Tile Drainage

By

*M. Saeed Minhas

Synopsis

Drainage is one of the most important single factors in maintaining continuing high returns from the lands. It is true that we cannot overlook such things as proper application of irrigation water, rotation of crops, application of fertilizers and grading of the land. However, it is not possible to continue profitable farming through correct management of the surface of the land alone. The sub-surface drainage of the soil spells out the measure of prosperity on the land. Where drainage is good, continuing high yields are obtained. Where drainage is moderate to slow, the productive years of the land are numbered unless drainage is improved by artificial means. Tile drain construction offers the means to this end. This paper deals with the method and technique of the design and installation of tile drains in arid regions especially in irrigated areas.

The spacing and depth of tile drains and the method of their installation have been dealt with in the light of the author,s experience gained on tile drain installations in Imperial Valley, California. In West Pakistan, we have not attempted to tile drain any area. The Chakanwali farm on Lower Chenab Canal which was tile drained some times back had a hackneyed and ill designed system which never funtioned effectively. There are large saline areas in West Pakistan where tile drains could be more economically and effectively used for draining them and this paper may serve as a guide and encourage the engineers to test the efficiency of a tile system. In recent years, our neighbour, Afghanistan has gone ahead with tile drainage installation on some of the farms in Helmand Valley Project. It is time that we also embark upon demonstration farm drainage programme by testing the tile drains on our farms.

Introduction

Saline and alkali soils are mainly associated with arid regions and where irrigation has been done in the past, the harmful effects have appeared in the form of water logging and concentration of salts in the root zone of the soil. In West Pakistan we have to deal with these conditions which have seriously effected the yield of the crops and have also thrown large areas out of cultivation. It is difficult to state whether tubewells or open drain or tiles or combination of these would serve to

*Executive Engineer WARSAK

improve the salinity and water table condition. So far attention has been focussed mainly on tubewells as a means of supplemental irrigation water and drainage. In certain areas, however, the tubewells are not likely to serve any purpose in as much there may be lack of suitable aquifers. Thus deep vertical drainage and even tapping of ground water would not be effective. The saline lands of such areas could be reclaimed only by additional canal supplies to meet the optimum water requirement of crops plus the water required to dissolve and leach the salts. Open drains or (covered) tile drains have then to be provided to take away the excess water drained as leachate.

Some considerable experience has been gained in the field of open drains in our county but these drains have generally served as storm water drains or seepage-cum-storm water drains. There are very few seepage drains and even their utility has been very limited because of their shallow depth. The open drains require much land and harbour weeds and plant diseases. They are an obstruction and inconvenience to tillage operations and most important of all that they require constant maintenace and heavy expenditure to be fully effective. Tile drains lend themselves to greater variation in layout and do not interfere with cultivation. They require a minimum of maintenance and there is no loss of land. If the soil conditions permit, the tile drains are perhaps the best and most efficient for the drainage of alkli and saline land. It is only where artesian pressures exist that the tile drains and even open drains become ineffective. Another limitation is the permeability of soil and land grades. Complex soil strata and flat slopes complicate the design and add to the recurring cost of tile drain as pumping from sumps may be required for disposal of drain water if no adequate gravity outfall is available. However, tile drains lend themselves to more variation in layout.

How a tile drain functions

Water move into tile drains by gravity. It enters through the joints between the titles, not through the wall as one might suppose. The walls of porous tiles may absorb water rapidly till saturated, but little water passes through them.

By effecting drainage of land with tiles, the excessive salt in the soil water is removed by applying excess water. The osmotic pressure is reduced thus helping the growth of plants. In swampy or water logged areas, land are relatively cold and crops are delayed in their growth. Root development is greather and plants are healthier on soils drained by tiles, because the saturated zone of soil is kept below, by lowering the water table between tile lines.

A drain cannot lower the water table below the depth to which the tile is laid; in fact except in its immediate vicinity, the water table will always stand somewhat higher than the tile.

Planning of tile drain system

Before any construction is started, it is necesary to make an overall survey and prepare a plan. The survey is carried out to provide information leading to the selection of an outlet for the drain, and determining the slope, size and other physical characteristics of the area. The rainfall and run off characteristics should also be known. The depth of water table and its fluctuation ; the sources and amount of ground water and its direction of movement through the soil should be determined as well to decide upon the direction and layout of drains. This is done by installing a network of piezometers and observing water levels.

For any drainage problem, the fundamental law pertaining to the flow of water through capillary interstices of saturated porous media known as Darcy' s Law has been supplied.

$Q = P\ I\ A$, where Q is the discharge

A = Area of cross-section

P = Coefficient of permeability

I = Hydraulic gradient

Area of Cross-section

The most tangible factor for analysis is that of cross section area (a) or the dimension of the material in which water movement takes place. This is accomplished through Stratum Survey. An evaluation of the thickness, elevation and sequence of stratification and of the texture and structure of the materials is done by means of soil samplers or augers. This helps in logging and classifying the soils. Soil colour, general texture, stratum sequence and association with adjacent borings are revealed by soil boring in a grid survey, indicating the dimension of the acquifer as well as the field characteristics of the strata in terms of permeability. The data on the texture and permeability of the soil and subsoil determines locations, depth, spacing and size of drains.

A suggested pattern of delineating soil profile conditions as related to drainage is the one adopted in Imperial Valley to indicate soil, slope, erosion, drainage problem and salinity. These conditions are shown on aerial photography by means of a fractional symbol followed Land Capability Class and Sub-class.

$$\frac{(\textit{Surface Texture})\ (\textit{1-5 feet})\ (\textit{5'-9'})}{\textit{Slope - Erosion - Drainage-Salinity}}$$

The first *letter* of the soil symbol will indicate the dominant condition with reference to surface to surface soil texture (Light, Medium, Heavy) in the zone 0 to 1′ and the 1st and 2nd digit would indicate the permeability in the 1-5 feet and 5-9′ zones. Symbols A, B & C are used for 0-1%, 2-3% 4-8% slopes. Similarly other symbols have been adopted for the remaining factors. The present land use is also mapped.

A simplified method of soil survey for determining the areal extent of aquifers and acquiclude for tile drainage would be to indicate the texture of top soil first. The bore holes being generally 10′ deep, the permeability of this profile should be indicated for layers 1 to 5′and 5—9′, adding information about a barrier or kankar crust appearing in this profile, Another important note of information required is the depth to saturated soil. This is explained by the adopted symbols :

$$\frac{M\ 5\ 3—8}{4{\cdot}0}$$

Explanation - Barrier

Permeability of zone 5—9′

Permeability of zone 1—5′

Texture of surface 0—1′

$$\frac{M\ \ 5\ \ 3—8}{4{\cdot}0}$$

Depth to saturated soil

Surface texture :

H = heavy soils
M = Medium soils
L = Light soils
C = Coarse
X = Texture undifferentiated as in river wash Permeability of subsurface zones (2nd & 3rd item of soil symbol)

1	= Very slow	— ·05 inch/hour
2	= Slow	— ·05—·1
3	= moderately slow	— ·10—·25
4	= moderate	— ·25 - 1·0
5	= moderately rapid	— 1.0—2·5
6	= Rapid	— 2·5—5·0
7	= Very repid	— above 5·0

Greater weight should be given to the permeability of 1—5′ section soil of profiles. In evaluating the permeability of the 5—9′ section, greater weight will be given to the permeability of 5—7′ portion, where a tile is generally placed.

The functioning of tile drain depends on a fair permeability of these zones and when the permeability at suitable intervals in a given field area is known, it is possible to assess the spacing of tile drains.

The degree of detail required of a stratum survey depends on the conditions encountered and the character of the information sought. When a detailed survey is required for tile drainage plans, a grid system should be surveyed with drilling points 100′ to 400′ apart. On large farms where experience has established uniformity of soil profile, bore holes may be 600 to 800′ apart. A local bench mark is established with an assumed elevation of 100′, eliminating the confusion about local datums. Elevation of each drill point determined. East west traverses are designated by letters and north south lines by numbers. Random borings have little value in most drainage investigations.

For tile drainage, the objective is to interpret the nature of starta as related to water movement, and so a summation of all field notes and observations on the spot has to be done interpreting the field characteristics of starta in terms of comparative permeability. While boring with a soil auger, texture of various layers become mixed, especially when ground is wet, and structure is also not readily distinguishable. Visual factors such as soil colour help in sifting the data. In fact, our experience in soil survey now being conducted in the doabs of the Punjab would be a good guide in stratum survey for farm drainage.

A soil chart or proforma which may be used by soil surveyor in planning farm drainage is given in Plates 1 & 2.

Permeability

There are three methods of determning quantitatively the coefficient of permeability of any single stratum or group of starta. These are as follows :

1. Field measurement.
   A direct measurement utilizing a well and measuring the discharge from the well and the equilibrium drawdown curve to it (P).

2. Laboratory measurement utilizing the permeameter.
   (a) Undisturbed specimens taken in the field.
   (b) Disturbed or prepared specimens. These are samples taken in a disturbed condition from the field site and prepared in the permeameter under standard procedure.

3. Indirect measurement of permeability.

The first technique is perhaps the most accurate but also the most time-consuming and subject to complications of varying field conditions. The second method is fairly accurate, when undisturbed samples are used. This method also is time-consuming and exacting. The indirect method is

not precise but it is rapid and reasonably simple. Greater accuracy is derived when these estimates are supplemented with undisturbed sample laboratory measurments.

To be practical, some more rapid technique of estimating permeability is necessary, even though it may involve sacrifice of some degree of accuracy.

* Attempt have been made to develop a relationship between some simple characteristics of a sediment and the coefficient of permeability. These include the plastic limit, moisture equivalent, water holding capacity of the sediment at various tensions and the character of the particle-size distribution curve. All these methods probably have merit when applied to special conditions.

In the Imperial Valley, an attempt was made to correlate the percentage of silt-plus-clay with the coefficient of permeability of a prepared specimen. The techniques involved required very little equipment and limited experience on the part of the technician.

As a result of conducting a large number of mechanical anaylses and preparing sample coefficients of permeability measurements in the Imperial Valley, a definite correlation was derived between the total silt plus-clay percent (grain particles smaller than 0·05 mm) and the coefficient of permeability. Upon completion of the mechanical analyses, the results were classified as to which of the groups the samples belonged. This classification was based upon the predominance of sand grains. A glance at the results of the mechanical analyses would indicate whether the proportion of sand fine sand, or very fine sand was greater.

A series of cards have been filed on the basis of silt-plus-clay content in the office of Soil Conservation Service, Imperial. These cards contain the mechanical analyses, coefficient of permeability, method of measurement, and laboratory number of sample run. The soil surveyor is guided by his knowledge and experience of local conditions as well as the laboratory studies on the soils of the area.

Hydraulic Gradient

In order to obtain overall water table information in connection with farm planning and attendent drainage design, a number of observation wells are installed in a grid system. Firstly borings are made and after obtaining information on the depth of saturated soil and occurence of aquifers, the wells are installed. The field borings when plotted in sequence indicate at what depths observation wells be driven. The water levels observed in these wells help in drawing water table contours which indicate direction of movement of ground water. The drain lines should generally run transverse to the direction of flow of ground water.

---

* NEAL has developed a relationship between plasticity index and permeability.

A source boundry like and irrigation canal or a drain would indicate its effect on water table in observation wells installed at right angles to it.

Small dia (1/2″, 5/8″) G.I. Pipe of shallow depth are a more economical means of determining water table conditions and hydraulic gradient. Small dia pipes used in subsoil water hydraulics have been described by Israelson as 'Piezometers'. These are driven vartically down to prescribed depth and the methods of their installation and water depth measurement are described in "Irrigation Principles & Practices" (Israelson). These have the advantage of ease in installation and removal for re-use. They measure hydrostatic pressure. By locating the termination points of piezometers at different depths, the hydrostatic pressure at those points is obtained to plot equipotential contours lines.

There is a difference between a piezometer and an ordinary well. There is no leakage outside of the piezometer pipe all water enters into it from the bottom. In wells, which are mostly perforated having frequent access points for water to travel from soil to well, the depth of water indicated is the hydrostatic pressure of the entire underground soil profile to the depth of well. The piezometer on the other indicates the hydrostatic pressure of the underground wather only at the bottom of the device.

DESIGN OF TILE DRAIN SYSTEM

A tile drain system consists of :

(i) Disposal point-a drain, natural or artificial or a sump or a pond.

(ii) Laterals-To drain the area.

(iii) Mains-To collect water from laterals.

(iv) Outlet-Lower extremity of main, emptying out into the disposal point.

For a block of land requiring drainage, longer main and short laterals are generally a good start. But the location of a seepage source, and the availbility of drain far out-fall of tile main as well as the field dimension and slopes are the factors influencing the design. As a rule, lateral should be placed along steeper slope of the field to reduce excessive depth of trench. Mains of large dia can be laid with less steep slopes. However, a compromise has always to be made in arriving at the correct design to suit local conditions.

The best preparation for a plot of land to be tiled is to level its surface and give suitable slopes to the field to avoide excessive waste of irrigation water. This also facilitates accurate planning of tile system and depth of trench for tile lines.

Layout and Location

The location of main drain, collecting water from laterals, is controlled by position of the outlet, size, shape and slope of the area.

When an area is not levelled, tile lines follow depession in the ground surface.

A system nf parallel laterals in the form of a grid iron system to secure field drainage is usually most effecitve where topography is flat and soil somewhat uniform. The laterals are sometimes laid in herring-bone pattern, which a main running diagonal. But, this requires careful planning to obtain an efficient and economical system.

Spacing of Tile Drain:

Two types of soil profiles may be considered to illustrate the influnce of drain depth, spacing etc., on the flow to tile drains:

(i) In highly permeable sandy soils of smaller depth, underlain by compact clays of low permeabilility 6 to 10 ft. below the land surface, as illustrated in plate 3(i) the ground water flow is essentialty horizontal toward the drains.

To simplify the illustration, the source of water flowing towards the drain may be considered a reservoir as shown on the left of plate 3 (i). The water surface is maintained in the reservoir and adjoining soil a distance of H ft above the clay. Flow from the reservoir to the drain is steady, it being assumed for simplicity that the seservoir is the only source of water.

Ground water actually flows to the drain from both sides. Let 2q represent the flow into a drain in lenght L. Then the ground-water flow from one side to the drain is q = av and from Darcy's law,

$$v = k\frac{h_f}{R} = k\left(\frac{H-h}{R}\right)$$

Consider the depth of saturated sand about midway between the reservoir and the drain as average ; then the average area of saturated soil, in drain length L through which the ground water flow is : $a = \left(\frac{H+h}{2}\right) \times L$ and the quantity of flow from the reservoir to the drain

$$q = \left(\frac{H+h}{2}\right) L \times k\left(\frac{H-h}{R}\right)$$

$$= \frac{KL\,(H^2 - h^2)}{2R}$$

The qnantity of flow to the drain from reservoir on both sdies would be

$$Q = 2q = \frac{KL\,(H^2 - h^2)}{R}$$

from which $R = \frac{KL\,(H^2 - h^2)}{Q}$ .....(1)

Computation of drain spacing using equation (1) must be regarded as only approximations because of the fact that permeability K varies greatly in field soils.

(ii) For soils of great depth and approximately uniform permeability, as illustrated in plate 3 (ii), the ground water flows toward the drain from all directions. With these soil conditions the radial flow through semicircular area of drain of dia = d (a little less than the actual area), is given by the formula :

$$Q = \frac{\pi\, KL\,(H-h)}{2{\cdot}3 \log \frac{R}{r}_{10}} = \frac{\pi\, KL\,(H-h)}{2{\cdot}3 \log \frac{S}{d}_{10}}$$

The basic differences of the two soil-and-water flow conditions of special importance are : For the first condition, if h is small as compared to H, the flow to the drain is proportonal approximately to the square of the effective depth (H-h), whereas in the second condition the flow is proportional to the first power of the effective depth.

Donnan has derived an equation comparable to equation (1), on the same assumption that the flow is horizontal towards the tile drain and this flow QR at any distance x, is proportional to the distance from a point midway between the tile lines where flow is zero. (Fig : 1). The flow to the tile drain is due to removal of water from a strip of soil one foot thick extending a distance $\frac{S}{2}$, on each side of the tile line S being the spacing of tile lines.

Q_R at any point at right angles to the tile drain is $= C\left(\frac{S}{2} - x\right)$, ... C being a constant.

When $X=0$, $Q_R = \frac{Q}{2}$, where Q is the flow in tile line.

$Q_R = \frac{Q}{2}$ so that $C = \frac{Q}{S}$

$\therefore Q_R = \frac{Q}{S}\left(\frac{S}{2} - x\right)$

$I = \frac{dy}{dx}$

A = y (1 foot section)

$$\therefore \frac{Q}{S}\left(\frac{S}{2} - x\right) = (P)(y)\frac{dy}{dx} \quad \text{.....Darcy's equation}$$

$$\text{OR} \quad \frac{Q}{2PS}\int (S-2x)\,dx = \int y\,dy$$

$$\text{Integrating} \quad -\frac{Q}{8\,PS}\left(S^2 - 4Sx + 4x^2\right) = \frac{y^2}{2} + C$$

$$\text{When } x = 0,\ y = a,\ \text{so } C = -\frac{QS}{8P} - \frac{a^2}{2}$$

$$\text{and thus} \quad \frac{Q}{8PS}\left(S^2 - 4Sx + 4x^2\right) = \frac{y^2}{2} + \frac{QS}{8P} + \frac{a^2}{2}$$

$$\text{Solving for P,} \quad P = \frac{Q}{S}\frac{(Sx - x^2)}{(y^2 - a^2)}$$

$$\text{and when } x = \frac{S}{2},\quad y = b$$

$$\text{so that } P = \frac{QS}{4(b^2 - a^2)}$$

$$\therefore S = \frac{4P(b^2 - a^2)}{Q}$$

This formula is applicable to the soil conditions of Imperial Valley, where generally the depth of permeable soil is restricted by an underlying stratum of low permeability. For other areas, criterion of permeability in relation to physical factor of soil may be established and correlated with a spacing formula derived for tile installation after experimentation in the fields.

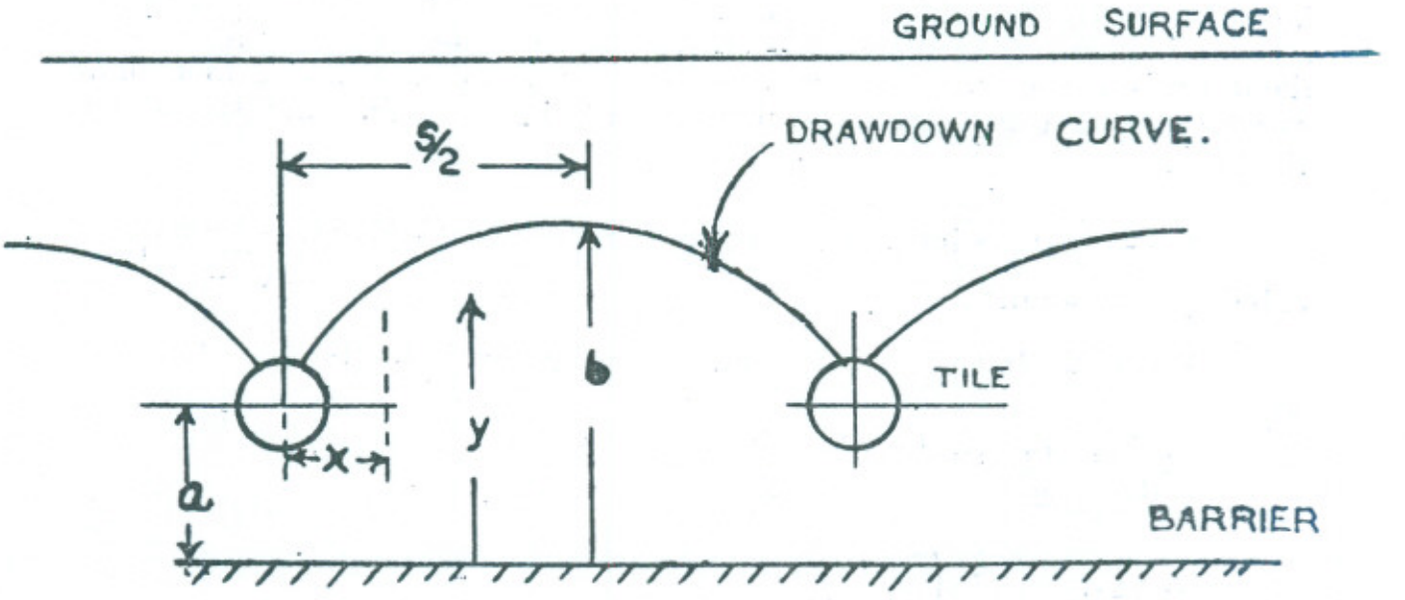


FIGURE 1

Q = Discharge of one tile line in gallons/day/ft. of tile line
Qt = Total discharge from field, per ft. of tile line in g/day
P = Permeability g/ft²/day
I = Hydraulic Gradient
C = Constant
a = Distance from average tile depth to barrier Stratum (ft)
b = Distance of draw down curve to barrier at mid point between tile lines
W = Width of field to be tiled (feet)

$$Q = \frac{Qt\ S}{W} \therefore S = \frac{4P(b^2 - a^2)}{\frac{Qt\ S}{W}}$$

$$\text{or } S^2 = \frac{4P(b^2 - a^2)}{Qt/W}$$

Depth of tile Drain :

The depth at which tile lines should be located is to be based on local conditions. In arid areas it is necessary to maintain a water table at such a depth that water rising by capillary from the water table will not reach the ground surface from which it can evaporate and deposit dissolved salts. For medium textured soils, the water table should be a minimum of about 5·0′. and for heavy soils about 6·0′. This means that drains should be 6·0′ deep or more. The root depth of crops in another factor which may permit lesser depth of tile lines.

Other Specifications of Tile Drains

Minimum slope of a lateral should be ·001′, the minimum dia of tile should in all cases be 4″ and minimum depth to invert 5·0′. To provid minimum depth, a slight decrease in tile grandiedt may be compensated for by increasing the dia, and/or by reducing length of line. A system of long mains and short laterals is economical in a grid system. 6″ collector drain should have not more than ten to twelve thousand linear feet of 4″ tile. Combination of 8″ and 6″ base line should not have more than twenty to twenty five thousand linear feet of 4″ tile.

There should be a gravel envelope consisting of a minimum of 2″ gravel around the tile.

Amount of gravel is for 4″ tile = 2 c.yds. per 100′
6″ tile = 2½ c.yds. per 100′
8″ tile = 2½ c.yds. per 100′
10″ tile = 3 c.yds.per 100′

Gravel size — Minimum 70% pass No. 4 screen and hold on No. 28 screen.

Man Holes or silt Boxes :

Placing of gravel around tile lines eliminates entry of silt into tile lines. Previously manholes and silt boxes were intalled on tile lines to clear them if clogged by silt or sand, but these are no more considered necessary.

However, at important junctions where two or more tile lines meet, a manhole will make the connections convenient. These are often made of 30 or 36 '' dia pipe placed one on top of another. The floor of the manhole should be of concrete and at least 1·0′ below the flow line of outlet tile. Top should be covered.

Outlet :

The water collected by underground system is deposited by the outlet structure into a stream or artificial drain or sump.

Outlet of a tile system shoud consist of a minimum of one standard length of concrete or corrugated metal pipe into a drain of 7·5′ depth or less, and 2 or more standard lengths of concrete or corrugated metal pipe into drains exceeding 7·5′ in depth.(Plate 4)

An outlet for tile drains should carry the water reaching it without submerging the tile for long after a heavy rain. The ideal outlet permits free flow at all times from the drains.

Provision of an outlet on our lands will generally involve the right of passage for tile drain through a neighbour's property. In fact the system of tile drains envisages work on cooperative basis. It would be uneconomical and ineffective to tile drain small area remain while the surrounding areas remain untouched. The tiled rainage is therefore contemplated as a community enterprise. The location of drains and outlet and cost should then be decided by mutual agreement of land owners. This will be discussed under '' conclusions''.

Location of Tile Drains in fields underlain by heavy clay mounds or clay strata :

A barrier of heavy textured soil impedes the movement of excess irrigation water or seepage. There are two types of soil barriers which cause the water table problem. The most spectacular type of barrier often encountered would be a long transverse subsurface dike or clay bar which lies at right angles to the general direction of subsurface seepage flow. The second and most common type of barrier is a layer or stratum of soil which uuderlies an entire area and prevents the natural release of ground water downward and out of the root zone of plant growth. Each of these types presents a problem in drainage design.

Seepage from the canal and from branches together with excess irrigation water, moves down slope and when this excess ground water reaches a transeverse subsurface clay dike or bar, it build up behind the barrier. Eventually the water table is at or near the ground surface. Evaporation soon produces a saline area where crops will not grow.

Borings with an auger reveal the location of the transvere clay barrier. Series of borings are made from across the transverse clay barrier. Borings are usually made of the soils in a regular grid pattern. Then after rough configuration of the undrground barriers is revealed, additional borings are made to bracket in a barrier of this type and determine its exact location. Aerial photographs and examination of the actual ground surface help to reveal the location of these dikes. Often contour maps are made of both the ground surface and the upper surface of the clay barrier. These contours, are of considerable value in planning the tile drainage system (Plate 5).

A water table investigation is generally made of those problem areas to locate the source and direction of flow of the underground seepage. Piezometric observation wells are usually placed at right angles to the clay barriers and in one or more lines crossing the barriers. When these data are plotted on profiles the drainage problem is instantly revealed.

In designing a tile drainage system the most important single factor is the position of the laterals with respect to the transverse barrier. Excess seepage and irrigation water originating up slope from the barrier tends to build up at the barrier and forms a high water table. The first drainage lateral should be placed as close as possible to the upstream face of the barrier and should run parallel to it. The lateral should be in the aquifer or sandy material, but very near the heavier clay barrier towards the ground surface. Additonal lines up slope from the key lateral are installed at a spacing dictated by a consideration of soil permeability, water table datum and surface crop conditions. A minimum of two lines should always be recommended in any barrier drainage system unless the aquifer area between the barrier mounds is extremely narrow. The lines recommended should have an azimuth closely paralleling the alignment of the dikes or mounds. In several cases the key lines has been located and staked in the field. Auger borings are made prior to finally locating the key lateral to be sure it will not be placed in the heavier soil.

Where the impervious clay strata lay horizontally, as in old lake bed deposits, the problem of drainage design is somewhat different from that on a transverse barrier problem. The clay layers are undulating in charcter and may vary in their depth considrably in as small an area as one field. This phenomenon has been observed many times and is depicted graphically by logging soil borings and plotting profiles and contour maps of the clay layers. Borings are made from nine to twelve feet in depth with soil augers. Usually borings are made in a grid, the spacing of holes depending on the comlexity of soil starta (an average of about six holes

are bored on each 25 acre parcel). The log sheet of the holes is used to plot a contour map of the top surface of the barrier layer. If the surface of the clay layer is at a depth of 5½ to 10 feet, an ordinary grid system of tile lines spaced according to a tile spacing formula is used. However, if this top surface is from three to six feet below ground surface, the tile lines are located so as to avoid being placed in the clay. Experimental studies have shown that drainage to the tile line from the midpoint between lines may be reduced several hundred percent by imbedding the tiles in the clay. The most advatageous location from the standpoint of drainage is six inches or more above the clay. The balance between placing a line six inches deeper or keeping it six inches shallower to avoid imbedding in clay is in favour of a shallower tile placed in the sandy soil. The tile systems in these shallow barrier areas need not follow a rigid "square-with-the-world" alignment. They may angle off or even have some curves, although it is difficult to get the tile contractors to install this type of system. The secret then of securing a good design on a horizontal barrier area is to have a good contour map of the top face or the underground clay layer. Using this as a guide, the tile system is designed primarily to traverse down the valleys and swales in the clay barrier. Plate 5 depicts the ground surface contours, barrier surface contours and the designed tile drainage system for 310 acre farm having an undulating barrier. The drainage system was designed to drain the natural underground pockets and as far as feasible to keep the laterals out of the heavy barrier material. The soil profile consisted of a heavy clay barrier with a two to eight feet mantle of stratified sand. The portions of the drainge system that lie in the heavy barrier material had very little effect in reclaming the surrouding saline soils.

The important factor to keep in mind in the barrier type of drainage system is that the productive lines are the ones laid in the aquifer. (Plate 8)

A few typical designs of the tile drain are discussed with reference to the Stratum Survey of farms suggesting solution of the various handicaps involved.

In Plate 6 is shown a farm appoximately 2540′ × 2800′. The dominant slope is in n (small) ortherly direction. On the north and south run a drain and a canal respectively. The tile system takes coverage of the seepage from the canal minor so that intercepter drain 8A at a distance of about 125′ from the toe of canal minor will arrest it. The laterals are in the direction of steeper slope and the diagonal layout of the tile drain balances the steep stope of the field south to north.

Towards the south of the field a barrier exists at a depth of 9′ and would not materially affect the location of the tile drain. This barrier has a tendency to emerge towards east to the surface and therefore tile line No. 1 has been truncated so as to keep out of the barrier zone.

Another feature of the system is installation of piezometers in the centre of the tile line and a tile discharge recorder at the out-fall to study the efficiency of tile drains.

In plate 7 is shown a farm of size 2250 × 2400. On the three sides of this farm are located the drains so that the main drain runs on the east. The irrigation ditch runs on the south and provision has been made to intercept seepage therefrom by running tile line 9A paralleled to the ditch at a distance of 50′ from the field boundary. Considering the effect of this intercepter, the laterals start at a distance of 150′ from tile line 9A.

From a study of Stratum Survey of this field, the tile lines are closely spaced in the area where the soil is heavy and the spacing is 350 ft. where the soil is medium.

The slope is even in both the directions of the field although the problem is complicated by the existance of a bench in the middle of the field going from south to north. Line I serves as a collecting drain and leads to the main drain running on the east of the field. Distances of tiles 2 & 9 from the side drain are reduced to increase the efficiency of drainage.

The table gives a break-up of the slopes of the tile lines and the different diameters used.

Plate 8

The farm is a long norrow 20 acre plot running east and west along the drain. The eastern third of the property is very saline and without crop growth. Boring revealed a heavy clay mound of undermined depth to to the east rising to within 2′ of the surface near the middle of the field. This clay mound was athwart the field from south to north and impeded the natural east to west flow of underground waters. The ground water had a tendency to rise at and behind the barrier, allowing the evaporation to build up the salts over the eastern portion. The problem was to intercept the ground flow before it reached the clay barrier. The tile layout fits the need of this plot. Lines 2,3 & 4 are parallel to the clay barrrier. Line 2 was placed as close as possible to the clay barrier. Line 3 & 4 are in the highly saline area lying in coarse sand. Line 5 was placed 90′ from the east fence to intercept seepage from the adjacent fields. The collecting drain No. I on the north drained effectively.

Plates 9 & 10 are illustrative of another form laid with tile drains.

CONSTRUCTION GF TILE DRA1NS

There are two types of tiles generally used for farm drainag

(1) Concrete tiles

(2) Clay tiles

These tiles must be manufactured to conform to specified physical tests such as weight per ft. run, number of feet per ton weight, length of joint, working head in ft. for operation, wall thickness and safe hydraulic internal pressure. The dimensions and weight of plain concrete pipes for use in irrigation and drainage as allowed by the ASTMC 11839 are recom-

mended to be adopted. The concrete used in the manufacture of concrete tiles should be designed properly making it as dense as possible. Since the concrete tiles are generally used in alkali soil they should be able to resist sulphating action. Use of puzzolana for resisting alkali is now-a-days widely adopted. Curing in steam followed by curing in water and then drying up are common practices adopted by concrete tile manufacturers with a view to attaining high strength and good density of concrete.

Concrete tiles can best be manufactured by machinery and in USA two types are commonly used :

(1) Packer head type machine equipped with packer head forms and other accessories such as concrete mixer, concrete conveyer belt and pressure system for sprinkling concrete pipe as well as steam chamber for curing.

(2) Tamping machine with accessories as mentioned above.

In the packer head machine, thickness of the wall can be kept from 1/2″ to 5/8″ necessitating use of fine gravel. Also it is more econmical for pipes size upto 10″ to 12″ although this machine can turn out concrete pipes upto 24″.

Taming machine can be used with greater advantage for concrete pipes above 10″ diameter. Also this machine can handle thick wall pipes of smaller diameters. The tiles used for drainage are very seldom reinforced.

Considering the condition in our country clay tiles are going to be cheaper and also shall effectively stand the sulphating action of the saline water. It is common knowledge that clay tiles manufactured by the indigenous industry are porous and therefore stress should be laid on compressing the clay by removing air from the pugged clay. This will necessitate the use of machinery. In the United States, for clay pipes manufacture Fate-Root-Heath Co. machines are widely used. The clay is thoroghly pugged and air removed by vacuum or compression. These tiles are made of 12″ length for smaller dia and of 2′ length upto 12″ diameter. Clay tiles upto 30″ dia are not common. For greater diameter concrte pipes have to be used because clay cannot roll itself into bigger diameter wall. Sewer pipes are made to more rigid specifications and are more expensive.

A local manufacturer at Sialkot has been manfacturing clay pipes with fine perforations for tubewell strainer. These can be modified for tile drainage purposes, stress being laid on compressing the clay to make the clay tile least absorbent. Crushing strength of 1600 lbs. per liner foot for tile upto 8″ dia and of 2000 lbs per liner foot of tile upto 16″ dia is recommended.

Tile Size

When the maximum amount of water to be drained from an area is known and slope of drain determined the size of tile can be found from standard tables or diagrams.

Tiles ase made in sizes starting from 4″ dia with increments of2″, upto 20″ or 24″. Five or seven inch dia tiles are not common.

Tiles larger than 20″ dia are expensive and then one should consider economy of an open ditch.

Trenching

The most interesting thing regarding tile installation is the ease and rapidity with which this work can be done by means of trenching machines. The most commonly used machines for trenching are those made by Garwood Industries Inc : Finlay, Ohio, known as Buckeye Traction Ditchers. The Cleveland Trenching Company also manufactnres ladder type, wheel type and crawler type ditchers and there are many others in this trade.

Trenching machines are ideal for digging and laying tile drains in saturated soils. The buckets of the machine attached to the digging wheel revolve as the machine moves forward. By adjusting the wheel to the depth to which tiles are to be laid the trench is excavated and the earth is thrown sideways by a conveyer belt. A shoe sliding along the bottom of trench, moulds the trench bottom into a smooth rounded surface which centres the tile as they are laid. The grade is maintained by a sighting rod attached to the digging wheel.

Targets on the lines marked out in the field before hand for laying the tiles are set, starting from the outlet end. Three targets are set ahead of machines according to surveyors' grades and at stakes generally 100′ apart. The operator starts the machine from the outlet end, turns the wheel until the target rod on the machine lines up with the first two targets set ahead on the ground. The machine is then set in forward position and a trench begins to appear back of the digging wheel. The operator sights aross the targets as the trencher moves over the lands, always keeping the digging wheel in alignment with the ground targets. The trenching machine is steered by a steering wheel like an automobile. On curves, auxiliary targets are set. Similarly when changing from one slope to another, oxtra targets are set ahead for the back grade.

For hand trenching, the procedure is the same as for excavating tsenches for laying sewers so that 2 upright stakes with a bar across are laid along the line. Depths of cut are indicated on each stake and the X-bar determines the depth of the drain by lowering the staff.

Laying the Tiles :

Like trenching, the tile laying should start from the lower end or outlet and progress up grades, folloing closely the excavation of the trench. In placing ties, they are turned until they fit closely together. If a tile is crooked or its ends are irregular, it is turned till it fits tightly at the top, leaving more open space at bottom. Tight butting of tiles is advocated in light soils. In heavy soils, the butting ends may be 1/16 to 1/8 inch apart,

The tile should be laid and blinded as soon as the trench is completed to grade, otherwise bank may cave in. Gravel should be immediately poured around the tile line, and tar paper placed on the top of tile and then earth dumped in for blinding to a depth of 4 to 6 inches. The earth should be worked under the tiles to support them. Top soil is better for blinding. Filling of trenehes by bulldozer follows blinding. On completing a tile line, its upper end should be closed with a brick or a piece of broken tile. Junctions between laterals and mains should be made with Y's and not with T's or elbows. If Y's are not available, make junctions by cutting and fitting straight tile lines. Generally there should be a drop from the branch into the main drain.

Changes in directions should be made by curves and not by sharp angles. The curves should be regular, with the outer side of joints covered with pieces of broken tile.

Costing

Digging the trench and laying and blinding the tile are generally one operation and contract rate is fixed per 100 ft. of tile line. This rate would be governed by the nature of the soil, size of tile and depth. The price increases repidly with depth. Back filling is usually done by the farmer himself.

Cost per area of tile drainage will depend also on the spacing of laterals.

Maintenance

For proper maintenance, a plan showing location of tile drains, spacing and depth should be available for every property and a reference point should be available to locate tiles for inspection. It is advisable to inspect the tile system at least once or twice a year by walking along the tile line. The condition of the soil along a dr-ain a few days after a heavy rain indicates how the drain is working. Wet spots show that is now being drained. A hole or a cave indicates that a tile has been broken or misplaced· Steps then should be taken to repair the lines.

Roots of trees near tile drains may enter them and obstruct flow. As a general practice, all water loving trees should be destroyed within 50′ of a tile drain.

Crop rotations and methods of cultivation that maintain a good soil structure help keep tile drains working.

Conclusions

Comprehensive research is needed to determine the proper depth and spacing under various conditions. Such a project should be carried on for a period of years to secure good results. Since basic research data are not available, we should draw on experience of various workers in the field of drainage.

Where there is no local experience to draw on, attempt should be made to utilize as deep tile with as wide spacing as practicable. Subsequently spcaiag can be reduced and depth also if found necessary. It is often desirable to lay tile lines at various depths and spacings over selected area observe results for a a few year before undertaking large scale operations. Drainage shows results after 2 or 3 years after construction of tile lines. It takes time for the ground water to form channels into a drain.

Conservation retations of deep rooted crops are essential to keep tight soil open.

Aerial photography done under the Colombo Plan, contact prints ane enlargements of which are now available from Survey of Pakistan will facilitate quick soil survey and planning of tile drains. The soil survey conducted by the Ground Water Development Organization, Lahore, would would be helpful in assessing the potential and susceptibility of an area to subsurface drainage by tiles.

Some organizations on the lines of Extension Service of the Department of Agriculture in U.S.A. should be set up to advise the farmer in planning tile drainage. A law should be made defining the obligations of Government or the Department of Irrigation to provide drainage outlet for farm drains into Government maintained drains. Some cooperative effort would be needed to bring about consolidation of lands for tile drainage projects and the proposed Extension service should play a major role in this direction.

To start with, the Department of Irrigation should set up model farm installed with tile drains and from the technique developed there and its efficiency established, the Extension Service should propagate and help the farmers in planning farm tile drainage.

Trenching machinery should be made available on hire basis to contractors for installation of tile drains. Manually dug drains are not going to be properly laid with tiles and success of manually handled tile drainage project would be in jeopardy.

Facilities for manufacture of tiles and laying down of standard is another pre-requisite.

Generally adequate land slopes and natural or aritificial drains of adequate depth to facilitate a good out-fall would not be available in West Pakistan. In such cases, sumps for collecting effluent from tile lines would be required. Pumps fitted with automatic float type switch would ensure proper pumping from sumps and hence the disposa l of drained water.

BIBLIOGRAPHY

Grant ... Concrete Products

Israelson ... Irrigation Principles and Practices, John Wiley & Son.

Walter W. Weir ... Land Drainage, Circular No. 391 (C.A.E. Station)

Aronovici, V.S. & Donnan, W.W. ... Soil permeability as a criterian of Drainage - Design - Amer. Ged. Union Trans. Vol. 27 (February 1946)

Donnan, Aronovici. Blaney. ... Report on Drainage Investigations in Imperial Valley - 1947 U.S. Deptt. of Agriculture.

Bradshaw & Donnan. ... 1. Solving drainage problem in Barrier areas S.C.S. 1950.

2. Method of determining Ground Water levels and movements - S.C.S. 1950.

and Practices, John

ircular No. 391 (C.A.E.

a criterian of Drainage - ed. Union Trans. Vol. 27

Investigations in Imperial Dept. of Agriculture.

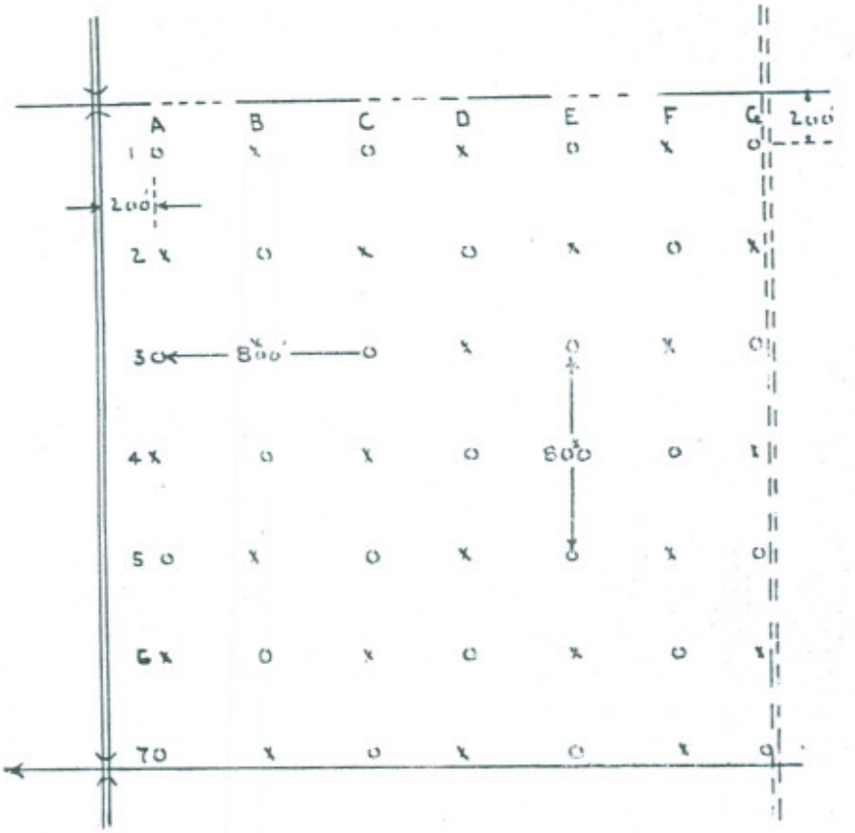
e problem in Barrier areas

termining Ground Water rments - S.C.S. 1950.

PLATE 1

FIELD/SY NO ——— VILLAGE OWNER ———

DATE OF SURVEY ——— TECHNICIAN ———



NOTE SAMPLE GRID FOR 160 ACRE FIELD
CONS. SURVEYOR MAY BORE MORE OR LESS HOLES DEPENDING ON SOIL COMPLEXITY
X INDICATES ADDITIONAL BORES

N

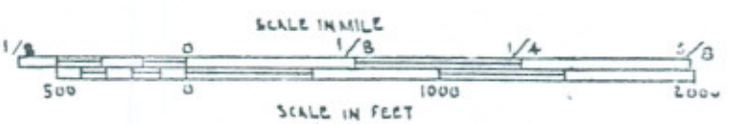


PLATE 2

SOIL CHART

SQUARE No. ——— VILLAGE ——— OWNER ———

TALUK ——— LAND USE ——— CROP CONDITION ———

PLAN ——— DATE SURVEY ———

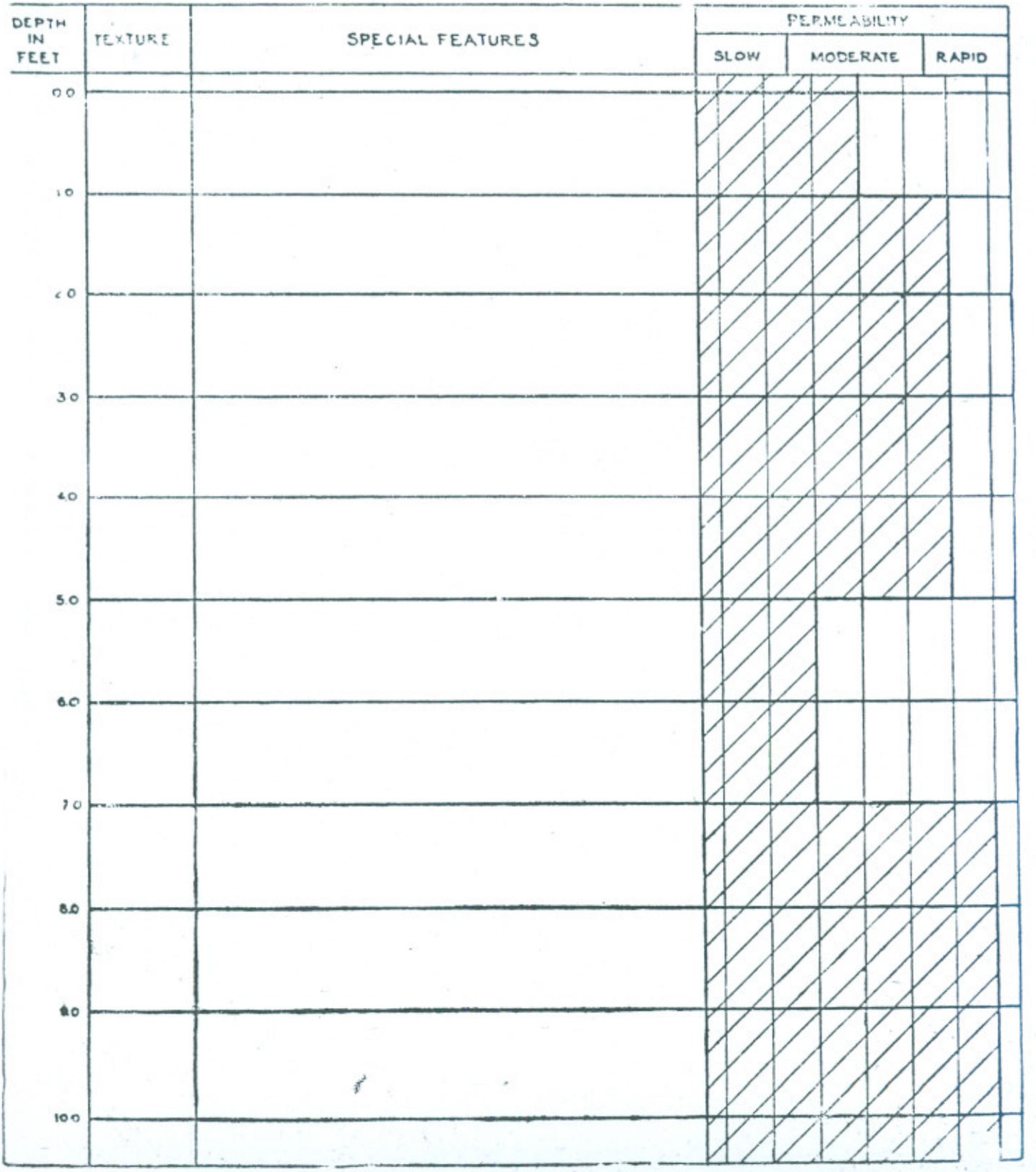
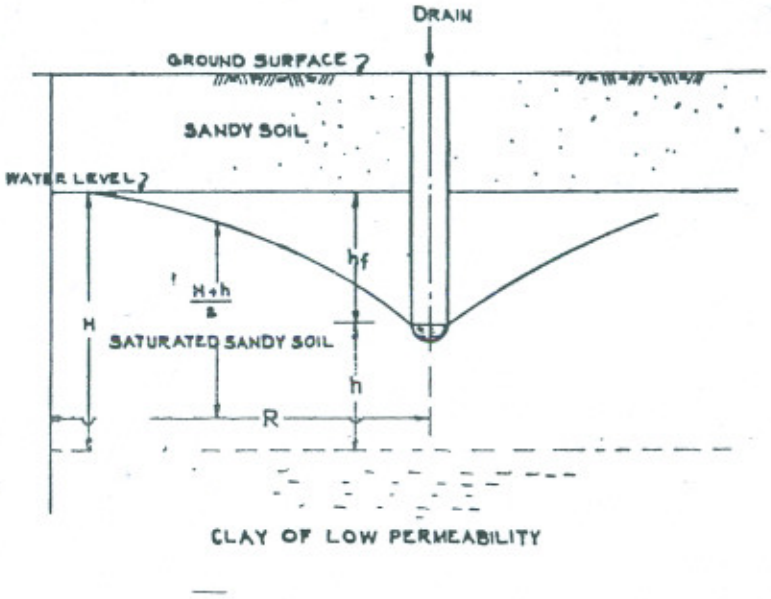
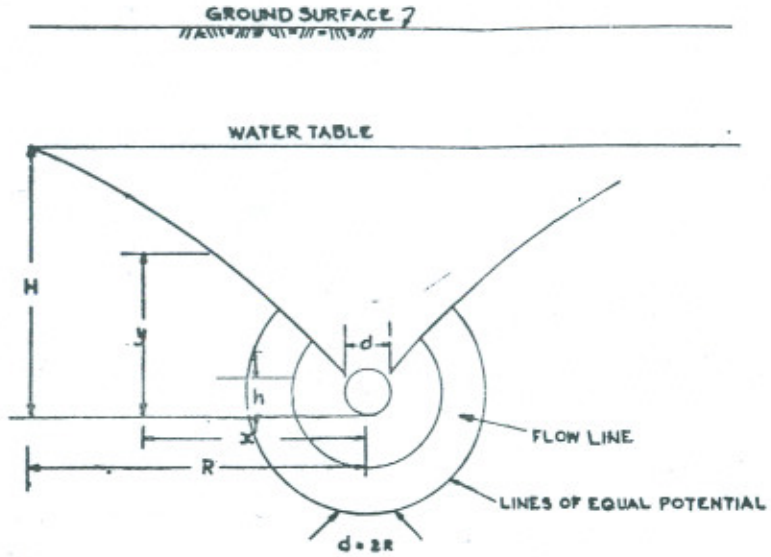
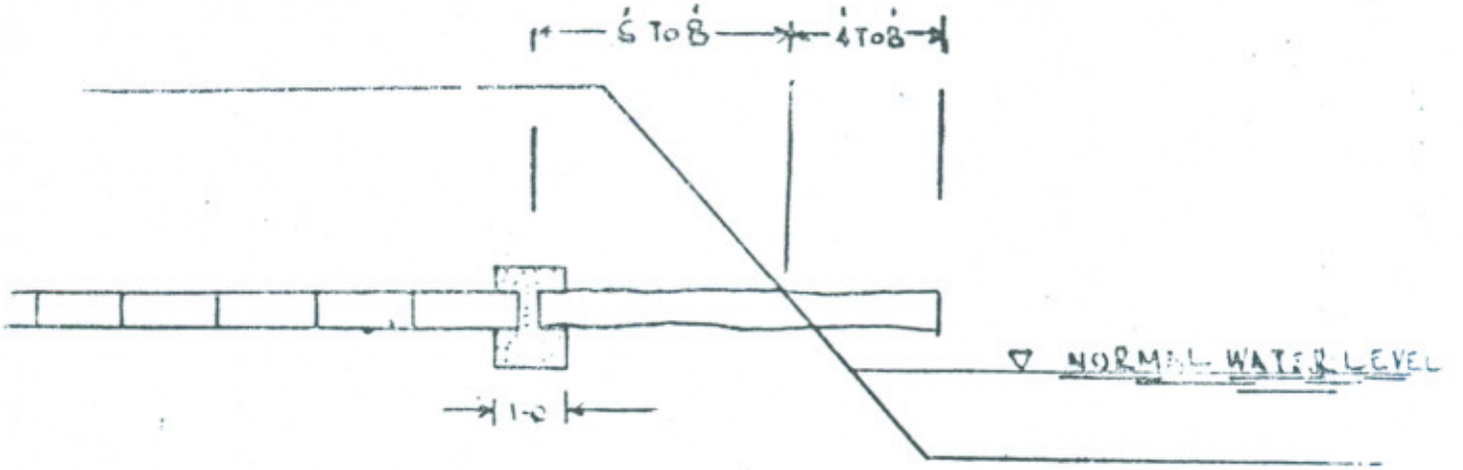


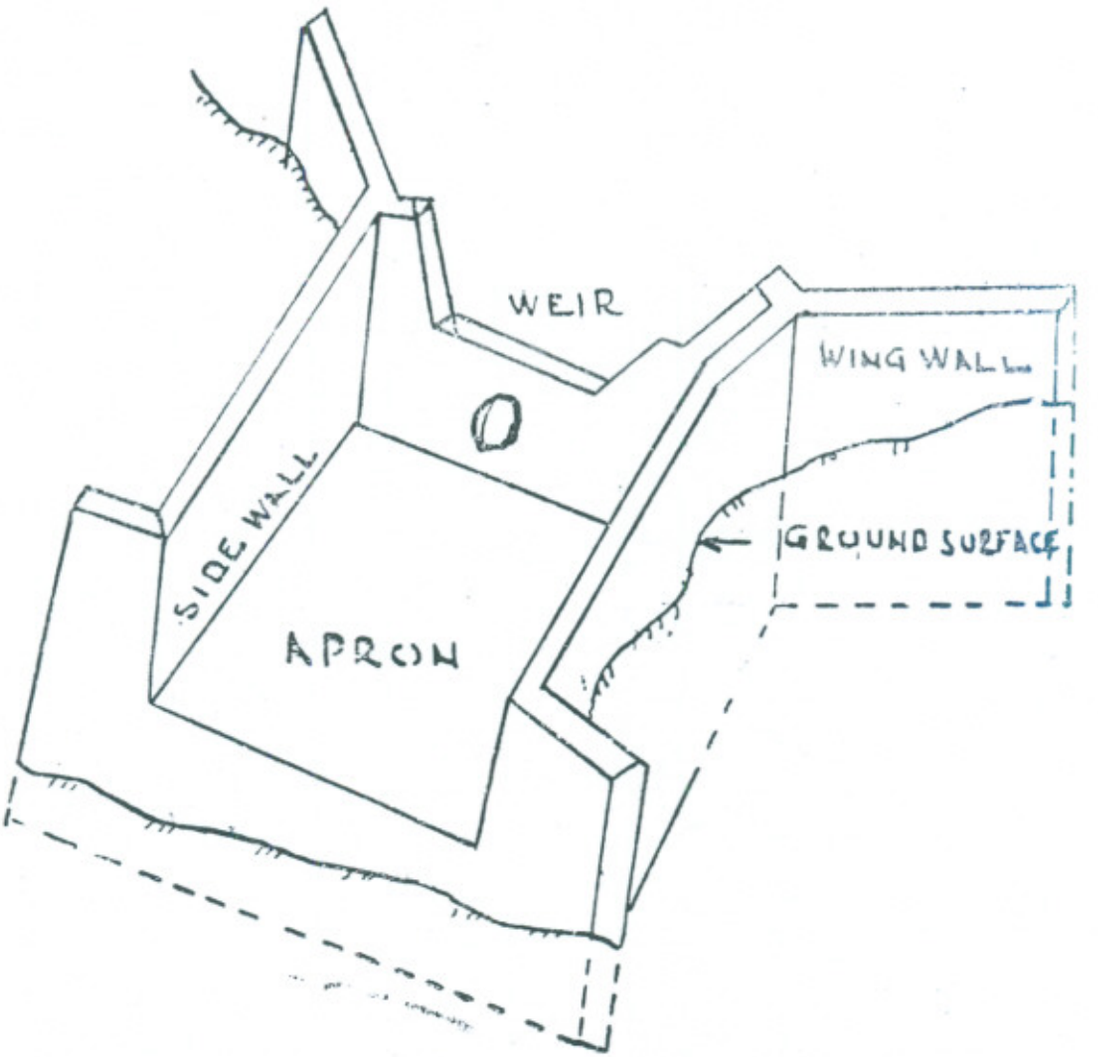
PLATE NO 3


DRAIN
GROUND SURFACE
SANDY SOIL
WATER LEVEL
hf
H+h/2
H
SATURATED SANDY SOIL
h
R
CLAY OF LOW PERMEABILITY


GROUND SURFACE
WATER TABLE
H
y
d
h
x
R
FLOW LINE
LINES OF EQUAL POTENTIAL
d = 2R

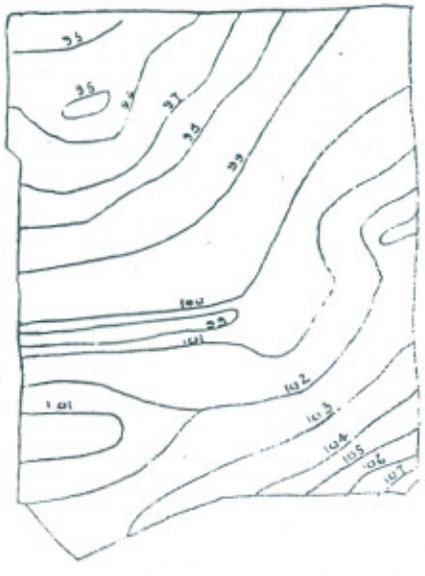


OUTLET FOR A TILE MAIN WHEN THERE IS NO SURFACE RUN OFF

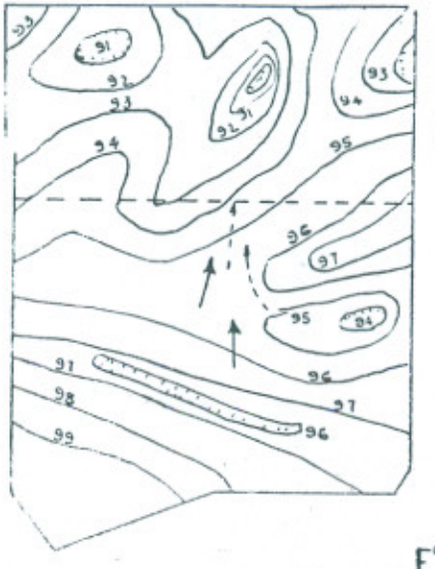


OUTLET FOR A TILE MAIN WHEN THERE IS SURFACE OVERFLOW FOR WHICH A SMALL WEIR IS MADE

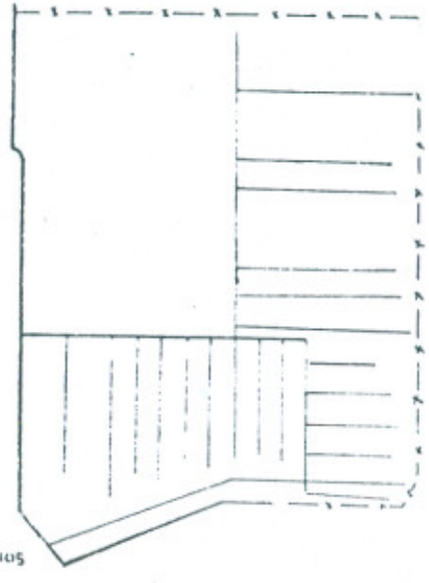
GROUND SURFACE CONTOURS



BARRIER SURFACE CONTOURS



DRAINAGE SYSTEM



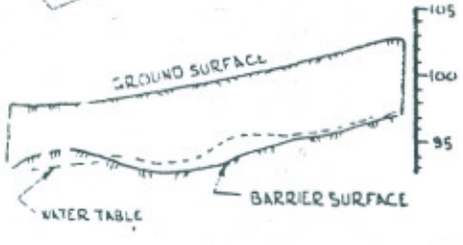
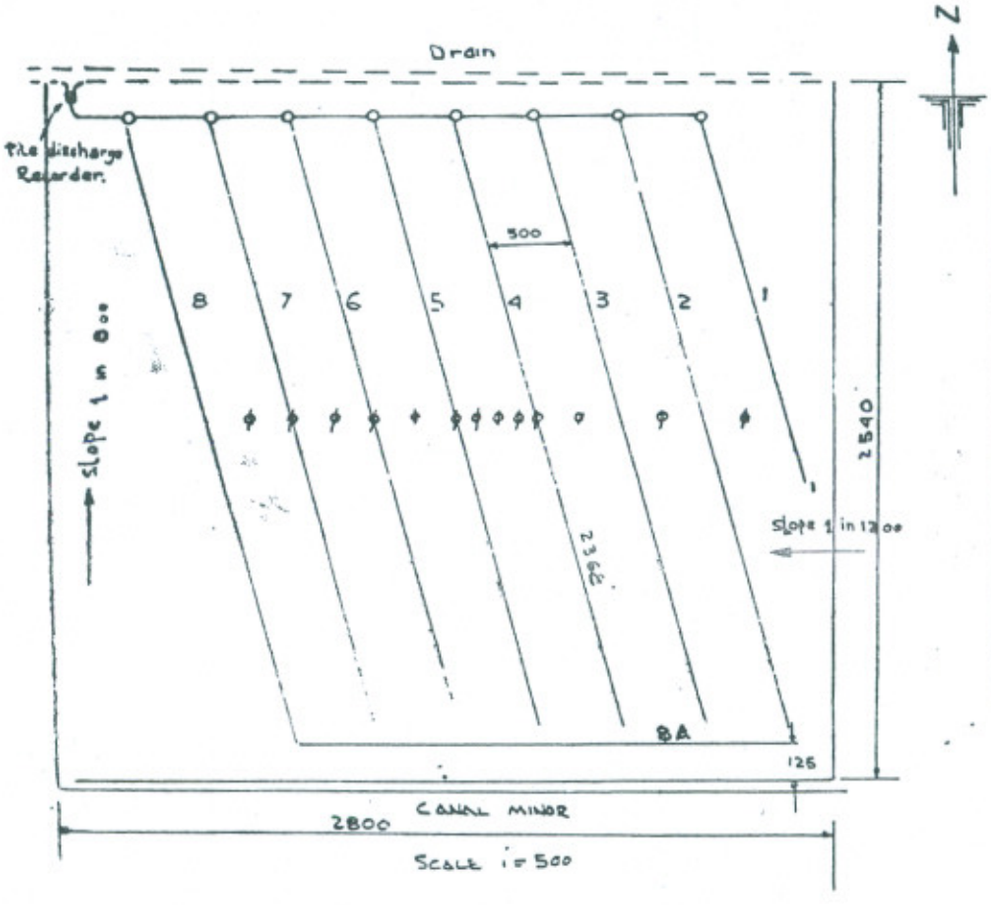


PLATE NO 5

PLATE NO 6


Drain
Tile discharge Recorder
500
8
7
6
5
4
3
2
1
Slope 1 in 800
2540
2362
Slope 1 in 1200
BA
125
CANAL MINOR
2800
Scale 1=500

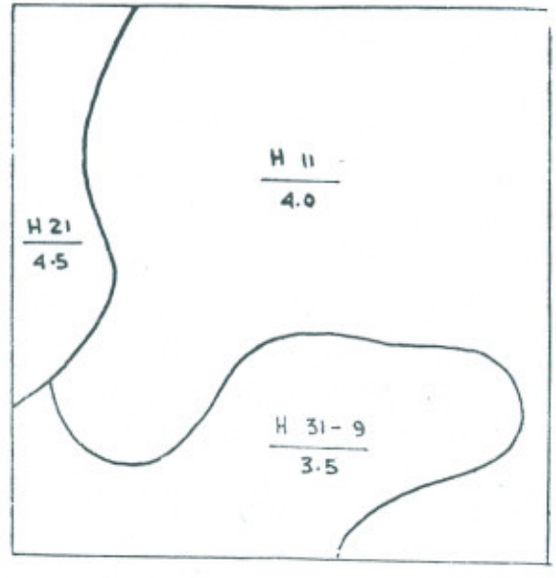
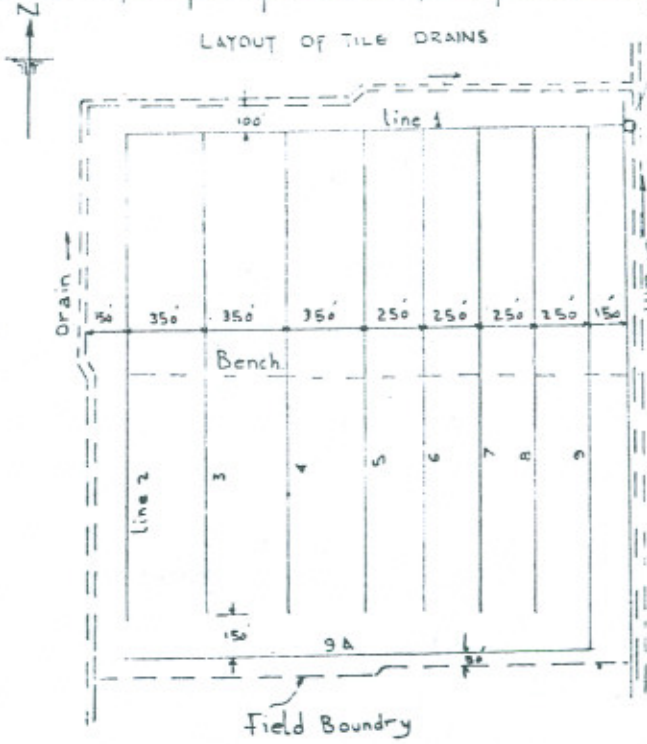

N
H 11
4.0
H 21
4.5
H 31-9
3.5

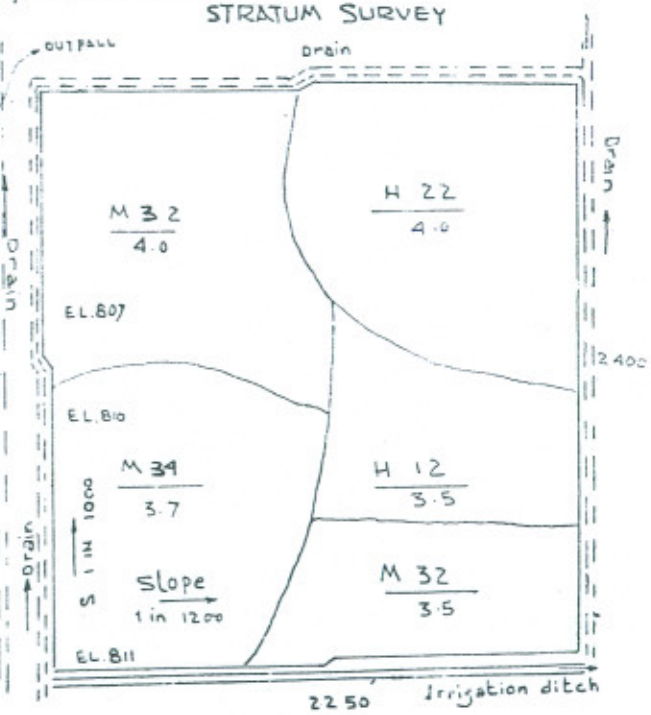
PLATE NO. 7

Line No	8"	6	5"	4"	Slope	station	to stn	Slope	station	to stn
1	950	1250			.001	0-00	22-00			
2 to 4			640	1500	.0022	0-00	15-00	.001	15-00	21-40
5 to 6			940	1200	.0015	0-00	12-00	.001	12-00	21-40
7 to 8			940	1200	.001	0-00	21-40			
9		1290	1000		.001	0-00	22-90			
9A			880	1200	.0019	0-00	20-80			
Total	950	1250	2290	17060						

LAYOUT OF TILE DRAINS

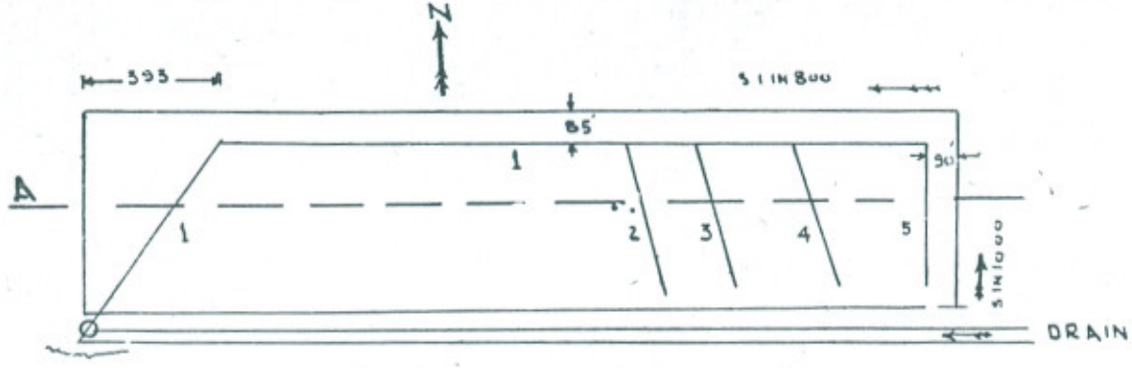


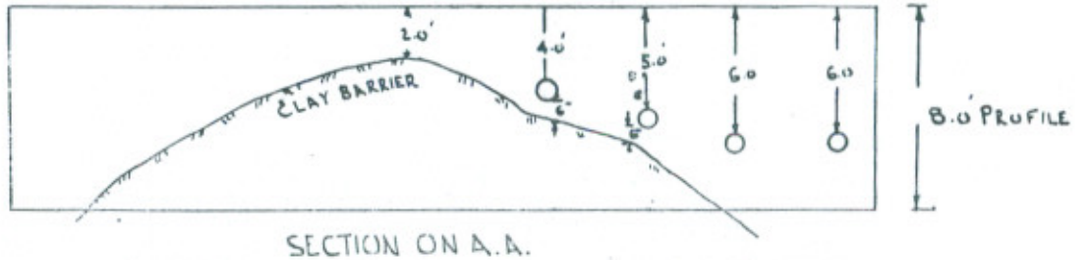
STRATUM SURVEY



SCALE 1=600

PLATE 8



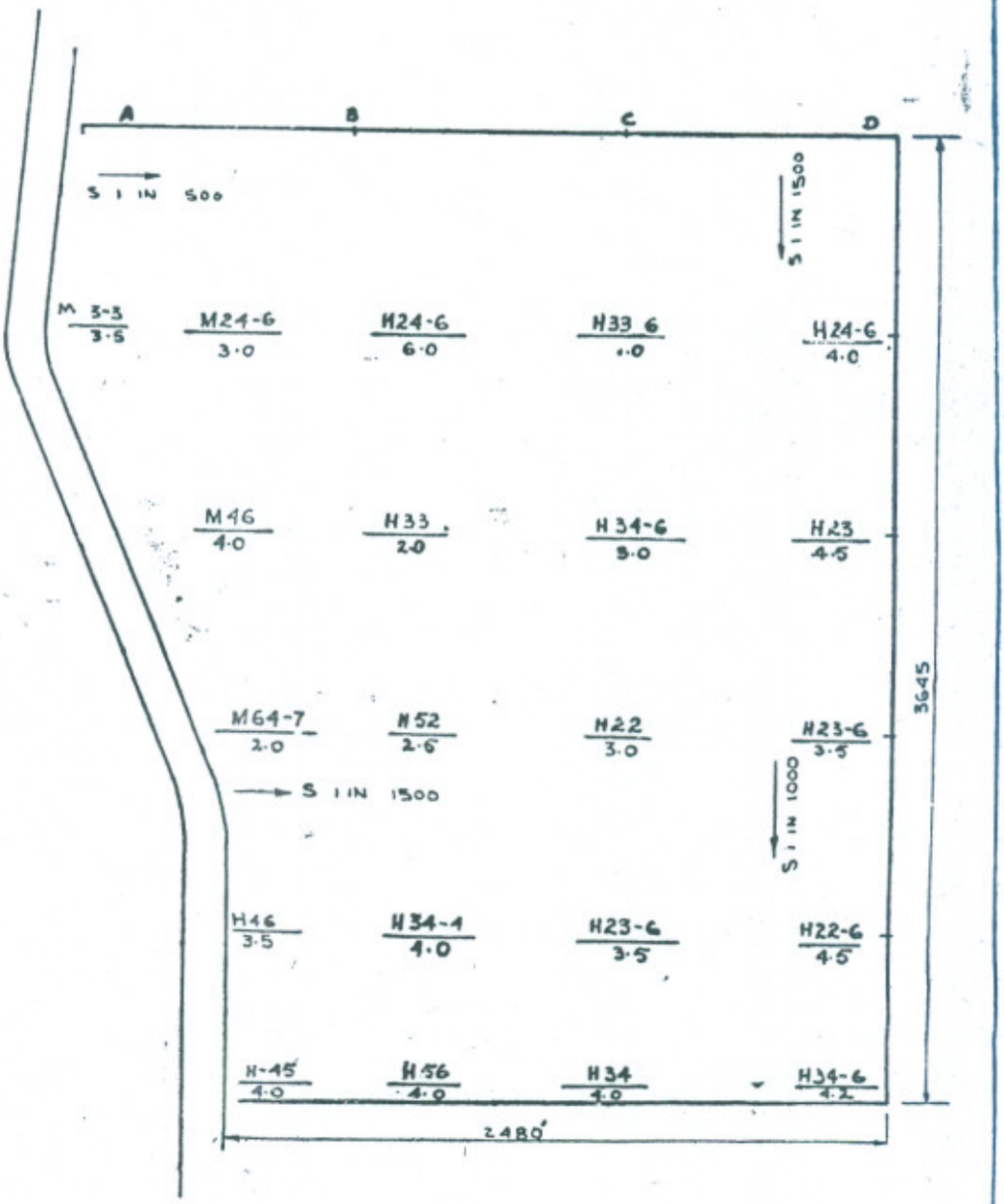


SECTION ON A.A.

SHOWING LOCATION & DEPTH OF TILES ABOVE CLAY BARRIER

LINE	8"	6"	4"	SLOPE	STATION FROM - TO	SLOPE	SECTION FROM TO
1		1573'	1200'	.0015'	0 - 12-00	.001	12.00 - 15-73
2			500'	.001	0 - 500		
3			500'	.001	0 - 500'		
4			500'	.001	0 - 500'		
5			474'	.001	0 - 474		

PLATE NO 9

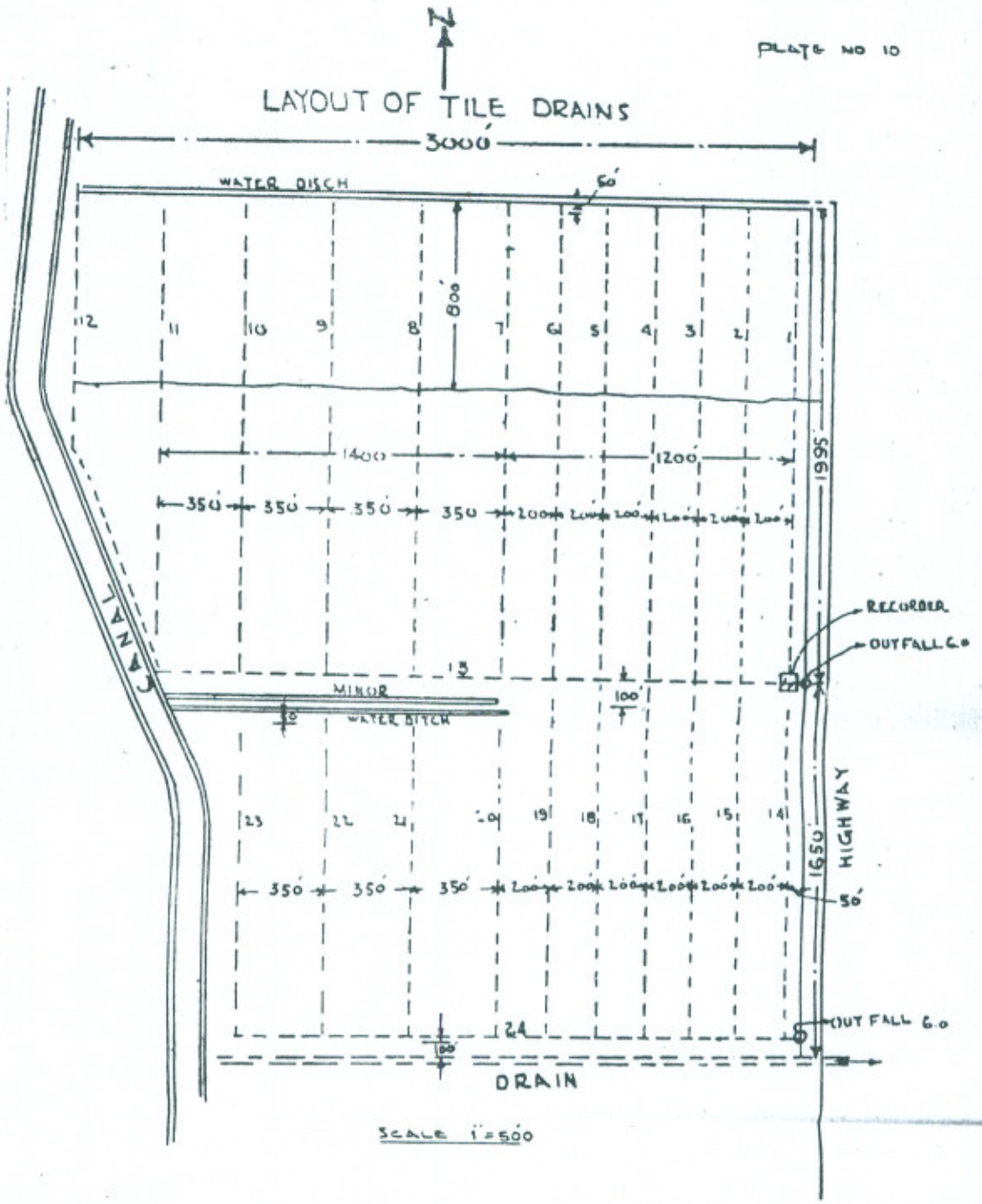


STRATUM SURVEY

SCALE 1" = 500'

PLATE NO 10

LAYOUT OF TILE DRAINS



Scale 1"=500

Line no.	8"	6"	4"	slope	station	to station	slope	station	to station	
1 to 11	-	745	1200	0.0015	0-00	12-00	.001	12-00	19-45	
12	-	820	1200	.0015	0-00	12-00	0.0015	12-00	20-20	
13	1100	1500	-	002	0-00	1500	0.0015	15-00	2600	
14 to 19	-	-	1450	.001	0-00	14-50				
20 to 23	-	-	1360	.001	0-00	13-60				
24	750	1500	-	.0015	0-00	15-00	.001	15-00	2250	