DESIGN CALCULATION NOTE ON THE IMPLEMENTATION DESIGN FOR THE KILIMANJARO AGRICULTURAL DEVELOPMENT CENTER PROJECT IN THE UNITED REPUBLIC OF TANZANIA

JUNE 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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FIGURES

I. GENERAL

This note presents design calculations made for designs of the Trial Farm and the Pilot Farm under the implementation design for the Kilimanjaro Agricultural Development Center Project. The note is to be read in conjunction with Design Report, Design Drawings and Tender Documents for the Project.

II. IRRIGATION WATER REQUIREMENTS

2.1 Calculation Procedures

Irrigation water requirements for the Project are estimated in the following manner:

i) Calculate potential evapotranspiration (ETo) by using a Modified Penman's formula.

ii) Multiply ETo by crop factors to obtain crop evapotranspirations.

iii) Subtract effective rainfall from the crop evapotranspirations. on a 15-day basis to obtain net irrigation water requirements.

iv) For paddy, add percolation of 4-6 mm/day, nursery requirements of 22 mm, and puddling requirements of 200 mm to the crop evapotranspiration in order to obtain net irrigation water requirements of paddy.

v) Divide the net irrigation water requirements by irrigation efficiency to obtain gross irrigation water requirements.

2.2 Modified Penman's Formula

Modified Penman's formula is as follows:

$$ETo = W \cdot Rn + (1 - W) \cdot f(u) \cdot (ea - ed)$$

$$ET = ETo \times Kc$$

Where, ETo : Potential evapotranspiration (mm/day)

W : Temperature-related weighing factor

Rn : Net radiation in equivalent evaporation (mm/day)

f (u): Wind-related function

(ea - ed): Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air (mbar)

ET : Crop evapotranspiration (mm/day)

Kc : Crop factor

Potential evapotranspiration (ETo) calculated by using meteorological data of Miwaleni station (1972 - 1979) are shown in the following table.

Potential Evapotranspiration (ETo) (mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.
6.7	6.8	6.8	5.8	4.8	4.3

Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
4.4	5.0	5.9	6.7	7.0	7.0

To calculate crop evapotranspirations, crop factors are quoted from "Crop Water Requirements" published by FAO.

The crop factors are shown in Fig.-2.1 to 2.6.

2.3 Effective Rainfall

Effective rainfall with 80% dependability is estimated from daily rainfall data (1970 - 1979) observed at Kahe NAFCO station on condition that the effective rate of total rainfall shown in "Irrigation Water Requirements - Technical Release No. 21" published by U.S Department of Agriculture can be applied. Estimated effective rainfall is shown below:

Effective Rainfall (mm/15-day)

Jan.		Feb.		Mar.		Apr.		May		Jun.	
-	-	-	-	-	10	28	27	19	11	-	-

Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
-	-	-	-	-	-	-	-	-	-	-	-

2.4 Irrigation Efficiency

Irrigation efficiency for the Trial Farm and the Pilot Farm is estimated as follows:

Irrigation Efficiency for the Trial Farm

Description	Upland field (%)	Paddy field (%)
1) Conveyance efficiency Operation efficiency	90	90
2) Application efficiency	65	90
3) Overall irrigation efficiency $3) = 1) \times 2) \times \frac{1}{100}$	58.5	81.0

Irrigation Efficiency for the Pilot Farm

Description	Upland field (%)	Paddy field (%)
1) Conveyance efficiency	90	90
2) Operation efficiency	85	85
3) Application efficiency	65	90
4) Overall irrigation efficiency $4) = 1) \times 2) \times 3) \times \frac{1}{100}$	49.7	68.9

2.5 Conclusion

Irrigation water requirements of paddy, maize, vegetable, beans, oil seeds and cotton are estimated as shown in Fig.-2.1 to 2.6.

III. DRAINAGE WATER REQUIREMENTS

3.1 Calculation Procedures

The Trial Farm and the Pilot Farm consist of upland fields and paddy fields. Since drainage characteristics of these fields are different, drainage water requirements on upland field and that on paddy field are separately estimated. The former is estimated by using MacMath's formula presented in "Drainage Manual" published by the U.S. Department of the Interior, Bureau of Reclamation, while the latter is estimated based on assumption that design rainfall should be drained from paddy fields within 48 hours.

3.2 MacMath's Formula

MacMath's formula is defined as follows:

$$Q = 2.3 \times C \times i \times S^{\frac{1}{5}} \times A^{\frac{4}{5}}$$

Where, Q : Flood discharge (ℓ/s)

C : Coefficient representing the basin characteristics (0.30)

i : Rate of rainfall (mm/hr.)

$$i = \frac{r_{24}}{24} \times \left(\frac{24}{1}\right)^{\frac{2}{3}}$$

r_{24} : Daily rainfall (mm/day)

S : Fall of main channel in meters per 1,000 meters between the furthest contributing point and the point of concentration (2.6 m/km)

A : Area of basin (ha)

3.3 Design Rainfall

Design rainfall in a 5-year recurrence interval is estimated at 63 mm/day by using Gumbel method on the basis of daily rainfall records observed at Kahe NAFCO station during the 10 years of 1970 to 1979. Drainage facilities are so designed as to have the capacity of the design rainfall; however, drainage facilities that have capacity of daily rainfall of 74 mm/day in a 10-year recurrence interval is also examined by using free boards of drainage canals and structures.

3.4 Conclusion

(1) Drainage water requirements for the Trial Farm

Drainage water requirements (Q_1) of upland field are estimated as follows:

$$Q_1 = 2.3 \times C \times i \times S^{\frac{1}{5}} \times A^{\frac{4}{5}}$$

$$i = \frac{r_{24}}{24} \cdot \left(\frac{24}{1}\right)^{\frac{2}{3}} = \frac{63}{24} \times \left(\frac{24}{1}\right)^{\frac{2}{3}} = 21.8 \text{ mm/hr.}$$

$$S^{\frac{1}{5}} = (2.6)^{\frac{1}{5}} = 1.2$$

$$A^{\frac{4}{5}} = (10.5)^{\frac{4}{5}} = 6.6$$

$$Q_1 = 2.3 \times 0.3 \times 21.8 \times 1.2 \times 6.6 = 119 \ (\ell/s/10.5 \text{ ha})$$

$$(11.3 \ \ell/s/ha)$$

Drainage water requirements (Q_2) of paddy field are estimated as follows on the assumption that runoff coefficient is 0.9:

$$Q_2 = \frac{(63 \text{ mm/hr} \times 10^{-3}) \times 10^4 \text{ m}^2}{48 \text{ hr.} \times 3{,}600 \text{ sec.}} \times 0.9 \quad \times 2.9 \text{ ha}$$

$$= 3.7 \ \ell/s/ha \times 2.9 \text{ ha} = 10.7 \ \ell/s/2.9 \text{ ha}$$

$$(3.7 \ \ell/s/ha)$$

(2) Drainage water requirements for the Pilot Farm

Drainage water requirements (Q_1) of upland field are estimated as follows:

$$Q_1 = 2.3 \times C \times i \times S^{\frac{1}{5}} \times A^{\frac{4}{5}}$$

$$A^{\frac{4}{5}} = (86)^{\frac{4}{5}} = 35.3$$

$$Q_1 = 2.3 \times 0.3 \times 21.8 \times 1.2 \times 35.3 = 638(\ell/s/86\ ha)$$

$$(7.4\ \ell/s/ha)$$

Drainage water requirements (Q_2) of paddy field are estimated at 84 (ℓ/s/22.5 ha) or 3.7 ℓ/s/ha in the same manners shown in the drainage water requirements of paddy field for the Trial Farm.

Schematic drainage diagram of the Pilot Farm is shown in attached Fig.-3.1.

IV. HYDRAULIC CALCULATIONS

4.1 Trial Farm

4.1.1 Hydraulic Formula

Pipelines of the closed type are used as irrigation facilities of the Trial Farm. For the hydraulic calculations of the pipelines, Hazen William's formula is employed as shown below while for those of drainage canals, Manning's formula as described in the following section is employed.

Hazen William's formula

$$V = 0.35464 \times C \times D^{0.63} \times I^{0.54}$$

$$Q = 0.27853 \times C \times D^{2.63} \times I^{0.54}$$

$$D = 1.6258 \times C^{-0.38} \times Q^{0.38} \times I^{-0.205}$$

$$I = \frac{hf}{L} = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$$

where, V : Velocity (m/s)

Q : Discharge (m^3/s)

D : Diameter of pipe (m)

I : Hydraulic gradient

hf: Friction loss of head (m)

L : Length of pipeline (m)

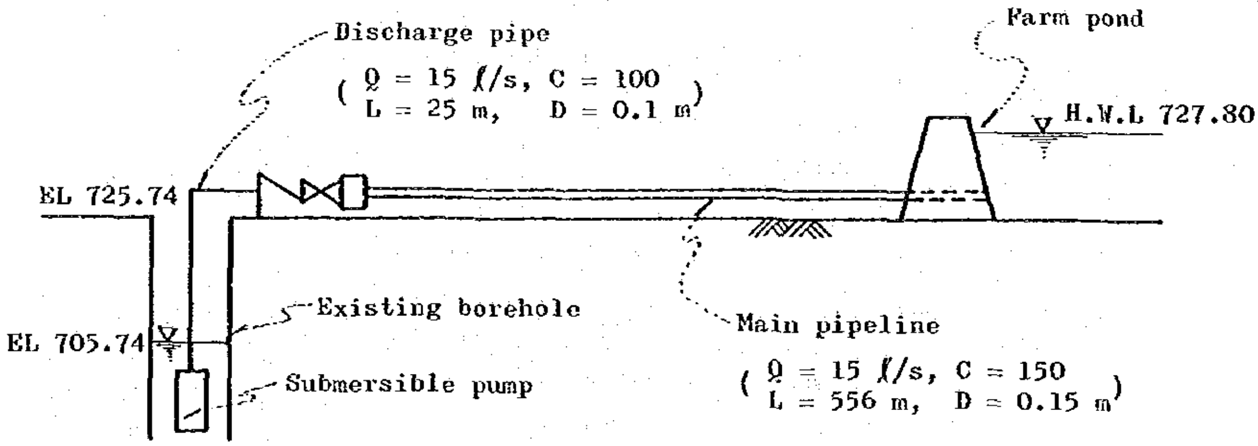
C : Coefficient of roughness

P.V.C pipe	Dia. $\leq$ 0.15 m	:	140
"	Dia. $\geq$ 0.20 m	:	150
Steel or iron pipe		:	100

In the hydraulic calculations of pipelines, various kinds of loss of head except friction loss of head are assumed at 10% of the total friction loss of head calculated by the above formula. The results of hydraulic calculations of No.2 and No.3 pipelines are shown in attached Table-4.1 and 4.2.

4.1.2 Submersible Pump

To calculate required horse power of a submersible pump provided to lift up a discharge of 15 ℓ/s from the existing borehole, water head (H) required for an operation of the pump is estimated at 27 m as follows:



$$H = H_1 + H_2 + H_3 = 1.64 + 2.36 + 22.0 = 27 \text{ (m)}$$

where, H_1 : Friction loss of head by discharge pipe (m)

H_2 : Friction loss of head by main pipe line (m)

H_3 : Difference of water surface elevations (728.80 - 705.74 ≒ 22 m)

H_1 and H_2 are calculated by the use of said Hazen William's formula.

Required horse power (P) of the submersible pump is calculated as follows:

$$P = \frac{0.163 \times \gamma \times Q \times H}{\eta} \times (1 + \alpha)$$

$$= \frac{0.163 \times 1 \times (0.015 \times 60) \times 27}{0.65} \times (1 + 0.20)$$

$$\fallingdotseq 7.5 \text{ kW}$$

where, P : Required horse power (kW)

γ : Specific gravity of water (1.0)

Q : Discharge (0.9 m^3/min.)

H : Total (water) head (m)

η : Pump efficiency

α : Allowances (0.20)

Principal features of the pump are as follows:

Power:	7.5 kW
Discharge:	15 ℓ/s
Water head:	27 m
Rating speed:	2,810 r.p.m
Frequency:	50 Hz

4.1.3 Sprinklers

(1) Principal Features of Sprinkler System

Principal features of sprinkler system for the Trial Farm are itemized as follows:

Crops: Vegetables (tomato, cabbage, onion)
sesame, maize

Peak daily consumptive use: 8 mm/day

Irrigation efficiency: 80 %
(Water application efficiency)

Gross irrigation water requirement: $\frac{8 \text{ mm/day}}{80} \times 100 = 10$ mm/day

T.R.A.M (Total readily available moisture): 32 mm

Irrigation interval: $\frac{\text{T.R.A.M}}{\text{Peak daily consumptive use}} = \frac{32 \text{ mm}}{8 \text{ mm/day}} = 4$ days

Net water applied per irrigation: 4 days x 8 mm/day = 32 mm

Gross water applied per irrigation: 4 days x 10 mm/day = 40 mm

Irrigation intensity: 10 mm/hr. < 14 mm/hr. (basic intake rate of the area)

Total irrigation area covered by sprinkler system: 240 m x 100 m = 2.4 ha
(1.8 ha for high riser
0.8 ha for low riser)

Spacing : L x B = 16 m x 16 m

L: Distance of sprinkler heads

B: Distance of portable sprinkler lines

Irrigation hour: $\frac{40 \text{ mm}}{10 \text{ mm/hr.}} = 4$ hr.

Shifting system of sprinkler lines: 2 times/day

Gross water applied by one sprinkler head (q_o):

$$q_o = \frac{M.L.B}{60.T} = \frac{40 \times 16 \times 16}{60 \times 4} = 42.67 \ (\ell/\text{min.})$$

T : Irrigation hour (4 hr.)

M : Gross water applied per irrigation (40 mm)

L : Distance of two sprinkler heads (16 m)

B : Distance of two portable sprinkler lines (16 m)

Height of riser: 1.0 m for low riser

2.0 m for high riser

Hydrants: Dia. 50 mm (16 m interval)

A model of sprinkler head selected is as follows:

Q (Discharge) : 42.60 ℓ/min.

P (Pressure) : 2.5 kg/cm^2

D (Diameter of irrigation area covered by a sprinkler)

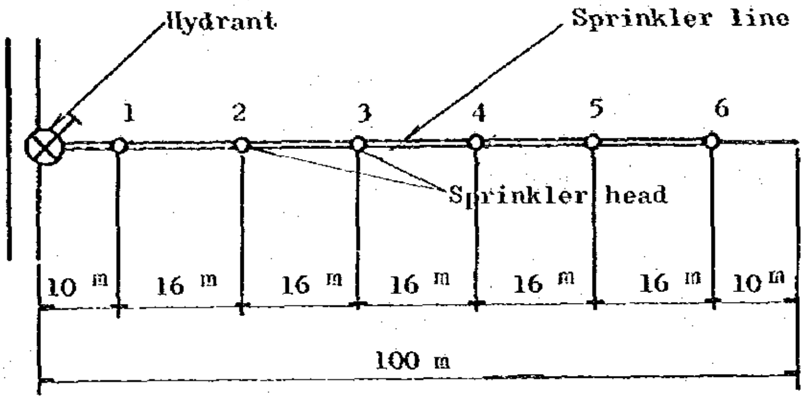
: 29.6 m

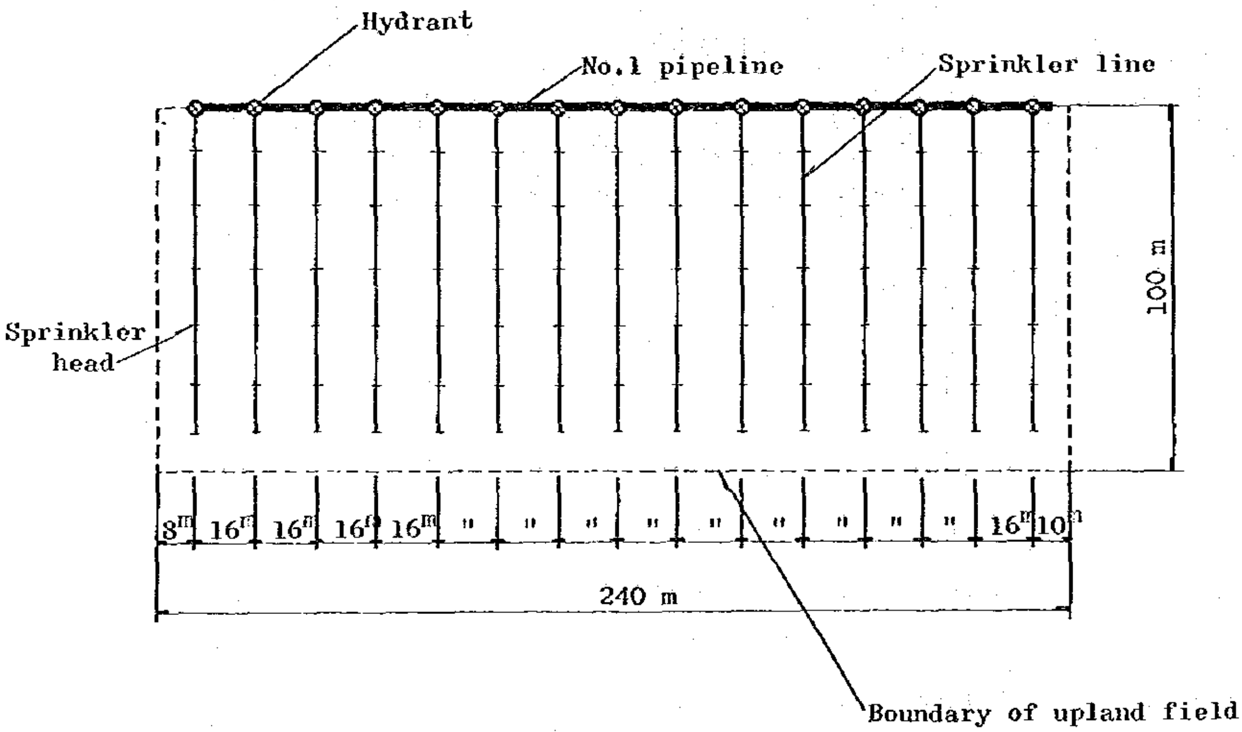
Nozzle size : 5.2 mm x 4.0 mm

(2) Layout of sprinkler system

Irrigation water is applied to the field by a sprinkler system with an irrigation interval of 4 days and an irrigation hour of 4 hours.

A sprinkler line is provided with 6 sprinkler heads. Two sprinkler lines are simultaneously operated and are to be shifted two times a day. Daily operation hour is 8 hours. Layout for the sprinkler system is shown below:





(3) Loss of head by a sprinkler line

Loss of head by a sprinkler line with 6 sprinkler heads is calculated at 3.09 m as shown below:

Sections	Discharge (ℓ/min)	Loss of head (m)
1 – 2	213.0	1.36
2 – 3	170.4	0.88
3 – 4	127.8	0.54
4 – 5	85.2	0.24
5 – 6	42.6	0.07
	Total	3.09 (0.3 kg/cm^2)

The loss of head is within ± 10 % of the pressure of sprinkler head (2.5 kg/cm^2) as follows:

$$2.5 \times 0.2 = 0.5\ (kg/cm^2) > 0.3\ (kg/cm^2)$$

4.1.4 Booster Pump

Discharge of a booster pump provided for a sprinkler system is:

$$Q = 42.6\ \ell/min \times 6\ pieces \times 2\ lines = 511.2\ \ell/min$$

Required water head (H) of the pump is calculated as shown below:

Item	Water head
Pressure of sprinkler head	25 m
Loss of head by hydrant	2 m
Height of riser	2 m
Loss of head by sprinkler system	3 m
Suction loss of head	3 m
Total	H = 35 m

Required horse power (P) of the pump is estimated as follows:

$$P = \frac{0.163 \times \gamma \times Q \times H}{\eta} \times (1 + \alpha)$$

where, P : Horse power (kW)

γ : Specific gravity

Q : Discharge (m^3/min)

H : Total head (m)

η : Pump efficiency (55 %)

α : Allowances

$$P = \frac{0.163 \times 1 \times 0.511 \times 35}{0.55} \times (1 + 0.15)$$

$$\doteq 6.10$$

Principal features of the pump thus determined are itemized below:

Power:	7.5 kW
Diameter:	80 mm
Discharge:	0.511 m^3/min
Total head:	35 m
Rating speed:	1,450 r.p.m.
Frequency:	50 Hz

4.1.5 Kinds of Pipes

Kinds of pipes required for the pipeline system of the Trial Farm should be polyvinyl chloride pipe (P.V.C pipe) except sprinkler line of polyvinyl pipe.

4.2 Pilot Farm

4.2.1 Hydraulic Formula

Irrigation and drainage canals for the Pilot Farm are of earthern trapezoidal open channel. For the hydraulic calculations of these canals, Manning's formula as shown below is employed:

$$Q = A \times V$$

$$V = \frac{1}{n} \times R^{2/3} \times I^{1/2}$$

where, Q : Discharge (m^3/s)

V : Velocity (m/s)

A : Flow area (m^2)

n : Coefficient of roughness

Irrigation canal (earth)	:	0.030
Drainage canal (earth)	:	0.033
Concrete	:	0.015
Corrugated pipe	:	0.025

R : Hydraulic radius (m)

I : Hydraulic gradient

Allowable velocity of the canals is determined at 0.2 to 0.6 m/s.

4.2.2 Cross Sections of Canals

Typical cross section of canals is trapezoidal open channel with a side slope of 1:1.5 or 1:2.0. Canal base width is determined so that velocity of the flow can be within the allowable velocity specified above. Freeboard of canals is determined at 0.20 to 0.30 m.

4.2.3 Loss of Head

Loss of head is calculated by using following formulas:

(1) Friction loss

$$hf = \left(\frac{n \times V}{R^{2/3}}\right)^2 \cdot L$$

where, hf: Friction loss (m)

L : Distance (m)

R : Hydraulic radius (m)

V : Velocity (m/s)

n : Coefficient of roughness

(2) Loss of head due to sudden enlargement of canal section

$$hse = fse \cdot \frac{V_1^2}{2g}$$

$$fse = (1 - A_1/A_2)^2$$

where, hse: Loss of head due to sudden enlargement of canal section (m)

V_1 : Velocity of upstream canal (m/s) fse: Coefficients as shown below

A_1/A_2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	(1.0)
fse	1.0	0.81	0.64	0.49	0.36	0.25	0.16	0.09	0.04	0.01	(0)

A_1 : Flow area of upstream canal (m^2)

A_2 : Flow area of downstream canal (m^2)

(3) Loss of head due to sudden contraction of canal section

$$hsc = fsc \times \frac{V_2^2}{2g}$$

where, hsc : Loss of head due to sudden contraction of canal section

V_2 : Velocity of downstream canal (m/s)

A_1 : Flow area of opstream canal (m^2)

A_2 : Flow area of downstream canal (m^2)

fsc: Coefficients as shown below

A_2/A_1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	(1.0)
fsc	0.50	0.48	0.45	0.41	0.36	0.29	0.21	0.13	0.07	0.01	(0)

4.2.4 Hydraulic Calculations

Hydraulic calculations of No.1 and No.2 secondary canals thus made are shown in attached Table-4.3 to 4.4. Schematic water distribution diagram of the Pilot Farm is shown in attached Fig.-4.1.

Table-4.1 Hydraulic Calculations of No. 2 Pipeline

Station	Discharge	Diameter of pipe	Velocity	Length of pipeline	Elevation of Energy Line	Loss of water head	Hydraulic gradient	Remarks
	(ℓ/sec)	(mm)	(m/sec)	(m)	(m)	(m)		
No.2 Pipeline								
No.0					(726.70)			BP
	26.6	250	0.542	14.00		0.016	0.00115	
No.0 + 14.0					726.684			BP of No.3 Pipe line
	21.5	150	1.217	6.50		0.069	0.01062	
No.0 + 20.50					726.615			
	21.5	250	0.438	308.50		0.241	0.00078	
No.3 + 29.00					726.374			No.1 Hydrant
	21.5	250	0.438	39.75		0.031	0.00078	
No.3 + 68.75					726.343			No.2 Hydrant
	21.5	250	0.438	40.00		0.031	0.00078	
No.4 + 8.75					726.312			No.3 Hydrant
	21.5	250	0.438	40.00		0.031	0.00078	
No.4 + 48.75					726.281			No.4 Hydrant
	21.5	250	0.438	40.00		0.031	0.00078	
No.4 + 88.75					726.250			No.5 Hydrant
	21.5	250	0.438	40.00		0.031	0.00078	
No.5 + 28.75					726.219			No.6 Hydrant

Table-4.2 Hydraulic Calculation of No.3 Pipeline

Station	Discharge	Diameter of pipe	Velocity	Length of pipeline	Elevation of energy line	Loss of water head	Hydraulic gradient	Remarks
	(ℓ/sec)	(mm)	(m/sec)	(m)	(m)	(m)		
No.3 Pipeline								
No.0					726.684			B.P.
	5.1	100	0.649	5.70		0.030	0.00534	
No.0 + 5.70					726.654			
	5.1	125	0.416	140.25		0.253	0.00180	
No.1 + 45.95					726.401			Bifurcation point
	5.1	125	0.416	17.00		0.031	0.00180	
No.0L + 17.00					726.370			No.1 Hydrant
	5.1	125	0.416	43.00		0.077	0.00180	
No.0R + 43.00					726.324			No.2 Hydrant
	5.1	125	0.416	60.00		0.108	0.00180	
No.1R + 3.00					726.216			No.3 Hydrant
	5.1	125	0.416	60.00		0.108	0.00180	
No.1R + 63.00					726.108			No.4 Hydrant

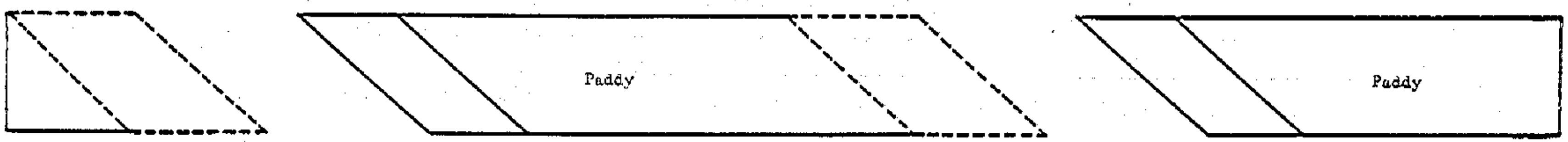
Table-4.3 Hydraulic Calculations of No.1 Secondary Canal

Station No.	Discharge (m^3/sec)	Distance (m)	Reduced Distance (m)	Works	Energy Gradient	Energy Loss (m)	Energy Line EL (m)	Velocity (m/sec)	Velocity Head (m)	Water Level (m)	Water Depth (m)	Canal Base EL (m)	Remarks
No.1 Secondary Canal (Canal length: 789.40 m)													
No.0+0.00			0.00				723.115	0.372	0.007	723.108	0.21	722.898	BP of No.1 Secondary Canal
	0.094	385.00		Canal B=0.75 m	1/625	0.616							
No.3+85.00			385.00				722.499	0.372	0.007	722.492	0.21	722.282	
				No.1 T.O.		0.003							TC-1-1, TC-1-2, CWS, 722.40 m
No.3+85.00			385.00				722.496						
	0.094	4.40		No.1 C.H.		0.031							
No.3+89.40			389.40				722.465	0.557	0.016	722.449	0.19	722.259	
	0.094	195.60		Canal B=0.50 m	1/222	0.869							
No.5+85.00			585.00				721.596	0.557	0.016	721.580	0.19	721.390	
				No.2 T.O.		0.003							TC-1-3, TC-1-4, CWS, 721.50 m
No.5+85.00			585.00				721.593						
	0.094	4.40		No.2 C.H.		0.031							
No.5+89.40			589.40				721.562	0.456	0.011	721.551	0.22	721.331	
	0.094	195.60		Canal B=0.50 m	1/385	0.501							
No.7+85.00			785.00				721.061	0.456	0.011	721.050	0.22	720.830	
				No.3 T.O.		0.003							TC-1-5, TC-1-7, CWS, 720.97 m
No.7+85.00			785.00				721.058						
	0.094	4.40		No.3 C.H.		0.031							
No.7+89.40			789.40				721.027						EP of No.1 Secondary Canal

Table-4.4 Hydraulic Calculations of No.2 Secondary Canal

Station No.	Discharge (m^3/sec)	Distance (m)	Reduced Distance (m)	Works	Energy Gradient	Energy Loss (m)	Energy Line EL (m)	Velocity (m/sec)	Velocity Head (m)	Water Level (m)	Water Depth (m)	Canal Base EL (m)	Remarks
No.2 Secondary Canal (Canal length: 974.40 m)													
No.0+0.00			0.00				722.565	0.373	0.007	722.558	0.24	722.318	BP of No.2 Secondary Canal
	0.112	170.00		Canal B=0.8 m	1/700	0.243							
No.1+70.00			170.00				722.322	0.373	0.007	722.315	0.24	722.075	
				No.1 T.O.		0.003							TC-2-1, TC-2-2, CWS, 722.23 m
No.1+70.00			170.00				722.319						
	0.112	4.40		No.1 C.H.		0.031							
No.1+74.40			174.40				722.288	0.373	0.007	722.281	0.24	722.041	
	0.112	174.20		Canal B=0.8 m	1/700	0.241							
No.3+47.60			348.60				722.047	0.373	0.007	722.040	0.24	721.800	
				No.2 T.O.		0.003							TC-2-3, TC-2-4, CWS, 721.96 m
No.3+47.60			348.60				722.044						
	0.112	4.40		No.2 C.H.		0.031							
No.3+53.00			353.00				722.013	0.322	0.005	722.008	0.26	721.748	
	0.112	9.00		No.1 D.R.		1.030							h = 1.030
No.3+62.00			362.00				720.983	0.322	0.005	720.978	0.26	720.718	
	0.112	208.00		Canal B=0.8 m	1/1,055	0.197							
No.5+70.00			570.00				720.786	0.322	0.005	720.781	0.26	720.521	
				No.3 T.O.		0.003							TC-2-5, TC-2-6, CWS, 720.70 m
No.5+70.00			570.00				720.783						
	0.112	4.40		No.3 C.H.		0.031							
No.5+74.40			574.40				720.752	0.322	0.005	720.747	0.26	720.487	
	0.112	156.50		Canal B=0.8 m	1/1,055	0.146							
No.7+30.90			730.90				720.606	0.322	0.005	720.601	0.26	720.341	
	0.112	7.10		No.2 D.R.		0.450							h = 0.450
No.7+38.00			738.00				720.156	0.322	0.005	720.151	0.26	719.891	
	0.112	32.00		Canal B=0.8 m	1/1,055	0.030							
No.7+70.00			770.00				720.126	0.322	0.005	720.121	0.26	719.861	
				No.4 T.O.		0.003							TC-2-7, TC-2-8, CWS, 720.04 m
No.7+70.00			770.00				720.123						
	0.112	4.40		No.4 C.H.		0.031							
No.7+74.40			774.40				720.092	0.303	0.005	720.087	0.27	719.817	
	0.112	125.60		Canal B=0.8 m	1/1,250	0.098							
No.9+0.00			900.00				719.994 719.994	0.303 0.647	0.005 0.021	719.989 719.973	0.27 0.16	719.719 719.813	
	0.112	70.00		Canal B=0.8 m	1/150	0.467							TC-2-9, TC-2-10, TC-2-11, CWS, 719.42 m
No.9+70.00			970.00				719.527	0.647	0.021	719.506	0.16	719.346	
				No.5 T.O.		0.003							
No.9+70.00			970.00				719.524						
	0.112	4.40		No.5 C.H.		0.031							
No.9+74.40			974.40				719.493						EP of No.2 Secondary Canal

Fig.-2.1 Water Requirements of Paddy



Item \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1. Crop Coefficient	1.16			1.08 1.09	1.12 1.16	1.22 1.24	1.16			1.08 1.09	1.12 1.16	1.22 1.24
	1.24 1.16			1.08	1.09 1.12	1.16 1.22	1.24 1.16			1.08	1.09 1.12	1.16 1.22
2. Averaged Crop Coefficient(kc)	1.20 1.16			1.08 1.09	1.11 1.14	1.19 1.23	1.20 1.16			1.08 1.09	1.11 1.14	1.19 1.23
3. Potential Evapotranspiration (ETo) (mm/day)	6.7 6.7			5.8 5.8	4.8 4.8	4.3 4.3	4.4 4.4			6.7 6.7	7.0 7.0	7.0 7.0
4. Consumptive Use (mm) = (2) x (3) x 15	121 117			94 95	80 83	77 80	80 77			109 110	117 120	125 130
5. Percolation (mm)	90 90			60 60	60 60	60 60	60 60			90 90	90 90	90 90
6. Effective Rainfall (mm)	0 0			28 27	19 11	0 0	0 0			0 0	0 0	0 0
7. Water Deficit (mm) = (4) - (5) + (6)	211 207			126 128	121 132	137 140	140 137			199 200	207 210	215 220
8. Cropping Intensity to Total Area	3/4 1/4			1/4 3/4	1 1	1 1	3/4 1/4			1/4 3/4	1 1	1 1
9. Nursery Water Requirements (mm)			1.9 8.8	9.0 2.3					1.9 8.8	9.0 2.3		
10. Puddling Water Requirements (mm)			40	100 60					40	100 60		
11. Net Water Requirements = (7) x (8) + (9) + (10)	158.3 51.8		1.9 48.8	140.5 158.3	121.0 132.0	137.0 140.0	105.0 34.3		1.9 48.8	158.8 212.3	207.0 210.0	215.0 220.0 (14.7 mm/day)
12. Gross Water Requirements (mm)												
= (11) x $\frac{1}{0.689}$ (mm)	229.8 78.7		2.8 70.9	204.0 229.8	175.7 191.6	198.9 203.4	152.4 49.8		2.8 70.9	230.5 308.2	300.5 304.8	312.1 319.4
" (ℓ/s/ha)	1.78 0.61		0.03 0.55	1.58 1.78	1.36 1.48	1.54 1.57	1.18 0.39		0.03 0.55	1.78 2.38	2.32 2.36	2.41 2.47

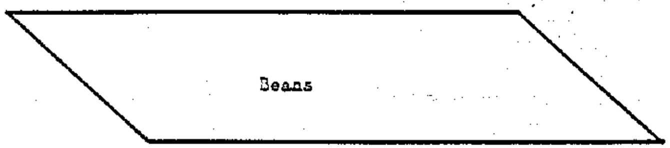
Fig.-2.2 Water Requirements of Maize

Item \ Month	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
		Maize						Maize				
1. Crop Coefficient		0.39 0.45	0.66 0.93	1.09 0.87	1.05 0.87	0.75		0.39 0.45	0.66 0.93	1.09 1.12	1.05 0.87	0.75
		0.39	0.45 0.66	0.93 1.09	1.12 1.05	0.87 0.75		0.39	0.51 0.81	1.05 1.13	1.11 0.98	0.75
2. Averaged Crop Coefficient (kc)		0.39 0.42	0.56 0.80	1.01 1.11	1.09 0.96	0.81 0.75		0.39 0.42	0.59 0.87	1.07 1.13	1.08 0.93	0.75
3. Potential Evapotranspiration (ETo) (mm/day)		6.8 6.8	5.8 5.8	4.8 4.8	4.3 4.3	4.4 4.4		5.9 5.9	6.7 6.7	7.0 7.0	7.0 7.0	6.7
4. Consumptive Use (mm) = (2) x (3) x 15		40 43	49 70	73 80	71 62	54 50		35 38	60 88	113 119	114 98	76
5. Effective Rainfall (mm)		0 10	28 27	19 11	0 0	0 0		0 0	0 0	0 0	0 0	0
6. Water Deficit (mm) = (4) - (5)		40 33	21 43	54 69	71 62	54 50		35 38	60 80	113 119	114 98	76
7. Cropping Intensity to Total Area		1/4 3/4	1 1	1 1	1 8/9	15/36 1/36		3/8 23/24	1 1	1 1	1 5/6	1/6
8. Net Water Requirements (mm) = (6) x (7)		10.0 24.8	21.0 43.0	54.0 69.0	71.0 55.2	22.5 1.40		13.1 36.4	60.0 80.0	113.0 119.0	114.0 81.7	13.0
9. Gross Water Requirements (Earth-lined canal)												
= (8) x $\frac{1}{0.497}$ (mm)		20.2 49.9	42.3 86.6	108.7 138.9	142.9 111.1	45.3 2.9		26.4 73.2	120.7 161.0	227.4 239.4	229.4 164.4	26.2
" (ℓ/s/ha)		0.16 0.39	0.33 0.67	1.84 1.08	1.11 0.86	0.35 0.1		0.20 0.56	0.93 1.24	1.75 1.85	1.77 1.27	0.20

Fig.-2.3 Water Requirements of Vegetables

Item \ Month	Jul.	Aug.		Sep.		Oct.		Nov.		Dec.		Jan.		Feb.
				Vegetables						Vegetables				
1. Crop Coefficient (kc)		0.39	0.44	0.60	0.83	1.03	1.04	0.97/ 0.39	0.44	0.60	0.83	1.03	1.04	0.97
2. Potential Evapo- transpiration (ETo) (mm/day)		5.0	5.0	5.9	5.9	6.7	6.7	7.0	7.0	7.0	7.0	6.7	6.7	6.8
3. Consumptive Use (mm) = (1) x (2) x 15		30	33	54	74	104	105 (7 mm/day)	102/41	47	63	88	104	105	99
4. Effective Rainfall (mm/days)		0	0	0	0	0	0	0	0	0	0	0	0	0
5. Water Deficit (mm) = (3) - (4)		30	33	54	74	104	105	102/41	47	63	88	104	105	99
6. Crop Intensity to Total Area		2/3	1	1	1	1	1	1/3/ 2/3	1	1	1	1	1	1/3
7. Net Water Requirements (mm) = (6) x (7)		20	33	54	74	104	105	34/27	47	63	88	104	105	33
8. Gross Water Requirements (Earth-Lined canal) = (8) x $\frac{1}{0.497}$ (mm)		40.2	66.4	108.7	148.9	209.3	211.3	68.4/54.3 (122.7)	94.6	126.8	177.1	299.3	211.3	66.4
" (ℓ/s/ha)		0.31	0.51	0.84	1.15	1.61	1.63	0.95	0.73	0.98	1.37	1.61	1.63	0.51

Fig.-2.4 Water Requirements of Beans



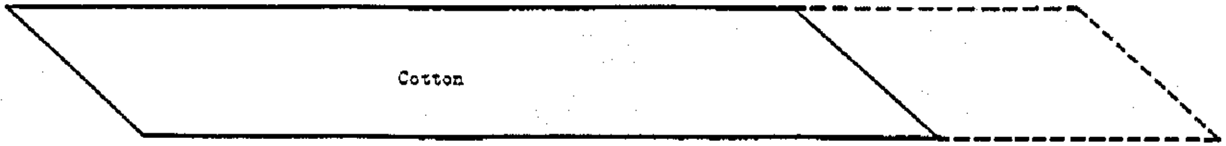
Item \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1. Crop Coefficient			0.40 0.53	0.79 1.02	1.11 1.08	0.88 0.56	0.40					
			0.40	0.53 0.79	1.02 1.11	1.08 0.88	0.56 0.40					
2. Averaged Crop Coefficient (kc)			0.40 0.47	0.66 0.91	1.07 1.10	0.78 0.72	0.48 0.40					
3. Potential Evapotranspiration (ETo) (mm/day)			6.8 6.8	5.8 5.8	4.8 4.8	4.3 4.3	4.4 4.4					
4. Consumptive Use (mm) = (2) x (3) x 15			41 48	58 <u>80</u>	78 <u>79</u> (5.3 mm/day)	64 47	32 27					
5. Effective Rainfall (mm)			0 10	28 27	19 11	0 0	0 0					
6. Water Deficit (mm) = (4) - (5)			41 38	30 53	59 69	64 47	32 27					
7. Crop Intensity to Total Area			1/4 3/4	1 1	1 1	1 8/9	15/36 1/36					
8. Net Water Requirements (mm) = (6) x (7)			10.3 28.5	30.0 53.0	59.0 69.0	64.0 41.8	13.4 0.8					
9. Gross Water Requirements (Earth-lined canal) = (8) x $\frac{1}{0.497}$ (mm)			20.8 57.4	60.4 106.7	118.8 138.9	128.8 84.2	27.0 1.6					
" (ℓ/s/ha)			0.16 0.45	0.47 0.83	0.92 <u>1.08</u>	1.00 0.65	0.21 0.02					

Fig.-2.5 Water Requirements of Oil Seeds

Item \ Month	Aug.	Sep.		Oct.		Nov.		Dec.		Jan.		Feb.
		Oil Seeds										
1. Crop Coefficient		0.48	0.49	0.56	0.71	0.89	1.02	1.03	0.88	0.75		
			0.48	0.49	0.56	0.71	0.89	1.02	1.03	0.88	0.75	
2. Averaged Crop Coefficient (kc)		0.48	0.49	0.53	0.64	0.80	0.96	1.03	0.96	0.82	0.75	
3. Potential Evapotranspiration (ETo) (mm/day)		5.9	5.9	6.7	6.7	7.0	7.0	7.0	7.0	6.7	6.7	
4. Consumptive Use = (2) x (3) x 15 (mm)		43	44	54	65	84	101	109 (7.3 mm/day)	101	83	76	
5. Effective Rainfall (mm)		0	0	0	0	0	0	0	0	0	0	
6. Water Deficit = (4) - (5) (mm)		43	44	54	65	84	101	109	101	83	76	
7. Crop Intensity to Total Area		1/4	3/4	1	1	1	1	1	1	3/4	1/4	
8. Net Water Requirements (mm/days) = (6) x (7)		10.8	33.0	54.0	65.0	84.0	101.0	109.0 (7.3 mm/day)	101.0	62.3	19.0	
9. Gross Water Requirements (Earth-lined canal) = (8) x $\frac{1}{0.497}$ (mm)		21.8	66.4	108.7	130.8	169.1	203.3	219.4	203.3	125.4	38.3	
" (ℓ/s/ha)		0.17	0.52	0.84	1.01	1.31	1.57	1.70	1.57	0.97	0.30	

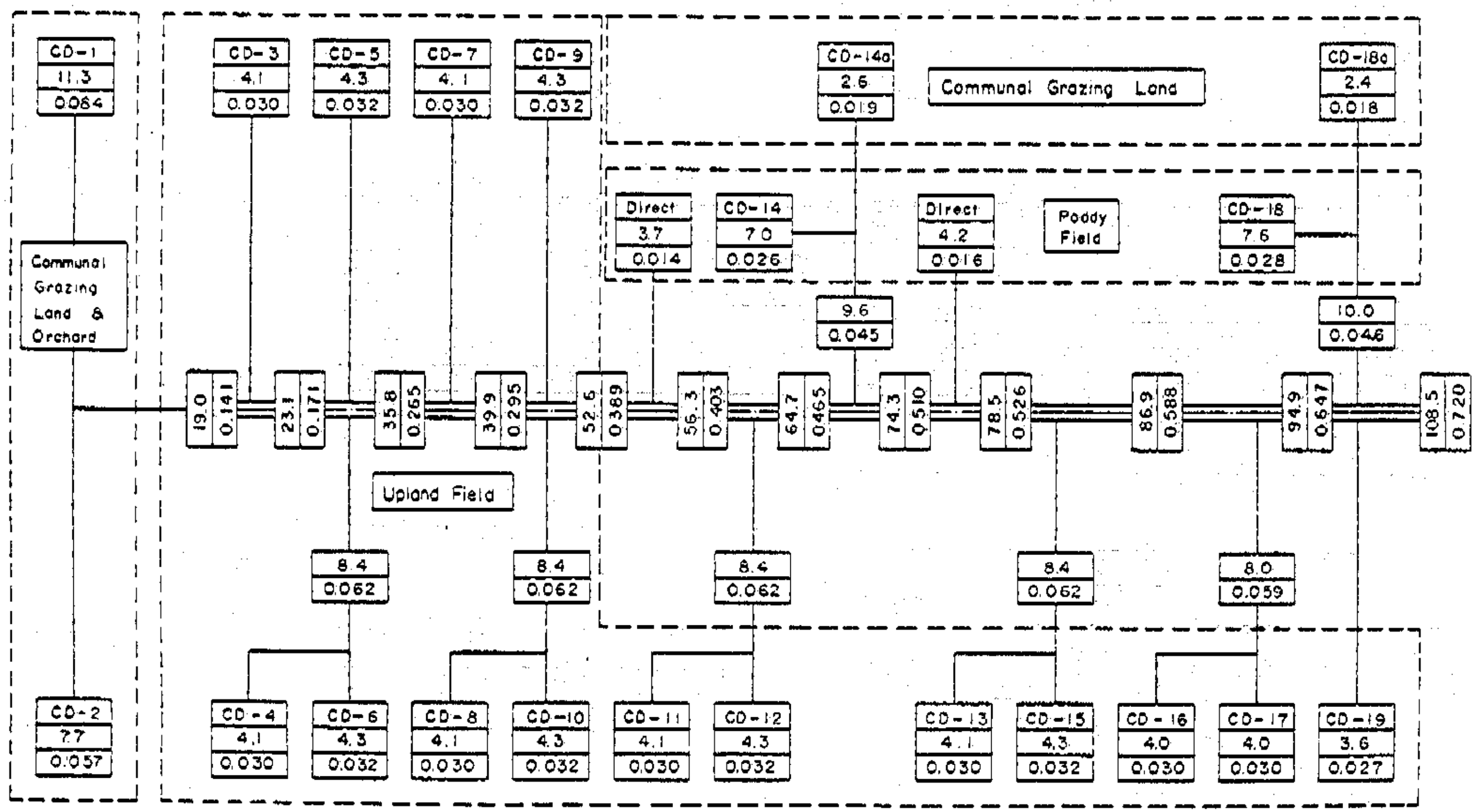
Fig.-2.6 Water Requirements of Cotton

Item \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.



Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1. Crop Coefficient			0.39 0.42	0.50 0.68	0.90 1.09	1.19 1.21	1.15 1.04	0.88 0.79				
			0.39	0.42 0.50	0.68 0.90	1.09 1.19	1.21 1.15	1.04 0.88	0.79			
2. Averaged Crop Coefficient (kc)			0.39 0.41	0.46 0.59	0.79 1.00	1.14 1.20	1.18 1.10	0.96 0.84	0.79			
3. Potential Evapotranspiration (ETo) (mm/day)			6.8 6.8	5.8 5.8	4.8 4.8	4.3 4.3	4.4 4.4	5.0 5.0	5.9			
4. Consumptive Use (mm) = (2) x (3) x 15			40 42	40 51	57 72	74 78	78 73 (5.2 mm/day)	72 63	70			
5. Effective Rainfall (mm)			0 10	28 27	19 11	0 0	0 0	0 0	0			
6. Water Deficit (mm) = (4) - (5)			40 42	12 24	38 61	74 78	78 73	72 63	70			
7. Crop Intensity to Total Area			1/4 3/4	1 1	1 1	1 1	1 1	1 3/4	1/4			
8. Net Water Requirements (mm) = (6) x (7)			10 32	12 24	38 61	74 78	78 73 (5.2 mm/day)	72 47.3	17.5			
9. Gross Water Requirements (Earth-lined canal) = (8) x $\frac{1}{0.497}$ (mm)			20.2 64.4	24.2 48.3	76.5 122.8	148.9 157.0	157.0 146.9	144.9 95.2	35.3			
" (ℓ/s/ha)			0.16 0.50	0.19 0.38	0.59 0.95	1.15 1.22	1.22 1.14	1.12 0.74	0.28			

Fig. – 3.1 Schematic Drainage Diagram



LEGEND

Main drain

Collector drain

b
c

a
b
c

a : Name of drainage canal

b : Catchment area (ha)

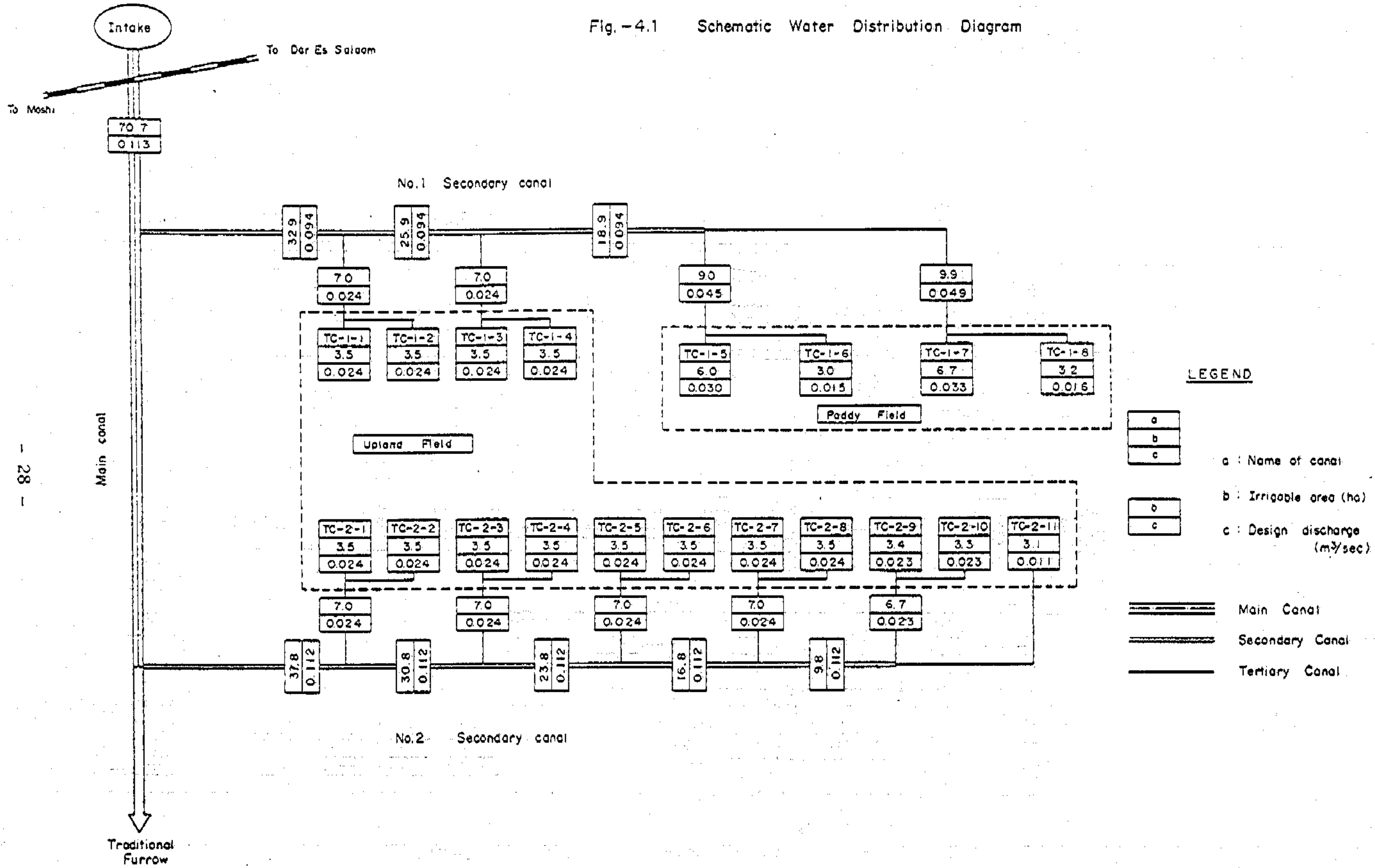
c : Design discharge (m³/sec)

Unit drainage requement

for paddy field : 0.0037 (m³/sec/ha)

for Dry field : 0.0074 (m³/sec/ha)

Fig. -4.1 Schematic Water Distribution Diagram



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