assumed, in other words, it is very likely that the soil exhibited large variations in hydraulic conductivities. Such variations will effect the calculations such that only an approximate shape of the water table will be obtained.

2.3.b Movement of Water in Soil

Since this research deals with subirrigation, one of the main points of interest is, of course, the flow of water beneath the water table. Toth (1963) produced a mathematical model, incorporating the three different types of saturated flow that exist:

1) Local flow: Flow from topographic highs to topographic lows (topography here implies the topography of the water table).
2) Intermediate flow: Flow from recharge areas to discharge areas.
3) Regional flow: Flow from the basin recharge area to the basin discharge area.

In this research, only the intermediate and the local flow predominate. The flat topography and the existance of a low permeability clay below a depth of 2 m cause the regional flows to be very small. The local flow from the topographic highs, above the drains, to the topographic lows, at midspacing, are the most important, since the main concern is an even or relatively even water table. Furthermore, the flow from the irrigated plots to the drained plots could well be described as an intermediate flow. Freeze and Witherspoon (1966, 1967) found that variations in subsurface permeability influence the general flow pattern beneath the water table considerably.

2.4 Friction Losses in a Subsurface Irrigation System

A subirrigation system, distributing water to the field from a control chamber, will be subjected to certain friction losses. This implies that a head difference needs to be maintained for flow to occur. If the friction loss can be estimated, then the control chamber can be designed accordingly.

Head losses may be catagorized as follows:

1) h(ent) : the entrance head loss of the flow of water from the control chamber into the distributor pipe.
2) h(coll): the head loss in the collector drain.
3) h(tee) : the head loss resulting from a tee connection.
4) h(elb) : the head loss encountered at an elbow (a 90-deg. turn in the drain pipe).
5) h(lat) : the head loss in the laterals.
6) h(exit): the head loss due to the resistance encountered by the flow of water exiting the laterals.
7) h(conv): the head loss due to the convergence of the flow lines near the drain.

Gallichand (1983) found that the biggest head loss that occurs in a subirrigation system is the exit head loss, furthermore it seemed that the head loss due to pipe flow was relatively small when compared to other losses. Since the flow was laminar, the Darcy-Weisbach equation was used to calculate the friction losses in the pipe.

In order to distinguish between laminar and turbulent flow, the Reynolds number needs to be calculated, using the following equation:

$$R = dQ/vA \qquad (8)$$

where:

R = the Reynolds number

Q = the discharge (m^3/sec)

A = the cross-sectional area of the pipe (m^2)

d = the pipe diameter (m)

v = the kinematic viscocity (m^2/sec)

Equation (8) implies that higher Reynolds numbers will be obtained with higher flows, since R is directly proportional to Q. According to Streeter et al. (1979), the flow is considered laminar for Reynolds numbers less than 2000. For R values greater than 20000, rough-turbulent flow, Manning's equation gives good results. For flows with R values between 2000 and 20000, the transition zone, no single equation is completely satisfactory for estimating friction losses.

Approximate estimates of head losses can be made with Manning's equation, or other equations. Solving for S_e, the slope of the energy grade line, the friction loss in corrugated plastic drain pipes may be calculated:

$$S_e = 10.294n^2Q^2/d^{5.333} \qquad (9)$$

where:

S_e = the slope of the energy grade line (m/m)

n = the roughness coefficient (0.016 for plastic drain pipes)

Q = the discharge (cu.m/sec)

d = diameter of the pipe (m)

The head loss that occurs due to exit resistance may be calculated using the radial flow equation given by Bravo and Schwab (1977):

$$Q = 2\pi KL(h_s - h_r)/(\ln(r_s) - \ln(r)) \qquad (10)$$

where:

Q = the flow rate into an ideal drain (cu.m/day)

K = the hydraulic conductivity (m/day)

L = length of drain (m)

h_r= hydraulic head at the ideal drain radius r (m)

h_s= hydraulic head at a radius of r_s (m)

The ideal drain radius may be defined as the effective drain radius r_e. Mohammad and Skaggs (1982) found that the effective drain radius for different types of tubing varies between $8.0 * 10^{-7}$ cm and 3.9 cm. Modifying equation (10) to include the effective drain radius and solving for the head loss, yields the following equation:

$$h(exit) = \ln(r_s/r_e)Q/2\pi KL \qquad (11)$$

where:

r_e = the effective drain radius (m)

h(exit)= the exit head loss ($h_s - h_r$) (m)

Therefore the exit head loss may be obtained theoretically by solving the above equation.

Finally, the last friction loss that occurs is the loss due to the convergence of the flow lines near the drain. This may only be evaluated theoretically if flow nets are drawn. The convergence head loss is then obtained from the following formula:

$$h(conv) = (n_{PD}/n_{CH})E/K \qquad (12)$$

where:

E = the evapotranspiration rate (m/day)

h(conv)= head loss due to the convergence of the flow lines (m)

n_{PD}= number of potential drops, vertical from the drain to the water table above the drain

n_{CH}= number of flow channels

Therefore, the total head loss in the subirrigation system may be calculated by:

$$h(tot) = h(ent) + h(coll) + h(tee) + h(elb) + h(lat) + h(exit) + h(conv) \quad (13)$$

Gallichand (1983) found that a head difference between 40 to 70 cm had to be maintained to achieve steady state conditions.

CHAPTER III

EXPERIMENTAL LAYOUT

3.1 Experimental Site

Mr. Leandre Charbonneau's farm is located approximately 24 km south of Sorel, Quebec, as shown on figure 1. The experimental field itself, is situated on the Chemin des Allonges in the Paroisse de St-Louis of Richelieu county.

The topography of the 10 hectare field is relatively flat, with only small variations of elevation. The topographical map is given in figure 2.

A subsurface drainage system was installed in this field in 1972. Since the dominant soil series is of the St. Samuel type, a spunbonded nylon filter was placed over the top 2/3 of the drain to protect it from sedimentation. However, during the subirrigation experiments carried out in the summer of 1982, it was found that some parts of the drainage system were either blocked or had some sediment deposits.[1] Therefore, in the fall of 1982, new drains were installed in the six experimental plots that had not functioned properly. Furthermore, Mr. Charbonneau carried

1. It is noteworthy, that since 1972 new envelope fabrics have been developed and used completely around the drain tubes. Also, nylon is no longer used because it has been found that nylon degrades in many soils. (Rollin A. 1984 Unpublished Chemical Engineering Communications)

out further land levelling to decrease the variation in elevation. At present time, the maximum variation is about 50 cm.

The soil, itself, consists of a dark brown fine sandy loam top layer, up to 30 cm thick. Underneath, there is an olive pale medium sand, going down to about 160 cm. A clay, which may be considered to be the impermeable layer, is located beneath it. Some areas in the field could be described as imperfectly drained, since it was too wet to be seeded in the spring of 1983. In the past, it was observed by the owner that during drier summers (about 3 years out of 5) the crop suffered from water deficiency, compared to nearby silty soils. This indicated that more water had drained out and less was retained as available water for the crop.

Maize has been grown on this field since 1967. It was also observed that very few plant roots penetrated the soil deeper than 35 cm.

3.2 Experimental Design

In the spring of 1982, a modification was made to the subsurface drainage layout, such that an eight replicate experimental design could be made. Each replicate was set up in such a way, that it consisted of both an irrigated plot and a non-irrigated plot, separated by a buffer zone. Each plot contained two subsurface drainage pipes. The experimental layout is shown in figure 2 and 3, the plot sizes are given in table A57.

In order to observe the water table distribution in the various parts of the experimental field, water table pipes were installed at locations indicated in figure 3. Each plot, non-irrigated and irrigated, contained two rows of observation pipes, approximately 40 meters apart. Each row of observation pipes consisted of three water table pipes in each of the non-irrigated plots, 15 meters apart, and five water table pipes in each of the irrigated plots, 7.5 meters apart. It was necessary to install this many pipes, to obtain adequate profiles of the water table distribution. Overall, there were eight rows of water table pipes in the field of sixteen plots.

Furthermore, to observe the shape of the water table just above the irrigating drains, water table pipes were placed at 15 cm, 50 cm and 100 cm distance from the irrigating drain.

To observe the leakage from irrigated to non-irrigated plots, sets of water table pipes were placed at 7 meter intervals, from the irrigating drains toward the non-irrigating drain.

The water table pipes were installed with the help of an auger. First, a 10 cm diameter hole was augered and the water table pipe was lowered into the hole, leaving 10 cm sticking out. Original sandy soil was placed and tamped into the space, surrounding the water table pipe. Secondly, the elevations of the tops of the pipes and the ground beside the pipes were taken, using an engineer's level. The contour map, shown in figure 2, was drawn using these ground elevations.

3.3 Materials and Equipment

At the onset of this experiment in the spring of 1982, four control chambers were built. These chambers were designed such that the whole system could function either as a subsurface drainage system or as a controlled subsurface drainage/irrigation system. Figure 5 shows both the design and the dimensions of a typical water level control chamber.

With the drain valves open, the field is drained in the usual manner, however, with the drain valves closed, the outflow is stopped and the water table in the field may be raised or lowered as required. Pumping water into the control chamber will cause the water to flow backward through the drain pipes into the field, thereby raising the water table. On the other hand, excessive precipitation will cause the water table to rise above the overflow drain, thereby draining all unwanted water.

To measure the water table height in the field, 19 mm I.D. 1.5 meter long PVC water table pipes were used. These pipes were sealed at one end to stop the entry of soil into the pipe. Soil water entered these pipes via 6.4 mm diameter holes drilled at regular intervals along the length of the pipe. A spunbonded polyester filter material was wrapped around the pipe to inhibit the entry of fine sand particles. Furthermore, the pipes could be closed at the top with a removable cap. The cap was intended to prohibit the entry of surface water, which would have given erroneous readings regarding the water table depth, on the other hand, the caps could be removed, so that water table readings could be taken without difficulty.

To pump water into the control chambers, a portable centrifugal tractor-driven pump was used for most of the period. Due to problems with the tractor, a small auxillary pump, capable of supplying approximately 40 Imp. gpm, was employed. The water was pumped to the chambers via 50 and 37 mm diameter PVC tubing, which were laid out on the soil surface between the rows of corn.

3.4 Ancillary Features

A temporary weather station, set up near the field, was used to measure the daily maximum and minimum temperatures, rainfall and pan evaporation from the 1st of July to the 31st of August. Standard meterological thermometers in a Stevenson screen, a tapered raingauge and a Class-A evaporation pan were utilized. The readings were taken at 8 am and at 6 pm. The weather data for both July and August is presented on table A1 of appendix A.

To be able to supply the field with irrigation water, a dam was built in the municipal drain, thereby creating a reservoir. The dam, located about 1 km downstream of the field, consisted of a steel frame, which was anchored to a concrete base. Wood planks were used to contain the water behind the dam. The complete structure, excluding the concrete base, can be removed in fall and reinstalled in spring.

The ditch reservoir was depleted by July 19th, due to an extremely dry summer, therefore a secondary water supply was needed. A 55 m deep well was drilled and the water pumped out to the field via a 10 cm diameter non-perforated subsurface drainage pipe. Unfortunately, the well was completed at a too late a date to have had any significant benefit on this experiment.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Water Table Shapes in Irrigated and Non-irrigated Plots

Gallichand (1983) tried to obtain the water table distribution in the irrigated plots by theoretical methods, using both the Hooghoudt equation and the flow net analysis. The two methods gave different answers. The problem lies in the fact that the hydraulic conductivity used in the Hooghoudt equation is an average value for the whole field. However, due to the spatial variation of the hydraulic conductivity in the field, his results, using the Hooghoudt equation was inadequate. As far as the flow net analysis is concerned, the results were closer to the experimental values determined by his measurements. This is probably due to the flow net analysis being less sensitive to the spatial variation of the hydraulic conductivity.

In this research, the deflection m at midspacing could not be predicted, since steady state was not attained. One objective of this research was to observe the change in the water table levels under conditions of irrigation and non-irrigation. Steady state conditions, as such, were never achieved, since the water supply had been depleted by the time the water table had reached the desired height. The amounts and timing of water pumped into each chamber are given in table I.

In all eight irrigated plots, the water table exhibited the typical shape, as can be seen from figures 6 to 21. The water table distribution of both the 13/07/83 and 15/07/83 are shown on these drawings, indicating the upward changes of the water table elevation in this two day interval. The ground surface, in the vicinity of the irrigating drains, became moist, when the water table was within 40 cm.

The special water table pipes placed within 0.15 m, 0.50 m and 1.00 m indicated that the water table appeared like a bubble above the drain, but then dropped off rather rapidly, about 25 cm to 40 cm, in a 7.5 m distance from the drain.

The water table in the non-irigated plots remained, at or below the drain level for the whole duration of the experiment. Precipitation, that fell in that time period, never penetrated the soil more than 15 cm. For the period from the 06/07/83 to the 19/07/83, the water table at mid-spacing dropped 8 to 10 cm in the non-irrigated plots. The water level in these plots was too low for the drains to function, since no discharge occured at the drain outlet and also, the water table was almost completely flat, almost parallel to the soil surface. This is shown in figures 22 to 35.

4.2 Calculation of the Head Losses

To be able to design an efficient subirrigation system, i.e. the number and sizes of the control chambers, it is necessary to obtain the friction losses involved in such a system. As has been shown in the Review of Literature, the total head loss may be calculated using equation (13). However, in order to use the proper equation to evaluate each individual component of equation (13), it is first necessary to calculate the Reynolds number R, in order to determine whether the flow in the drain pipes is laminar or not. This value may be obtained by the following formula:

$$R = dV/v \qquad (14)$$

where:

R = the Reynolds number

d = the pipe diameter (m)

V = the discharge velocity (m/sec)

v = the kinematic viscosity (m^2/sec)

Since the flow volume was measured with a flow meter, results shown in table I, it is possible to calculate the discharge velocity:

$$V = Q/A \qquad (15)$$

where:

Q = the flow rate (cu.m./sec)

A = the cross-sectional area of the pipe (m^2)

Combining equations (14) and (15) yields equation (8):

$$R = dQ/Av \qquad (8)$$

The kinematic viscosity v is taken to be equal to 9.6 x 10^{-7} m^2/sec, since the water temperature varied only between 21 deg-C and 24 deg-C. This estimate seems sufficient, since such a small variation in temperature influences the R values only slightly.

Since a subirrigation system is to be designed for large fields only, the head loss calculation here was done for the largest experimental system available, that is to say, for plots A-5, A-6, A-7 and A-8 serviced by control chamber 4. The total area of these four plots is approximately 17700 m^2. Similar calculations, done by Gallichand (1983), were conducted only for the single plots A-2 and A-4, serviced by control chambers 2 and 1 respectively. The exact location of each control chamber is shown in figure 2.

Table II shows the Reynolds numbers calculated using equation (8). Since this particular system included four laterals, the assumption was made that each lateral carried equal volumes of water. Therefore the four R value columns shown in table II, give the result for each section of collector pipe, from the control chamber to the collector elbow. Since the values obtained range up to 22780, indicating transitional flow, it is clear that the equations for laminar flow may not be used, rather an equation, such as Manning's formula has to be used to obtain the head loss in the various sections of the pipe.

The following subsections will deal with the individual components of the head loss:

4.2.a Head Loss in the Collector Pipe

All friction losses in the pipe may be calculated using Manning's formula. To obtain the losses incurred at the pipe entrance, the tee connections and the elbow, the same equation may be used, however the equivalent length of pipe has to be taken for each individual case. Schwab (1966) states that for a 10 cm drainage pipe, the equivalent length for the pipe entrance at the control chamber may be taken to be 1.83 m, whereas the equivalent length for both the elbow and the tee connections is 6.71 m.

To evaluate the friction losses in the collector pipe itself, the actual lengths were used. Since, however, the volume of the flow decreases by one quarter after each tee connection in this system, four calculations had to be made for each initial flow volume. Using equation (9):

$$S_e = 10.29n^2Q^2/d^{5.333} \qquad (9)$$

One may obtain the head loss in each particular section of pipe by multiplying the slope of the energy grade line S_e by the length of pipe in question:

$$h = S_e l \qquad (16)$$

where:

l = the length or equivalent length of pipe (m)

h = the head loss (m)

The result of the calculations for h(ent), h(tee) and h(elb) is given in table III. Since there are three tee connections in this particular part of the subirrigation system, three h(tee) losses are calculated.

The head loss values for each section of collector are given in table IV. Again, the assumption made here is that each lateral will take exactly one quarter of the total flow entering the system. Given the fairly uniform and equal rise of the water table in the four irrigated plots, connected to this control chamber, it seems to be a fairly reasonable assumption. Figure 2 shows the exact location of the control chambers and the pipe system analysed above.

4.2.b Head Loss in the Lateral

To obtain the head loss in the lateral, Manning's equation may again be employed, however one modification needs to be made. The difference here is that the laterals are perforated and Q, the flow rate, decreases with distance from the collector, therefore the flow has to be evaluated at each point in the lateral, so that the head loss may be calculated. Assuming that the flow rate in the lateral decreases linearly, the following equation may be used:

$$Q_{lat} = Q_{col}((L - x)/L) \qquad (17)$$

where:

Q_{lat} = the flow in the lateral at a particular distance x away from the collector (m^3/day)

Q_{col} = the flow that enters the lateral (m^3/day)

L = the total length of the lateral (m)

If one assumes, that within a small distance, such as one meter, the flow is constant, then h(lat) may be calculated by substituting Q_{lat} into equations 8 and 16, then using an iterative approach, the head loss may be calculated. The result, given in table V, shows the head losses that occur after the first 54 m of the second lateral from the left.

4.2.c Head Loss due to Exit Resistance

Gallichand (1983) found that the exit head loss was the largest single head loss, however he found this only by deduction, not by direct measurement or calculation. Unfortunately, due to several reasons, it was not possible to experimentally obtain the exit head loss in this research, however, as already stated in the Review of Literature, Mohammad and Skaggs (1982) found that the effective radius of a drain depends on the drain perforation area. In Quebec, the minimum drain perforation area is 21 cm^2/m of drain. According to the research done by Mohammad and Skaggs (1982), the effective drain radius r_e for a 10 cm diameter pipe with a perforation area of 21 cm^2/m is approximately 1.5 mm. Since the exact perforation area of the drain pipes used in this experiment is not known, the minimum value is assumed for the sake of the calculation of the exit head loss.

Substituting r_e = 0.0015 m into equation (11), h(exit) is calculated for a 10 cm diameter corrugated plastic drain pipe. L, the unit length, is taken to be 1 m. Since the flow is assumed to decrease linearly, the mean flow per unit length may be calculated from:

$$Q_o = Q_{col}/L_{lat} \qquad (18)$$

where:

Q_o = flow out of drain per unit length (m^3/day)

Q_{col} = flow into lateral from collector (m^3/day)

L_{lat} = length of the lateral (130 m)

Combining equations (18) and (11), one obtains the following:

$$h(exit) = (\ln(r_s/r_e)Q_{col}/L_{lat})/2\pi KL \quad (19)$$

Substituting the various values for the components in equation (19), such as L = 1 m, r_e = 0.0015 m and r_s = 0.05 m and from Rashid-Noah (1981) the hydraulic conductivity K= 1.564 m/day, the resulting equation for the exit head loss is:

$$h(exit) = 0.0027476 * Q_{col} \quad (20)$$

The values, obtained from equation (20) for the exit head loss, are given in table VI.

4.2.d Head Loss due to the Convergence of the Flow Lines

In order to be able to calculate this particular component of the total head loss, it was first necessary to draw the flow nets. Since n_{PD}, in equation (12), is dependent on the vertical distance between the water table above the drain and the drain itself, three flow nets with different H values, 50 cm, 65 cm and 80 cm, which were thought to represent the best averages of the irrigated experimental plots A-5 through A-8, were drawn. The flow net diagrams are given in Appendix B. The values for n_{PD} and n_{CH}, for the three different cases, are given in table VII. Using equation (12):

$$h(conv) = (n_{PD}/n_{CH})Q_o/K \qquad (12)$$

and substituting the appropriate n_{PD} and n_{CH} values, one is able to calculate the convergence head loss. The hydraulic conductivity K is taken to be 1.564 m/day, i.e. the average K value obtained by the auger hole method. Q_o, the flow rate out of the drain per unit length, is calculated from the volume of flow that enters the lateral at the collector. The results of this calculation are given in table VIII.

4.2.e Total Head Loss in the Subirrigation System

To obtain the total head loss, one has to add up all the individual head losses that occur from the control chamber to the point of interest. In this example, the head losses evaluated were up to water table pipe A-11. Using equation (13):

$$h(tot) = h(ent) + h(coll) + h(tee) + h(elb) + h(lat) + h(exit) + h(conv) \quad (13)$$

the total head loss may be calculated. However, some components of the previous equation equal to zero or are slightly altered. The component h(elb) = 0, since, for this example, the elbow of the collector does not come into consideration. Furthermore, h(coll) consists of several different components:

$$h(coll) = h(coll.AB)+h(coll.BC)+h(coll.CD)+h(coll.DE) \quad (21)$$

All the components on the right side of this equation constitute the various collector sections from tee connection to tee connection up to the elbow. Figure 2 shows the various sections, with point A being the control chamber and point E, the elbow. Points B, C and D are the tee connections. Since water table pipe A-11 (see Figure 3) is the point of interest, the final two components of equation (21) are equal to zero.

Similarly, h(tee) consists of several components:

$$h(tee) = h(tee.B)+h(tee.C)+h(tee.D) \qquad (22)$$

Here, the final component is equal to zero, for similar reasons as mentioned above.

Finally, by substituting equations (21) and (22) into equation (13), one may now calculate the total head loss involved in the subirrigation system between the control chamber 4 and water table pipe A-11, which is above one of the subsurface irrigation pipes. The result of this example is shown in table IX.

4.3 Water Losses from Irrigated Plots

Water is lost due to leakage from irrigated to non-irrigated plots and by evapotranspiration. The water loss due to evapotranspiration seems to be, by far, the largest of the two components. Since it is the main objective of a subirrigation system to supply sufficient moisture to the plant roots, it is desirable to know what quantities of water are required to satisfy this demand on any particular day in the growing season. To be able to calculate the maximum amount of water required, it is necessary to assume that the actual evapotranspiration rate equals the potential rate. Then:

$$Q_e = E\, L_{lat}\, S \qquad (23)$$

where:

Q_e = volume of water required for evapotranspiration (m^3/day)

L_{lat} = length of the lateral (m)

E = potential evapotranspiration rate (m/day)

S = the drain spacing (m)

One complete drain spacing needs to be considered in equation (23), since each drain services all the land from midspacing to midspacing. Because all four plots, A-5 to

A-8, receive their water from control chamber four, the total area of all four plots needs to be considered. Therefore, the total area is:

$$A = 150 \text{ m} * 118 \text{ m} = 17700 \text{ m}^2$$

Then, the required volume to satisfy the maximum evapotranspiration demand is:

$$Q_e = 17700 * E \qquad (24)$$

To be able to obtain the leakage component of the water losses, one needs to use Darcy's law and the shape of the water table between the irrigating and the non-irrigating drain. The volume of flow in the y-direction is given by:

$$Q_1 = -KY(\partial y/\partial x) \qquad (25)$$

where:

Q_1 = the leakage per unit length

K = the hydraulic conductivity

Y = the vertical distance between the impermeable layer and the water table at point x

$\partial y/\partial x$ = the hydraulic gradient at point x

Point x has to lie near the midspacing between the irrigating and the non-irrigating drain. This is because the area from the irrigating drain to the midspacing is still considered to be the irrigated plot. The result of equation (25) still needs to be multiplied by the total length of the border region of the field.

Adding both Q_e and Q_l together, yields the required volume of water that needs to be supplied to the irrigated field. The final result of this calculation is given in table X. One should notice that water supplied in excess of the losses will raise the water table, in case of a deficit the water table will be lowered. Also, it should be noted in table X, that leakage prior to the 13/07/83 is zero, since the gradient was very small.

4.4 Water and Time Requirements in Raising the Water Table

The time required to raise the water table depended very much on the volume of water pumped into the control chamber and on the depth of the water table itself. The former is self-explanatory, however the latter merits an explanation. The evapotranspiration rate varies according to the water table depth, since a low water table will deliver less water to the soil surface by capillary rise, than a high water table. Furthermore, leakage from the irrigated to the non-irrigated plots will be negligible if there is only a small difference in water table elevation between the two. As the water table is raised, both leakage and actual evapotranspiration rates increase, thereby slowing the rate of the water table rise.

To give an example of the previous explanation: On the 07/07/83, the water table depth at midspacing in plot A-5 line C was 1.025 m below the soil surface. Water delivered to plot A-5 was 31.71 m^3/day. This value is obtained by dividing the pumping rate, table I, by 4, since control chamber 4 serviced four plots. The result was that the water table rose exactly 10 cm at midspacing during that day. On the 13/07/83, the water table depth at the same location was 0.815 m. With a similar amount of water pumped and a similar potential evapotranspiration rate, the water table rose only 4.4 cm. This indicates that both leakage and actual evapotranspiration rates had increased. One should note that the actual evapotranspiration rate will only increase until the potential rate is attained.

The actual time taken to raise the water table in the field from drain depth varied widely, however by studying the data tables in Appendix A, one may notice, that increases of water table elevations in excess of 5 cm is quite common. On the average, the water table was raised approximately 40 cm in the irrigated plots during the experiment. One should realize though, that the pumping rates were not very steady, i.e. no pumping took place on the 09/07/83 and only very small amounts of water were pumped on the 10/07/83. This was mainly due to mechanical failure of the pumping equipment.

The volume of water required to raise the water table depends very much on the daily consumptive use of the crop and on the leakage. To be able to raise the water table, water in excess of the losses have to be pumped in. Furthermore, the drainable porosity of the soil influences the water quantity significantly. Assuming that the drainable porosity is 10%, then to raise the water table in the field, serviced by control chamber 4, 10 cm, one needs to supply about 177 m^3. Added to this are the water losses due to leakage and evapotranspiration. This gives some indication of the quantity of water that is required to raise the water table.

4.5 Comparison of the Subirrigation Performance in 1982 and 1983

The results of the subirrigation experiment carried out in the summer of 1982 by Gallichand, showed that of the eight irrigated plots only two were considered a success. The causes for the failure in the remaining six plots were at first not known. In the fall of 1982, the drain pipes were dug up and inspected. It was found that some pipes were partially blocked with sediment. The decision was then made to replace all the drains in those plots that had not functioned properly, that is all plots with the exception of A-2 and A-4. All new drains were enveloped with a knitted polyester filter material.

The result of the subirrigation experiment, carried out in 1983, showed all irrigated plots working well. The water table, in all plots, responded to the input of irrigation water. Spot checks, made within a few hours of pumping startup, showed water table elevation increases above the drains. The two plots that had worked well in 1982, again performed adequately in 1983.

It appears therefore, that the exchange of the malfunctioning drains in the six plots, had solved the water delivery problems of the previous year.

Yield increases, which were indicated in 1982, were substantiated in 1983. Even with a relatively short irrigation period of two weeks, due to shortage of water, the yield in the irrigated plots was double that of the non-irrigated plots as may be seen in table XI.

One of the objectives of the subirrigation experiment in 1982 was to attain steady state conditions, whereas in 1983, the speed at which a water table may be raised was important. Looking at the crop yield, one might deduce, that steady state conditions with a water table at 60 cm below the surface might not be neccessary. Perhaps it suffices to have such an elevated water table only during critical periods of plant development.

CHAPTER V

OPERATIONAL GUIDE OF A SUBSURFACE IRRIGATION SYSTEM

To be able to operate a subirrigation system efficiently, one should note the following points:

1) The top elevation of the control chambers, should be at or slightly above ground level. They should not interfere with the normal operation of the farmer.
2) In fall, prior to harvest, the valves in the control chambers should be opened and the soil allowed to drain. This improves the trafficability of the land.
3) Valves should remain open until spring, to allow the soil to be drained adequately for spring seeding.
4) Valves should be closed as soon as possible after seeding etc., has been carried out. This conserves as much soil moisture as possible to aid in the germination process.
5) The overflow pipes in the control chambers should be set, such that the water table does not rise so high as to limit the aeration of the soil in the root zone.
6) If the water table starts falling below a certain level in the control chamber, irrigation water needs to be added. By pumping intermittently, the water table will be allowed to fluctuate between two predetermined levels.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary

A modification of a subsurface drainage system was made, such that it could also be used as a subsurface irrigation system. An experimental layout, containing eight irrigated and eight non-irrigated plots, was devised. Two rows of water table pipes were installed in each plot, to be able to observe the water table distribution.

The flow rate of the irrigation water was measured at each control chamber using water meters. Weather data was obtained from a temporary weather station, set up near the experimental field. All observations were taken in the summer of 1983.

6.2 Conclusions

According to the results obtained in this research, the following conclusions were drawn:

1) The water distribution system worked very well in all experimental plots. The water table rise in the irrigated

plots varied from 22 cm to 53 cm in a period of two weeks. The water table elevation dropped in all non-irrigated plots by approximately 10 cm in the same period. The difference in elevation between the non-irrigated and irrigated plots varied from 50 cm to 90 cm. The average water table depth in the irrigated plots was 75 cm on the final full day of irrigation, whereas it was 1.30 m below the surface in the non-irrigated plots.

2) Leakage at the onset of irrigation is negligible. It increases as the water table is raised. The importance of leakage losses will however decrease when the irrigated area is increased.

3) Theoretical head losses average around 20 cm. With higher flow rates, this would naturally increase.

4) Yields in the irrigated plots were almost double that of the non-irrigated plots.

5) Technically speaking, it is possible to convert a subsurface drainage system to one that accommodates both a subsurface irrigation system and a subsurface drainage system, given that the land is relatively level. It would be advisable to design future drainage systems, such that it incorporates the subirrigation aspect, i.e. designing for the minimum number of control chambers etc.

6) The problem of poor water distribution during the first year of subirrigation was due to the fact that sediments had entered the drains and blocked them. Replacing these blocked

pipes alleviated the problem.

7) The speed at which the water table may be raised depends primarily on the depth of the water table, the volume of water pumped and on the drainable porosity of the soil. In this experiment, upward water table changes of up to 10 cm per day were achieved. To be able to raise the water table, irrigation water in excess of the losses, i.e. evapotranspiration and leakage, has to be added. The losses depended on the height of the water table and on the potential evapotranspiration rate. Values for losses from plots A-5, A-6, A-7 and A-8 (approximately 1.75 ha) ranged between 60 and 90 m^3/day.

Recommendations for Future Research

According to the observations made during the subirrigation experiments carried out in the summers of 1982 and 1983, several specific points would still need some attention:

1) Head losses in the pipe system and the exit head loss should be measured experimentally to see the validity of the theoretical values obtained in this research.

2) The yield relative to the water table depth should be determined.

3) The effect on crop yield of steady state and fluctuating water tables should be examined.

4) Research is needed to determine, if nutrient and fertilizer losses are decreased by use of water table control chambers to reduce the total annual drainage and leaching.

5) The economic costs and benefits of production scale subsurface irrigation systems need to be evaluated.

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TABLES

TABLE I : FLOW RATE INTO CONTROL CHAMBERS

(CUBIC METERS/DAY)

DATE	CHAMBER 1	CHAMBER 2	CHAMBER 3	CHAMBER 4
06/07/83	20.37	10.75	31.10	69.76
07/07/83	37.04	19.55	56.55	126.83
08/07/83	13.25	16.62	48.07	107.81
09/07/83	-	-	-	-
10/07/83	9.26	4.89	14.14	31.71
11/07/83	29.63	15.64	45.24	101.47
12/07/83	38.89	20.53	61.83	133.18
13/07/83	29.63	15.64	45.24	101.47
14/07/83	35.18	18.75	53.72	120.49
15/07/83	-	-	-	-
16/07/83	44.52e	23.74e	71.57e	148.40
17/07/83	37.74e	20.13e	53.30	125.80
18/07/83	40.07e	45.36	41.68	133.57
19/07/83	1.33	25.38	23.68	62.46

NOTE: e = estimated flow

Pump was shut down at 12:00 on the 19/07/83

TABLE II : REYNOLDS NUMBERS FOR THE VARIOUS SECTIONS OF THE COLLECTOR SERVING PLOTS A-5 THROUGH A-8

DATE	SECTION COLL. AB	COLL. BC	COLL. CD	COLL. DE
06/07/83	10711	8033	5356	2678
07/07/83	19474	14605	9736	4868
08/07/83	16553	12415	8277	4138
09/07/83	-	-	-	-
10/07/83	4869	3652	2434	1217
11/07/83	15580	11685	7790	3895
12/07/83	20449	15337	10224	5112
13/07/83	15580	11685	7790	3895
14/07/83	18500	13875	9250	4625
15/07/83	-	-	-	-
16/07/83	22786	17089	11393	5696
17/07/83	19316	14487	9658	4829
18/07/83	20509	15381	10254	5127
19/07/83	19180	14385	9590	4795

TABLE III : ENTRANCE, TEE AND ELBOW HEAD LOSS VALUES

DATE	H(ENT) (m)	H(TEE.B) (m)	H(TEE.C) (m)	H(TEE.D) (m)	H(ELB) (m)
06/07/83	0.00065	0.00240	0.00135	0.00060	0.00015
07/07/83	0.00216	0.00792	0.00446	0.00198	0.00050
08/07/83	0.00156	0.00573	0.00322	0.00143	0.00036
09/07/83	-	-	-	-	-
10/07/83	0.00014	0.00050	0.00028	0.00012	0.00003
11/07/83	0.00138	0.00507	0.00285	0.00127	0.00032
12/07/83	0.00238	0.00874	0.00492	0.00218	0.00055
13/07/83	0.00138	0.00507	0.00285	0.00127	0.00032
14/07/83	0.00195	0.00715	0.00402	0.00179	0.00045
15/07/83	-	-	-	-	-
16/07/83	0.00306	0.01123	0.00632	0.00271	0.00070
17/07/83	0.00220	0.00807	0.00454	0.00202	0.00050
18/07/83	0.00248	0.00910	0.00512	0.00227	0.00057
19/07/83	0.00217	0.00796	0.00448	0.00199	0.00049

TABLE IV : COLLECTOR HEAD LOSS VALUES

DATE	COLLECTOR SECTION AB (m)	BC (m)	CD (m)	DE (m)
06/07/83	0.00322	0.00619	0.00253	0.00064
07/07/83	0.01063	0.02046	0.00836	0.00210
08/07/83	0.00768	0.01479	0.00604	0.00152
09/07/83	-	-	-	-
10/07/83	0.00066	0.00128	0.00052	0.00013
11/07/83	0.00680	0.01310	0.00535	0.00135
12/07/83	0.01172	0.02256	0.00921	0.00232
13/07/83	0.00680	0.01310	0.00535	0.00135
14/07/83	0.00959	0.01847	0.00754	0.00190
15/07/83	-	-	-	-
16/07/83	0.01455	0.02800	0.01144	0.00288
17/07/83	0.01082	0.02084	0.00851	0.00214
18/07/83	0.01220	0.02349	0.00959	0.00242
19/07/83	0.01067	0.02055	0.00839	0.00211

TABLE V : LATERAL HEAD LOSS VALUES UP TO W.T. PIPE A11

DATE	FLOW INTO LATERAL (cu.m/day)	LATERAL HEAD LOSS (m)
06/07/83	17.44	0.00079
07/07/83	31.71	0.00260
08/07/83	26.95	0.00188
09/07/83	–	–
10/07/83	7.93	0.00016
11/07/83	25.37	0.00166
12/07/83	33.30	0.00288
13/07/83	25.37	0.00166
14/07/83	30.12	0.00235
15/07/83	–	–
16/07/83	37.09	0.00356
17/07/83	31.45	0.00256
18/07/83	33.39	0.00288
19/07/83	31.23	0.00252

TABLE VI : EXIT HEAD LOSS VALUES

DATE	FLOW INTO LATERAL (cu.m/day)	EXIT HEAD LOSS (m)
06/07/83	17.44	0.04792
07/07/83	31.71	0.08712
08/07/83	26.95	0.07405
09/07/83	-	-
10/07/83	7.93	0.02178
11/07/83	25.37	0.06970
12/07/83	33.30	0.09148
13/07/83	25.37	0.06970
14/07/83	30.12	0.08276
15/07/83	-	-
16/07/83	37.09	0.10192
17/07/83	31.45	0.08641
18/07/83	33.39	0.09174
19/07/83	31.23	0.08581

TABLE VII : VALUES OBTAINED FROM THE FLOW NETS

H (m)	N(CH)	N(PD)
0.50	4	2.50
0.65	4	3.25
0.80	4	3.50

N(CH) = NUMBER OF FLOW CHANNELS

N(PD) = NUMBER OF POTENTIAL DROPS BETWEEN THE IRRIGATING DRAIN AND THE WATER TABLE ABOVE

TABLE VIII : CONVERGENCE HEAD LOSS VALUES

DATE	FLOW INTO LATERAL (cu.m/day)	CONVERGENCE HEAD LOSS (m)
06/07/83	17.44	0.06969
07/07/83	31.71	0.12672
08/07/83	26.95	0.10770
09/07/83	-	-
10/07/83	7.93	0.03169
11/07/83	25.37	0.10138
12/07/83	33.30	0.13307
13/07/83	25.37	0.10138
14/07/83	30.12	0.12036
15/07/83	-	-
16/07/83	37.09	0.14822
17/07/83	31.45	0.12568
18/07/83	33.39	0.13343
19/07/83	31.23	0.12480

TABLE IX : TOTAL HEAD LOSS VALUES

DATE	FLOW INTO SYSTEM (cu.m/day)	TOTAL HEAD LOSS (m)
06/07/83	69.76	0.13221
07/07/83	126.83	0.26207
08/07/83	107.81	0.21661
09/07/83	-	-
10/07/83	31.71	0.05649
11/07/83	101.47	0.20194
12/07/83	133.18	0.27775
13/07/83	101.47	0.20194
14/07/83	120.49	0.24665
15/07/83	-	-
16/07/83	148.37	0.31686
17/07/83	125.80	0.26112
18/07/83	133.57	0.28044
19/07/83	124.92	0.25896

NOTE: TOTAL HEAD LOSS CALCULATED IS THE HEAD LOSS BETWEEN THE CONTROL CHAMBER 4 AND WATER TABLE PIPE A11.

TABLE X : WATER REQUIREMENTS IN PLOTS A-5 THROUGH A-8

DATE	E.T. REQUIREMENTS (cu.m/day)	LEAKAGE (cu.m/day)	TOTAL REQUIREMENTS (cu.m/day)
06/07/83	60.38	-	60.38
07/07/83	64.73	-	64.73
08/07/83	61.25	-	61.25
09/07/83	50.98	-	50.98
10/07/83	60.38	-	60.38
11/07/83	60.90	-	60.90
12/07/83	65.77	-	65.77
13/07/83	60.03	3.15	63.18
14/07/83	68.38	10.10	78.48
15/07/83	82.30	12.84	95.14
16/07/83	69.08	15.13	84.21
17/07/83	77.43	15.67	93.10
18/07/83	67.51	16.20	83.71
19/07/83	69.95	16.18	86.13

TABLE XI: YIELD FROM EXPERIMENTAL PLOTS

NON-IRRIGATED PLOT	YIELD (kg/hect)	IRRIGATED PLOT	YIELD (kg/hect)
B-1	2301	A-1	4206
B-2	2118	A-2	3882
B-3	3128	A-3	4673
B-4	2278	A-4	2955
B-5	3490	A-5	4625
B-6	2828	A-6	3943
B-7	1722	A-7	5814
B-8	1583	A-8	5465
MEAN	2431	MEAN	4445

FIGURES

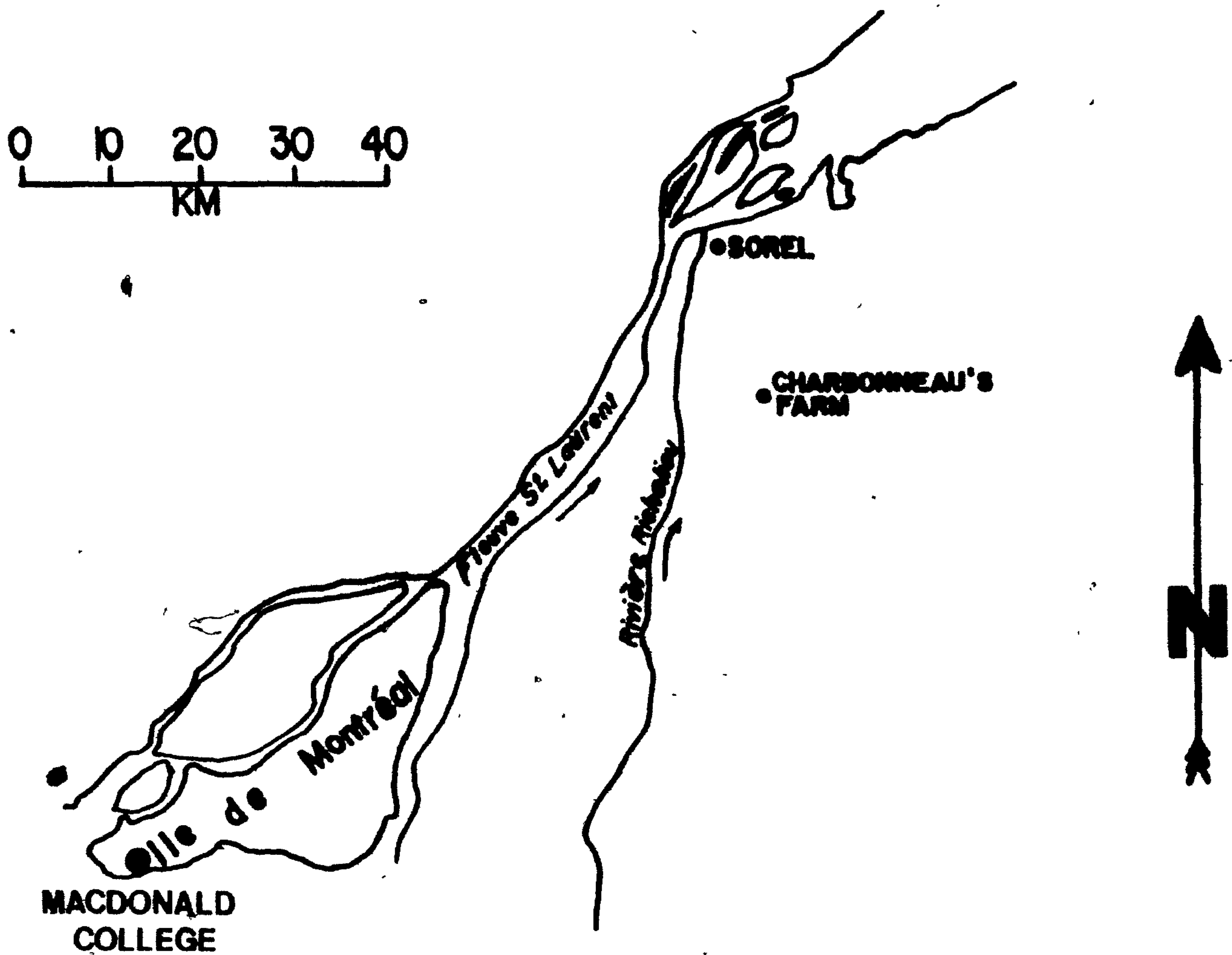


Figure I : **Location Map**

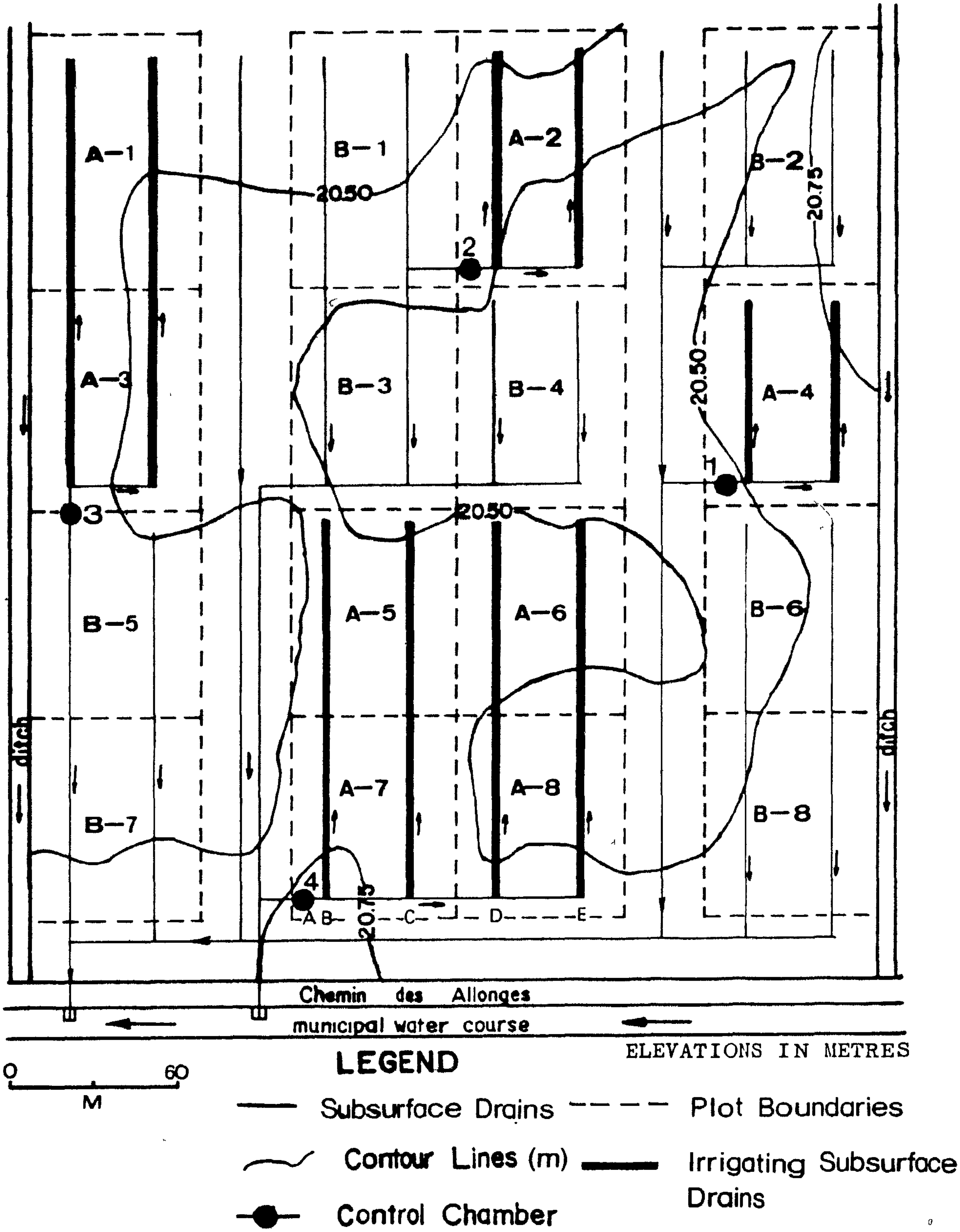


FIGURE 2: DRAINAGE SYSTEM WITH CONTOUR LINES

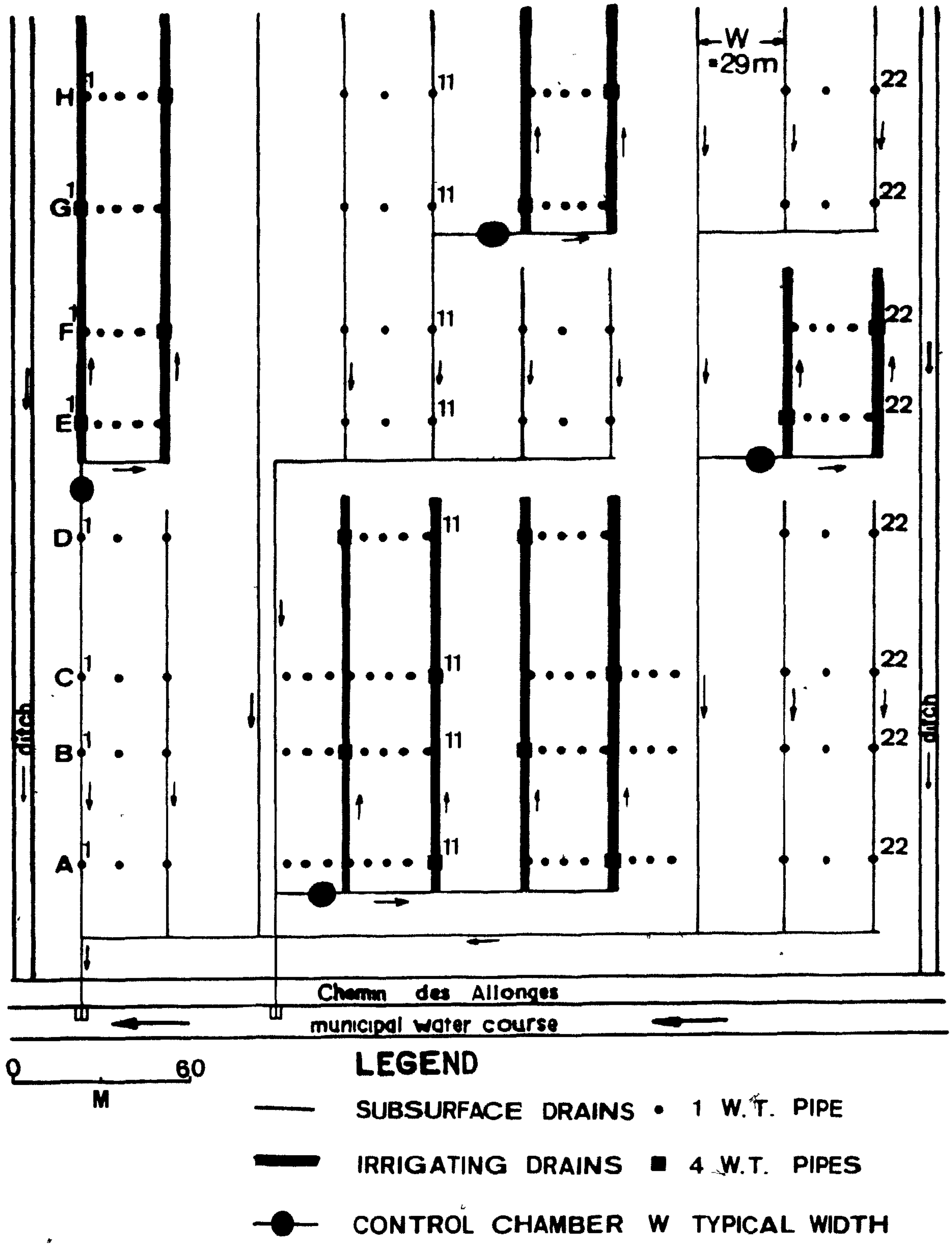


FIGURE 3: DRAINAGE SYSTEM WITH WATER TABLE PIPES

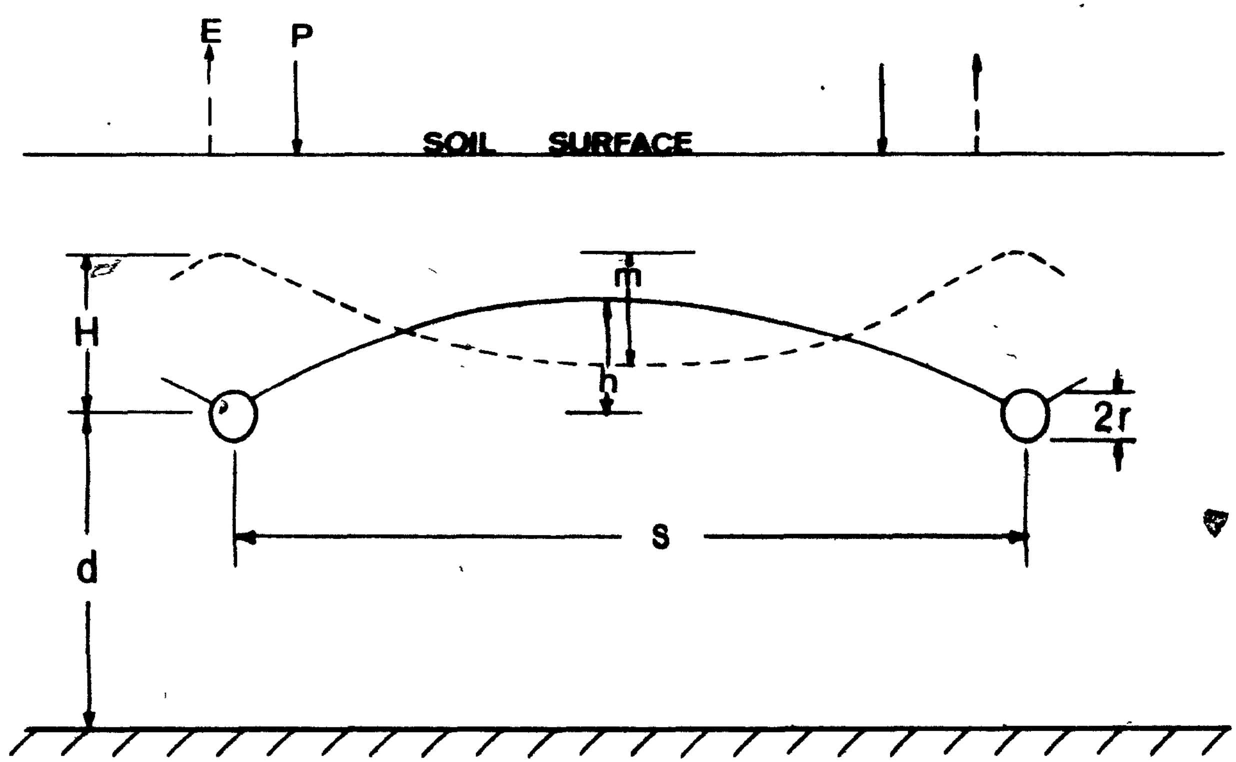
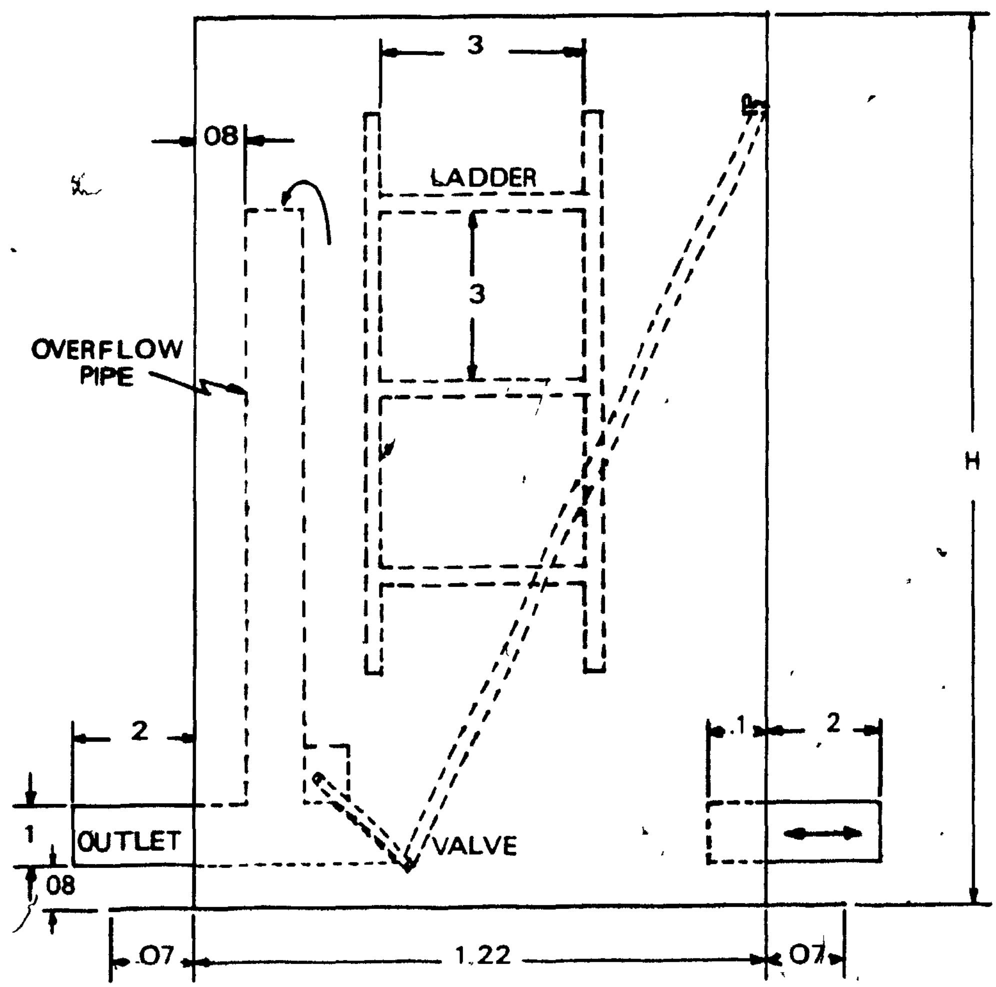


FIGURE 4: WATER TABLE DISTRIBUTION IN SUBIRRIGATION AND SUBSURFACE DRAINAGE



scale **1:12.5**
ALL DIMENSIONS IN METERS

FIGURE 5: DIAGRAM OF A CONTROL CHAMBER (REDRAWN FROM GALLICHAND, 1983)

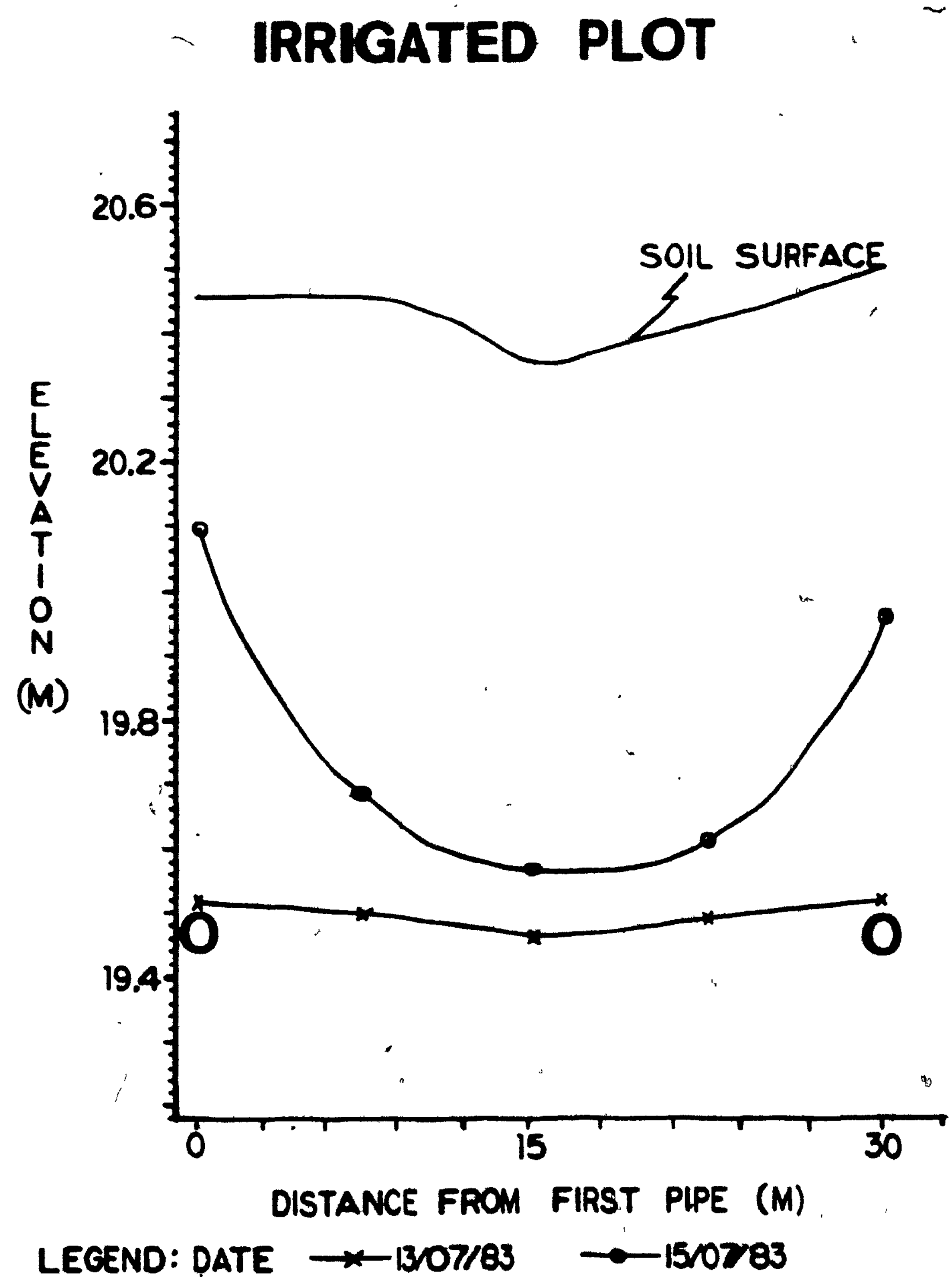


FIGURE 6 : WATER TABLE CHANGE
IN PLOT A - 1
LINE G

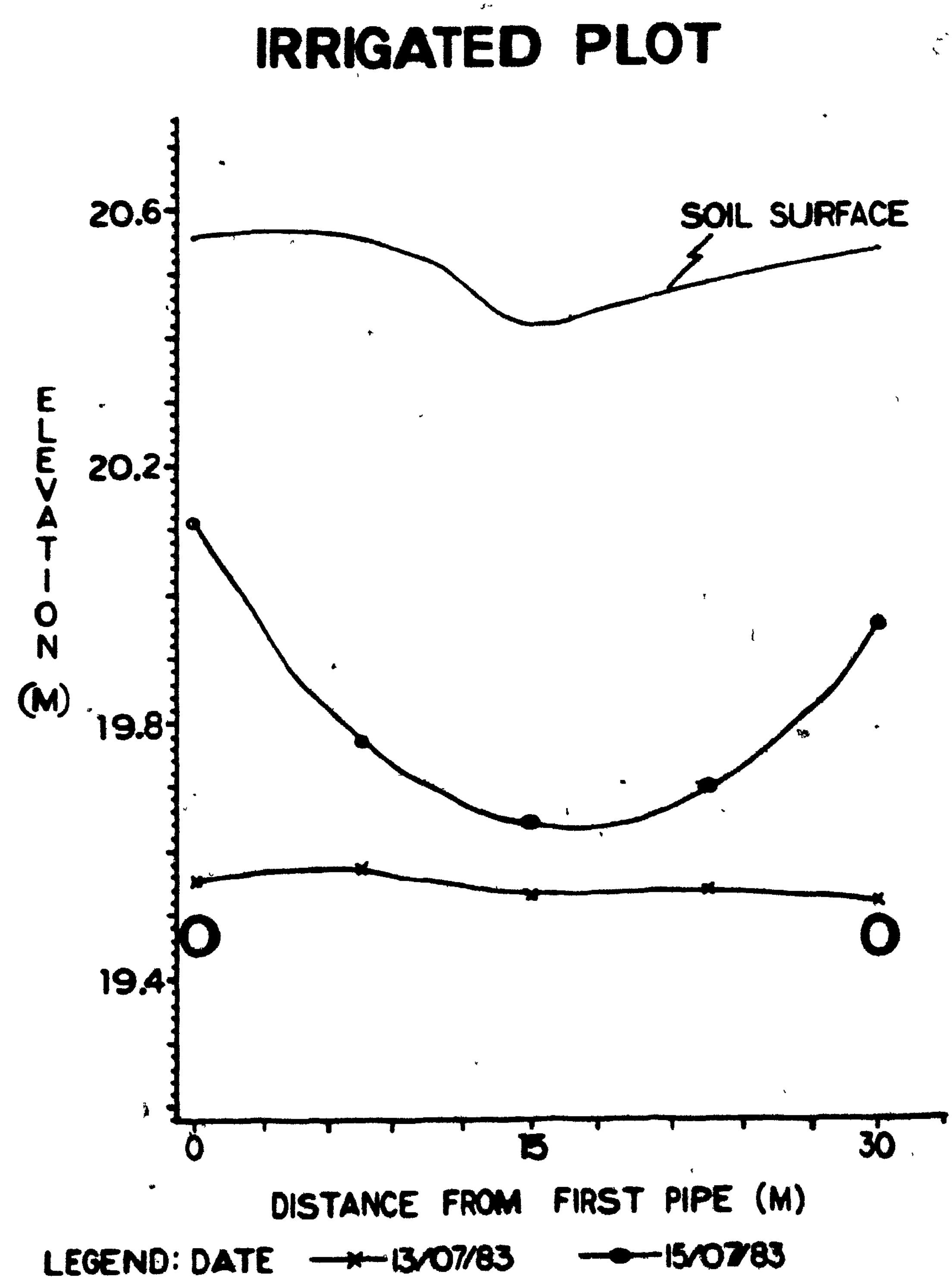


FIGURE 7 : WATER TABLE CHANGE
IN PLOT A-1
LINE H

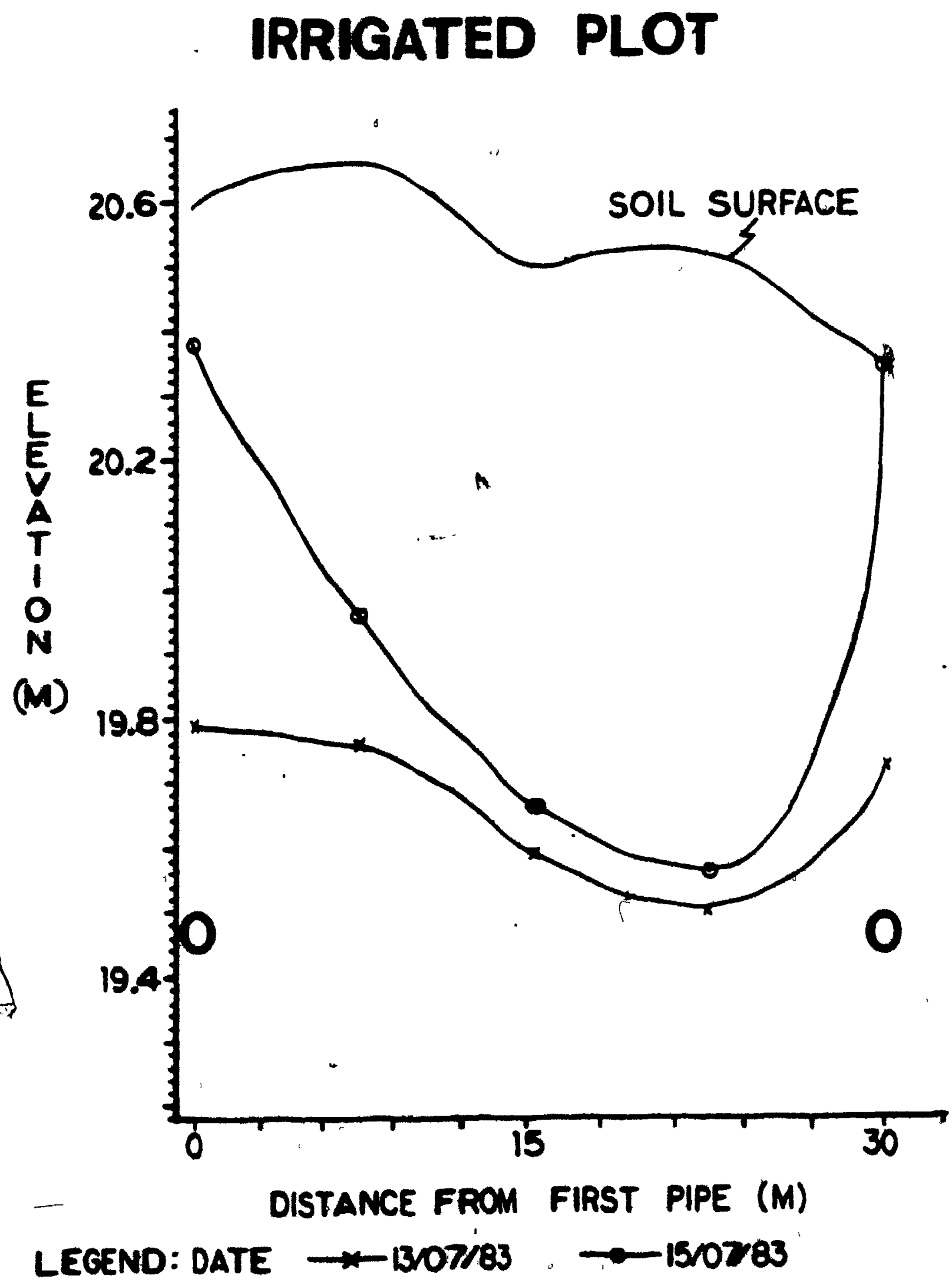


FIGURE 8 : WATER TABLE CHANGE IN PLOT A-2 LINE G

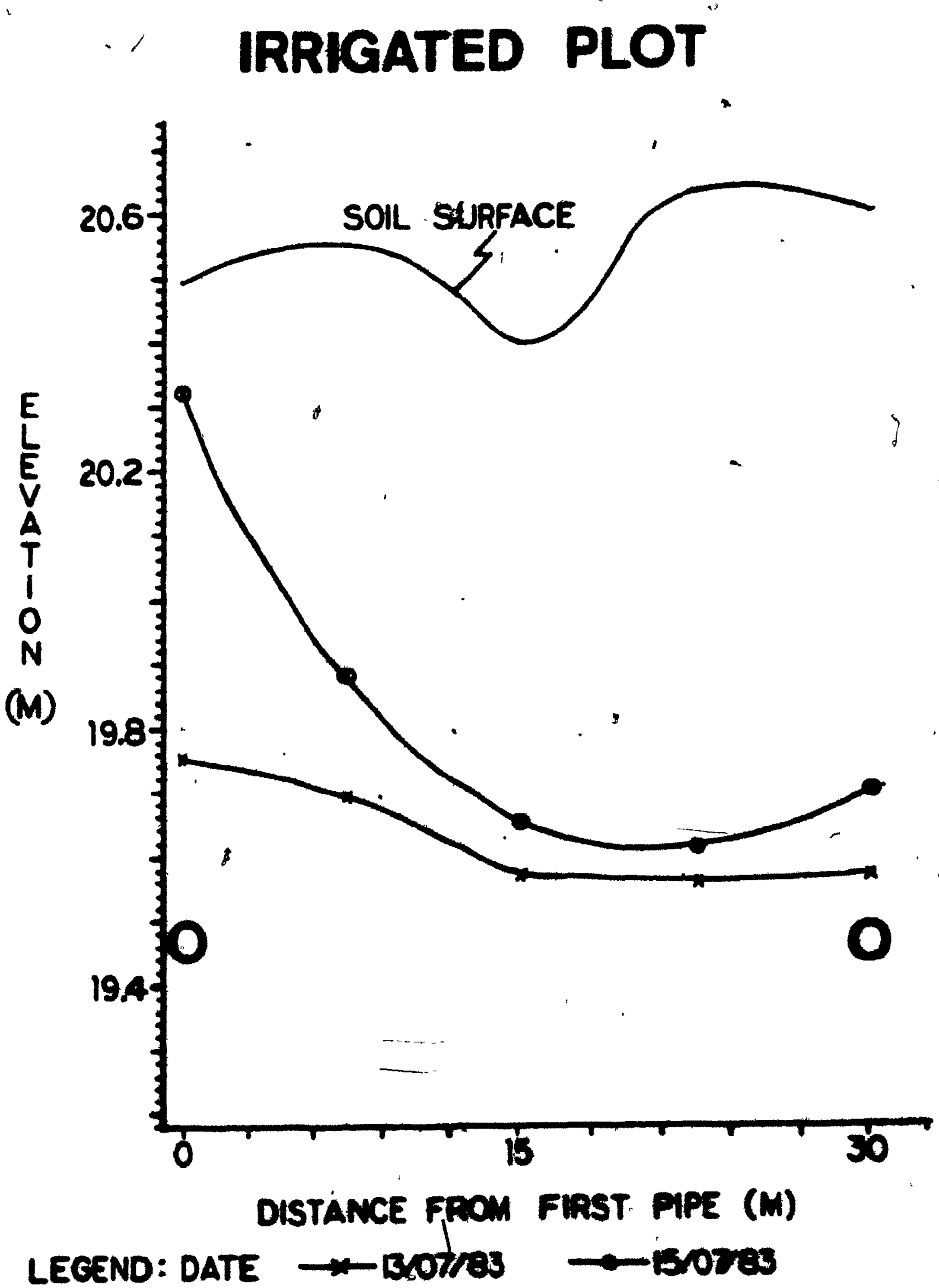


FIGURE 9 : WATER TABLE CHANGE IN PLOT A-2 LINE H

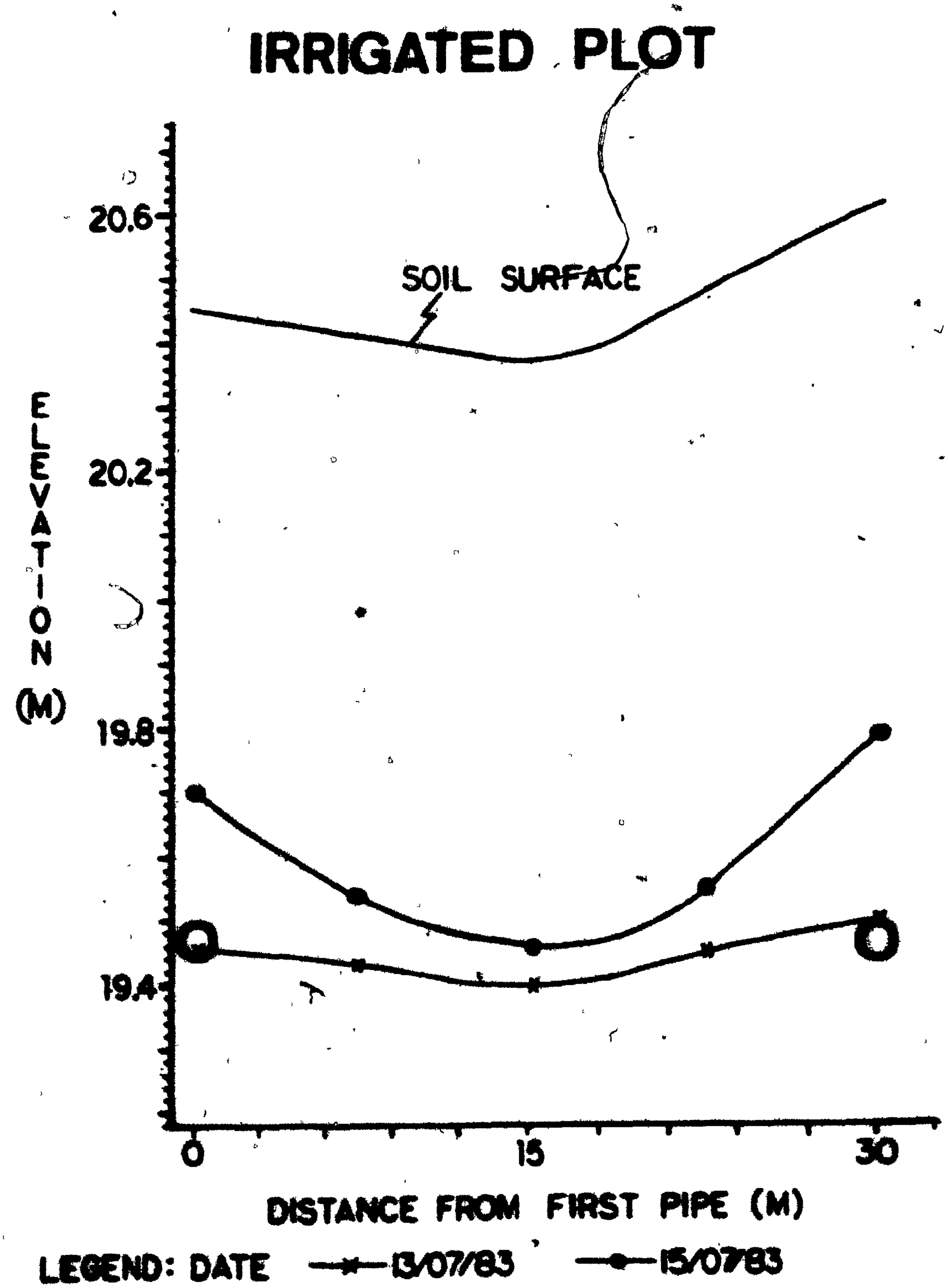


FIGURE 10: WATER TABLE CHANGE
IN PLOT A-3
LINE E

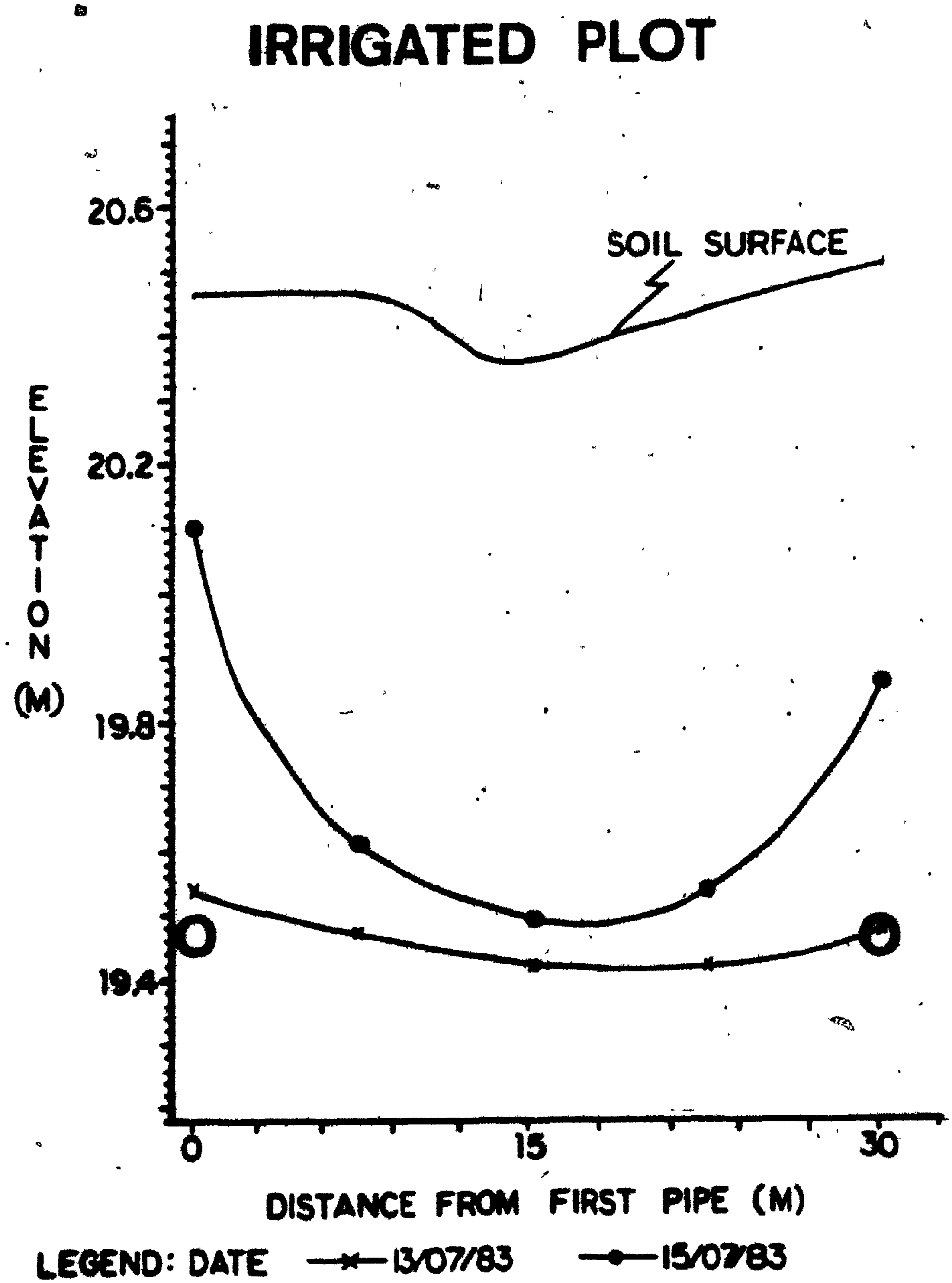


FIGURE 11: WATER TABLE CHANGE IN PLOT A-3 LINE F

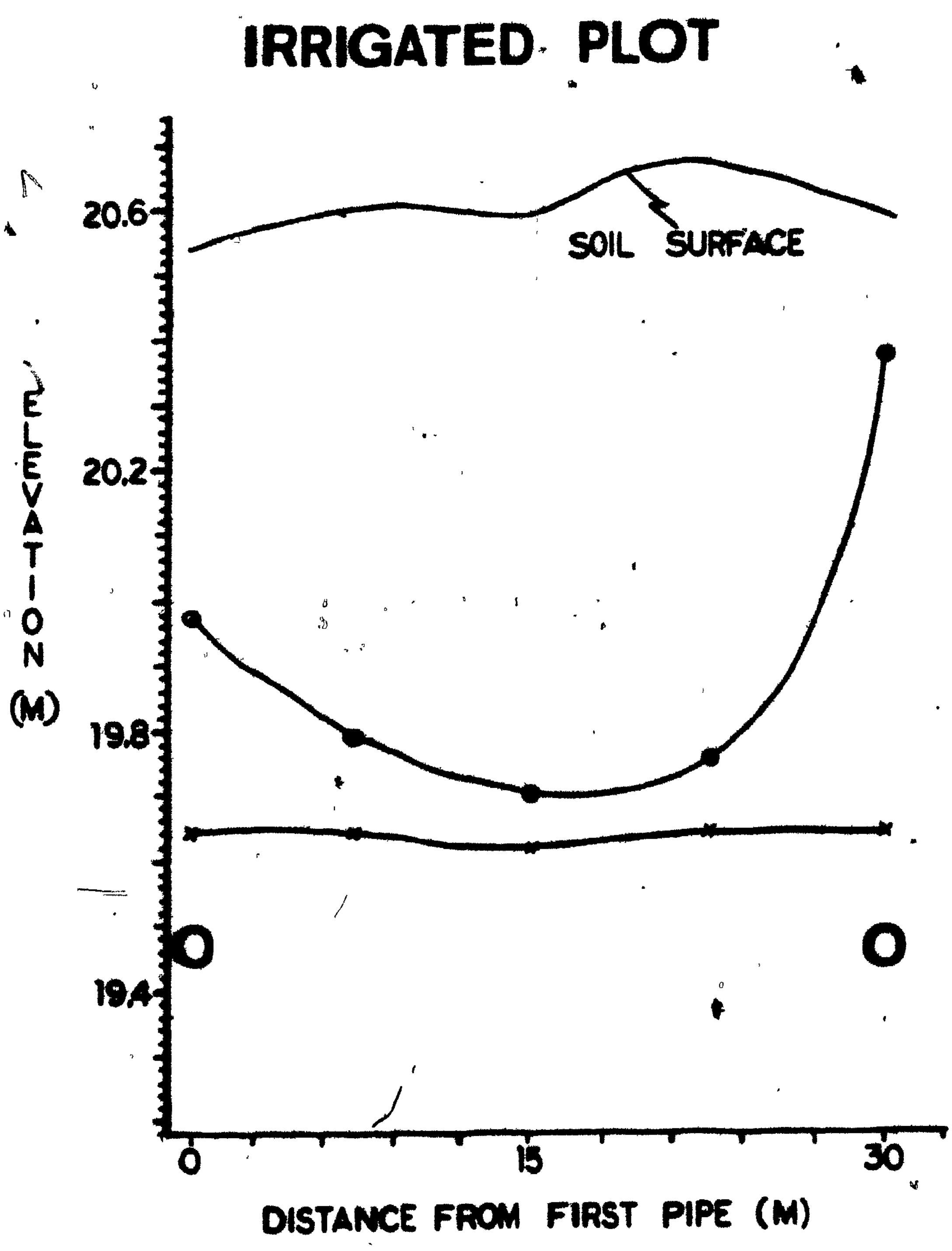
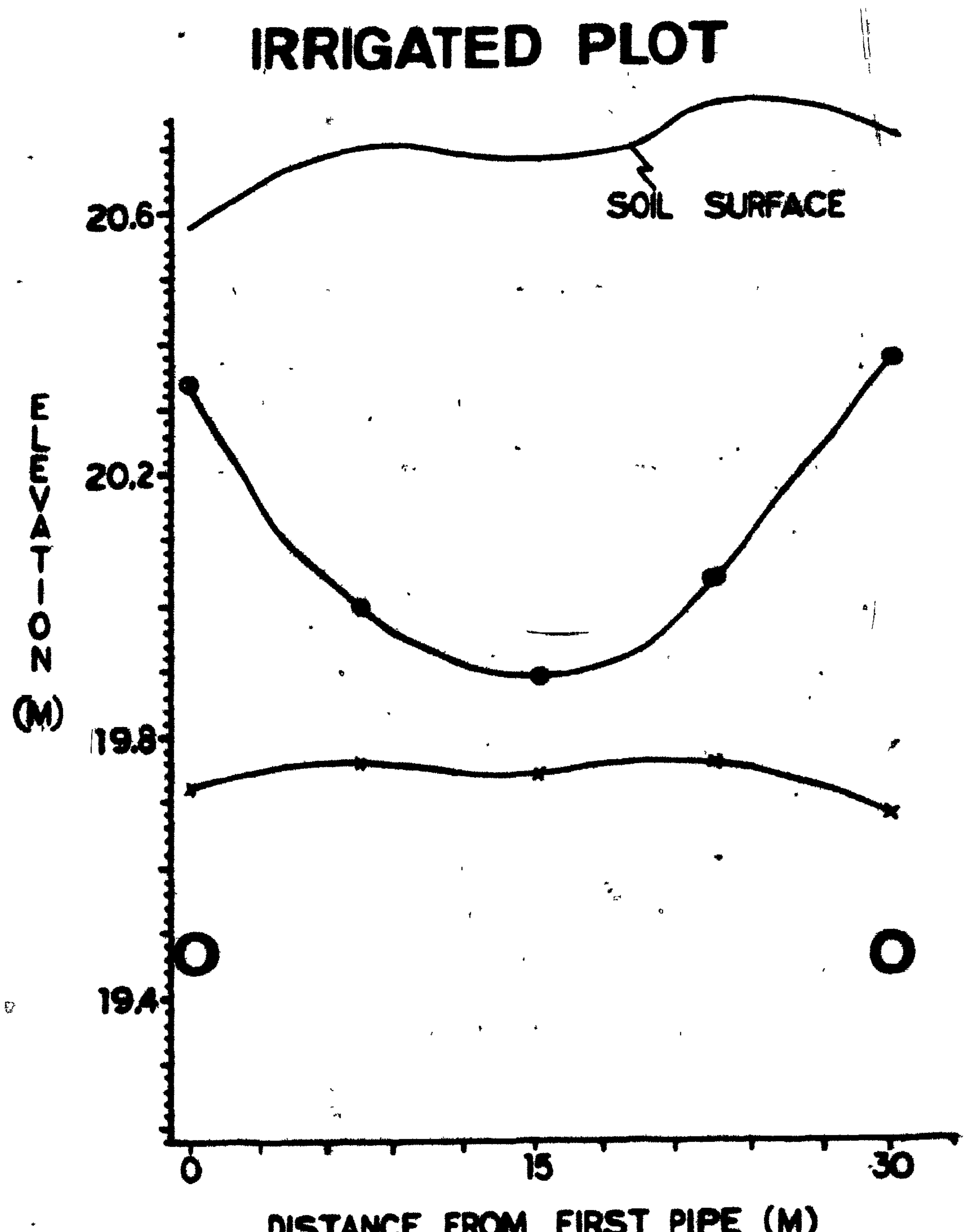


FIGURE 12: WATER TABLE CHANGE IN PLOT A-4 LINE E



LEGEND: DATE —×— 13/07/83 —●— 15/07/83

FIGURE 13: WATER TABLE CHANGE
IN PLOT A-4
LINE F

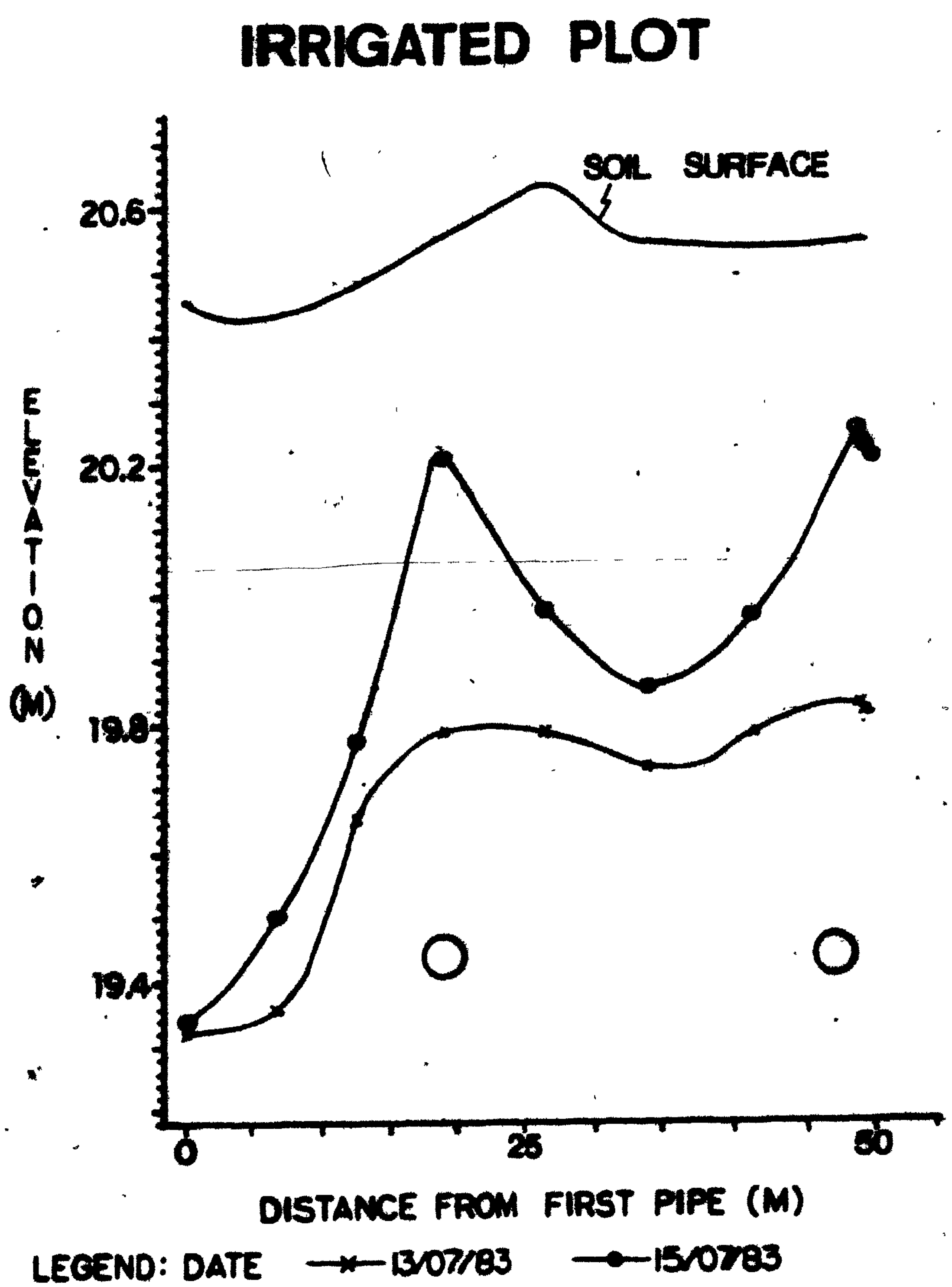


FIGURE 14: WATER TABLE CHANGE
IN PLOT A – 5
LINE C

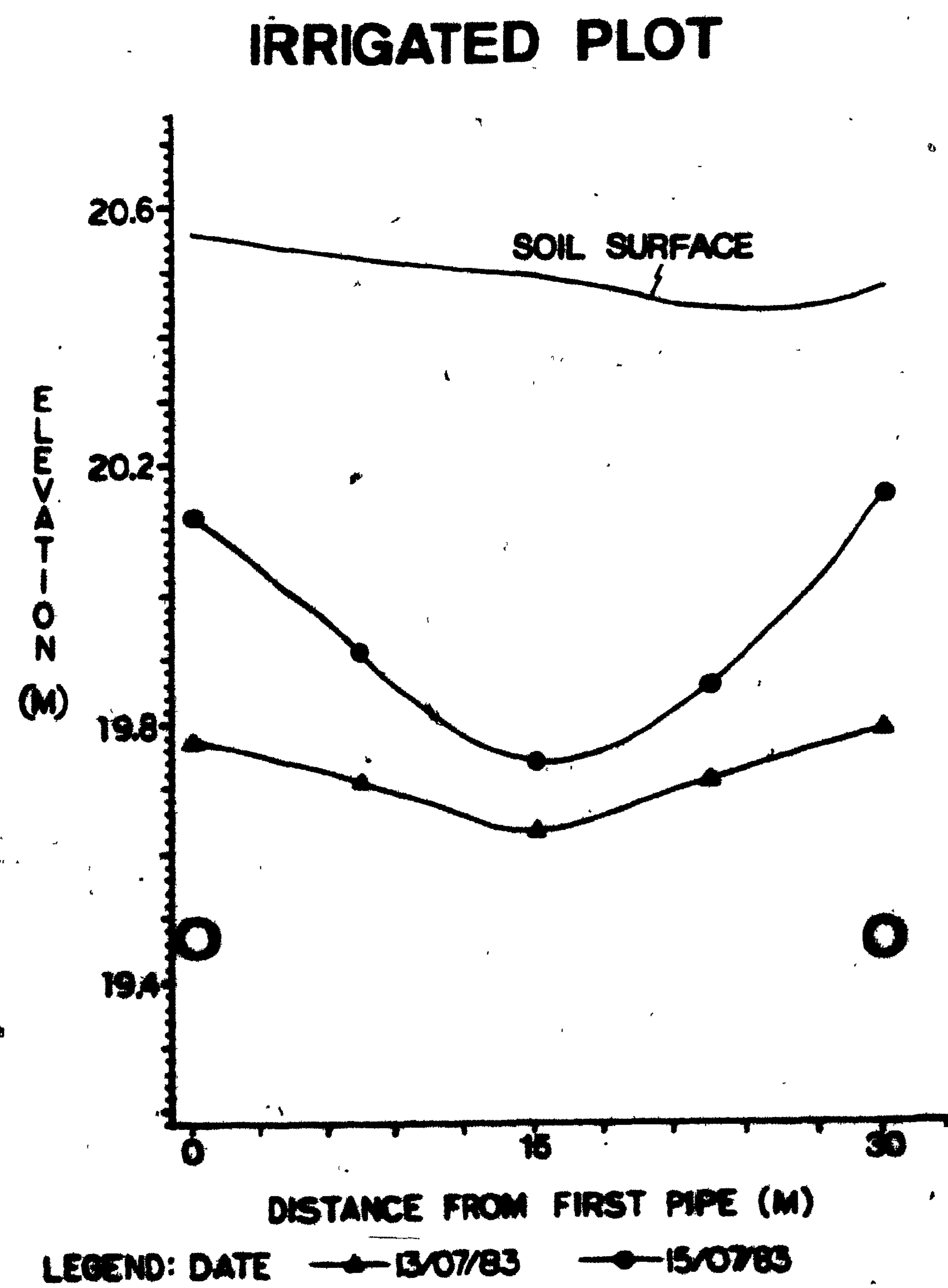


FIGURE 16: WATER TABLE CHANGE
IN PLOT A-5
LINE D

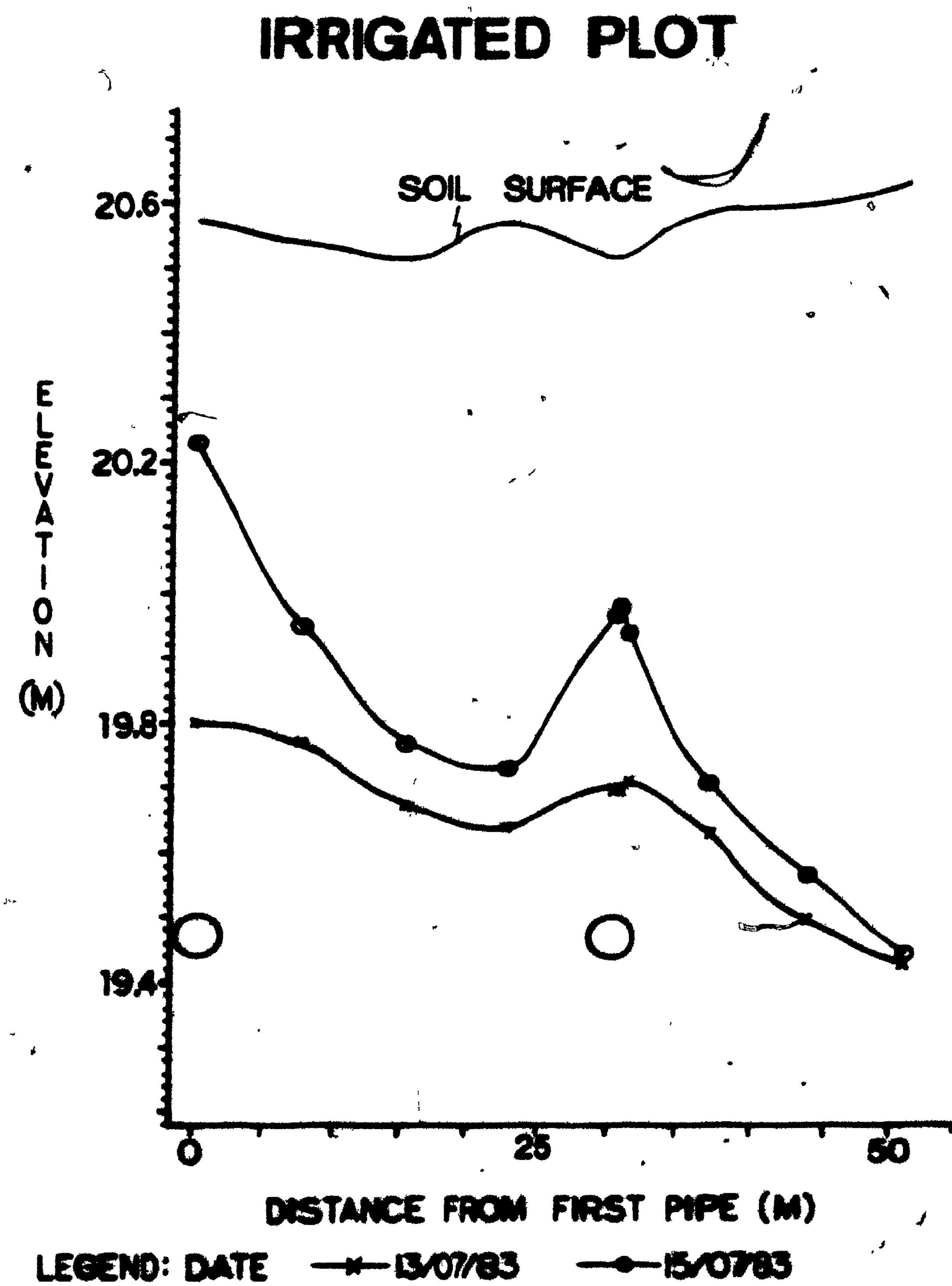


FIGURE 16: WATER TABLE CHANGE IN PLOT A-6 LINE C

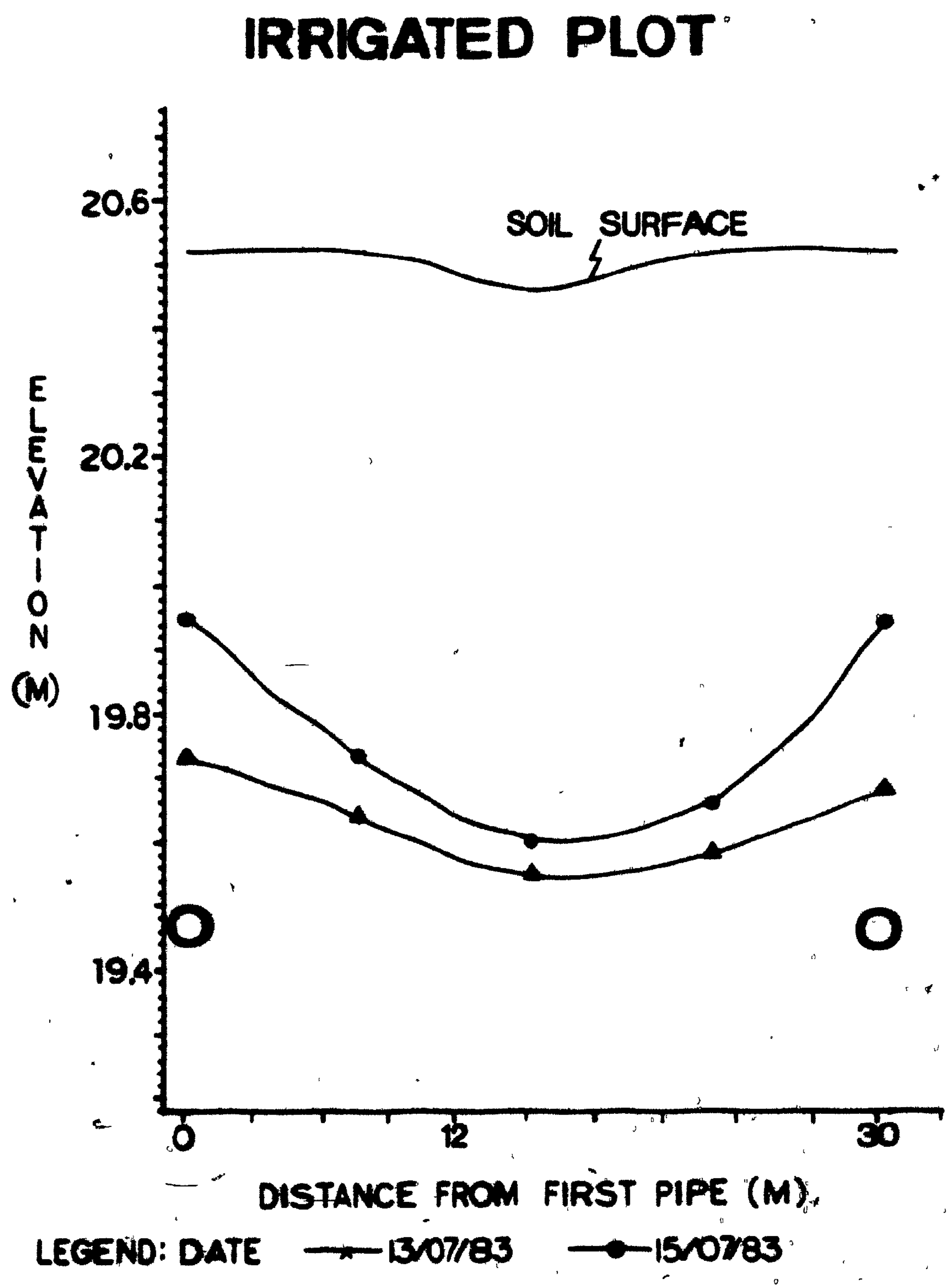


FIGURE 17: WATER TABLE CHANGE IN PLOT A-6 LINE D

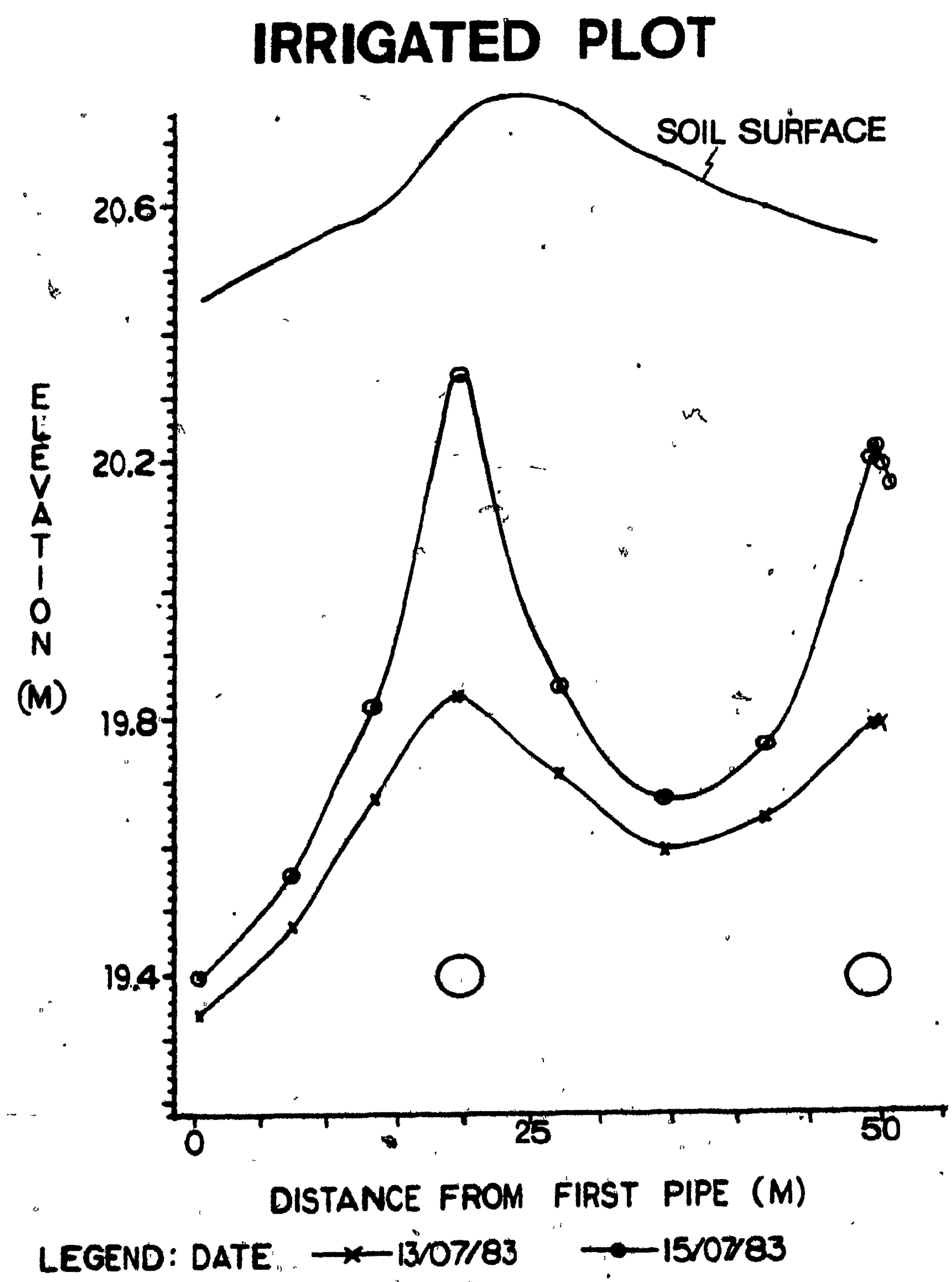


FIGURE 18 : WATER TABLE CHANGE IN PLOT A-7 LINE A

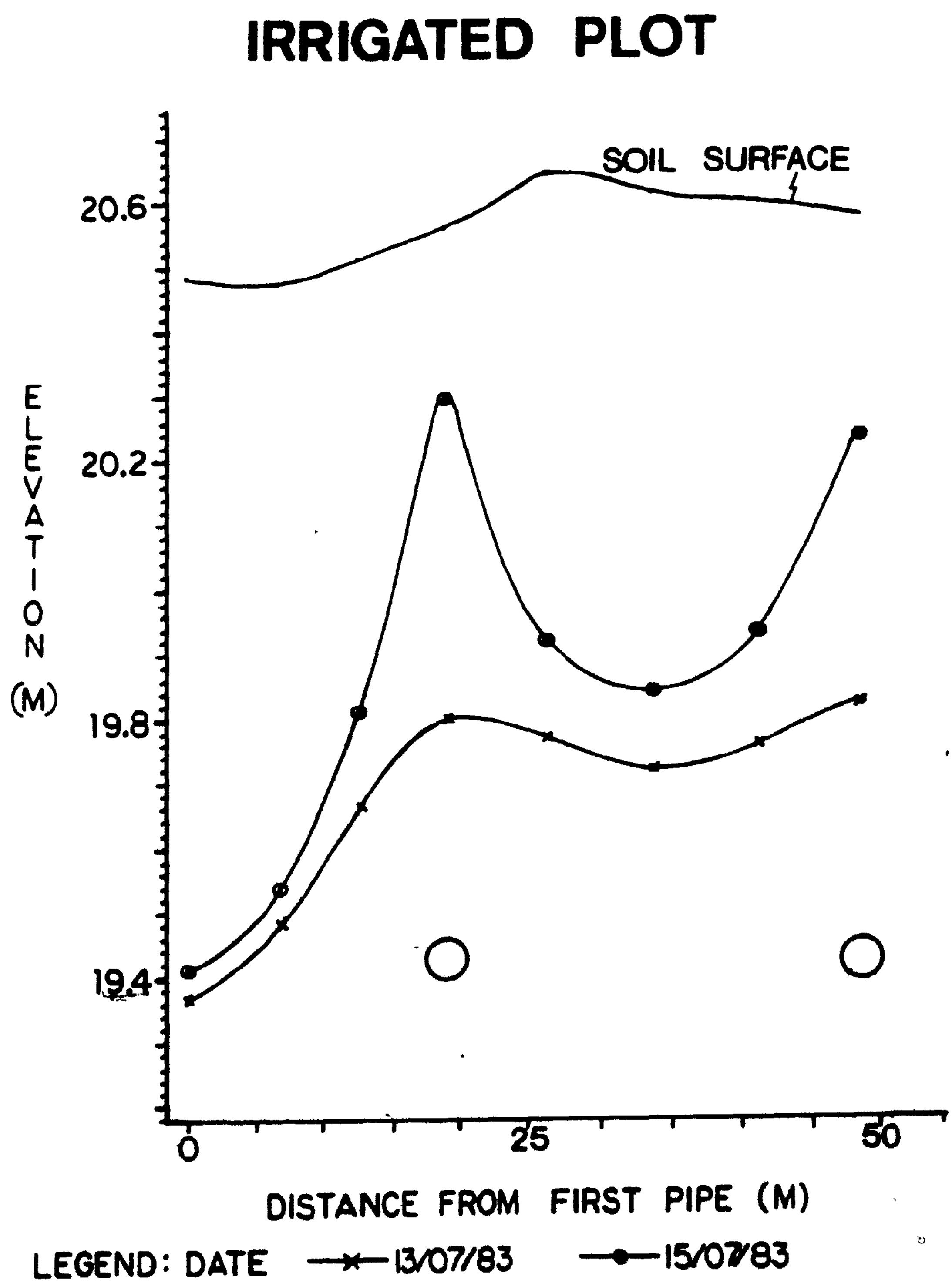


FIGURE 19 : WATER TABLE CHANGE IN PLOT A-7 LINE B

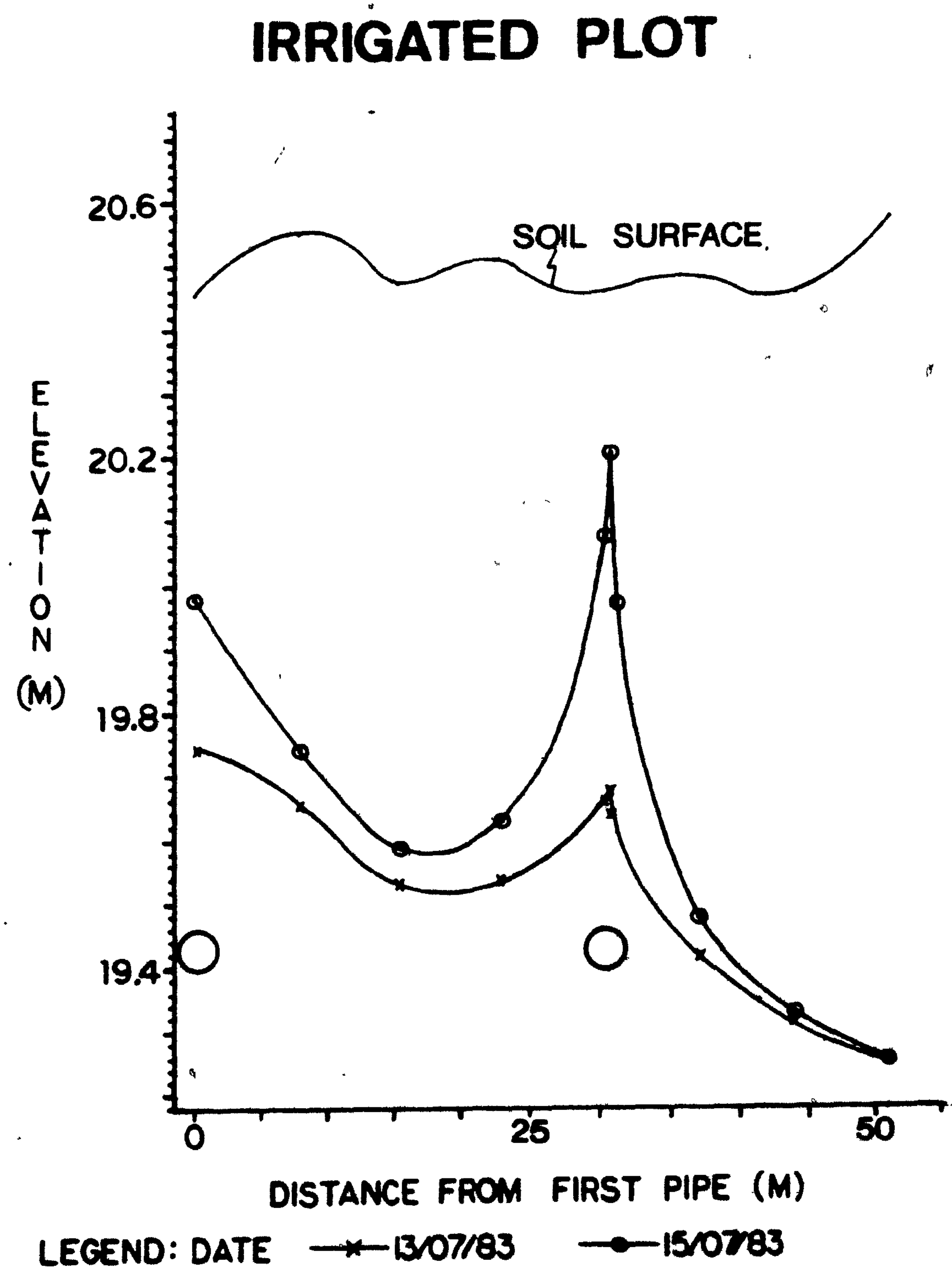


FIGURE 20: WATER TABLE CHANGE IN PLOT A-8 LINE A

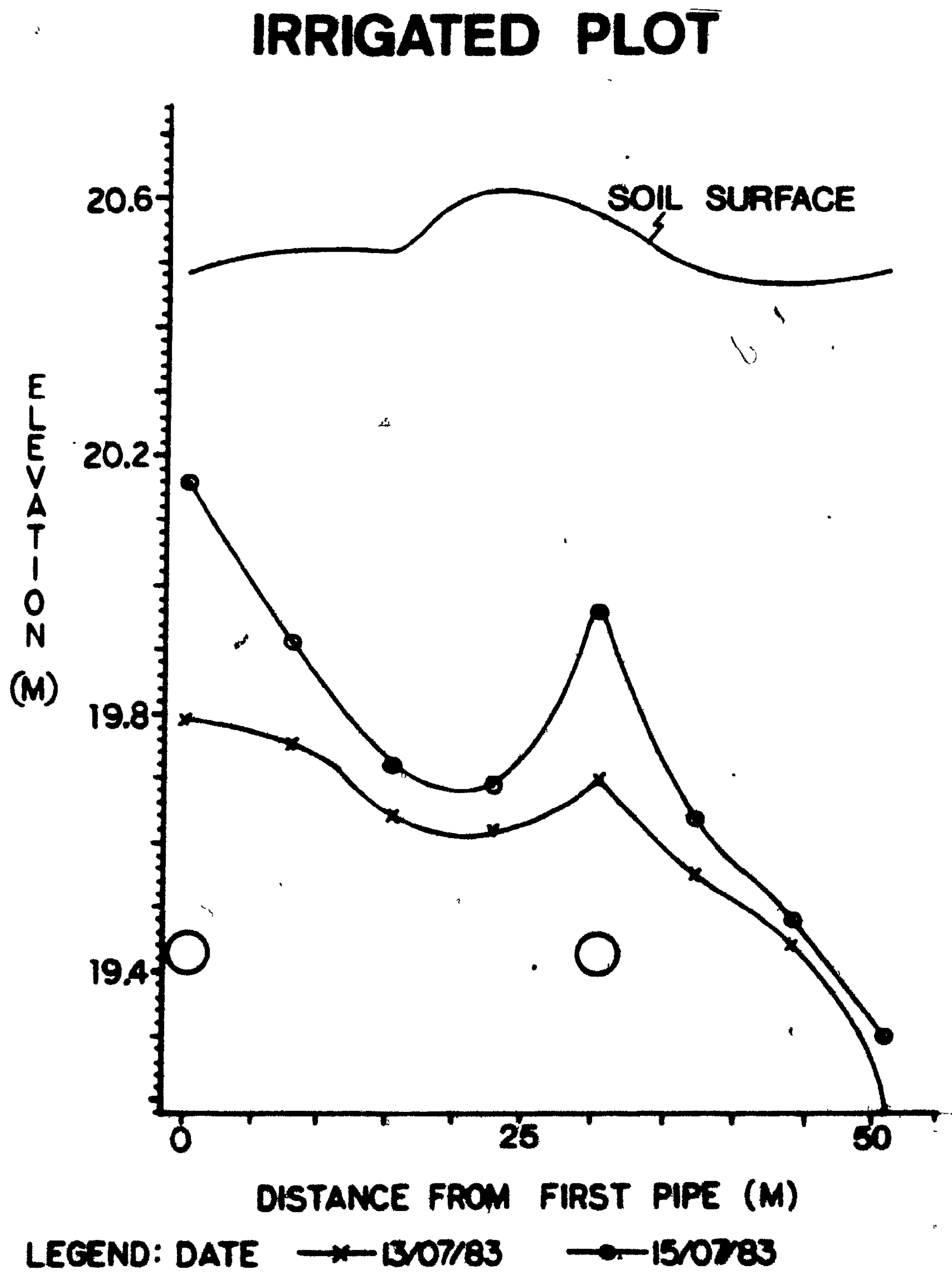


FIGURE 21: WATER TABLE CHANGE IN PLOT A-8 LINE B

NON-IRRIGATED PLOT

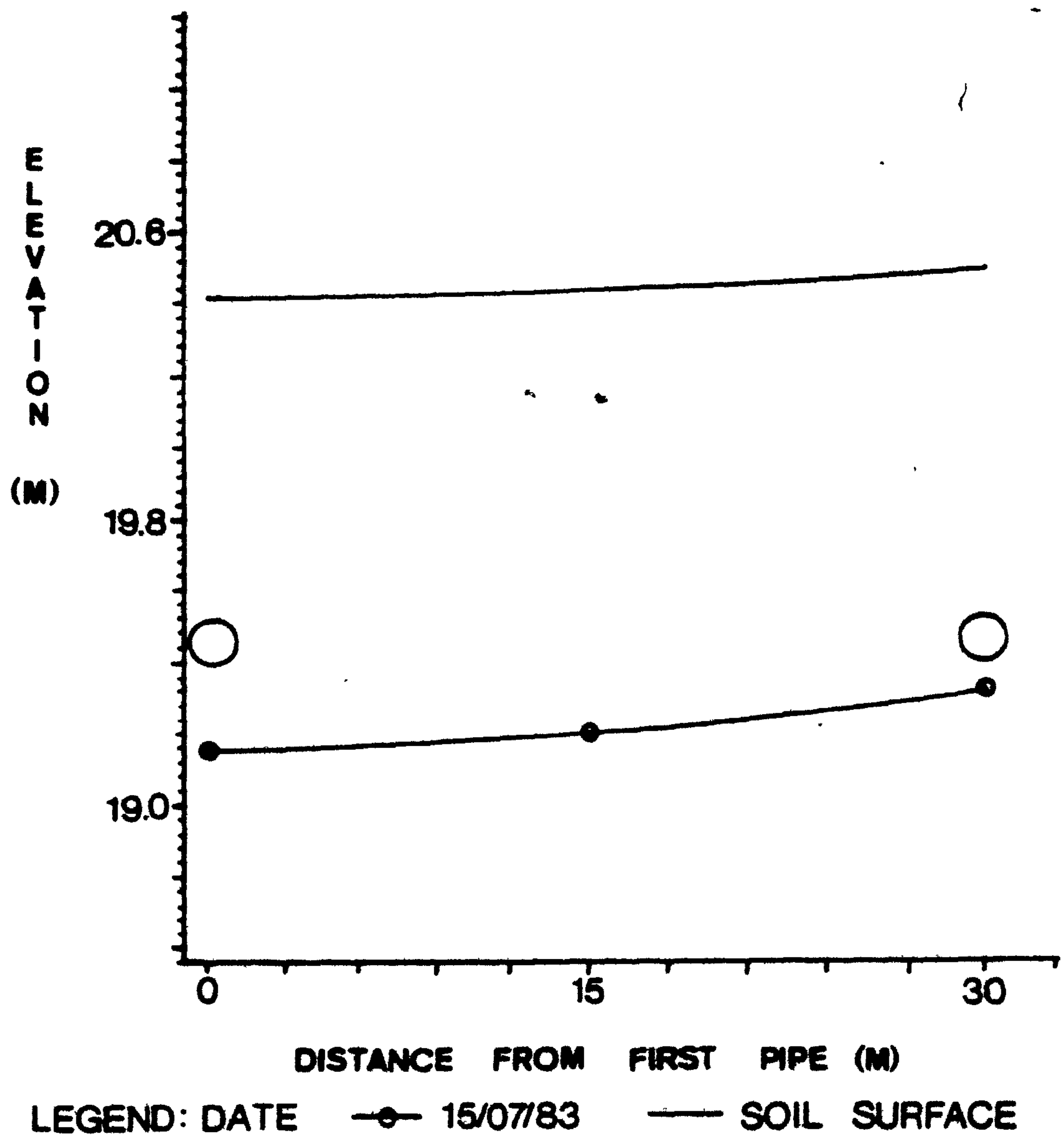


FIGURE 22 : WATER TABLE LEVEL
IN PLOT B – 1
LINE G

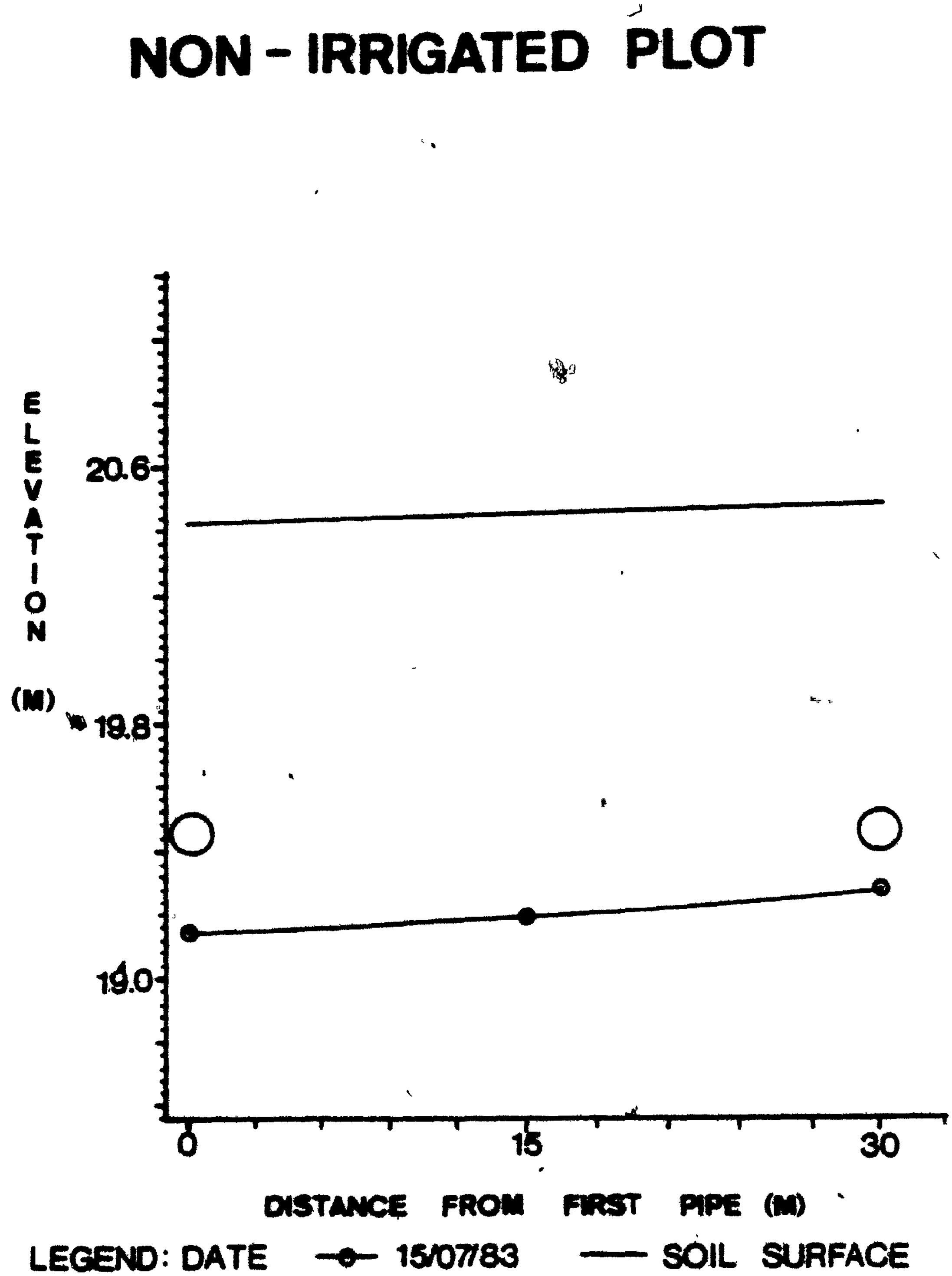
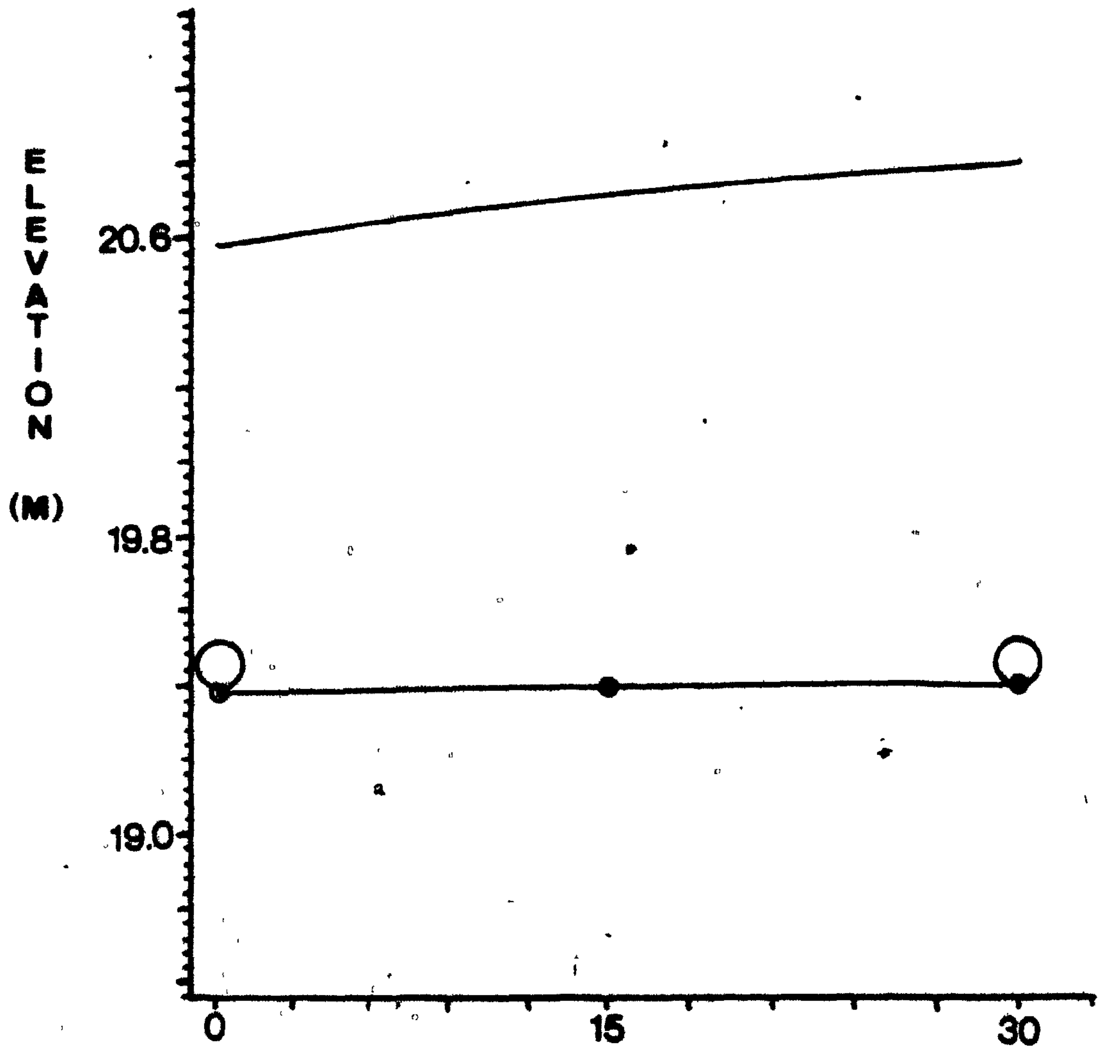


FIGURE 23 : WATER TABLE LEVEL
IN PLOT B-1
LINE H

NON-IRRIGATED PLOT



LEGEND: DATE —o— 15/07/83 —— SOIL SURFACE

FIGURE 24 : WATER TABLE LEVEL
IN PLOT B – 2
LINE G

NON-IRRIGATED PLOT

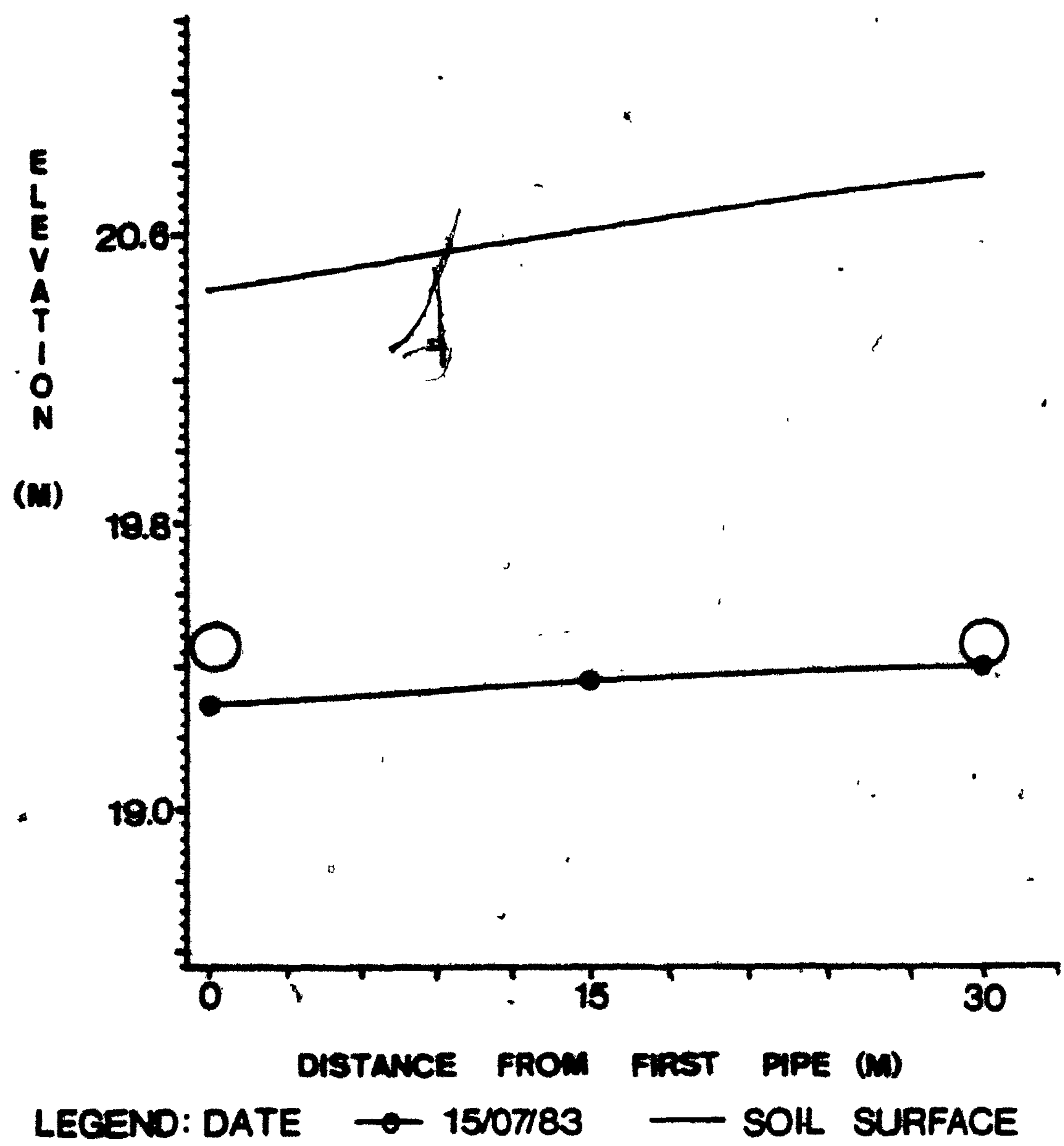
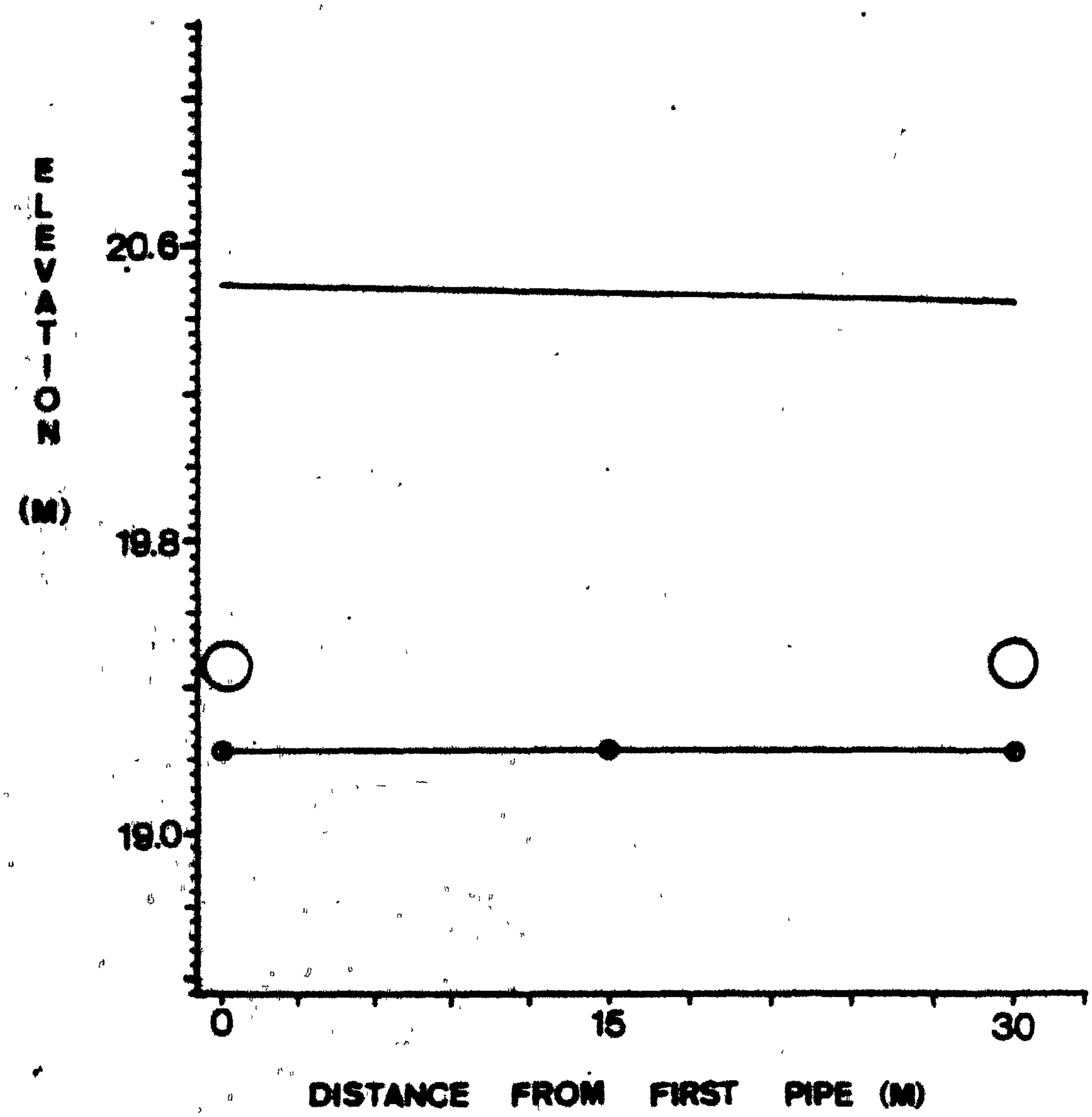


FIGURE 25 : WATER TABLE LEVEL
IN PLOT B-2
LINE H

NON - IRRIGATED PLOT



LEGEND: DATE —●— 15/07/83 —— SOIL SURFACE

FIGURE 26 : WATER TABLE LEVEL
IN PLOT B—3
LINE E

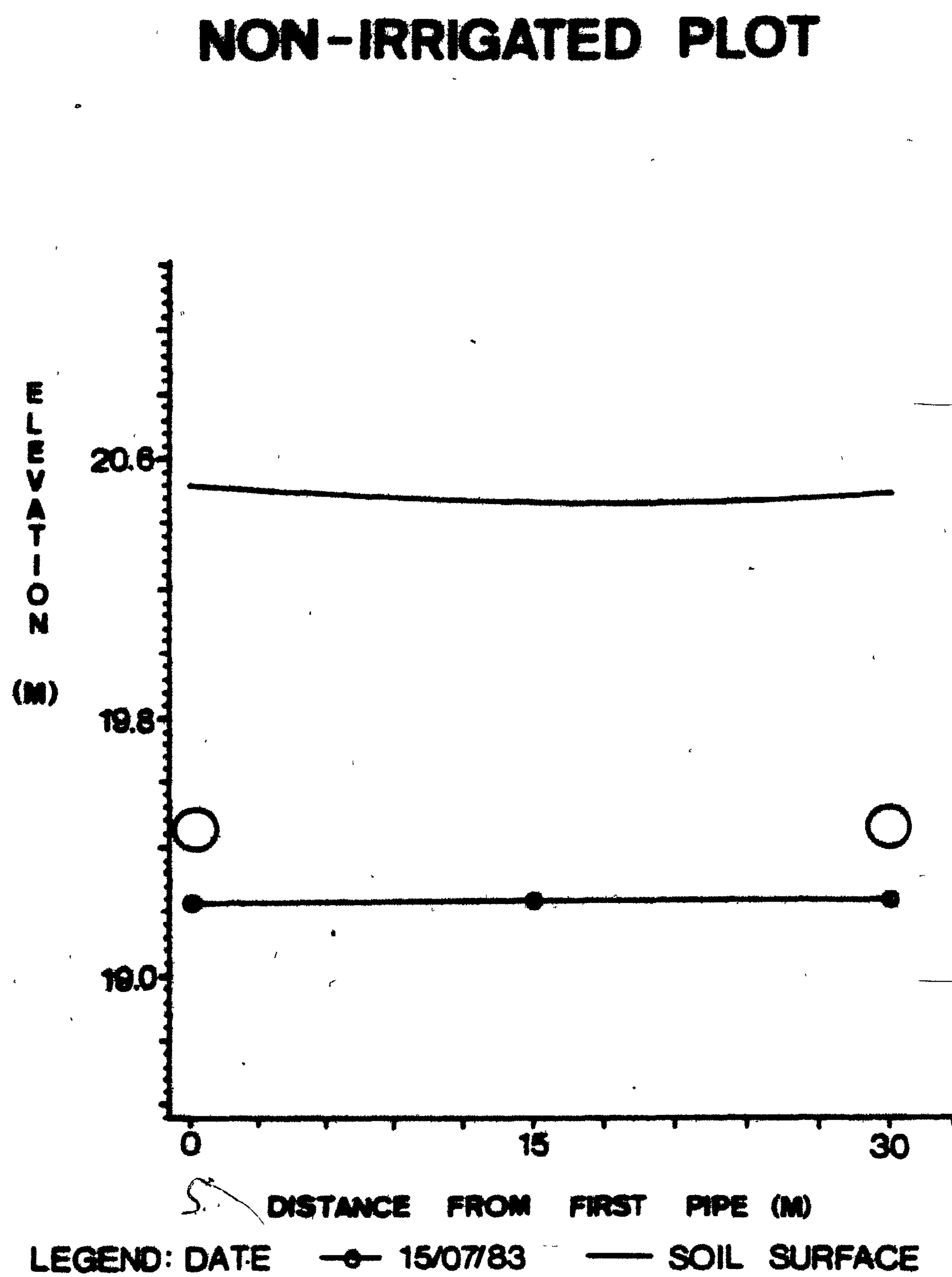


FIGURE 27: WATER TABLE LEVEL IN PLOT B-3 LINE F

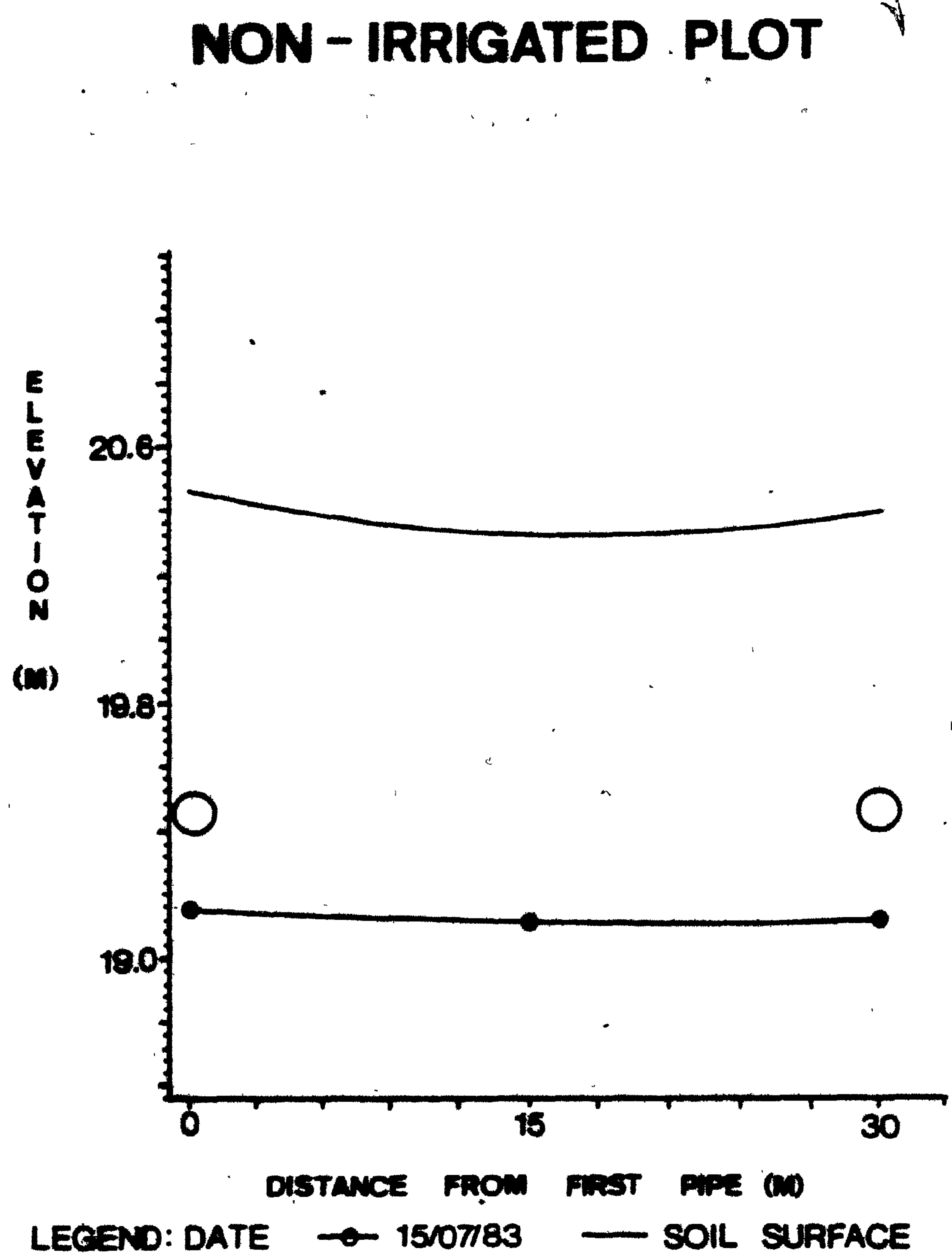
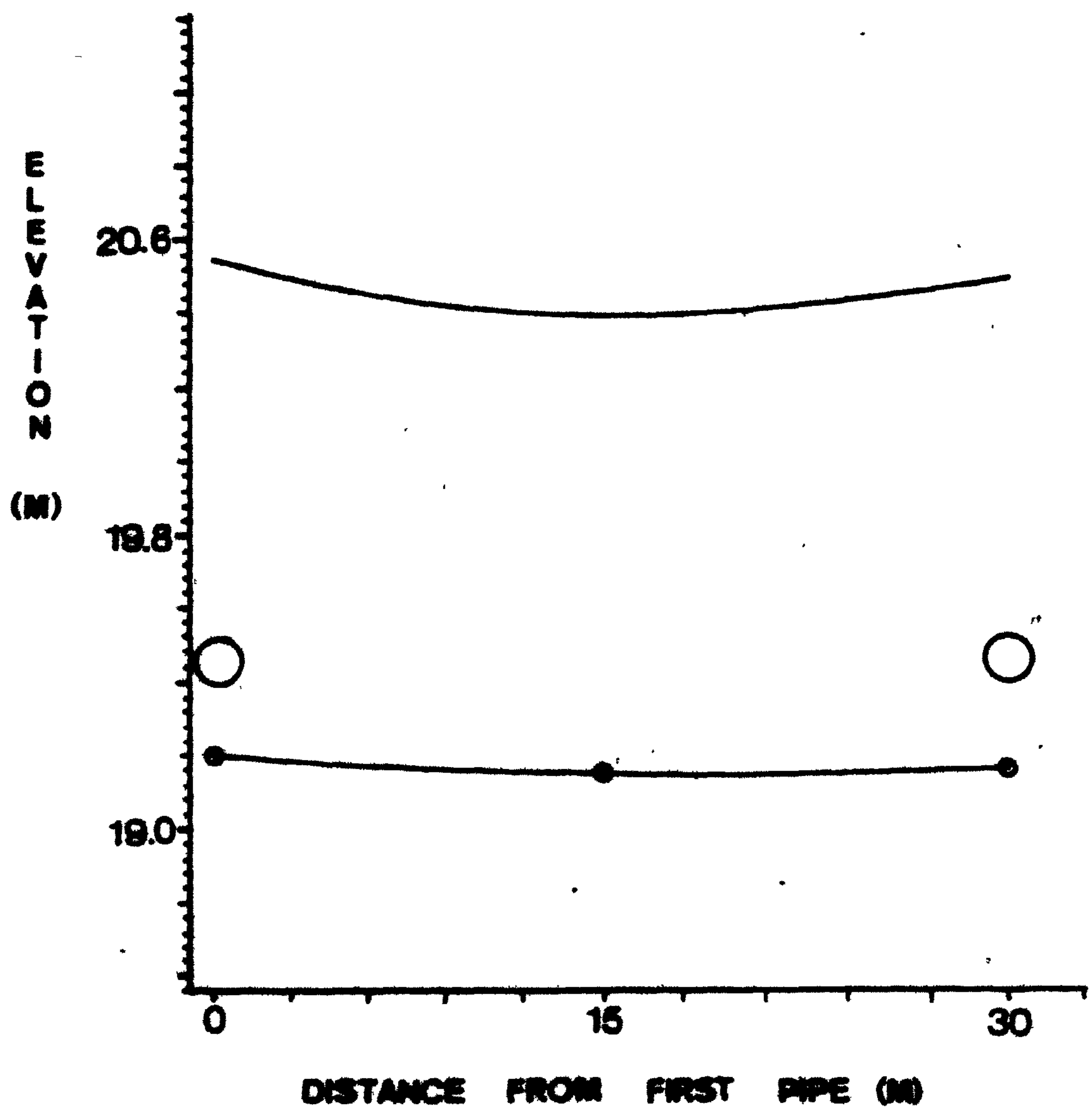


FIGURE 28 : WATER TABLE LEVEL
IN PLOT B—4
LINE E

NON - IRRIGATED PLOT



LEGEND: DATE —•— 15/07/83 —— SOIL SURFACE

FIGURE 29: WATER TABLE LEVEL
IN PLOT B-4
LINE F

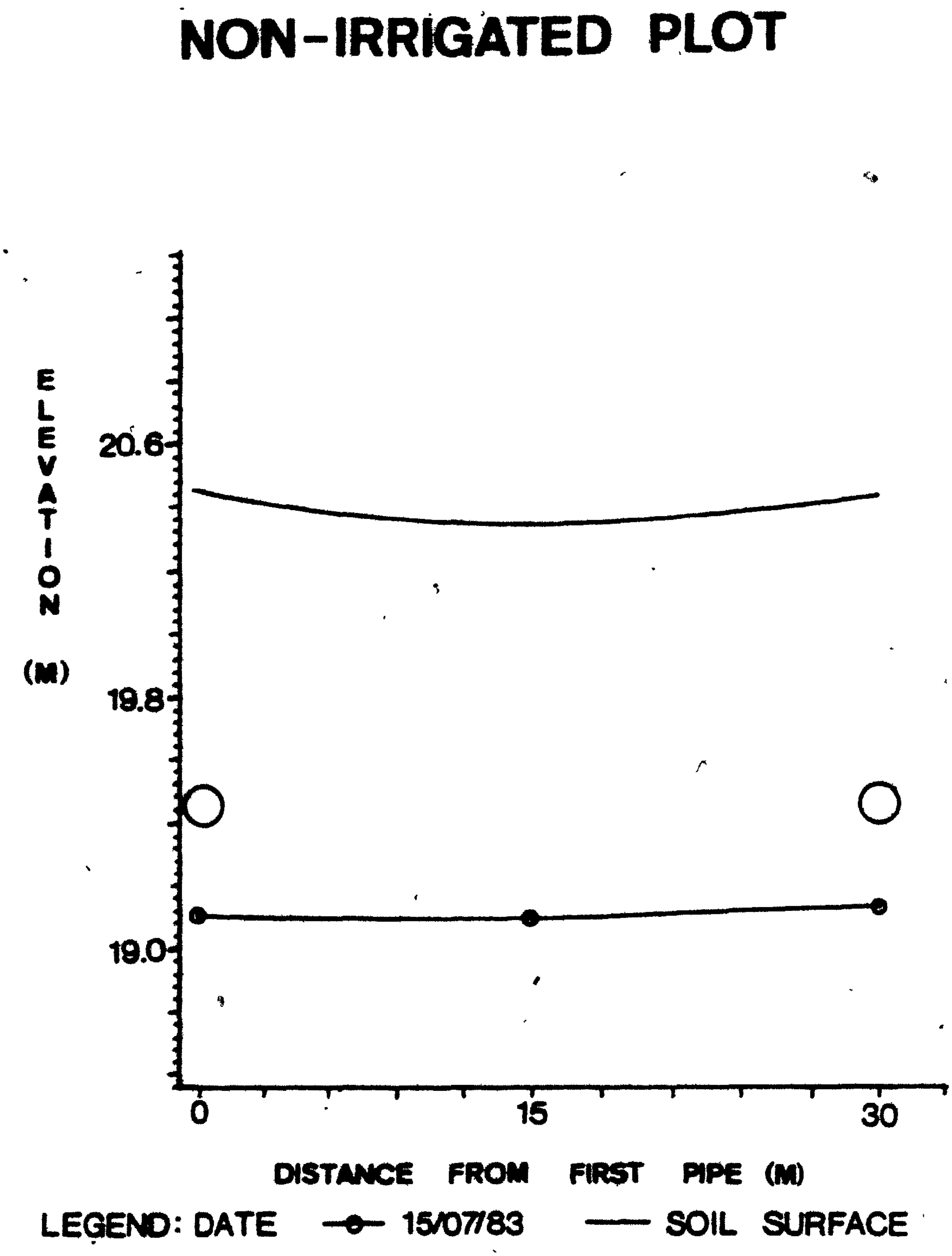


FIGURE 30 : WATER TABLE LEVEL
IN PLOT B – 5
· LINE C

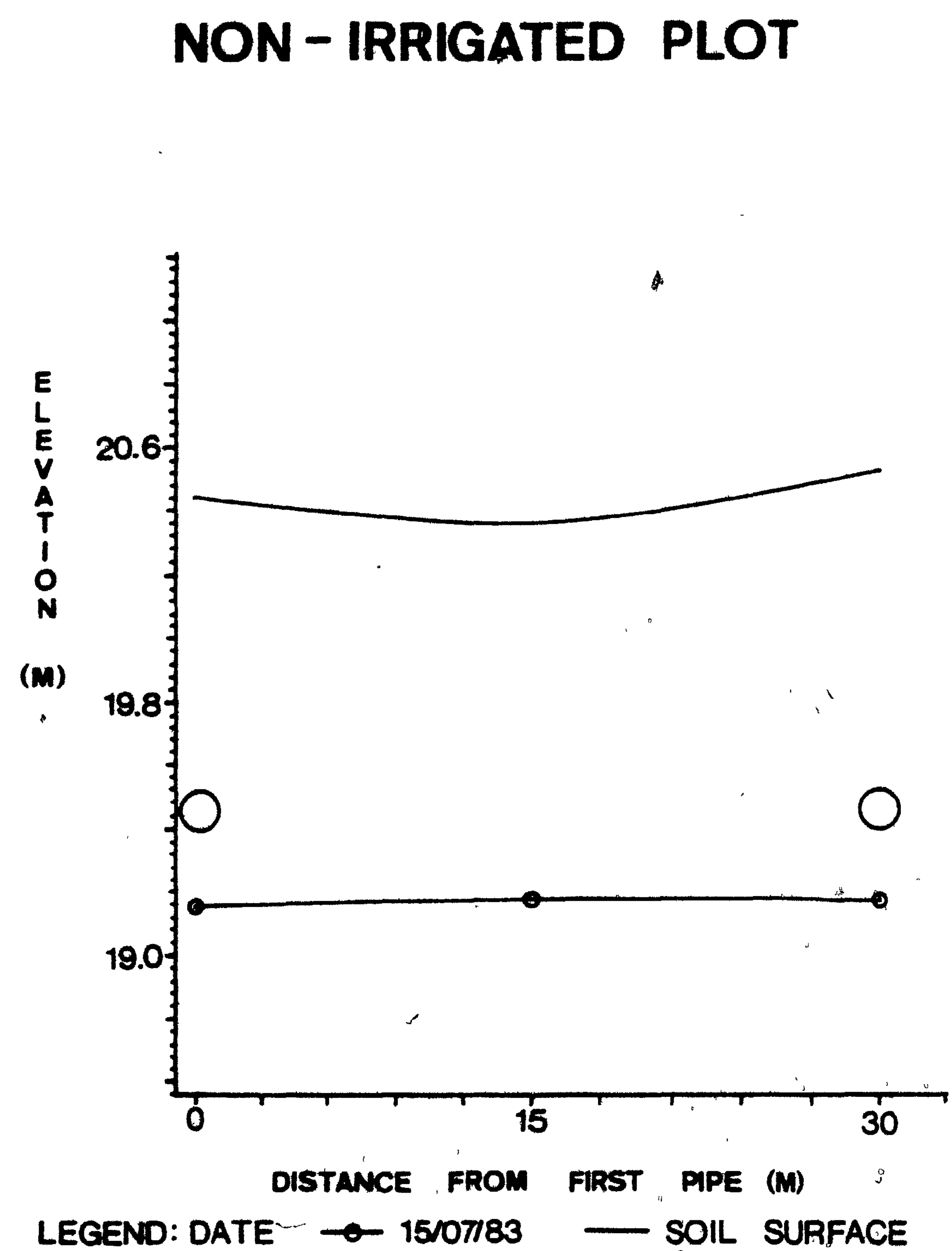


FIGURE 31 : WATER TABLE LEVEL
IN PLOT B-5
LINE D

NON-IRRIGATED PLOT

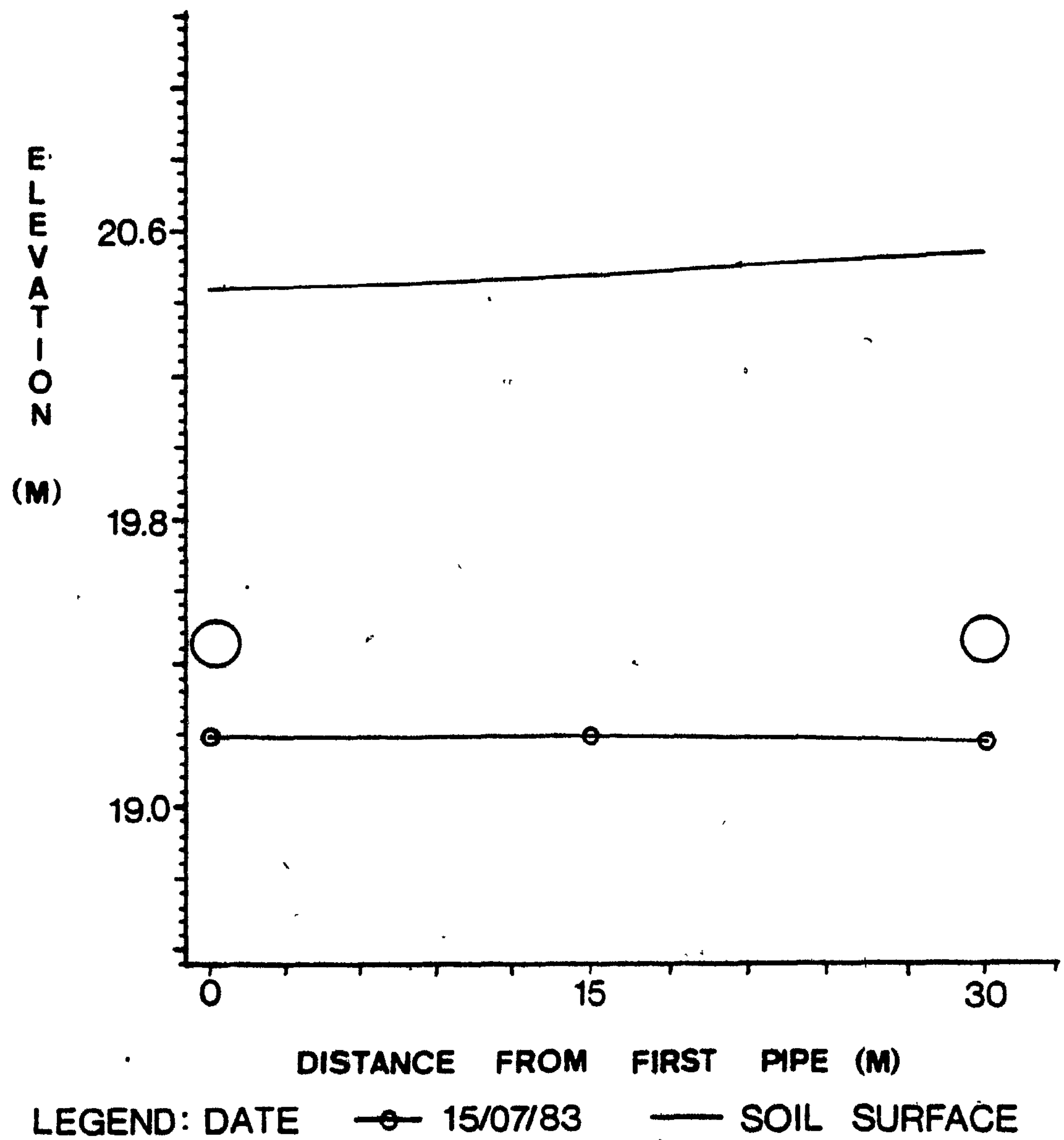


FIGURE 32 : WATER TABLE LEVEL
IN PLOT B-6
LINE C

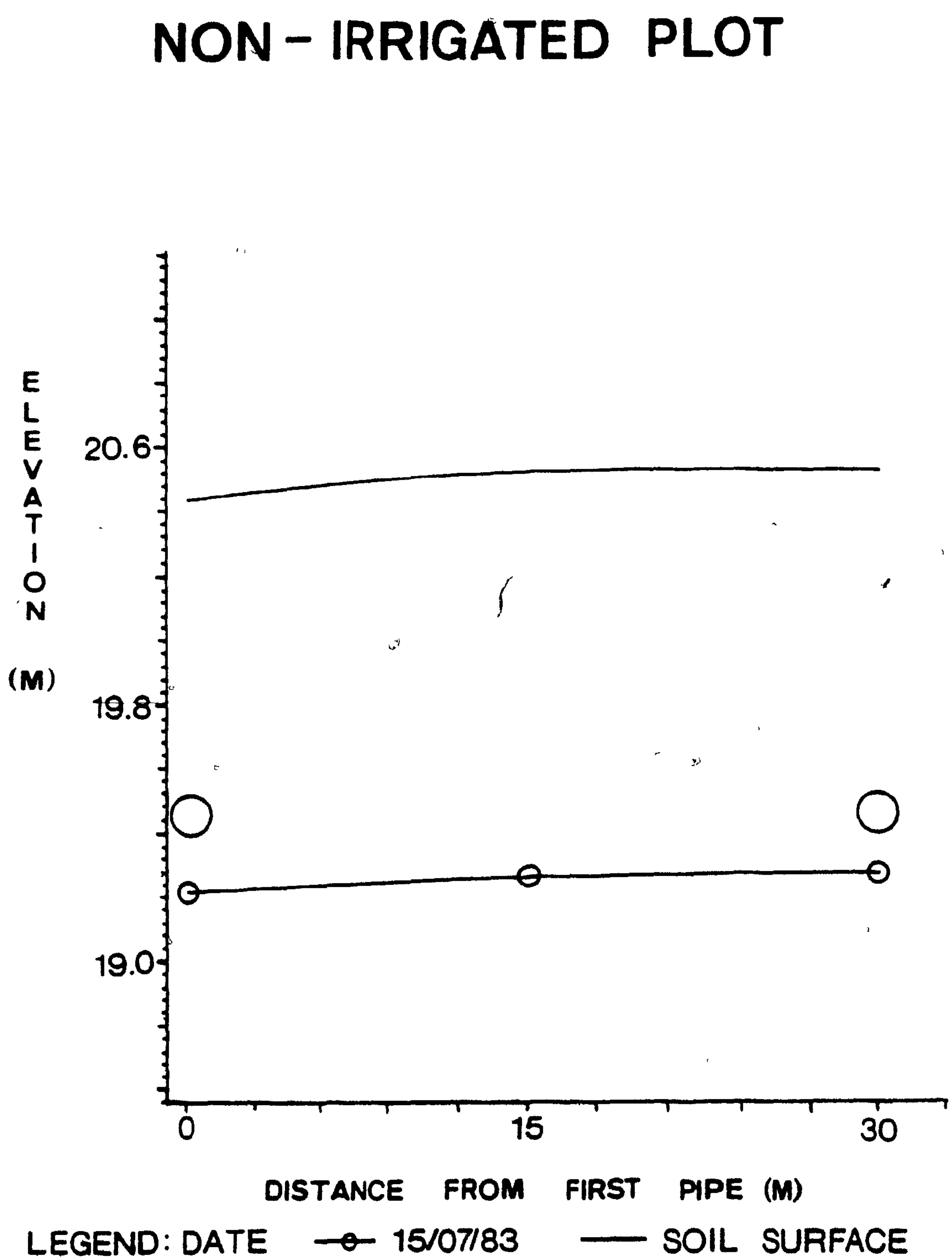


FIGURE 33 : WATER TABLE LEVEL
IN PLOT B-6
LINE D

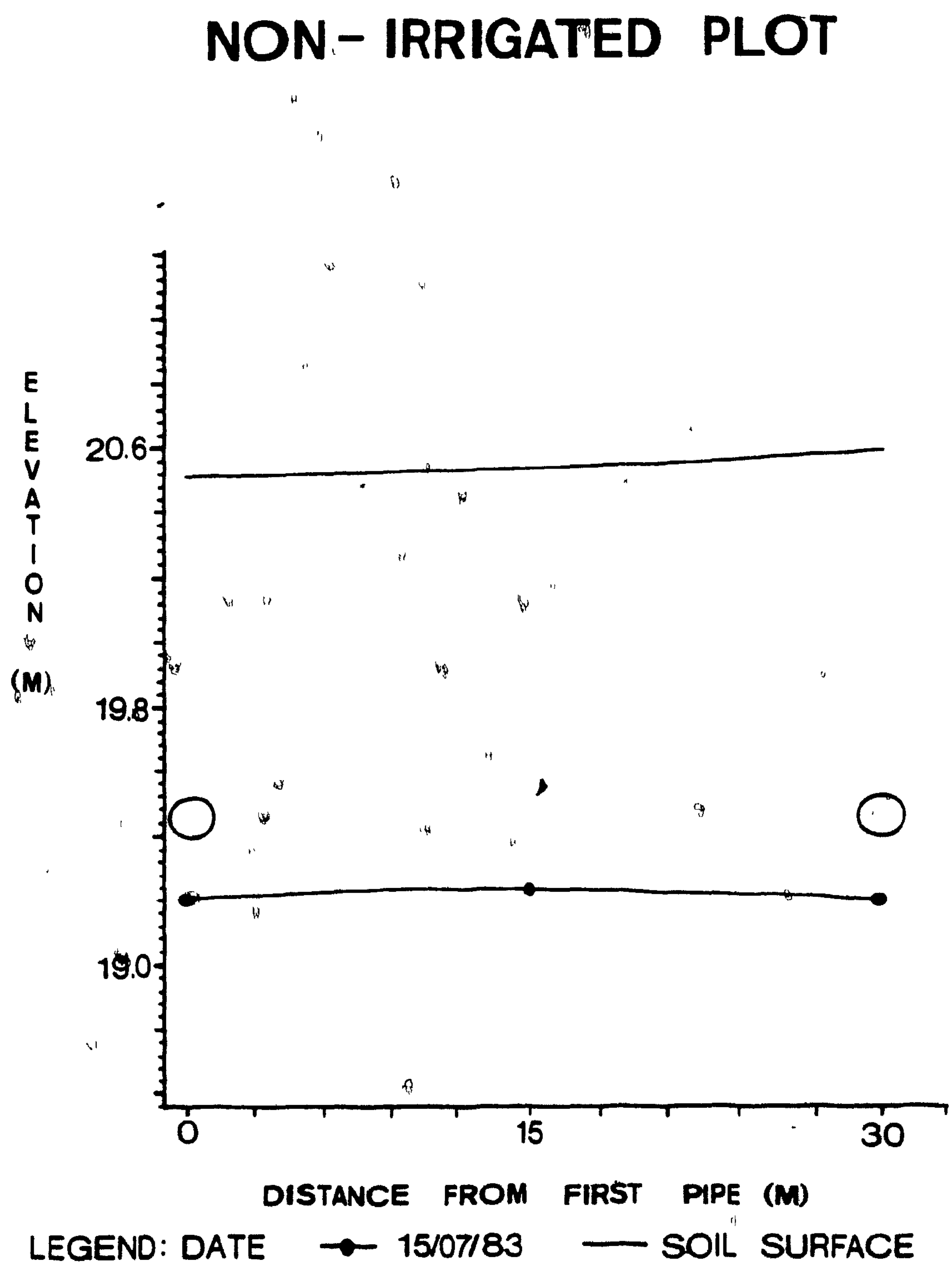


FIGURE 34: WATER TABLE LEVEL IN PLOT B-8 LINE A

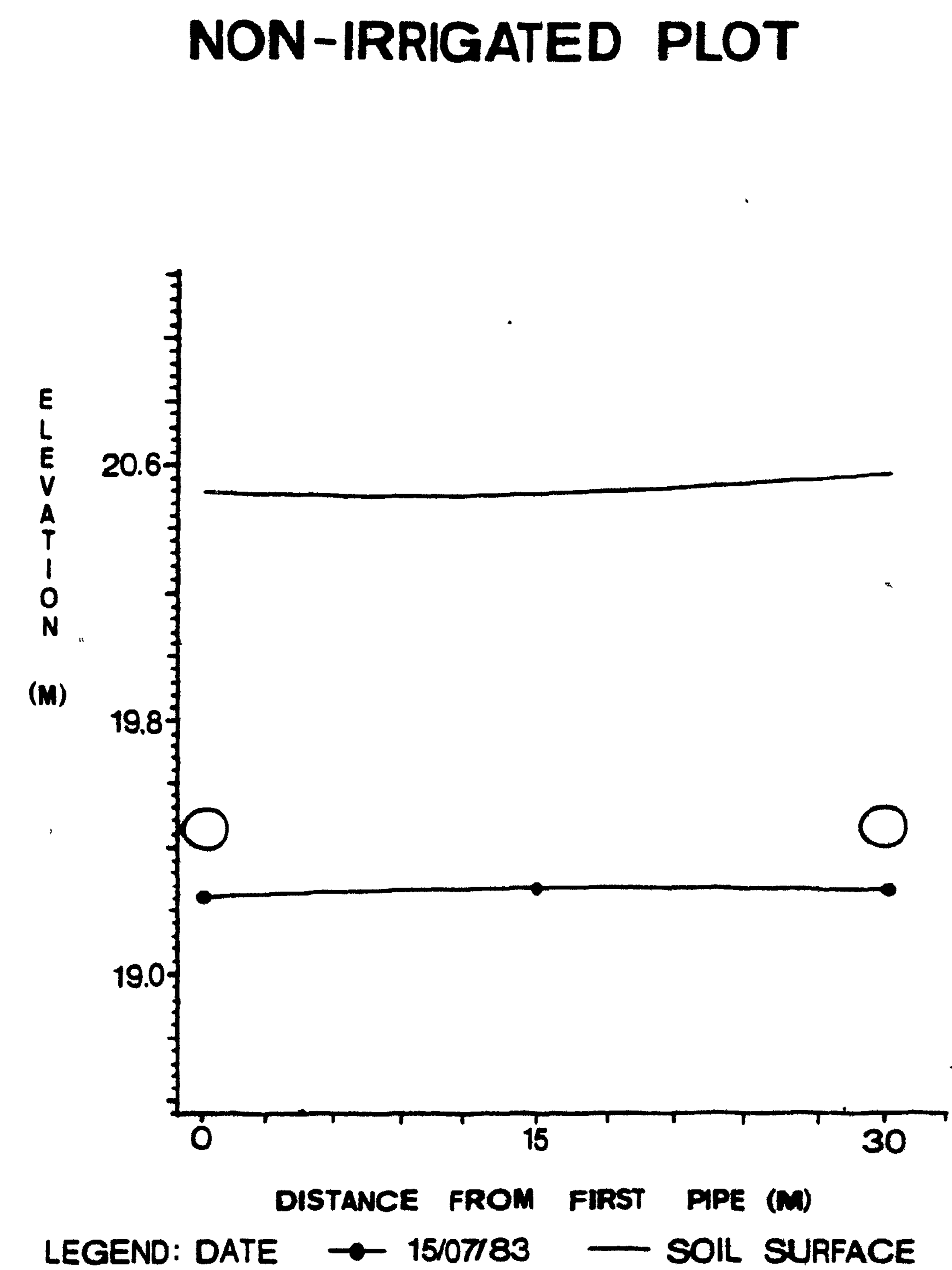


FIGURE 35 : WATER TABLE LEVEL
IN PLOT B-8
LINE B

APPENDIX A

Table A1 : Weather data for Charbonneau's Farm

July 1983

Date	Temp (deg.C) Max	Min	P.E. (mm)	Prec. (mm)	Pan Evap. (mm)
01	31.0	19.5	4.94	-	5.74
02	26.5	15.0	4.06	-	3.43
03	31.5	18.5	4.89	-	3.43
04	34.5	19.0	5.23	3.05	6.65
05	34.0	12.0	4.50	1.91	4.56
06	24.0	11.5	3.47	-	3.94
07	24.0	14.0	3.72	-	3.85
08	24.5	11.5	3.52	-	5.14
09	22.5	7.5	2.93	-	8.14
10	24.0	11.5	3.47	-	5.31
11	23.0	14.0	3.50	4.70	0.50
12	24.0	16.0	3.78	-	6.85
13	28.0	8.5	3.45	-	7.28
14	26.5	15.0	3.93	2.29	5.46
15	31.5	18.5	4.73	0.25	6.34
16	28.0	14.0	3.97	-	7.87
17	29.0	18.0	4.45	-	7.28
18	29.0	12.0	3.88	-	7.11
19	31.0	11.5	4.02	4.32	5.86
20	31.0	17.0	4.54	0.76	6.16
21	26.5	15.0	3.93	2.03	5.46
22	27.0	10.0	3.50	2.29	5.28
23	29.0	14.0	4.07	1.52	8.03
24	27.0	13.0	3.78	0.25	2.82
25	29.0	10.0	3.69	-	-
26	29.0	11.0	3.78	-	11.14c
27	29.0	12.0	3.88	-	2.57
28	30.0	20.0	4.73	0.76	4.19
29	27.0	19.0	4.35	8.13	1.28
30	31.5	8.0	3.74	-	7.71
31	30.0	18.0	4.54	6.35	7.63

Note: c = cumulative data

AUGUST 1983

Date	Temp (deg.C) Max	Min	P.E. (mm)	Prec. (mm)	Pan Evap. (mm)
01	29.0	19.0	4.19	-	4.28
02	28.0	14.5	3.71	0.51	4.41
03	30.0	17.5	4.14	-	6.77
04	30.0	15.0	3.93	-	3.43
05	32.0	18.0	4.36	-	5.14
06	32.5	15.0	4.14	4.32	4.75
07	25.5	16.5	3.66	-	-
08	28.0	11.0	3.40	21.59	14.48c
09	21.0	8.0	2.53	-	4.37
10	22.0	7.0	2.53	-	4.03
11	24.0	11.5	3.10	-	4.45
12	22.5	6.0	2.49	-	2.23
13	23.0	5.0	2.44	-	-
14	27.0	3.0	2.62	-	10.28c
15	30.0	13.0	3.75	-	4.71
16	30.0	15.0	3.93	-	5.82
17	27.0	17.0	3.84	2.03	1.60
18	27.0	17.5	3.88	0.25	2.57
19	31.0	20.0	4.45	0.51	5.65
20	27.0	11.0	3.31	-	9.76
21	27.0	8.5	3.10	0.76	5.39
22	21.5	11.5	2.88	1.91	1.91
23	26.0	2.5	2.49	-	6.81
24	24.5	9.0	2.92	-	3.43
25	29.0	11.0	3.49	-	6.25
26	31.5	16.0	4.14	31.75	7.00
27	30.0	12.0	3.66	1.52	4.52
28	29.0	-	-	0.51	-
29	-	-	-	2.54	5.87c
30	-	-	-	-	-
31	-	-	-	-	-

Note: c = cumulative data
PE was calculated using the Thornthwaite equation.

TABLE A2 : GROUND ELEVATION AT VARIOUS WATER TABLE PIPES

W.T. PIPES	ELEVATION (m) LINES							
	A	B	C	D	E	F	G	H
1	20.51	20.45	20.45	20.44	20.46	20.46	20.47	20.55
2	20.36	20.33	20.34	20.36	20.47	20.46	20.45	20.55
3	20.59	20.48	20.43	20.52	20.47	20.36	20.45	20.41
3A	20.45	20.48	20.45	20.38	-	-	-	-
3B	20.53	20.47	20.43	20.40	-	-	-	-
3C	20.59	20.51	20.48	20.38	-	-	-	-
4	20.73	20.62	20.56	20.57	20.45	20.44	20.45	20.48
5	20.75	20.56	20.63	20.57	20.41	20.51	20.45	20.54
6	20.66	20.58	20.55	20.58	20.37	20.48	20.35	20.51
7	20.60	20.56	20.54	20.56	20.48	20.47	20.42	20.46
8	20.54	20.64	20.55	20.52	20.61	20.45	20.50	20.48
9	20.58	20.61	20.54	20.49	20.49	20.52	20.41	20.42
10	20.58	20.60	20.54	20.44	20.46	20.47	20.43	20.45
11	20.56	20.58	20.52	20.47	20.44	20.49	20.49	20.48
12	20.45	20.48	20.57	20.52	20.46	20.54	20.64	20.49
13	20.55	20.49	20.54	20.52	20.32	20.39	20.58	20.55
14	20.47	20.47	20.51	20.52	20.39	20.49	20.58	20.40
15	20.51	20.48	20.57	20.52	20.54	20.55	20.59	20.63
16	20.46	20.52	20.52	20.52	20.60	20.57	20.66	20.60
17	20.34	20.52	20.51	20.46	20.59	20.58	20.50	20.60
18	20.45	20.61	20.50	20.52	20.67	20.58	20.52	20.59
19	20.42	20.57	20.51	20.52	20.59	20.70	20.34	20.58
19A	20.48	20.49	20.59	20.67	-	-	-	-
19B	20.46	20.47	20.60	20.61	-	-	-	-
19C	20.58	20.49	20.63	20.63	-	-	-	-
20	20.51	20.51	20.44	20.43	20.61	20.68	20.58	20.45
21	20.55	20.50	20.48	20.52	20.60	20.77	20.72	20.61
22	20.58	20.56	20.53	20.52	20.64	20.72	20.80	20.76

TABLE A3 : WATER TABLE PIPES

PLOT A-1 : LINE H

DEPTH (m)

DATE	TIME	PIPES				
		H1	H2	H3	H4	H5
06/07/83	12:10	1.209	1.206	1.080	1.157	1.225
07/07/83	13:50	0.765	1.034	1.005	1.015	0.840
08/07/83	12:25	0.693	0.949	0.924	0.928	0.767
11/07/83	11:30	0.748	0.952	0.913	0.938	0.824
12/07/83	12:30	0.764	0.965	0.870	0.923	0.867
13/07/83	12:38	1.002	0.981	0.882	0.937	1.019
14/07/83	9:55	0.478	0.825	0.845	0.842	0.617
15/07/83	13:05	0.438	0.782	0.769	0.780	0.590
16/07/83	11:55	0.444	0.684	0.688	0.682	0.554
17/07/83	13:35	0.600	0.716	0.667	0.703	0.687
18/07/83	12:05	0.760	0.823	0.846	0.797	0.831
19/07/83	13:37	0.850	0.872	0.804	0.849	0.920
19/07/83	18:47	0.902	-	0.842	-	0.962
20/07/83	11:45	0.976	0.981	0.873	0.937	1.022
20/07/83	19:45	1.010	-	0.905	-	1.062
22/07/83	13:25	1.096	1.085	0.966	1.036	1.134

TABLE A4 : WATER TABLE PIPES

PLOT A-1 : LINE G

DEPTH (m)

DATE	TIME	PIPES				
		G4	G5	G6	G7	G8
06/07/83	11:40	1.120	1.138	1.047	1.114	1.166
07/07/83	13:20	0.703	1.017	1.000	1.005	0.860
08/07/83	11:55	0.682	0.942	0.931	0.958	0.804
11/07/83	11:00	0.705	0.962	0.926	0.963	0.815
12/07/83	12:00	0.733	0.940	0.875	0.930	0.833
13/07/83	12:06	0.933	0.949	0.890	0.935	0.966
14/07/83	9:25	0.322	0.834	0.863	0.874	0.539
15/07/83	12:35	0.362	0.774	0.784	0.807	0.544
16/07/83	11:25	0.344	0.636	0.682	0.690	0.510
17/07/83	13:00	0.497	0.670	0.659	0.695	0.645
18/07/83	11:25	0.697	0.788	0.745	0.790	0.811
19/07/83	12:55	0.776	0.825	0.797	0.837	0.882
19/07/83	16:49	0.842	-	0.860	-	0.951
20/07/83	11:35	0.907	0.934	0.866	0.930	1.010
20/07/83	19:52	0.933	-	0.905	-	1.043
22/07/83	12:55	1.003	1.012	0.933	0.996	1.093

TABLE A5 : WATER TABLE PIPES

PLOT A-2 : LINE H

DEPTH (m)

DATE	TIME	PIPES				
		H12	H13	H14	H15	H16
06/07/83	11:59	1.093	1.147	0.997	1.218	1.225
07/07/83	13:40	0.440	0.960	0.935	1.142	0.912
08/07/83	12:15	0.512	0.885	0.871	1.092	0.940
11/07/83	11:20	0.334	0.860	0.878	1.118	0.933
12/07/83	12:20	0.396	0.877	0.836	1.068	0.967
13/07/83	12:28	0.737	0.857	0.830	1.070	1.029
14/07/83	9:45	0.162	0.711	0.760	1.046	0.874
15/07/83	12:55	0.171	0.667	0.750	1.023	0.900
16/07/83	11:45	0.260	0.659	0.720	1.006	0.929
17/07/83	13:25	0.234	0.689	0.743	1.012	0.941
18/07/83	11:55	0.323	0.703	0.750	1.034	0.980
19/07/83	13:27	0.576	0.756	0.795	1.061	1.028
19/07/83	18:42	0.706	-	0.836	-	1.073
20/07/83	11:35	0.790	0.910	0.857	1.118	1.128
20/07/83	19:35	0.826	-	0.894	-	1.148
22/07/83	13:15	0.924	1.020	0.941	1.199	1.207

TABLE A6 : WATER TABLE PIPES

PLOT A-2 : LINE G

DEPTH (m)

DATE	TIME	PIPES				
		G15	G16	G17	G18	G19
06/07/83	11:50	1.127	1.223	1.115	1.170	1.051
07/07/83	13:30	0.452	1.025	1.080	1.103	0.030
08/07/83	12:05	0.560	0.920	0.982	1.055	0.244
11/07/83	11:10	0.378	0.912	0.985	1.068	0.010
12/07/83	12:10	0.438	0.940	0.943	1.033	0.015
13/07/83	12:18	0.797	0.897	0.915	1.016	0.622
14/07/83	9:35	0.197	0.716	0.885	0.992	0.010
15/07/83	12:45	0.215	0.677	0.837	0.965	0.000
16/07/83	11:33	0.307	0.681	0.806	0.940	0.040
17/07/83	13:10	0.313	0.693	0.810	0.940	0.020
18/07/83	11:35	0.368	0.710	0.820	0.966	0.108
19/07/83	13:05	0.575	0.756	0.847	0.986	0.430
19/07/83	18:40	0.733	-	0.888	-	0.580
20/07/83	11:45	0.824	0.935	0.928	1.049	0.679
20/07/83	19:30	0.864	-	0.958	-	0.716
22/07/83	13:06	0.976	1.064	1.016	1.114	0.793

TABLE A7 : WATER TABLE PIPES

PLOT A-3 : LINE F

DEPTH (m)

DATE	TIME	PIPES				
		F1	F2	F3	F4	F5
06/07/83	11:30	1.126	1.140	1.057	1.140	1.201
07/07/83	13:10	0.687	1.047	1.024	1.082	0.962
08/07/83	11:45	0.673	0.992	0.974	1.028	0.911
11/07/83	10:50	0.585	1.010	0.978	1.043	0.947
12/07/83	11:50	0.704	0.986	0.933	1.006	0.957
13/07/83	11:58	0.923	0.985	0.944	1.016	1.040
14/07/83	9:15	0.318	0.925	0.935	0.977	0.706
15/07/83	12:25	0.357	0.846	0.870	0.898	0.648
16/07/83	11:15	0.368	0.726	0.785	0.768	0.497
17/07/83	12:50	0.504	0.717	0.708	0.745	0.625
18/07/83	11:15	0.684	0.800	0.760	0.817	0.803
19/07/83	12:45	0.784	0.829	0.798	0.855	0.877
19/07/83	18:52	0.859	-	0.862	-	0.950
20/07/83	11:25	0.910	0.925	0.862	0.944	1.006
20/07/83	20:00	0.940	-	-	-	1.035
22/07/83	12:45	1.010	0.996	0.924	1.007	1.093

TABLE A8 : WATER TABLE PIPES

PLOT A-3 : LINE E

DEPTH (m)

DATE	TIME	PIPES				
		E4	E5	E6	E7	E8
06/07/83	11:00	1.142	1.080	1.048	1.145	1.270
07/07/83	12:40	0.904	1.015	1.017	1.075	1.023
08/07/83	11:15	0.881	0.961	0.982	1.023	0.995
11/07/83	10:20	0.895	0.995	0.991	1.046	1.018
12/07/83	11:20	0.904	0.970	0.963	1.032	1.032
13/07/83	11:28	0.989	0.976	0.965	1.030	1.107
14/07/83	8:45	0.672	0.924	0.960	0.985	0.774
15/07/83	11:55	0.748	0.871	0.911	0.926	0.824
16/07/83	10:45	0.513	0.780	0.855	0.849	0.631
17/07/83	12:20	0.629	0.784	0.801	0.825	0.760
18/07/83	10:45	0.790	0.834	0.830	0.890	0.930
19/07/83	12:15	0.840	0.855	0.890	0.916	0.978
19/07/83	18:55	0.932	-	0.909	-	1.049
20/07/83	10:55	0.994	0.944	0.923	1.000	1.112
20/07/83	20:07	1.020	-	0.946	-	1.138
22/07/83	12:15	1.075	1.008	0.982	1.070	1.210

TABLE A9 : WATER TABLE PIPES

PLOT A-4 : LINE F

DEPTH (m)

DATE	TIME	PIPES				
		F18	F19	F20	F21	F22
06/07/83	11:20	1.039	1.118	1.083	1.169	1.119
07/07/83	13:00	0.612	0.975	1.039	1.052	0.761
08/07/83	11:35	0.435	0.888	0.964	0.954	0.612
11/07/83	10:40	0.567	0.880	0.918	0.940	0.697
12/07/83	11:40	0.488	0.916	0.914	0.973	0.665
13/07/83	11:48	0.860	0.943	0.935	1.014	1.044
14/07/83	9:05	0.219	0.770	0.884	0.815	0.354
15/07/83	12:15	0.235	0.696	0.788	0.731	0.344
16/07/83	11:05	0.268	0.651	0.722	0.676	0.330
17/07/83	12:40	0.316	0.714	0.730	0.754	0.474
18/07/83	11:05	0.270	0.655	0.702	0.683	0.403
19/07/83	12:35	0.519	0.695	0.724	0.724	0.580
19/07/83	18:38	0.697	-	0.777	-	0.782
20/07/83	11:15	0.778	0.862	0.837	0.918	0.875
20/07/83	19:22	0.808	-	0.875	-	0.908
22/07/83	12:35	0.890	0.970	0.951	1.037	1.003

TABLE A10 : WATER TABLE PIPES

PLOT A-4 : LINE E

DEPTH (m)

DATE	TIME	PIPES				
		E15	E16	E17	E18	E19
06/07/83	11:10	1.032	1.079	1.063	1.134	-
07/07/83	12:50	0.795	0.990	1.017	1.059	0.585
08/07/83	11:25	0.695	0.912	0.965	0.998	0.464
11/07/83	10:30	0.774	0.933	0.955	1.006	0.626
12/07/83	11:33	0.780	0.943	0.946	1.010	0.442
13/07/83	11:38	0.903	0.962	0.968	1.033	0.945
14/07/83	8:52	0.540	0.865	0.939	0.965	0.230
15/07/83	12:05	0.570	0.814	0.889	0.920	0.224
16/07/83	10:55	0.579	0.793	0.857	0.895	0.240
17/07/83	12:30	0.708	0.831	0.860	0.910	0.331
18/07/83	10:55	0.656	0.828	0.869	0.912	0.297
19/07/83	12:25	0.747	0.864	0.890	0.936	0.680
19/07/83	18:35	0.846	-	0.914	-	0.871
20/07/83	11:05	0.903	0.953	0.943	1.004	0.929
20/07/83	19:16	0.931	-	0.970	-	0.955
22/07/83	12:25	0.989	1.032	1.022	1.087	1.016

TABLE A11 : WATER TABLE PIPES

PLOT A-5 : LINE D

DEPTH (m)

DATE	TIME	PIPES D7	D8	D9	D10	D11
06/07/83	10:37	1.160	1.147	1.135	1.073	1.080
07/07/83	12:17	0.565	0.909	1.020	0.882	0.522
08/07/83	10:52	0.708	0.827	0.925	0.780	0.591
11/07/83	9:57	0.517	0.885	0.963	0.820	0.406
12/07/83	10:57	0.821	0.891	0.904	0.805	0.691
13/07/83	11:05	0.790	0.813	0.855	0.729	0.683
14/07/83	8:22	0.308	0.697	0.826	0.657	0.239
15/07/83	11:32	0.440	0.611	0.751	0.583	0.317
16/07/83	10:22	0.270	0.556	0.679	0.530	0.169
17/07/83	10:53	0.468	0.595	0.689	0.559	0.351
18/07/83	10:22	0.296	0.558	0.667	0.530	0.200
19/07/83	11:27	0.390	0.597	0.703	0.578	0.297
19/07/83	18:30	0.752	-	0.830	-	0.658
20/07/83	10:32	0.847	0.840	0.848	0.763	0.740
20/07/83	19:06	0.900	-	0.923	-	0.786
22/07/83	11:52	0.983	0.971	0.965	0.882	0.877

TABLE A12 : WATER TABLE PIPES

PLOT A-5 : LINE C

DEPTH (m)

DATE	TIME	PIPES C4	C5	C6	C7	C8
06/07/83	10:10	1.160	1.205	1.133	1.120	1.143
07/07/83	11:50	0.563	0.986	1.025	0.926	0.615
08/07/83	10:25	0.697	0.886	0.925	0.854	0.630
11/07/83	9:30	0.575	0.926	0.929	0.844	0.577
12/07/83	10:30	0.761	0.934	0.877	0.838	0.728
13/07/83	10:38	0.766	0.842	0.815	0.746	0.724
14/07/83	7:55	0.380	0.733	0.771	0.649	0.342
15/07/83	11:05	0.350	0.654	0.689	0.572	0.292
16/07/83	9:55	0.236	0.602	0.627	0.520	0.261
17/07/83	10:26	0.390	0.625	0.630	0.543	0.346
18/07/83	9:55	0.352	0.584	0.599	0.508	0.287
19/07/83	11:00	0.268	0.620	0.633	0.553	0.308
19/07/83	18:14	0.720	-	0.753	-	0.664
20/07/83	10:05	0.807	0.858	0.783	0.751	0.756
20/07/83	19:07	0.861	-	0.863	-	0.818
22/07/83	11:25	0.940	0.988	0.923	0.894	0.897

TABLE A13 : WATER TABLE PIPES

PLOT A-6 : LINE D

DEPTH (m)

DATE	TIME	PIPES				
		D15	D16	D17	D18	D19
06/07/83	10:32	1.140	1.176	1.155	1.223	1.175
07/07/83	12:12	0.755	0.988	1.050	1.073	0.811
08/07/83	10:47	0.746	0.912	0.969	1.006	0.828
11/07/83	9:52	0.737	0.954	0.993	1.022	0.587
12/07/83	10:52	0.832	0.939	0.945	0.995	0.871
13/07/83	11:00	0.786	0.876	0.912	0.943	0.847
14/07/83	8:17	0.581	0.837	0.894	0.924	0.622
15/07/83	11:27	0.572	0.785	0.855	0.871	0.584
16/07/83	10:17	0.470	0.743	0.812	0.826	0.514
17/07/83	10:48	0.520	0.747	0.805	0.826	0.590
18/07/83	10:17	0.355	0.711	0.792	0.815	0.495
19/07/83	11:22	0.380	0.730	0.804	0.817	0.515
19/07/83	18:28	0.747	-	0.882	-	0.834
20/07/83	10:27	0.829	0.901	0.904	0.958	0.918
20/07/83	19:02	0.877	-	0.964	-	0.967
22/07/83	11:47	0.952	1.010	1.007	1.062	1.025

TABLE A14 : WATER TABLE PIPES

PLOT A-6 : LINE C

DEPTH (m)

DATE	TIME	PIPES				
		C12	C13	C14	C15	C16
06/07/83	10:17	1.172	1.150	1.145	1.200	1.175
07/07/83	11:57	0.600	0.899	1.007	1.135	0.820
08/07/83	10:32	0.690	0.799	0.915	1.010	0.831
11/07/83	9:37	0.597	0.845	0.932	1.018	0.783
12/07/83	10:37	0.779	0.859	0.891	0.970	0.857
13/07/83	10:45	0.773	0.772	0.836	0.926	0.819
14/07/83	8:02	0.404	0.654	0.802	0.907	0.616
15/07/83	11:12	0.337	0.592	0.736	0.835	0.548
16/07/83	10:02	0.282	0.550	0.678	0.770	0.507
17/07/83	10:33	0.397	0.575	0.670	0.758	0.555
18/07/83	10:02	0.320	0.530	0.648	0.738	0.481
19/07/83	11:07	0.328	0.577	0.672	0.756	0.518
19/07/83	18:25	0.757	-	0.787	-	0.784
20/07/83	10:12	0.824	0.809	0.819	0.890	0.847
20/07/83	19:04	0.880	-	0.882	-	0.894
22/07/83	11:32	0.960	0.931	0.934	1.003	0.960

TABLE A15 : WATER TABLE PIPES

PLOT A-7 : LINE B

DEPTH (m)

DATE	TIME	PIPES				
		B7	B8	B9	B10	B11
06/07/83	10:00	1.150	1.185	-	1.152	1.160
07/07/83	11:40	0.526	1.048	1.100	1.030	0.691
08/07/83	10:15	0.674	0.955	1.017	0.927	0.671
11/07/83	9:20	0.547	0.976	0.998	0.935	0.661
12/07/83	10:20	0.706	0.936	0.945	0.925	0.758
13/07/83	10:28	0.756	0.875	0.892	0.843	0.758
14/07/83	7:45	0.322	0.805	0.860	0.764	0.420
15/07/83	10:55	0.274	0.717	0.770	0.669	0.348
16/07/83	9:45	0.227	0.665	0.707	0.617	0.330
17/07/83	10:16	0.317	0.667	0.694	0.625	0.360
18/07/83	9:45	0.350	0.625	0.673	0.593	0.361
19/07/83	10:50	0.269	0.654	0.684	0.630	0.387
19/07/83	18:12	0.706	-	0.801	-	0.713
20/07/83	9:55	0.798	0.876	0.839	0.823	0.796
20/07/83	16:58	0.853	-	0.904	-	0.868
21/07/83	15:20	0.903	0.977	0.942	0.931	0.926
22/07/83	11:15	0.927	0.996	0.961	0.961	0.926

TABLE A16 : WATER TABLE PIPES

PLOT A-7 : LINE A

DEPTH (m)

DATE	TIME	PIPES				
		A4	A5	A6	A7	A8
06/07/83	9:40	1.318	1.320	1.228	1.173	1.130
07/07/83	11:20	0.806	1.194	1.202	1.100	0.737
08/07/83	9:55	0.794	1.110	1.142	1.033	0.658
11/07/83	9:00	0.774	1.136	1.125	1.026	0.700
12/07/83	10:00	0.896	1.123	1.094	1.000	0.765
13/07/83	10:06	0.904	1.045	1.070	0.959	0.753
14/07/83	7:25	0.386	0.997	1.057	0.928	0.436
15/07/83	10:35	0.404	0.906	0.997	0.840	0.335
16/07/83	9:25	0.375	0.853	0.927	0.759	0.295
17/07/83	9:56	0.510	0.843	0.879	0.748	0.364
18/07/83	9:25	0.514	0.810	0.866	0.707	0.329
19/07/83	10:30	0.610	0.826	0.858	0.732	0.400
19/07/83	16:10	0.858	-	0.915	-	0.732
20/07/83	9:35	0.966	1.000	0.950	0.879	0.796
20/07/83	16:55	1.020	-	0.994	-	0.847
21/07/83	15:00	1.080	1.101	1.032	0.968	0.880
22/07/83	10:56	1.106	1.133	1.066	0.967	0.909

TABLE A17 : WATER TABLE PIPES

PLOT A-8 : LINE B

DEPTH (m)

DATE	TIME	PIPES B15	B16	B17	B18	B19
06/07/83	9:56	1.093	1.130	1.162	1.230	1.230
07/07/83	11:39	0.629	0.896	1.037	1.206	0.920
08/07/83	10:14	0.622	0.806	0.957	1.130	0.887
11/07/83	9:19	0.600	0.848	0.967	1.086	0.870
12/07/83	10:21	0.682	0.854	0.929	1.037	0.900
13/07/83	10:27	0.687	0.773	0.880	0.993	0.868
14/07/83	7:44	0.391	0.673	0.853	0.970	0.670
15/07/83	10:54	0.317	0.606	0.796	0.915	0.608
16/07/83	9:29	0.265	0.563	0.753	0.880	0.576
17/07/83	10:17	0.303	0.585	0.730	0.834	0.600
18/07/83	9:44	0.285	0.534	0.709	0.816	0.543
19/07/83	10:52	0.335	0.580	0.711	0.809	0.611
19/07/83	18:23	0.686	–	0.804	–	0.727
20/07/83	9:54	0.744	0.804	0.810	0.928	0.906
20/07/83	19:13	0.798	–	0.891	–	0.966
21/07/83	15:22	0.853	0.900	0.929	1.017	1.003
22/07/83	11:12	0.860	0.916	0.940	1.033	1.020

TABLE A18 : WATER TABLE PIPES

PLOT A-8 : LINE A

DEPTH (m)

DATE	TIME	PIPES A12	A13	A14	A15	A16
06/07/83	9:41	1.065	1.175	1.134	1.182	1.112
07/07/83	11:24	0.736	1.039	1.098	1.123	0.770
08/07/83	9:59	0.672	0.957	1.020	1.048	0.705
11/07/83	9:04	0.714	0.962	1.004	1.045	0.754
12/07/83	10:06	0.748	0.957	0.963	1.011	0.810
13/07/83	10:12	0.713	0.897	0.939	0.970	0.804
14/07/83	7:29	0.538	0.863	0.928	0.951	0.489
15/07/83	10:39	0.470	0.807	0.877	0.876	0.377
16/07/83	9:29	0.449	0.759	0.807	0.793	0.340
17/07/83	10:02	0.467	0.751	0.770	0.775	0.388
18/07/83	9:29	0.422	0.725	0.751	0.737	0.322
19/07/83	10:37	0.506	0.732	0.747	0.746	0.390
19/07/83	18:19	0.716	-	0.834	-	0.788
20/07/83	9:39	0.767	0.877	0.858	0.909	0.849
20/07/83	19:01	0.821	-	0.918	-	0.899
21/07/83	15:07	0.864	0.960	0.940	0.992	0.937
22/07/83	10:57	0.869	0.982	0.965	1.002	0.962

TABLE A19 : WATER TABLE PIPES

PLOT B-1 : LINE G

DEPTH (m)

DATE	TIME	PIPES G9	PIPES G10	PIPES G11
06/07/83	11:45	1.191	1.168	1.172
07/07/83	13:25	1.189	1.165	1.167
08/07/83	12:00	1.195	1.176	1.182
11/07/83	11:05	1.233	1.210	1.184
13/07/83	12:13	1.243	1.222	1.175
15/07/83	12:40	1.257	1.234	1.171
17/07/83	13:05	1.272	1.248	1.182
19/07/83	13:00	1.283	1.261	1.180
22/07/83	13:00	1.305	1.273	1.200

TABLE A20 : WATER TABLE PIPES

PLOT B-1 : LINE H

DEPTH (m)

DATE	TIME	PIPES		
		H9	H10	H11
06/07/83	12:05	1.211	1.214	1.216
07/07/83	13:45	1.210	1.213	1.212
08/07/83	12:20	1.221	1.220	1.210
11/07/83	11:25	1.260	1.250	1.220
13/07/83	12:33	1.267	1.256	1.210
15/07/83	13:00	1.284	1.263	1.197
17/07/83	13:30	1.299	1.270	1.194
19/07/83	13:32	1.313	1.284	1.206
22/07/83	13:20	1.326	1.293	1.236

TABLE A21 : WATER TABLE PIPES

PLOT B-2 : LINE G

DEPTH (m)

DATE	TIME	PIPES		
		G20	G21	G22
06/07/83	11:53	1.147	1.243	1.310
07/07/83	13:33	1.142	1.243	1.310
08/07/83	12:08	1.151	1.254	1.316
11/07/83	11:13	1.182	1.290	1.355
13/07/83	12:21	1.195	1.308	1.369
15/07/83	12:48	1.204	1.321	1.386
17/07/83	13:13	1.215	1.334	1.385
19/07/83	13:06	1.223	1.344	1.393
22/07/83	13:08	1.241	1.365	1.397

TABLE A22 : WATER TABLE PIPES

PLOT B-2 : LINE H

DEPTH (m)

DATE	TIME	PIPES		
		H20	H21	H22
06/07/83	11:56	1.100	1.173	1.301
07/07/83	13:37	1.099	1.173	1.300
08/07/83	12:12	1.107	1.183	1.282
11/07/83	11:17	1.146	1.220	1.338
13/07/83	12:25	1.157	1.237	1.348
15/07/83	12:52	1.170	1.254	1.358
17/07/83	13:22	1.190	1.269	1.370
19/07/83	13:12	1.205	1.288	1.377
22/07/83	13:12	1.228	1.297	1.388

TABLE A23 : WATER TABLE PIPES

PLOT B-3 : LINE E

DEPTH (m)

DATE	TIME	PIPES		
		E9	E10	E11
06/07/83	11:05	1.214	1.182	1.191
07/07/83	12:45	1.210	1.181	1.185
08/07/83	11:20	1.215	1.188	1.190
11/07/83	10:25	1.248	1.219	1.220
13/07/83	11:33	1.253	1.227	1.224
15/07/83	12:00	1.268	1.240	1.229
17/07/83	12:25	1.280	1.249	1.232
19/07/83	12:20	1.299	1.264	1.237
22/07/83	12:20	1.311	1.279	1.262

TABLE A24 : WATER TABLE PIPES

PLOT B-3 : LINE F

DEPTH (m)

DATE	TIME	PIPES		
		F9	F10	F11
06/07/83	11:25	1.236	1.176	1.197
07/07/83	13:05	1.232	1.175	1.194
08/07/83	11:40	1.240	1.185	1.200
11/07/83	11:45	1.272	1.216	1.234
13/07/83	12:53	1.287	1.230	1.240
15/07/83	12:20	1.295	1.243	1.245
17/07/83	12:45	1.303	1.257	1.249
19/07/83	12:40	1.313	1.275	1.260
22/07/83	12:40	1.325	1.295	1.278

TABLE A25 : WATER TABLE PIPES

PLOT B-4 : LINE E

DEPTH (m)

DATE	TIME	PIPES		
		E12	E13	E14
06/07/83	11:07	1.244	1.160	1.232
07/07/83	12:47	1.242	1.167	1.230
08/07/83	11:22	1.247	1.166	1.234
11/07/83	10:27	1.275	1.196	1.264
13/07/83	11:35	1.277	1.202	1.265
15/07/83	12:02	1.290	1.214	1.278
17/07/83	12:27	1.297	1.237	1.288
19/07/83	12:22	1.305	1.250	1.299
22/07/83	12:22	1.320	1.253	1.312

TABLE A26 : WATER TABLE PIPES

PLOT B-4 : LINE F

DEPTH (m)

DATE	TIME	PIPES		
		F12	F13	F14
06/07/83	11:27	1.290	1.185	1.283
07/07/83	13:07	1.288	1.197	1.288
08/07/83	11:42	1.292	1.193	1.282
11/07/83	10:47	1.325	1.227	1.315
13/07/83	11:55	1.329	1.230	1.319
15/07/83	12:22	1.337	1.240	1.327
17/07/83	12:47	1.340	1.251	1.334
19/07/83	12:42	1.342	1.263	1.336
22/07/83	12:42	1.350	1.269	1.337

TABLE A27 : WATER TABLE PIPES

PLOT B-5 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C1	C2	C3
06/07/83	10:05	1.295	1.187	1.242
07/07/83	11:45	1.288	1.180	1.233
08/07/83	10:20	1.294	1.191	1.241
11/07/83	9:25	1.328	1.228	1.272
13/07/83	10:33	1.343	1.238	1.281
15/07/83	11:00	1.353	1.254	1.295
17/07/83	10:21	1.366	1.272	1.309
19/07/83	10:55	1.382	1.294	1.311
22/07/83	11:20	1.405	1.307	1.343

TABLE A28 : WATER TABLE PIPES

PLOT B-5 : LINE D

DEPTH (m)

DATE	TIME	PIPES		
		D1	D2	D3
06/07/83	10:42	1.226	1.125	1.296
07/07/83	12:22	1.223	1.123	1.290
08/07/83	10:57	1.228	1.132	1.296
11/07/83	10:02	1.264	1.160	1.330
13/07/83	11:10	1.281	1.170	1.344
15/07/83	11:37	1.294	1.185	1.351
17/07/83	10:58	1.305	1.195	1.360
19/07/83	11:32	1.322	1.206	1.370
22/07/83	11:57	1.340	1.220	1.386

TABLE A29 : WATER TABLE PIPES

PLOT B-6 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C20	C21	C22
06/07/83	10:22	1.192	1.234	1.297
07/07/83	12:02	1.185	1.229	1.295
08/07/83	10:37	1.194	1.235	1.301
11/07/83	9:42	1.228	1.274	1.333
13/07/83	10:50	1.237	1.280	1.345
15/07/83	11:17	1.249	1.289	1.360
17/07/83	10:38	1.260	1.303	1.372
19/07/83	11:12	1.274	1.315	1.390
22/07/83	11:37	1.290	1.336	1.392

TABLE A30 : WATER TABLE PIPES

PLOT B-6 : LINE D

DEPTH (m)

DATE	TIME	PIPES		
		D20	D21	D22
06/07/83	10:27	1.168	1.220	1.196
07/07/83	12:07	1.165	1.211	1.195
08/07/83	10:42	1.172	1.216	1.201
11/07/83	9:47	1.217	1.253	1.235
13/07/83	10:55	1.220	1.258	1.243
15/07/83	11:22	1.218	1.270	1.248
17/07/83	10:43	1.223	1.278	1.260
19/07/83	11:17	1.227	1.288	1.270
22/07/83	11:42	1.236	1.302	1.285

TABLE A31 : WATER TABLE PIPES

PLOT B-7 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A1	A2	A3
06/07/83	9:30	1.357	-	1.275
07/07/83	11:15	1.358	-	1.266
08/07/83	9:50	1.353	1.127	-
11/07/83	8:55	1.381	1.160	1.270
13/07/83	10:00	1.390	1.170	-
15/07/83	10:27	1.390	1.183	-
17/07/83	9:50	1.390	1.194	-
19/07/83	10:25	1.395	1.207	-
22/07/83	10:45	1.425	1.221	1.486

TABLE A32 : WATER TABLE PIPES

PLOT B-7 : LINE B

DEPTH (m)

DATE	TIME	PIPES		
		B1	B2	B3
06/07/83	10:06	1.290	1.146	1.280
07/07/83	11:45	1.287	1.140	1.270
08/07/83	10:20	1.292	1.153	1.275
11/07/83	9:25	1.320	1.190	1.300
13/07/83	10:33	1.323	1.199	1.310
15/07/83	11:00	1.324	1.214	-
17/07/83	10:21	1.325	1.226	-
19/07/83	10:56	1.330	1.242	-
22/07/83	11:20	1.333	1.250	1.436

TABLE A33 : WATER TABLE PIPES

PLOT B-8 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A20	A21	A22
06/07/83	9:46	1.250	1.270	1.320
07/07/83	11:29	1.245	1.263	1.308
08/07/83	10:04	1.250	1.266	1.312
11/07/83	9:09	1.280	1.296	1.344
13/07/83	10:17	1.289	1.306	1.357
15/07/83	10:44	1.307	1.315	1.365
17/07/83	10:07	1.310	1.318	1.372
19/07/83	10:42	1.321	1.323	1.387
22/07/83	11:02	1.334	1.335	1.398

TABLE A34 : WATER TABLE PIPES

PLOT B-8 : LINE B

DEPTH (m)

DATE	TIME	PIPES B20	PIPES B21	PIPES B22
06/07/83	9:51	1.229	1.196	1.257
07/07/83	11:34	1.225	1.189	1.252
08/07/83	10:09	1.231	1.193	1.257
11/07/83	9:14	1.255	1.217	1.282
13/07/83	10:22	1.262	1.225	1.294
15/07/83	10:49	1.271	1.232	1.300
17/07/83	10:12	1.280	1.243	1.302
19/07/83	10:47	1.287	1.251	1.308
22/07/83	11:07	1.301	1.256	1.309

TABLE A35 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-5 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C3A	C3B	C3C
13/07/83	10:38	1.128	1.074	0.830
14/07/83	7:55	1.126	0.970	0.773
15/07/83	11:05	1.114	0.927	0.710
16/07/83	9:55	1.090	0.885	0.660
17/07/83	10:26	1.070	0.865	0.661
18/07/83	9:55	1.067	0.855	0.633
19/07/83	11:00	1.060	0.850	0.654
20/07/83	10:05	1.074	0.907	0.809
22/07/83	11:25	1.110	0.973	0.913

TABLE A36 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-6 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C19A	C19B	C19C
13/07/83	10:45	0.958	1.101	1.202
14/07/83	8:02	0.926	1.094	1.196
15/07/83	11:12	0.876	1.060	1.180
16/07/83	10:02	0.834	1.030	1.161
17/07/83	10:33	0.830	1.015	1.149
18/07/83	10:02	0.817	1.016	1.150
19/07/83	11:07	0.829	1.010	1.146
20/07/83	10:12	0.944	1.064	1.163
22/07/83	11:32	1.048	1.140	1.215

TABLE A37 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-7 : LINE B

DEPTH (m)

DATE	TIME	PIPES		
		B3A	B3B	B3C
13/07/83	10:28	1.105	0.992	0.847
14/07/83	7:45	1.098	0.981	0.775
15/07/83	10:55	1.071	0.931	0.704
16/07/83	9:45	1.048	0.892	0.664
17/07/83	10:16	1.028	0.870	0.675
18/07/83	9:45	1.024	0.862	0.636
19/07/83	10:50	1.017	0.860	0.663
20/07/83	9:55	1.040	0.931	0.848
21/07/83	15:20	1.080	0.997	0.945
22/07/83	11:15	1.098	1.020	0.969

TABLE A38 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-7 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A3A	A3B	A3C
13/07/83	10:08	1.114	1.060	0.922
14/07/83	7:25	1.085	1.026	0.863
15/07/83	10:35	1.058	0.974	0.776
16/07/83	9:25	1.040	0.938	0.734
17/07/83	9:56	1.028	0.925	0.760
18/07/83	9:25	1.030	0.930	0.726
19/07/83	10:30	1.024	0.913	0.738
20/07/83	9:35	1.021	0.957	0.897
21/07/83	15:00	1.072	1.031	0.995
22/07/83	10:55	1.085	1.062	1.035

TABLE A39 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-8 : LINE B

DEPTH (m)

DATE	TIME	PIPES		
		B19A	B19B	B19C
13/07/83	10:27	0.939	1.030	1.310
14/07/83	7:44	0.910	1.020	1.254
15/07/83	10:54	0.854	0.993	1.194
16/07/83	9:29	0.807	0.960	1.135
17/07/83	10:17	0.813	0.948	1.103
18/07/83	9:44	0.796	0.946	1.102
19/07/83	10:52	0.808	0.947	1.102
20/07/83	9:54	0.960	1.008	1.114
21/07/83	15:22	1.042	1.067	1.134
22/07/83	11:12	1.051	1.068	1.143

TABLE A40 : SPECIAL WATER TABLE PIPES

LEAKAGE FROM IRRIGATED TO DRAINED PLOT

PLOT A-8 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A19A	A19B	A19C
13/07/83	10:12	1.056	1.138	1.318
14/07/83	7:29	1.050	1.147	1.322
15/07/83	10:39	1.004	1.129	1.319
16/07/83	9:29	0.946	1.104	1.307
17/07/83	10:02	0.910	1.088	1.300
18/07/83	9:29	0.898	1.086	1.299
19/07/83	10:37	0.887	1.081	1.300
20/07/83	9:39	0.996	1.105	1.305
21/07/83	15:07	1.061	1.138	1.322
22/07/83	10:57	1.073	1.142	1.324

TABLE A41 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-1 : LINE H

DEPTH (m)

DATE	TIME	PIPES		
		H6	H7	H8
06/07/83	12:10	1.190	1.142	1.147
07/07/83	13:50	0.713	0.779	0.822
08/07/83	12:25	0.738	0.703	0.753
11/07/83	11:30	0.794	0.755	0.790
12/07/83	12:30	0.838	0.805	0.841
13/07/83	12:38	0.985	0.938	0.964
14/07/83	9:55	0.590	0.560	0.600
15/07/83	13:05	0.565	0.537	0.586
16/07/83	11:55	0.524	0.488	0.527
17/07/83	13:35	0.660	0.618	0.654
18/07/83	12:05	0.800	0.758	0.792
19/07/83	13:37	0.880	0.837	0.863
20/07/83	11:45	0.990	0.944	0.974
22/07/83	13:25	1.101	1.055	1.080

TABLE A42 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-1 : LINE G

DEPTH (m)

DATE	TIME	PIPES		
		G1	G2	G3
06/07/83	11:40	1.146	1.111	1.130
07/07/83	13:20	0.782	0.710	0.686
08/07/83	11:55	0.737	0.668	0.650
11/07/83	11:00	0.769	0.697	0.658
12/07/83	12:00	0.801	0.726	0.682
13/07/83	12:08	0.958	0.910	0.930
14/07/83	9:25	0.474	0.386	0.361
15/07/83	12:35	0.458	0.359	0.354
16/07/83	11:25	0.397	0.330	0.345
17/07/83	13:00	0.545	0.488	0.500
18/07/83	11:25	0.738	0.685	0.692
19/07/83	12:55	0.807	0.866	0.781
20/07/83	11:35	0.934	0.894	0.914
22/07/83	12:55	1.033	0.993	1.012

TABLE A43 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-2 : LINE H

DEPTH (m)

DATE	TIME	PIPES		
		H17	H18	H19
06/07/83	11:59	1.187	1.190	1.188
07/07/83	13:40	0.914	0.950	0.970
08/07/83	12:15	0.930	0.950	0.964
11/07/83	11:20	0.930	0.965	0.980
12/07/83	12:20	0.964	0.993	1.010
13/07/83	12:28	1.016	1.025	1.025
14/07/83	9:45	0.865	0.889	0.904
15/07/83	12:55	0.893	0.914	0.927
16/07/83	11:45	0.919	0.935	0.943
17/07/83	13:25	0.934	0.950	0.960
18/07/83	11:55	0.973	0.983	0.994
19/07/83	13:27	1.014	1.021	1.030
20/07/83	11:35	1.134	1.118	1.119
22/07/83	13:15	1.190	1.194	1.195

TABLE A44 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-2 : LINE G

DEPTH (m)

DATE	TIME	PIPES		
		G12	G13	G14
06/07/83	11:50	1.111	1.123	1.117
07/07/83	13:30	0.552	0.500	0.462
08/07/83	12:05	0.608	0.584	0.545
11/07/83	11:10	0.458	0.415	0.385
12/07/83	12:10	0.545	0.491	0.450
13/07/83	12:18	0.774	0.788	0.785
14/07/83	9:35	0.268	0.230	0.202
15/07/83	12:45	0.274	0.244	0.221
16/07/83	11:33	0.351	0.319	0.308
17/07/83	13:10	0.355	0.338	0.315
18/07/83	11:35	0.397	0.386	0.370
19/07/83	13:05	0.557	0.565	0.566
20/07/83	11:45	0.806	0.816	0.814
22/07/83	13:05	0.954	0.968	0.962

TABLE A45 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-3 : LINE F

DEPTH (m)

DATE	TIME	PIPES		
		F6	F7	F8
06/07/83	11:30	1.169	1.170	1.141
07/07/83	13:10	0.937	0.952	0.950
08/07/83	11:45	0.885	0.907	0.903
11/07/83	10:50	0.920	0.938	0.930
12/07/83	11:50	0.930	0.949	0.937
13/07/83	11:58	1.007	1.014	0.985
14/07/83	9:15	0.681	0.710	0.724
15/07/83	12:25	0.622	0.660	0.660
16/07/83	11:15	0.471	0.496	0.487
17/07/83	12:50	0.597	0.612	0.603
18/07/83	11:15	0.772	0.786	0.763
19/07/83	12:45	0.842	0.847	0.822
20/07/83	11:25	0.975	0.977	0.950
22/07/83	12:45	1.058	1.060	1.034

TABLE A46 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-3 : LINE E

DEPTH (m)

DATE	TIME	PIPES		
		E1	E2	E3
06/07/83	11:00	1.148	1.066	1.115
07/07/83	12:40	0.903	0.830	0.871
08/07/83	11:15	0.866	0.783	0.843
11/07/83	10:20	0.890	0.786	0.865
12/07/83	11:20	0.896	0.799	0.871
13/07/83	11:28	0.998	0.910	0.960
14/07/83	8:45	0.658	0.564	0.640
15/07/83	11:55	0.747	0.649	0.717
16/07/83	10:45	0.500	0.402	0.476
17/07/83	12:20	0.625	0.520	0.597
18/07/83	10:45	0.794	0.698	0.758
19/07/83	12:15	0.845	0.755	0.810
20/07/83	10:55	1.004	0.916	0.965
22/07/83	12:15	1.094	0.996	1.046

TABLE A47 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-4 : LINE F

DEPTH (m)

DATE	TIME	PIPES		
		F15	F16	F17
06/07/83	11:20	1.017	0.963	-
07/07/83	13:00	0.650	0.573	0.600
08/07/83	11:35	0.507	0.413	0.435
11/07/83	10:40	0.605	0.528	0.563
12/07/83	11:40	0.594	0.489	0.496
13/07/83	11:48	0.842	0.787	0.843
14/07/83	9:05	0.298	0.187	0.216
15/07/83	12:15	0.320	0.218	0.237
16/07/83	11:05	0.317	0.230	0.260
17/07/83	12:40	0.430	0.327	0.330
18/07/83	11:05	0.353	0.262	0.276
19/07/83	12:35	0.518	0.457	0.502
20/07/83	11:15	0.766	0.708	0.761
22/07/83	12:35	0.877	0.821	0.875

TABLE A48 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-4 : LINE E

DEPTH (m)

DATE	TIME	PIPES		
		E20	E21	E22
06/07/83	11:10	1.078	1.068	1.108
07/07/83	12:50	0.651	0.826	0.902
08/07/83	11:25	0.517	0.741	0.843
11/07/83	10:30	0.660	0.819	0.891
12/07/83	11:33	0.498	0.781	0.883
13/07/83	11:38	0.954	0.960	1.005
14/07/83	8:52	0.260	0.601	0.710
15/07/83	12:05	0.269	0.623	0.721
16/07/83	10:55	0.289	0.624	0.718
17/07/83	12:30	0.392	0.737	0.815
18/07/83	10:55	0.378	0.686	0.769
19/07/83	12:25	0.672	0.807	0.860
20/07/83	11:05	0.913	0.942	0.967
22/07/83	12:25	1.030	1.026	1.070

TABLE A49 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-5 : LINE D

DEPTH (m)

DATE	TIME	PIPES		
		D4	D5	D6
06/07/83	10:37	1.171	1.177	1.190
07/07/83	12:17	0.805	0.694	0.672
08/07/83	10:52	0.784	0.744	0.747
11/07/83	9:57	0.807	0.676	0.647
12/07/83	10:57	0.906	0.859	0.865
13/07/83	11:06	0.844	0.818	0.827
14/07/83	8:22	0.570	0.465	0.434
15/07/83	11:32	0.540	0.492	0.485
16/07/83	10:22	0.460	0.372	0.348
17/07/83	10:53	0.570	0.522	0.518
18/07/83	10:22	0.475	0.394	0.372
19/07/83	11:27	0.418	0.457	0.452
20/07/83	10:32	0.889	0.867	0.881
22/07/83	11:52	1.018	1.002	1.018

TABLE A50 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-5 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C9	C10	C11
06/07/83	10:10	1.137	1.136	1.110
07/07/83	11:50	0.620	0.640	0.640
08/07/83	10:25	0.628	0.628	0.610
11/07/83	9:30	0.584	0.600	0.590
12/07/83	10:30	0.726	0.732	0.717
13/07/83	10:38	0.720	0.714	0.686
14/07/83	7:55	0.348	0.364	0.364
15/07/83	11:05	0.297	0.310	0.306
16/07/83	9:55	0.266	0.281	0.275
17/07/83	10:26	0.349	0.355	0.342
18/07/83	9:55	0.291	0.300	0.292
19/07/83	11:00	0.311	0.330	0.327
20/07/83	10:05	0.747	0.743	0.719
22/07/83	11:25	0.892	0.892	0.867

TABLE A51 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-6 : LINE D

DEPTH (m)

DATE	TIME	PIPES		
		D12	D13	D14
06/07/83	10:32	1.146	1.116	1.147
07/07/83	12:12	0.822	0.695	0.768
08/07/83	10:47	0.788	0.697	0.747
11/07/83	9:52	0.788	0.483	0.735
12/07/83	10:52	0.860	0.782	0.839
13/07/83	11:00	0.804	0.746	0.787
14/07/83	8:17	0.640	0.322	0.579
15/07/83	11:27	0.625	0.462	0.587
16/07/83	10:17	0.548	0.238	0.481
17/07/83	10:48	0.589	0.392	0.536
18/07/83	10:17	0.496	0.263	0.391
19/07/83	11:22	0.515	0.287	0.410
20/07/83	10:27	0.833	0.784	0.914
22/07/83	11:47	0.951	0.911	0.957

TABLE A52 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-6 : LINE C

DEPTH (m)

DATE	TIME	PIPES		
		C17	C18	C19
06/07/83	10:17	1.167	1.190	1.097
07/07/83	11:57	0.802	0.922	0.853
08/07/83	10:32	0.820	0.896	0.823
11/07/83	9:37	0.768	0.885	0.814
12/07/83	10:37	0.848	0.927	0.848
13/07/83	10:45	0.808	0.878	0.795
14/07/83	8:02	0.599	0.636	0.647
15/07/83	11:12	0.531	0.518	0.572
16/07/83	10:02	0.496	0.464	0.539
17/07/83	10:33	0.544	0.606	0.575
18/07/83	10:02	0.464	0.518	0.516
19/07/83	11:07	0.499	0.527	0.536
20/07/83	10:12	0.839	0.890	0.808
22/07/83	11:32	0.949	1.012	0.929

TABLE A53 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-7 : LINE B

DEPTH (m)

DATE	TIME	PIPES		
		B4	B5	B6
06/07/83	10:00	1.204	1.145	1.167
07/07/83	11:40	0.792	0.687	0.540
08/07/83	10:15	0.780	0.702	0.695
11/07/83	9:20	0.815	0.710	0.609
12/07/83	10:20	0.882	0.805	0.733
13/07/83	10:28	0.826	0.756	0.769
14/07/83	7:45	0.590	0.487	0.350
15/07/83	10:55	0.535	0.428	0.288
16/07/83	9:45	0.502	0.399	0.247
17/07/83	10:16	0.529	0.431	0.356
18/07/83	9:45	0.500	0.420	0.411
19/07/83	10:50	0.415	0.413	0.295
20/07/83	9:55	0.869	0.804	0.818
21/07/83	15:20	0.976	0.908	0.927
22/07/83	11:15	1.005	0.940	0.953

TABLE A54 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-7 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A9	A10	A11
06/07/83	9:40	1.032	1.165	1.145
07/07/83	11:20	0.650	0.784	0.802
08/07/83	9:55	0.683	0.720	0.731
11/07/83	9:00	0.655	0.765	0.776
12/07/83	10:00	0.744	0.817	0.821
13/07/83	10:08	0.781	0.787	0.772
14/07/83	7:25	0.425	0.480	0.507
15/07/83	10:35	0.359	0.387	0.404
16/07/83	9:25	0.326	0.343	0.366
17/07/83	9:56	0.386	0.405	0.416
18/07/83	9:25	0.358	0.369	0.371
19/07/83	10:30	0.429	0.439	0.452
20/07/83	9:35	0.836	0.830	0.811
21/07/83	15:00	0.927	0.924	0.903
22/07/83	10:55	0.951	0.943	0.926

TABLE A55 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-8 : LINE B

DEPTH (m)

DATE	TIME	PIPES B12	B13	B14
06/07/83	9:55	1.065	1.084	1.075
07/07/83	11:39	0.748	0.720	0.655
08/07/83	10:14	0.692	0.662	0.627
11/07/83	9:19	0.702	0.688	0.638
12/07/83	10:21	0.736	0.729	0.695
13/07/83	10:27	0.696	0.688	0.676
14/07/83	7:44	0.497	0.480	0.432
15/07/83	10:54	0.419	0.404	0.362
16/07/83	9:29	0.374	0.360	0.320
17/07/83	10:17	0.406	0.392	0.350
18/07/83	9:44	0.350	0.337	0.310
19/07/83	10:52	0.413	0.405	0.366
20/07/83	9:54	0.744	0.737	0.728
21/07/83	15:22	0.845	0.846	0.834
22/07/83	11:12	0.861	0.853	0.848

TABLE A56 : SPECIAL WATER TABLE PIPES

WATER TABLE DISTRIBUTION ABOVE DRAIN

PLOT A-8 : LINE A

DEPTH (m)

DATE	TIME	PIPES		
		A17	A18	A19
06/07/83	9:41	1.056	1.107	1.040
07/07/83	11:24	0.384	0.789	0.726
08/07/83	9:59	0.352	0.736	0.680
11/07/83	9:04	0.412	0.793	0.731
12/07/83	10:06	0.586	0.834	0.768
13/07/83	10:12	0.697	0.807	0.742
14/07/83	7:29	0.248	0.561	0.510
15/07/83	10:39	0.128	0.472	0.431
16/07/83	9:29	0.081	0.436	0.398
17/07/83	10:02	0.082	0.470	0.428
18/07/83	9:29	0.060	0.403	0.366
19/07/83	10:37	0.062	0.475	0.430
20/07/83	9:39	0.778	0.858	0.783
21/07/83	15:07	0.869	0.940	0.868
22/07/83	10:57	0.888	0.961	0.885

TABLE A57 : PLOT DIMENSIONS

PLOT	LENGTH (m)	WIDTH (m)	AREA (m^2)
A-1	100	59	5900
B-1	100	57	5700
A-2	100	58	5800
B-2	100	58	5800
A-3	80	59	4720
B-3	80	57	4560
A-4	80	58	4640
B-4	80	58	4640
A-5	80	60	4800
B-5	80	59	4720
A-6	80	58	4640
B-6	80	58	4640
A-7	70	60	4200
B-7	70	59	4130
A-8	70	58	4060
B-8	70	58	4060

APPENDIX B

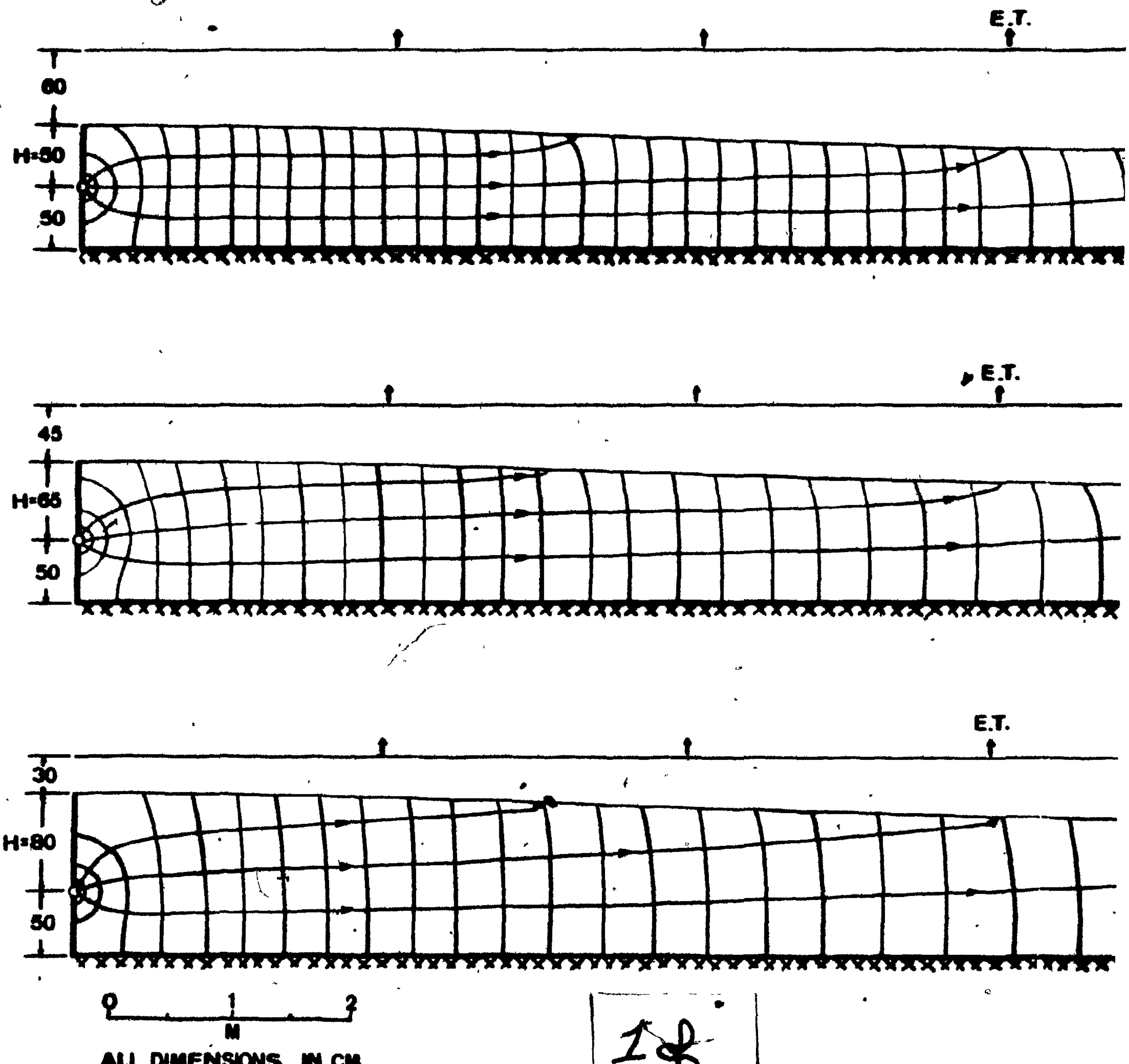
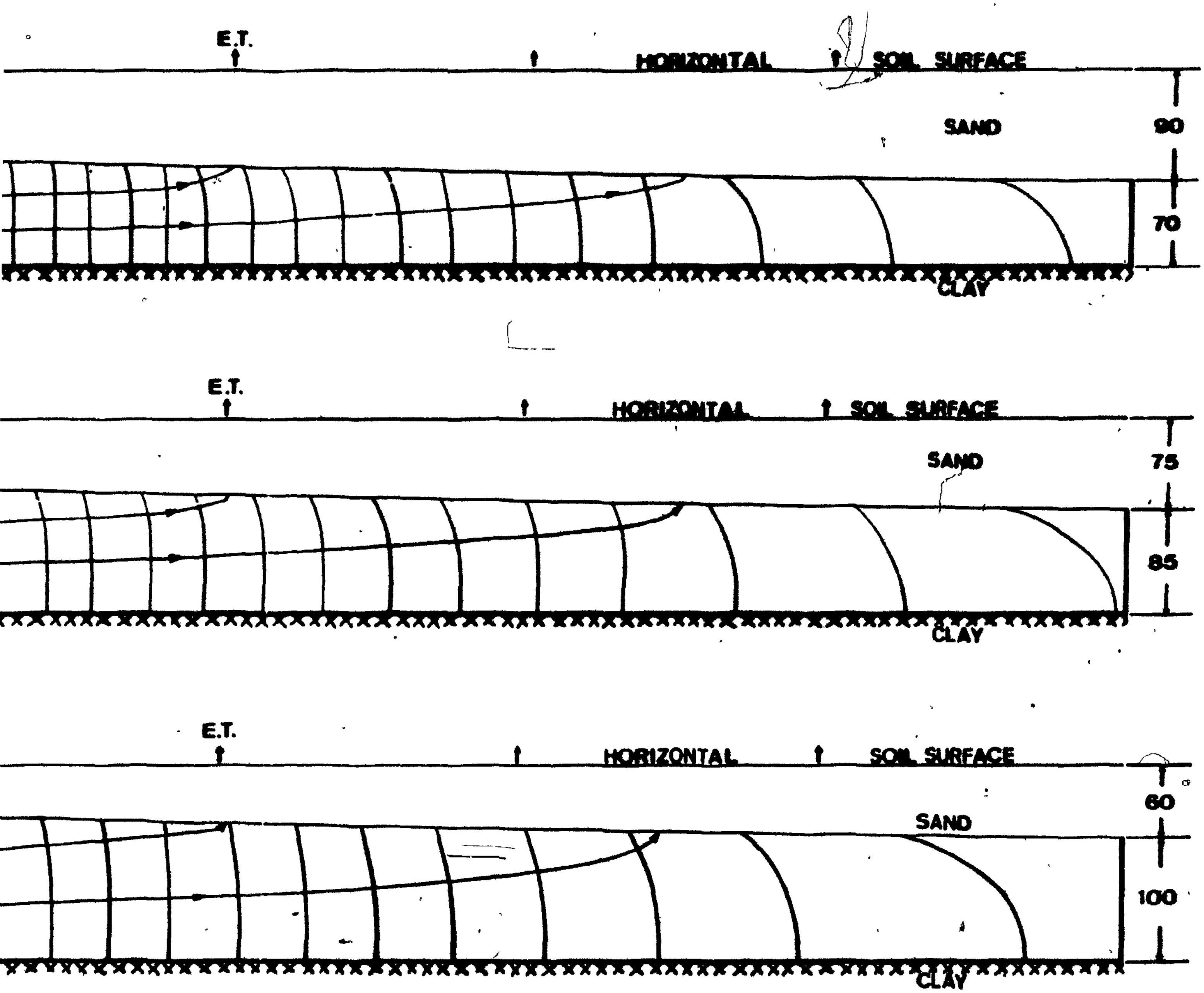


FIGURE B1 : FLOW NET DIAGRAMS FOR H VALUES OF 50, 65 AND 80 CM. FOR STEADY STATE SUBSURFACE IRRIGATION.



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65 AND 80 CM.
ON.

APPENDIX C

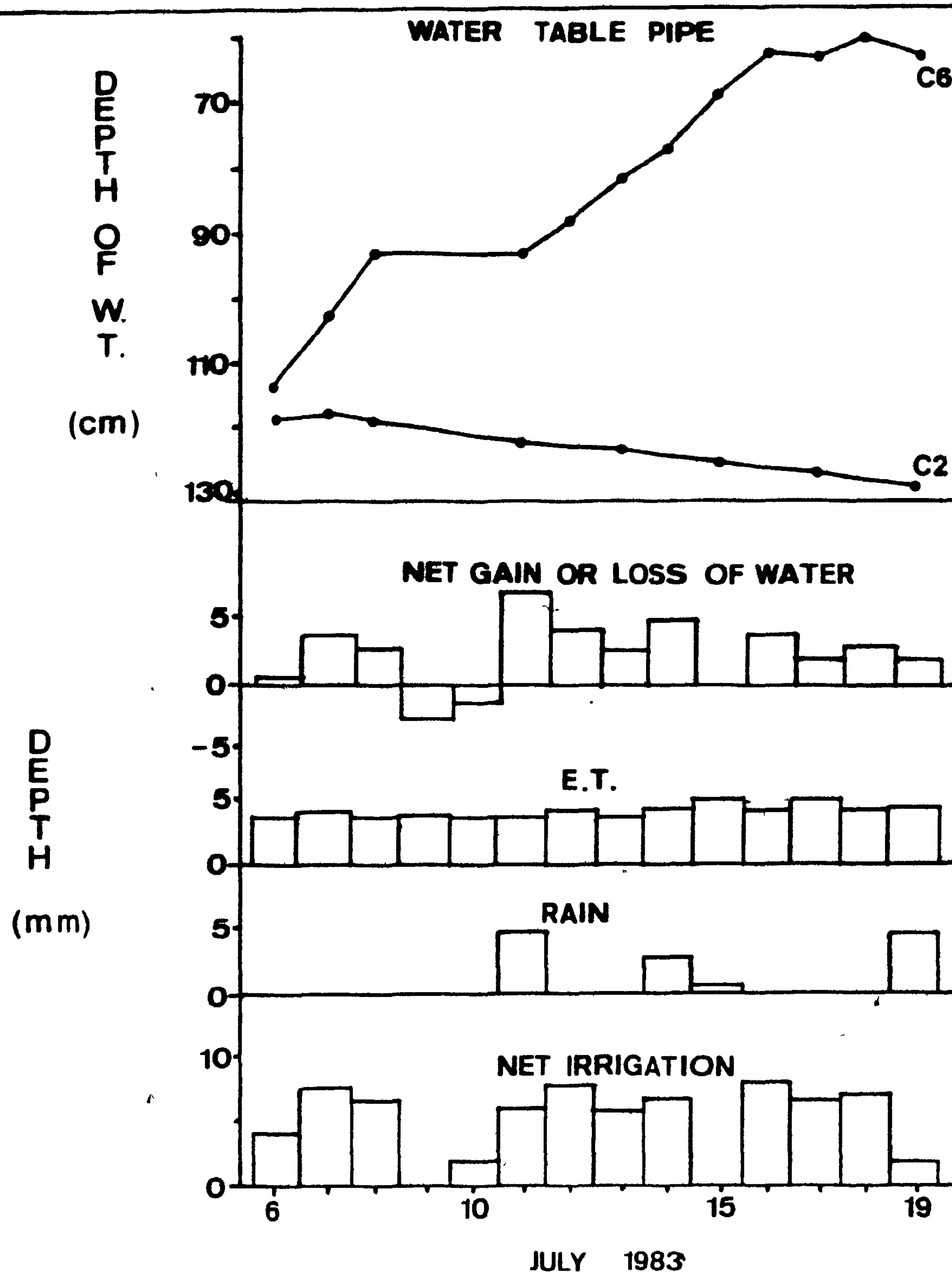

FIGURE C1 : IRRIGATION SCHEDULE AND WATER TABLE RESPONSE