SURFACE AND TRICKLE IRRIGATION SYSTEM DESIGN FOR AN AREA IN EAST AFRICA.

by

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INTRODUCTION

In semi-ared regions of the tropics, water deficiency has forced crop production to be limited to only the rainy seasons. The rainy seasons are usually short, ranging from 3 to 4 months of the rear in which satisfactory plant growth could be maintained. The date of planting is usually determined by the coming of the rains. Therefore, the quality, the quantity and period of growth of crops relies on rainfall. Due to the effects of weather, people who inhabit these regions used to live as nomadic herdsmen, moving from one area to another with their herds in ksearch of pasture.

Irrigation has been practised in some of these arid regions for centuries. Some irrigation systemes are still in operation, and some have long been abandoned because the land, due to accumulation of salts that were either brought by the irrigation water, or those that were released by the parent material of the soil had been rendered unproductive. The soils that remained productive despite the fact that the irrigation waters had a considerable amount of dissolved salts, are the soils that have good natural drainage, through which the salts are leached out.

The soils with no natural drainage, however, could be put into production, even when mildly saline water is used for irrigation, by installing a subsurface drainage system that would carry away from the root zone, the salts that are being leached down with the percolating water.

PROJECT OBJECTIVE

The objectives of this project were;

1. To design a furrow irrigation system for an area of 277 acres located at 10 degrees north latitude in East Africa. The crops to be grown are; Alfalfa, Cotton, and, corn.

2. To desigh a drip/trickle irrigation system for a citrus grove of 30 acres on the same location. The drawings for the surface irrigation system and the trickle irrigation system are given on pages 10b and 21b respectively.

Soil, water, and, crop characteristics.

Soil: Clay loam

pH 8.2 with reasonably good aggregation.

Hydraulic conductivity varies from site to site with values from 0.13 m/day to 3.2 m/day in the upper stratum and from o.14

to 1.7 meters per day in the lower stratum.

The upper stratum lies down to 4 feet depth. The lower stratum goes down to 40 feet depth. The soil has a water intake rate of 1 - 2 gallons/min. per 100 feet of furrow.

Water:

The irrigation water is obtained from a river that flows parallel to northern side of the field to be irrigated.

The river water level varies from 135 feet in the dry season to an elevation of 150 feet during the rainy season. However, the river is assumed to have enough discharge even during the dry season to supply the irrigation water required.

The river water has a suspended sediment content of 100 PPm.

Electrical conductivity of 1740 micromhos/cm a total solids content of 1010 PPm or 1.33 tons per acre - foot.

Cation and anion concentration of the water in milli equivalents per litre:

Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	SO_4^-	Cl^-	NO_3^-
5.2	2.1	7.5	0.1	1.0	1.8	12.0	0.15

BORON 0.8 PPm

Crops:

The field crops that would be grown in the furrow irrigated area are: Corn (Zea mays); Cotton (Gossipium anomalium) and Alfalfa (Medicago sativa).

CROP CHARACTERISTICS

Crop	Salt tolerance in millimohs/cm	Rooth depth in ft	Moisture Use ¢Pd	PH level
Alfalfa	2 - 4	3 - 4	0.3	6.5 - 7.5
Corn	4 - 6	2 - 4	0.3	Up to 6.5
Cotton	6 - 8	6 - 8	0.25	Not affected
	2._4.0		0.3	

D A T A

Total area to be irrigated	=	307 acres
Area to be irrigated with furrows	=	277 acres
Area to be irrigated with the trickle system	=	30 acres

YEAR	RAINFALL In Inches			EVAPOTRANSPIRATION		
	AVERAGE	10 Yr Wet	10 Yr Dry	AVG.	10 Yr Wet	10 Yr Dry
JAN.	2.0	4.0	1.5	5.8	5.6	5.9
FEB.	1.7	2.9	1.1	5.9	5.7	6.0
MARCH	1.1	1.4	0.6	6.0	5.9	6.1
APRIL	0.7	1.1	0.2	6.2	6.2	6.3
MAY	1.6	2.9	0.8	6.4	6.4	6.5
JUNE	2.5	3.3	1.3	6.2	6.2	6.3
JULY	3.6	5.6	2.9	5.9	5.7	6.1
AUG.	10.8	11.6	7.2	5.4	5.2	5.8
SEPT.	9.3	10.2	6.8	5.4	5.2	5.6
OCT.	12.6	14.1	10.2	5.5	5.2	5.6
NOV.	4.5	5.0	3.7	5.7	5.4	5.8
DEC.	2.6	3.4	1.9	5.8	5.6	5.9
TOTAL:	53.0	65.5	38.2	70.2	68.3	71.9

MAXIMUM Irrigation Water Needed = 33.6 inches

SURPLUS Water = 16.4 inches

FURROW IRRIGATION

Area to be irrigated: 27 acres

Crops to be grown: CORN
COTTON
ALFALFA

Crop Characteristics:

CROP	Salt Tolerance EC x 1000	Root Depth Avg.	Moisture Use, ipd
ALFALFA	2 - 4	3 - 4	0.3
CORN	4 - 6	2 - 4	0.3
COTTON	6 - 8	6 - 8'	0.25

SOIL: Clay Loam

Intake Rate: 1 - 2 gal /min per 100' of furrow

PH = 8.2

Water holding capacity = 2" - 2.5" per foot

Irrigation Water Characteristics:

RIVER Water:

EC = 1740 micromhos/cm

Total solid content = 1010 ppm or 1.33 tons/acre-foot

Cation and Anion Concentrations in Milli equivalent per Litre:

	Ca	M_g	Na	K	Hco_3	So4	cl	No_3	Boron PPM
mg/lit.	5.2	2.1	7.5	0.1	1.0	1.8	12.0	0.15	0.8

Suspended Sediment Content is 100 PPM.

CALCULATIONS:

From the previous Table:

Annual irrigation water needed = 33.6 inches

Avg. Annual evapotranspiration = 70.2 inches

= 0.1923 in./day

10 year dry evapotranspiration = 71.9

= 0.1970 in./day

USE ET. = 0.20 in./day for the design

Taking the water holding capacity of the soil at 2 in./ft and an average root zone of 4 feet:

Total available water = $4' \times \frac{2''}{ft}$ = 8 inches

IF IRRIGATION Water is applied at 50% water deficiency:

Irr. application = 0.5 x 8 = 4"

– at irrigation efficiency of 70%

The IRRIGATION APPLICATION = 0.4/0.70

= 5.71 inches

WITH A ET. = 0.20

Application Interval = 4/0.2

= 20 days

Applying 0.3 in./hr 16 hours per day, with total application of 4.8 inches, a nice, steady percolation rate could be achieved.

FURROW:

The general land grade is 0.4%

The maximum non-erosive flow for this grade =

$Q = a/5$ (from FAO/UNESCO source book. see references)

$a = 10$ in the British Unit

$Q = 10/0.4 = \underline{25}$ gpm

Since furrows are usually dug by normal tillage equipment, and for convenience of sowing and harvesting machinery, the furrows are spaced 40 inches apart.

At an application depth of 0.3 in./hr, the furrows are required to carry:

$$GPM = \frac{S_f \times L_f \times 0.3 \text{ in./hr}}{96.3}$$

S_f = furrow spacing

L_f = allowable furrow length

96.3= conversion factor

At a maximum non-errosive rate of flow of 25 GPM, the maximum allowable length of the furrow is:

$$L_f = \frac{25 \text{ gpm} \times 96.3}{S_f \times 0.31 \text{ in./hr}} = \frac{25 \times 96.3}{3.4 \text{ in} \times 0.31 \text{ in./hr}}$$

$$= \underline{2284.16} \text{ ft}$$

USING THE SECOND PLAN

PAGE 10b

18.51 acres are irrigated each day.

FURROW length = 850 ft

\# of furrows = 950/3.4

= 279

$$Q \text{ furrow} = \frac{0.3 \text{in./hr} \times 3.4' \times 850 \text{ ft}}{96.3}$$

= 9.00 GPM gives a slow and constant percolation rate.

Dimensions of triangular furrows:

Roughness coefficient n = 0.04

In clay soils a slope of 1:1 is satisfactory.

Area $A = Zd^2$ $Z = 1$ in this case

Wetted Perimeter $P = 2d \quad Z^2 + 1 = 1.41d$

Hydraulic Radius $R = Zd/2 \quad Z^2 + 1 = d/2.82$

Top Width $t = 2dZ = 2d$

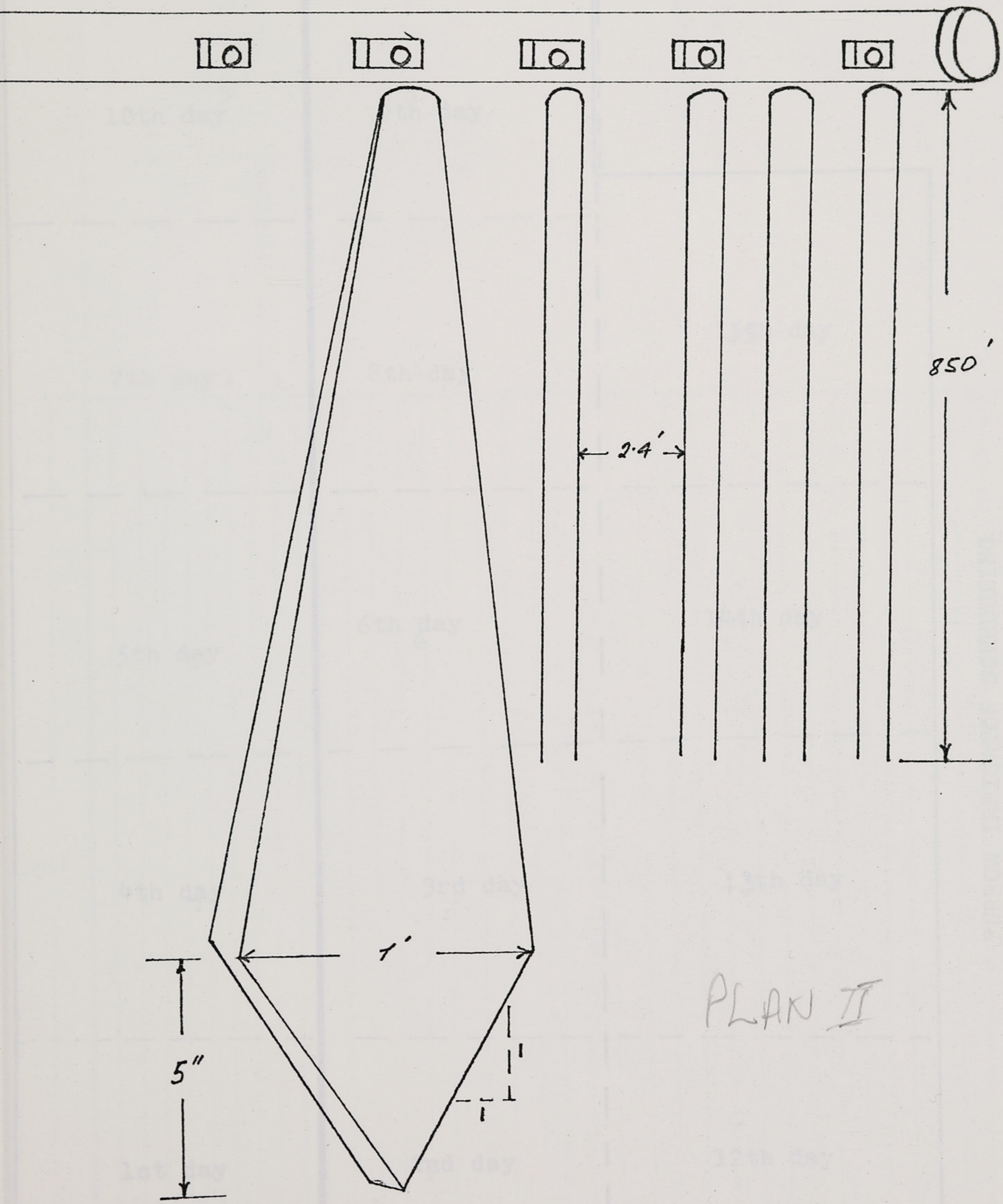
d in ft	A ft^2	P ft	R ft	t ft	V $\frac{ft}{sec}$	Q = VA
0.4	0.16	1.13	0.14	0.8	0.71	0.11 cfs
0.45	0.20	1.27	0.16	0.90	0.78	0.16
0.50	0.25	1.41	0.18	1.0	0.84	0.21
0.55	0.30	1.55	0.20	1.10	0.9	0.27

Since the design discharge is much less than the capacity of the smallest furrows, use:

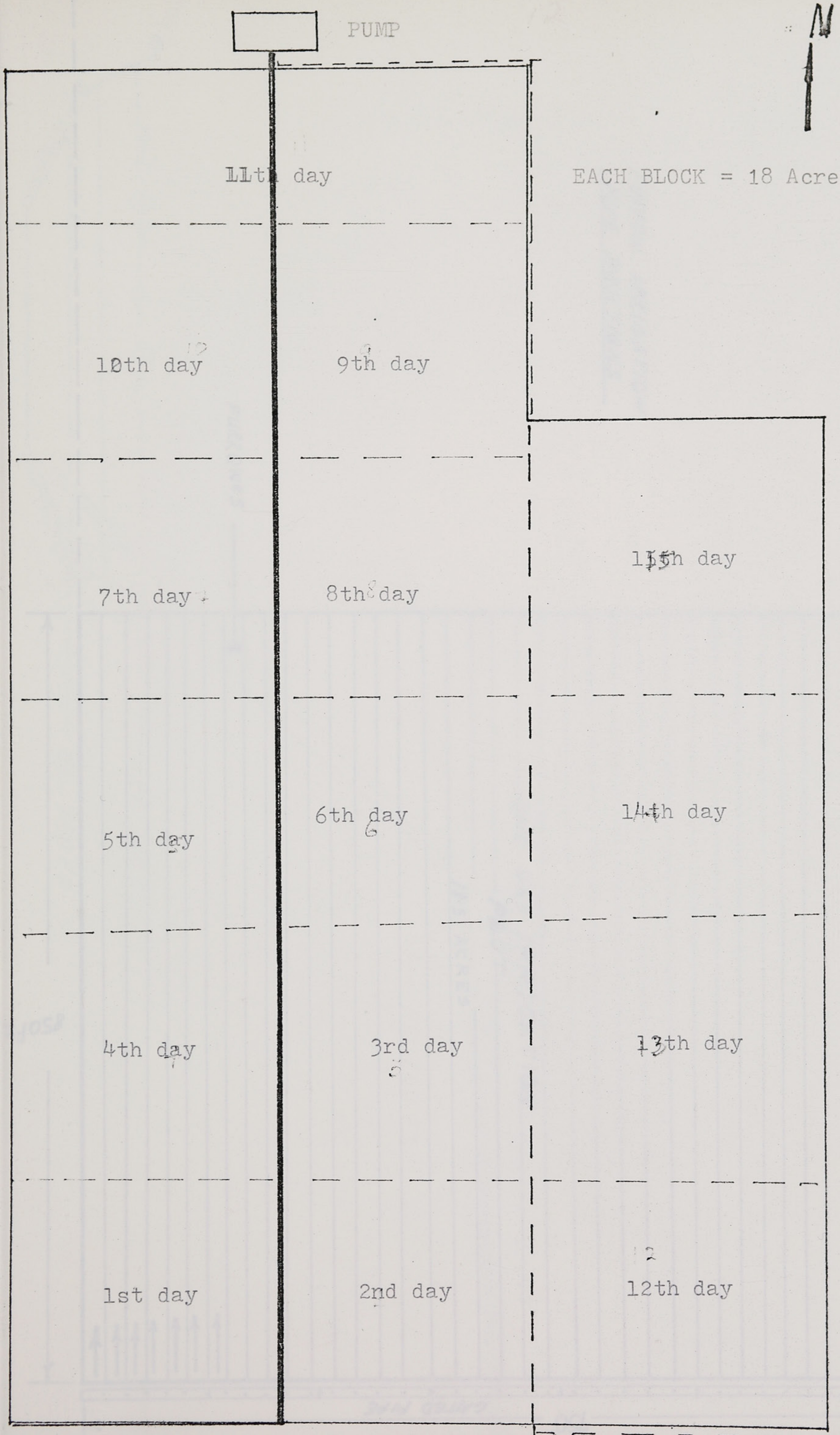
d = 0.4, . FT. 1.1 triangular furrow

t = 0.8 FT

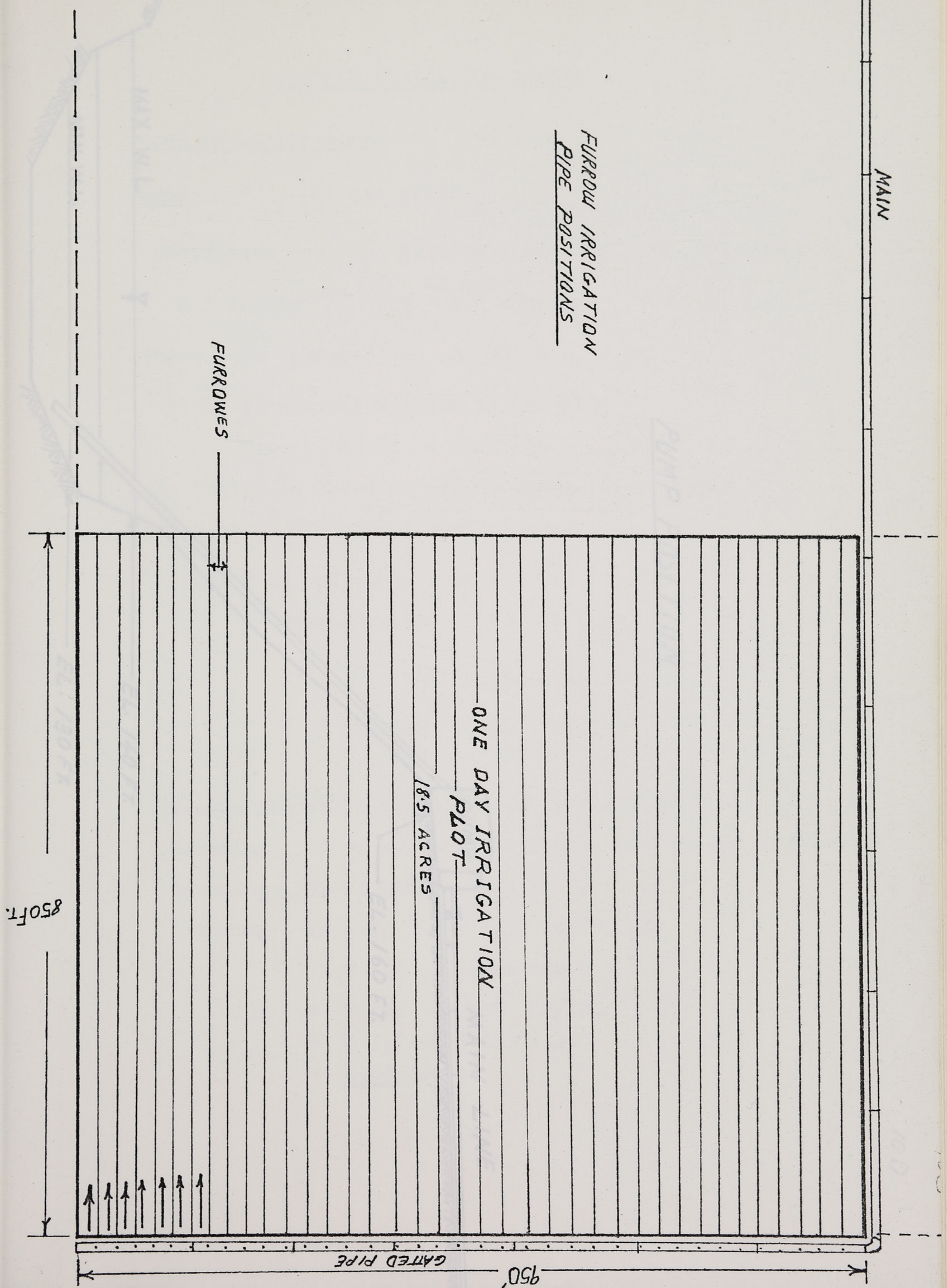
FURROW SPACINGS AND DIMENSIONS



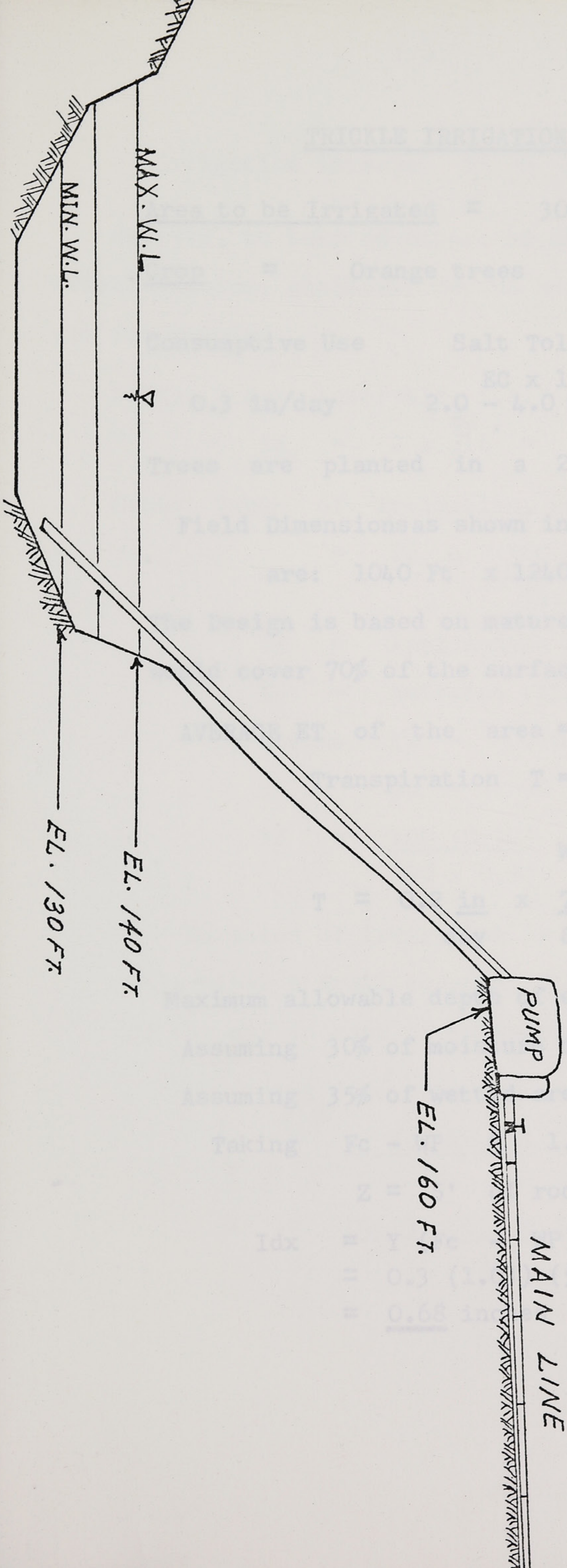
PLAN II



FURROW IRRIGATION SCHEDULING


FURROW IRRIGATION
PIPE POSITIONS
MAIN
FURROWES
ONE DAY IRRIGATION
PLOT
18.5 ACRES
850FT.
GATED PIPE
950'

PUMP POSITION



10D

TRICKLE IRRIGATION DESIGN

Area to be Irrigated = 30 acres

Crop = Orange trees

Consumptive Use	Salt Tolerance	PH Tolerance
	EC x 103	
0.3 in/day	2.0 - 4.0 mmhos/cm	

Trees are planted in a 20' x 20' GRID

Field Dimensions as shown in the Plan

are: 1040 Ft x 1240 Ft

The Design is based on mature orange trees that would cover 70% of the surface area

AVERAGE ET of the area = 0.2 i /day

$$\text{Transpiration } T = ET \left(\frac{Ps}{85}\right)$$

Where Ps = 70

$$T = 0.2 \frac{in}{day} \times \frac{70}{85} = 0.16 \text{ in/day}$$

Maximum allowable depth of each irrigation:

Assuming 30% of moisture depletion between irrigation:

Assuming 35% of wetted area

Taking Fc - WP = 1.30 in/ft

Z = 5' of root depth

$$Idx = Y\,(Fc - WP)\; ZP/100$$
$$= 0.3\,(1.03)\,(5)\,(.35)$$
$$= \underline{0.68} \text{ inches}$$

Irrigation Interval $Ii = \frac{Idx}{T} = \frac{0.68}{0.16} = 4.25$ days

However, to take advantage of the efficiency of the trickle system, shallower depths and frequent intervals are recommended.

Using 2 day intervals i.e. - $Ii = 2$ days

$$Id_x = 2 \times .16 = 0.32 \text{ inches}$$

Gross depth of irrigation, therefore

$$= Id = \frac{100\ Id_x}{TR.\ EU}$$

TR = Application efficiency

EU = Emission efficiency in %

Assume TR = 0.90

EU = 90

$$Id = \frac{100\ (0.32)}{90 \times 0.90} = 0.4 \text{ in.}$$

Duration of irrigation is taken as 20 hours a day. This gives a small constant flow and leaves some hours of the day in case of malfunction and repair.

The discharge required per tree:

$$q_a = \frac{K\ Id\ Se\ Si}{It}, \quad K = 0.623$$

$$= \frac{0.623 \times 0.4 \times 20' \times 20'}{20} = 4.98 \text{ gal/hr}$$

Emitter = 1 multi-EXIT Emitter with 4 outlets, is chosen which gives 5/4 = 1.25 gal/hr per emission point.

Calculating $P = \frac{100 \quad n \quad Sep \quad Sw}{St \; Sr}$

N = Number of emission points

SEP = Spacing between emission points

SW = Width of the wetted strip

St = Spacing between trees

Sr = Spacing between rows

Sr = St = 20

n = 4

FROM FIG. 3.3 KARMELI

Se = Sep = 4.66

Sl = Sw = 4.9

$P = \frac{100 \times 4 \times 4.66 \times 4.9}{20 \times 20} = 22.83\%$ (too small)

TRY n = 6

$P = \frac{100 \times 6 \times 4.66 \times 4.9}{20 \times 20} = 34.25 \quad 35\%$ (Good)

A Six EXIT Emitter which has a discharge of 0.833gal/hr is used.

SYSTEM LAYOUT:

Number of Operational Units

$N \leq \frac{Ii \quad 24}{It} = \frac{2 \times 24}{20} = 2.4$ days

USE $N = 2$

Number of Sub Units is 8

AREA OF EACH Sub Unit $= \frac{30}{8} = \underline{3.75}$ acres

$$A_s = 163350 \text{ ft}^2$$

Optimum Lateral length $= K\, A_s^{0.45}$

Optimum Manifold length $= K\, A_s^{0.55}$

$K_l = 0.771$

$K_m = 0.648$

$$L \text{ length} = 0.771\,(163350)^{0.45} = 170.985 \text{ ft}$$

$$L_m = 0.648\,(163350)^{0.53} = 477.29 \text{ ft}$$

IF Number of Sub Units $= 4$

Area of each Sub Unit $= \frac{30}{4} = 7.5$ acres

$$= \underline{326700.00} \text{ ft}^2$$

The layout for both systems is attached

In the second case:

$$L_l = 0.771\,(326700)^{0.45} = \underline{234} \text{ ft}$$

$$L_m = 0.648\,(326700)^{0.55} = \underline{698.81} \text{ ft}$$

Since these values come closer to the layout length, the second plan is more economical.

Lateral and Manifold Design

The length of the laterals L_l = 260 ft

L_m = 620 ft

Number of emitters per lateral $= \frac{260}{20} = 13$

$N_e = 13$

Q_a = The average lateral flow rate

$= K\, n_e\, q_a$

$K = 1/60$ for English Units

q_a = 5 gallons/hour

$$Q_a = \frac{1}{60}(13)(5 \text{ gal/hr}) = 1.08 \text{ gpm}$$

The average Manifold flow

$Q_m = N_L \cdot 2 \cdot Q_a$

N_L = No. of laterals per manifold

$Q_m = 31 \times 2 \times 1.08$ gpm

$= 66.96 \simeq 67$ gpm

Lateral Head Loss

$$\Delta H_L = \frac{J\, n_e\, (L + L_f)\, F}{100}$$

for $N_e = 13$. $F = 0.391$

L = Length of lateral between emitters

L_f = 3.3 to 10 ft for in line with barbed (or bayonet) connection.

Size Selection of the lateral fusing and ΔH values

Q = 1.08 gpm Assume L_f = (3.3 + 10)/2 = 6.65 ft

ID d in inches	J Ft/100 ft	$\Delta H_L = J^{ne}$ L + L_f)F/100 = J(1.3546)
PVC	0.50	3	4.06
POLY	0.580	1.5	2.03
PVC	0.625	1.25	1.69
PVC	0.75	0.5	0.677

Manifold Size and Friction Loss

Qm = 67 gpm

ΔHm = $\frac{JLmF}{100}$ F for 31 outlets = 0.368

Lm = 620 ft

ΔHm = 2.2816 (J)

	d	J	H_m = 2.2816 (J)
IPS Class 88 100	2.0	4.7	10.72
IPS Class 100	2.5	1.9	4.34
"	3.0	0.7	1.60
PIP Class 100	4	0.32	

PIPES Selected:

Lateral = 0.50 in. PVC H_l = 4.06 ft

Manifold = 2.5" IPS Class 100 PSI H_m = 4.34 ft

Total ΔH in the Sub Unit # 4

$$\Delta H = H_L + \Delta Hm + \Delta El$$

The largest ΔEL occurs at Sub Unit # 4

$$\Delta EL = \frac{\% \text{ Slope } (Lm)}{100} = \frac{0.32\ (620)}{100}$$

$$= 2 \text{ ft}$$

$$\Delta H = 4.1 + 4.34 + 2$$

$$= 10.44 \text{ ft}$$

- EMISSION UNIFORMITY CALCULATION

- Minimum discharge ratio for Sub Unit # 4

$$\left(\frac{q_n}{q_a}\right)_s = 1.00 - Rfn' \cdot X \cdot \frac{\Delta H_L + \Delta Hm + \Delta EL}{Ha}$$

$x = 0.64$

Rfn = 0.22 for non-tapered pipes

Ha that would give the desired

Qa of 5 gph = 18 ft

$$\left(\frac{q_n}{q_a}\right)_s = 1.00 - 0.22\ (.64)\ \frac{10.44}{18}$$

$$= 0.92$$

- $$EUs = 100\left(1.0 - \frac{1.27}{\sqrt{e}}\, v\right)\left(\frac{q_n}{q_a}\right)_s$$

$v = 0.033$ & $e = 1$

$$EUs = 100\ (1.0 - 1.27\ (0.033)\ (0.92)$$

$= 88.14$ Close to the assumed value at 2% variation

INLET pressure to lateral = Average Manifold Pressure

$$H_l = H_A$$

$$H_A = H_a + 0.77\,\Delta H_l + \frac{EL}{2}$$

$$H_A = 18\text{ ft} + 0.77\,(4.1) + \frac{00}{2}$$ laterals are on the contour

$$= \underline{\underline{21.16}}\text{ ft}$$

$$H_d = H_a - (0.23\,\Delta H_l \pm \Delta EL/2)$$

Hd = The lateral downstream pressure

$$H_d = 18 - (0.23\,(4.1)$$

$$= \underline{\underline{17.054}}\text{ ft}$$

$$H_l - H_d = 4\text{ ft}$$

= 19.42% variation allowable

The inlet pressure head to the manifold:

$$H_m = H_A + R_h\,\Delta H_m \pm \Delta EL/2$$

Rh = 0.77 for non-tapered manifolds

$$H_m = 21.16 + 0.77\,(3) + \frac{2}{2}\text{ ft}$$

$$= \underline{\underline{24.47}}\text{ ft} + 5\text{ ft}$$ for head created by "T"s and "ELBOWS"

$$H_m = \underline{\underline{29.47}}\text{ ft}$$

AVERAGE ΔHm = 3 ft

Hm of the four Sub Units

Sub Unit # 1 $\Delta EL = - \frac{.77}{100} \times 620 = -4.77$

Required $Hm^1 = 21.16 + 0.77\,(3) - \frac{4.77}{2} = \underline{21.1}$ ft

$Hn^2 = 21.16 + 0.77\,(3) + \frac{1.22}{2} = \underline{24.58}$ ft

$Hn^3 = 21.16 + 0.77\,(3) - \frac{6.01}{2} = \underline{20.47}$ ft

The Sub Unit flow rate and pressure head requirement:

Qs = Qn = $\underline{67}$ gpm

Hs = Hm = $\underline{29.5}$ ft

The maximum discharge ratio for the Sub Unit:

$$\text{is } \left(\frac{qx}{qa}\right)_s = 1.00 + Rf' \cdot x \cdot \frac{\Delta H_2 + \Delta H_m + \Delta EL}{H_A}$$

$$= 1.00 + 0.58 \cdot .64 \times \frac{10.44}{18}$$

$$= \underline{1.215}$$

(1.25 x 100)/91.02 = $\underline{\underline{1.37}}$

i.e: The wettest area will receive 1.37 times more than the required depth of application.

MAIN LINE SELECTION

1. System capacity $Q = 24\ Q_n$

$= 24\ (67)$

$=$ 134 gpm/Operational Unit

Or $Q = K \frac{A}{N} \frac{qa}{Se\ Se} = \frac{726 \times 30 \times 5}{2 \times 20 \times 20}$

$=$ 136.13 gpm/ Operational Unit

Mainline discharge	Q_{main}	=	136.13 gpm
Submain "	Q_{sub}	=	136.13 gpm
Manifold "	Q_m	=	136.13/2 = 68.1 gpm

Mainline Pipe at Q = 136.13 gpm

	Dia.	J	$\Delta H = JL/100$
IPS Class 100	5"	0.25	2.20
"	4"	0.65	5.72

USE 4" Pipe

$\Delta H = 5.72$ ft

TOTAL DYNAMIC HEAD OF PUMP

Hs = 29.5ft
Friction loss in Main=5.72ft
Elevetion to Sub Unit #4=32ft
Assumed Friction Loss in Control Heead=25ft

TOTAL HEAD ≑ 92 ft

Q total = 134 gpm

$$Bhp = \frac{QHt}{K.efficiency}$$

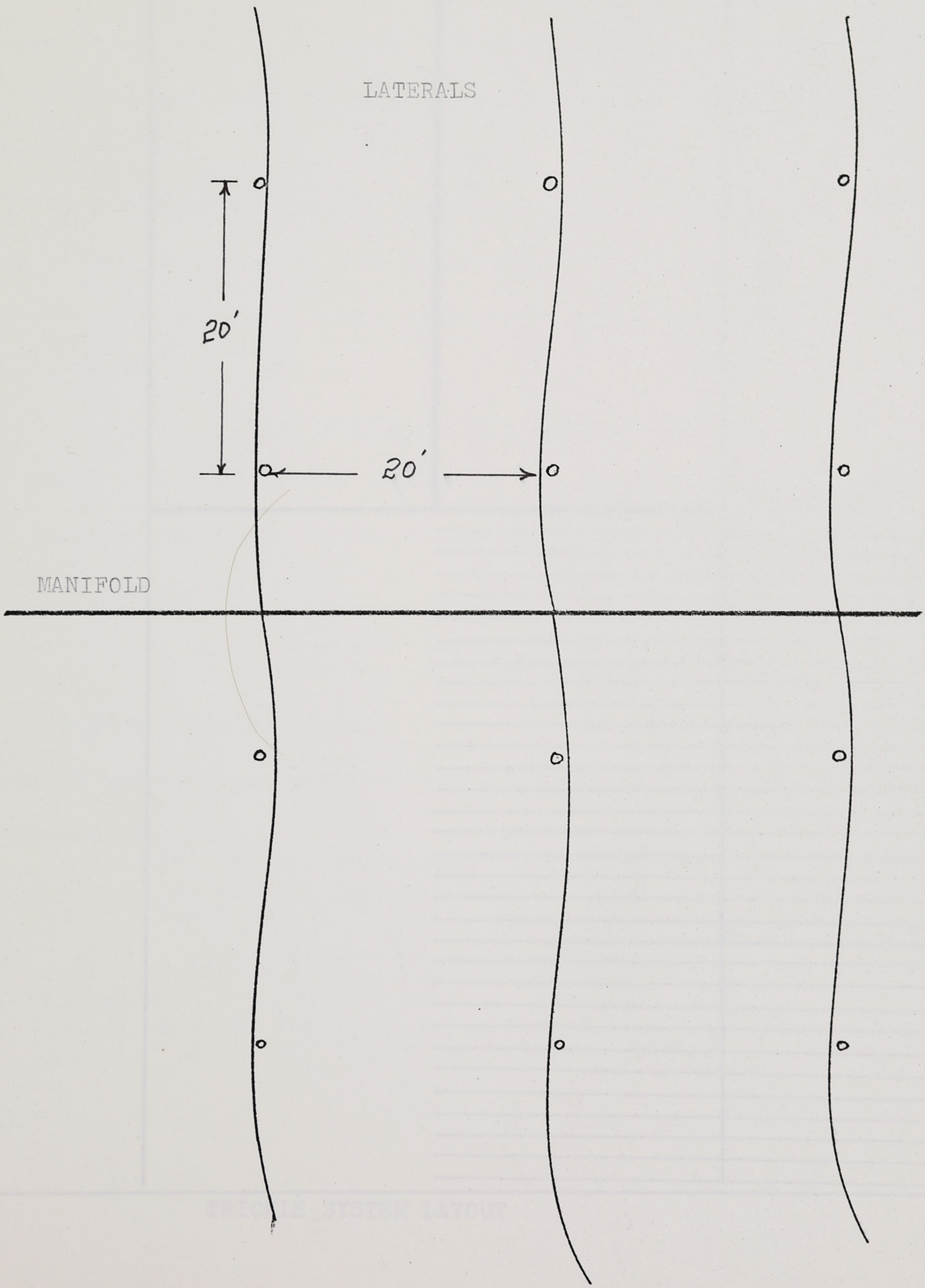
K = 39.6

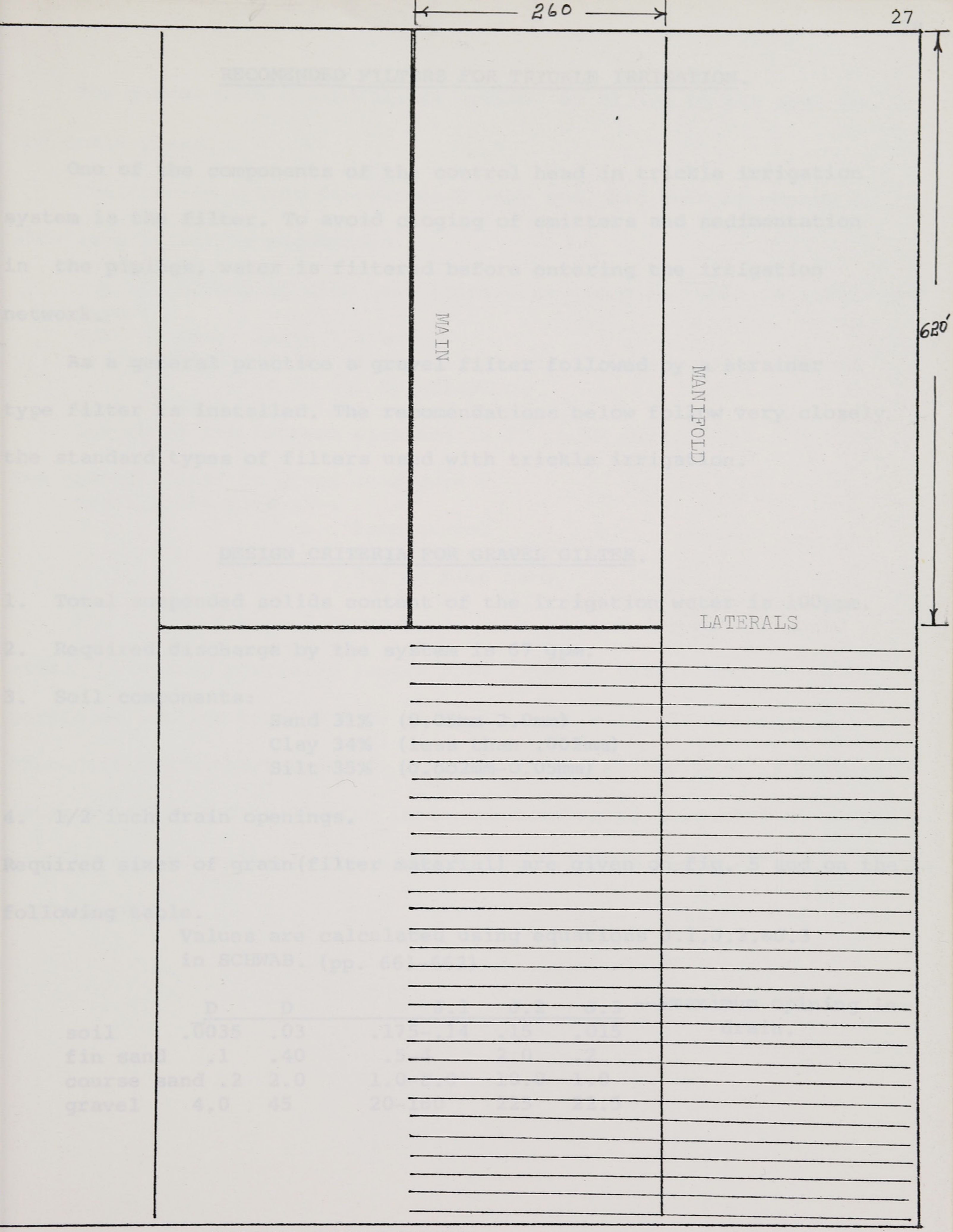
@ an effecincy of 80%

$$Bhp = \frac{134gpm \times 92\ ft}{39.6 \times .80} = 3.89\ Hp$$

Reqired Bhp = 4Hp

TREES AND LATERALS ORIENTATION





TRICKLE SYSTEM LAYOUT

RECOMENDED FILTERS FOR TRICKLE IRRIGATION.

One of the components of the control head in trickle irrigation system is the filter. To avoid cloging of emitters and sedimentation in the pipings, water is filtered before entering the irrigation network.

As a general practice a gravel filter followed by a strainer type filter is installed. The recomendations below follow very closely the standard types of filters used with trickle irrigation.

DESIGN CRITERIA FOR GRAVEL GILTER.

1. Total suspended solids content of the irrigation water is 100ppm.
2. Required discharge by the system is 67 gpm.
3. Soil components:

   Sand 31% (0.05mm-2.0mm)
   Clay 34% (less than .002mm)
   Silt 35% (0.oo2mm-0.05mm)

4. 1/2 inch drain openings.

Required sizes of grain (filter material) are given on fig. 5 and on the following table.

Values are calculated using equations J.1, J.2, &J.3 in SCHWAB. (pp. 661-662)

	D	D	J.1	J.2	J.3 ---maximum opining in drain.
soil	.0035	.03	.175-.14	.15	.015
fin sand	.1	.40	.5-4	2.0	.2
course sand	.2	2.0	1.0-8.0	10.0	1.0
gravel	4.0	45	20-160	225	22.5

The gravel with a permissible opening of 22.5mm is put next to the drain pipes.

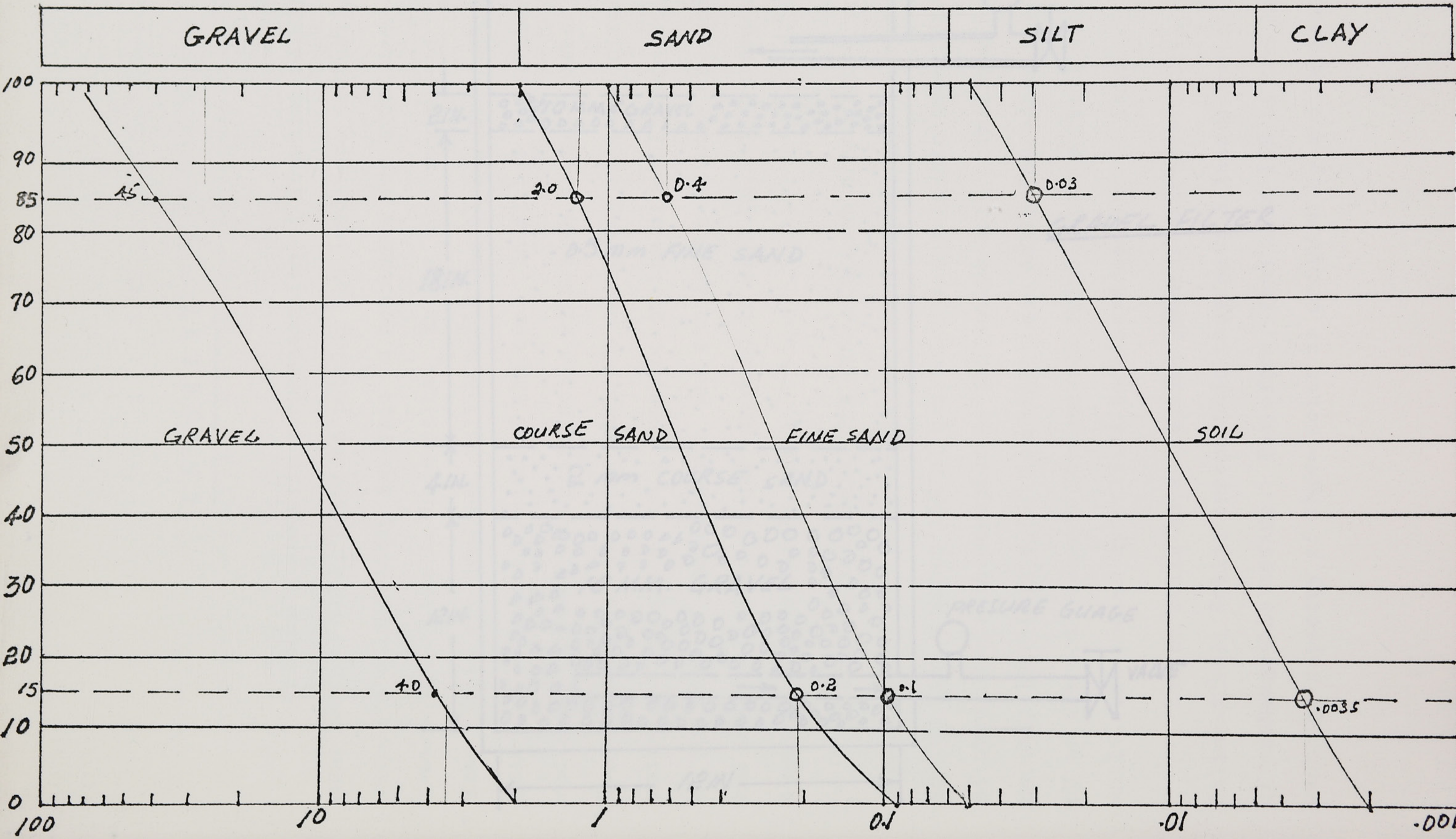
The trickle system discharges 80,400 gpd. For this discharge a slow sand filter is recomended.

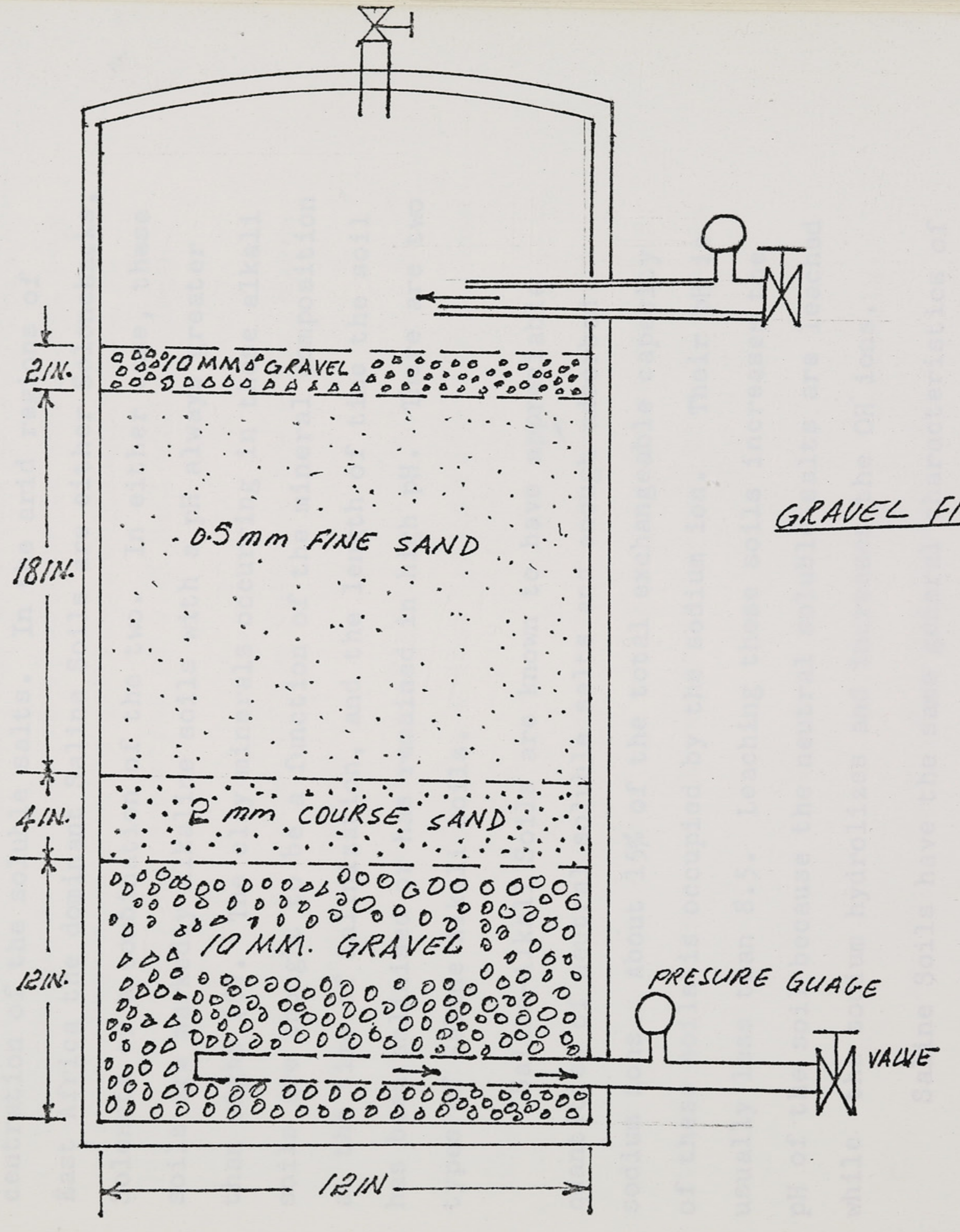
Specifications of slow sand filters as given in table 24.1(Fair and Geyer)
Size of bed: Large,1/2 acre
Depth of bed: 12 in. of gravel, 42 in. of sand usually reduced to 24 in. by scraping.
Size of sand: Effective size 0.25 to 0.3
Length of run between cleaning is 20 to 30 days.

The gravel filter is given in figure 6.
Grain sizes used are:
lomm gravel
2 mm course sand
0.5 mm fine sand

The 0.5 mm fin sand corresponds to a 40-mesh screen and could effectively stop particles larger than 0.5mm in size. However particles smaller kthan 0.5 mm could pall and clog the emitters. Therefore the author recomends a screen type strainer with an 80-mesh outer cylinder and a 120-mesh inner cylinder to be installed in series w with the gravel filter. The screens stop 0.172 mm and 0.127 mm particles respectively.

FILTER DISTRIBUTION CURVES





GRAVEL FILTER

LEACHING

To make a specific recommendation of leaching requirement for the soil, prior to putting the land into production, requires a laboratory analysis to determine the exact concentration of the soluble salts. In the arid regions of East Africa the dominant Saline Soils are either Solonchacks, Solonets or a combination of the two. In either case, these soils are markedly alkaline soils with a pH always greater than eight (8). The clay minerals occurring in these alkali soils are thought to be a function of the mineral composition at the time of Salinization, and the length of time the soil has been salinised or has remained in high pH. There are two types of Saline Alkali soils.

Saline-Alkali Soils are known to have appreciable quantities of neutral soluble salts and enough adsorbed sodium ions. About 15% of the total exchangeable capacity of these soils is occupied by the sodium ion. Their pH is usually less than 8.5. Leaching these soils increases the pH of the soil because the neutral soluble salts are leached while the sodium hydrolizes and increases the OH^- ions.

Saline Soils have the same general characteristics of Saline-Alkali Soils, except that they have a lesser amount of exchangeable sodium. Therefore, less than 15% of the cation exchange capacity of these soils is occupied by sodium ions.

With a pH of 8.2 our soil falls in this category. Besides sodium, the dominant exchangeable ions of Solonchaks soils are calcium and magnesium. However, as previously mentioned, the leaching of these soils depletes the amount of the calcium and magnesium ions. These elements exist in the soil as Carbonates, Sulphates, Chlorides, Nitrates and Borates. While the nitric acid salts, are very important as plant nutrients, a concentration of 0.07 to 1% of nitrate is considered very harmful. Many saline soils are known to contain 2 to 5% Sodium Chloride, but a content of 0.1% NaCl would depress yield considerably.

This complex nature of the salts in the soils, makes proper management difficult.

The widely used method of getting the Sodium out of the root zone, is to get the sodium carbonate or bicarbonate into a more leachable form.

Gypsum and Hydrogen Sulphate are the two compounds added to the soil. After the reaction, the sodium attaches itself with sulfate ion, in which it becomes more leachable.

The reaction:

$$Na_2\ Co_3 + Ca\ So_4 \rightleftharpoons Ca\ Co_3 + Na_2\ So_4$$

or Leachable

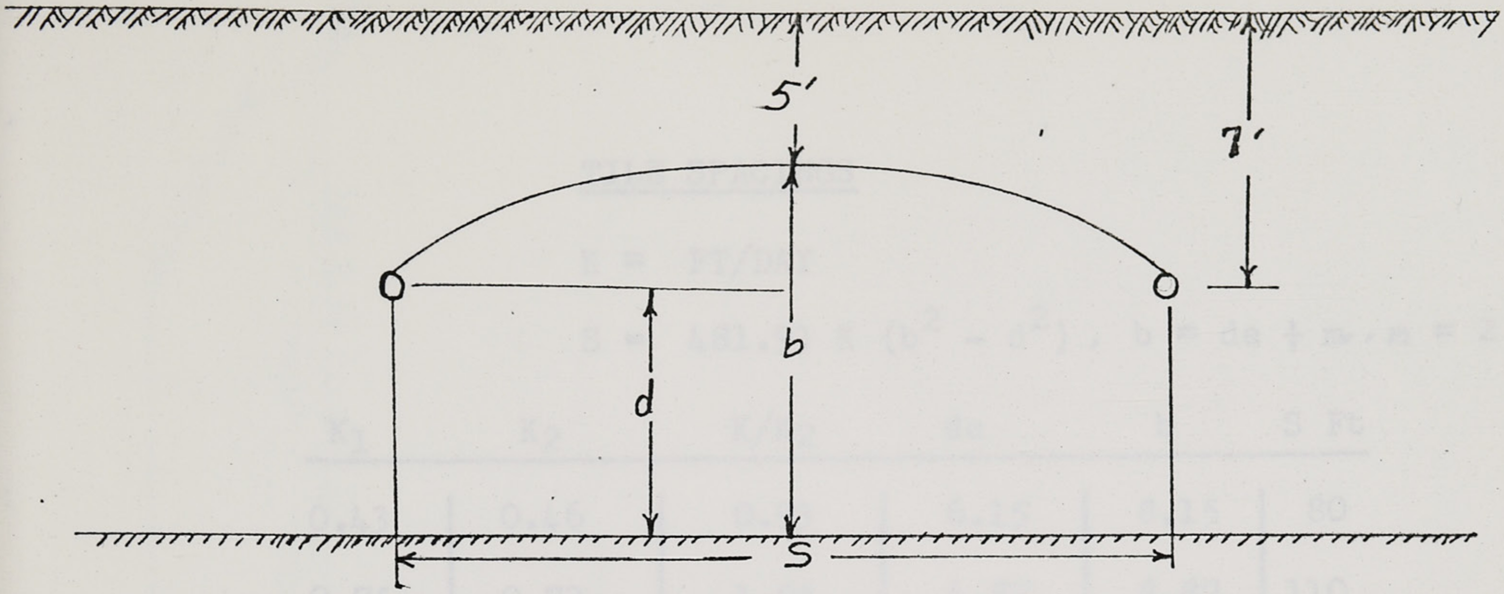
$$Na_2\ Co_3 + H_2\ So_4 \rightleftharpoons Co_2 + H_2\ O + Na_2\ So_4$$

The gypsum is cultivated into the soil and leaching water is applied thereafter. Given the salt concentration of the irrigation water as 1740 Micromhos/cm.

Leaching Requirements:

CROP	SALT TOLERANCE In Mmhos/cm	LEACHING REQUIREMENTS %	In/Ft
Orange	2 - 4	44	5.5
Corn	5 - 8	29	4.9
Cotton	4 - 6	22	3.3
Alfalfa	5 - 8	22	3.3

Leaching could be done intermittently with the irrigation water or once or twice a year, a complete leaching could be done. The intermittent method is well suited for sandy soils with a high percolation rate, but for a soil as heavy as a clay loam, the extra water in the root zone might cause aeration problems. The one or two times program could be carried out between crops or during a fallow period without interfering with the production of crops.



Tile Spacings

Calculated Using Eq. 17.5 and FIG. 17.5 in SCHWAB

Eq. 17.5 $S = \frac{4k\,(b^2 - d^2)}{Q}$

$Q = Si$, i = excess irrigation water applied @ irrigation application rate of 4.8 inches per day and an intake rate of one gpm per 100 ft. of furrow the extra water percaulating in to the soil is appro-imately 0.1 inches per day.

Therefore i = 0.0083 ft./day

Water table depth to be maintained at 5 ft.

Tile depth at 7 feet.

Upper stratum is up to 4 feet deep.

Impervious layer is at 23 feet depth.

Therfore d = 23 - 7 = 16 feet

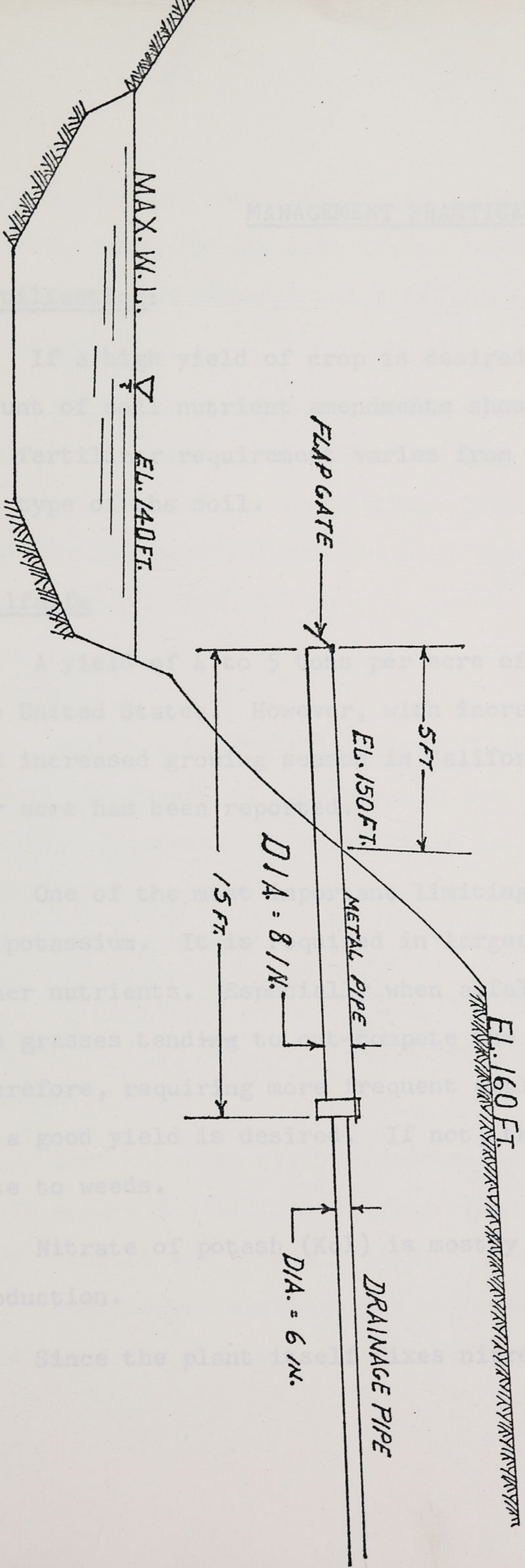
TILE SPACINGS

K = FT/DAY

$S = 481.93\ K\ (b^2 - d^2)$, $b = de \div m$, $m = 2$

K_1	K_2	K/K_2	de	b	S Ft
0.43	0.46	0.93	6.15	8.15	80
0.75	0.72	1.05	6.87	8.87	110
0.72	0.75	0.96	6.87	8.87	110
0.95	1.02	0.94	8.29	10.29	140
1.28	1.21	1.05	8.87	10.87	160
1.15	1.28	0.90	8.87	10.87	160
1.41	1.48	0.96	9.45	11.45	180
1.21	1.31	0.93	8.87	10.87	160
1.48	1.54	0.96	9.45	11.45	180
1.84	1.64	1.12	9.45	11.45	180
2.10	1.77	1.17	9.74	11.74	200
2.20	1.77	1.24	9.74	11.74	200
1.88	1.84	0.98	9.74	11.74	200
7.61	2.00	3.80	9.74	11.74	200
2.13	2.16	0.98	9.74	11.74	200
2.46	2.39	1.03	9.74	11.74	200
1.67	3.05	0.55	10.87	12.87	250
3.64	3.61	1.10	11.45	13.45	300
4.17	3.94	1.06	--	--	350
10.50	5.58	1.88	--	--	400

POSITION OF OUTLET PIPE



MANAGEMENT PRACTICES

Fertilization:

If a high yield of crop is desired, a considerable amount of soil nutrient amendments should be added to the soil. The fertilizer requirement varies from crop to crop, and on the type of the soil.

Alfalfa

A yield of 4 to 5 tons per acre of alfalfa is common in the United States. However, with increased use of fertilization and increased growing season in California, a yield of 16.2 tons per acre has been reported.

One of the most important limiting nutrients in alfalfa is potassium. It is required in larger amounts than any of the other nutrients. Especially when alfalfa is grown with grass, the grasses tend~~ing~~ to out-compete the alfalfa for potassium, therefore, requiring more frequent applications of potassium if a good yield is desired. If not, the alfalfa stands degenerate to weeds.

Nitrate of potash (Kcl) is mostly recommended for alfalfa production.

Since the plant itself fixes nitrogen from the air very little nitrogen fertilizer is added, except a small amount at seeding time, if the soil is low in organic matter. This applies to all mineral soils including the clay loam in our case.

Phosphorus content in alfalfa plant is very low. Since phosphorous tends to be fixed in clay soils, it is not usually readily available to plants. Ordinary superphosphate is usually broadcasted into the soil prior to seeding or on already established alfalfa.

Corn

Hughes & Henzen write that 100 bushels of corn crop removed 160 pounds of nitrogen, 50 lbs of phosphoric acid and 80 lbs of potash. Here, nitrogen is the main nutrient, but additional quantities of nutrients are likely to be lost by the leaching water.

Depending on the nitrogen reserve of the soil that could be released to the soil, supplemental chemical fertilizer should be added.

Some nitrogen carrying fertilizers are: Urea (CO $(NH_2)2$, with a 42-45% nitrogen content; Ammonium Nitrate NH_4NO_3 with a 33% content are commonly used:

Phosphorous carriers are superphosphates 7-22% phosphorous and Diamonium phosphate with 20-23% phosphorous could be used.

Potassium chloride and potassium sulfate are commonly used to replenish potassium in the soil.

Cotton

In the United States, the average fertilizer application for cotton is known to be 355 lbs per acre. The fertilizer should be applied close enough to the seeds for proper germination.

A rotation of two or more years of alfalfa before the cotton crop have shown a greater yield in cotton crop. As far as the type of fertilizers are concerned, the fertilizers mentioned before are used. Recommendation as to the ratio of the different fertilizers to be used should be preceded by a laboratory analysis of the soil, or trends of other fields with the same soil type should be followed.

Fertilizing through the trickle system:

Where liquid fertilizers are available, the field could be fertilized through the system:

Some of the commercial fertilizers, their nutrient content and solubility are given below. (Taken from GOLDBERG .... Drip Irrigation text).

	Salt INDEX	% N	P_2O_5	K_2O	Solubility g/Litre
Ammonium Sulphate	69	20	0	0	700
Ammonium Nitrate	105	33.5			1185
Urea	75	42-46			1190
Mono-ammonium Sulphate	30	11	48		225
Di-ammonium Phosphate	34	21	54		413
Potassium Nitrate	74	12-14		44-46	135
Potassium Sulfate	46		48		67

Any combination of the above could be used as desired. The more readily soluble nutrients are recommended to be used because they cause less precipitation in the system. Even when these are used, precipitation does occur in the small tubings and Ca Co_3 cloggings in the emitters are known to occur. Helpful practice is flushing after fertilization. Since the most readily available nutrients like nitrates are also easily leached, a more frequent application of these nutrients is advisable. The limiting factor to this kind of practice is cost. The more soluble fertilizers are usually expensive, hence, the cost of fertilizer should be weighed against the intended yield return. With regard to liquid fertilizers the elements that cause the most problems in using the trickle system are the phosphate fertilizers. Most of these fertilizers are the least soluble and therefore, precipitate very readily in the trickle system that might be costly to the operation. Since clogging also impedes the correct discharge of water to the soil, the efficiency of the trickle system is likely to be affected to the extent that it may not be profitable to operate it. Therefore, the more usual application of phosphorous directly to the surface and broadcasting it is advisable. The fact that phosphorous should be put close to the roots is important since, it is usually fixed as soon as it touches the surfact becoming unavailable to the plant.

When choosing the right fertilizer, the salt index can be used as a relative measure of toxicity of individual elements. The lower the salt index, the safer it is to use the specific fertilizer. The elements with high salt index tend to increase the osmotic pressure of the soil hence, reducing the capacity of the plant to extract moisture.

GENERAL COMMENT

Irrigating with Saline Water requires precise management practices. The failure of irrigation projects to include precaution measures against accumulation of salts has put a number of areas out of production. Some of these lands may be reclaimed, but at this point in time, it is more economical to move along and cultivate unspoiled land than to bring abandoned lands into production.

In many areas of the world, there are no set standards nor is there enough knowledge to rate the quality of water. The United States Salinity Laboratory classifies our irrigation water as High-Salinity Water.

According to the Salinity Laboratory, this water cannot be used for irrigation on soils with restricted drainage. It goes on to say that, even with adequate leaching, special management for salinity content may be required.

The USSR evaluation classifies a water with salt content of one (1) to two (2) grams per liter, as water causing salinity hazard. Our irrigation water has a 1.2 gram per litre salt content. This means, if the irrigation water is used without leaching and adequate drainage, and if the required 33.6 inches of water is applied per year for a perennial crop, there would be an accumulation of 3.72 tons of salt per acre. Therefore, in one year alone, this land may be out of production or it could only support the highly salt tolerant crops.

Even with leaching, the concentration of the individual ions may cause a problem, if other methods of salinity control are not exercised. The concentration of these elements and the degree of hazard they cause vary from one type of soil to the other.

The Soluble-Sodium percentage is one such method used to calculate the degree of hazard.

$$SSP = \frac{\text{Soluble-Sodium (me/l)}}{\text{total soluble cation concentration (me/l)}} \times 100$$

The hazard limit of SSP is 60%. According to this formula, our irrigation water has an SSP of only 33.5% and therefore, it could be used. But it also depends on the cation exchange capacity of the soil. Therefore, there is a strong need to analyse the soil before using the water.

Another criteria is the Sodium-adsorption ratio:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

with dividing points for low, medium and high electrical conductivities. According to this, our water falls into the medium Sodium water concentration category, which means that the water could be used without any sodium hazard.

As essential as Boron is to plants, its required concentration is very low and above that concentration, plants are very sensitive to Boron. Tolerance of the crops

45

intended to be produced are as follows:

CROP	Boron TOLERANCE in PPM
Orange	1.0 PPM
Cotton	2.00 "
Corn	2.00 "
Alfalfa	4.00 "

Our irrigation water concentration is 0.8 PPM which is a very high beginning. However, its availability to plants depends more on the chemistry of the soil than on its concentration. It is known that Boron is fixed by lime, and that calcium in some way hinders the movement of Boron into the plant.

The most immediate problem of salt concentrations are those that occur in the least watered areas of the land. Both furrow and trickle irrigation systems water only strips of the land. As shown in Fig.2 , most of the salt concentration occurs on top of the furrows. This affects the proper germination of seeds. Various ways of eliminating thishazard could be used by management.

1. Leaching, by flooding the field completely would eliminate the risk of having the seedlings killed at a young age, when they are much more sensitive to salts.

2. Another method is choosing the proper placement of seeds. With the knowledge of the concentration of salts around the furrow, seeds could be placed as in B, C, D of Fig.4

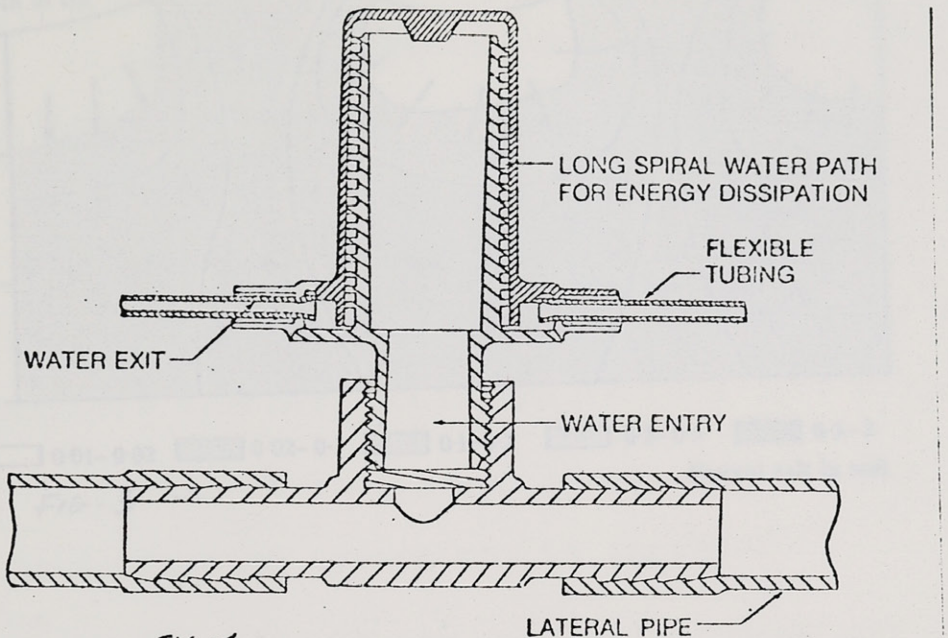


FIG. 1.

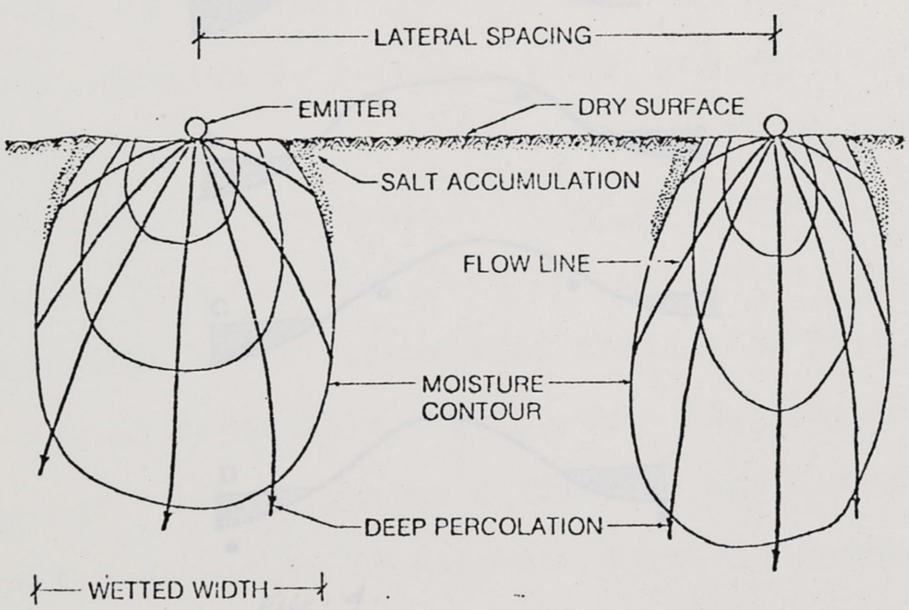


Figure 2.1. *Typical soil moisture pattern under trickle irrigation.*

CONCENTRATION OF SALTS IN FURROW. IRRIGATED LANDS.

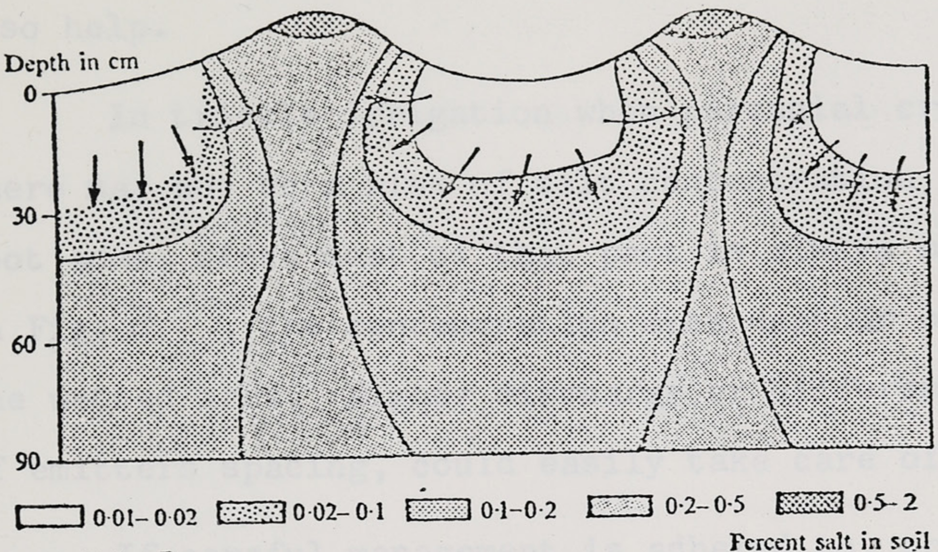


FIG. 3

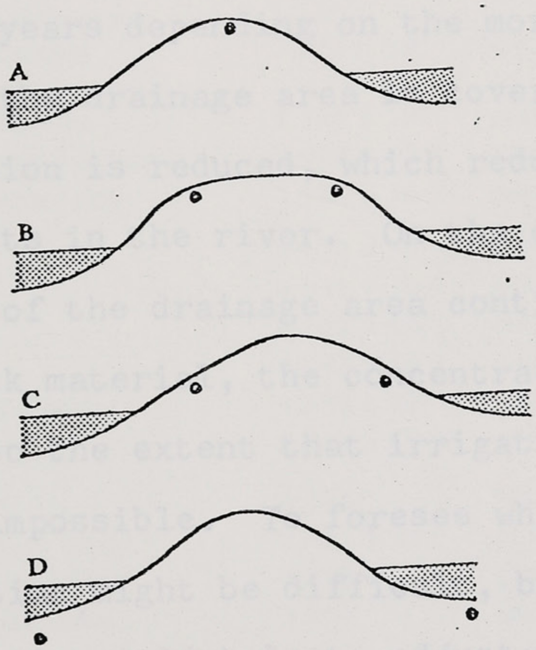


FIG. 4.

3. Alternating furrows, in successive seasons could also help.

In trickle irrigation when perennial crops are grown, there may not be a risk of salt concentration in the immediate root zone, since most of that part is always moist. As shown in Fig. 2 , the concentration area depends on the width of the wetted area. Higher discharge or different arrangement of emitters spacing, could easily take care of the problem.

If careful management is adhered to, the permanency of the irrigation system may be successful.

The quality of the irrigation water may change, over ten or twenty years depending on the morphology of the drainage area. If the drainage area is covered with vegetation, sediment, erosion is reduced, which reduces the concentration of soluble salts in the river. On the other hand, if the deterioration of the drainage area continues, depending on the parent rock material, the concentration of soluble salts may increase to the extent that irrigation with the river water may be impossible. To foresee what might happen in twenty years time, might be difficult, but occasional water and soil analysis would help to adjust management practices accordingly.

LIST OF CONVERSTION FACTORS (cont.)

MULTIPLY	BY	TO OBTAIN
gallons	3.785×10^{-3}	cubic meters
gallons	3.785	liters
gallons/minute	2.228×10^{-3}	cubic feet/second
gallons/minute	6.308×10^{-2}	liters/second
hectares	2.471	acres
hectares	1.076×10^{5}	square feet
inches	2.540	centimeters
inches	2.540×10^{4}	microns
kilograms	2.205	pounds
kilograms/square centimeter	9.678×10^{-1}	atmospheres
kilograms/square centimeter	3.281×10^{1}	feet of water
kilograms/square centimeter	1.422×10^{1}	pounds/square inch
kilograms/hectare	8.922×10^{-1}	pounds/acre
kilograms/leter	1.198×10^{-1}	pounds/gallon
liters	1.000×10^{3}	cubic centimeters
liters	3.531×10^{-2}	cubic feet
liters	6.102×10^{1}	cubic inches
liters	2.642×10^{-1}	gallons
liters/second	1.585×10^{1}	gallons/minute
liters/hour	2.642×10^{-1}	gallons/hour
meters	3.281	feet
meters of water	9.681×10^{-1}	atmospheres
meters of water	1.422	pounds/square inch
meters/second	3.281	feet/second
meters/second/second	3.281	feet/second/second
microns	1.000×10^{-6}	meters
microns	1.000×10^{-3}	millimeters
microns	3.937×10^{-5}	inches
millimeters	1.000×10^{3}	microns
pounds	4.536×10^{-1}	kilograms
pounds/acre	1.121	kilograms/hectare

LIST OF CONVERSION FACTORS (cont.)

MULTIPLY	BY	TO OBTAIN
pounds/gallon	1.198×10^{-1}	kilograms/liter
pounds/square inch	6.804×10^{-2}	atmospheres
pounds/square inch	2.307	feet of water
pounds/square inch	7.031×10^{-2}	kilograms/ square centimeter
pounds/square inch	7.031×10^{-1}	meters of water
square feet	2.296×10^{-5}	acres
square feet	9.294×10^{-6}	hectares
square feet	9.294×10^{-2}	square meters
square inches	6.452×10^{2}	square millimeters
square meters	2.471×10^{-4}	acres
square meters	1.076×10^{1}	square feet
square millimeters	1.550×10^{-3}	square inches
temperature (°C) + 17.780	1.800	temperature (°F)
temperature (°F) − 32.000	5/9	temperature (°C)

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