TABLE SHOWN DRAINAGE MODULI IN THE IRRIGATION PROJECTS

Item No.	Projects	Sources of Discussion	Methodology	*Drainge	Drainage Modulus for Main Drain in L/sec/rai — For Drainage Area (rai): 2,000 to 5,000	5,000 to 10,000	10,000 to 20,000	20,000 to 50,000	50,000 to 100,000	100,000 to 200,000	200,000 to 500,000	500,000 to 1,000,000
5	Mae Klong (Feasibility Report	Ilaco	Criteria and Assumptions 1) No ponding depth 2) 5 day -consecutive rainfall 3) 10 year return period 4) 75% of rainfall is taken into account 5) No mention of drainage area	0.42	-	-	-	-	-	-	-	-
6	Mae Klong (Pilot Project)	JICA	Criteria and Assumptions 1) Ponding depth = 100 mm. 2) Max. daily rainfall 3) 10-years return period 4) No mention of drainage area	0.80	-		-	-	-	-	-	
7	Lam Takong (Feasibility Report)	TAHAL	Criteria and Assumptions 1) Initial (pre-rain) water depth in paddies = 75 mm. 2) Drainage modulus $= \frac{\text{3-day storm} - 75/2}{3}$ 3) 3-day consecutive rainfall 4) 5-year return period	0.64	0.004A For Area> 1,000 ha : Q = 35M 5/6 A = hectare			-	M = Area in sq. miles			
8	Lam Pao	TAHAL	Criteria and Assumptions 1) Ponding depth 38 mm. 2) 3-days consecutive rainfall 3) 5-years return period	0.64	0.004A For A > 1,000 hectares Q = 35M 5/6 A = hectare				M = Area in sq. miles			

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TABLE SHOWS DRAINAGE MODULI IN THE IRRIGATION PROJECTS

Item No.	Projects	Sources of Discussion	Methodology	*Drainge	Drainage Modulus for Main Drain in L/sec/rai — For Drainage Area (rai): 2,000 to 5,000	5,000 to 10,000	10,000 to 20,000	20,000 to 50,000	50,000 to 100,000	100,000 to 200,000	200,000 to 500,000	500,000 to 1,000,000
9	Nam pong stageII	TAHAL	Criteria and Assumptions 1) Ponding depth 38 mm. 2) 3-day consecutive rainfall 3) 5-year return period	0.59	0.0037A For A > 1,000 hectare Q = 36M 5/6 A = hectare M = Area in sq. miles							
10	Nong Wai Pioneer - Agriculture	ILACO	Criteria and Assumptions	1.00	-	-	-	-	-	-	-	-
					(90)*	(85)*	(80)*	(75)*	(70)*	(65)*	-	-
11	Nong Wai Pioneer -Agriculture	Sanyu	Rational Formula Criteria and Assumptions 1) Ponding depth 300 mm. for 1/3-1/4 of the total area 2) 5-day consecutive rainfall 3) 10-year return period	1.00	0.90	0.85	0.80	0.75	0.70	0.65		
12	Nong Wai Pioneer Agriculture Project (Design Criteria On land Consolidation)	Sanyu	Rational Formula Q = 0.002778 R.A.F Q = CMS. r = rainfall intensity (mm./hr.) $= \frac{R}{24}\left(\frac{24}{T}\right)^{2/3}$ R = Proposed daily rainfall (mm) t = drainage time (hr.) $Q_1 = A_L \times q_1 = 0.0013\ A_L$ (inside L.C.) $Q_2 = 0.0013A_L + 0.0016\ A_0$ (L.C+ No. L.C.) A_L = Land Consolidation area (rai) A_0 = Area outside L.C (rai)	1.3	-	-	-	-	-	-	-	

* Drainage Modulus of farm level for Area 0-2,000 rai in L/sec/rai

* Figures in parenthesis are reduction factors of drainage modulus of farm level

4. Standardization of Design criteria

It is ten years since the Land Consolidation Act was officially promulgated and more than 100,000 ha have already constructed. RID should have assembled much data through implemented projects. This is the time to establish the standard criteria for land consolidation.

The reason why it should be established are:

i) The Thai government invests a great deal of capital in the land consolidation projects every year while on the other hand beneficiaries have a responsibility to refund their debts.
From this point of view, at present, each project has different criteria.

ii) Elimination or reduction of labor of planning and designing

Thailand, of course, can be divided into four regions and they have different climatic conditions and not only the soil property but also the topography varies.
Consequently, the contents of the standard criteria might be limited to general matters such as common factors as to whole proposed area should be decided. Manuals will be able to supplement other matters which are different in each region.

I. Guidelines for design of on-farm works for ChaoPhya Irrigated Agriculture Development Project

(prepared by ILACO for official training)

1. Design criteria

1.1 Irrigation Ditches

The ditches are designed with a minimum capacity of 0.17 l/sec/rai or about 9 mm/24 hours. The design capacity of the main irrigation system amounts to 0.13 l/sec/rai. The slightly higher capacity of the on-farm irrigation system has been adopted for two reasons. Firstly, to cope with the additional water supply when during the wet season the main system is sometimes operated at more than full capacity. Secondly, to allow a proper rotation of the water supply among the service units during the dry season, when the main system is sometimes operated at partial supply.

The discharge should always be a multiple of 30 l/sec, depending on the area commanded as shown in Table I.1.

Table I.1 - Discharge table for irrigation

Area commanded in rai	Discharge in l/sec
0 - 175	30
176 - 350	60
351 - 525	90
526 - 700	120
701 - 875	150
876 - 1,050	180

The supply of each farm outlet should be 30 l/sec. It is felt that this amount can be handled by a farmer's family. If rice is grown, this will certainly cause no difficulties. For upland crops, additional labour will be needed to handle the flow. For farm intakes asbestos-cement pipes with a diameter of 0.20 m are used. A supply of 30 l/sec to the farm means some 0.10 m head loss in the pipe. The pipes have no gates, but have to be closed with home-made plugs or mud dams around the down-stream end of the pipes.

The maximum area to be served per outlet is 25 rai. Larger holdings are given more than one outlet. In case of small holdings there is sometimes one outlet for two holdings but, in general, every holding has its own inlet pipe.

The minimum bed width should be 0.5 m. The width should remain uniform as long as possible, also in order to facilitate maintenance activities.

The minimum slope should be 20 cm/km. A steeper slope, however, leads to a better cross-section and a more favourable water flow. In determining the slope, it should be reckoned with that structures account for part of the head losses. It is not necessary to fix a maximum slope for the ditches in the project area.

The maximum velocity allowed is 0.50 m/sec. Owing to the very flat topographical conditions in the project area this velocity will not easily be surpassed in the irrigation ditches and drains.

The dimensions of minor irrigation ditches have been designed according to the Chezy Manning formula for a uniform steady flow. The dimensions have been worked out in Table I.2.

Table I.2 - Dimensions of irrigation canals with side slopes 1 : 1 and K_m = 20 [1)]

Discharge in l/sec	0.2 % o 20 cm/km			0.3 % o 30 cm/km			0.4 % o 40 cm/km			0.5 % o 50 cm/km			0.6 % o 60 cm/km			0.7 % o 70 cm/km			0.8 % o 80 cm/km			1.0 % o 100 cm/km		
	b [2)]	d [3)]	v [4)]	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v
30	0.50	0.36	0.10	0.50	0.32	0.11	0.50	0.30	0.13	0.50	0.28	0.14	0.50	0.26	0.14	0.50	0.26	0.15	0.50	0.24	0.16	0.50	0.23	0.18
60	0.50	0.51	0.12	0.50	0.46	0.14	0.50	0.43	0.15	0.50	0.40	0.16	0.50	0.39	0.18	0.50	0.38	0.19	0.50	0.36	0.20	0.50	0.34	0.21
90	0.60	0.59	0.13	0.60	0.53	0.15	0.50	0.53	0.17	0.50	0.50	0.18	0.50	0.48	0.20	0.50	0.46	0.21	0.50	0.44	0.22	0.50	0.42	0.23
120	0.60	0.68	0.14	0.60	0.62	0.16	0.60	0.57	0.18	0.50	0.56	0.19	0.50	0.54	0.21	0.50	0.53	0.22	0.50	0.51	0.24	0.50	0.48	0.25
150	0.70	0.72	0.15	0.70	0.65	0.17	0.60	0.64	0.19	0.60	0.60	0.21	0.60	0:58	0.22	0.60	0.55	0.24	0.50	0.57	0.25	0.50	0.54	0.27

1) Calculated with the Manning formula

$v = k_M R^{2/3} S^{1/2}$, in which:
- v = water velocity in $m.sec^{-1}$
- k_M = roughness coefficient in $m^{1/3}.sec^{-1}$
- R = hydraulic radius in m
- S = slope, dimensionless

2) b = bed width in m

3) d = water depth in m

4) v = velocity in $m.sec^{-1}$

As vegetation and minor obsturctions will hinder the flow considerably in these small watercourses, a roughness coefficient of k_m = 20 has been adopted.

As the soils are fine-textured and the irrigation ditches are small, the side slopes have been taken at 1 : 1.

The design of the water level in a canal depends entirely on the water levels needed in the plots. These so-called demand levels are the average surface levels of the highest lying parts plus 0.20 m (10 m for water-depth and overcoming irregularities in the surface and 10 cm for head losses in the inlet pipe and the field supply ditch). All other levels in the design, like bank, road and bed levels, are derived from the water level in the canal.

The design water level of the irrigation ditch should be such that it can cope with the full supply even if the supply canal runs at 70 % of full supply.

The minimum free board in the irrigation ditch should be 0.3 m.

The bank level is the water level plus free board.

The bed level is the water level minus water depth.

The road level is the water level plus free board plus 0.10 m.

The diameter of the culverts should be not less than 0.40 m.

1.2. Drains

A drainage modulus of 46 mm/24 hours or 0.85 l/sec/rai has been adopted for areas not exceeding 2,000 rai. The drains in the service units belong to this category.

In Table I.3 the discharge related to the area to be drained has been indicated.

Table I.3 - Discharge table for drains

Area to be drained in rai	Discharge in m^3/sec
Less than 100	0.085
Between 100 and 200	0.170
" 200 " 300	0.255
" 300 " 400	0.340
" 400 " 500	0.425
" 500 " 750	0.635
" 750 " 1,000	0.850

The dimensions of the drains are calculated with the Chezy Manning equation, taking the side slopes at 1 : 1 (Table I.4)

Table I.4 - Dimensions of drains with side slopes 1 : 1 and $k_M = 40$ [1)]

Discharge in l/sec	Slope																							
	0.2 % o			0.3 % o			0.4 % o			0.5 % o			0.6 % o			0.8 % o			1.0 % o			1.5 % o		
	b [2)]	d [3)]	v [4)]	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v	b	d	v
85	0.50	0.43	0.21	0.50	0.39	0.25	0.50	0.36	0.28	0.50	0.34	0.30	0.50	0.32	0.32	0.50	0.30	0.36	0.50	0.28	0.39	0.50	0.25	0.44
170	0.50	0.61	0.25	0.50	0.55	0.30	0.50	0.51	0.33	0.50	0.48	0.36	0.50	0.46	0.38	0.50	0.43	0.42	0.50	0.40	0.46	0.50	0.36	0.54
255	0.60	0.70	0.28	0.60	0.63	0.33	0.60	0.59	0.36	0.50	0.59	0.39	0.50	0.57	0.42	0.50	0.52	0.47	0.50	0.50	0.52	0.50	0.44	0.60
340	0.70	0.77	0.30	0.70	0.69	0.35	0.70	0.64	0.39	0.70	0.61	0.42	0.60	0.62	0.45	0.60	0.57	0.51	0.60	0.54	0.55	-	-	-
425	0.80	0.82	0.32	0.70	0.78	0.37	0.70	0.72	0.41	0.70	0.68	0.45	0.70	0.65	0.48	0.70	0.61	0.53	0.70	0.57	0.59	-	-	-
635	1.00	0.93	0.35	0.90	0.87	0.41	0.90	0.81	0.46	0.80	0.80	0.50	0.80	0.76	0.53	0.80	0.71	0.59	-	-	-	-	-	-
850	1.10	1.04	0.38	1.00	0.98	0.44	0.90	0.94	0.49	0.90	0.89	0.54	0.90	0.85	0.57	-	-	-	-	-	-	-	-	-

1) Calculated with the Manning formula

$v = k_M R^{2/3} S^{1/2}$, in which : v = water velocity in $m.sec^{-1}$

k_M = roughness coefficient in $m^{1/3}.sec^{-1}$

R = hydraulic radius in m

S = slope, dimensionless

2) b = bed width in m

3) d = water depth in m

4) v = velocity in $m.sec^{-1}$

A roughness coefficient of K_m = 40 has been adopted.

The minimum slope is taken at 20 cm per kilometre.

The minimum bed width should be 0.50 m. It is important that the bed width should be kept the same as much as possible. It is better to have an overcapacity in part of the drain together with a uniform bed than and adapting capacity with a varying bed width.

The depth of the drain must be at least 0.6 m below the average surface level. In depressions the minimum drain depth to be allowed is 0.5 m.

In drains with a profile larger than the minimum profile the supply level should be designed 0.10 m below the surface level. The 0.10 m extra head is needed to discharge the water from the fields into the drains.

Abrupt changes in bed level, due to a larger area to be drained, have to be avoided. If the difference in level is more than 0.50 m, a drop structure with protection of downstream bed and side slopes has to be considered. Smaller differences in level can be overcome by giving the upstream drain a steeper slope and thus an overcapacity.

The maximum velocity permitted is 0.50 m/sec. In small drains with a steeper slope adapted to a lower bed level of the collector drains, this maximum permissible velocity should not be surpassed.

1.3. Farm Roads

The road width should be 4.5 m, namely 3.5 m top width and 0.5 m shoulder at either side.

In order to obtain proper dewatering of the road, the top level of the road body must always be 0.1 m higher than the bank level of the irrigation ditch. For the same reason, the road must be an average 0.6 m above the surface level of the plots. This last criterion is especially important if the road traverses an area not commanded by gravity irrigation.

It is difficult to give quantitative specifications for road building. Anyway, the road body should contain no organic matter and it should be very well compacted.

2. Design of irrigation ditches and farm roads

The design sequence is shown in Figures II.1A through II.1E and in Figure II.2.

step 1 - Draw the new cadastral layout on the spot height map.

step 2 - Draw the proposed future outlets to the plots of each ditch on the spot-height map, situating them opposite the heighest-lying parts of the plot. The demand level, which is the supply level required in the ditch to allow gravity irrigation in the plot, is also noted down at every outlet. This map is used for the next step. (Fig. II.1D)

step 3 - Make a longitudinal profile of the actual situation of the ditch under design on millimetre paper. Indicate the locations of the various outlet pipes in the longitudinal profile and indicate their related demand levels on the vertical axis. The proposed water level must now meet the demand levels. Drop structures, check structures, culverts and division boxes have to be taken into account because they also may influence the design of the water level.

3.1 (See Figures II.1D and II.1E) The location of a division box is obvious. It should be determined how the discharge can best be divided. If head were available, the distribution would be Q_3 = 30 l. for canal section D - E, Q_2 = 60 l. for canal section D - B - C. In this example, however, no head is available. As the irrigated areas of Q_2 and Q_3 are very unequal, a division of the discharge is impossible. Therefore, both Q_2 and Q_3 have to be designed for full supply. The division box is then operated by closing one outlet and opening the other one completely.

3.2 At location A in Fig. II.1E, one check should be installed at 400 m distance from the C.H.O. Irrigation should be effected by $\frac{90}{30}$ = 3 pipes simultaneously. There are only 2 pipes between the check and the division box. A rotation schedule is impossible for this sector. The topography also counteracts the installation of a check at location A, because it is a depression. From a topographical point of view location B is more favourable.

CONTOUR MAP

Scale approximate 1 : 5000

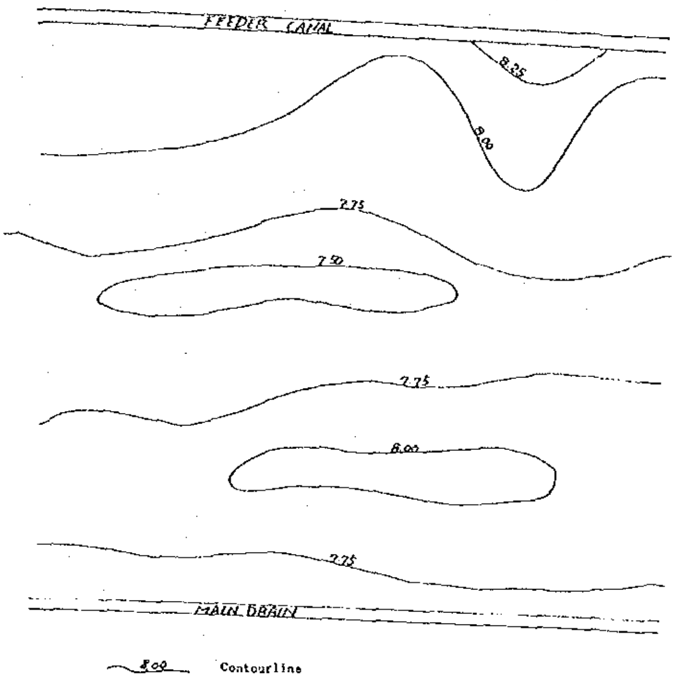


Fig.II.3A

LAYOUT

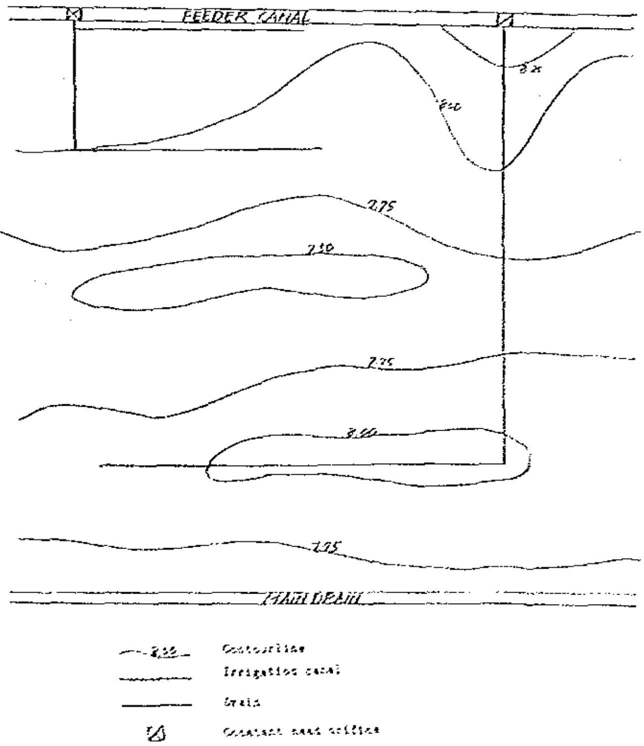
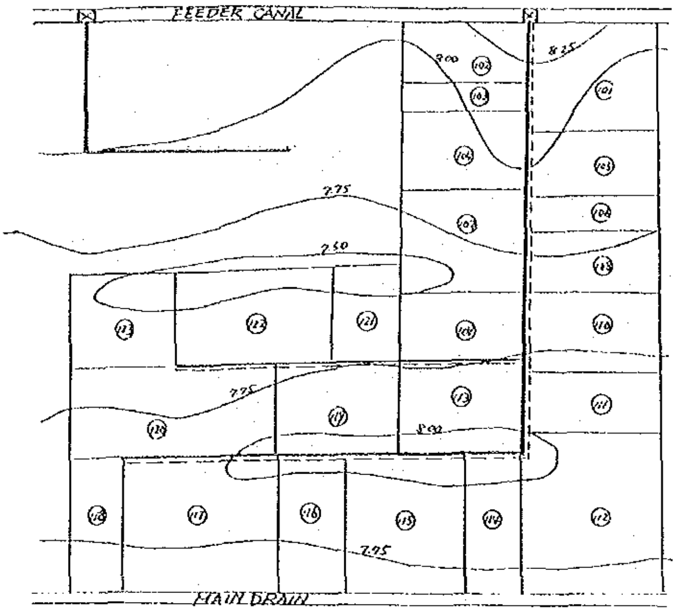


Fig. II.3B

REALLOCATION PLAN

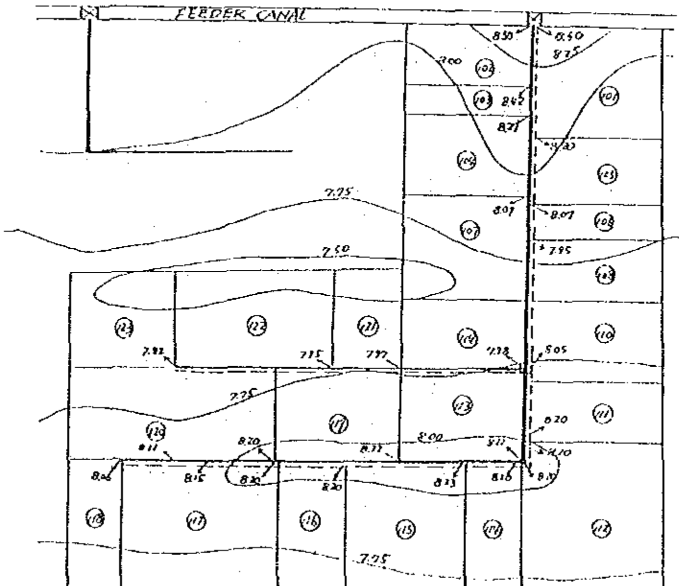


Contourline
Irrigation canal
Drain
Farm road
Plot boundary
Plot number
Constant head orifice

Fig. II.1C

DESIGN OF IRRIGATION CANALS AND ROADS

STEP 2 DETERMINE THE LOCATION OF IRRIGATION INLETS AND THE DEMAND LEVELS



Contourline
Irrigation canal
Drain
Farm road
Plot boundary
Plot number
Constant head orifice

7.95 Irrigation pipe with demand level
Division box

The road is planned at that side of the canal where it minimizes the amount of culverts in the canal

Fig. II.1D

DESIGN OF IRRIGATION CANALS AND ROADS

STEP 3 DETERMINE THE LOCATION OF STRUCTURES

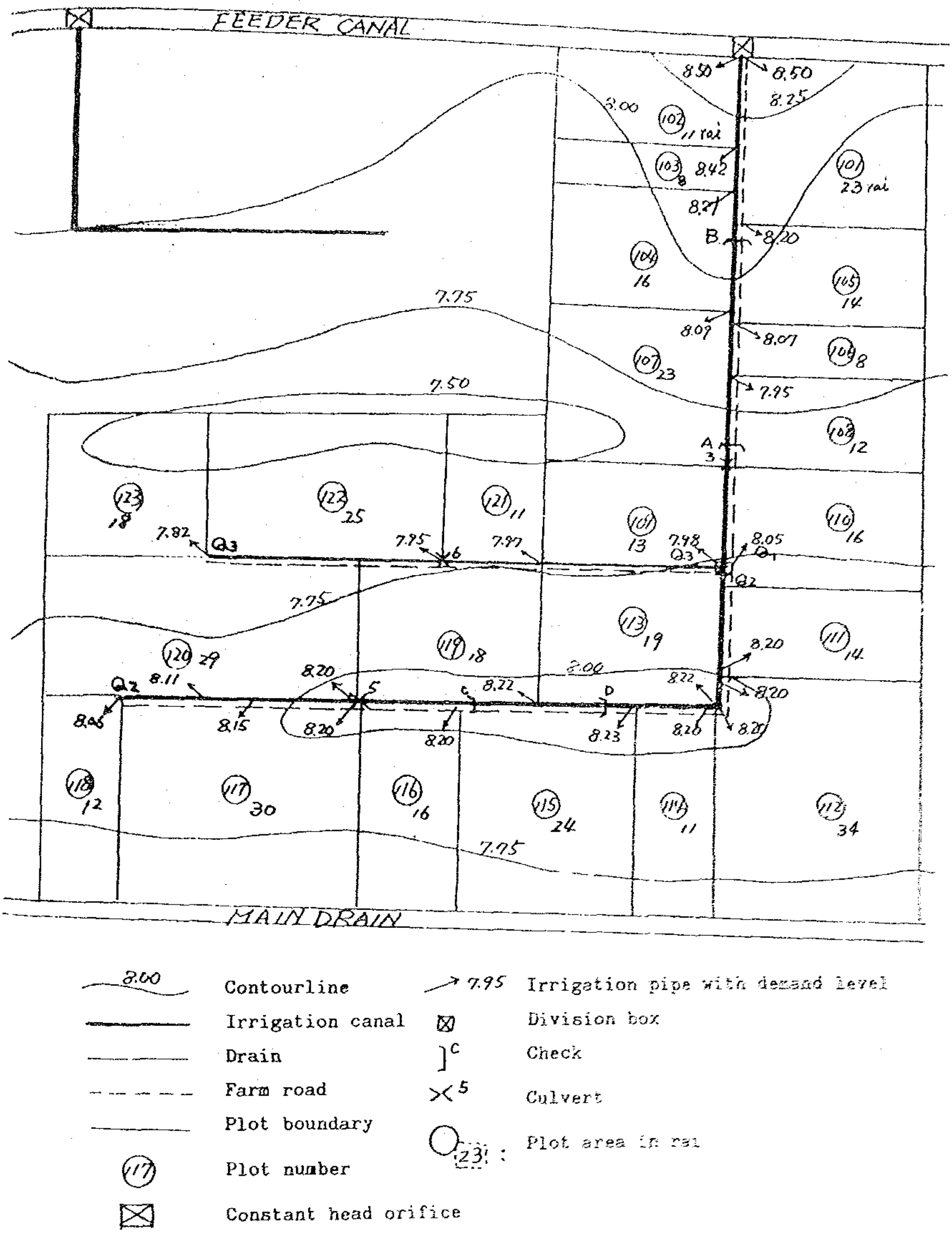


Fig. II.12

It should now be investigated whether a rotation schedule is possible for both the upstream and the downstream areas.

101	-	23 rai	→ combination 1
102	-	11 rai	→ combination 3
103	-	8 rai	→ combination 2
104	-	16 rai	→ combination 2
105	-	14 rai	→ combination 3
		72 rai	

Thus each combination of pipes irrigates about 24 rai, so upstream of the check structure at location B a rotation schedule is possible.

106	-	8 rai	→ combination 2
107	-	23 rai	→ combination 1
108	-	12 rai	→ combination 3
109	-	13 rai	→ combination 3
110	-	16 rai	→ combination 2
		72 rai	

Again, each combination irrigates about 24 rai, so in the sector between the check structure at location B and the division box a rotation schedule is possible as well.

Therefore, the check structure will be located at point B, while location A is abandoned.

Downstream of the division box, at 400-m distance, point C is indicated. This is a high spot, so there are no objections as regards topography. Is a rotation schedule possible?

111	-	14 rai	
112	-	34 rai	→ if necessary, 2 pipes
113	-	19 rai	
114	-	11 rai	
115	-	24 rai	
119	-	18 rai	
		120 rai	

Each combination would cover 40 rai. As three combinations of 40 rai are impossible, no rotation schedule can be applied.

Therefore, the location of the check should be changed, preferably in upstream direction. There are many irrigation pipes in the bend of the ditch. It would be recommendable to place the check nearer to these points. Location D is tried.

111 - 14 rai ⟶ combination 3
112 - 34 rai ↘ (if necessary, 2 pipes) combination 1
113 - 19 rai ⟶ combination 3
114 - 11 rai ↘
115 - 24 rai ⟶ combination 2
102 rai

Each combination covers about 34 rai.

Thus a rotation schedule upstream is possible.

116 - 16 rai ⟶ combination 1
117 - 30 rai (if necessary, 2 pipes) ↗ 1 pipe 19 rai com.*1 ↘ 1 pipe 11 rai com.*3
118 - 12 rai ⟶ combination 3
119 - 18 rai ⟶ combination 2
120 - 29 rai (if necessary 2 pipes) ↗ 1 pipe 17 rai com.*2 ↘ 1 pipe 12 rai com.*3

Each combination covers about 35 rai.

A rotation schedule downstream is possible, too.

Thus, point D is suitable for the location of a check, whereas point C is cancelled.

3.3 Only the plots at the ditch side of the road have to be opened up. Normally, plot 102 is accessible by means of the O&M. road along the main canal. If this is not the case, culvert 1 should be projected. Culvert 2 opens up plots 103 and 104, Culvert 3 plots 107 and 109. Culvert 4 is intended for the road crossing to plots 113, 121, 122 and 123. Culvert 5 makes plots 119 and 120 accessible and culvert 6 plots 121 and 122. If the culverts are designed with a diameter of 0.50 m, the losses are 2 cm per culvert (See Fig. II.3). Even at a minimum slope of 2 cm per 100 m, there is no fear of accumulation of backwater. In this

*Combination

case, another 1 cm per 100 m may be used for backing up the water in the culverts. The case is different if the culverts are designed with a 0.40 m diameter. Then the losses are 4.5 cm per culvert. Culverts 1 and 2 together accumulate 9 - 3 = 6 cm backwater in the C.H.O. This may cause a less efficient operation of the C.H.O., especially in the case of divided discharges. Then the designed full supply water level behind both culvert 1 and culvert 2 should be lowered by 4 cm.

step 4 - (See Fig. II-2)

- The design water level of the ditch should be such that it can cope with the full supply if the lateral is operated at 70 %. This means that the proposed water level plus minimum losses in the C.H.O. and culvert should not be higher than the water level of the lateral at 70 % supply. The average minimum loss in the C.H.O. can be taken at 0.15 m. The constant head loss of the first gate is 0.06 m. The exact loss of the second gate and culvert can be derived from Fig. II-3.

Often the criterion of 100 % supply in the service unit with 70 % in the lateral cannot be fulfilled. Therefore, it should be determined how large the area not under command with partial supply of the lateral will be, taking into account existing structures in the laterals. If this area is too large, there are two possibilities to solve the problems, viz:

a. always operate the lateral at full supply
b. build an additional check structure in the lateral.

The designer should discuss this problem with the appropriate authorities to decide which is the best solution. If the area, not under command at partial supply of the lateral, is small, it is not strictly necessary for the designer to take immediate action. The area not commanded with partial supply being small or large, the designer must adapt the water level in the service unit to the existing situation. In the first ditch section this means a designed water level just behind the C.H.O. equal to the water level in the lateral at 70 % supply minus 0.15 m losses. From the C.H.O onwards the water level decreases with a minimum slope to the point where it intersects the desired water level determined earlier. After this point the water level is again determined. The water levels in the laterals at partial supply can be derived from the original design with the help of table II.1. However, it should be noted that the levels in the original designs of the laterals were changed during construction.

Table II.1 - Water depths in canals supplying service units

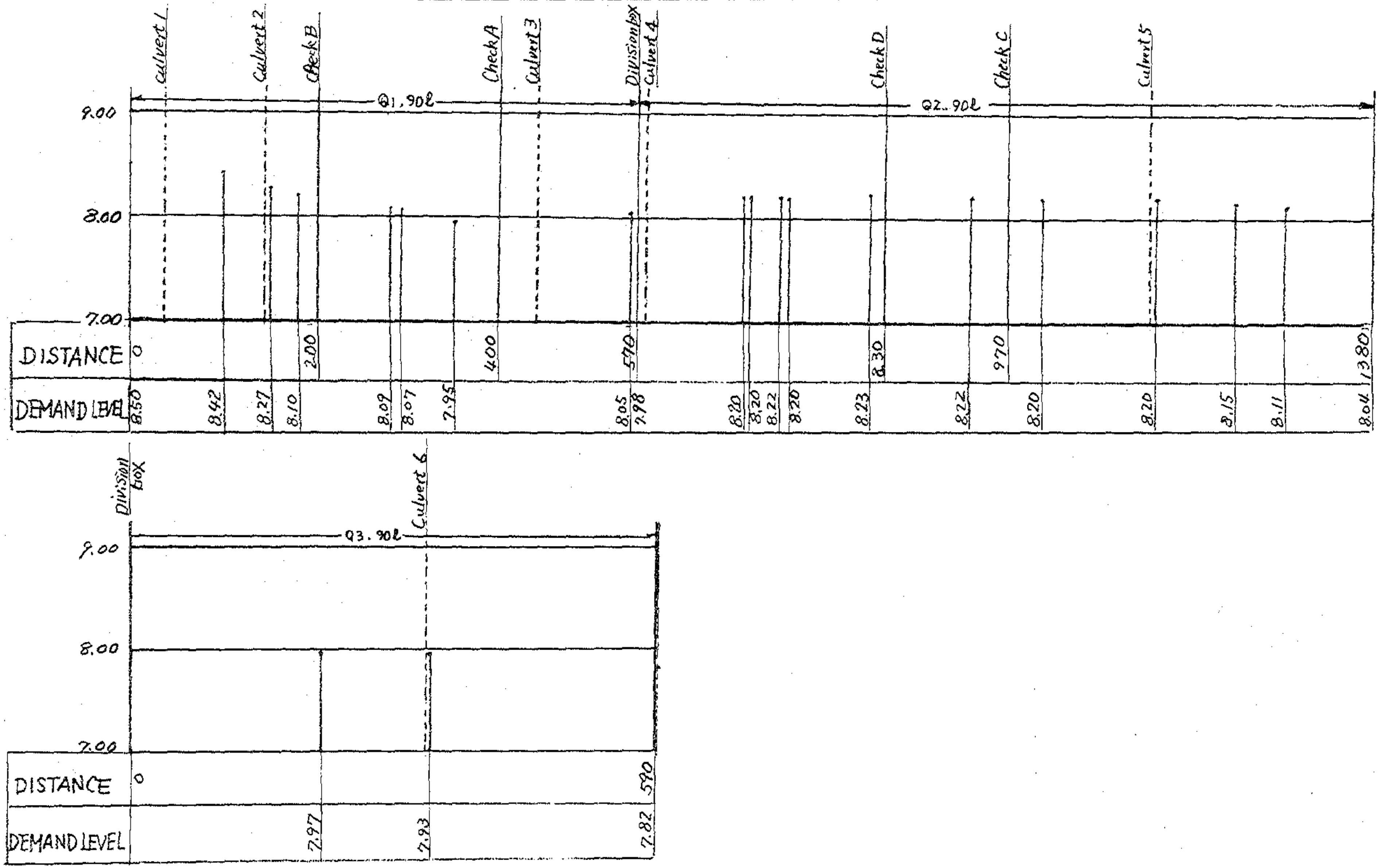
100 % supply	80 % supply		70 % supply	
d^*_{100}	d_{80}	Difference between d_{100} and d_{80}	d_{70}	Difference between d_{100} and d_{70}
0.80	0.70	0.10	0.66	0.14
1.00	0.88	0.12	0.82	0.18
1.20	1.06	0.14	0.98	0.22
1.50	1.32	0.18	1.23	0.27
1.80	1.58	0.22	1.48	0.32
2.00	1.76	0.24	1.64	0.36
2.50	2.20	0.30	2.05	0.45
3.00	2.64	0.36	2.46	0.54

* d = water depth in m.

Fig. II.2

DESIGN OF IRRIGATION CANALS AND ROADS

STEP 4 DEMAND LEVELS IN LONGITUDINAL PROFILE



HEAD LOSSES IN CULVERTS OF LESS THAN 10m LENGTH

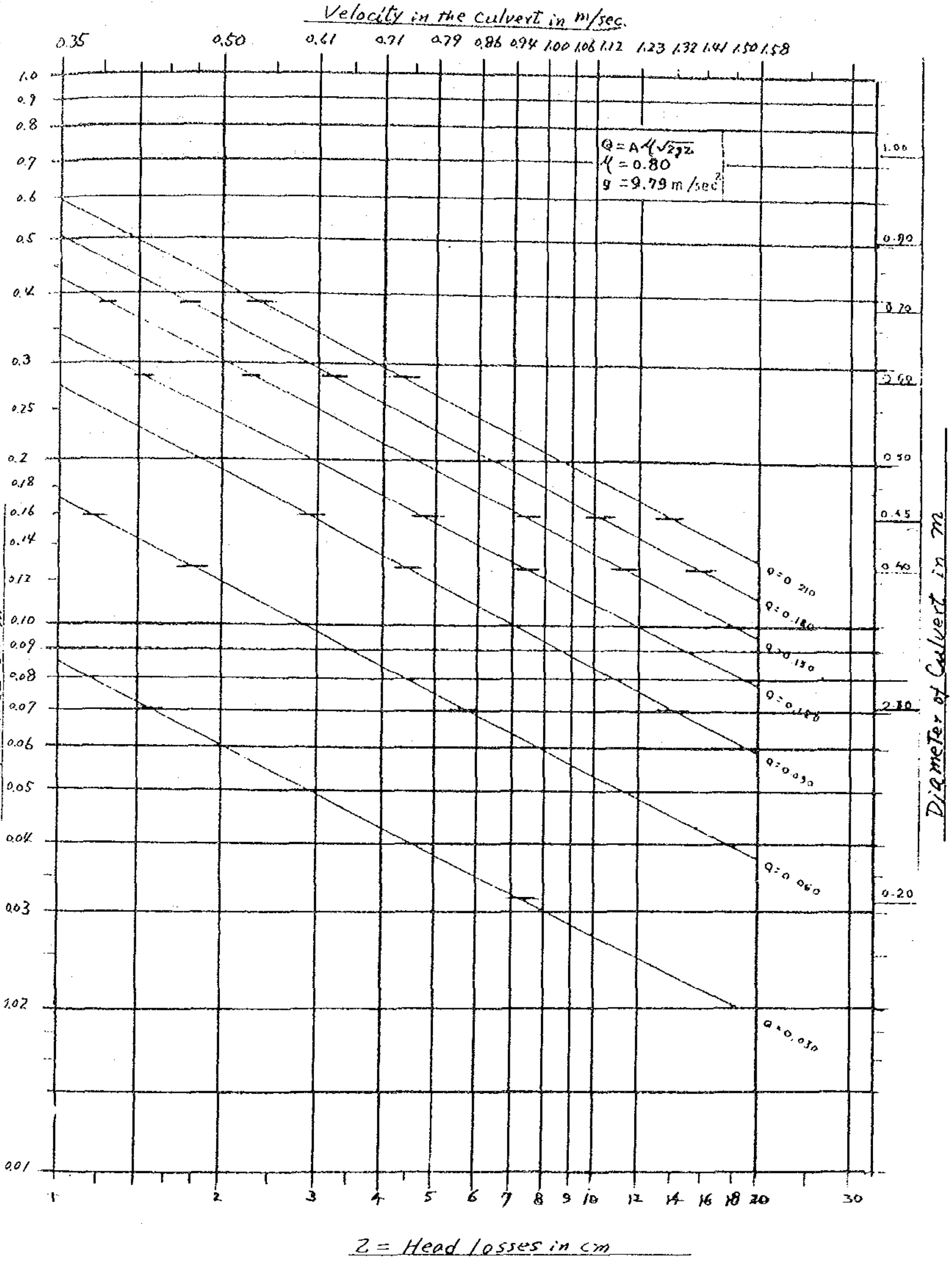


Fig II.3

step 5 - Next, the bed, bank and road levels are derived from the design water level according to the criteria. As stated earlier, the changes in slope resulting in a change in water depth can best be realized at a culvert or drop structure.

step 6 - In addition to the farm roads along the ditches, connecting and maintenance roads along the main drain should be designed. Especially the maintenance road along the main drain should be located high enough above the field surface to allow the passage of vehicles while the fields are irrigated. Generally this will be 1 m above the field level. In case individual fields dewater into the main drain, culverts through the bank have to be provided for. It is better practice to have all fields drain into collector drains.

3. Design of structures

The designs and drawings of all structure are made by personnel engaged in land consolidation according to the regulations and specifications of the Design Section of the Technical Division of the Royal Irrigation Department.

3.1 Culverts

Culverts are necessary obstacles in a ditch to provide access to the plots. Normally, a culvert is located at the boundary between two plots giving access to both. Though one culvert causes only a few centimetres of head losses, many culverts together cause a considerable amount of head losses. Only half of the available slope in the canal should be used for head losses in the culverts. Especially in flat areas like the project area,the danger exists that the backwater curve upstream of a culvert has not faded out at the preceding culvert, resulting in accumulating of head losses. If there are many culverts in a ditch, the discharge may become less than originally designed. In designing, it should, therefore, be made sure that the backwater curve of a culvert does not influence the head loss of the preceding culvert.

With the help of Figure II.3, the head losses in culverts can be determined. The available slope, taking into account head losses between a culvert and the preceding structure, is known. If the actual head losses are higher than the available fall, a small drop in the water level downstream of the preceding culvert is necessary. The drop in the water level must be as high as the head losses in the culvert. In practice, a very small drop in the water level behind a culvert is easily realized without consequences for the structure. For this reason, changes in slope, bed width and water depth should preferably coincide with a culvert. The diameter of culverts should be not less than 0.40 m, because smaller culverts easily block up and are difficult to maintain. Preferably, only culverts of at least 0.50 m diameter should be used.

3.2. Constant head orifices

The inlet structures supplying the irrigation ditches in the service units are constant head orifices (C.H.O.'s) as recommended in the Northern Chao Phya Study. With a C.H.O., the water flow is regulated and measured in the same structure. The C.H.O. consists of a stilling pool and two gates, viz. the orifice gate and the turnout gate placed on the upstream and downstream sides of the pool respectively. The first gate regulates the degree of opening and the second gate the water depth downstream of the orifice. Thus it is possible to keep a constant difference in head on the orifice with the help of the turnout gate. With a constant head and a constant orifice gate opening, the discharge will be constant. If the water level downstream of the structure is designed rather low, a sill has to be constructed to maintain a constant downstream water level and to prevent the outflowing water from scouring the bank and the bed of the irrigation ditch. Generally, the C.H.O.'s designed for the land consolidation project are standardized with a 0.40 m wide orifice gate.

3.3. Check structures

Check structures are designed in the irrigation ditches in the service units to secure a full supply level at partial water supply of the laterals by backing up the water during irrigation. The influence of a check structure on the backwater curve is estimated to be about 400 m. The location of check structures should not be based entirely on this distance. more important for their location is the topography of the plots expressed in demand levels. There where the demand levels are highest irrigation is difficult, so these places are the most suitable for locating a check structure to secure the supply levels. Moreover, the location of a check structure should fit in a future irrigation rotation schedule. To check the latter requirement, the following procedure is used.

Divide the total ditch discharge (Q) in X parts of 30 litres ($X = \frac{Q}{30}$) Each part of 30 l is to irrigate an area Y, equal to the total area (A) between two checks, divided by X ($Y = \frac{A}{X}$). Write down the pipe numbers between the checks with the areas commanded by them. Try to make X combinations of Y rai with the areas commanded by each pipe.

Example : Assume the ditch discharge to be 90 l/sec. Then $X = \frac{90}{30} = 3$

When the area between two checks is 90 rai, $Y = \frac{90}{X} = 30$ rai

Pipe number	Area commanded
1	10 rai
2	25 rai
3	10 rai
4	5 rai
5+6	30 rai (one owner with two pipes)
7	10 rai

To make 3 combinations of 30 rai each :

I pipe numbers 2 + 4

II pipe numbers 1 + 3 + 7

III pipe numbers 5 + 6

If the right combinations can be formed as in the example, an ideal irrigation rotation schedule is possible. In practice, such combinations cannot always be made. Then there are three possibilities, viz.

a) Relocation of the check structure. Unfortunately, this is not always possible due to the topographical conditions.

b) Installation of more inlet pipes. This solution involves higher cost and will, therefore, be adopted only if the pipe combination possibilities deviate very much from the ideal combinations.

c) Accepting the fact that no ideal rotation schedule can be achieved. Sometimes excess irrigation water can be used to fill the downstream canal. Otherwise, this situation will result in a lower operation efficiency.

If the check structure is open, its influence on the water level is negligible and there are practically no head losses. The crest length is preferably designed equal to the bed width. Structural designs and drawings are made according to the R.I.D regulations as in the case of drop structures. The bed and side slope protections of check structures be 0.5 m long upstream and 2 m long downstream. It is advised to make the last metre of the downstream protections of some rough material, e.g. pitching to obtain a more gradual transition from the rather smooth concrete to the rougher earthen ditch.

3.4 Drop structures

A drop structure in a canal is planned if the topographical conditions cause the demand levels in a certain area to be much lower than in the area traversed before. The water levels of ditch sections of different levels are designed separately. If the difference between the water levels is more than 0.30 m, a drop structure is justified. In case the difference is less than 0.30 m, it is better to design the lower water level by means of a steeper slope and thus to save a drop structure. As a drop structure will also function as a check structure, the considerations for the decision concerning its location as mentioned in section 3 above are equally valid.

The crest level of a drop structure should be designed at such a level that the head losses in the structure do not influence the proposed water level. The crest length is preferably designed equal to the bed width. The bed and side slope protections have to be sufficiently long; upstream at least 1 m to prevent piping and seepage; downstream 3 m to prevent scouring. The last 1.5 m of the downstream protections should be of a rough type for the same reason as mentioned in section 3 above.

3.5 Division boxes

In designing the layout of irrigation ditches a subdivision of the ditches cannot always be avoided. In that event a division box will be required. This structure is to divide the water flow into fixed, well-balanced parts without influencing the water level, which is rather difficult.

Only if sufficient head is available to construct the division box as a pair of non-submerged weir, can an acceptable division of flows proportional to the areas to be commanded be obtained.

If no head is available for losses in the structure, a well-balanced division of flow is possible only if the two areas downstream are about the same and the flow can thus be divided into equal parts.

In case the two downstream areas under command are not of the same size and no head is available, the division box and the ditches to be served should be designed for the total discharge.

Example : In a ditch with a discharge (Q) of 120 l/sec. downstream part of the area commanded has to be irrigated by two separate ditches.

	Desired division of flow if proportional to the areas commanded	Q to be designed for outlets of division box and downstream ditches
Head available	60 and 60 l	60 and 60 l
	30 and 90 l	30 and 90 l
No head available	60 and 60 l	60 and 60 l
	30 and 90 l	120 and 120 l

4. Design of drains

step 1 Subdivide the block in which a drain has to be designed into catchment units and calculate their areas. It is advised to subdivide as little as possible in order to avoid too many changes in the drain profile. Determine the discharge for every subdivision of the drain.

step 2 Make a longitudinal profile of the actual situation on millimetre paper for every drain, as done for the irrigation ditches. If the centre line of a drain is located on a level point of the grid system, the actual level is known. If not, the actual level has to be interpolated from the surrounding level points.

step 3 Design a water level, except for drains with a minimum profile where this is unnecessary. Irrespective of the designed water depth, the bed level must be at least 0.60 m below the average surface level. In large drains, with water depths higher than 0.50 m, the water level is designed 0.10 m below the average surface level. The drain should be dimensioned according to Table I.4. Often the bed level of the downstream part of a drain is lower than the bed level of the upstream end with a minimum profile. The difference in bed levels is due to either a steep slope in the upstream part or a large catchment resulting in higher discharge and a higher water depth in the downstream part. In this case the bed level of the drain with a minimum profile can best be adapted to the level of the larger drain by giving it more slope. Of course this causes an overdimension of the small drain. As, however, especially in the smaller drains maintenance is generally poor, the overdimension replaces a few maintenance passes. If the difference in bed levels between two parts is too wide to be covered by slope adaptation, a drop structure has to be designed. This can be a very plain structure. Protections of side slopes and bed, and a sill at the downstream end will suffice.

step 4 Take care that the bed of the drain under design is situated about 0.10 m higher than that the collector drain. If the bed level of the drain is 0.30 m or more higher than that of the collector drain, it is better to adapt the slope or build an end structure. This end structure can be a simple side slope bed protection.

step 5 Have the designed drains drawn and meanwhile check the alignments in the field, if necessary. The necessity of checking can be derived from the aerial mosaics as follows. The centre lines of the drainage system are transferred to the mosaics. If they pass a suspected spot, a check in the field is required. Check also whether the main drain is not obstructed. It is senseless to design and construct an on-farm drainage system if the main drain does not operate properly.

J. STANDARD IN ON-FARM IRRIGATION SYSTEM DESIGN FOR PADDY FIELDS

reported in Thai language at the seminar held at EGAT in Sep. 1983

1. Preface

On-farm irrigation system designing which is discussed is limited only in the work of the Royal Irrigation Department of Thailand. Many steps are lined before and after the designing as follows :

1. Basic determination : What level and how to do are the ones which must be determined on the basis of the expenses or investments.
2. Data preparation:
   1) Soil characteristics and soil profile (25 cm depth) investigations.
   2) Landlord
   3) Landlord's name,location and size of the land.
3. Designing : will be discussed later.
4. Construction
5. Operation and maintenance : generally the Royal Irrigation Department try to push the farmers to manage themselves but, at present, the farmer need a lot of advice and practical trainings.
6. Planting improvement and marketing.

2. Designing steps :

1. Laws : There are 2 laws that back up the development of the paddy field.
   1.1 Dikes and Ditches Act
   1.2 Land Consolidation Act.
2. Irrigation method : Irrigation methods used are:
   2.1 Continuous irrigation : Irrigation water is delivered to the field all the time or everyday delivering just enough water required for each day.
   2.2 Rotational irrigation : Irrigation water is delivered for example weekly. The next irrigation will be 7 days later.

3. Paddy field development levels

3.1 Irrigation ditches based on the Dikes and Ditches Projects : The ditches can pass through any owner's lands which are practical for continuous irrigation. The expense is about 500 baht/rai. The basic data needed is only a contour map. The Dikes and Ditches Act is used.

3.2 Irrigation ditches that go along with the paddy fields : the ditches will run along the boundaries and rotational irrigation can be used. Data for designing and levels of development are differentiated:

- development by using the Dikes and Ditches Act required some contour maps and owner's maps. This is another step of development which is higher than that of 3.1. The construction cost is about 700 - 1,500 baht/rai. Normally, there are no roads but the drainage system may exist.
- development by using the Land Consolidation Acts is another step that is a higher development method than the former ones. There are roads that run into the fields and there are drainage systems. The construction cost is about 2,000 - 3,000 baht/rai.
- data preparations for designing need spot height maps, contour maps, landlord's maps and owner's names.

3.3 Complete designing : The irrigation and drainage systems are set properly and the lands are set squarely and levelly. The investment is about 3,500 - 4,000 baht/rai and may be as high as 6,000 baht/rai when land is steep.

4. Calculation for the size of ditches/design ditch discharge

The calculation is determined only for the maximum rate of flow in order to obtain the size of the canal. The rate of flow will be high during the land preparation and during the growth of rice while it is in the drought condition (no rain fall).

Convention Formula

The formula used by the Provincial Water Conservacy Bureau of Tiwan for the determination of maximum canal or pump capacity can be written as:

$$Q = \left[\frac{ADs}{N} + ADt\right]\frac{1}{1-L}$$

where

Q = canal or pump capacity (Maximum Discharge) in m^3/day

A = area to be irrigated in m^2

Dt	=	water requirement after transplanting field, hereafter called maintenance water m/day
Ds	=	Dss + Dst in m.
N	=	time required to prepare area A in days
L	=	conveyance loss in decimals
Dst	=	standing water requirement in m.
Dss	=	soil saturation water requirement in m.
	=	depth of soil saturation x soil void x (1-soil moisture content)

Example :

Depth of soil saturation	=	0.5 m.		
Soil void	=	40 %		
Soil moisture content	=	30 %		
Dss	=	0.5 x 0.4 x (1-0.3)	=	0.14 m.
A	=	300 rai	=	300 x 1,600 m^2
			=	480,000 m^2
Dt	=	8 mm/day	=	0.008 m
N	=	20 days		
L	=	20 %	=	0.2
Dst	=	20 mm	=	0.02 m
Depth of soil saturation	=	0.5 m		
Soil void	=	40 %	=	0.4
Soil moisture content	=	30 %	=	0.3
Dss	=	0.5 x 0.4 x (1-0.3)	=	0.14 m
Ds	=	Dss + Dst		
	=	0.14 + 0.02		
	=	0.16 m		

$$Q = \left[\frac{ADs}{N} + ADt\right]\frac{1}{1-L}$$

$$= \left[\frac{(480,000 \times 0.16)}{20} + (480,000 \times 0.008)\right]\frac{1}{1-0.2}$$

$$= [3,840 + 3,840]\frac{1}{0.8}$$

$$= 9,600\ m^3/day$$

$$Q = 0.111\ m^3/sec$$

The Q above is the maximum discharge which will be used to obtain the size of the canal. The discharge can be daily as :

Amount of water in daily (soaking)

$$= \frac{ADs}{N}$$

$$= \frac{480,000 \times 0.16}{20}$$

$$= 3,840 \ m^3/day$$

Maintaining water requirement is estimated from :

$\frac{A}{N} \times Dt$ in each day

$$= \frac{480,000 \times 0.008}{20}$$

$$= 192 \ m^3/day$$

The increase will depend on the day of delivery eg. day 2 = 192 x 2 and day 7 = 192 x 7 and etc.

$$\text{Total amount of water} = \frac{\text{Soaking water + Maintaining water}}{\text{Efficiency}}$$

Discharge in second = Q day/86,400

Watering for each day

day	Soaking water (m^3/day)	Maintaining water (m^3/day)	Water in m^3/day	Q_3day (m^3/day)	Q_3sec (m^3/day)
1	3,840	192	4,032	5,040	0.058
2	3,840	384	4,224	5,280	0.061
3	3,840	576	4,416	5,520	0.064
4	3,840	768	4,608	5,760	0.067
5	3,840	960	4,800	6,000	0.069
6	3,840	1,152	4,992	6,240	0.072
7	3,840	1,344	5,184	6,480	0.075
8	3,840	1,536	5,376	6,720	0.078
9	3,840	1,728	5,568	6,960	0.081
10	3,840	1,920	5,760	7,200	0.083
11	3,840	2,112	5,952	7,440	0.086
12	3,840	2,304	6,144	7,680	0.089
13	3,840	2,496	6,336	7,920	0.092
14	3,840	2,688	6,528	8,160	0.094
15	3,840	2,880	6,720	8,400	0.097
16	3,840	3,072	6,912	8,640	0.100
17	3,840	3,264	7,104	8,880	0.103
18	3,840	3,456	7,296	9,120	0.106
19	3,840	3,648	7,488	9,360	0.108
20	3,840	3,840	7,680	9,600	0.111
		water in 20 day		146,400 m^3	
after field preparation		3,840	3,840	4,800	0.056

The data above shows that the delivery of water will be increased from the first to the last day of land preparation. The maximum discharge is only for one day in the growing season which is the last day of land preparation.

As a result, one tries to avoid this system and tries to deliver the same amount of water during the period of land preparation.

Wen published the following equation in 1972. The publication was based on his M.S. thesis which was completed in 1970.

$$Q = \frac{ADt}{Ec(1-e-(Dt/Ds)N)}$$

Q = required canal capacity in m^3/day

A = total area prepared in m^2

Dt = maintaining water in m/day

Ds = water requirement for field preparation in m.

N = days to prepare the entire area

Ec = conveyance efficiency in decimals

e = base of natural logarithms

<u>Example</u>

A = 480,000 m^2

Dt = 0.008 m/day

Ds = 0.16 m/day

N = 20

Ec = 0.8

$$Q = \frac{480,000 \times 0.008}{0.8(1-e-(0.008/0.16)20)}$$

= 7,593.488 m^3/day

= 0.088 m^3/sec

Total amount of water = Q x conveyance efficiency

= 7,593.488 x 0.8 = 6,074.791 m^3/day

Maintaining water (MW) = Soaked Area x Dt

Soaking Water (SW) = Usable water - MW

Soaked Area (SA) = SW $\div$ Ds

ΣSA = total area of SA each day

Day	effective water (m^3)	MW_3 (m^3)	SW_3 (m^3)	SA_3 (m^3)	ΣSA_3 (m^3)
1	6,074.791	-	6,074.791	37,967.44	37,967.44
2	"	303.740	5,771.051	36,069.07	74,036.51
3	"	592.292	5,482.499	34,265.62	108,302.13
4	"	866.417	5,208.374	32,552.34	140,854.47
5	"	1,126.836	4,947.955	30,924.72	171,779.19
6	"	1,374.234	4,700.557	29,378.48	201.157.67
7	"	1,609.261	4,465.530	27,909.56	229,067.23
8	"	1,832.538	4,242.253	26,514.08	255,581.31
9	"	2,044.650	4,030.140	25,188.38	280,769.69
10	"	2,246.158	3,828.633	23,928.96	304,698.65
11	"	2,437.589	3,637.202	22,732.51	327,413.16
12	"	2,619.449	3,455.342	21,595.89	349,027.05
13	"	2,792.216	3,282.575	20,516.09	369,543.14
14	"	2,956.345	3,118.446	19,490.29	389,033.43
15	"	3,112.267	2,962.524	18,515.77	407,549.20
16	"	3,260.394	2,814.397	17,589.98	425,139.18
17	"	3,401.114	2,673.677	16,710.48	441,849.66
18	"	3,534.797	2,539.994	15,874.96	457,724.62
19	"	3,661.797	2,142.994	15,081.21	472,805.83
20	"	3,782.447	2,292.344	14,327.15	487,132.98
21 = A x Dt = 480,000 x 0.008 = 3,840 m^3/day = 0.044 m^3/sec					

<u>Remark</u> In day 20 water for soaking is delivered more than the required area (480,000 m^2)

Both methods are relied on land preparation and are still complicated for practical use in Thailand, because it's hard to maintain or control the required water especially if there are a lot of laterals which the farmers are not familiar with.

As a result, the study was conducted by starting at Num Pong and Lum Pao projects. In 1979, the data were collected and could be summarized as follows:

1. Farmers still practice the old method as usual as if there is no irrigation system existing.
2. Seedling preparation and transplanting were started when it had rained or when they had recieved the irrigation water.
3. At the same time, the plowing was begun by using family labors. Normally, each family had 2 buffaloes and they could do only ½ rai/day, 3 - 7 rai when they used plowing machine.
4. Seedlings used was about 1 month old while the agriculture extension service suggested that 15 - 20 day-old seedlings would give better result.
5. The second plow before transplanting could be done only at the speed of ½ rai/day.
6. The required maintaining water was about 10 cm. and it could be as low as 7 cm. 10 cm. depth of water in the field outside the irrigation project could last about 15 days.

From the basis above, the delivery of water can be set as follows:

1) At present, the irrigation water should be delivered as the farmers required. When they know the basic operation of the irrigation, the later improvements can be implemented.

2) Transplanting normally is time consuming depending on the capability of land preparation of the farmers. Therefore, at first the delivery water should be done as the interval rotation eg. one time per week.

As the basis are set as the above, the implementation should be as follows:

1. From the available data, the maximum water requirement for dry season is 10 cm, depth which obtained from evaportranspiration plus deep percolation.
2. Therefore, for 7 days needs 7 x 10 = 70 mm depth of water for each field.

3. If soaking is needed for the first plow and seedling bed preparation, the delivery of water may be done for only 1/3 of the field. The field will be ready in 3 weeks and in week 4 the seedlings will be ready for transplanting.
4. The delivery of water for transplanting is the same as for soaking.
5. In each delivery of water, it had to be determined as to who and when to receive the water.

When the farmers get used to the operation and are sure that they will get water in time, the delivery may be done as 8-9 days interval since in some months, the required water may be less than 10 mm/day.

The simple method for delivering water can be set as follows:

1) water requirement for rice = 10 mm/day = 0.01 m/day
2) area = 1 rai = 1,600 m^2
3) 1 rai requires 1,600 x 0.01 = 16 m^3/day
4) conveyance efficiency = 0.8

   required water = 16/0.8 = 20 m^3/day

   required canal capacity $= \frac{20}{24 \times 60 \times 60}$ m^3/sec

   = 0.00023 m^3/sec

   = 0.25 litre/sec

This method cannot be assure as the theory but may be practiced or improved for later application.

5. Structure and cross section area of the ditch

5.1 Ditch capacity : each farm inlet is 30 litre/sec ; therefore, the ditch capacity should be 30, 60, 90, 120 or 150 litre/sec.

5.2 Depth of the ditch : the farm inlet pipe has the diameter of 0.20 mm and will be lined about 5 cm above the bottom floor of the ditch and the delivery water should be at least about 5 cm above the pipeline; therefore, the depth of the ditch will be started at 30 cm and be gradually increased by 5 cm eg. 30,35, 40, 45, or 50 cm.

5.3 Slope gradient : since the size of the ditch is small, the maximum depth of water will be about 55 cm. and when adding about 20 cm of the ditch to the upper part of the dike is only 75 cm. Therefore, the slope gradient will be set as 1 : 1. In the case of sandy soil the slope of 1 : 2 may be used or concrete lining may be constructed.

5.4 The width of the bottom of the ditch : the widths are 30,40,50 cm since the capacity of the employed digging machine can do only the above sizes.

5.5 The size of the dike : the width of the dike is started at 50 cm which can protect the water going into the field and for animal to walk on. If there are any machines used, the size may be varied depending on the neccessity.

6. Longitudinal slope

Normally the longitudinal slope is 1:4,000. If the slope of some area is about 1:500, the concrete structure may be constructed.

The calculation for the size of the ditch by using Manning Formula

$Q = AV$

$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$

Q = maximum discharge, m^3/sec

V = velocity m/sec

N = coefficient of roughness = 0.03

S = longitudinal slope

R = hydraulic radius

= A/P

A = cross section area of the current in the canal, m^2

P = depth of water

Type	Width of the bottom floor of the canal, m	Depth of canal, m	slope			
			Q =30 litre/sec	Q = 60 litre/sec	Q = 90 litre/sec	Q = 120 litre/sec
T_1	0.30	0.30	1:4,000	1:1,500	-	-
T_2	0.40	0.40	-	-	1:1,500	-
T_3	0.50	0.45	-	-	1:4,000	-
T_4	0.50	0.55	-	-	-	1:4,000

7. Construction

7.1 Regulators at farm turnout

7.2 Check structure : it can be constructed as the concrete wall which has a water gate in it.

7.3 Drop or check drop : the construction is built when the land level had been changed. If the level is less than 1 m, the vertical drop may be used while if the level is more than 1 m, the inclined drop may be employed.

7.4 Pipe line : for delivering the water through the obstructions eg. road.

7.5 Division box

7.6 Farm inlet : normally concrete pipes with the diameter of 20 cm are used.

7.7 Regulators at the end of the canal for maintaining the water level or for draining the water.

8. Drainage system

8.1 For draining the excess rainfall.

8.2 For lowering the water table level.

8.3 The amount of water to be drained : will not be discussed in this paper.

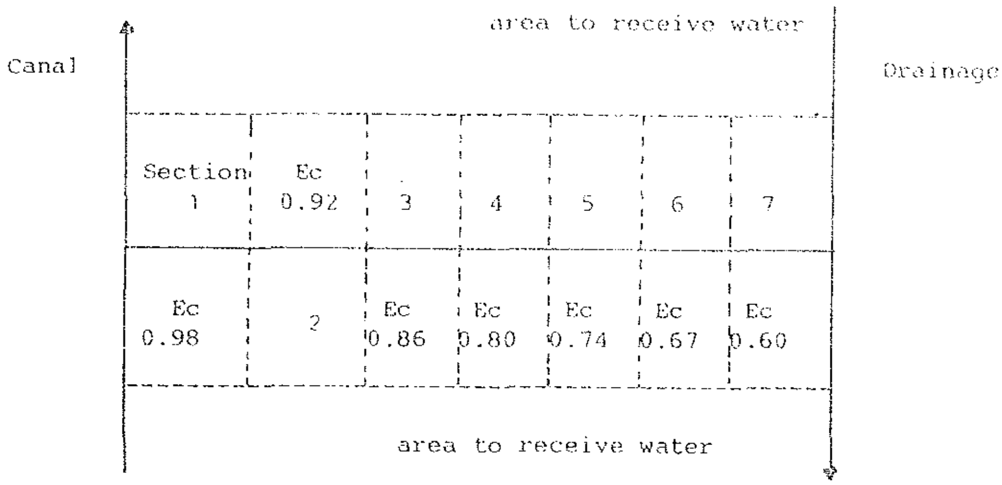
8.4 Drainage construction

8.5 The area may be allowed to be flooded if it is small and if it seldom occurs.

9. Conveyance efficiency

The losses of water are by percolation, leakage of the dike and etc. The efficiency is reduced when the distance is increased as the following table. If the land is soaked already, the losses will be reduced. The average losses that can obtained from this study is about 20 %.

Period	Conveyance Efficiency	Distance, m
1	0.98	250
2	0.92	500
3	0.86	750
4	0.80	1,000
5	0.74	1,250
6	0.67	1,500
7	0.60	more than 1,500



Since the efficiency is reduced depending on the distance, the further area to be irrigated will need more time to get the required amount of water. The schedules may be as follows :

1. Let the farm inlet receive the water of 30 litre/sec.
2. Ditch sizes can be 30, 60, 90, 120 or 150 litre/sec.
3. If the canal capacity is 30 litre/sec, the delivery can be done for 1 farm inlet.

   If 60 litre/sec, delivery will be 2 farm inlet.
   If 90 " " 3 "
   If 120 " " 4 "

4. Let the [illegible] time [illegible] for the [illegible]

[illegible]

Each delivery [illegible]

Irrigation [illegible]

[illegible]

If the conveyance efficiency [illegible] 70 mm depth of water [illegible] the efficiency is reduced, the irrigation area will be reduced as the following table:

Efficiency	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Area (ha)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table [illegible]

Pure (hr)	[illegible]							
	De[illegible]	Section 1 [illegible]	Section 2 [illegible]	Section 3 [illegible]	Section [illegible]	Section [illegible]	Section [illegible]	Section [illegible]
[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	?.964285714	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.5	1.4	1.4	[illegible]	[illegible]	1.2	[illegible]	[illegible]	[illegible]
2.0	1.?	1.2	1.?	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.3	2.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.1	[illegible]
[illegible]	[illegible]	[illegible]	8.9	[illegible]	[illegible]	7.1	6.5	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.8	[illegible]
[illegible]	[illegible]	[illegible]	9.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11.5	11.3	10.9	10.7	9.5	[illegible]	[illegible]	7.4	[illegible]
12.0	[illegible]	11.3	10.6	[illegible]	[illegible]	8.6	7.6	[illegible]
12.5	[illegible]	11.8	[illegible]	10.4	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12.7	12.3	11.5	10.9	[illegible]	[illegible]	8.4	[illegible]
[illegible]	[illegible]	12.8	12.0	[illegible]	10.4	[illegible]	8.7	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	11.6	10.8	[illegible]	9.0	[illegible]
14.5	14.0	13.7	[illegible]	12.3	[illegible]	10.3	9.4	8.4
[illegible]	[illegible]	[illegible]	13.2	12.4	11.6	10.7	9.7	[illegible]
15.5	[illegible]	14.6	13.8	12.9	[illegible]	[illegible]	[illegible]	9.0
16.0	15.4	15.1	14.2	13.3	12.3	11.4	10.3	9.3
16.5	15.9	15.6	14.6	13.7	12.7	11.8	10.7	9.5
17.0	16.4	16.1	15.1	14.1	13.1	12.1	11.0	9.8
17.5	16.9	16.5	15.5	14.2	13.5	12.5	11.3	10.1
18.0	17.4	17.0	16.0	14.9	13.9	12.8	11.6	10.4
18.5	17.8	17.5	[illegible]	15.3	14.3	13.2	12.0	10.7
19.0	18.3	18.0	16.9	15.8	14.7	13.6	12.3	11.0
19.5	18.8	18.4	17.3	16.2	15.0	13.9	12.6	11.3
20.0	19.3	18.9	17.7	16.6	15.1	[illegible]	12.9	11.6
20.5	19.8	19.4	18.2	17.0	15.8	[illegible]	13.2	11.9
21.0	20.2	19.8	18.6	17.4	16.2	[illegible]	13.6	12.1
21.5	20.7	20.2	19.1	[illegible]	16.6	[illegible]	13.9	[illegible]
22.0	21.2	20.8	19.5	[illegible]	[illegible]	[illegible]	14.2	[illegible]
22.5	21.7	21.3	20.0	18.7	17.4	16.1	14.5	[illegible]
23.0	22.2	21.8	20.4	19.1	17.7	16.4	[illegible]	[illegible]
23.5	22.7	22.2	20.9	[illegible]	18.1	16.8	15.2	[illegible]
24.0	23.1	22.7	21.3	[illegible]	18.5	17.1	15.5	[illegible]
24.5	23.6	23.2	21.7	[illegible]	[illegible]	[illegible]	15.8	14.2
25.0	[illegible]	[illegible]	22.2	20.7	[illegible]	17.6	16.2	[illegible]

Time (hr)	Area (rai)							
	Ec=1	Section 1 Ec = 0.98	Section 2 Ec = 0.92	Section 3 Ec = 0.86	Section 4 Ec = 0.80	Section 5 Ec = 0.74	Section 6 Ec = 0.67	Section 7 Ec = 0.60
25.5	24.6	24.1	22.6	21.1	19.7	18.2	16.5	14.8
26.0	25.1	24.6	23.1	21.6	20.1	18.6	16.8	15.0
26.6	25.6	25.0	23.5	22.0	20.4	18.9	17.1	15.3
27.0	26.0	25.5	24.0	22.4	20.8	19.3	17.4	15.6
27.5	26.5	26.0	24.4	22.8	21.2	19.6	17.8	15.9
28.0	27.0	26.5	24.8	23.2	21.6	20.0	18.1	16.2
28.5	27.5	26.9	25.3	23.6	22.0	20.3	18.4	16.5
29.0	28.0	27.4	25.7	24.0	22.4	20.7	18.7	16.8
29.5	28.4	27.9	26.2	24.5	22.8	21.1	19.1	17.1
30.0	28.9	28.3	26.6	24.9	23.1	21.4	19.4	17.4
30.5	29.4	28.8	27.1	25.3	23.5	21.8	19.7	17.6
31.0	29.9	29.3	27.5	25.7	23.9	22.1	20.0	17.9
31.5	30.4	29.8	27.9	26.1	24.3	22.5	20.4	18.2
32.0	30.9	30.3	28.4	26.5	24.7	22.8	20.7	18.5
32.5	31.3	30.7	28.8	27.0	25.1	23.2	21.0	18.8

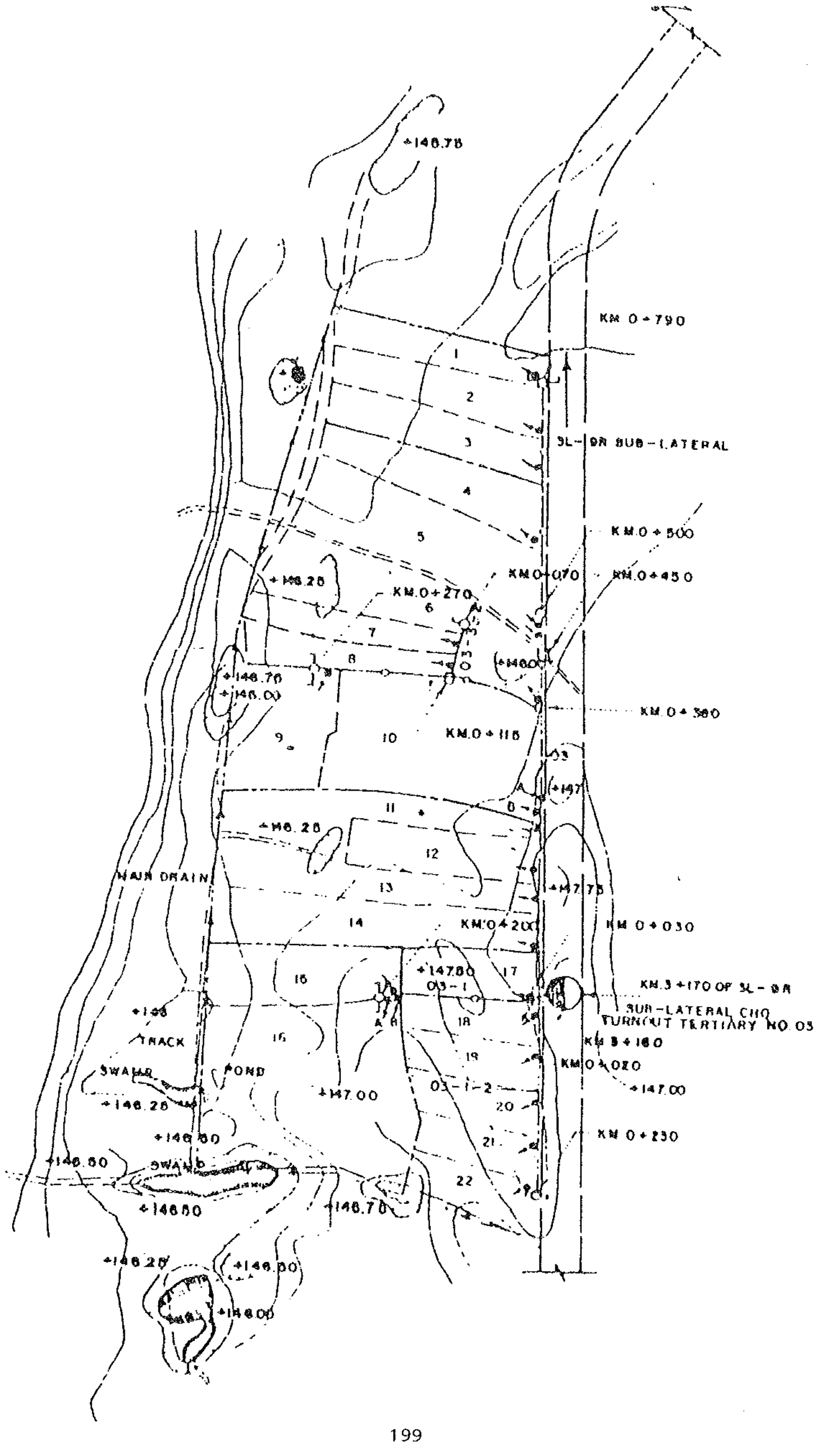
10. Practicing

Simple method for delivering irrigation water:

1. Mapping and numbering the fields to be irrigated and recording the distances between eg. regulators, division boxes and etc.
2. Recording the sizes and locations of the fields.
3. From 2, obtaining the time to irrigate from Table [illegible].
4. Setting time for delivery of irrigation water.

Sample : Delivery schedule

1. Following step 1
2. Size and location of the field


+146.75
KM 0+790
SL-9R SUB-LATERAL
KM.0+500
KM0+070
KM.0+450
+146.25
KM.0+270
+146.75
+146.00
KM.0+380
KM.0+115
+147
+146.25
+147.75
MAIN DRAIN
KM 0+030
KM.0+200
+147.80
KM.3+170 OF SL-9R
SUB-LATERAL CHO
TURNOUT TERTIARY NO.03
KM 3+160
KM 0+020
+147.00
TRACK
SWAMP
POND
+146.25
+147.00
KM 0+230
+146.50
+146.50
SWAMP
+146.50
+146.75
+146.25
+146.50
+146.00

STEP 2				STEP 3
canal	field number	area (rai)	located in the area of canal	time required-hr
03-1-2 from the main canal	17	5.6	1	6.0
	18	4.9	"	5.5
	19	5.1	"	5.5
	20	5.1	"	5.5
	21	5.1	"	5.5
	22	7.2	"	7.5
	TOTAL	33.0		35.5
03-1 200 m from the main canal	15	12.1	1	13.0
	16	34.4	"	47.0
	TOTAL	46.5		60.0
03 380 m from the main canal	14	15.4	2	17.5
	13	10.2	"	11.5
	12	7.7	"	9.0
	11	12.7	"	14.5
	10	24.1	"	27.0
	TOTAL	70.1		79.5
03-3 and 03-3-3 650-575 from the main canal	9	11.7	3	14.0
	8	6.7	"	8.0
	7	5.6	"	7.0
	TOTAL	24.0		29.0
03 790 from the main canal	6	17.8	4	23.0
	5	2.0	"	26.0
	4	11.0	"	14.5
	3	9.5	"	12.5
	2	9.3	"	12.0
	1	7.4	"	9.5
	TOTAL	57.0		97.5
Grand Total		230.6		301.5

From the total area, the discharge of the ditch is

$$Q = 230.6 \times 0.00023$$
$$= 0.053 \ m^3/sec$$

actual Q use = $0.06 \ m^3/sec$ or 60 litre/sec

Therefore, the canal can deliver the water for 2 farm inlets and the actual very time = total delivery time ÷ 2

canal	Total delivery time (hr)	Actual delivery time (hr)
13-1-2	35.5	17.75 use 18
03-1	60	30
03 first part	79.5	39.75 use 40
03-3 and 03-3-2	29	14.5
03 last part	97.5	48.75 use 49

Time schedule

The ditch 03-1-2 requires 18 hours of water delivery time. If started at 7:00, the finishing time will be at 01:00 of the next day which is not a suitable time to work on. It should be rescheduled by rotating with the ditch 03-1.

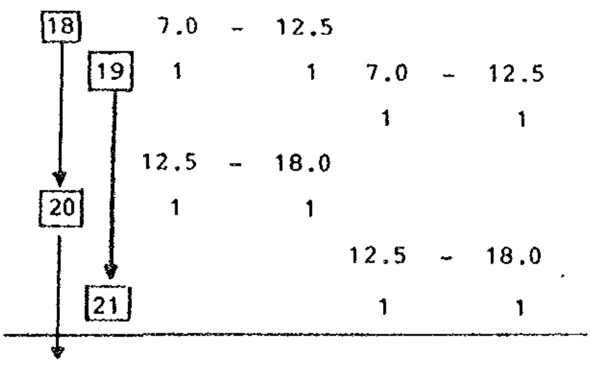
The ditch 03-1, total time = 18 + 30 = 48 hours. If delivery starts at 7:00, the finishing time will be 7:00, then followed by the ditch 03 schedule.

The ditch 03 (first part) requires 40 hours. If started at 7:00, the finishing time will be 23:00 which is considered late at night and is not suitable for operation; therefore, it should be determined with the ditches 03-3 and 03-3-2.

The ditches 03-3 and 03-3-2, total time = 40 + 14.5 = 54.5 hours. If the delivery starts at 7:00, the finishing time will be 13:30

The ditch 03 (last part) required 49 hours, starting at 13:30, finishing at 14:30.

Samples : Time schedule



change direction to 03-1

[15] 18.0 - 07.0
1 2

[16] A 18.0-07.0 change direction to 03-1-1
1 2

---

[17] 07.0 - 14.5
2 2 07.0 - 14.5 (over 1.5)
change direction to 03-1
[22] 2 2

---

[16] B 14.5 - 7.5
2 3

14.5 - 7.5 change direction to 03-3-2
[16] A 2 3

---

[13] 7.5 - 19.0
3 3

7.5 - 16.5
[12] 3 3

[11] 19.0 -10.0 (over 0.5)
3 4

[14] 16.5 - 10.0 change direction to 03-3-2
3 4

10.0 - 18.0
[8] 4 4

10.0 - 18.0 (over 1)
[7] 4 4 change direction to 03-2

---

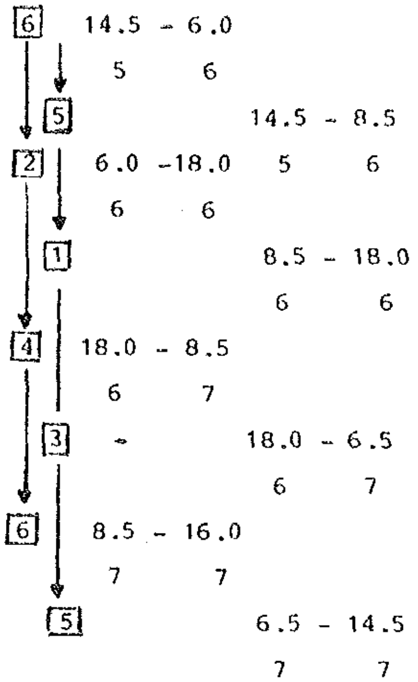
[9] 18.0 - 8.0
4 5 18.0 - 8.0
[10] A 4 5 change direction to 03

---

[10] B 8.0 - 14.5
5 5 8.0 - 14.5
[10] A 5 5

---

[10] B 8.0 - 14.5
[10] A 5 5 8.0 - 14.5
5 5



Remark : The decimal 5 = ½ hour

Time schedule for field owner

Field # 18

1) At the division box 003 of the ditch 03, close the gates of the 03 and the 03-1, open for 03-1-2.

2) Open the farm inlet # 18 every Monday at 7:00.

Field # 19

1) Open farm inlet # 19 and close # 17, 20 and 21.

2) Open farm inlet every Monday at 7:00.

Field # 20

1) Open farm inlet # 20 and close # 18.

2) Open every Monday at 12:30.

Field #21

1) Open farm inlet #21 and colse # 19.

2) Open every Monday at 12:30.

Field # 15

1) At the division box 0 + 020 km of the ditch 03-1, open the gate of the ditch 03-1 and close the ditch 03-1-2.

2) Open farm inlet # 15 every Monday at 16:00.

Field # 16

1) Open farm inlet 16A on Monday at 18:00.

2) At division box, open the gate of the canal 03-1, close the ditch 03-1-2 then open farm inlet # 16B on Tuesday.

Farm # 17

1) At division box 0 + 020 km of the ditch 03-1, open the gate of the ditch 02-1-2, close 03-1.
2) Open farm inlet # 17 every Tuesday at 7:00.

Field # 22

Open farm inlet # 22 and open farm inlets # 20 and 21 every Tuesday at 7:00.

Field # 13

1) At division box of the ditch 03, close the gate of the ditch 03-2.
2) Open farm inlet # 13 every Wednesday at 7:30.

Field # 11

Open farm inlet # 11 and open farm inlet # 13 every Wednesday at 17:00.

Field # 14

Open farm inlet # 14 and open farm inlet # 12 every Wednesday at 16:30.

Field # 8

1) At division box 0 + 380 km of the ditch 03, open the gate of the ditch 03-3. At division box of the ditch 03-3-2, open the gate every Thursday at 10:00
2) Open farm inlet # 8 at all time.

Field # 7

Open farm inlet at all time, alternate opening with Field # 8.

Field # 9

At division box 0 + 115 km, open the gate of the ditch 03-3 and close 03-3-2 and open farm inlet # 9 on Thursday at 18:00.

Field # 10

1) Open farm inlet # 10A on Thursday at 18:00.
2) At division box 0 + 380 km, close the gate of the ditch 03-3, and open farm inlet 10 B on Friday at 8:00.

Field # 6

1) At division box 0 + 380 km, open the gate of the ditch 03 and close 03-3
2) Open farm inlet every Friday at 14:30.
3) Open farm inlet on Sunday at 8:30.

Field # 5

1) Open farm inlet # 5 on Friday at 6:30.

2) Open farm inlet # 5 on Sunday at 6:30.

Field # 2

Open farm inlet # 2 and also # 6 on Saturday at 6:00.

Field # 1

Open farm inlet # 1 and close # 5 on Saturday at 8:30.

Field # 4

Open farm inlet # 4 and close # 2 on Saturday at 18:00.

Field # 3

Open farm inlet # 3 and close # 1 on Saturday at 18:00.

Notice : Before the operation begins, the farmers must understand the schedule thoroughly.

Since this mehtod is only a simple operation, it cannot be used as the standard one. It has to be improved or studied during the operation. Two factors that should be involved are as follows:

1. Maximum water requirement : obtained from evapotranspiration, percolation and run off. This is a simple way to obtain data but cannot be used as the standard one. The upper surface of the block is the same level as the field. Then measuring the water level by using a ruler which has mm scale. The measurements are at the intervals of 5-7 days. The differences of the two measurements divided by the interval days is the amount of water loss per day.

2. Conveyance loss : There is no simple method to obtain the conveyance loss value; therefore, the measurement should be done in every place that the water passes or runs into in order to get the optimum value for that specific area.

Sumary : In the method of delivering water which has been discussed above, the author would like to show only the ideas or trends of irrigation designing and does not intend for it to be used for designing directly. Planting and marketing improvements are so complicated that the one who is concerned with them should make a study in order to get the practical ways in relation to irrigation designing.

CHAPTER VI.

FARM WATER MANAGEMENT

A. General Statement on Water Management

Water Management, in a broad sense of the term, is construed to mean the whole series of organized work to take care of water as it is taken out from a source of water or a reservoir, distributed and diverted by relevant facilities and introduced to farms by ditches; the work also includes the regulation and measurement of volume of water for irrigation, its adequate supply at right times, draining off of oversupplied water and other adjustment functions. These series of work, needless to say, are to be carried out in close cooperation with farming techniques with an eye to enhancing agricultural productivity. Water management in its narrow sense is understood to mean the processing of irrigation water after the point where it is channeled into lateral canals - - the part of the work which has more direct bearing on farmers' organizations.

In preparing curriculum the following may have to be taken into account:

(1) To establish irrigation system based on relevant facilities and see to efficient utilization of water:
Attention should be paid to setting a water utilization plan in accordance with irrigation water requirement per acreage which varies by different stages of the plant growth, as well as by different weather conditions, and to minimizing the loss of water.

(2) To see to rational distribution of water:
It is important to take into account factors in utilizing water, such as operation of turnouts and outlets, gauging of water volume, introduction of the rotation system, etc., and also such managerial and maintenance factors necessary for keeping waterways and other structures relevant to water utilization in good shape.

(3) To form a system of guidance to help farmers set up their organization for water control:
Here a specific technical guidance is necessary.

Now, as for an agricultural development project in Southeast Asia, the following three factors may be pointed out as important in carrying it out: (a) regional peculiarity, (b) natural conditions, (c) farmers' will for development. Taking these factors into account, the scope and structure of relevant facilities and installations may be determined in accordance with the scope of the project concerned, depending on which the quality and subject matters of education for farmers, as well as objective criteria for water fee to be collected may be fixed.

Of special importance in water control is to lay down a network of branch canals and lesser waterways so as to make the control as much intensive as possible. That is, when the irrigation water is diverted from laterals to farm ditches, its volume should be gauged at the diversion gates, and then should be introduced to paddies by opening intakes. At that, it is necessary to set up dykes around each paddy to keep optimum volume of water in it, and to try to have a best possible supply of water while taking into consideration the length of ditches, the distance between them, the land slope, etc.

One of the cruxes of a water utilization plan is to determine an optimum volume of water to be supplied. It should be based on unit volume of water required at each farm and may vary depending on conditions of soil and climate, kinds of crops, methods of irrigation, as well as on when and how long it is needed. In the case of a paddy field, the volume is often determined by gauging the water requirement in depth. Even in that case the determination should be affected by such relevant factors as the area of the field concerned, the nature of soil, the underground water level, etc.

Also of importance is to provide for a supply system of water in a rainy season or at a time of an extraordinary droughty water level as part of an irrigation plan and especially to prepare for an occasion of water famine or flood in making a water utilization plan. This should apply also to regions where double cropping is possible on account of irrigation being done the whole year.

Another important matter in operating the irrigation facilities is to see to it that the possible loss of water between the source of water and end facilities is kept as small as possible. For this purpose it is advisable to record the volume of the water flow at such major points as an intake gate, diversion works, spillways, irrigation channels, end ditches, etc. Especially the loss of water while flowing through driving channel generally tends to great because of leakage caused by breaches and cracks in the slope of canal, evaporation through blades of water grass, changes in the section of the water flow, etc., which reduce the volume of water flow. To counter this it may be desirable to execute linings, but if it is necessary to save expenditure on it, it may at least be advisable to repair them from time to time.

In order to have a successful going of those irrigation and water utilization plans it is important to secure cooperation from farmers' organization concerned, and this makes their education and guidance a very important matter.

B. The Government Organization in charge of water management

1. Headquarters of Royal Irrigation Department

- **Division of Operation & Maintenance**
  - **Water Management & Operation**
    - Data Analysis
    - Water Management & Operation
      - ChaoPhya & North
      - MaeKlong & etc.
      - Northeast
      - South
  - **On-farm Usage Development**
    - Activity Promotion
    - On-farm irrigation & Water usage
    - On-farm water usage training
  - **Irrigation Agriculture**
    - Mae Tang Water Usage Research Station
    - Phitsanulok "
    - Huay Ban Yang "
    - Sam Chook "
    - Greater MaeKlong "
    - Petchburi "
    - Nakornsrithammarat "
    - Pattanee "
    - Demonstration Center for agriculture in the Greater MaeKlong irrigated agriculture development area.

2. Regional office of Royal Irrigation Department

The Royal Irrigation Department divided the whole country into 12 regions as administrative area and in each area a regional office has been established.

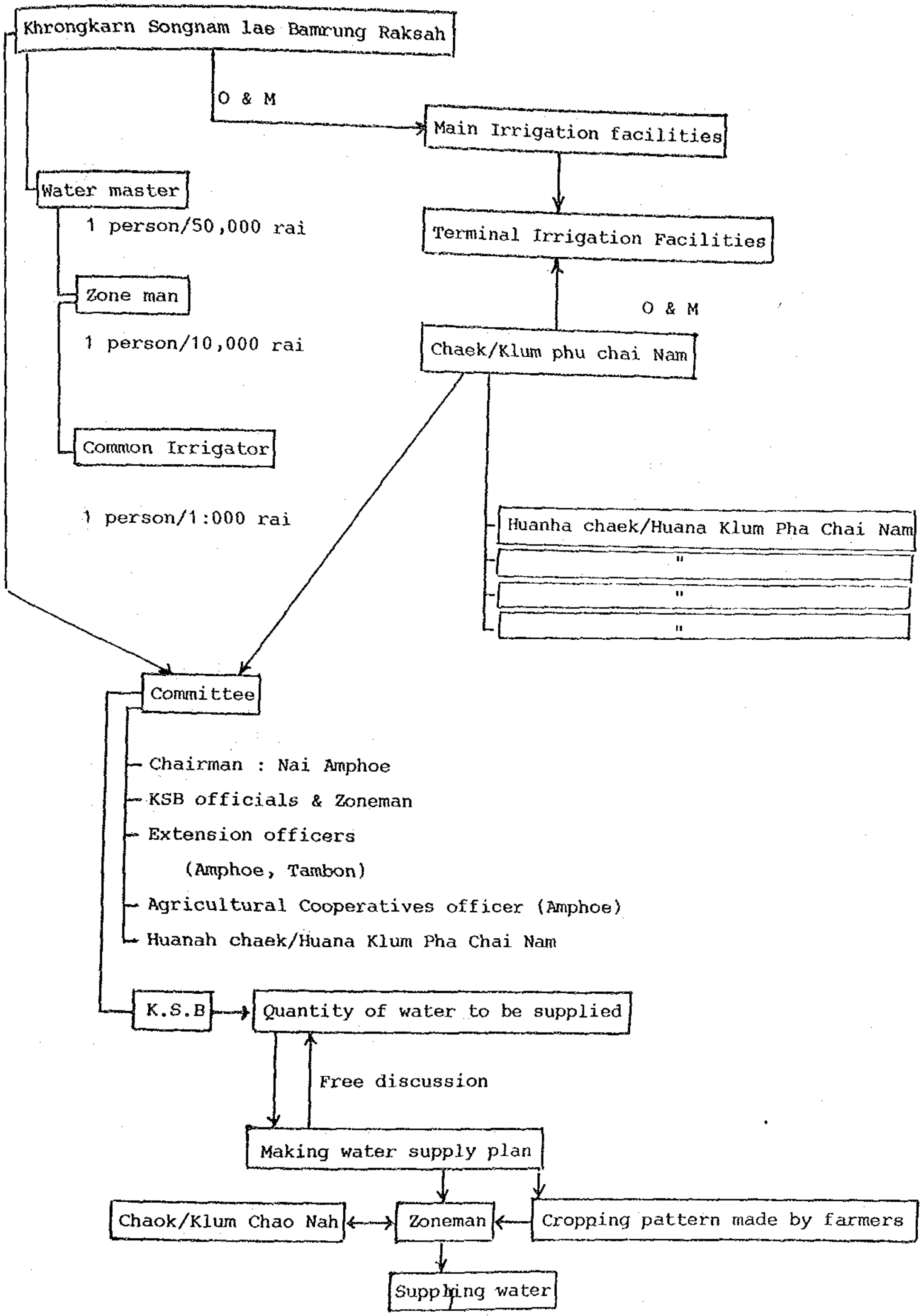
The regional office is responsible for the operation and maintenance of main irrigation and drainage facilities including roads, implementation of small scale irrigation projects and so on in their administrative areas.

Operation and maintenance offices are also established under the Regional offices and have been taking charge of water management respectively.

Regarding these O&M offices, an example of the Regional 10 Office can be shown as follows:

- RID
  - O&M Division
    - Office of Region 10
      - Kamphaeng Saen O&M Office (A = 50,650 ha)
      - Nakhon Pathom " (A = 60,048 ha)
      - Nakhon Choom " (A = 46,240 ha)
      - Ratchaburi(Left Bank) " (A = 34,208 ha)
      - Tha Maka " (A = 50,304 ha)
      - Ratchaburi(Right Bank)" (A = 53,968 ha)
      - Phanomtuen " (A = 59,072 ha)
      - Songpeenong " (A = 55,424 ha)
      - Banglen (A = 56,240 ha)

3. General organization of water management in Thailand



Note:

Khrongkarn Songnam lae Bamrung Raksah (K.S.B)
: Office of Operation and Maintenance, RID

Water master : personnels of K.S.B in charge of water management
Zone man : permanent employee belonging to K.S.B
Those who supply irrigation water from main canals to laterals/sub-laterals.

Common irrigator : Temporary laborers selected among farmers.
Those who are assistants of zoneman.

Chaek (Thai language) : Water users' group
Klum Pha Chai Nam : "
Huana (Thai Langauge) : Leader

C. The problems with which water management in Thailandare confronted.

Some main problems and constraints in water management may be considered as follows:-
(According to Mr. Paitoon Palayasoot, Director of CLCO.)

1. Since the main distribution systems of some irrigation projects were designed for supplementing water for rice in the wet season only, therefore, the irrigation and drainage systems at the farm level were not completed.

2. Information and guidance on water management and irrigated agriculture are insufficiently given to farmers by the Government Agencies.

3. Several Government Departments are currently dealing with agricultural development and assistance to farmers. However, because of lack of coordination, limited personnel and insufficient funding, the services provided to farmers are inadequate to met the requirements of an intensive irrigated agriculture.

4. Lack of adequately trained personnel in farm water management.

5. The institutional farmwork to implement farm water management is not effective yet.

6. Inadequate financial supports.

Countermeasure to improve the water management in Thailand.
(According to Mr. Paitoon Palayasoot)

The achievement of farm water management is not only dependent on engineering and technical improvements. Agriculture, economics, institutional and social aspects have to be integrated with. Provision of other facilities such as training, extension work, credit supply, marketing, supply of agricultural inputs must be undertaken simultaneously together with the technical measures.

It has been ascertained that there is a great need to increase the basic knowledge among the operational staff with respect to the principles underlying the operational of the distribution system. In view of the urgent need and the considerable benefits to be gained from improved irrigation efficiency, the training institute should be established to achieve this goal. The institute would have to organize well-balanced training courses for project engineers, water masters and zoneman and would also be responsible for field guidance during the on-the-job training period of RID's operation staff.

The purpose of the water management training programme is to impart to zoneman and water masters appropriate knowledge and understanding of the basic principles underlying operation and maintenance of an irrigation system, with the aim being to achieve an optimum and dependable irrigation water supply to all the service units comprising an irrigated area and, within the service units, to all the farmers.

The main subjects dealt with training seminar of zonemen and water masters jointly are summarized as follows:-

* Irrigation principles
* O & M at lateral level
* O & M at service unit level
* Human resources management and development
* Irrigated crop production

For the water masters, an additional training focussing on their specific duties and responsibilities should be provided.

D. Water Master and Zonemen, Job Description

1. The Watermaster

1. To supervise and guide all personnel and to control all O&M activities within the area of his "Part".
2. To assist the Project Engineer in formulation of tentative yearly proposals for irrigation programs and cropping schedules.
3. To co-ordinate with the personnel of other units in order to keep the system running smoothly, and settle all mutual problems of operation and maintenance.
4. Before each cropping season, to collect the information from the Zonemen's staff and together with the Water Management and Control Unit of the Project and the Engineers Office prepare plans and programs on cropping, water management and water delivery schedules (including allotments among the laterals) for all canals.
5. To collect progress reports of all irrigation and agricultural activities from the Zonemen's staff and together with the Water Management Unit Plan the changes in the water delivery schedules necessitated by rainfall, and/or deviations from the cropping schedule.
6. Submit reports on rehabilitation, repairs, calamity damages and other proposed works within the "Part" and together with the Project Engineer, his Assistant, and the Office Engineer plan major repairs or maintenance with hired equipment or equipment from the main or regional office.
7. To maintain contact with Water User's Associations officials.
8. To promote Water User's Groups, help them function smoothly and together with the Zonemen, Chak Leaders and above officials help arbitrate farmer's disputes not settled at a lower level.
9. To operate and maintain the Main Canals and in the case of the LAMPAO Project the 1R and 2R laterals of the RMC.

2. The Zoneman

1. To supervise and guide all personnel under his charge.
2. To supervise and control directly all O&M activities along the secondary canals in his zone, beginning at the downstream side of the lateral turn-outs (except in the case of major repairs that will be under the direction of the Maintenance Foreman or Watermaster).
3. To supervise and control indirectly all irrigation and maintenance

works in the tertiaries and farm ditches in his zone by keeping close contact with the Farmer, Chak Leaders and Tertiary Operators through his Assistant Zonemen.

4. To help organize and promote the Water User's Groups helping them to function smoothly, to act as temporary or honorary chairman or director (if necessary) and to audit their books during the initial stages until they are incorporated into a larger body.

5. To assist the Watermaster and Project Engineer in formulation of tentative yearly proposals for irrigation programs and cropping schedules.

6. With the help of the Watermaster, to co-ordinate his work with the personnel of the other zones and units in order to keep the system running smoothly and to settle all mutual problems of operation and maintenance.

7. Before each cropping season with the aid of his Assistant Zonemen to determine the cropping pattern in his zone for the coming season either by direct canvas of the farmers or by estimation together with the water allotment of his zone and the conveyance capabilities of the canals.

8. To submit above data to the Watermaster with the assistance of the Hydraulic Technician and the Water Management and Control Unit plan the water delivery tables for the laterals and sub-laterals in his zone.

9. After approval by the Water Management Unit, to disseminate the water delivery tables among the farmers through the Water Users' Groups.

10. Through the Assistant Zonemen to advise and direct the Tertiary Operators and Chak Leaders on planning their water delivery schedules (on the rotational system if necessary) and setting up controls for their implementation.

11. To collect from his Assistants progress reports of all irrigation and agricultural activities and requests for increased or reduced irrigation water, forward them together with the precipitation records to the Watermaster and together with the Hydraulic Technician and the Water Management Unit plan and implement the necessary changes in the water delivery schedules of the laterals, sub-laterals and tertiaries.

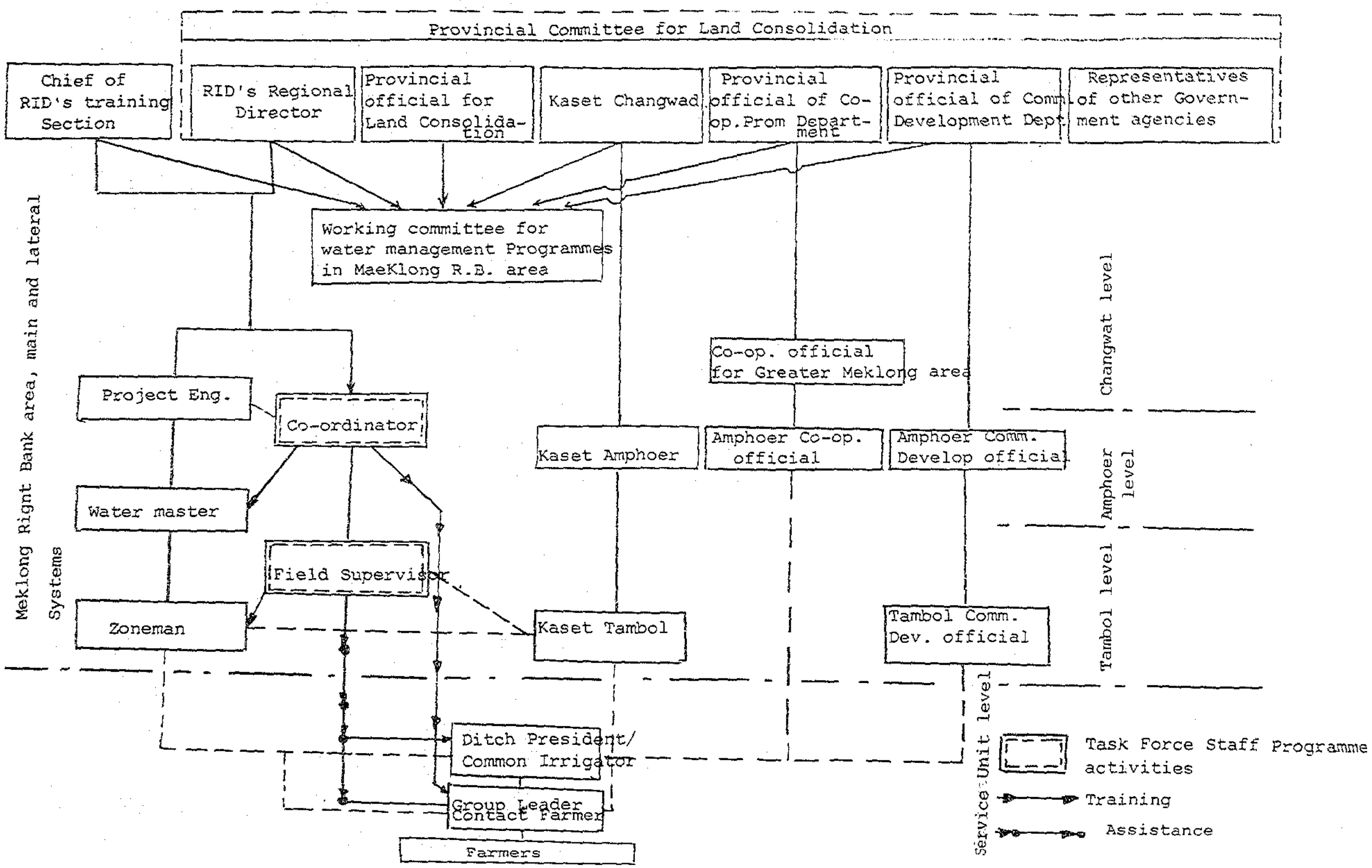
12. To control all canals and gates operation, measurement of discharges, flashboard operation in FTO's, etc. beginning from the downstream side of the lateral CHO's.

13. To direct his gate tenders and maintenance workers in routine, inspection, maintenance and repairs of all structures measuring devices

and canals within their means.

14. To submit reports on rehabilitation, repairs, calamity damages and other proposed works within the zone and together with the Maintenance Foreman to plan their implementation.
15. To submit to his superiors all information on any alteration as development works in his zone, changes of land use, land ownership, tenancy status, etc.
16. To prepare daily and monthly records as suggested in other chapters of this Manual paying particular notice to their accuracy.
17. To attend regular training courses and sessions of the National Extension Services.
18. To study plans of improvement, organization and maintenance in his zone.
19. To perform any other duties assigned to him by his superiors.

E. An example of water management organization established in the MaeKlong Right Bank Land Consolidation area



F. Effectiveness of Water Management

The author made this report by extracting information from Mr. Direk Tongaram's report which was given to me. The original report was entitled "Estimation of Water Requirement for Rice in Thailand", and was written in Thai, so the author asked Mr. Tanasit Aundkasit to translate it into English and then summarized it.

1. Standard of making the charts

1.1 Water requirement for rice

Evapotranspiration and percolation were the main bases obtained from the experimental stations which were considered optimum for that climatic and geographic conditions.

1.2 Season

Estimation for both wet and dry seasons.

1.3 Location

The area of Thailand was seperated into 9 regions.

1.4 Rice varieties

RD varieties, age from 120 - 130 days.

1.5 Water requirement period for rice

114 days, 30 days for field preparation and 84 days after transplanting.

1.6 Water requirement for field preparation

200 mm. for wet season and 300 mm. for dry season.

1.7 Effective rainfall

The records for Central regions is in the passed 25 years while other regions is in the passed 20 years.

1.8 Irrigation efficiency

The study was in the range of 20 to 80 %.

1.9 Products

From the studies were 50 - 80 tang/rai in dry season and 30 - 60 tang/rai in wet season.

1.10 Returns

4,000 baht/kwean

2. How to use the charts

Explanation is given by taking the Central plain in dry season as an example.

2.1 Rice variety : RD, age from transplanting to harvesting : 120 days.

2.2 Transplanting and field preparation:

2.2.1 transplanting period : 25 days

2.2.2 amount of water that used in field preparation and after transplanting : 300 mm.

2.3 Water requirement in the rice field (research from Samchuk station, dry season, 1980)

2.3.1	rice evapotranspiration	7.55	mm/day
2.3.2	percolation rate	0.67	mm/day
	Total	8.22	mm/day

2.3.3 days to irrigate after transplanting 84 days

2.3.4 water requirement in the rice field 8.20 x 84 = 690 mm.

2.3.5 total water requirement in the rice field 300 + 690 = 990 mm.

2.4 Rainfall during growing season (Jan - May)

2.4.1	average rainfall	230	mm.
2.4.2	effective rainfall	210	mm. (91 %)

2.5 Irrigation requirement : 990 - 210 = 780 mm

2.6 Irrigation efficiency : 40 - 50 %

Description	Irrigation Efficiency		difference + increase - decrease
	40	50	
(1) Irrigated water for 1 rai all dry season			
m^3 .... (A)	3,120	2,496	- 624
mm .... (B)	1,950	1,560	- 390
(2) Flowrate at 1 m^3/sec can work on the rice field			
rai/m^3/sec ...... (C)	3,157	3,946	+ 789
m^3/sec/rai	0.000316	0.000253	
(3) Products (Kwean)			
If the product 50 tang/rai .... (D)	1,579	1,973	+ 394
If the product 60 tang/rai	1,894	2,367	+ 273
(4) Returns (million); ฿ 4,000			
If product 50 tang/rai .... (E)	6.31	7.89	+ 1.58
If product 60 tang/rai	7.57	9.47	+ 1.90

Note : Calculation was done as follows:

In case of 40 % of efficiency.

(1)

$$\frac{780 \text{ mm}}{1{,}000 \text{ mm/m}} \times \frac{1}{0.4} = 1{,}950 \text{ mm} \quad ....(B)$$

$$\frac{1{,}950 \text{ mm}}{1{,}000 \text{ mm/m}} \times 1{,}600 \text{ m}^2\text{/rai} = 3{,}120 \text{ m}^3 \text{....} \quad (A)$$

(2)

Net water requirement per day

$$\frac{780 \text{ mm}/1{,}000 \text{ mm/m}}{114 \text{ days}} = 6.84 \text{ mm/day}$$

m^3/s/rai :

$$\frac{6.84 \text{ mm/day}}{1{,}000 \text{ mm/m}} \times 1{,}600 \text{ m}^2/\text{rai} \times \frac{1}{0.4} \times \frac{1}{86{,}400 \text{ sec/day}}$$

$= 0.0003167 \text{ m}^3/\text{s/rai}$

therefore rai/m^3/sec :

1 m^3/s/0.0003167 m^3/s/rai = 3,157 rai

(3) Products

1 kwean = 100 tang

1 tang = 10 kg

if 50 tang/rai (500 kg/rai)

3,157 rai x 50 tang/rai = 157,850 tang = 1,579 kwean (D)

if 60 tang/rai

$$\frac{3{,}157 \text{ rai} \times 60 \text{ tang/rai}}{100 \text{ tang/kwean}} = 1{,}894 \text{ kwean}$$

(4) Returns (million baht)

if unit price : ฿ 4,000/kwean

in case of 50 tang/rai 1,579 kwean x ฿ 4,000 = 6.31 mill.฿

in case of 60 tang/rai 1,894 kwean x ฿ 4,000 = 7.57 mill.฿

Namely, as you can see in the above example, the 10 % raised efficiency of 1 m^3/sec is able to increase the gross income at 1.58 Mill.฿ in case of that the unit price of husked rice is 4,000 ฿/kwean.

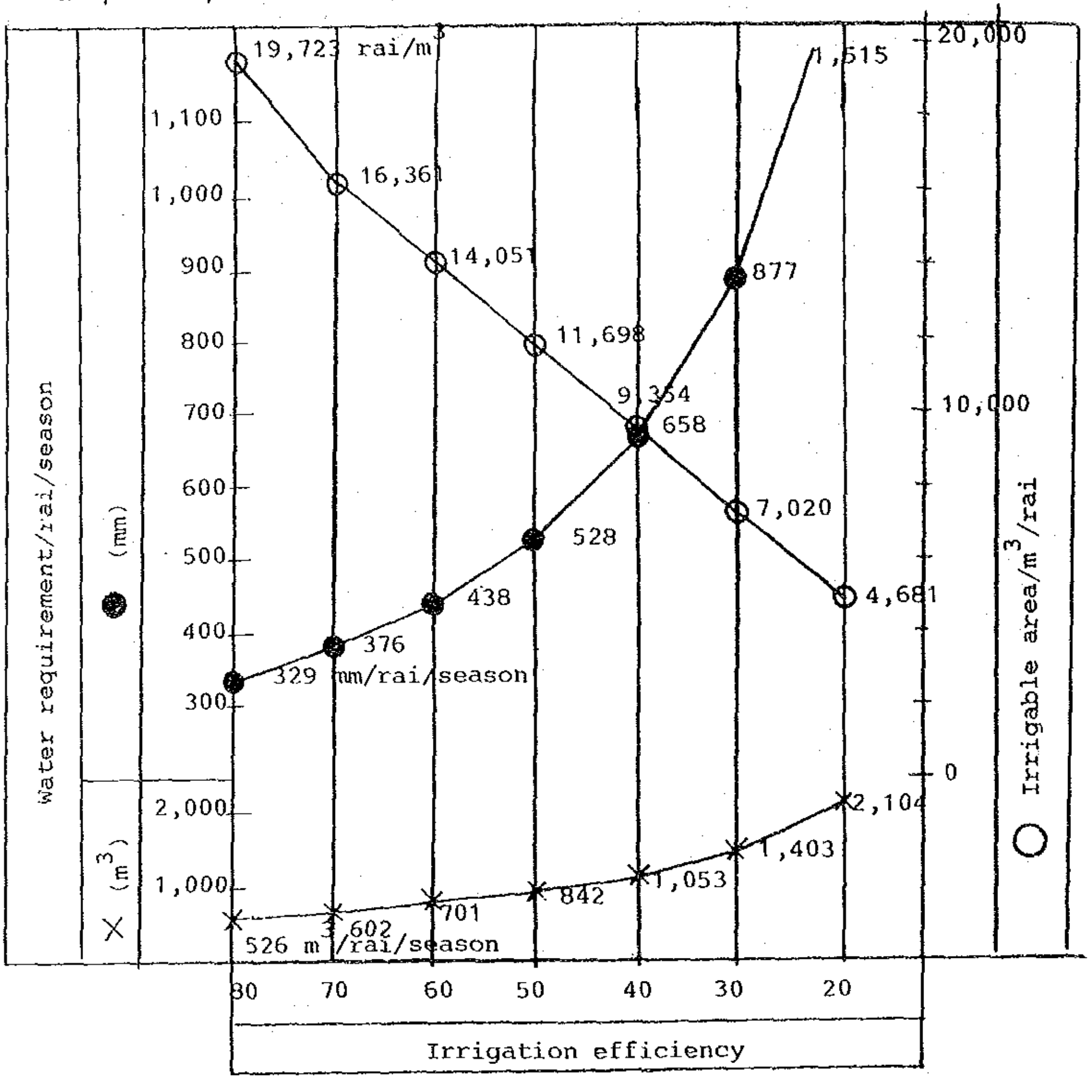
When considering this fact, everybody can understand how important good water management is.

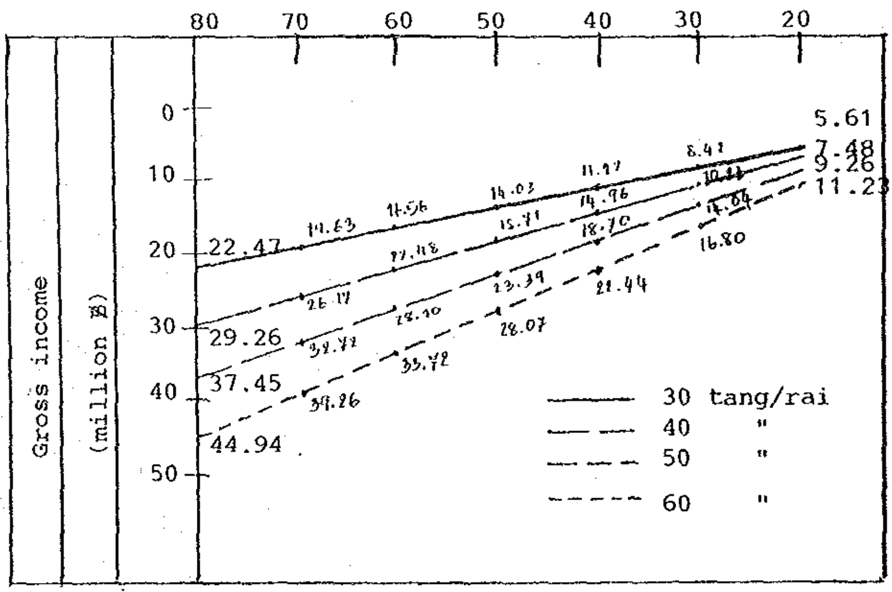
Water requirement for wet season rice in the Central region

Rice variety : RD Age : 120 - 130 days

Period : Jul. - Nov. Effective rainfall : 496 mm

Evapotranspiration + percolation : 6.06 mm





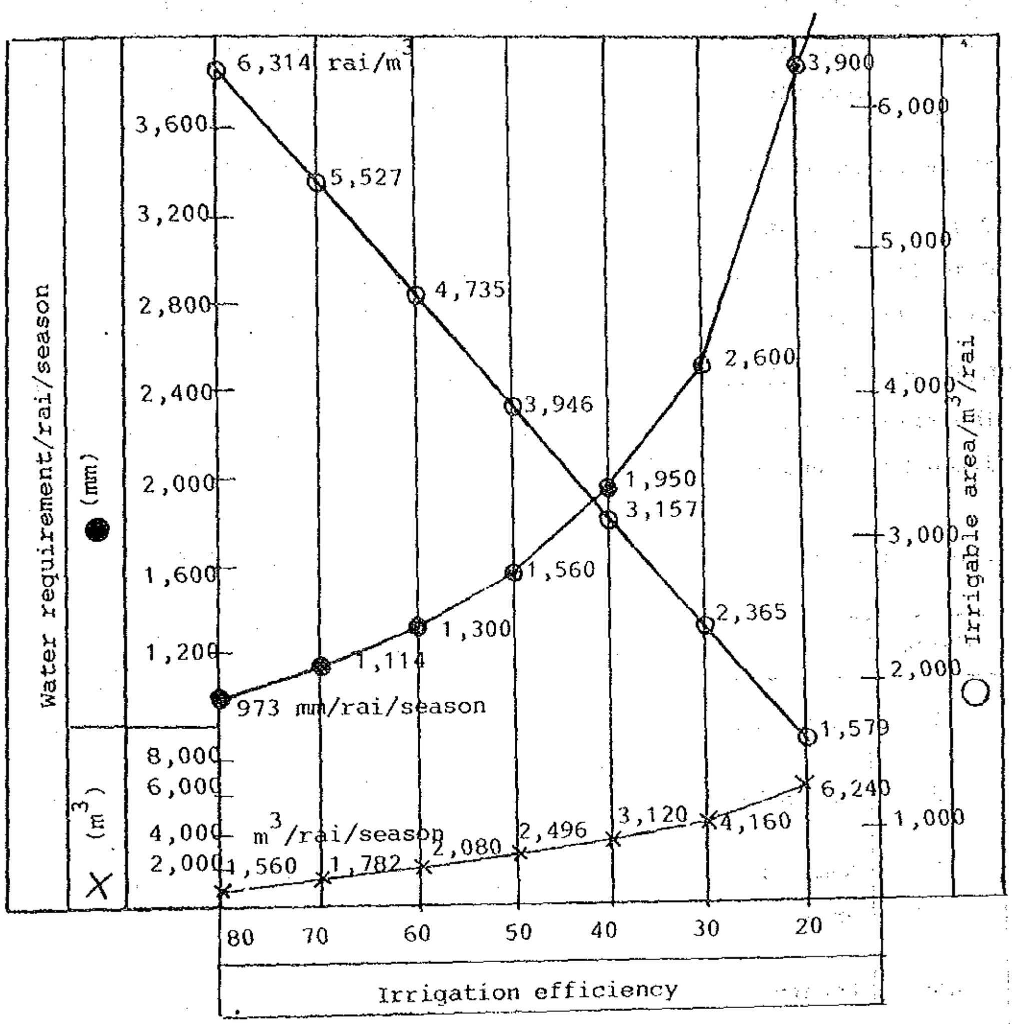
Water requirement for dry season rice in the Central region

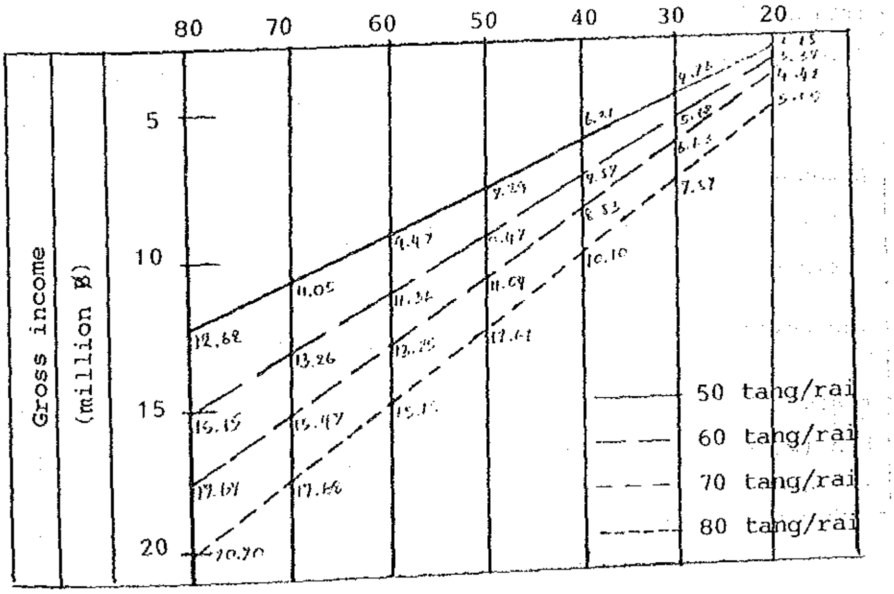
Rice variety : RD Age : 120-130 days

Period : Jan.-Nov.

Effective rainfall : 210 mm

Evapotranspiration + percolation : 8.22 mm





H. Some actual examples of water management scheme.

1. From the Nong Wai Pioneer Agriculture Project.

Rotation design within the Chak

(Note : The Chak means a rotation block which is irrigated by the terminal irrigation system branched off the secondary canal, the lateral and the sub-lateral)

Three cases of rotation design for chaks are given here:

Case I Irrigated area between 400 - 600 rai

Case II Irrigated area between 100 - 300 rai

Case III Irrigated area more than 800 rai

Each chak is divided into 4 - 7 groups for easy distribution of water. The time schedule calculation for each group or section of the main ditch has a weekly rotation period.

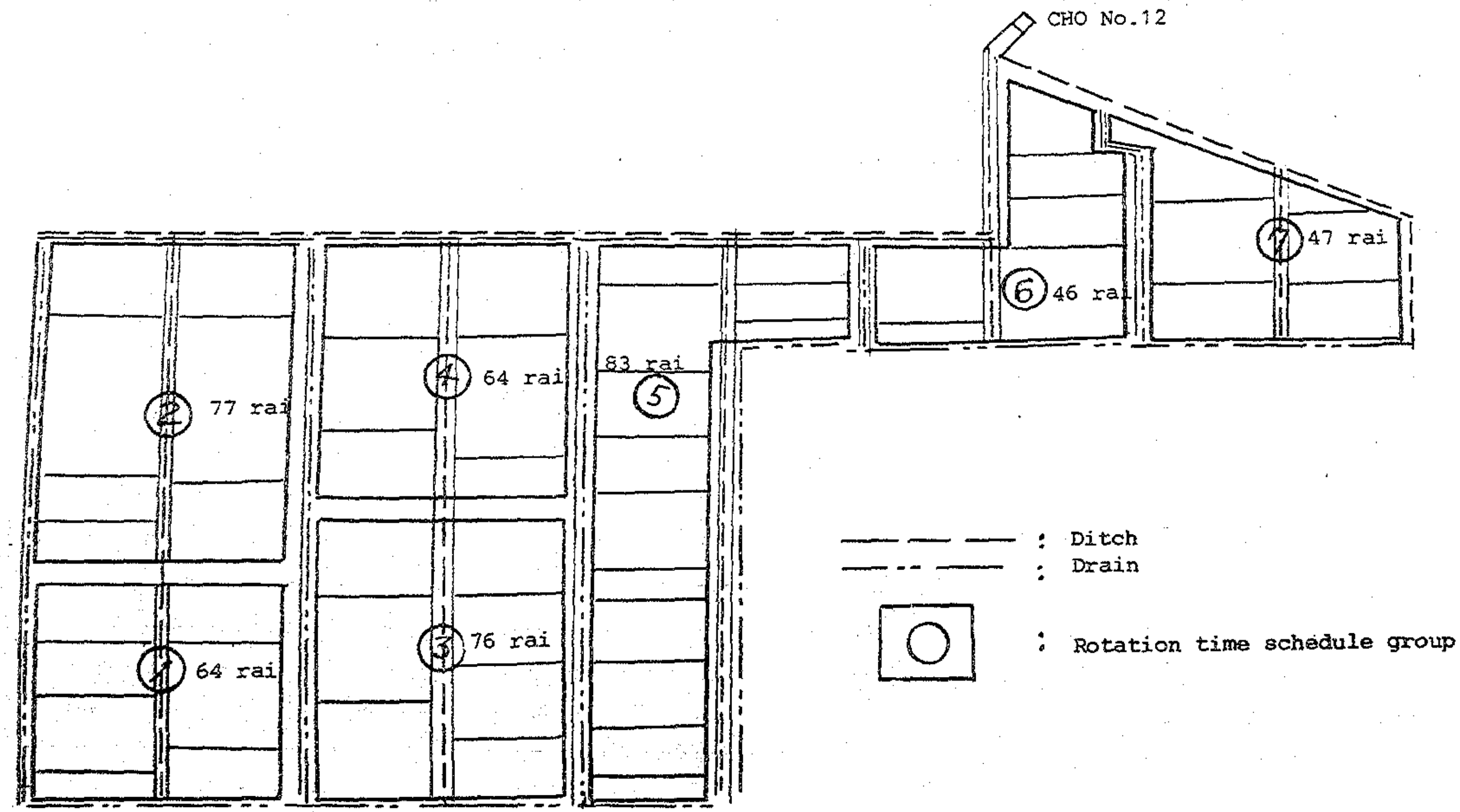
Time schedule calculation

Column	Calculation procedure
1	Group number
2	Irrigated area in each group, in rai
3	Name of ditch and sub-ditch that pass through that particular area
4&5	Length of particular ditch or sub-ditch to each particular irrigated area in Col.2 and divided into concrete lined ditch (LD) and earthen ditch (ED). The seepage rate has been taken as 0.3 per cent and 1.0 per cent, respectively (see Col.9)
6	Discharge (l/sec) -- Use the revised design discharge based on water duty of 0.21 l/sec/rai at CHO head for the total irrigable area in wet season. The revised discharge is 0.21 x 458 = 96 l/sec.
7	Basic time allocation (BTA), in hours, of subgroup out of 168 hrs (week) proportional to the irrigated area in Col.2, e.g., for group 1

Column	Calculation procedure
	$\frac{168 \times 64}{457} = 23.53$ hr.
8	Transport time (TT) in hours, calculated as follows:
	$Q = Av$ or $V = \frac{Q}{A}$
	Q = discharge m^3/sec
	A = cross section area m^2
	V = velocity m/sec
	d = depth = 0.5 m
	b = bed width = 0.50 m
	z = side slope = 1:1
	$A = \frac{1}{2} (0.5 + 1.5) \times 0.5 = 0.5\ m^2$
	$V = \frac{Q}{A} = \frac{0.096}{0.5} = 0.192$ m/sec
	Transport length (Col.4 + Col.5) = 900 + 780 = 1,680 m
	Transport time $= \frac{L}{V \text{ per hour}}$
	Transport time $= \frac{1,680}{0.192 \times 3,600} = 2.43$ hr.
9	Transmission loss (TL)
	Seepage for concrete lined ditch per 100 m = 0.3 per cent
	Seepage earthen ditch per 100 m = 1 per cent
	For the transport length 900 m for concrete lined ditch and 780 m for earthen ditch
	The percentage of the transmission loss $= \frac{900}{100} \times 0.3 + \frac{780}{100} \times 1\ \% = 10.50\ \%$
10	The time adjustment for transmission loss (TTL) for the basic time allocation $= \frac{10.50 \times 23.53}{100} = 2.47$ hr
11	Total time compensated (TTC) = basic time allocation (Col.7) + total transmission loss (Col.10)

Column	Calculation procedure
	= 23.53 + 2.47 = 26.00 hr The total time with compensation = 175.72
12	Time adjustment (AT) Constant of adjustment = $\frac{\text{Total time required (168) - Transport time}}{\text{Total time with compensation}}$ Adjusted time = Total time compensated (Col.11) x Constant of adjustment = 26.00 x 0.906 = 23.57 hr
13	Final time compensated (FTC) = The transport time (Col.8) + Compensated time adjustment (Col.12) = 23.57 + 2.43 = 26.00 hr
14	Final time in hr-min. = 26 hr - min
15	Adjusted final time (AFT) = 26 hr
16	Time schedule Start from Monday 06.00 The first group time schedule is Monday 06.00 - Tuesday 08.00.

After understanting the above calculation procedure, refer to the following examples.


CHO No.12
1
64 rai
2
77 rai
3
76 rai
4
64 rai
5
83 rai
6
46 rai
7
47 rai
: Ditch
: Drain
: Rotation time schedule group

CASE-1

CALCULATION OF TIME SCHEDULE FOR INTRODUCTION OF ROTATION SYSTEM UNDER CHO NO.12 km 4+100 of 3L LATERAL

G	Area (rai)	Ditch No.	Length of Ditch (m) LD	ED	Discharge (l/sec)	BTA (hr)	TT (hr)	TL (%)	TTL (hr)	TTC (hr)	AT (hr)	FTC	Final time (hr)	(min)	AFT (hr)	Time Schedule
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		16
1	64	12	900	780	96	23.53	2.43	10.50	2.47	26.00	23.57	26.00	26	00	26	Mon.06.00-Tue.08.00
2	77	12	900	340	96	28.31	1.79	6.10	1.73	30.04	27.23	29.02	29	01	29	Tue.08.00-Wed.13.00
3	76	12.7	900	340	96	27.94	1.79	6.10	1.70	29.64	26.87	28.66	28	40	29	Wed.13.00-Thu.18.00
4	64	12.7	900	-	96	23.53	1.30	2.7	0.63	24.16	21.9	23.20	23	12	23	Thu.18.00-Fri.17.00
5	83	12.5	580	-	96	30.51	0.84	1.74	0.53	31.04	28.14	28.98	28	59	29	Fri.18.00-Sat.22.00
6	46	12.3	-	-	96	16.90	-	-	-	16.90	15.32	15.32	15	19	15	Sat.22.00-Sun.13.00
7	47	12.1	-	-	96	17.28	0.55	3.8	0.66	17.94	16.26	16.82	16	49	17	Sun.13.00-Mon.06.00
	457					168	8.70			175.72	159.29	168				

Note:

LD = Concrete lined ditch

ED = Earthen ditch

BTA = Basic time allocated

TT = Transport time

TTL = Total transmission loss

TTC = Total time compensated

AT = Adjusted time

FTC = Final time compensated

AFT = Afjusted final time

Case II

In the case of an irrigated area of 100 - 300 rai served by some particular CHO, especially in an extensive area.

Consideration and calculation sample for CHO No.3,5 and 7 -- km 1+105, 2+340, and 2+520 of 3L (Table 2)

Size of the Plot and Discharge Consideration

- CHO No.3 km 1+105 serves 44 rai
  Revised discharge is 0.21 x 44 = 9 l/sec
- CHO No.5 km 2+340 serves 80 rai
  Revised discharge is 0.21 x 80 = 17 l/sec
- CHO No.7 km 2+520 serves 289 rai
  Revised discharge is 0.21 x 289 = 61 l/sec

The required discharges are too small in comparison to the delivery of the standard ditch. To serve the water efficiently and equitably, the water allocation of 3 CHO can be combined 9+17+61 = 87 l/sec. The total discharge can be distributed to each one of the CHO according to the rotation time schedule within a week.

Time allocation calculations are similar to the first case

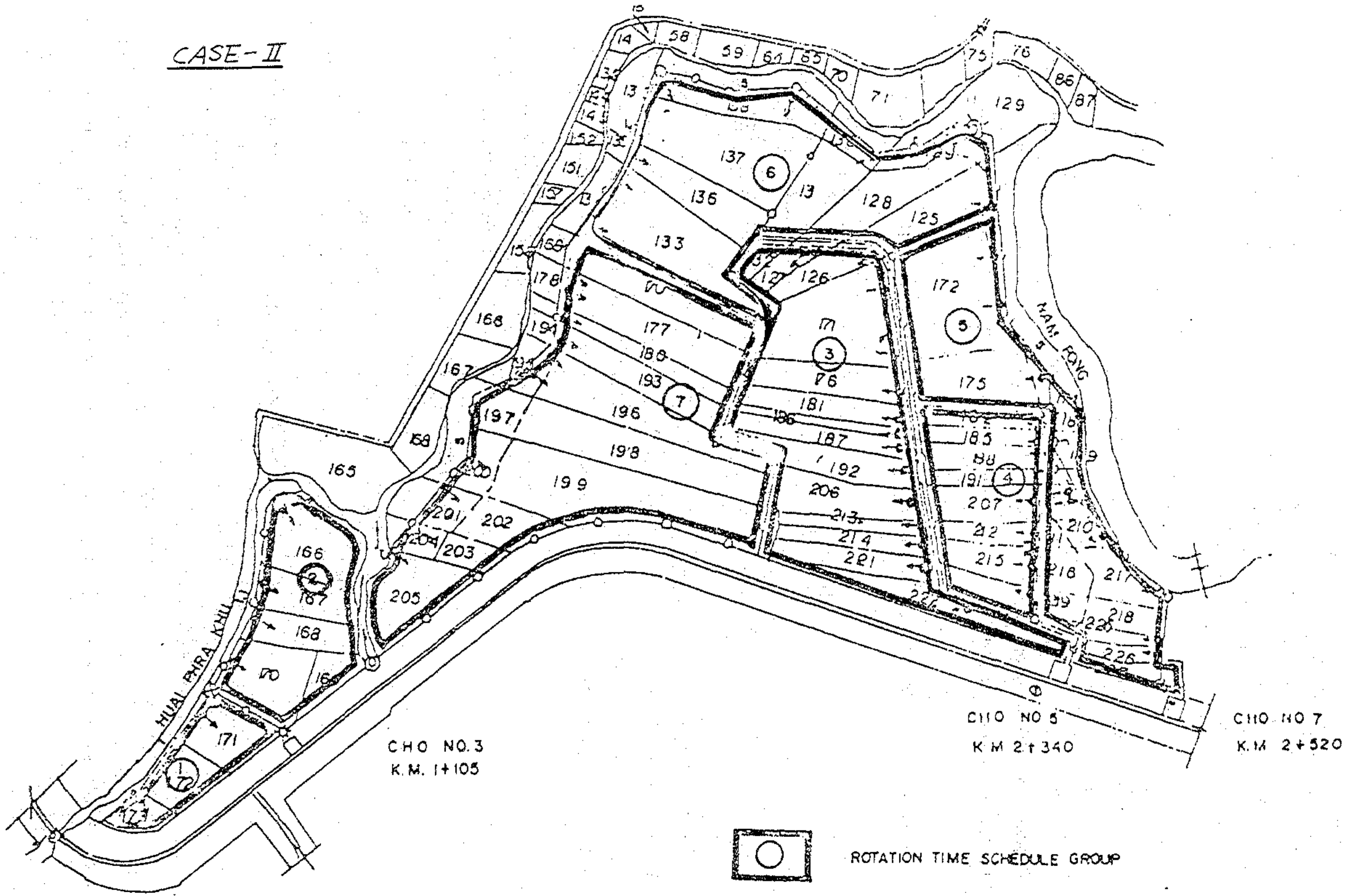
Allocated time is given in Table 2.

CHO Opening and Closure Arrangement

The first CHO (No.3) should be opened on Monday 06.00 according to calculated period.

Ditch No.1 would get water till Monday 11.00 and then rotate to ditch No.1.1 till Monday 23.00 and then CHO No.3 is closed. After that CHO No.5 would be opened and closed according to the schedule.

CASE-II


HUAI PHRA KHU
NAM PONG
CHO NO.3
K.M. 1+105
CHO NO 5
K.M 2+340
CHO NO 7
K.M 2+520
ROTATION TIME SCHEDULE GROUP

CASE-II

CALCULATION OF TIME SCHEDULE FOR INTRODUCTION OF ROTATION SYSTEM
UNDER CHO NO.12 km 4+100 of 3L LATERAL

G	Area (rai)	Ditch No.	Length of Ditch (m) LD	ED	Discharge (l/sec)	BTA (hr)	TT (hr)	TL (%)	TTL (hr)	TTC (hr)	AT (hr)	FTC	Final time (hr)	(min)	AFT (hr)	Time Schedule
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		16
1	64	12	900	780	96	23.53	2.43	10.50	2.47	26.00	23.57	26.00	26	00	26	Mon.06.00-Tue.08.00
2	77	12	900	340	96	28.31	1.79	6.10	1.73	30.04	27.23	29.02	29	01	29	Tue.08.00-Wed.13.00
3	76	12.7	900	340	96	27.94	1.79	6.10	1.70	29.64	26.87	28.66	28	40	29	Wed.13.00-Thu.18.00
4	64	12.7	900	-	96	23.53	1.30	2.7	0.63	24.16	21.9	23.20	23	12	23	Thu.18.00-Fri.17.00
5	83	12.5	580	-	96	30.51	0.84	1.74	0.53	31.04	28.14	28.98	28	59	29	Fri.18.00-Sat.22.00
6	46	12.3	-	-	96	16.90	-	-	-	16.90	15.32	15.32	15	19	15	Sat.22.00-Sun.13.00
7	47	12.1	-	-	96	17.28	0.55	3.8	0.66	17.94	16.26	16.82	16	49	17	Sun.13.00-Mon.06.00
	457					168	8.70			75.72	59.29	168				

Note:
LD = Concrete lined ditch
ED = Earthen ditch
BTA = Basic time allocated
TT = Transport time
TTL = Total transmission loss
TTC = Total time compensated
AT = Adjusted time
FTC = Final time compensated
AFT = Afjusted final time

Case III

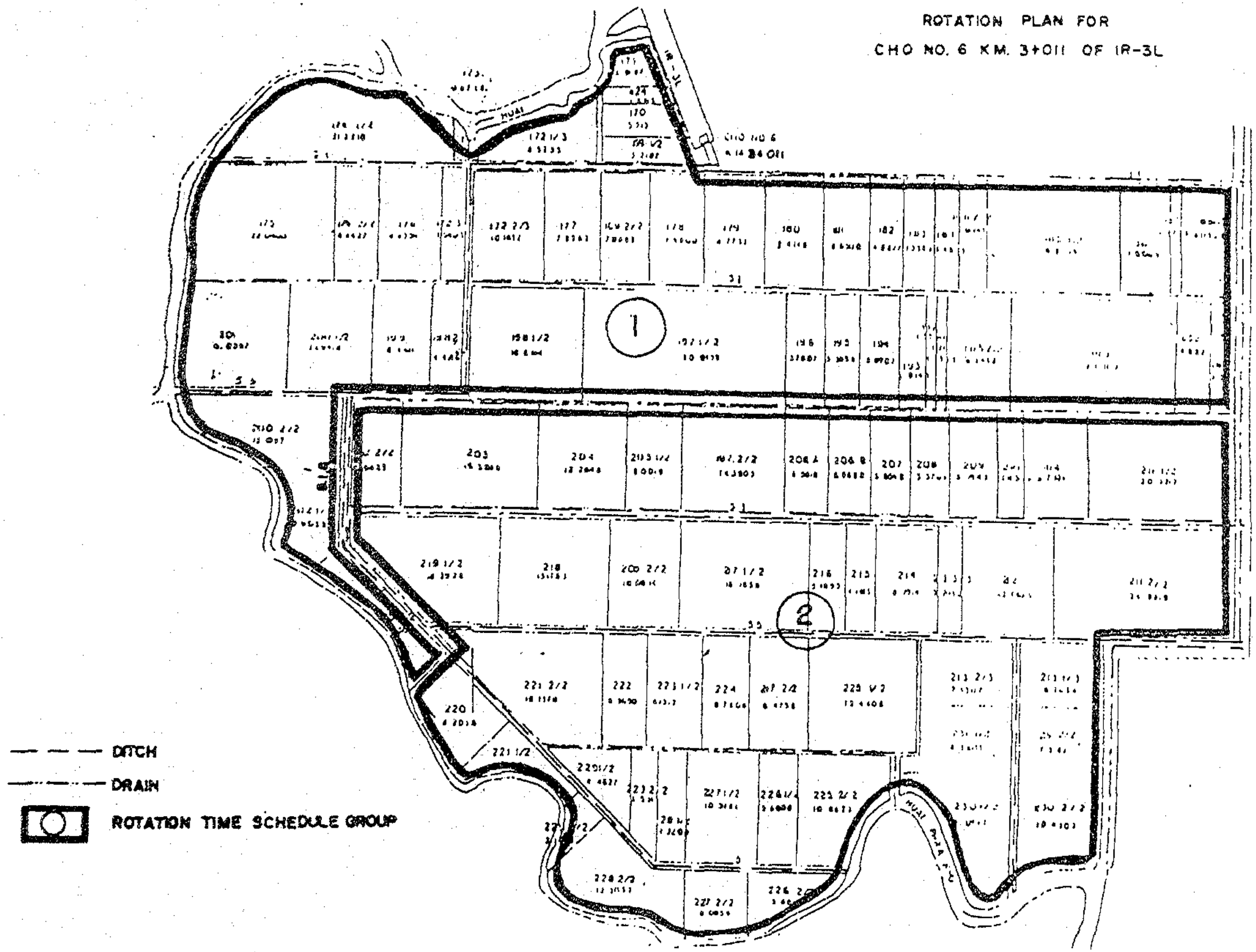
In the case of a large area (more than 800 rai) where the sub-ditch cannot contain the full discharge, the area and discharge should be divided. The example of the CHO No.6 km 3+011 of 1R-3L is shown as follows;

STATEMENT SHOWING THE AREA
AND DISCHARGE ALLOCATION

No.	Area Allocation (rai)	Ditch No.	Discharge Allocation (l/sec)	Size of Pipe Provided for Division Box-- ø diameter (cm)	Days required (days)
Group 1					
1	21	5.2	9	10	3
2	64	5.4	29	20	3
3	41	5.6	19	20	3
4	28	5.6.1	13	15	3
5	222	5.1	100	-	3
	376		170		
Group 2					
1	124	5.3	48	30	4
2	236	5.5	92	-	4
3	78	5	30	-	4
	438		170		

The time allocation between groups 1 and 2 is on the basis of area served, adjusted for travel time and seepage losses.

ROTATION PLAN FOR CHO NO. 6 KM. 3+011 OF IR-3L



2. From the MaeKlong Irrigation Project

Criteria taken into account for the sub-division of the service units into rotation blocks are:

- the rotation blocks' irrigation water delivery period should preferably be a multiple of 12 hours,
- rotation blocks with a delivery period shorter than one day should be avoided,
- the rotation blocks should preferably have approximately the same size, and consequently the same delivery period,
- the service units should preferably comprise of 3-5 rotation blocks,
- each rotation block should be served by at least two or three farm inlets in case of respectively a 60 and 90 l/sec ditch capacity,
- it should be avoided to have plots belong to two different rotation blocks.

The rotation block's irrigation water delivery time is calculated as follows:

$$\frac{\text{area of the rotation block}}{\text{total service unit area}} \times 7 \text{ days}$$

An example of a rotation schedule is worked out in the following table and figure.

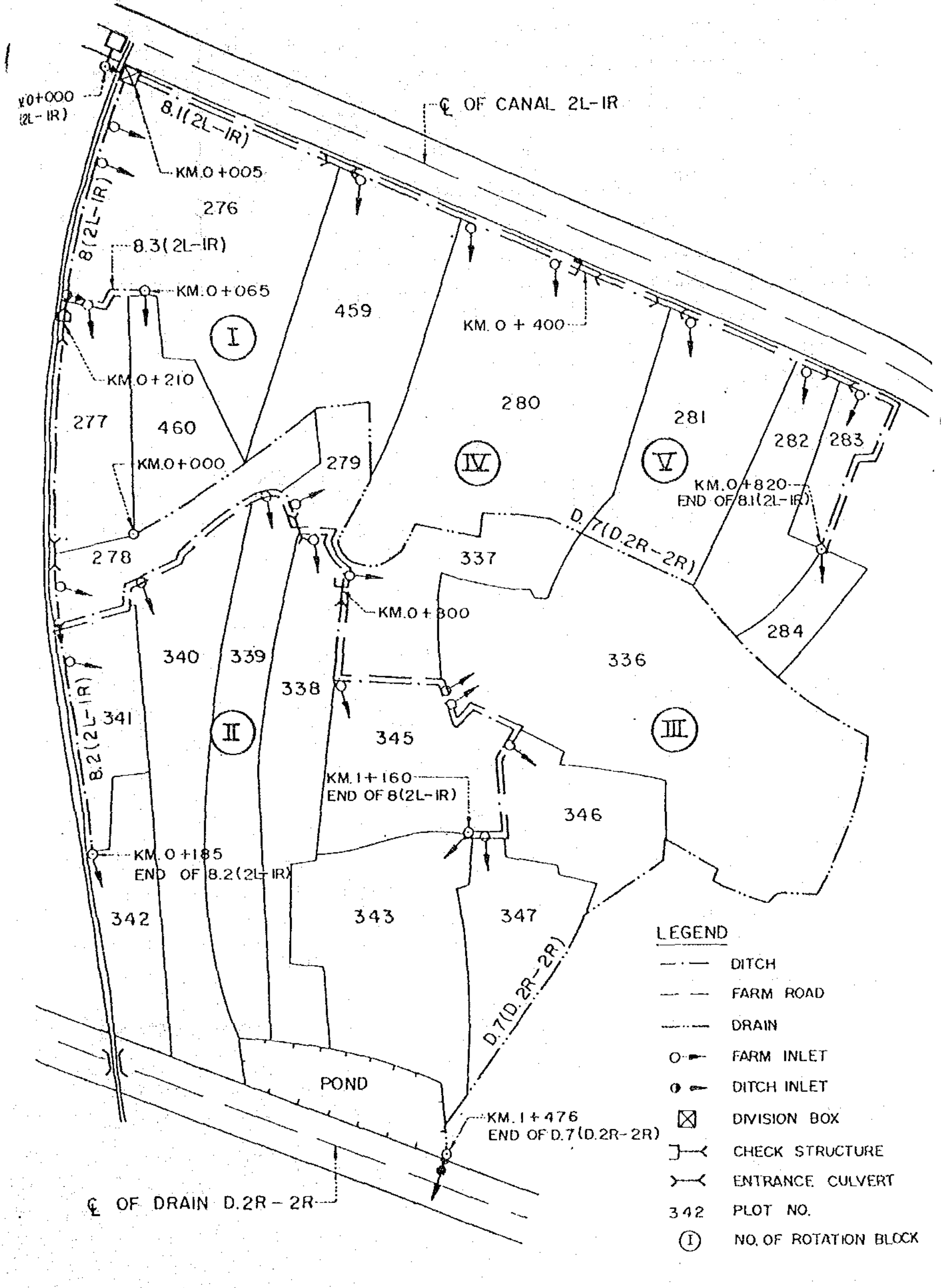
Example of a rotation schedule[1)]

Ditch	From	To	Block	Pilot No.	Area/Plot	Total block area	Approx. irr. time/week (day)
	Km				rai-ngan-wah[2)]		
8(2L-1R)	0+000	0+210	I	276	23-0-85		
8.3(2L-1R)	0+000	0+065		277	7-2-42		
				460	6-1-32	37-0-59	1
8(2L-1R)	0+210	0+800	II	278	5-3-61		
8.2(2L-1R)	0+000	0+185		341	6-0-61		
				342	5-2-20		
				340	14-3-18		
				339	10-3-09		
				338	10-3-80		
				279	3-0-41		
				337	7-3-75	65-0-65	2
8(2L-1R)	0+800	1+160	III	345	10-2-79		
				343	14-3-48		
				347	7-0-58		
				346	7-2-08		
				336	33-0-92	73-1-85	2
8.1(2L-1R)	0+000	0+400	IV	459	14-0-03		
				280	27-0-56	41-0-59	1
	0+400	0+820	V	281	12-1-94		
				282	7-0-07		
				283	3-1-98		
				284	2-3-59	25-3-58	1
Total command area					242-3-26	242-3-26	7

Note: 1) see the following figure

2) 1 wah^2 = 4 m^2, 1 ngan = 400 m^2, 1 rai = 4 ngan = 400 wah^2

ROTATION BLOCKS



I. Rice cultivation methods and water management techniques

In the report which was submitted to the JICA HQ. from the Technical Guidance Mission in November, 1983, Dr. Yasutomi gave recommendations about the Water Management scheme of the Mae Klong Pilot Project No.1 (Intensive method).

His recommendations may be summarized as follows and I would like to add some comments to each item.

1. Water Management techniques should be developed on the basis of the direct sowing method.

	Season	Method	Yield (kg/ha)	Gross income (฿/ha)	Labor expenses (฿/ha)	Net income (฿/ha)
ChaoPhya P/P	Wet	Direct sowing	5,162.5	17,036.2	10,671.2	6,365.0
		Trans-※ planting	4,954.0	15,161.4	11,468.2	3,675.2
	Dry	Direct sowing	4,014.7	13,337.5	8,518.8	4,818.8
		Trans-※ planting	4,785.3	15,787.5	8,662.5	7,125.0
MaeKlong P/P		Direct sowing	5,444	16,331.2	8,781.2	7,550.0
		Trans-※ planting	5,098	15,300.0	8,956.2	6,343.7

※ by rice transplanter

Looking at the table, you would be able to understand easily that the merit of direct sowing is to be able to exclude the laboring transplanting work which amounts to most of the labor expenses, furthermore, the yield per unit area is rather higher than the transplanting. On the other hand, the direct sowing cultivation method demands many well levelled paddy fields, so working expenses concerning this matter cannot be avoided. Bad levelled fields may cause about a 30 per cent decrease in net income.

Regarding the Farm Water Management, further examination about the said two methods are required though, in the Mae Klong Pilot Project, the direct sowing method shows better results than the transplanting method in both the wet and dry seasons.

For this reason, future water management techniques should be developed on the basis of the direct sowing method.

- (comment)

  Basically, this recommendation can be accepted.

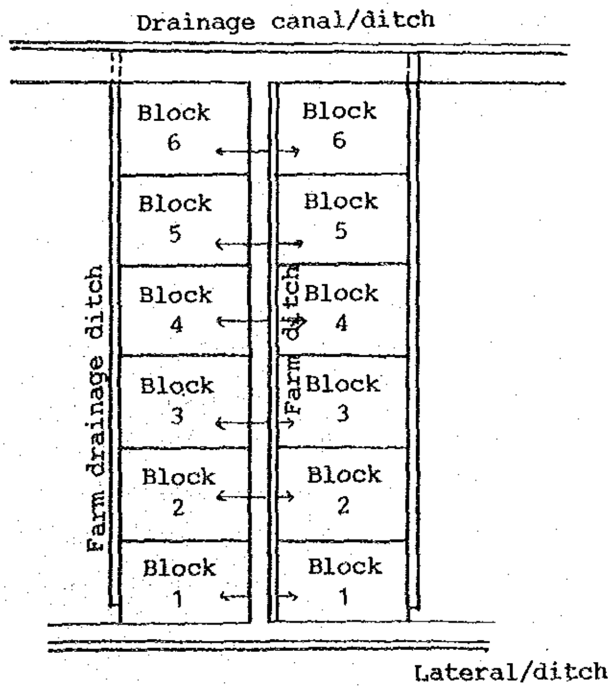
2. Water management based on the direct sowing in flooded paddy field and transplanting.

2.1 Fundamental rotational irrigation method

In the case of water management for direct sowing, irrigation requirement (duty of water) so varies in accordance with the condition of land levelling that it is necessary to raise its accuracy.

Hereupon the level of one's skill on land levelling comes into question; moreover, rotating irrigation system for supplying with irrigation requirement would be introduced if the water source does not have enough volume/capacity.

Taking the case of the MaeKlong Pilot Project No.1 illustrated below, the author would like to examine the possibility of the rotational irrigation method.



in which:

Area of the farm section	:	38.4 has (48 plot x 0.8 ha/plot)
Capacity of the farm ditch	:	24 l/sec.
Evapotranspiration	:	4 mm/day
Percolation	:	1 mm/day

therefore, irrigable area by this ditch is:

$$\frac{0.024\ m^3/sec \times 60\ sec/min \times 60\ min/hr \times 24\ hr/day}{0.005\ m/day \times 100\ m \times 100\ m} = 41.47\ ha$$

$$41.47\ ha > 38.4\ ha$$

In the growth stage (Tillering-ripening), the volume of water to be supplied by the ditch is enough though, problems occur in the preparatory period (Plowing, Puddling).

The problem is that now we should deal with the preparatory water for plowing and puddling which has been proposed for 190 mm. in the detailed design.

$$\frac{0.024\ m^3/sec \times 86,400\ sec/day}{38.4\ ha \times 10,000\ m^2/ha} \times 1,000\ mm/m = 5.4\ mm/day$$

As mentioned above, only 5.4 mm/day of the volume of irrigation requirement can be supplied to one farm section (38.4 ha), it means that 35.18 days is required.

If farm working for preparation of planting is conducted all at once at one farm section, it is clear that irrigation requirement leaves a deficiency.

Considering this fact, it is recommended that six-block rotational irrigation system be introduced.

This recommended idea should be mentioned in detail for readers as follows:

One farm section should be divided into six rotational blocks which has eight plots viz. four plots on the left hand side and the other four plots on the right hand side of the farm ditch and its area is 6.4 hectares as shown in the figure

$$\frac{0.024\ m^3/sec \times 86,400\ sec/day}{6.4\ ha \times 10,000\ m^2/ha} \times 1,000\ mm/m = 32.4\ mm/day$$

can be supplied to one rotation block.

Even though 5 mm/day of supplied water would be consumed with evaporation and percolation, 27.4 mm (32.4 - 5 = 27.4 mm) of water can be used for farm working; so that the proposed 190 mm of preparatory water can be supplied by a 7-day rotation period.
(190 mm ÷ 27.4 mm/day = 7 days)

However, there still remains a problem.

If the first rotating irrigation after direct sowing falls on the following preparatory irrigation, as the volume of irrigation water is fixed, either of the two working process will be hindered.

This is a question of water management.

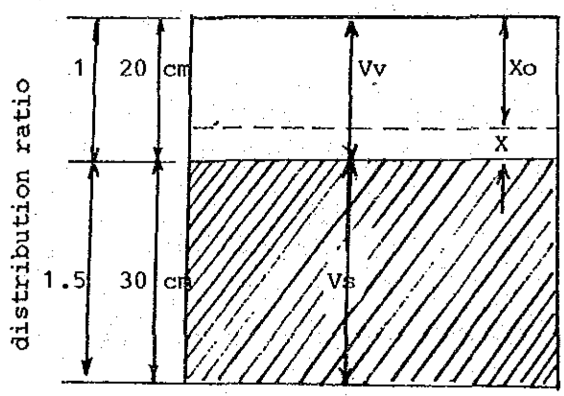
The author would like to describe how to solve it in the following chapter.

2.2 Introducing the preliminary irrigation for soaking

Concerning this matter, Dr.Yasutomi examined the soil aspect.

Taking the result of the fundamental survey for water management at the Trial Farm into account, average porosity and crack depth would be 40 % and 50 cm respectively.

Structure of soil



Vv = Xo + X
in which
Vv : Porosity
Xo : Gas
X : Liquid
Vs : Solid

Therefore: $\frac{Vv}{Vs + Vv} = 0.4$ ....(1)

$\frac{Vs}{Vv} = 1.5$ ....(2)

Without any water in the void, Xo should be maximum (20 cm).
Natural moisture ratio (y) can be shown:

$$y = \frac{X}{2.65 \times 30} \qquad X = 79.5\,y$$

$$4X = X_o - X = X_o - 79.5\,y \qquad \ldots\ldots\ldots\ldots(3)$$

in which the specific gravity of soil = 2.65

Therefore, preliminary water requirement can be expected to be nearly 200 mm.

As a matter of fact, soil is expected to have 10 - 30 % of natural moisture ratio, so average natural moisture ratio would be 20 %.

$$X = X0 - X = 20 - 79.5 \times y = 20 - 15.9 = 4.1 \text{ cm}$$

Preliminary water requirement (PI) should be 4.1 cm.

$$PI = 41 \text{ mm} + \alpha . x \qquad \ldots\ldots\ldots\ldots(4)$$

in which

x = Days of Irrigation for one rotation block

α = Evaporation from the field surface

= 3.8 ~ 2.4 (Dry season, Wet season)

Irrigable capacity of a farm ditch for one rotation block is 32.4 mm per day.

$$\left(\frac{24 \text{ l/sec} \times 0.001 \times 86{,}400 \text{ sec/day}}{6.4 \text{ ha} \times 10{,}000} = 0.0324 \text{ m/day} = 32.4 \text{ mm/day}\right)$$

This 32.4 mm/day is less than the value of the preliminary water requirement (41 mm), though it is expected to fill the 96.5 % of void in the soil with this water.

(Natural moisture ratio is equivalent to 15.9 cm, viz

0.2 x 30 cm x 2.65 = 15.9 cm,

(15.9 cm + 3.24 cm) ÷ 20 cm (volume of void) = 95.7 %)

The purpose of the preliminary irrigation are:

i) To make the soil swell so that the leakage of water is prevented as little as possible.

ii) To make concreted soil soft for plowing.

(comment)

Basically, introducing prelimanary irrigation can be accepted, though water requirement for preliminary irrigation which was decided from the study on the basis on soil porosity cannot be accepted. The reasons will be proved by the results of the fundamental survey.

At the beginning of irrigation, supplied water from a firm inlet flows into the soil according to Darcy's law and along the cracks. In addition to that, some of the water leaks to other plots. The flow is so complex that collecting actual data at different sizes of plots can only give the correct answer.

The result of the practical water management experiment showed that amount of preparatory water 270.3 mm and 281.7 mm respectively.

3. Advisable rice planting methods from the viewpoint of farm water management

Existing rice planting methods can be divided into the following three types, viz. direct seeding culture of paddy rice on upland field, direct sowing in flooded paddy field and transplanting culture.

The initial stage of farm water management is affected remarkably according to the planting method.

ⓐ In the case of direct seeding culture of paddy rice on upland field:

Preparatory irrigation (PI) → (Manuring fertilizer application ↓) → Land levelling (L) → Seeding (S) → (Herbicide ↓) → Flooding (Soil Submergance) (F) → Rotating irrigation during growing stage (I) → Harvesting(H)

ⓑ In the case of direct sowing in flooded paddy field

(PI) → Plowing (PL) → (F) → Puddling (P) → (Herbicide ↓) → (L) → (S) → Drainage(D) → (F) → (I) → (H)

ⓒ In the case of transplanting

(PI) → (PL) → (P) → (L) → (Nursery bed ↓) → Transplanting → (I) → (H)

(Note) Preparatory irrigation is conducted for making plowing and land levelling easier and for accelerating disappearance of cracks so that leakage of water can be prevented.

3.1 Water management for direct sowing in flooded paddy field

Present cultivation calendar of direct sowing method can be shown as follows:

No.	days	Description	
1	- 10	Puddling	To keep the 15 cm of standing water
2	- 5	Puddling and Land levelling	
3	- 4	Spraying of Chemicals (Suturn G)	
4	- 0	Broadcasting	
5			
6	+ 2	Drainage	Commencement of irrigation
7	+ 7	Spraying of chemicals (Furudan)	
8	+ 16 + 20	Spraying of chemicals (Basal)	
	+ 16 17 (week)	Drainage*	
	+ 17 18 (week)	Completion of Drainage*	

* Agronomical Researches "On Land and Water Utilization of Paddy Field in Thailand" Thai Joint Research Project, Oct.1978 Takashi Haraki et al.

a Preparatory irrigation

As mentioned before, preparatory irrigation aims at making plowing work easier besides keeping leakage water as low as possible and the water for this purpose must be supplied at least one week before puddling.

Required amount of water can be estimated using the following algebraic expression, viz. $Y = 41 \text{ mm} + \alpha . X$ taking the rotating irrigation system into account.

Swelled and softened soil with preparatory irrigation water can be expected to discharge its duties to meet the requirements for puddling water within 190 mm estimated in the detailed design. Evaporation from the soil surface may be very small because capillary stage between the outer layer and the lower layer is cut by plowing.

ⓑ Irrigation for puddling

Irrigation water for puddling is supplied about 10 days before puddling.

Keeping 15 cm of standing water depth is usually required for plowing and puddling.

Required irrigation period for this purpose depends on the capacity of the ditch, though in the case of 30 mm/day it would be five days.

Considering evaporation and leakage, seven days would be required.

In general, initial water requirement in depth in the puddling period is high when compared with the regular value.

Supposing that it is 10 mm/day, the regular value in the latter half as of land levelling would be looked on as 5 mm/day.

ⓒ Drainage just after broadcasting

According to the rice cultivation calendar, broadcasting is carried out under flood condition but standing water is drained off two days later.

Considering water utilization aspect, this method would cause a shortage of water.

Consequently, an effective utilization of drained water should be considered not to drain off to the drainage ditch/canal to the neighboring plots so that the drained water can be used for puddling water for other plots.

Fertilizer which was given before broadcasting would be lost if standing water drains off to the drainage ditch/canal but it would still be effective if the drainage water can be supplied toward irrigation water for the neighboring plots.

ⓓ Irrigation after budding

Owing to the drainage after sowing, germination and growth are hastened. Irrigation is initiated when the plant height reached a height of 5～6 cm. In the case of the MaeKlong Pilot Project, supplying 15 cm of standing water which is ideal from the cultivation aspect is different from the capacity of the farm ditches.

ⓔ Drainage for harvesting

Drainage can be commenced at the time when the earing season ends. Even in the dry season, the supply of small amount of irrigation water such as 5mm/day will suffice during this period. Besides, effective rainfall can be expected in the wet season.

3.2 Direct seeding culture of paddy rice on upland fields

It is necessary to study to what extent this cultivation method is of advantage in Thailand. Thinking of the water management aspect, effective use of irrigation water would be expected by adopting this cultivation method. When comparing this cultivation method with direct sowing in a flooded paddy field, only puddling before seeding is the different element; e.g. puddling is not needed for direct seeding culture of paddy rice on upland field.

It means that under insufficient irrigation water conditions, this cultivation method is available.

Since concreted soil with lots of cracks which was left as it was for a long time after harvesting makes plowing work difficult, giving improved conditions is necessary. In order to improve the bad conditions for plowing, supplying the preparatory irrigation water is considered as suggested already.

In the basic equation for preparatory irrigation water ($Y = 41$ mm + $\alpha.X$), the value of the Y should be taken as much as possible. Let's suppose that $\alpha = 4$ mm/day and $X = 3$ days, the Y goes 53 mm. and getting this amount of water, soil would be saturated.

This cultivation method, however, has problems to be solved such as time and labor for weed control, for land levelling under unflooded conditions, restriction of varieties etc. Mutual cooperation among cultivation techniques, land levelling techniques and water management techniques is required.

3.3 Water management for transplanting cultivation

If farmers do not make standing water drain off at the time of planting, any problems concerning this matter cannot be seen in particular. Standing water after transplanting might dwindle to zero by the next time of scheduled rotating irrigation, in order to cope with this problem, a spare day should be scheduled at the end of each week.

4. Amount of rainfall

So far, in the report, the amount of rainfall has not been taken into account at all.

According to the data that was obtained at the Suphanburi Rice Research Station in 1977 and 1978, the annual amount of rainfall was 720 mm in 1977.

(720 mm/365 days = 1.97 mm/day)

Let's suppose that the period of the wet season crop is from August to November and the period of the dry season crop is from March to July.

During these periods, the months which need lots of water are August and September in the wet season and March and April in the dry season respectively.

In August and September, the average monthly amount of rainfall is 108.16 mm/month (3.6 mm/day).

In March and April, on the other hand, the average amount of rainfall is 61.0 mm/month (2.0 mm/day). (See Annex-2)

These amounts of rainfall are available for use for the crops. It means that 3.6 mm/day of effective rainfall can be expected to add 5.4 mm/day※ of the irrigation water requirement in the wet season.

$$(※ \ 5.4 \text{ mm/day} = \frac{0.024 \text{ m}^3\text{/sec} \times 86{,}400 \text{ sec/day}}{38.4 \text{ ha} \times 10{,}000 \text{ m}^2\text{/ha}} \times 1{,}000 \text{ mm/m})$$

For this reason, water management in the wet season can be expected to become fairly easy, but in the dry season, severe water management will be necessary because of the lack of effective rainfall.

5 Summary

From the point of water utilization toward the paddy rice, water management techniques may be summarized as follows:

i) In comparison with the transplanting method, the direct sowing method does not need water for seedling culture,so that it can economized in water, viewed from a different angle, however, since standing water is drained off for sowing, how to raise the standing water after budding becomes a problem.

ii) In order to prevent the leakage of water through the borders and the field surface, it is important to irrigate about one week in advance of plowing; furthermore, levee coating (repair of levees by the method of soil coating) is advisable to prevent water loss from levees.

iii) Drainage water at direct sowing culture must not be drained off to the drainage canals/ditches but should be drained off to the next fields as irrigation water.

This is one of the ways to make up for the serious shortage of water.

iv) Direct seeding culture of paddy rice on upland fields does not need very much water, but it does not always follow that it is a good cultivation method.
Even though preparatory irrigation makes better soil conditions for plowing, land levelling would be still very difficult.

v) From the viewpoint of farm water management, it is possible to say that the transplanting culture holds and advantage over other direct sowing cultures.

vi) Water requirement should be adjusted in both wet and dry seasons as to effective rainfall.
In this case, 3.6 mm/day of rainfall can be expected in the wet season.

J. Fundamental survey for water management

1. Preface

The Thai Irrigated Agriculture Development Project (I.A.D.P.) has three sub-projects.

Two of them, that is, the Chao Phya Pilot Project and the Mae Klong Pilot Project are based on land consolidation and aim at the following things on the assumption that to enhance the standard of living of the project farmers with an increased income gained by increased yield per unit paddy field under a double cropping system , by training the farmers well with improved farming techniques through effective utilization of irrigation water at the modernized on-farm development area.

:- To plan and execute the improvement of the agricultural physical infrastructure, such as field rearrangement, farm roads, irrigation and drainage facilities and empoldering dikes (as required in Chao Phya), in each pilot area;

:- To advise on technical matters to farmers and staff concerned in the pilot areas for effective water management;

:- To conduct trials with improved agricultural techniques of rice cultivation mainly at the trial farm;

:- To provide training and guidance to farmers in the pilot areas and their vicinities on improved agricultural techniques;

:- To introduce and demonstrate improved agricultural techniques at a few model farms which will be selected in the pilot areas;

:- To foster and strengthen the farms' organization for water management, joint co-operative activities for distribution of agricultural materials, collection and forwarding of agricultural products and other activities necessary in the pilot areas including their vicinities when the necessity arises.

Among the activities mentioned above, it is needless to say that water management occupies an important position.

Despite the improvement works of the agricultural physical infrastructure, it would be difficult to increase rice yield without good water management.

It is easy to say, however, but difficult to do for the following reasons:

:- Farmers have no experience in farming of irrigated agriculture.
:- This activities apply to lots of the farmers.
:- It is impossible to regulate their farming programs.
:- Maintenance of the irrigation ditches is insufficient.
:- The number of the personal concerned is not enough.
:- Cooperation between agriculture civil engineering and agricultural extension is requested.
:- The area concerned is too wide to manage.

Lastly I want to point out that water management ought to be done by using actual data not design data.

2. Readjustment works (Rehabilitation)

In order to execute good water management, we must grasp the present condition perfectly.

After that if there are problems about irrigation and drainage facilities and paddy field (land levelling) readjustment works should be excused first.

Under the existing circumstances, we cannot deny that many problems exist in the project area therefore readjustment works should be given the highest priority.

Taking all things into consideration, it is prerequisite to make each plot of the paddy field within the project area irrigable.

i) Irrigation water must flow to the tail of the ditches.

ii) Elevation of the water surface ought to be kept high enough compared with the elevation of each plot.

3. Collection of data from the field to execute good water management

3-1 To grasp the present condition

i) Lateral .... hydrometry (checking discharge)

ii) Intake .... "

iii) Ditch .... (existing situation)

- vegetation
- soil erosion
- longitudinal slope
- cross-section
- hydrometry

iv) Offtake and farm inlet

v) Land levelling .... (existing situation)

- spot high survey

3-2 To collect data from the field

i) Max. Length of an earth ditch

There is no doubt that the maximum length of an earth ditch varies according to vegetation, longitudinal slope, size of cross-section and soil property and these are vital factors.

We might be able to make it clear by checking the present irrigation situation.

In a case where we consider that an earth ditch is too long to fulfil its function, some of its length should be lined concrete.

ii) The time required for irrigation and drainage

According to the design report, the rotational irrigation method is proposed to irrigate one distribution sub-system (24 farm plots) for a 48 day period, by supplying water at the rate of two days per farm plot.

ii-i In order to establish the practical rotational irrigation method at the project area, we must measure the time required to fill a plot with water.

ii-ii The time required for drainage must also be measured.

iii) Bearing capacity, moisture ratio

After draining, bearing capacity at each point will be measured by a cone penetrometer and also will the moisture ratio.

iv) Checking assumed numerical values used in detailed design (Chao Phya Pilot Project)

iv-i Nursery bed

a) Area: One-twentieth of paddy field area

b) Water : requirement 300 mm

iv-ii Land preparation

a) Pre-irrigation for plowing 15 mm (plowing depth 150 mm, increasing soil moisture from 10 percent to 20 percent)

b) Land preparation

b-i Saturation of surface soil layer:
60 mm (plowing depth 150 mm, with 40 percent of soil porosity)

b-ii Standing water above soil surface : 100 mm

iv-iii Irrigation efficiency

a)	field efficiency	80 %
b)	Conveyance efficiency	90 %
c)	Overall efficiency	72 %

v) Establishment of an experimental/trial water management block

v-i Cropping pattern

v-ii Irrigation schedule

v-iii Appointment of a responsible person

4. Investigation Irrigation at the farm level

4-1 Purpose

Lots of assumed items are used in the detailed designs of both the Chao Phya P/P and the Mae Klong P/P.

Originally a pilot project is undertaken to offer technical data before the major project begins.

In connection with this, the data used in the detailed design should be confirmed and should be offered to other projects following the pilot project.

4-2 Data used in the detailed design

i) Chao Phya Pilot Project

For nursery bed

Acreage nursery bed	:	5 % of the total acreage of related paddy fields
Water requirement	:	300 mm
Average water amount	:	300 x 0.05 = 15 mm

Land preparation

Pre-irrigation water : 15 mm

(Plowing depth 150 mm. increasing soil moisture from 10 % to 20 %)

Land preparation

:-	Saturation of surface soil layer	:	60 mm
	(Plowing depth 150 mm with 40 % of soil porosity)		
:-	Standing water above soil surface	:	100 mm
	Total	:	190 mm

Irrigation efficiency

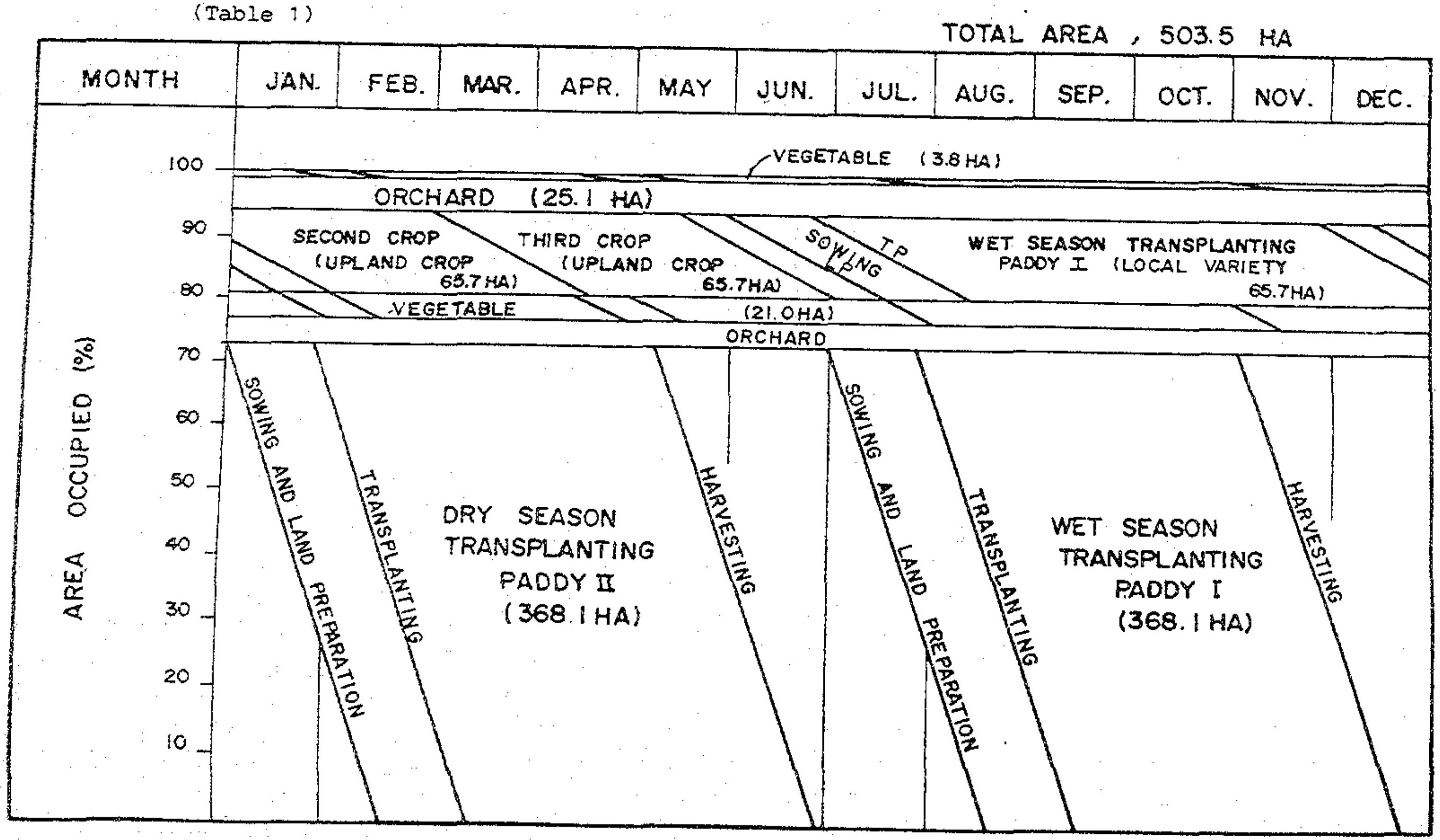
:-	Field efficiency	80 %
:-	Conveyance efficiency	90 %
:-	Overall efficiency	72 %

Peak water requirement 9.6 mm/day

Estimation of irrigation requirements extracted from the detailed design

PROPOSED CROPPING PATTERN

(Table 1)



NOTE ; LP : LAND PREPARATION
TP : TRANSPLANTING

Consumptive use of crops is estimated by using evapo-transpiration (ET) calculated by penman method and crop factor.

(Table-2) Consumptive use of crops

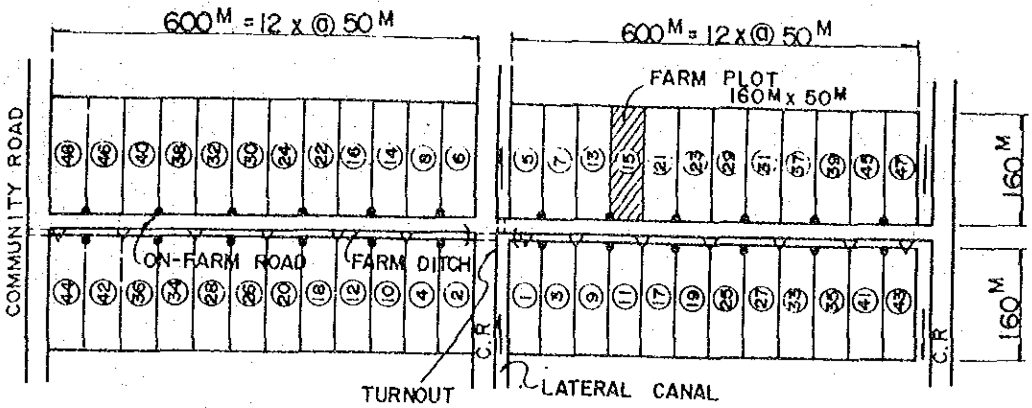
Month		Potential ETP (mm/day)	Paddy Rice Plant A K	Paddy Rice Plant A C.U	Paddy Rice Plant B K	Paddy Rice Plant B C.U	Paddy Rice Plant C K	Paddy Rice Plant C C.U	Paddy Rice Plant D K	Paddy Rice Plant D C.U	Upland-type Crops: Upland Crops Plant A K	Upland Crops Plant A C.U	Upland Crops Plant B K	Upland Crops Plant B C.U	Vegetable Orchard K	Vegetable Orchard C.U
Jan.	I	3.9	0.85	3.3											0.80	3.1
	II	3.9	0.85	3.3	0.85	3.3									0.80	3.1
Feb.	I	4.7	0.90	4.2	0.65	4.0	0.85	4.0			0.30	1.4			0.80	3.7
	II	4.7	1.06	5.0	0.90	4.2	0.85	4.0	0.85	4.0	0.50	2.4	0.30	1.4	0.80	3.7
Mar.	I	5.2	1.17	6.1	1.06	5.5	0.90	4.7	0.85	4.4	0.85	4.4	0.50	2.6	0.80	4.2
	II	5.2	1.19	6.2	1.07	6.1	1.06	5.5	0.90	4.7	1.02	5.3	0.85	4.4	0.80	4.2
Apr.	I	5.7	1.13	6.4	1.19	6.7	1.17	6.8	1.06	6.0	0.95	5.4	1.02	5.8	0.80	4.6
	II	5.7	1.03	5.9	1.13	6.4	1.19	6.8	1.17	6.7	0.80	4.6	0.95	5.4	0.80	4.6
May	I	5.0	0.90	4.5	1.03	5.2	1.13	5.7	1.19	6.0	0.65	3.3	0.80	4.0	0.80	4.0
	II	5.0			0.90	4.5	1.03	5.2	1.13	5.7	0.20	1.0	0.65	3.3	0.80	4.0
Jun.	I	4.6					0.90	4.1	1.03	4.7			0.20	0.9	0.80	3.7
	II	4.6							0.90	4.1					0.80	3.7
Jul.	I	4.2	0.85	3.6											0.80	3.4
	II	4.2	0.85	3.6	0.85	3.6									0.80	3.4
Aug.	I	4.0	0.90	3.6	0.85	3.4	0.85	3.4							0.80	3.2
	II	4.0	1.06	4.2	0.90	3.6	0.85	3.4	0.85	3.4					0.80	3.2
Sep.	I	3.8	1.17	4.4	1.06	4.0	0.90	3.4	0.85	3.2					0.80	3.0
	II	3.8	1.19	4.5	1.17	4.4	1.06	4.0	0.90	3.4					0.80	3.0
Oct.	I	3.9	1.13	4.4	1.19	4.6	1.17	4.6	1.06	4.1					0.80	3.1
	II	3.9	1.03	4.0	1.13	4.4	1.19	4.6	1.17	4.6					0.80	3.1
Nov.	I	4.0	0.90	3.6	1.03	4.1	1.13	4.8	1.19	4.8					0.80	3.2
	II	4.0			0.90	3.6	1.03	4.1	1.13	4.8					0.80	3.2
Dec.	I	3.9					0.90	3.6	1.03	4.0					0.80	3.1

NOTE : K : Coefficient

CU : Consumptive use in millimeter per day

:- Irrigation block

An irrigation block consists of 48 plots (field blocks), that is its acreage is 38.4 ha (0.8 ha/plot x 48) and is to be irrigated by an offtake attached to a ditch.



Upland-type Crops (Unit : mm)

Month		Perco-lation	Plant A				Plant B				Plant C				Plant D				Average Field water Requirements	Upland crops			Vegetable Orchard
			C.U	A.S	Total		C.U	A.S	Total		C.U	A.S	Total		C.U	A.S	Total			Plant A	Plant B	Average F.W.R	
		(1)	(2)	(3)	(4)	(5)	(2)	(3)	(4)	(5)	(2)	(3)	(4)	(5)	(2)	(3)	(4)	(5)	(6)				
Jan.	I	15	50	30	95	6.3													2.0				3.1
	II	16	53	160	229	14.3	53	30	99	6.2									6.5				3.1
Feb.	I	15	63		78	5.2	60	160	23	15.7	60	30	105	7.0					9.0	1.4		0.7	3.7
	II	13	65		78	5.0	55		68	5.2	52	160	225	17.3	52	30	95	7.3	9.0	2.4	1.4	1.9	3.7
Mar.	I	15	98		113	7.5	83		98	6.5	71		86	5.7	86	160	241	16.1	7.0	4.4	2.6	3.5	4.2
	II	16	99		115	7.2	92		108	6.8	88		104	6.5	75		91	5.7	6.8	5.3	4.4	4.9	4.2
Apr.	I	15	96		111	7.4	101		116	7.7	102		117	7.8	93		105	7.0	7.6	5.4	5.8	5.6	4.6
	II	15	89		104	6.9	96		111	7.4	102		117	7.8	101		116	7.7	7.4	4.6	5.4	5.0	4.6
May	I	15	68		83	(5.5)	78		93	6.2	86		101	6.7	90		105	7.0	4.6	3.3	4.0	3.7	4.0
	II	16					72		88	(5.5)	83		99	6.2	91		107	6.7	2.3	1.0	3.3	2.2	4.0
Jun	I	15									62		77	(5.1)	71		86	5.7	0.2		0.9	0.5	3.7
	II	15													62		77	(5.1)	-				3.7
Jul	I	15	5	15	84	5.6													1.8				3.4
	II	16	58	160	234	14.6	58	15	89	5.6									6.4				3.4
Aug	I	15	54		69	4.6	51	160	226	15.1	51	15	81	5.4					8.2				3.2
	II	16	67		83	5.2	58		74	4.6	51	60	227	14.2	54	15	85	5.3	7.8				3.2
Sep.	I	15	66		81	5.4	60		75	5.0	54		69	4.6	48	160	223	14.9	5.4				3.0
	II	15	68		83	5.5	66		81	5.4	60		75	5.0	51		66	4.4	5.3				3.0
Oct.	I	15	66		81	5.4	69		84	5.6	69		84	5.6	62		77	5.1	5.5				3.1
	II	16	64		80	5.0	70		86	5.4	74		90	5.6	74		90	5.6	5.4				3.1
Nov.	I	15	54		69	(4.6)	62		77	5.1	68		83	5.5	72		87	5.8	3.7				3.2
	II	15					54		69	(4.6)	62		77	5.1	68		83	5.5	1.8				3.2
Dec.	I	15									54		69	(4.6)	60		75	5.0	0.2				3.1
	II	16													56		(71)	4.4	-				3.1

Peak water requirement

Kind	Acreage (ha)	Water requirement in depth (mm/day)	Efficiency (%)	Unit-duty of water (l/s/ha)	Duty of water (m^3/s)
Paddy rice	433.8	9.6	72	1.54	2.67
Others	69.7	4.6	59	0.90	0.60
Total	503.5				

ii) <u>Mae Klong Pilot Project</u>

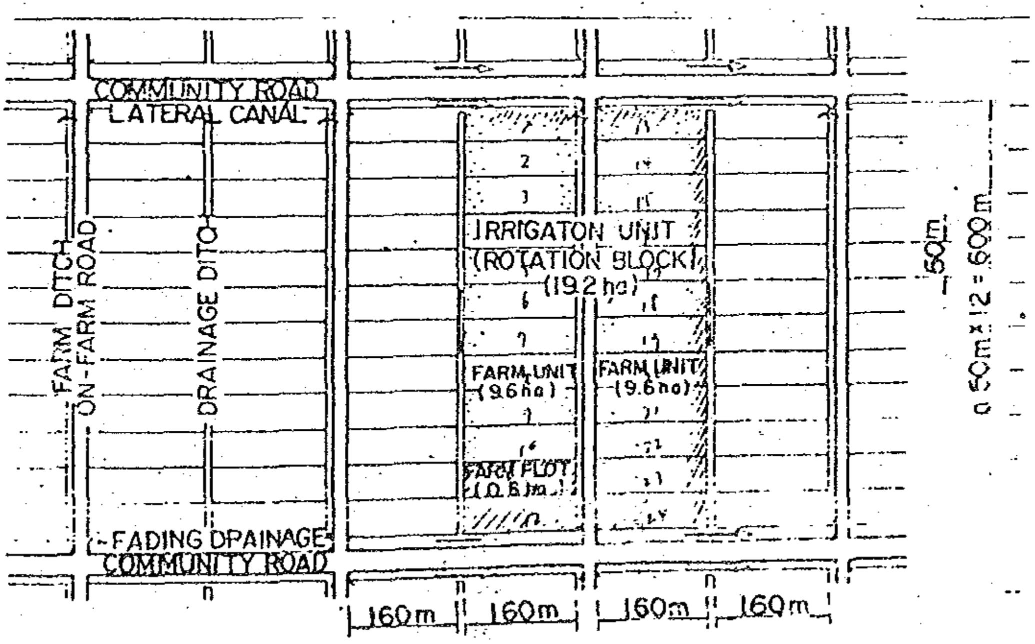
:- Peak irrigation requirement in the wet season. The water right in the wet season should cover the following range of demands in both areas :

No. 1 Pilot Project area within 0.3 m^3/sec

No. 2 Pilot Project area within 0.541 m^3/sec

:- The water right in the dry season should be identified on the basis of those plans for water resources development in the upstream basin of the Mae Klong River and on-farm development in the downstream basin.

a) Estimate of water requirement

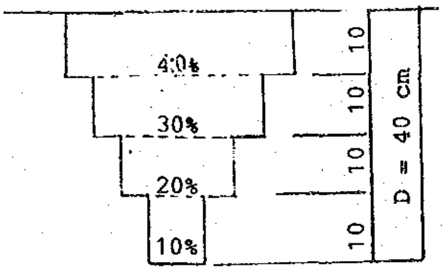


Monthly Evapotranspiration

Month	mm/d	Month	mm/d	Month	mm/d
Jan.	3.42	May	4.51	Sept.	3.54
Feb.	4.18	Jun.	4.06	Oct.	3.53
Mar.	4.80	Jul.	3.75	Nov.	3.43
Apr.	5.20	Aug.	3.80	Dec.	3.20

Annual total 1,441 mm

Field capacity. The maximum field capacity of water in the paddy field is assumed to be 100 mm in depth. The field capacity in upland field mainly depends on the Total Readily Available Moisture (TRAM) inherent in the individual soils. Assuming that the following scheme presents the soil Moisture Extraction Pattern (SMEP), the TRAM was determined from the result of soil analysis to be 47 mm.



Field capacity (FC) ....34.1 % (by weight)

Moisture content at PP 3.8 (Wp).............22.2 %

Apparent specific gravity (Sa)............. 1.59

Crop Factor (K)

Growing stage	High Yield Paddy	Local Variety Paddy	Upland crops	Sugarcane
1	0.85	0.85	0.20	0.40
2	0.87	0.87	0.24	0.80
3	0.95	0.95	0.40	1.00
4	1.06	1.06	0.66	1.20
5	1.10	1.10	0.96	1.25
6	1.20	1.20	1.02	1.20
7	1.19	1.19	1.00	1.15
8	1.15	1.15	0.90	1.10
9	1.10	1.10	0.75	1.10
10	1.03	1.03	0.60	1.00
11	0.90	0.90	0.20	0.90
12				0.80

Percolation rate and other water requirements

The percolation rate in the paddy fields is determined to be 10 mm/day based on the field survey results and soil conditions. Crops other than paddy require 40 mm of pre-irrigation water before sowing.

On the other hand, rice requires the following amounts of water for puddling and preparing the field.

	Transplant field		Nursery bed	
	Dry season	Rainy season	Dry season	Rainy season
Preparatory	30	15	30	15
Puddling	160	160	120	120
Total	190	175	150	135

Irrigation requirement

The following is the definition of 'irrigation requirement' as applied to this study.

- Net water requirement (NWr) = CU + Pe

  Pe = Percolation loss

- Water requirement (Wr) = (NWr + Lp - E)/Ef

  Lp = Land preparation water

	E	= Effective rainfall
	Ef	= Field efficiency
Diversion requirement	(Dr)	= Wr/Ed
	Ed	= Conveyance efficiency

Irrigation efficiency

The following shows the estimated irrigation efficiency.

	Paddy field	Upland field
Field efficiency (Ef)	80%	65%
Conveyance efficiency (Ed)	90%	90%
Overall efficiency	72%	59%

The peak of irrigation requirement in the dry season will occur on the last day of the puddling period of the dry season paddy (later part of February)

NWr = 397 + 1 = 4.97 mm

CU = Ep x K = 4.18 x 0.95 = 397 mm

P = 1 mm

$$(4.97 \times \frac{23}{24} + 150 \times \frac{1}{48}) \div 0.8 = 9.85 \text{ mm}$$

Dr 9.85/0.9 = 10.94 mm

Irrigation discharge per 1 farm ditch

$(10.94 \times 19.2 \text{ ha}) \div 86{,}400 = 0.024 \text{ m}^3/\text{s}/19.2 \text{ ha}$

4.4 Irrigation test at the Trial Farm

This test aimed at seizing the essence of the matter of water management. The contents of the test are as follows:

:- Soil test sampled at plot 7

:- Surveying the condition of land grading

:- Checking the first stage consumptive use of water (pre-irrigation for plowing)

:- Range of irrigation water by the hour

:- Checking the amount of puddling water

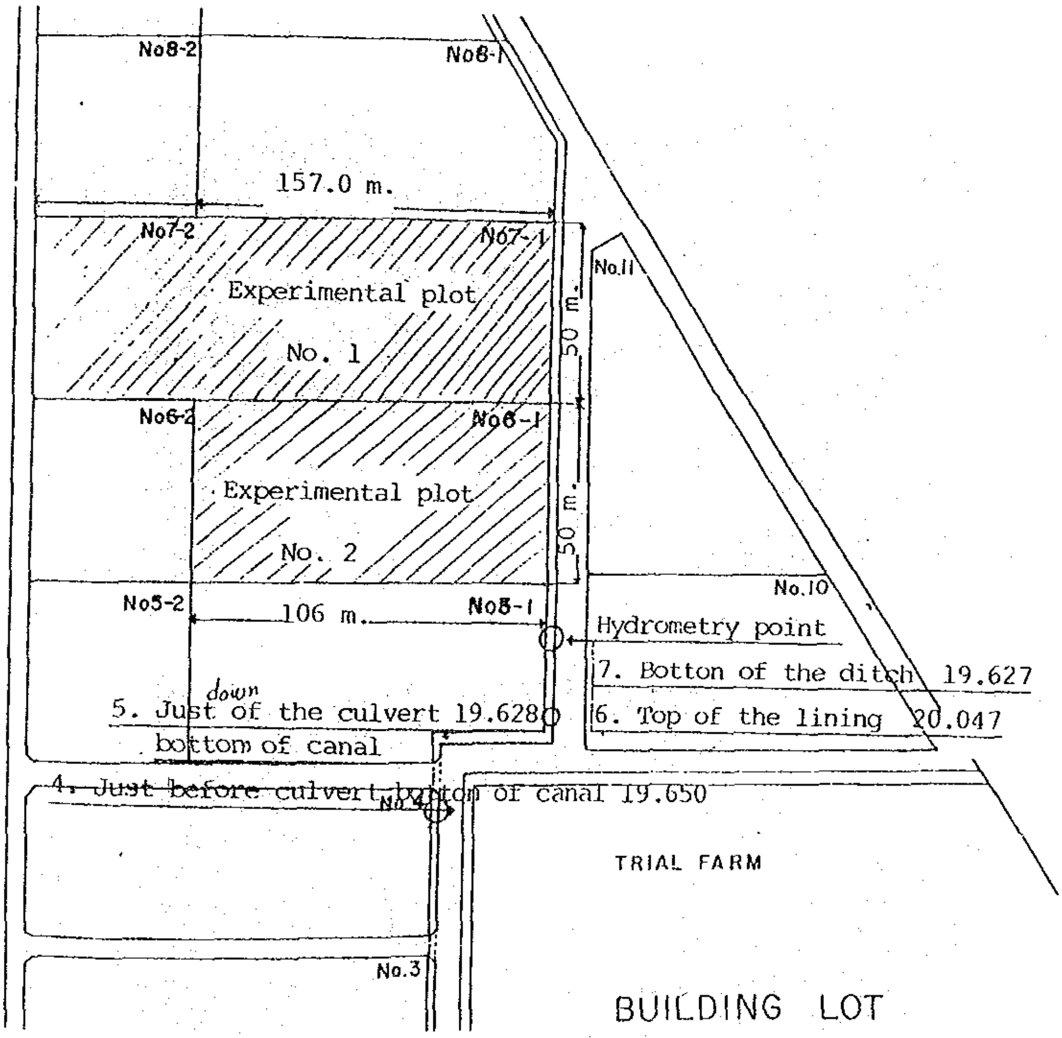
:- And its time to fill a standard plot

:- Range of supplied water by the hour

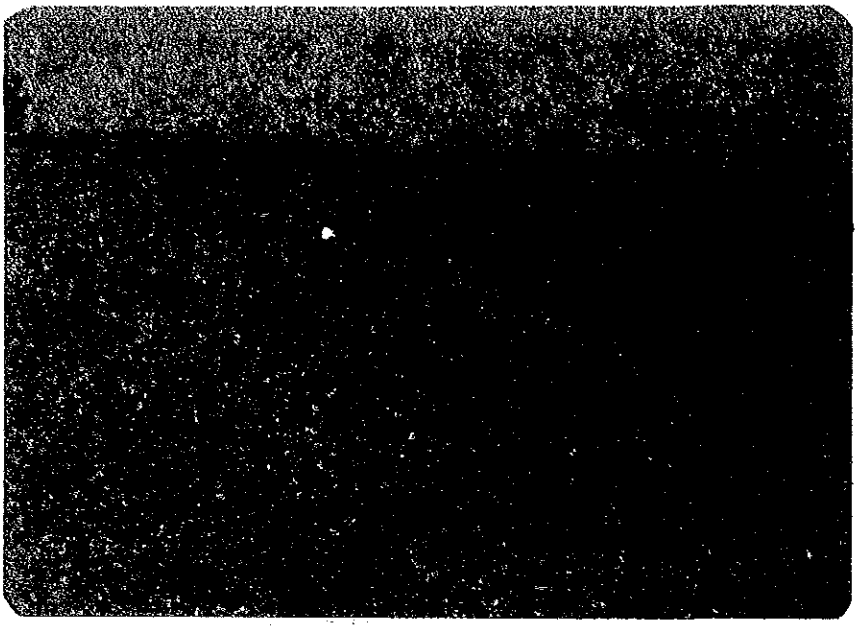
:- Change of moisture ratio in course of time

:- Change of bearing capacity in course of time

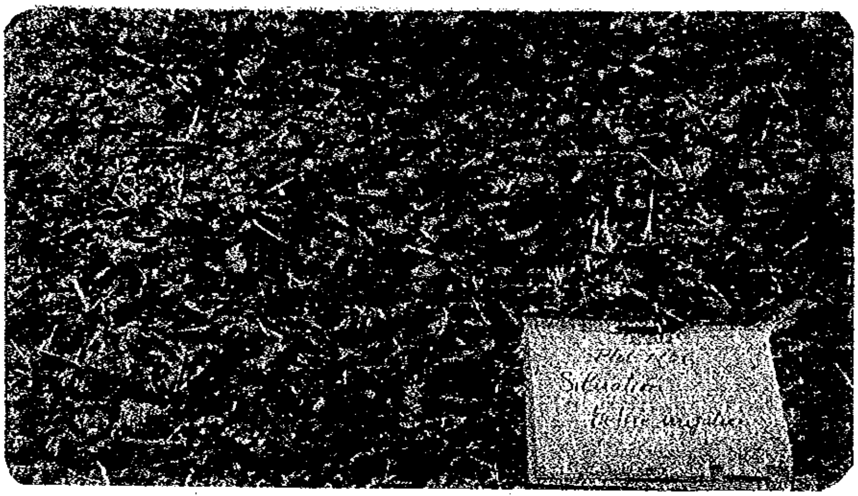
i) Investigation place



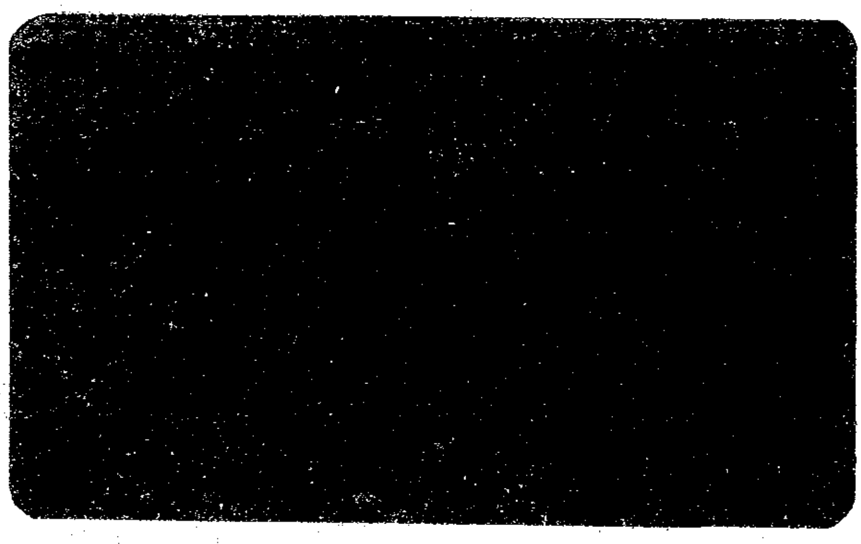
ii) Situation of the experimental plot

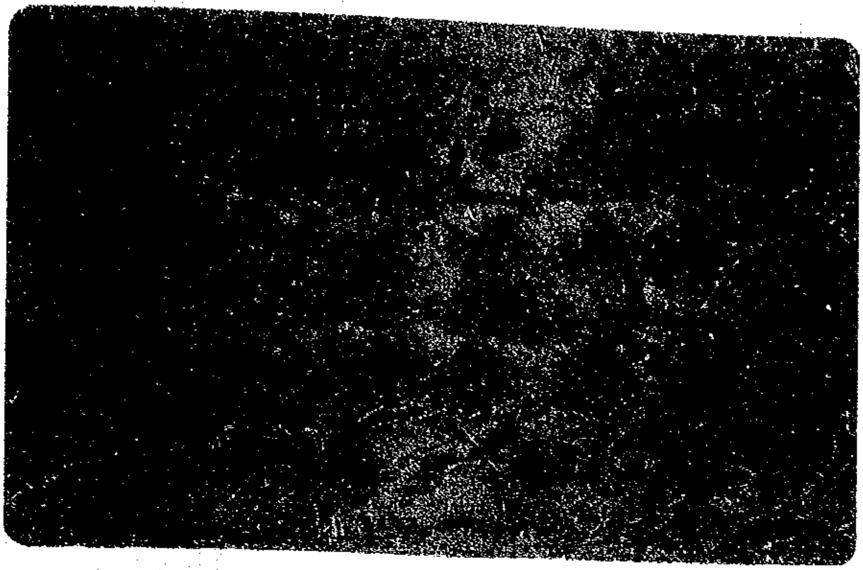


Experimental plot No.2



Experimental plot No.1





Preceding crop : paddy
Drained out water : Nov.26, 1982
Harvesting : Dec. 14, 1982
Plowing : Non
Leveling condition : Surveyed Jan. 19, 1983

Survey point	E.L.	Difference
1	19.535	0.051
2	19.541	0.045
3	19.510	0.014
4	19.500	0.004
5	19.505	0.009
6	19.505	0.009
7	19.527	0.031
8	19.525	0.029
9	19.535	0.039
10	19.505	0.009
11	19.517	0.021
12	19.472	- 0.024
13	19.515	0.019
14	19.482	- 0.014
15	19.500	0.004

Temporary dike

16	19.484	- 0.012
17	19.464	- 0.032
18	19.450	- 0.046
19	19.440	- 0.056
20	19.442	- 0.054
21	19.457	- 0.039
Mean	19.496	

:- Plot No.2

Preceding crop : Paddy

Drained out water : Nov.26, 1982

Harvesting : Dec.14, 1982 (combine harvester)

Plowing : 1st, Jan.4, 1983 (Rotavating)

2nd, Jan.11,1983 (- ditto -)

Levelling condition : Surveyed Jan.19, 1983

Field No.6

Survey point	E.L.	Difference
1	19.484	0.014
2	19.493	0.023
3	19.529	0.059
4	19.446	- 0.024
5	19.475	0.005
6	19.480	0.010
7	19.502	0.032
8	19.465	- 0.005
9	19.445	- 0.029
10	19.470	0.000
11.	19.460	- 0.010
12	19.467	- 0.003
13	19.480	0.010
14	19.455	- 0.019
15	19.405	- 0.065
Mean	19,470	

iii) Soil test

A soil sample was gathered at experimental plot No.1 and carried out at the Pakred laboratory, RID. The items of the soil test were;

:- Specific gravity test

:- Grain-size Analysis

:- Consistency test (Liquid limit, Plastic limit)

:- Compaction test

:- Permeability test

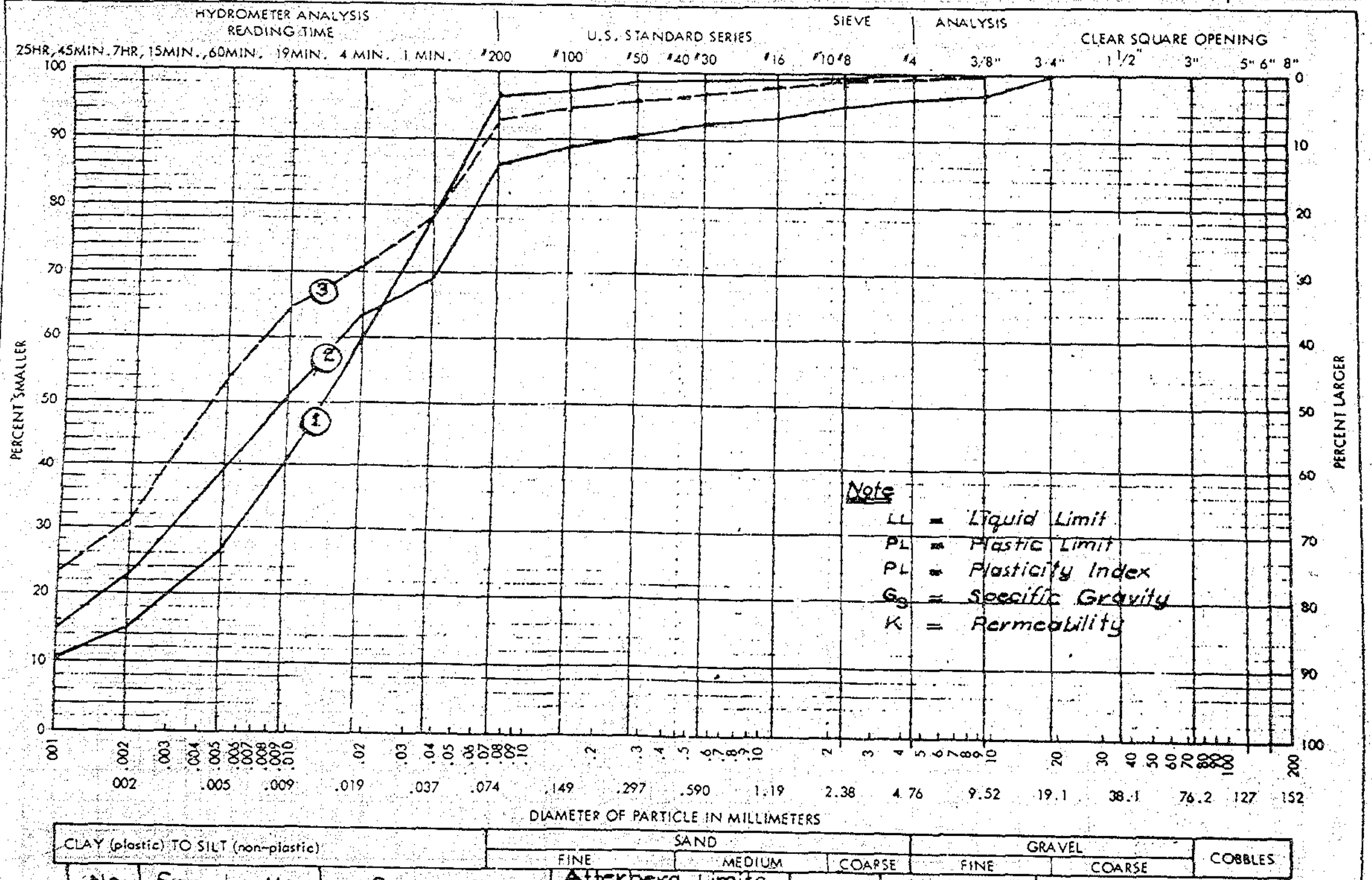
:- Density and unconfined compression test.

Royal Irrigation Department

Project The Greater Mae Klong

GRADATION TEST

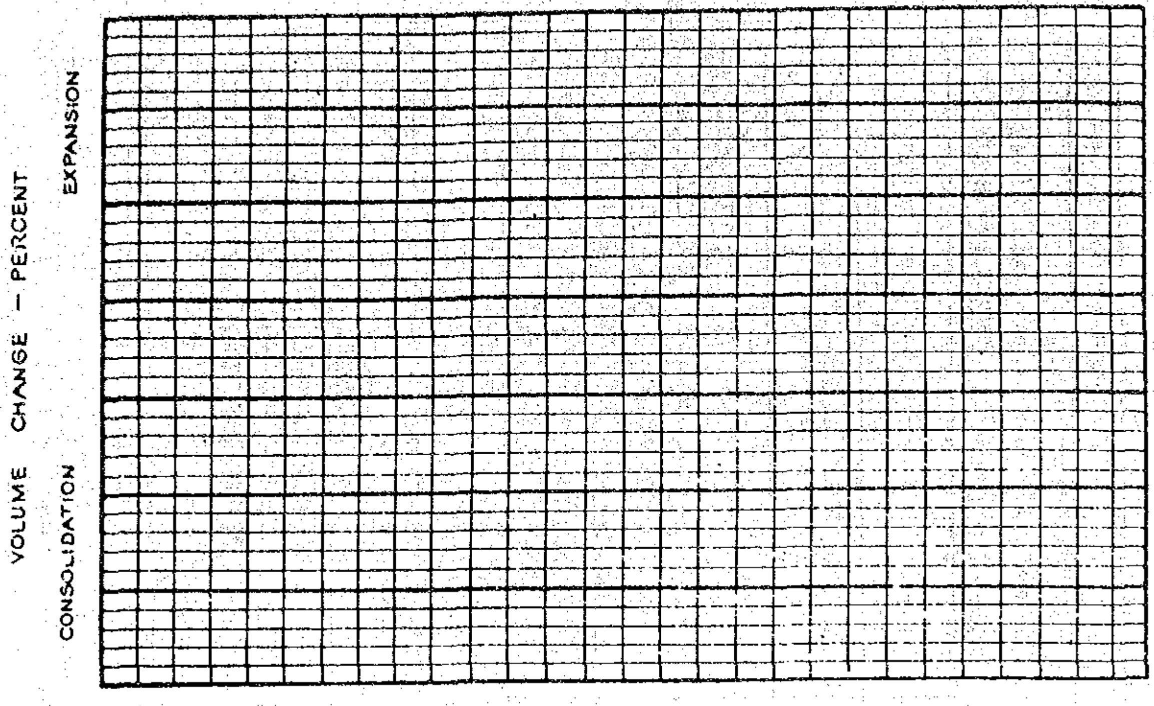
Memo. 60/2526



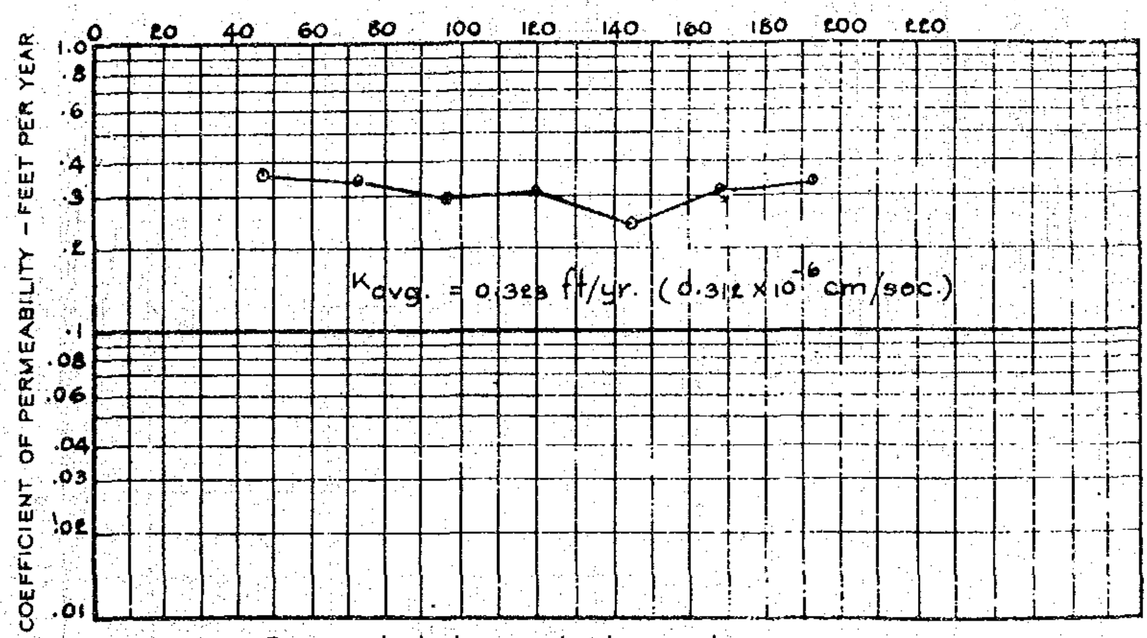
Notes:

No.	Sample No.	Sample Frome	Atterberg Limits L.L.	P.L.	P.I.	G_s	K, cm./sec	Soil Classification
①	P/P No. 1	Txial From	39.2	26.8	12.4	2.60	0.312 x 10^{-6}	ML
②	P/P No. II	Earth Ditch - 07 -	46.9	29.5	16.5	2.65	—	ML
③	P/P No. III	E[illegible]th Ditch - 10	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]

PERMEABILITY - SETTLEMENT TEST



TIME IN HOURS



REMARKS Compacted to 95% $\gamma d_{max.}$ at o.m.c.

($\gamma d_{max.}$ = 1.595 gm./cc, o.m.c. = 20.2%)

INITIAL CONDITION	FINAL CONDITION
PLACEMENT USED	CONSOLIDATION(%)
DRY DENSITY(gm/cc) 1.510	CONSOLIDATED,DRY DENSITY (PCF)
WATER CONTENT(%) 20.4	
CONSOLIDATION LOAD(PSI)	WATER CONTENT(%) 23.9
(DEPTH OF FILL)	PENETRATION RESISTANCE (PSI)
CLASSIFICATION	
SIZE OF SPECIMEN Ø 6 x 2	COEFFICIENT OF PERMEABILITY(K) (cm/sec) 0.312x10^{-6}

ROYAL IRRIGATION DEPARTMENT
RESEARCH & LABORATORY SECTION
SOIL MECHANICS LABORATORY

Greater Mae Klong

SAMPLE NO. P/P. No. 1

DRAWN VV. CHECKED Va. DATE 24-3-83

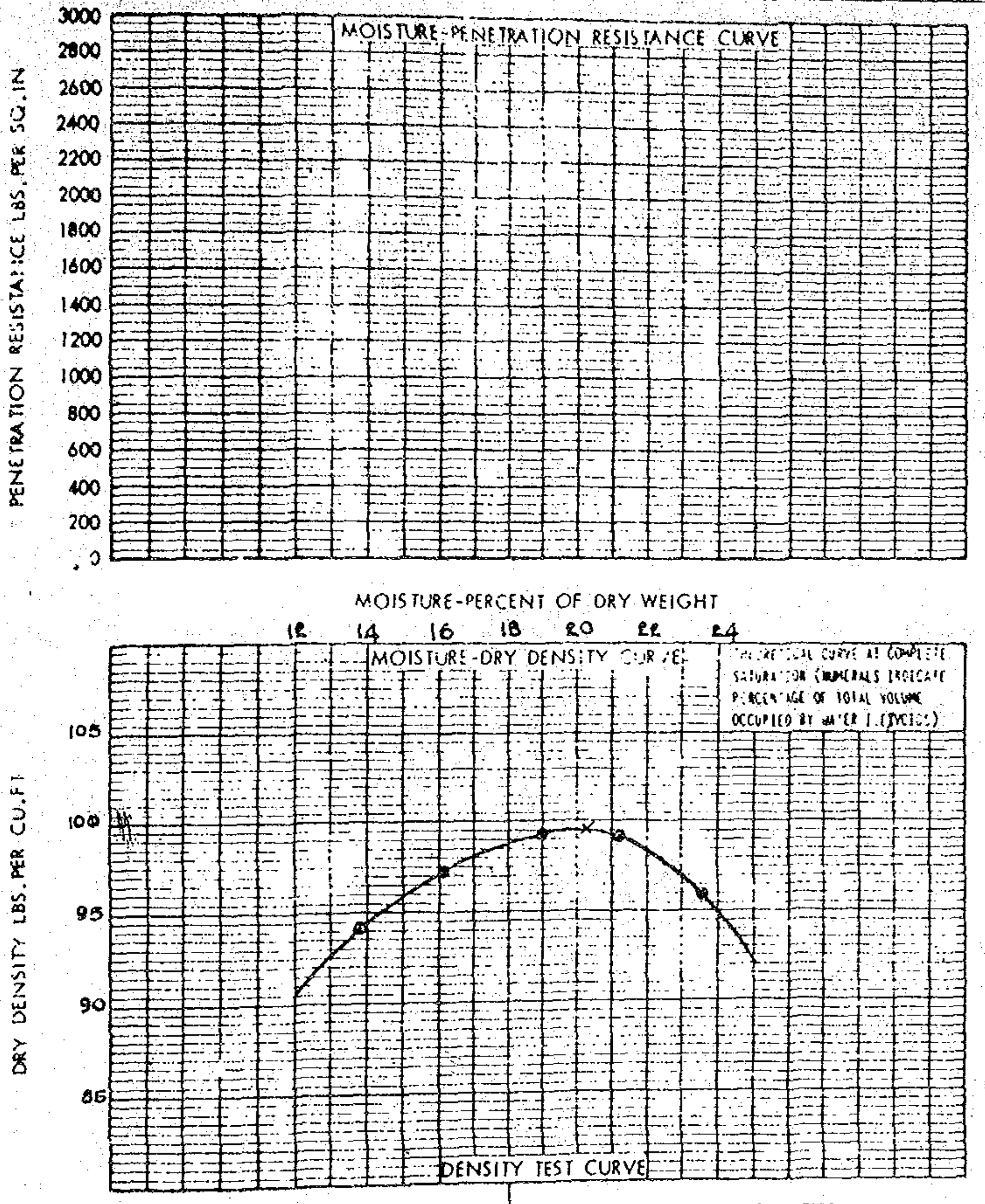
SHEET 2 OF 2

Division of Research and Laboratory
Roya Irrigation Department

ว.ท.4-38
(ก.ค.2519)

COMPACTION TEST CURVE

Project. แม่กลองใหญ่ P/P No. 1 Memo. 60/๒๕๒๖

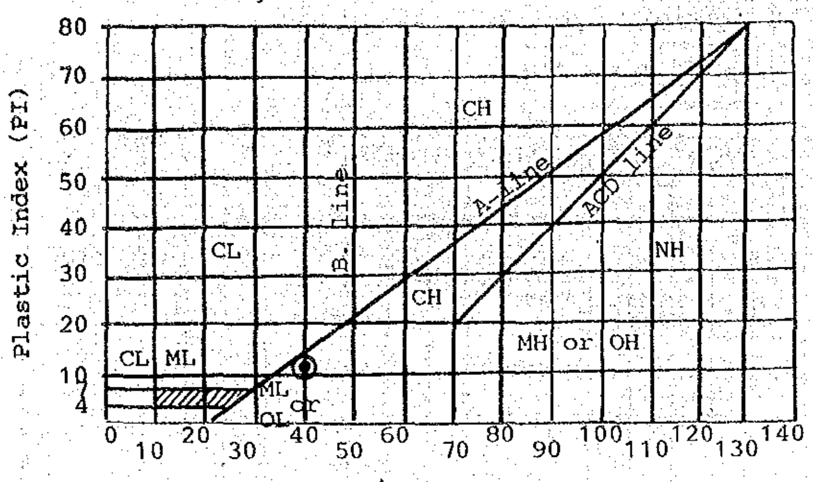


COMPACTION		SOIL PROPERTIES
25 BLOWS PER LAYER	12 IN. DROP	SPECIFIC GRAVITY ... 99.5 MAX. DRY DENSITY
3 LAYERS	1/30 CU. FT.	SOIL CLASSIFICATION ... 20.2 OPT. MOISTURE %
5.5 LB. HAMMER		% LARGER THAN TESTED ... PEN. RES. AT OPT. MOIS.(P.S.I.)

Drawn P1. Checked VS. Date 8-2-83 Sheet 2 of 3

This soil can be classified as follows:

Plasticity chart



Liquid limit (L.L)

ML

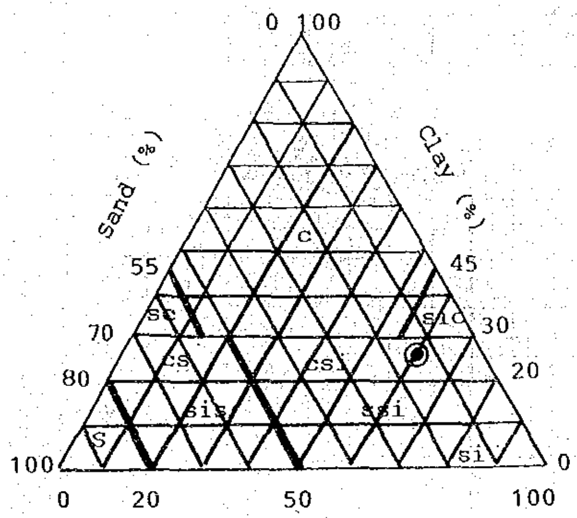
M : Silt

(MO : Swedish)

L : Low liquid limit

(L.L < 50 %)

Triangular diagram



Silt (%)

Silty clay

This soil is not suitable as a material of construction (for road, earth ditch) because it lacks strength and lacks stability against water.

:- Density and unconfined compression test.

This test was carried out as a part of fundamental investigation into irrigation of a field.
The object of this test is to investigate many cracks that appear after drainage owing to shrinkage of the soil and afterward it encrusts.
The hardening of the field surface makes it easy to use agricultural machinery but on the other hand it makes it difficult to plow.
Therefore, this test was executed with the object of getting the numerical value of shrinkage and compressive strength.

- Sampling

  Place : Block 7 in the Trial Farm

  Situation : 3 days after irrigation

- Results

Items	No.1	No.2	Mean
Weight (mold + Humid soil)	2,530 g	2,524 g	2,527 g
Weight (mold + Dry soil)	2,132 g	2,113 g	2,123 g
Weight (mold)	780 g	762 g	771 g
Moisture content	29.4 %	30.4 %	29.9 %
Soil volume	939.9 cm^3	939.9 cm^3	-
- Field density	1,862 g/cm^3	1,875 g/cm^3	1,869 g/cm^3
Shrinkage ratio			
- Volume before dry	939.9 cm^3	939.9 cm^3	-
- Volume after dry	825.0 cm^3	837.1 cm^3	846.1 cm^3
- Shrinkage ratio	87.3 %	89.1 %	88.5 %
Compression load	1,700 Kg	1,400 Kg	1,550 Kg
- Compression stress	20.6 Kg/cm^3	16.8 Kg/cm^3	18.7 Kg/cm^3
Remarks	some cracks appeared after drying	some cracks appeared after drying	-

mean humid soil weight 2,527 - 771 = 1,756 g

mean dry soil weight 2,123 - 771 = 1,352 g

mean moisture content 1,756 - 1,352 = 404 g

mean moisture ratio 404 ÷ 1,352 = 29.9 %

Porosity of the soil

Total volume (mean) 939.3 cm^3

water 404 cm^3

soil volume (939.9 - 404)/2.60 = 206.1 cm^3

void 939.9 - (404 + 206.1) = 328.9 cm^3

Porosity

(328.9 ÷ 939.9) x 100 = 35 %

The distinguishing characteristic of this soil can be said to be as follows

:- Uniformity coefficient (Uc)

$$Uc = \frac{D60}{D10} = \frac{0.02}{0.001} = 20$$

$Uc \geqq 10$ therefore grain distribution in not bad

:- Plasic index

$$Ip = Wl - Wp = 39.2 - 26.8 = 12.4$$

:- Liquidity Index

$$Il = \frac{W - Wp}{Ip} = \frac{29.9 - 12.4}{12.4} = 1.4$$

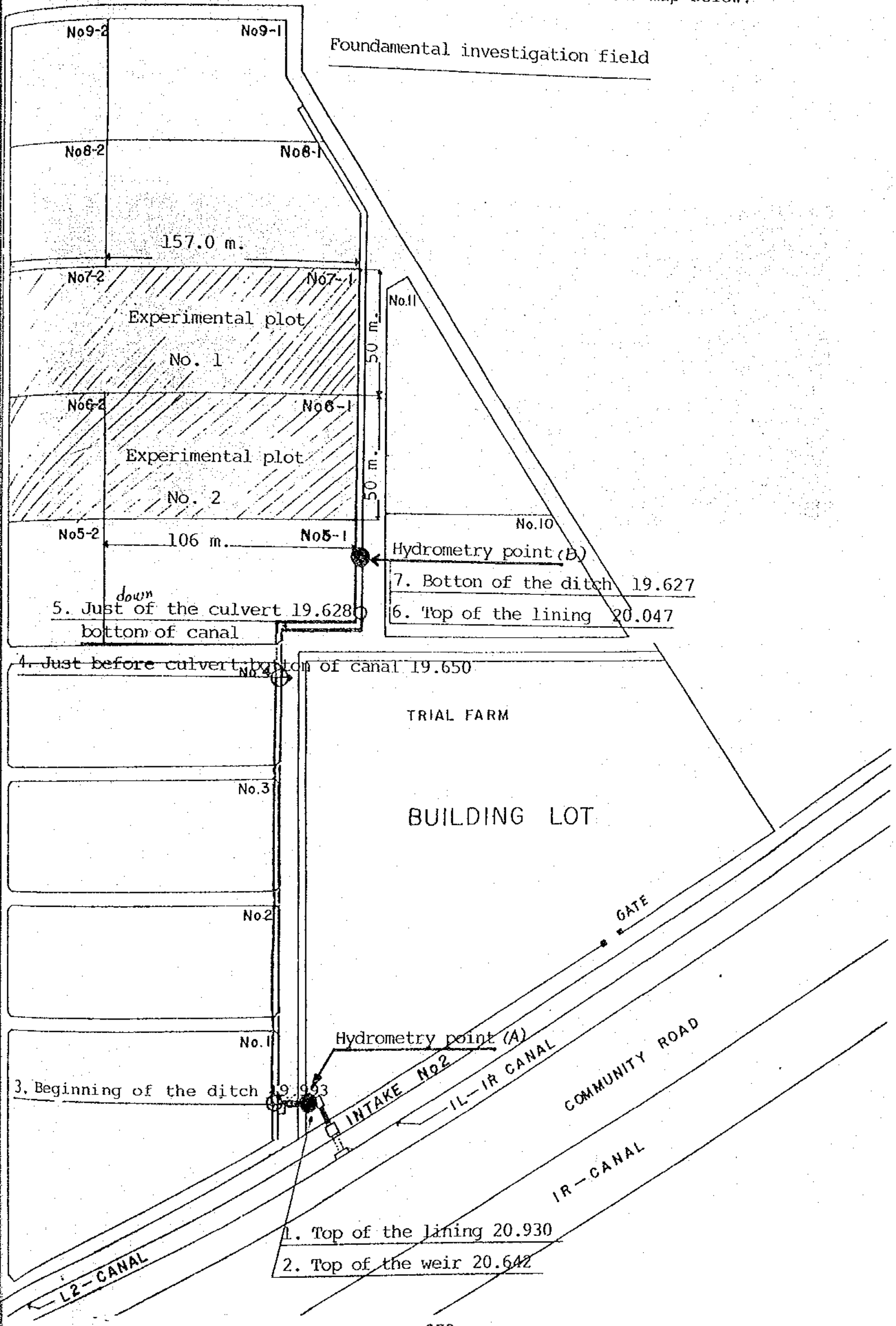
This soil is very sensitive to water, namely in the case of increasing moisture ration it liquescents: on the other hand in the case of decreasing moisture ratio it stiffens.

As a result it makes plowing impossible.

<u>According to this unconfined compression test the compression stress was shown to be 18.7 Kg/cm^2</u>

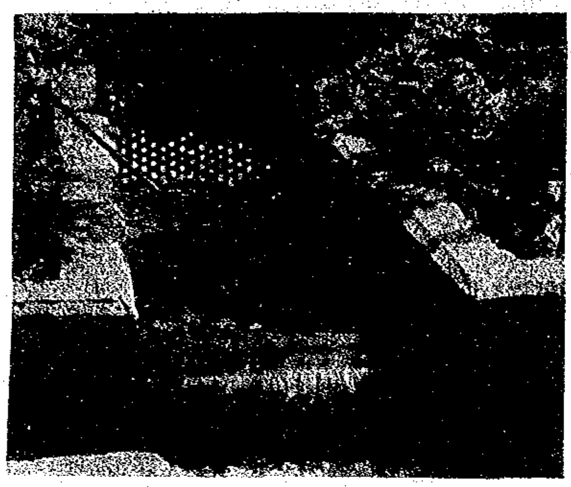
iV) The Mode of investigation

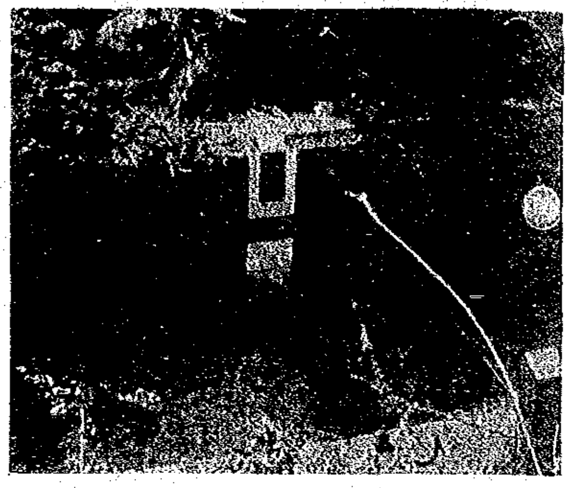
Two control sections were set up as shown in the map below.



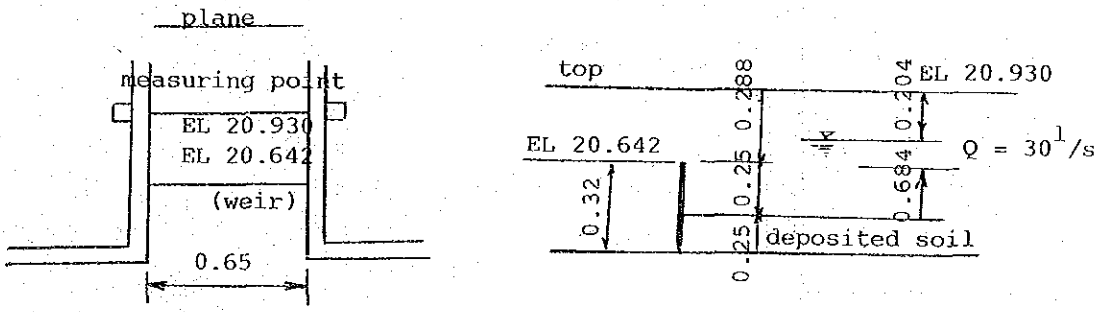
Discharge which was supplied to a plot was decided as 30 l/s. according to the design criteria of the "Mae Klong Right Bank Project and the Pitsanulok Project".

This discharge was controled at the two weirs. Refer to the map attached to the previous page.
Hydrometry point (A)





(fig-2)



$$Q = C.B.H.^{3/2}$$

$$C = 1.758 + \left[\frac{0.00295}{h} + 0.237\frac{h}{D}\right] \left[1 + E\right]$$

In which

C = Coefficient of discharge

B = Width of the weir (= 0.65 m)

H = Overflow depth

D = Height from the bottom to the top (= 0.25 m)

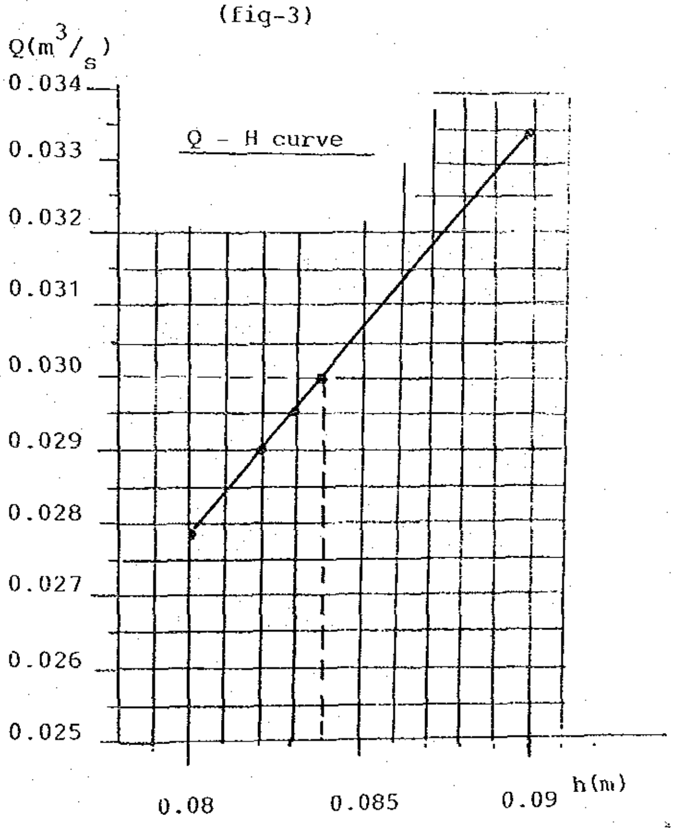
E = Correct factor ($D \leqq$ / m E = 0)

In this case, according to the design criteria the discharge should be 30 l/s

(Table-1)

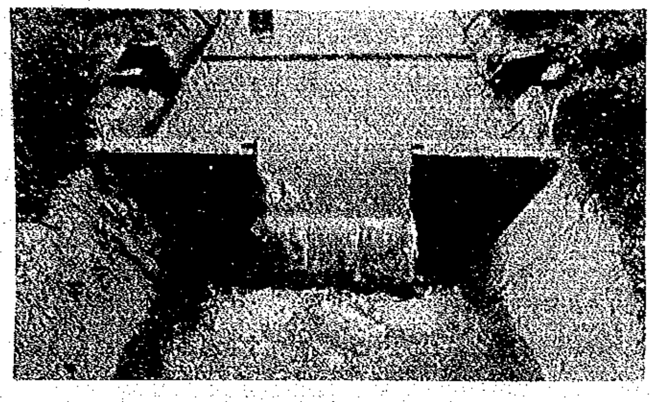
h m	Q m 3/5
0.08	0.0278
0.082	0.0290
0.083	0.0295
0.084	0.0300
0.09	0.0334

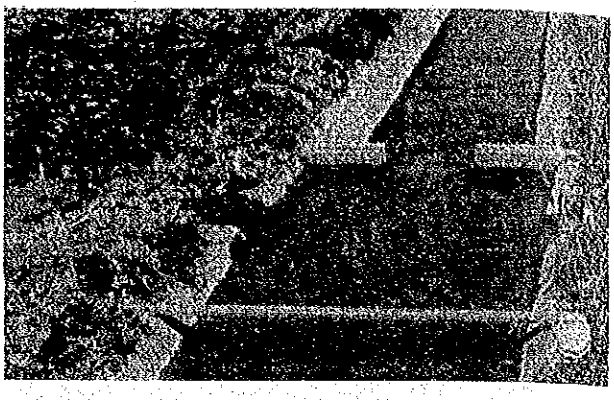
(fig-3)



Hydrometry point (B)

The discharge was checked at this point again.

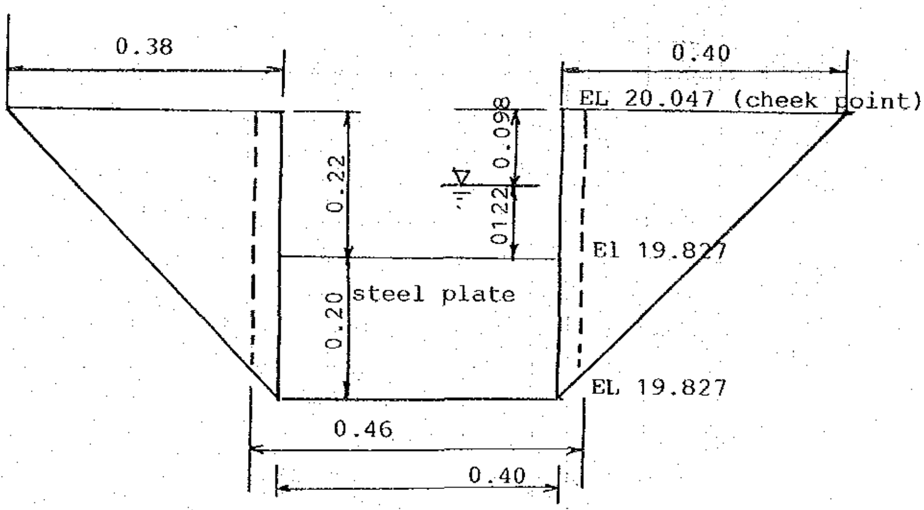




- Check weir

is set up to check the discharge at just above the farm inlet of experimental plot No.2.

(fig-4)



$$Q = cbh^{3/2}$$

$$C = 1.838 \left(1 + \frac{0.0012}{h}\right) \left(1 - \frac{\sqrt{h/b}}{10}\right)$$