No.

Technical Notes For Basic Study of On-Farm Water Management

— PART-I IRRIGATION ASPECTS —

1st MARCH, 1984

NATIONAL WATER MANAGEMENT
TRAINING CENTRE, KOTA BHARU,
KELANTAN, MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTRIBUTOR : IR. HASSAN AWANG
Y. MURAMATSU

ARTIST : MAARUF KASSIM

NATIONAL WATER MANAGEMENT
TRAINING CENTRE, KOTA BHARU,
KELANTAN, MALAYSIA

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PREFACE

The water management means to use the limited water as effectively as possible for a crop cultivation under the improved farming practice. The limited water is to be distributed equally into each field. Thus, the equitable distribution of water will be one of the main purpose of water management.

The water management is to be carried out under the improved farming practice, which aims high yield crop production. In case of paddy cultivation, the water depth in the field is to be controlled within the suitable water depth in order to get high yield. Thus, the other main aims of the water management will be to keep the water in the field to the most suitable depth in each paddy growing stage. This water controll is so called "on-farm water management".

Based upon the above consideration, this note deals with the necessary fundamentals and investigation method. Some results of interium findings will be discussed later. However, the study was carried out for only few seasons, therefore the results are only indicative. The purpose of this note is to investigate the situation in more detail. I hope this kind of study will be continued. Finally, for the practical use, detailed operation manual of measuring instruments will be attached.

1st. March, 1984

Y. Muramatsu

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1. INTRODUCTION

1-1. General out-line of on-farm water management

1-1-1. Targets of on-farm water management

Targets of on-farm water management are:

(1) To increase and stabilize the yield or to increase land productivity,

(2) To decrease and stabilize labour requirement or to increase labour productivities,

(3) And to rationalize water utilization or to save water resources.

1-1-2. Increment of land productivity

(1) Improvement of varieties

Generally, improved high yielding varieties are easily suffered from disease damage as well as water stress. Therefore, standing water level should be controlled properly, not only for the cultivation and growth of plant, but also for chemical application.

(2) Maximization and activation of soil fertility

Compared with uplang field, paddy field has different characteristics due to standing water. Efficiency of soil fertility is closely related to the activity of soil micro-organism, and activity of soil micro-organism is affected by standing water. Therefore, in order to maximize the efficiency of soil fertility, appropriate on-farm water control is required.

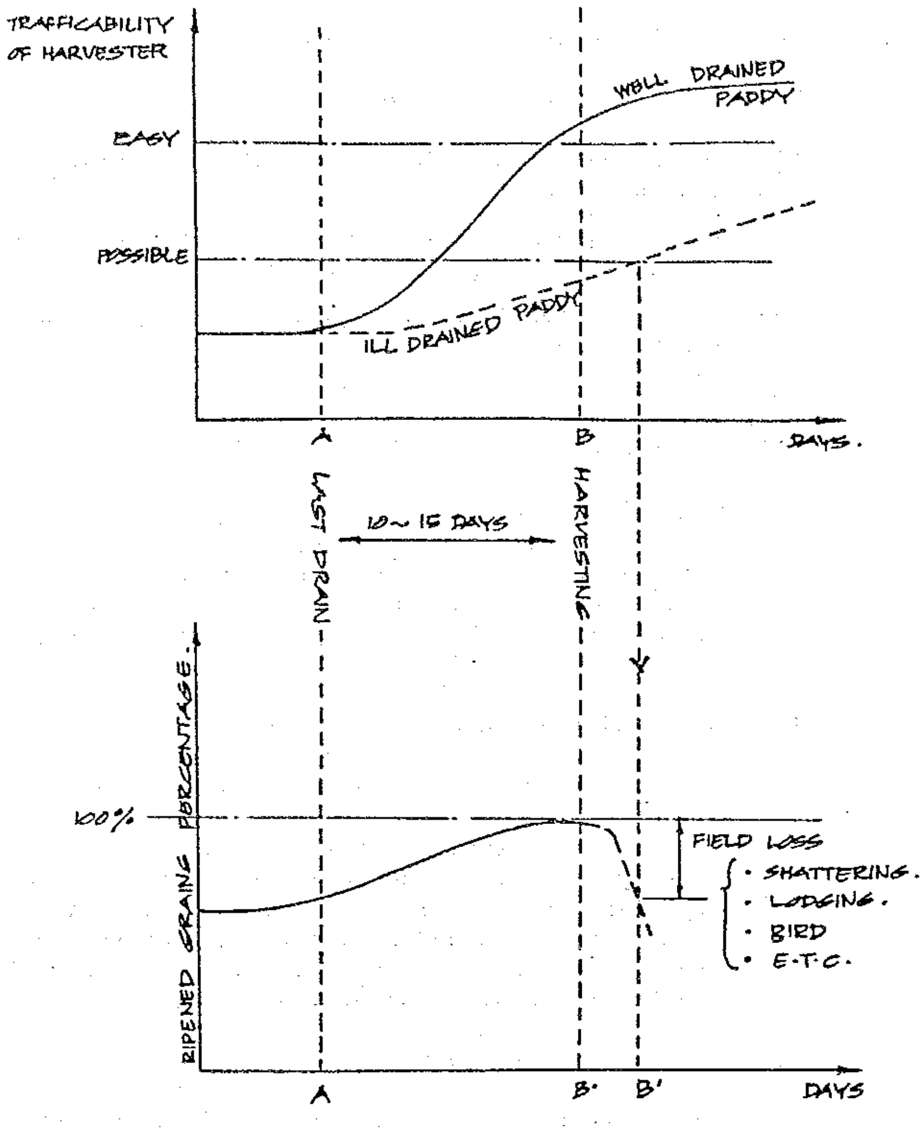
(3) Weed and insect control

There are two ways to control weed and insects by on-farm water management, one is direct effect by standing water and the other is water depth control for suitable chemical application.

(4) Minimization of post maturity loss

In order to get enough soil bearing capacity for harvester at the requested harvesting time, prompt drainage from paddy field is required. (See Fig. 1)

SIGNIFICANCE OF PROMPT DRAINAGE (FIG. 1)

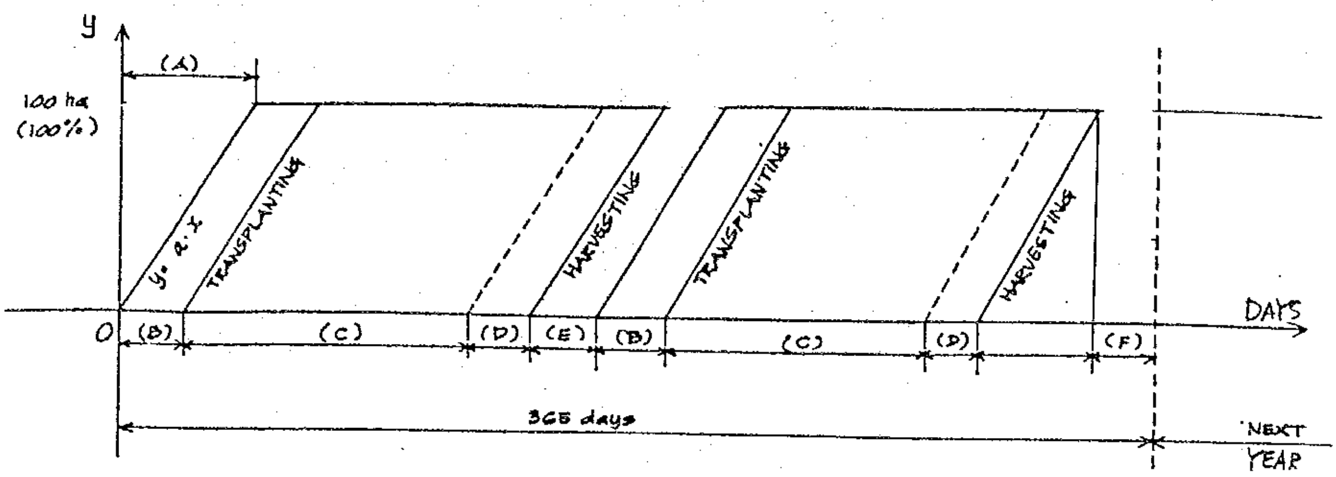


(5) Shortening of cultivation period

In accordance with the introduction of new photoperiod non-sensitive varieties, presaturation period should be shortened through providing the necessary on-farm facilities. (See fig. 2)

SIGNIFICANCE OF PROMPT IRRIGATION (FIG. 2)

EXAMPLE: 100 ha (1 IRRIGATION BLOCK)



where;

- A: presaturation period (if the amount of irrigation water is enough, A depends on the capacity or density of on-farm facilities)
- B: land preparation period
- C: cultivation period (C depends on variety, 100-150 days)
- D: withdrawal of water (10 - 15 days)
- E: preparation period for next season
- F: fallow period for disease protection (certain amount of area should be fallowed at the same time, 20-40 days)
- a: irrigation effeciency (ha/day)

  if "a" = 100, then "A" will be 1 day, but farmers cannot follow the following cultivation activities, therefore, "A" should be matched with the following working efficiency.

EXAMPLE: days for "A"

Lets suppose B=15 days, C=120 days, D=10 days, E=15 days, and F=40 days;

Then, A=365-(15*2+120*2+10*2+15+40) = 20 days

Therefore, A should be 20 days for complete double cropping

1-1-3. Increment of labour productivities

(1) Farming mechanization

As mentioned in 1-1-2, (4), in order to introduce farm machine, suitable paddy soil condition should be prepared. Paddy soil should have enough bearing capacity for farming machine. The bearing capacity of paddy soil is closely related to the soil moisture, and it will be controlled through proper water management.

(2) Labour saving cultivation

For the introduction of labour saving cultivation, such as direct seed ing, precise water depth control is required.

(3) Equalization of labour requirement through the season

Peak of labour requirement will occur in transplanting and harvesting period. For the equalization of labour requirement, group farming is most effective, and for the group farming, well planned cropping schedule should be established. To make possible those schedule, well facilitated farm will be required.

1-1-4 Rationalization of water utilization

By rationalization of irrigation method and providing of on-farm facilities, we can reduce irrigation loss. (See Fig. 3)

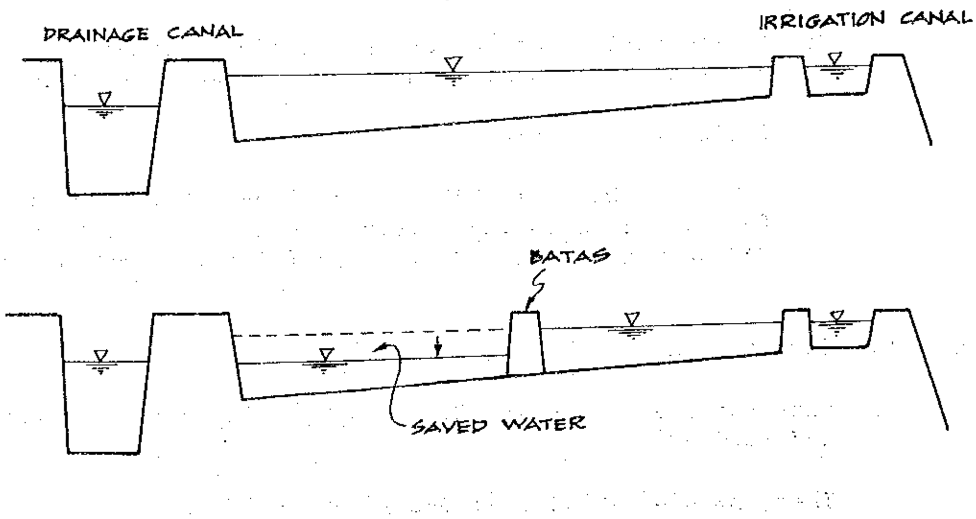


FIG. 3. NECESSITY OF ON-FARM FACILITIES

(AS ONE EXAMPLE)

And also we can maximize rainfall utilization by selecting the most effective cropping pattern in accordance with rainfall pattern. A a matter of course, repeating use of water should be considered.

In conclusion, "On-farm water management" will be summerized as fig. 4 "issue clarification" and fig. 5 "position of basic water management techniques".

ISSUE CLARIFICATION: (FIG. 4 (½))

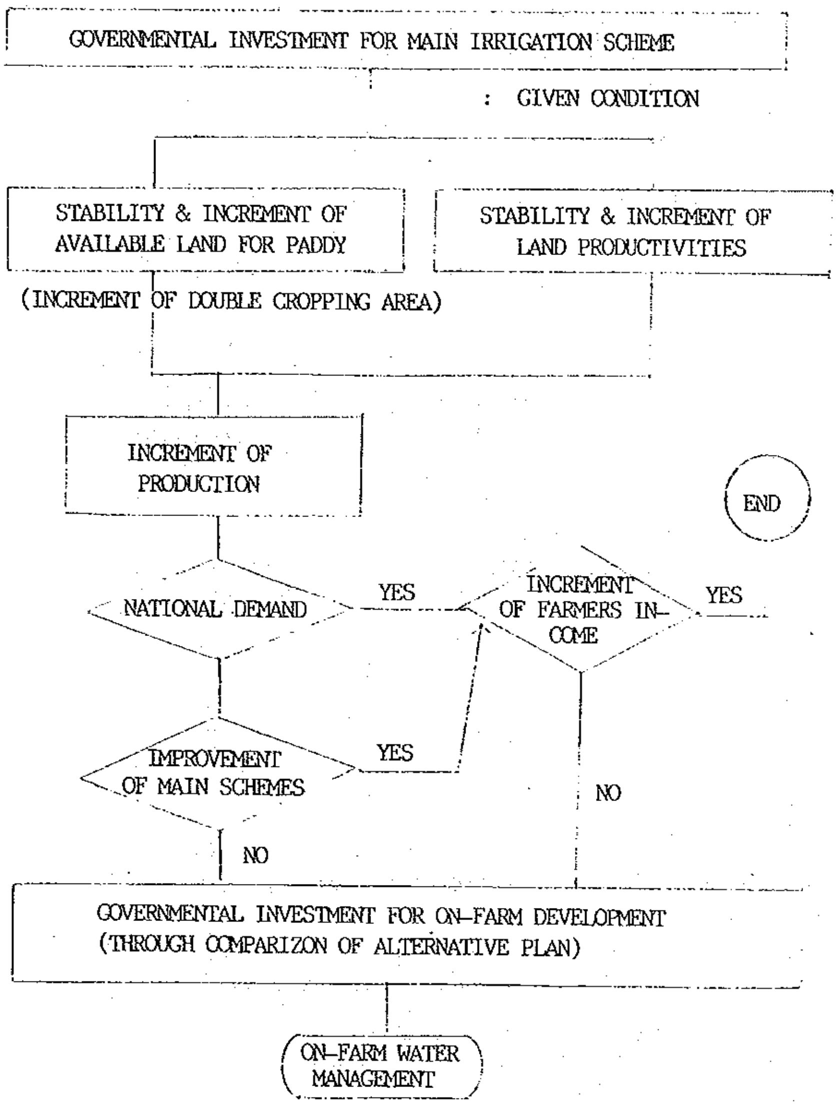
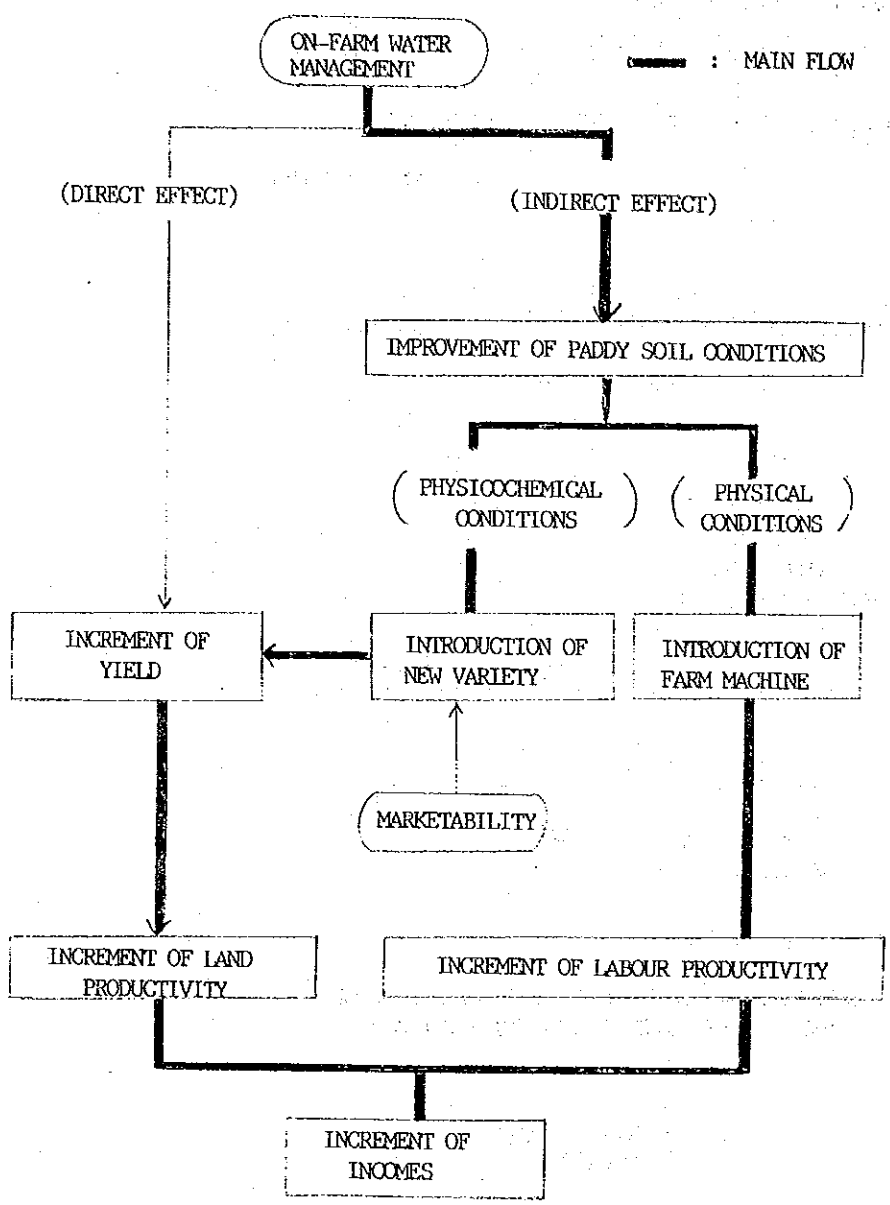
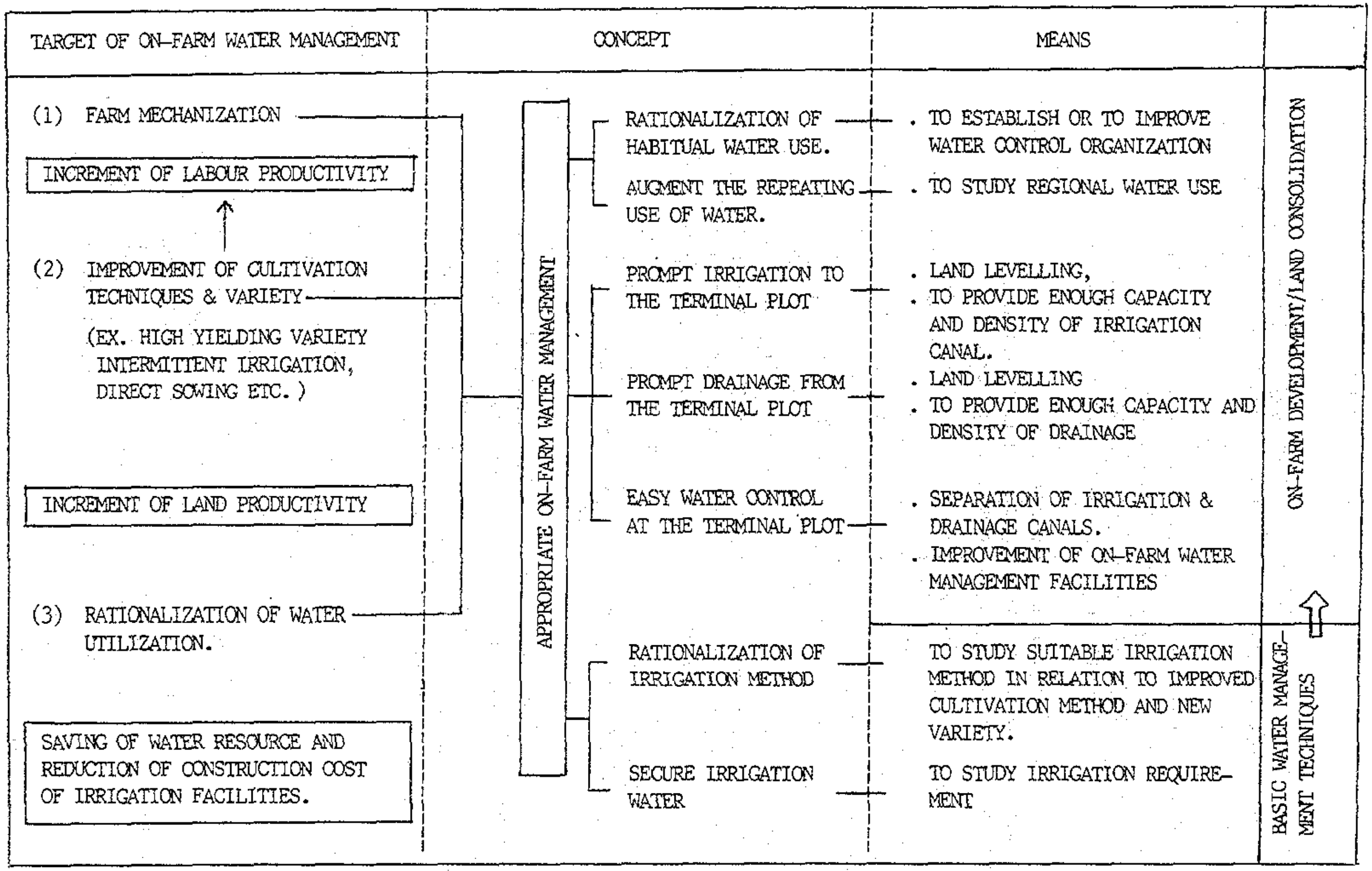


FIG. 4 (2/2)


ON-FARM WATER MANAGEMENT
: MAIN FLOW
(DIRECT EFFECT)
(INDIRECT EFFECT)
IMPROVEMENT OF PADDY SOIL CONDITIONS
(PHYSICOCHEMICAL CONDITIONS)
(PHYSICAL CONDITIONS)
INCREMENT OF YIELD
INTRODUCTION OF NEW VARIETY
INTRODUCTION OF FARM MACHINE
MARKETABILITY
INCREMENT OF LAND PRODUCTIVITY
INCREMENT OF LABOUR PRODUCTIVITY
INCREMENT OF INCOMES


TARGET OF ON-FARM WATER MANAGEMENT
CONCEPT
MEANS
(1) FARM MECHANIZATION
INCREMENT OF LABOUR PRODUCTIVITY
(2) IMPROVEMENT OF CULTIVATION TECHNIQUES & VARIETY
(EX. HIGH YIELDING VARIETY INTERMITTENT IRRIGATION, DIRECT SOWING ETC.)
INCREMENT OF LAND PRODUCTIVITY
(3) RATIONALIZATION OF WATER UTILIZATION.
SAVING OF WATER RESOURCE AND REDUCTION OF CONSTRUCTION COST OF IRRIGATION FACILITIES.
APPROPRIATE ON-FARM WATER MANAGEMENT
RATIONALIZATION OF HABITUAL WATER USE.
AUGMENT THE REPEATING USE OF WATER.
PROMPT IRRIGATION TO THE TERMINAL PLOT
PROMPT DRAINAGE FROM THE TERMINAL PLOT
EASY WATER CONTROL AT THE TERMINAL PLOT
RATIONALIZATION OF IRRIGATION METHOD
SECURE IRRIGATION WATER
. TO ESTABLISH OR TO IMPROVE WATER CONTROL ORGANIZATION
. TO STUDY REGIONAL WATER USE
. LAND LEVELLING,
. TO PROVIDE ENOUGH CAPACITY AND DENSITY OF IRRIGATION CANAL.
. LAND LEVELLING
. TO PROVIDE ENOUGH CAPACITY AND DENSITY OF DRAINAGE
. SEPARATION OF IRRIGATION & DRAINAGE CANALS.
. IMPROVEMENT OF ON-FARM WATER MANAGEMENT FACILITIES
TO STUDY SUITABLE IRRIGATION METHOD IN RELATION TO IMPROVED CULTIVATION METHOD AND NEW VARIETY.
TO STUDY IRRIGATION REQUIREMENT
ON-FARM DEVELOPMENT/LAND CONSOLIDATION
BASIC WATER MANAGEMENT TECHNIQUES

1-2. On-farm water management in East coast rice belts

Due to a different natural soil fertility, East coast and West coast of Malaysian rice belts should have different on-farm water management. Fig. 6 shows one example of the difference of soil fertility.

Paddy soil of West coast area, with Muda as a centre area, consists of marine alluvial, and soil fertility is comparatively high. On the other hand, that of East coast area, with Kemubu as a centre area, consists of river alluvial and a granite as a parents rock. Therefore, soil fertility is low and the deficiency of phosphoric acid and other elements are observed.

Fig. 7 shows the relationship between rice cultivation history and soil nutrient in demonstration farm (D/F) of our centre.

Evidently, soil nutrient of group E is low due to non-cultivation. But that of group B which cultivation was started from O/S '80 and intermittent irrigation has been carried out together with mid-season drainage, is also low as same as group D. Group D has been cultivated only in rainy season.

D/F was newly consolidated paddy field in '79, therefore initial soil condition was slightly different in each lot due to the mixing of top soil and hard pan. Also due to a different fertilizer application, the difference of present soil nutrient might be not only caused by the different cultivation history. However, it seems to me that the difference indicates the following facts;

* Resulting from intensive on-farm water control, such as intermittent irrigation or mid-season drainage, soil fertility will be leaching in the case of poor soil fertility field like East coast area.

* Judging from the result of group D, during fallow period, soil organic matter might be almost completely disassembled and soil fertility is not accumulative.

Based upon above consideration, regarding to the soil fertility, what we have to do at first is to introduce complete double cropping in order to shorten the fallow period so far as not too short to result disease and insect damage.

Through complete double cropping and their cultivation activities, the soil fertility will be ccumulated.

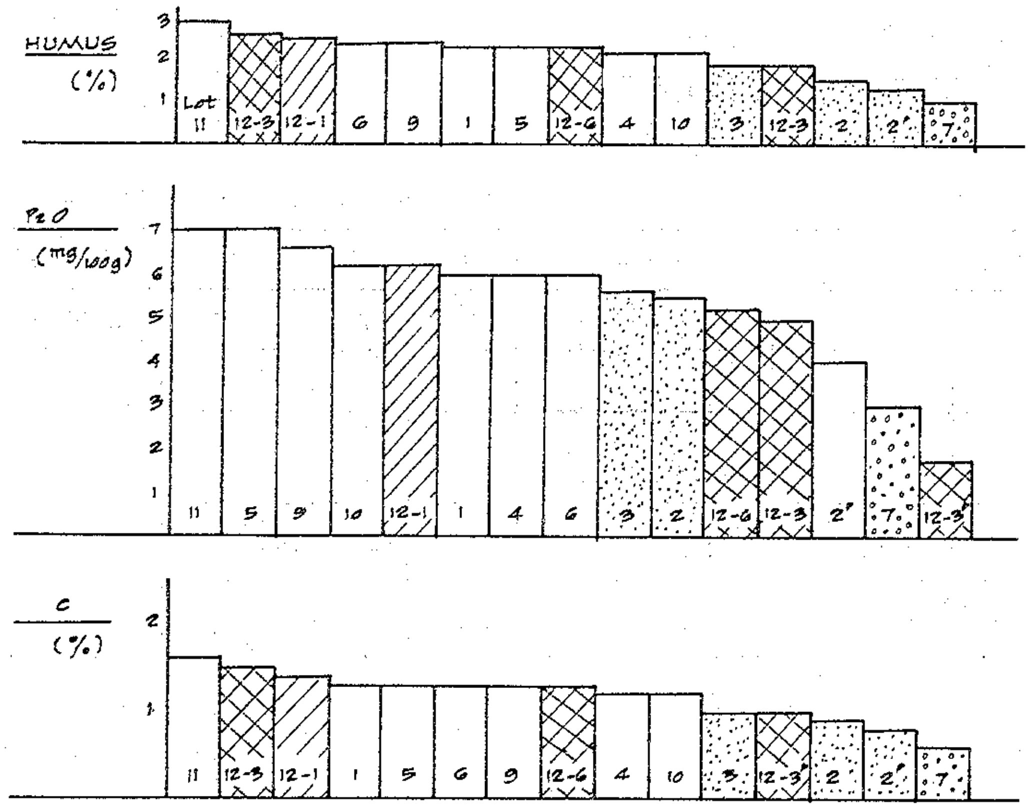
	PH	EC(1:5)	HUMUS	C	AVAILABLE	P_2O_5 ABSORP.	CEC	EXCHANGEABLE BASE						
	(H_2O)	(m mho/cm)	(%)	(%)	P_2O5	COEFFICIENT		CaO	Ca	MgO	Mg	K_2O	K	TOTAL
					(mg/100g)		(me/100g)	(mg/100g)	(me/100g)	(mg/100g)	(me/100g)	(mg/100g)	(me/100g)	(me/100g)
EAST COAST ※	5.1	0.10	1.5	0.9	2.6	500	8.3	15	0.5	35	1.8	40	0.08	2.4
WEST COAST ※	4.5	0.21	9.8	5.7	9.5	900	30.2	165	5.9	69	3.4	120	0.25	9.6

※ NOT REPRESENTATIVE, AS ONE EXAMPLE

FIG. 6 DIFFERENCE OF SOIL NUTRIENT

AVAILABLE P_2O5 WAS MEASURED BY BRAY II METHOD

CULTIVATION HISTORY AND SOIL NUTRIENT (FIG. 7)



SOIL NUTRIENT WERE STUDIED
BY MOTOMATSU ON APRIL, 1983

GROUPING:

- A: Lot 1.4.5.6.9.10.11
- B: Lot 2.3.2'
- C: Lot 12-1
- D: 12-3, 12-6, 12-3'
- E: Lot 7

A: .CULTIVATION STARTED FROM M.S. 1979/80 (8TH. C.) (EXCEPT LOT 1)
.CONTINUOUS IRRIGATION
.W-CROPPING

B: .CULTIVATION STARTED FROM O.S. 1980 (7TH. C.)
.INTERMITTENT IRRIGATION
.W-CROPPING

C: .CULTIVATION STARTED FROM O.S. 1981 (5TH. C.)
.CONTINUOUS IRRIGATION
.W-CROPPING

D: .CULTIVATION STARTED FROM O.S. 1981 (2TH. C.)
.CONTINUOUS IRRIGATION
.SINGLE CROPPING.

E: .FALLOW (0)

DIFFERENCE BETWEEN BEFORE AND AFTER THE CONSTRUCTION OF P/F NO. 1 FIG. 8)

(1) OUTLINE OF P/F No. 1

(1) OFF-TAKE NAME : P3T1S6K

(2) AREA : 18.08 ha

(3) NUMBER OF FARMERS: 61

(4) NUMBER OF LOTS : 137

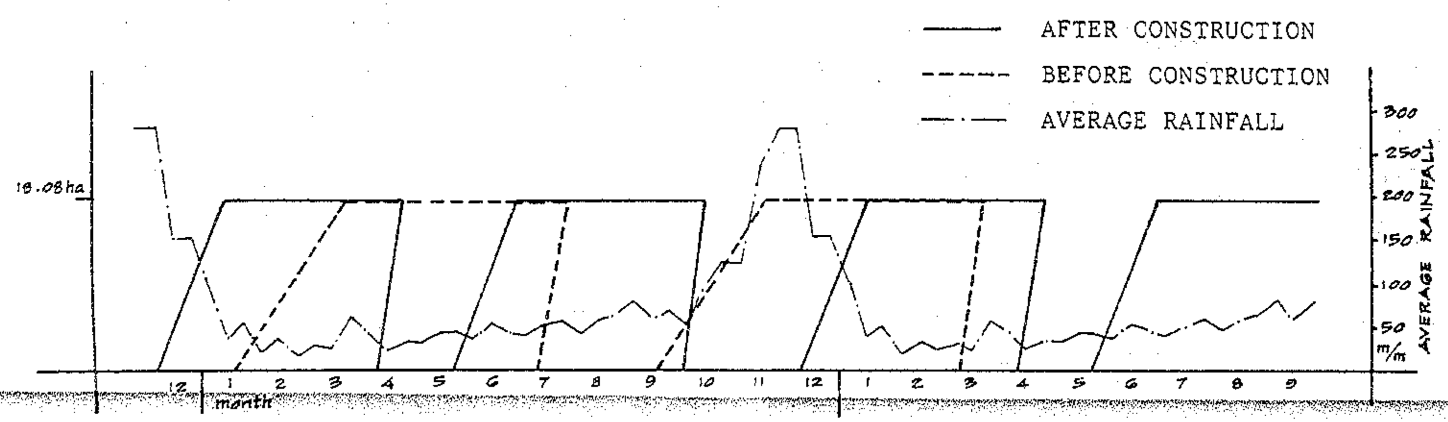
(5) AVERAGE AREA PER FARMER : 0.13 ha

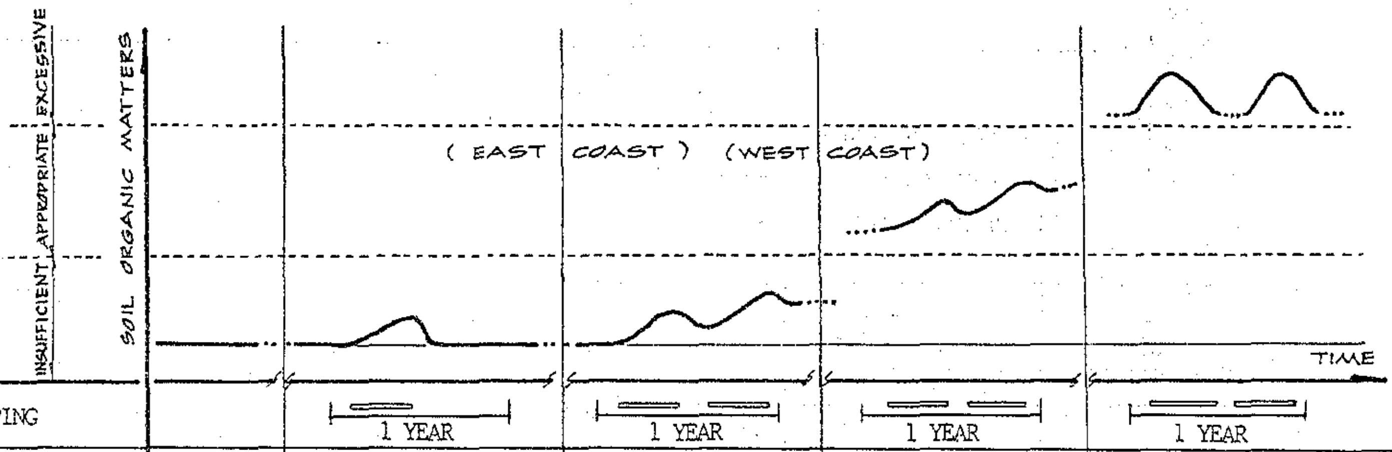
(6) ELEVATION : 6.0 - 6.90 m

(2) DIFFERENCE:

	BEFORE	AFTER
IRRIGATION SYSTEM	LOT TO LOT	ROTATIONAL IRRIGATION & LOT TO LOT
PRESATURATION PERIOD	57 DAYS	36 DAYS
CANAL DENSITY	NONE	88 m/ha
DRAIN DENSITY	NONE	93 m/ha
FARM ROAD DENSITY	NONE	93 m/ha
PRESATURATION PERIOD DISCHARGE	22.0 l/sec.	22.0 l/sec
NORMAL IRRIGATION PERIOD DISCHARGE	14.2 l/sec.	14.2 l/sec.
YIELD	AVERAGE (O.S.1977-O.S. 1980) 3.68	M.S. 1982/83 4.59

(3) DIFFERENCE OF CROPPING SCHEDULE:





CROPPING						
SOIL ORGANIC MATTERS		NATURAL CONDITION	CONSUMPTIVE STAGE	ACCUMULATIVE STAGE	APPROPRIATE STAGE	EXCESSIVE STAGE
WATER MANAGEMENT FACILITY		RAIN-FED	MAIN CANAL PREPARATION STAGE(10-20m/ha)	ON-FARM CANAL PREPATATION STAGE (30-50 m/ha)	LAND CONSOLIDATION STAGE (60 - 100 m/ha)	
ON-FARM WATER MANAGEMENT METHOD		RAIN-FED	LOT TO LOT IRRIGATION	.SAME CROPPING SCHEDULE .START OF O & M BY FARMERS	.START OF BATAS MAINTENANCE .UNDER DRAINAGE .MID-SEASON DRAINAGE	
ON-FARM WATER MANAGEMENT ORGANIZATION		FARMER	GOVERNMENT OFFICER	GOVERNMENT OFFICER/FARMERS ORGANIZATION		FARMERS ORGANIZATION
SOIL NUTRIENT (by MOTOMATSU)	Lot	OUT-SIDE 1	LOT 12-3	LOT 11	MUDA CLASS 1 (EXAMPLE)	TARGETS (KEMUBU AREA)
	pH	5.1	4.8	4.9	4.4	5.5 - 6.0
	Humus (%)	1.5	2.5	2.8	9.8	> 3.0
	$P_2O_5(\frac{mg}{100g})$	2.6	5.0	7.0	9.5	10 - 20
	CEC(mg/100g)	8.3	8.5	-	30.2	> 15
	Fe_2O_3(%)	1.6	1.4	-	0.6	1.5 - 4.0

We have already sufficient main canal and main drainage system, but regarding to the on-farm facilities which is necessary for complete double cropping as discussed in 1-1-2, they are not enough. It takes nearly 2 month for the presaturation of one irrigation block due to the lack of on-farm irrigation facilities and it causes delay of cropping schedule. (See fig. 8)

Real intensive on-farm water management such as intermittent irrigation or mid-season drainage will be introduced after completed on-farm facilities and after accumulated soil fertility up to proper level in the East coast area. (See Fig. 9)

Agriculture is closely related to the natural condition, it is a fate of agriculture. Drastic exchange of natural condition must be resulted in drastic disaster. There is no golden road to success. Modern technique may assist its improvement of natural condition, but final victory can be obtained only through daily cultivation effort.

2. Presentation of terminology

2-1. Necessity of presentation

"On-farm water management", as a science, is a new field of study and is involving wide area of scientific investigation. Therefore some terminologies are not matured and this leads to confusion. Standardization or unification of terminology is the first step of every science. From this point of view, I would like to present terminology. In order to expect higher accuracy, further discussion by each specialist is required.

2-2. Facilities and irrigation water

NAME OF FACILITIES STATED BY BELOW CONTENTS	HEAD-WORK	MAIN & LATERAL CANAL	OFF-TAKE FOR ONE IRRIGATION UNIT	ON FARM OFF-TAKE	FARM (LOT)
CONTENTS	DIVERSION REQUIREMENT ←	FARM DELIVERY REQUIREMENT ← CONVEYANCE LOSS IN THE MAIN CANAL & LATERAL	IRRIGATION REQUIREMENT ← FARM DITCH LOSS	WATER REQUIREMENT EFFECTIVE RAIN FALL FARM LOSS	← EVAPOTRANSPIRATION = EVAPORATION + TRANSPIRATION PERCOLATION = HORIZONTAL PERCOLATION (= SEEPAGE) + VERTICAL PERCOLATION
DEFINITION	GROSS DUTY OF WATER = DIVERSION REQUIREMENT		PUDDLING REQUIREMENT = PRE-SATURATION + FLOODING WATER	NET DUTY OF WATER = IRRIGATION REQUIREMENT	CONSUMPTIVE USE = EVAPORATION + TRANSPIRATION
EFFICIENCY		CONVEYANCE EFFICIENCY = (FARM DELIVERY REQUIREMENT)/(DIVERSION REQUIREMENT)		FIELD EFFICIENCY = (CONSUMPTIVE USE)/(NET DUTY OF WATER)	

2-3. Soil moisture content and available water

pF	0	1	2	3	4	5	6	7
ATMOSPHERIC PRESSURE	10^{-3}	10^{-2}	10^{-1}	1	10^{1}	10^{2}	10^{3}	10^{4}
SOIL MOISTURE CONSTANT	MAXIMUM WATER HOLDING CAPACITY		(FIELD CAPACITY)	MOISTURE EQUIVALENT	FIRST WILTING POINT / WILTING POINT		AIR DRY	OVEN DRY
CLASSIFICATION	GRAVITY WATER			AVAILABLE WATER	UNAVAILABLE WATER			

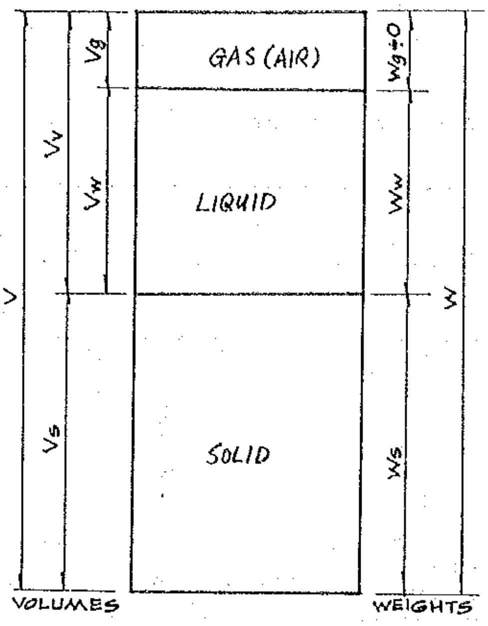
Note: 1) pf 0 is a saturated soil with all air excluded. The amount of water in the soil at saturation is equal to the volume of pore spaces.

2) Field capacity is the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially decreased. Essentially the same as "specific retention", a more general term used in studies of ground water, except that specific retention is generally given as a percentage by volume whereas field capacity is usually given as a percentage of weight.

3) Moisture equivalent is the soil moisture content held against a force of 1000 times gravity in a specially designed centrifuge.

4) Wilting point is the moisture content of soil, expressed as a percentage of the dry weight, at the time when the leaves of a plant growing in the soil first undergo a permanent reduction in their moisture content, as the result of the deficiency in the soil-moisture supply.

2-4. SOIL MECHANICS



(1) MOISTURE CONTENT $W = \frac{Ww}{Ws} \times 100$ (%)

(2) POROSITY $n = \frac{Vv}{V}$

(3) VOID RATIO $e = \frac{Vv}{Vs}$

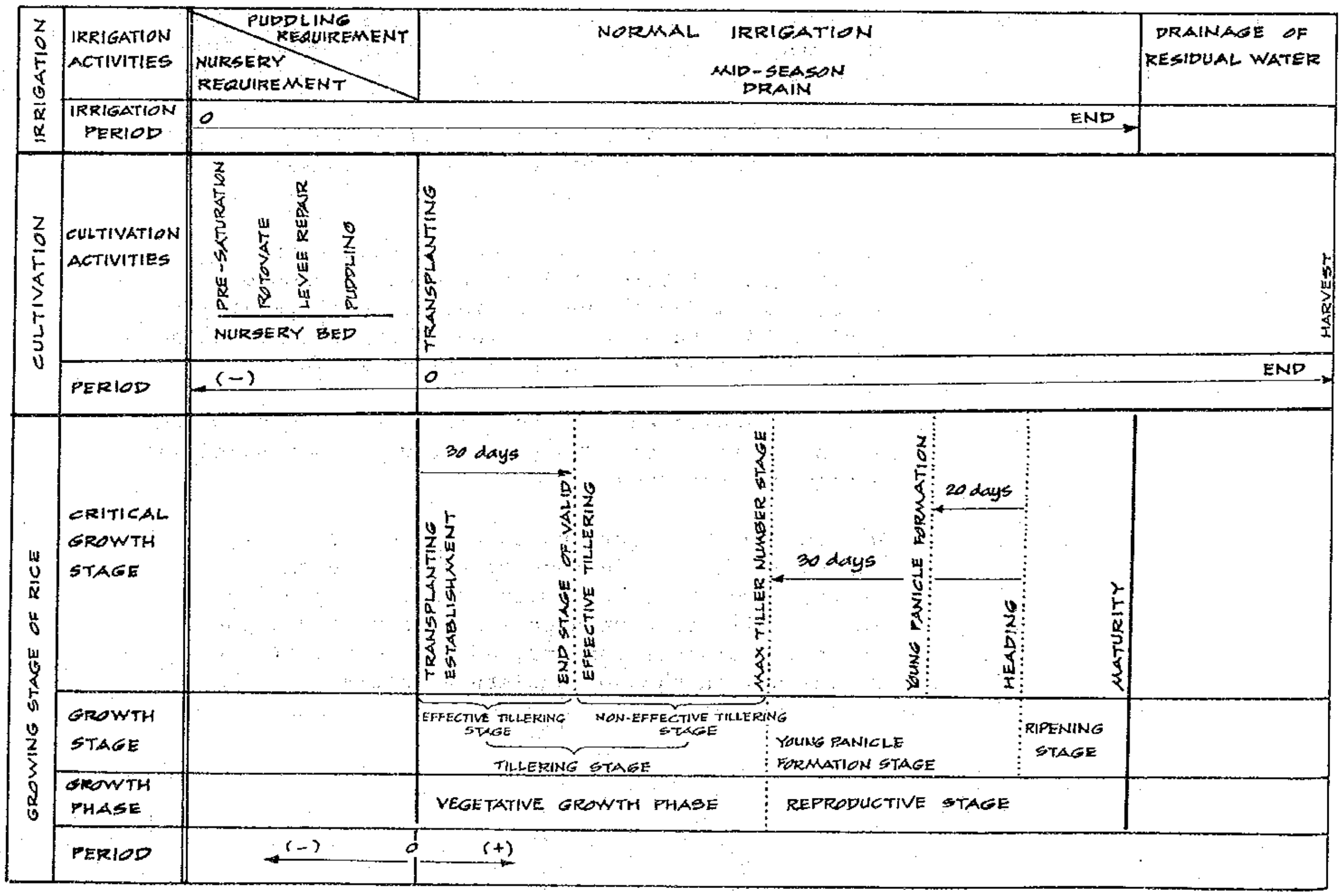
(4) DEGREE OF SATURATION $S = \frac{Vw}{Vv}$

$\left(n = \frac{e}{1+e} \; ; \quad e = \frac{n}{1-n} \right)$

(5) TOTAL UNIT WIEGHT $\gamma t = \frac{W}{w}$

(6) DRY UNIT WEIGHT $\gamma D = \frac{Ws}{V}$

2-5. IRRIGATION ACTIVITIES AND GROWING STAGE OF RICE



3. WATER REQUIREMENT

3-1. Factors of determination

As defined in chapter 2. water requirement is consists of evaporation, transpiration and percolation. Each term will be defined as follows;

Evaporation:

1. The process by which water is charged from the liquid or the solid state into the gaseous state through the transfer of heat energy.
2. The product or result of evaporating.

Transpiration: The emission or exhalation of watery vapour from the living plant.

Percolation: A type of laminar flow occuring in inter-connected openings of saturated granular material under hydraulic gradients commonly developed underground. The difference between percolation and seepage is that the latter is through unsaturated material while the former is through saturated material. As regards distinction between 'percolation' and 'infiltration', the latter is the movement of water through the soil surface into the soil body while the former refers to the movement of water within the soil body.

But, generally, in the case of water requirement, 'percolation' includes seepage and infiltration.

Determination factors of those elements are shown in fig. 10.

Fig. 10 Factors of determination of water requirement

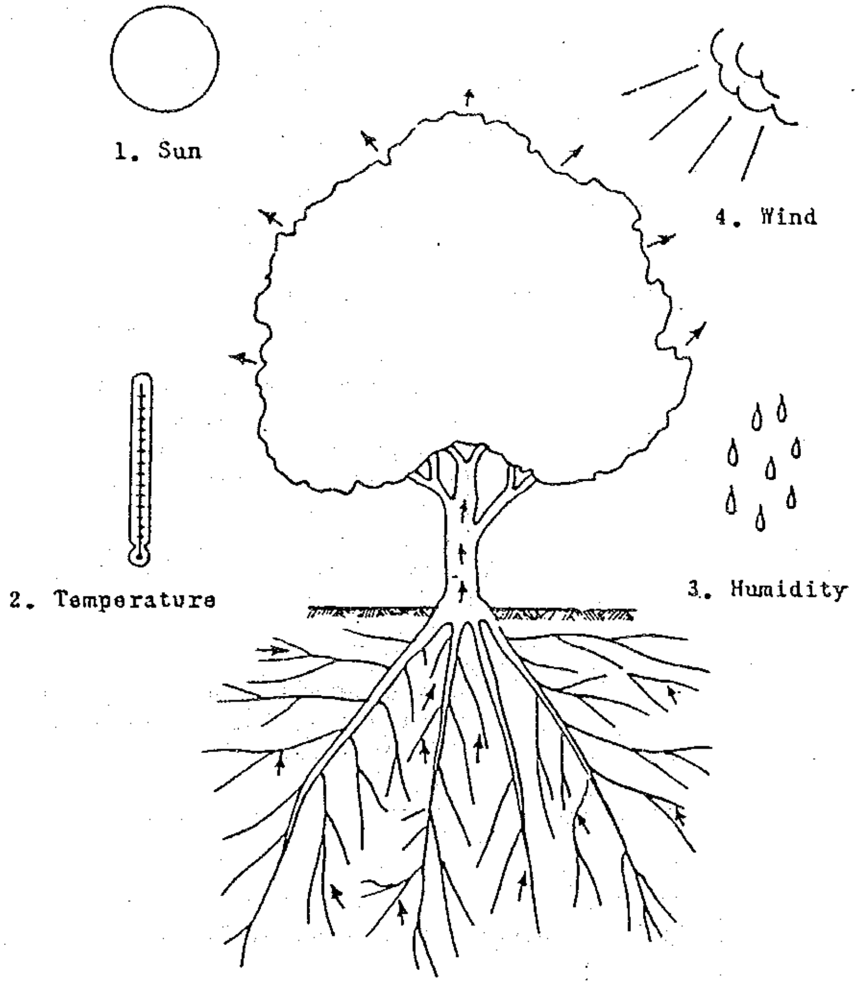
- water requirement
  - evapotranspiration —
    - climatic condition
    - cultivation method
    - variety
    - paddy condition
  - percolation —
    - physical property of soil
    - ground water level
    - paddy condition
    - irrigation method

3-2. Evapotranspiration

3-2-1. Climatic condition

Transpiration is mainly influenced by climatic condition.

These factors incluence transpiration (FIG. 11)



(FAO: IRRIGATION & DRAINAGE PAPER 1)

According to those facts, many formulas were thought out. Following two formulas are representative ones.

1. PENMAN METHOD:

$$ET = \frac{\Delta H + 0.27\ Ea}{\Delta + 0.27}$$

$H = RA\ (1-r)(0.18 + 0.55\ n/N)$

$\quad - \sigma\ Ta^4\ (0.56 - 0.092\sqrt{ld})(0.01 + 0.09\ n/N)$

$Ea = 0.35\ (la-ld)(1 + 0.0098\ U_2)$

H = daily head budget at surface in mm H_2O/day

RA= mean monthly extra terrestrial radiation in mm H_2O/day

r = reflection coefficient of surface

n = actual duration of bright sunshine

N = maximum possible duration of bright sunshine

σ = Boltzman constant

σTa^4 = mm H_2O/day

ld= saturation vapor pressure at mean dew point (i.e. actual vapor pressure in the air)mm Hg

Ea= evaporation in (mm) H_2O/day

la= saturation vapor pressure at mean air temperature in mm Hg

U_2= mean windspeed at 2 meters above the ground (miles/day)

Er= evapotranspiration in mm H_2O/day

U_1= measured windspeed in miles/day at height h in feet

Δ = slope of saturated vapor pressure curve of air at absolute temperature Ta in ^oF (mm Hg/^oF)

$$U_2 = U_1\ \frac{\log 6.6}{\log h}$$

2. BLANEY-CRIDDLE METHOD:

$$U = K \sum pt = KF$$

U = consumptive use of crops; inches for a given time period

F = sum of the consumptive use factors for the period (sum of the products of mean temperature and percent of annual day-time hours)(txp)/100

K = empirical coefficient (annual irrigation season, or growing season)

t = mean temperature in degrees Fahrenheit

p = percentage of day-time hours of the year, occuring during the period

f = monthly consumptive-use fractors, (txp)/100

K = monthly coefficient, u/f

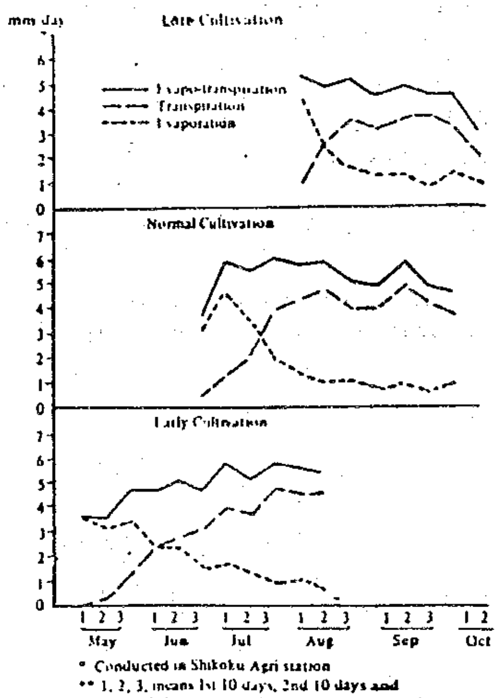
U = Kf = monthly consumptive use, inches.

REFER TO: "ESTIMATING POTENTIAL EVAPOTRANSPIRATION USING THE PENMAN PROCEDURE" HYDROLOGICAL PROCEDURE NO. 17, J.P.T

3-2-2. Cultivation method

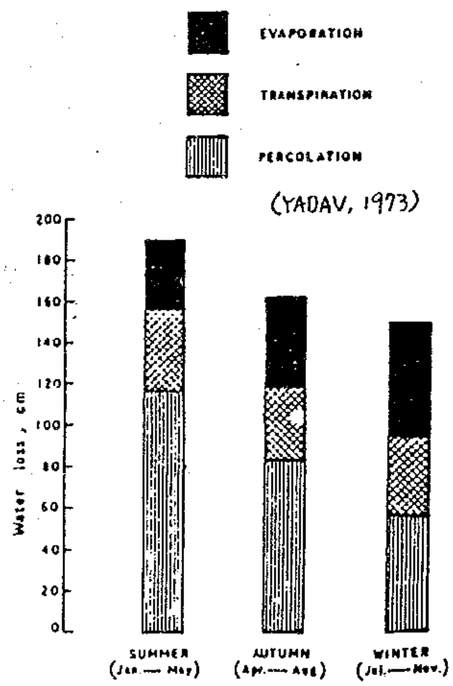
Cultivation method is also related to the evapotranspiration in conjunction with the climatic condition of planted area.

ET & CULTIVATION PERIOD: (FIG. 12)



* Conducted in Shikoku Agri station
** 1, 2, 3, means 1st 10 days, 2nd 10 days and third 10 days respectively

(RICE IRRIGATION IN JAPAN)

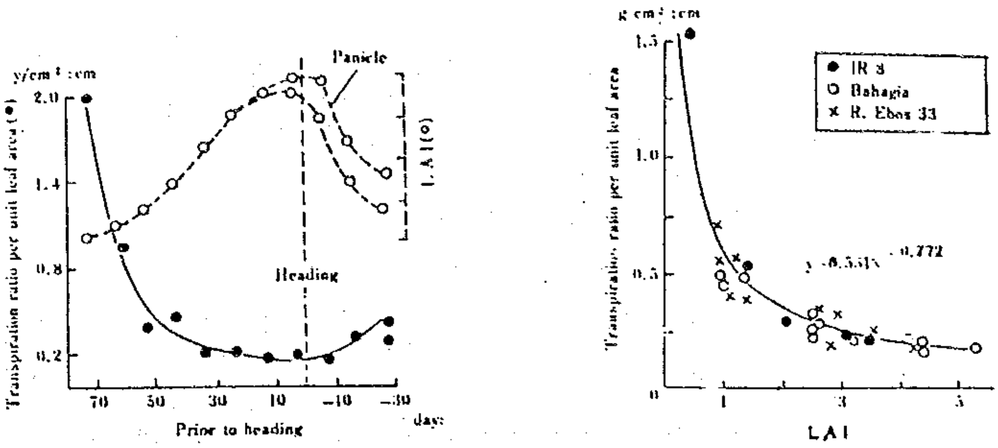


(YADAV, 1973)

3-2-3. Variety

Third factor influenced to the evapotranspiration is variety. Due to a different leaf area and length of roots, different variety has different evapotranspiration character.

TRANSPIRATION & LEAF AREA (FIG. 13)



Changes in transpiration ratio per unit leaf area and leaf area index (Bahagia, Malaysia)

Relation between transpiration ratio per unit leaf area and leaf area index (Malaysia)

SOURCE: K. SUGIMOTO, 1971

3-2-4. Paddy condition

In collaboration with climatic condition, evapotranspiration is also affected by paddy condition

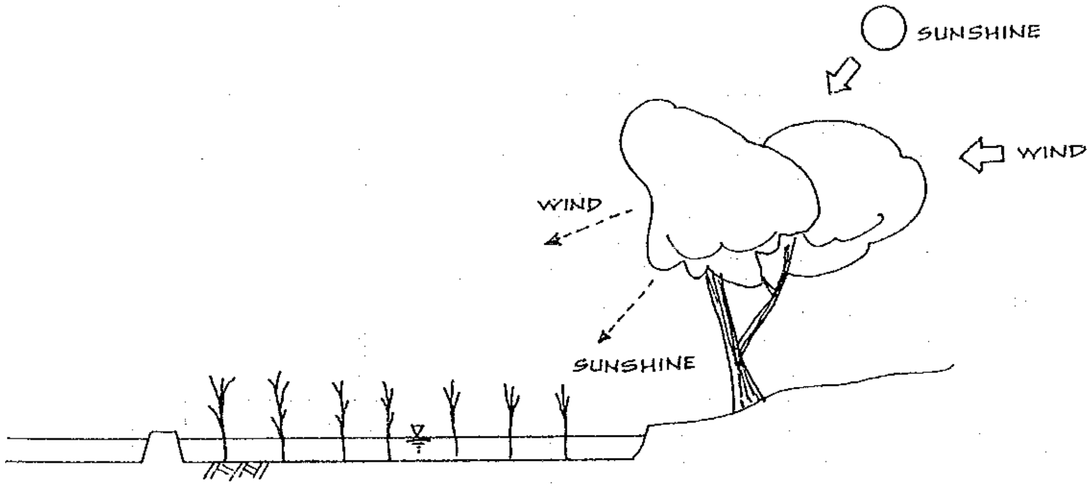


FIG. 14

3-3. Percolation

Percolation is mainly depends on the paddy soil physical condition. As shown in Fig. 15, each soil type has their peculiar permeability ratio. Also in general, a profile of paddy soil consists of two layers, top soil and hard pan.

VERTICAL PERCOLATION IN m/m/DAY (FIG. 15)

SOIL	PERCOLATION
SANDY LOAM	3 - 6 mm
LOAM	2 - 3 mm
CLAY LOAM	1 - 2 mm

Judging from many case studies conducted in Japan, soil permeability is also related to the groundwater level after drain. Putting all factors together, permeability of paddy soil as a whole can be judged by the combination of two layer's permeability and by the groundwater level after drain.

JUDGEMENT OF PADDY SOIL PERMEABILITY: (FIG. 16)

TOP SOIL	HARD PAN	GROUNDWATER LEVEL (AFTER DRAIN)		
		0 - 0.3 m	0.3 - 0.7 m	MORE THAN 0.7 m
SANDY LOAM (S.L.)	S.L.	L	L	L
	LOAM	M	M - L	M - L
	CLAY	S	S - M	S - L
LOAM	S.L.	M	M	M
	LOAM	M	M	M
	CLAY	S	M	M
CLAY	S.L.	S	S	S
	LOAM	S	S	S
	CLAY	S	S	S

NOTE: L, M, S, SHOWS PERMEABILITY IN PUDDLED PADDY SOIL.
L : 10^{-3}cm/SEC., M : 10^{-4}-10^{-5}cm/SEC., S : 10^{-6}cm/SEC.

As defined in 3-1, percolation is a laminar flow under hydraulic gradient, so if you find out hydraulic head, you can classify the paddy percolation condition. (Fig. 17) For the conversion of permeability to percolation, Fig. 18 is useful.

CLASSIFICATION OF PADDY FIELDS IN ACCORDANCE WITH (FIG. 17) PERCOLATION ELEMENTS.

HYDRAULIC HEAD \ PERMEABILITY (m/sec.)	10^{-3}	10^{-4}–10^{-5}	10^{-6}
LARGE–NEARBY SURFACE WATER TABLE IS BELOW 1.0 m	A	D	G
MEDIUM–NEARBY SURFACE WATER TABLE IS 0.3 – 1.0 m	B	E	H
SMALL–NEARBY SURFACE WATER TABLE IS 0 – 0.3 m	C	F	I

JUDGEMENT

A : EXCESSIVELY DRAINED PADDY FIELD.
SOIL DRESSING OR SUBSOIL COMPACTION IS NECESSARY.

B, D, E : ROUGHLY CLASSIFIED TO BE SUITABLE CONDITIONS.

C : SEPARATION OF IRRIGATION & DRAINAGE CANALS OR IMPROVEMENT OF DRAINAGE CANAL IS NECESSARY.

F, H : INFERIOR CATEGORY FROM THE POINT OF VIEW OF NATURAL DRAINAGE.

G : SUBSOIL IMPROVEMENT IS NECESSARY.

I : EXCESSIVELY ILL DRAINED PADDY FIELDS
SHALLOW AND DENSE UNDERDRAIN OR SUBSOIL BREAKING IS NECESSARY.

RELATION BETWEEN PERMEABILITY COEFFICIENT AND PERCOLATION: (FIG. 18)

PERMEABILITY COEFFICIENT	PERCOLATION	
n x 10^{-6} cm/sec	0.86 - 8.6 m/m day	CLAY
n x 10^{-5} "	8.6 - 86 "	
n x 10^{-4} "	86 - 860 "	
n x 10^{-3} "	860 - 8.600 "	
n x 10^{-2} "	8.600-86.000 "	SAND

. IN THIS TABLE, HYDRAULIC GRADIENT IS TAKEN AS ONE.

. BUT ACTUALLY, HYDRAULIC GRADIENT IS FAR SMALLER THAN 1 AND ITS ORDER SHOWN 10^{-1} TO 10^{-2}

3-4. Measurement method

3-4-1. Measuring number

The minimum number of measuring point of water requirement in depth is standardized as shown in Fig. 19 in Japan.

MINIMUM NUMBER OF MEASURING POINTS OF WATER REQUIREMENT IN DEPTH. (FIG. 19)

AREA OF GROUP	NUMBER OF MEASURING POINTS	AREA OF GROUP	NUMBER OF MEASURING POINTS
0 - 20 ha	3	150 - 200 ha	9
20 - 40	4	200 - 250	10
40 - 60	5	250 - 300	11
60 - 80	6	300 - 350	12
80 - 100	7	350 - 400	12
100 - 150	8	400 - 500	13

3-4-2. Measuring method

There are two ways to measure the water requirement, one is so called "decreased water depth measurement method" and the other is "water balance method". Out-line of both method is as follows.

Method	Contents
decreased water depth measurement method	* Water depth decreased is measured on a daily basis, in principle, throughout the entire irrigation period. The water level is measured by hook-gauge or scale once a day, usually at 9.00 A.M. * This measurement indicates the water requirement as a whole as the sum of evapotranspiration and percolation. As the former is considered as constant to some extent, and can be determined by various method, the percolation rate can be easily obtained.
water balance method	* This method is applied to an area in which at least the surface inflow and outflow can be measured. * Surface inflow and outflow is measured in principle, on a daily basis. * In most cases, water is measured by flumes or weirs with water level recorders. * Following equation will be used: $Is + R + Ig = Os + Og + E + S$ Where: Is : Surface inflow (Irrigation) R : Precipitation Ig : Subsurface inflow Os : Surface outflow Og : Subsurface outflow E. : Evapotranspiration S : Storage in or on the soil

3-4-3. Decreased water depth measurement method

(1) INSTRUMENT, DEVICES.

SEE PAGE 32

(2) DATA SHEET.

When we arrange the results of the study and measured data, following data sheet will be used.

DAILY WATER CONSUMPTION RECORD

DATE: ____________

LOT No.	AREA	DIKES	JUST BEFORE		TODAY		ACTIVITIES (JUST BEFORE)			CALCULATION		
			TIME	DEPTH	TIME	DEPTH	RAIN-FALL	WATER SUPPLY	DRAIN	TIME	VALUE	C/DAY
			A	B	C	D	E	F	G	H	I	J
	M²		h·m	mm	h·m	mm	m.m	mm	mm	h·m	mm	mm

H: THE PERIOD FROM A TO C.

I: (B+E+F) − (C+G)

J: WATER CONSUMPTION PER DAY.

(3) EFFECTIVE RAINFALL:

- Daily rainfall of more than 80 - 150 m/m, depending upon mainly batas conditions, is considered as non-effective since this may overflow the border ridge of the paddy fields and can not be stored in the field.
- According to another report, daily rainfall of less than 5 m/m is considered as non-effective but there are many point which are uncertain. Therefore, detailed study is necessary from the statistical point of view.

(4) DIAGRAMMATIC ILLUSTRATION OF WATER DEPTH DECREASE.

a. ILL-DRAINED PADDY FIELD;

b. WELL-DRAINED PADDY FIELD:

3-4-4. Water balance method

(1) INSTRUMENT, DEVICES:

SEE FIG.

(2) DATA SHEET:

LIKE FOLLOWING DATA SHEET WILL BE USED:

IRRIGATION DAILY DATE: ____________

LOT NO.	OFF-TAKE NO.	DISCHARGE TIME			DISCHARGE				TOTAL	
		START	STOP	TOTAL	START		STOP		TIME	DISCHARGE
					cm	l/m	cm	l/m	min.	m^3
					A	B	C	D	E	F

NOTE: A: OVERFLOW HEIGHT AT OFF-TAKE MEASUREMENT WEIR.
B: CONVERTED AMOUNT OF FLOW.
$F = (B+D)/2 \times E \div 1000$ (m^3)

DRAINAGE DAILY. DATE: ____________

LOT NO	OUT-LET NO.	DRAINAGE TIME			DRAINAGE				TOTAL	
		START	STOP	TOTAL	START		STOP		TIME	DRAINAGE
					cm	l/m	cm	l/m	min.	m^3
					A'	B'	C'	D'	E'	F'

NOTE: A': OVERFLOW HEIGHT AT OUT-LET MEASUREMENT WEIR.
B': CONVERTED AMOUNT OF DRAINAGE.
F': $(B'+D')/2 \times E' \div 1000$ (m^3)

(3) CALCULATION

TOTAL WATER CONSUMED (W)

$$W = E + Og - Ig \quad \ldots\ldots\ldots \quad (1)$$

$$W = Is + R - Os - S \quad \ldots\ldots\ldots \quad (2)$$

WHERE:

E = EVAPOTRANSPIRATION

Og = SUBSURFACE OUTFLOW

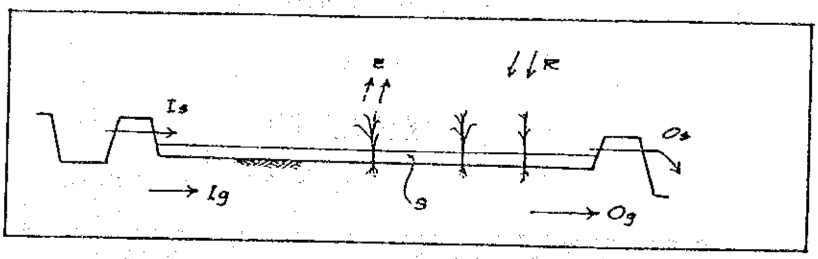
Ig = SUBSURFACE INFLOW

Is = SURFACE INFLOW (IRRIGATION)

R = PRECIPITATION

Os = SURFACE OUTFLOW

S = STORAGE IN OR ON THE SOIL



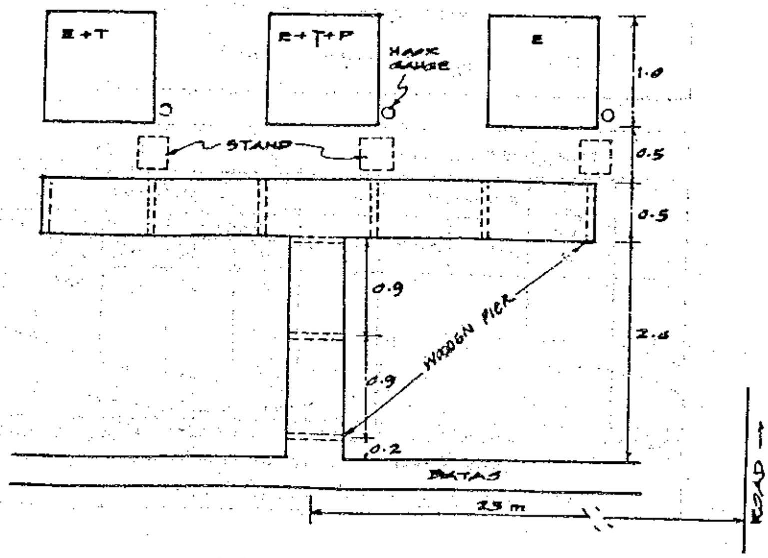
IN THE CASE OF INTENSIVE MEASUREMENT FOR A SHORT PERIOD, R AND S CAN BE IGNORED, AND FOLLOWING RELATION EXISTS.

$$(Is-Os) = (Og-Ig) + E \quad \ldots\ldots \quad (3)$$

3-5. Measuring devices

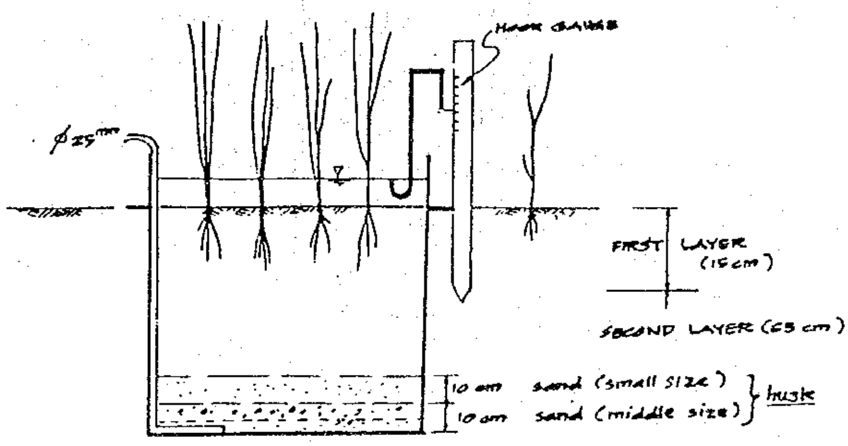
3-5-1. Water requirement

(1) N.W.M.T.C. type lysimeter



LYSIMETER SETTING PLAN

LYSIMETER (With bottom) DETAIL:



Note:

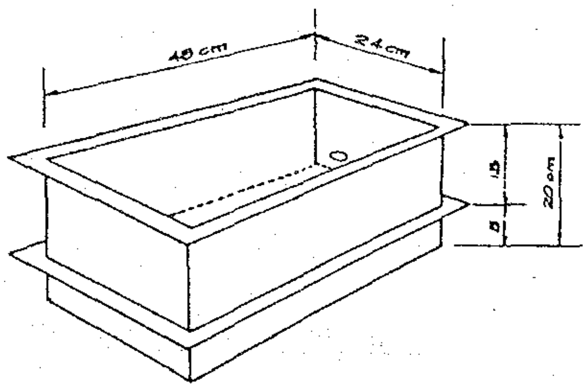
* The size of the box should not be smaller than 1 m^2.

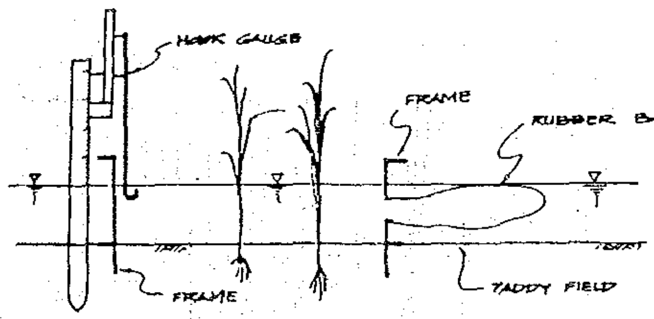
* In order to provide the soil in the box with the same rate of percolation as in the actual field, water should occasionally be sucked up from the lower part and measured.

* The box should be set more than 1m away from the border ridges.

(2) N-type lysimeter

(1) DIMENSION:





(2) Operation

This device is lightly inserted into the soil at the depth of about 5 cm. A rubber bag is attached to the wall to maintain equal water levels in and outside the lysimeter. The size of the device is determined by the capacity of the rubber bag to control the water level.

It has been demonstrated that two bags can regulate the water level within 2 cm for a 24 x 48 cm box. The sequence of operation is as follows;

1. Insert the box into the soil and attach rubber bags.
2. Raise the rubber bags so that the water in them can be poured into the box.
3. Measure the water level in the box.
4. After a certain period of time, usually 24 hours, raise the rubber bags again so that the water contained in them is poured into the box.
5. Measure water level in the box.

(3) Applicable range and reliability:

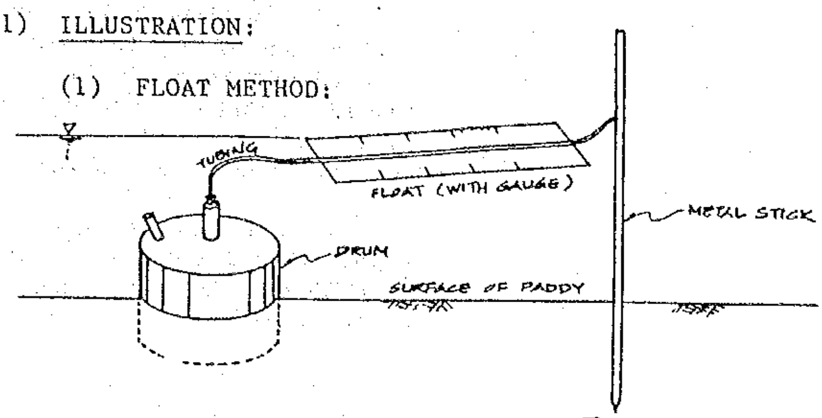
DECREASE WATER DEPTH	NEARLY 200 mm/day	NEARLY 50 mm/day	BELOW 20 mm/day
RELIABI-LITY	. CAREFULLY STUDY IS REQUIRED. . IMPOSSIBLE TO MEASURE MORE THAN 4 HOURS	. RELIABLE . A LITTLE DIFFI-CULT TO MEASURE MORE THAN 24 HOURS. . BETTER TO MEA-SURE WITHIN 12 HOURS	. HIGHLY RELIABLE . POSSIBLE TO MEASURE 24 HOURS.

3-5-2. Percolation

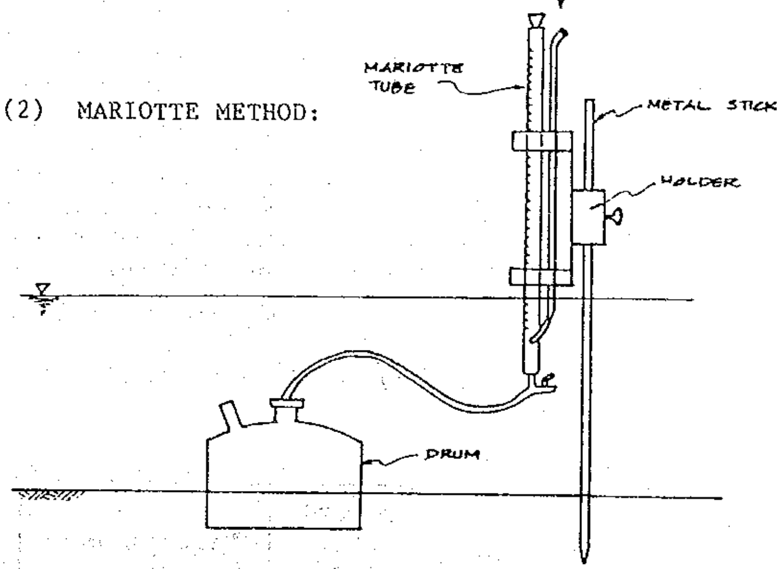
LEAKAGE CAPACITY TESTER

(1) ILLUSTRATION:

(1) FLOAT METHOD:



(2) MARIOTTE METHOD:



(2) APPLICABLE RANGE AND RELIABILITY:

PERMEABILITY \ DECREASE WATER DEPTH	MORE THAN 200 mm/day	NEARLY 50 mm/day	BELOW 20 mm/day
MORE THAN 10^{-3} cm/sec.	. POSSIBLE TO MEASURE . HIGHLY RELIABLE	. A LITTLE DIFFICULT TO MEASURE . CAREFUL STUDY IS REQUIRED	. IMPOSSIBLE TO MEASURE
BELOW 10^{-4} cm/sec.	. POSSIBLE TO MEASURE . HIGHLY RELIABLE	. POSSIBLE TO MEASURE . HIGHLY RELIABLE	. A LITTLE DIFFICULT TO MEASURE . CAREFUL STUDY IS REQUIRED

(3) OPERATION MANUAL:

SEE PAGE . 147

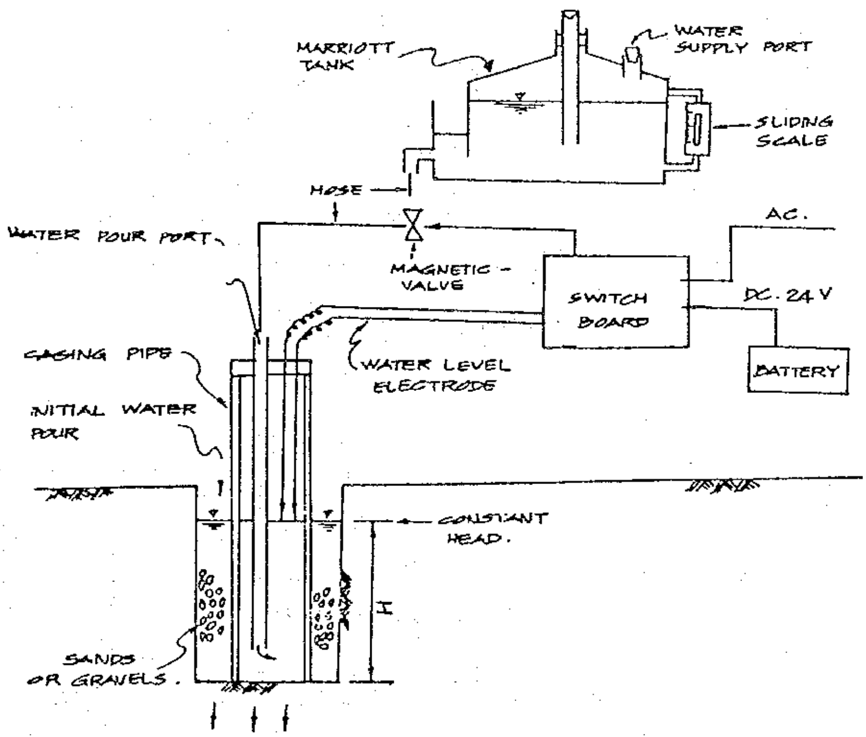
(4) DATA SHEET:

DATA SHEET FOR LEAKAGE CAPACITY TESTER							
GROWING STAGE	DATE	LOT NO.	MEA-SURE-MENT SITE	MEASURE-MENT PERIOD	AMOUNT OF LEAK-AGE	WATER LEVEL OF DRAINAGE	NOTE
					(5 min or 1 min)		

3-5-3. Permeability

MODEL 420

(1) SYSTEMATIC DRAWING OF MODEL 420:



(2) Outline

The field permeability measuring instrument (model 420) is designed to measure the water percolation in the field.

The sequence of operation is as follows;

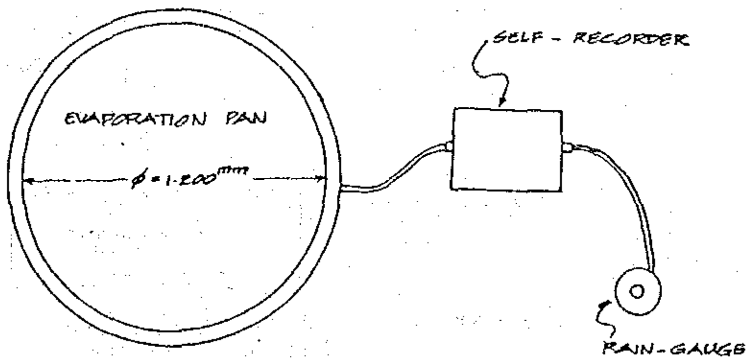
1. Make a hole of 10 cm in diameter and optional depth in field.
2. Set a casing pipe vertically in the hole and pour water into the hole. When the water level is down, water is supplied automatically from the marriotte tank.
3. After the water supply reached a stationally state (constant head), the coefficient of water permeability is calculated from the relation between time and amount of percolated water.

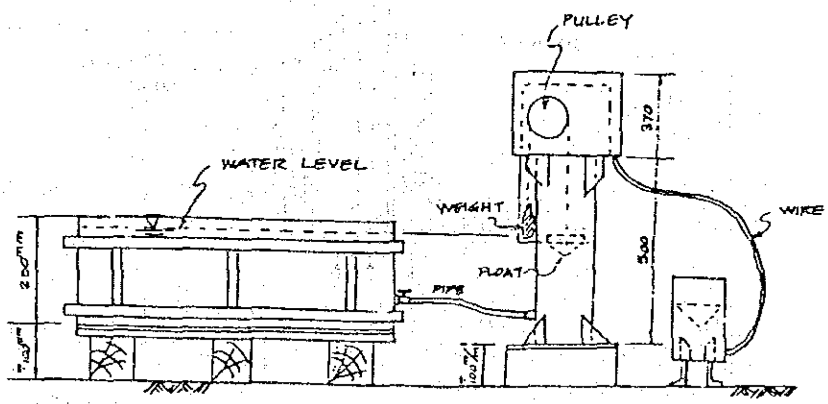
(3) Detailed operation manual

See page 155

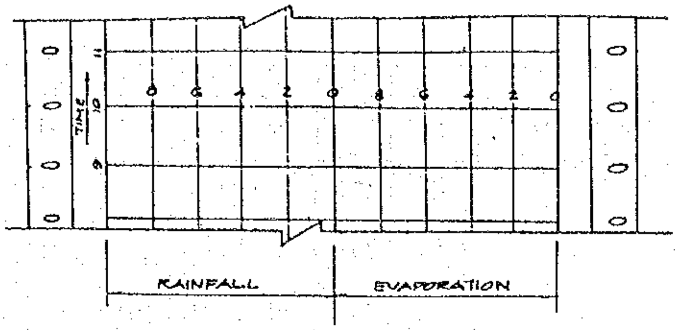
3-5-4. Evaporation

(1) ILLUSTRATION: (SELF-RECORDING RAINFALL & EVAPORATION GAUGE)





(2) RECORDING PAPER:

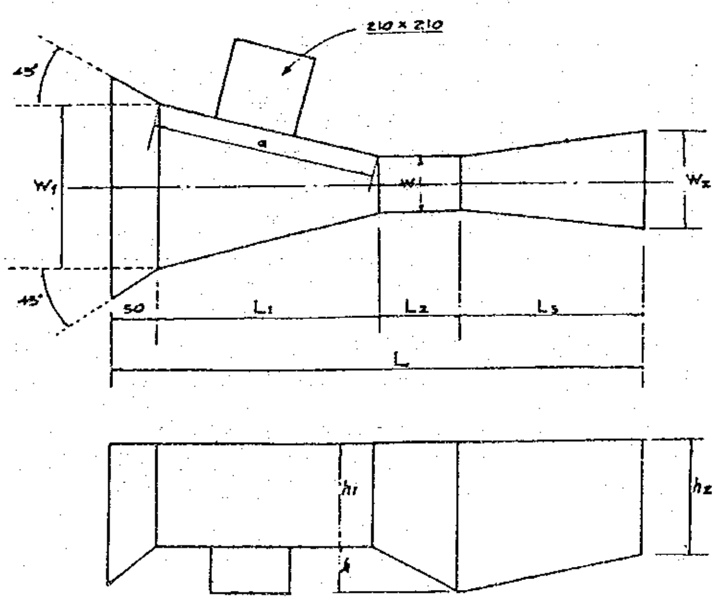


(3) SPECIFICATION:

	EVAPORATION	RAINFALL
MEASURING RANGE ACCURACY	0 – 10 mm ± 1 mm	CONTINUOUSLY INTERGRATING ± 3%
RECORDING PERIOD	1 MONTH,	3 MONTHS
ELECTRIC POWER	BATTERIES	(1.5V x 5)
ROLLING SPEED	12 mm/HOUR 6 mm/HOUR	(FOR 1 MONTH) (FOR 3 MONTH)
ACCURACY OF ROLLING SPEED	± 2 min./day	± 20 min./month

3-5-5. Flow measurement (Parshall flume)

(1) DIMENSION OF PARSHALL FLUME:



W	W1	W2	L1	L2	L3	L	h	h1	h2
2(inch)50.0 m/m	200	150	400	100	250	750	50	120	145
3 76.2	259	175	457	153	305	915	57	150	176
5 127.0	349	248	550	260	350	1.160	97	200	271
6 152.4	397	294	610	305	400	1.315	114	200	276
9 229.0	575	381	865	305	455	1.625	114	200	276
1(ft.)305.0	845	610	1.340	610	910	2.860	229	200	276

(2) OPERATION MANUAL:

SEE: PAGE 161

(3) CALCULATION FORMULA:

(UNDER THE CONDITION OF COMPLETE OVERFLOW)

W	q
2 (in)	$q = 0.096\ Ha^{1.55}$
3	$q = 0.141\ Ha^{1.55}$
5	$q = 0.179\ Ha^{1.69}$
6	$q = 0.264\ Ha^{1.58}$
9	$q = 0.466\ Ha^{1.53}$
1 (ft)	$q = \frac{3.711}{115.66 x W^{0.026}} x\ W\ x\ Ha^{1.39.W^{0.026}}$
NOTE	q : 1/sec. W : cm Ha : OVERFLOW DEPTH (cm)

(4) Calculation table

2 in TYPE

H(cm)	H(cm) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0		Q=(l/sec) 0.003	0.009	0.015	0.025	0.036	0.047	0.060	0.074	0.089
1	Q=(l/sec) 0.105	0.121	0.139	0.157	0.176	0.196	0.216	0.237	0.259	0.282
2	0.306	0.330	0.354	0.379	0.404	0.431	0.458	0.485	0.513	0.542
3	0.571	0.601	0.631	0.662	0.693	0.725	0.757	0.790	0.823	0.857
4	0.892	0.926	0.961	0.996	0.032	1.069	0.106	1.143	0.181	0.219
5	0.258	1.297	0.537	1.377	1.417	1.458	1.499	1.541	1.583	1.625
6	1.668	1.711	0.754	1.798	1.845	1.888	1.933	1.978	2.024	2.070
7	2.117	2.164	2.211	2.258	2.306	2.355	2.404	2.453	2.502	2.552
8	2.602	2.652	2.703	2.754	2.806	2.858	2.910	2.962	3.015	3.068
9	3.122	3.176	3.230	3.284	3.339	3.394	3.449	3.505	3.561	3.617
10	3.674	3.731	3.788	3.345	3.903	3.961	4.020	4.079	4.138	4.197
11	4.257									

3 in TYPE

H(cm)	H (cm) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0		Q=(l/sec) 0.004	0.012	0.022	0.034	0.048	0.064	0.081	0.100	0.120
1	Q=(l/sec) 0.141	0.163	0.187	0.212	0.237	0.264	0.292	0.321	0.351	0.381
2	0.413	0.445	0.479	0.513	0.548	0.583	0.620	0.657	0.696	0.734
3	0.774	0.814	0.855	0.897	0.940	0.983	1.027	0.071	1.117	0.162
4	1.209	1.256	1.304	1.352	1.401	1.451	1.501	1.552	1.604	1.656
5	1.709	1.762	1.816	1.870	1.925	1.981	2.037	2.093	2.150	2.208
6	2.266	2.325	2.335	2.445	2.505	2.566	2.627	2.689	2.752	2.815
7	2.878	2.942	3.007	3.072	3.137	2.203	3.269	3.336	3.404	3.472
8	3.540	3.609	3.678	3.748	3.818	3.889	3.960	4.832	4.104	4.176
9	4.249	4.322	4.396	4.471	4.545	4.621	4.696	4.772	4.849	4.926
10	5.003	5.081	5.157	5.237	5.316	5.396	5.476	5.555	5.637	5.118
11	5.799									

5 in TYPE

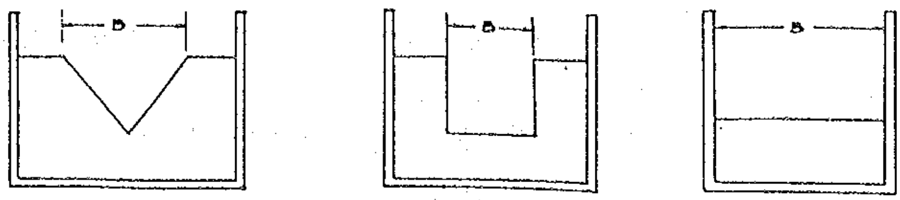
	H (cm) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
H(cm) 0		Q=(l/sec) 004	012	024	038	056	076	098	123	150
1	Q=(l/sec) 179	211	244	279	316	355	396	439	483	529
2	577	626	677	730	784	840	898	957	1.017	1.079
3	1.142	1.207	1.274	1.341	1.411	1.481	1.553	1.627	1.702	1.778
4	1.855	1.934	2.014	2.096	2.179	2.263	2.348	2.435	2.523	2.612
5	2.702	2.794	2.887	2.981	3.077	3.173	3.271	3.370	3.471	3.572
6	3.675	3.779	2.884	3.990	4.097	4.206	4.315	4.426	4.538	4.651
7	4.765	4.881	4.997	5.114	5.233	5.353	5.474	5.596	5.719	5.843
8	5.968	6.094	6.222	6.350	6.400	6.610	6.742	6.675	7.008	7.143
9	7.728	7.445	7.553	7.692	7.832	7.973	8.115	8.258	8.402	8.547
10	8.693	8.840	8.988	9.317	9.287	9.438	9.590	9.743	9.897	10.052
11	10.208									

9 in TYPE

	H (cm) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
H (cm) 0		Q=(l/sec) 014	040	074	115	161	213	270	331	397
1	Q=(l/sec) 466	539	616	696	780	867	957	1.049	1.145	1.244
2	1.346	1.450	1.557	1.667	1.779	1.893	2.010	0.130	2.252	2.376
3	2.503	2.631	2.762	2.895	3.031	3.168	3.308	3.449	3.593	3.739
4	3.886	4.036	4.188	4.341	4.496	4.654	4.813	4.974	5.137	5.301
5	5.468	5.636	5.806	5.978	6.151	6.326	6.503	6.682	6.862	7.044
6	7.227	7.412	7.599	7.787	7.977	8.169	8.361	8.556	8.752	8.950
7	9.149	9.350	9.552	9.756	9.961	10.148	10.376	10.586	10.797	11.009
8	11.223	11.438	11.655	11.875	12.083	12.314	12.536	12.760	12.985	13.212
9	13.439	13.668	13.899	14.154	14.364	14.598	14.834	15.071	15.309	15.549
10	15.790	16.032	16.276	16.521	16.767	17.014	17.265	17.521	17.765	18.016
11	18.269									

3-5-6. Flow measurement (Sharp-crested weir)

(1) DIMENSION OF WEIRS



TRIANGLE WEIR　　RECTANGULAR WEIR　　UNCONTRACTED WEIR

SIZE AND RANGE OF WEIR

SIZE OF WEIR	WIDTH B(m)	RANGE OF HEAD	RANGE OF DISCHARGE
60 DEGREE TRIANGEL W.	0.45	0.040 - 0.120	m^3/min. 0.018 - 0.26
90 " "	0.60	0.070 - 0.200	0.110 - 1.5
90 " "	0.80	0.070 - 0.260	0.11 - 2.9
RECTANGULAR WEIR	0.90	0.030 - 0.270	0.21 - 5.5
" "	1.20	0.030 - 0.312	0.28 - 9.0
UNCONTRACTED WEIR	0.60	0.030 - 0.150	0.36 - 4.0
" "	0.90	0.030 - 0.225	0.54 -11.4
" "	1.20	0.030 - 0.300	0.72 -24
" "	1.50	0.030 - 0.375	0.90 -42
" "	2.00	0.030 - 0.750	1.2 -86

(2) CALCULATION FORMULA:

(1) RECTANGULAR WEIR:

ITAYA - TEJIMA FORMULA

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

$$C = 1.785 + \frac{0.00295}{h} + 0.237\frac{h}{D} - 0.428 \times \sqrt{\frac{(B-b)h}{B.D}} + 0.034 \times \sqrt{\frac{B}{D}}$$

WHERE:

Q : DISCHARGE (m^3/sec)
C : DISCHARGE COEFFICIENT
b : WIDTH OF THE NOTCH (m)
B : WIDTH OF THE CANAL (m)
h : HEAD FROM THE WEIR (m)
D : NOTCH HEIGHT FROM THE BOTTOM (m)

THE APPLICABLE RANGE OF THIS FORMULA:

$0.5^m \leqq B \leqq 6.3^m$ $\qquad$ $bD/B^2 \geqq 0.06$

$0.15^m \leqq b \leqq 5^m$ $\qquad$ $0.03^m \leqq h \leqq 0.045\sqrt{b}$

$0.15 \leqq D \leqq 3.5^m$

IF WITHIN ABOVE RANGE, ERROR WILL BE WITHIN ± 1.4%

(2) TRIANGLE WEIR (90^o):

NUMACHI-KUROKAWA-FUCHIZAWA FORMULA:

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

$$C = 1.354 + \frac{0.004}{h} + (0.14 + \frac{0.2}{\sqrt{D}})(\frac{h}{B} - 0.09)^2$$

WHERE:

Q : DISCHARGE (m^3/sec)

h : HEAD FROM THE WEIR (m)

C : DISCHARGE COEFFICIENT

D : NOTCH HEIGHT FROM THE BOTTOM (m)

B : WIDTH OF THE CANAL (m)

APPLICABLE RANGE OF THIS FORMULA:

$0.5^m \leqq B \leqq 1.2^m$

$0.1^m \leqq D \leqq 0.75^m$

$0.07^m \leqq h \leqq 0.26^m$ (AND $h \leqq b/3$)

IF WITHIN ABOVE RANGE ERROR WILL BE WITHIN ± 1.4%

(3) UNCONTRACTED WEIR:

ISHIHARA-IDA FORMULA:

$$Q = CB\,h^{3/2}$$

$$C = 1.785 + (\frac{0.00295}{h} + 0.237\,\frac{h}{D})(1 + E)$$

WHERE:

Q : DISCHARGE (m^3/sec.)

C : COEFFICIENT OF DISCHARGE

h : HEAD FROM THE WEIR (m)

B : WIDTH OF THE CANAL (m)

D : NOTCH HEIGHT FROM THE BOTTOM (m)

E : CORRECTION TERM

$D < 1m$: $E = D$

$D > 1m$: $E = 0.55\ (D-1)$

THE APPLICABLE RANGE OF THIS FORMULA

$B \geqq 0.5m$

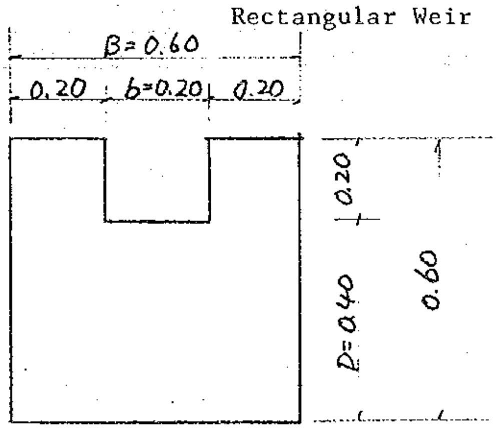
$0.3m \leqq D \leqq 2.5m$

$0.03m \leqq h \leqq 0.8m$ (HOWEVER, $h \leqq D$ AND $h \leqq \frac{B}{4}$)

IF WITHIN ABOVE RANGE, ERROR WILL BE WITHIN $\pm$ 1.8%

(3) CALCULATION TABLE:

Rectangular Weir



$$Q = cbh^{3/2}\ (m^3/s)$$

$$C = 1.785 + \frac{0.00295}{h} + 0.237\frac{h}{D} - 0.428\sqrt{\frac{(B-b)h}{BD}} + 0.034\sqrt{\frac{B}{D}}$$

B = 0.6, b = 0.2, D = 0.4 —— 0.3 (m)

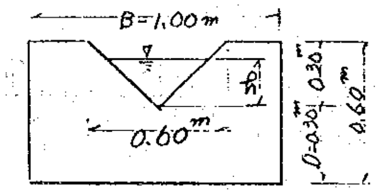
RECTANGULAR WEIR

Q = l/min.

h (cm)	0	1	2	3	4	5	6	7	8	9
1	24.7	28.2	31.7	35.5	39.4	43.4	47.3	51.6	55.7	60.2
2	64.7	69.2	73.9	78.9	83.8	88.6	93.7	99.0	104.3	109.6
3	115.2	120.6	126.0	132.0	137.4	143.2	149.4	155.4	161.4	167.4
4	174.0	180.0	186.6	193.2	199.2	205.8	213.0	219.6	226.2	232.8
5	240.0	247.2	253.8	261.0	268.2	275.4	282.6	290.4	297.6	305.4
6	312.6	320.4	328.2	336.0	343.8	351.6	359.4	367.2	375.6	383.4
7	391.5	399.6	408.0	416.4	424.8	433.2	441.6	450.0	458.4	467.4
8	475.8	484.8	493.2	502.2	511.2	520.2	529.2	538.2	547.2	556.2
9	565.8	574.8	584.4	593.4	603.0	612.6	621.6	631.6	640.8	630.4
10	660.0	670.2	679.8	689.4	699.6	709.2	719.4	729.6	739.2	740.4
11	760.0	769.8	780.0	801.0	811.2	821.4	823.8	832.2	842.4	834.2
12	864.0	874.2	885.0	895.8	906.6	917.4	928.2	939.0	949.8	961.2
13	972.0	983.4	994.2	1005.6	1017.0	1028.4	1039.2	1050.6	1062.0	1073.4

Traiangle Weir

Kurokawa Fuchizawa Numachi's Formula



$$Q = ch^{5/2} \quad (m^2/sec)$$

$$C = 1.354 + \frac{0.004}{h} + (0.14 + \frac{0.2}{\sqrt{D}})(\frac{h}{B} - 0.79)^2$$

Limit of application: $0.5 \leqq B \leqq 1.2$ $\quad 0.1 \leqq D \leqq 0.75$ $\quad 0.07 \leqq h \leqq 0.26$ $\quad h = \frac{1}{3}B$ (m)

Discharge : Q (l/min.)

Water level: h (cm)

TRIANGLE WEIR

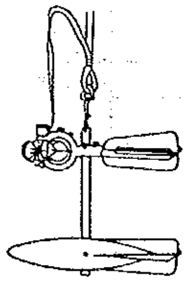
Discharge : Q (l/min.)
Water level: h (cm)

ℓ / h	0.0	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
7	110	114	118	122	126	130	134	139	143	148
8	152	157	162	167	172	177	182	188	193	198
9	204	210	215	221	227	233	239	245	252	258
10	264	271	278	285	292	299	306	313	320	327
11	335	342	350	358	366	374	382	390	398	407
12	415	424	433	442	451	460	469	478	488	497
13	507	516	526	536	546	556	566	577	588	598
14	609	620	637	642	653	665	676	688	693	711
15	723	735	747	759	772	784	797	809	822	835
16	848	862	876	889	902	916	930	944	959	973
17	987	1001	1016	1031	1046	1062	1077	1092	1107	1122
18	1138	1154	1170	1186	1202	1219	1236	1252	1269	1286
19	1303	1320	1338	1355	1373	1391	1408	1426	1444	1463
20	1481									

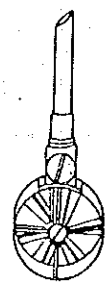
3-5-7. Flow measurement (Current meter) (FROM "HYDRAULIC MEASUREMENT" -O.T.C.A-)

1. Types and Characteristics of Current Meters

Current meters are devices which measure the speed of water movement. The cup type of wheel is best for relatively slow speeds, whereas the vane type measures larger speeds more accurately. Each of these meters must be calibrated, because they do not automatically give the magnitude of the velocity itself. Meters of the vane or propeller type offer the least resistance to flow. The standard procedure for determining the magnitude of velocity by use of current meters is to count the number of revolutions during a certain period of time, as determined by a stop watch or a clock. For an anemometer, the number of revolutions is read from a dial for a given period of time.



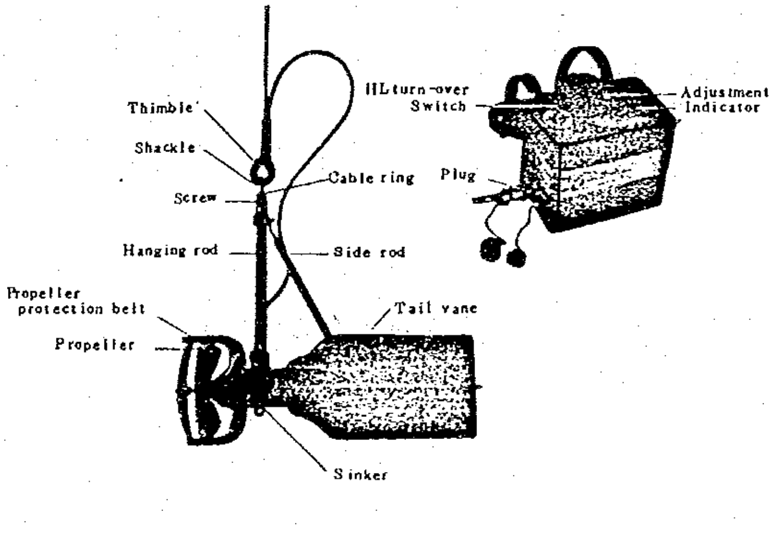
1. Cup type



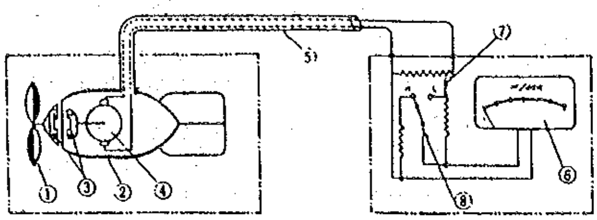
2. Vane type

Current meters

1. Flow detecting unit 2. Counter unit



CM-1B type Electric Current Meter



Mechanism of the Current Meter

(1) Propeller (2) Outer fram (3) Magnet

(4) Generator (5) Insulation cord (6) Indicator

(7) Resistance for revision (8) Switch

(1) <u>CM-1B type Electric Current Meter</u>

1) How to use;

1. Fix the hanging rod by using the side rod.
2. Attach the propeller.
3. Put on the velt of indicating meter.
4. Connect the cord with indicating meter.
5. Change the switch low or high according to flow velocity.

2) Characteristics;

1. Direct measurement by using special generator.
2. Velocity from 0.1 m/s to 3 m/s can be measured.
3. Water-proff frame, so that this instrument can be used in rain.
4. Consumption goods such as power supply and battery are not necessary.
5. Remote measurement is available.
6. Direction of the instrument is stable in the flow.

3) Notice;

1. Before measuring, spin test should be conducted.

2. When attaching the propeller, care to fix too hard.

3. When velocity is more than 1 m/s, remove the stick and rod.

4. At the time of no using the stick rod, hang the instrument by using cord.

(2) Price meter

The Price meter is developed in C.S. and improved by the U.S. Geological Survey and now it is the most common type. It will measure velocities from 0.3 m/s to 6 m/s. It is rugged, easily dismantled for cleaning, can be used in turbid water without damage by silt.

Six conical cups mounted around a vertical axis rotate under the action of the moving water. Every revolution causes a click in a set of headphones. The operator merely counts the number of clicks in a fixed time or measures time required for a specified number of clicks. Tail vanes keep the meter pointing into the current and a heavy weight helps it vertically under the point of measurement.

It is disadvantageous that at the time of flood, axise of conical cups can not prevent from root of weed and dust.

Small type Electric Price meter

$$V = 0.683 \times N + 0.017$$

(Applicable range is from 0.08 m/s to 0.90 m/s)

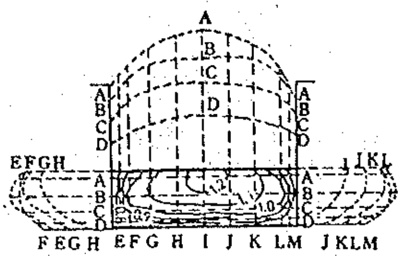
2. Measurement of Velocity Distribution in the Rectangular Canal

1) Velocity distribution

i) Knowledge

Owing to the free surface and to the friction along the canal wall, the velocities in a rectangular channel are not uniformly distributed in the channel section. The measured maximum velocity usually appears to occur below the free surface at a distance of 0.05 to 0.25 of the depth.

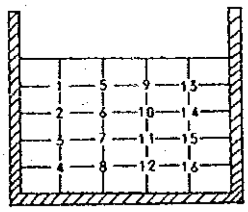
Example



Velocity Distribution in a Rectangular Channel

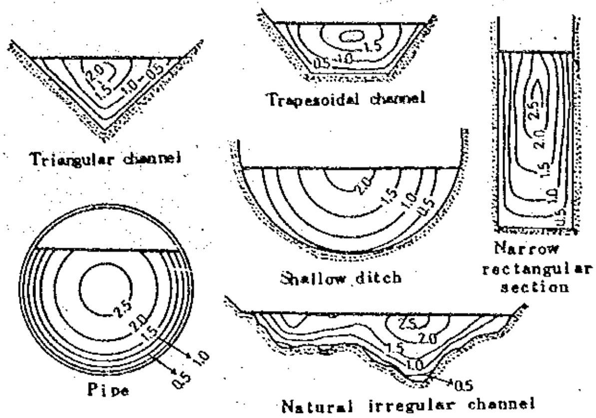
ii) Measurement

iii) Drawing the curves of equal velocity in a canal section.

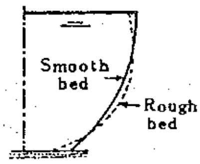


The general patterns for velocity distribution in several channel sections of shapes are illustrated below.

The velocity distribution in a channel section depends also on other factors, such as the unusual shape of the section, the roughness of channel, and the presence of bends. In a board, rapid, and shallow stream or in a very smooth channel, the maximum velocity may often be found at the free surface. The roughness of the channel will cause the curvature of the vertical velocity distribution curve to increase. On a bend the velocity increases greatly at the convex side, owing to the centrifugal action of the flow. Contrary to the usual belief, a surface wind has very little effect on velocity distribution.



Typical curves of equal velocity in various channel sections.

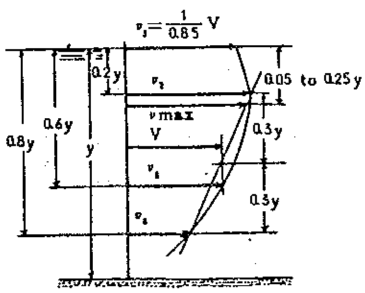


Effect of roughness on velocity distribution in an open channel

2) Calculating mean velocity and Q (discharge) in the canal.

i) Current-Meter Measurements. The construction of a weir for measuring the flowrate in large canals, streams, or rivers is impractical for many obvious reasons, but existing spillways whose coefficients are known may frequently serve as measuring devices. The standard method of river flow measurement is to measure the velocity by means of a current meter and integrate the results in a manner similar to that used for pilot tube measurements.

Fundamental to the use of a current meter is some knowledge of the general properties of velocity distribution in open flow. As in pipes, the velocities are reduced at the banks and bed of the channel, but it must be realized that in open flow the roughness and turbulences are of such great and irregular magnitudes that the velocity distribution problem cannot be placed on the precise basis which it enjoys in pipe flow. However, from long experience and thousands of measurements, the United States Geological Survey has established certain average characteristics of velocity distribution in streams and rivers which serve as a basis for current-meter measurements. These characteristics of velocity distribution in a vertical are shown in Fig. 11 and may be amplified by the following statements: (1) the curve may be assumed parabolic; This is merely a convenient approximation;



Standard velocity distribution in a vertical in open flow.

it does not imply laminar flow. (2) the location of the maximum velocity is from 0.05y to 0.25y below the water surface; (3) the mean velocity occurs at approximately 0.6y below the water surface; (4) the mean velocity is approximately 85 percent of the surface velocity; (5) a more accurate and reliable method of obtaining the mean velocity is to take a numerical average of the velocities at 0.2y and 0.8y below the water surface. These average values will, obviously, put apply perfectly to a particular stream or river, but numerous measurements with the current meter will tend toward accurate results since deviations from the average values will tend to compensate, thus giving a greater accuracy than can be obtained from individual measurements.

DATA SHEET FOR FLOW MEASUREMENT

NAME OF RIVER: ______________________ LOCATION: ______________________

DATE & TIME: ______________________ WEATHER: ______________________

NAME OF RECORDER: ______________________ WIND DIRECTION & WIND FORCE: ______________________

NATURE OF ASHORE: ______________________

METHOD OF FLOW MEASUREMENT

TYPE OF CURRENT METER

CHECK: ✓ (MEASURING RANGE)

☐ 1. CURRENT METER MODEL CM-15 (0.02 m/s – 1.00 m/s)

☐ 2. HIROI TYPE CURRENT METER (0.16 m/s – 1.49 m/s)

☐ 3. OTHERS (   ) (m/s –   m/s)

NO. OF CURRENT METER: ______________________

COEFFICIENT OF CURRENT METER & FORMULA

1. CM-15 & HIROI TYPE:

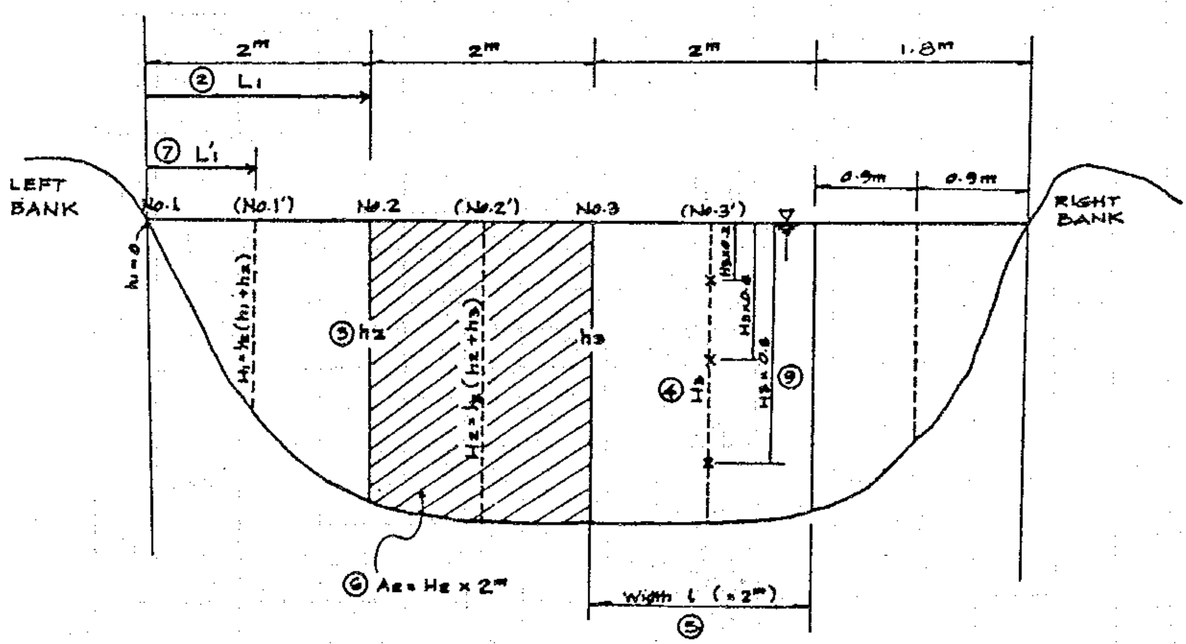
V (m/sec)=A x N + B   A = ________   B = ________

WHERE N = NO. OF REVOLUTION PER SECOND.

$$(N = (\text{COUNT VALUE } R) \times \frac{1}{\text{COUNT TIME } T})$$

2. OTHERS:

LEGEND (REFER PAGE 2):

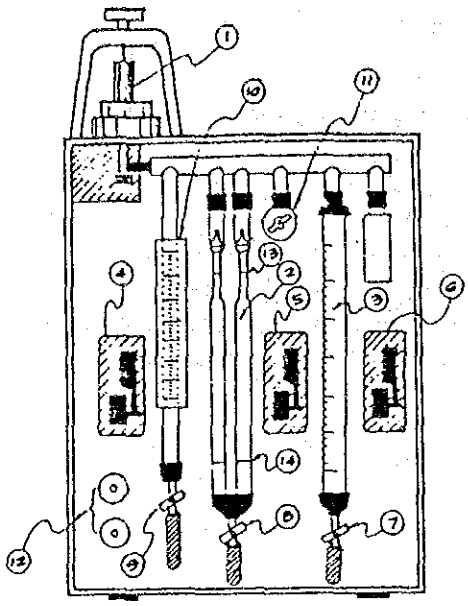


DATA SHEET FOR FLOW MEASUREMENT

(1) NO. FOR WATER DEPTH MEASUREMENT	(2) L: LENGTH FROM LEFT BANK (m)	(3) h: WATER DEPTH (m)	(4) H: MEAN WATER DEPTH (m)	(5) l: WIDTH OF SECTION (m)	(6) A: AREA OF SECTION (+H x 1) (m^2)	(7) L': LENGTH FROM LEFT BANK TO FLOW MEASUREMENT POINT	(8)	(9) FLOW MEASUREMENT DEPTH H x (m)	(10) R: ROUND NUMBER OF CURRENT METER	(11) T: COUNT TIME (SEC.)	(12) N: R/T	(13) V: VELOCITY OF FLOW V= A X N + B	(14) Vm: MEAN VELOCITY $Vm=\frac{1}{4}(V_{0.2}+2V_{0.6}+V_{0.8})$	(15) VOLUME OF WATER FLOW A + Vm	(16) NO. FOR VELOCITY MEASUREMENT	NOTE
1							0.2									
							0.6								1'	
2							0.8									
							0.2									
							0.6								2'	
3							0.8									
							0.2									
							0.6								3'	
4							0.8									
							0.2									
							0.6								4'	
5							0.8									
							0.2									
							0.6								5'	
6							0.8									
							0.2									
							0.6								6'	
7							0.8									
							0.2									
							0.6								7'	
8							0.8									
							0.2									
							0.6								8'	
9							0.8									
							0.2									
							0.6								9'	
10							0.8									
							0.2									
							0.6								10'	
11							0.8									
							0.2									
							0.6								11'	
12							0.8									
							0.2									
							0.6								12'	
13							0.8									
							0.2									
							0.6								13'	
14							0.8									
													TOTAL:			

3-5-8. Three phase distribution (Actual volumenometer)

(1) ILLUSTRATION:

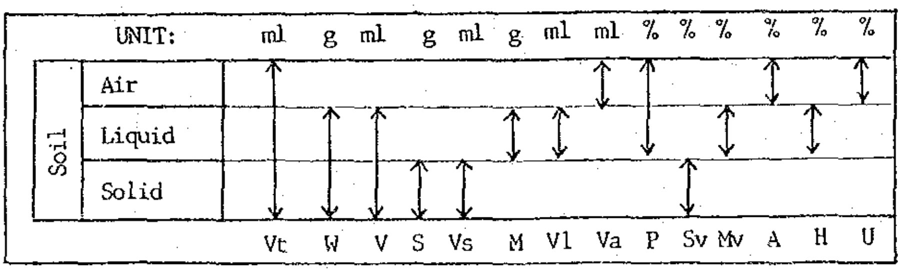


(1) SAMPLE CHAMBER
(2) U-SHAPED TUBE
(3) MEASURING TUBE (A)
(4) HANDLE FOR PUMP 1
(5) HANDLE FOR PUMP 2
(6) HANDLE FOR PUMP 3
(7) COCK K3
(8) COCK K2
(9) COCK K1
(10) MEASURING TUBE (B)
(11) COCK K
(12) TEST PIECES
(13) POINT E
(14) POINT I

(2) SPECIFICATIONS:

SAMPLE CAPACITY	100 ml
MEASURING RANGE	25 - 100 ml
ACCURACY	± 0.1 ml
DIMENSIONS	40 x 17 x 55 cm
WEIGHT	12 kg.

(3) CALCULATION:



(1) TOTAL VOLUME : Vt
(2) TOTAL WEIGHT : W
(3) ACTUAL VOLUME : V

(4)	WEIGHT OF SOLID PHASE	:	S = W – M
(5)	VOLUME OF SOLID PHASE	:	Vs = (W–V)/(d–1) WHERE D : SPECIFIC GRAVITY = S/Vs
(6)	WEIGHT OF SOIL WATER	:	M = Vl
(7)	VOLUME OF SOIL WATER	:	Vl = V – Vs
(8)	VOLUME OF SOIL AIR	:	Va = 100 – V
(9)	POROSITY	:	P = 100 – Vs
(10)	SOLID RATIO	:	Sv = Vs
(11)	WATER RATIO	:	Mv = Vl
(12)	AIR RATIO	:	A = Va
(13)	WATER SATURATION PERCENTAGE	:	H = Mv/p x 100
(14)	AIR PERCENTAGE	:	U = 100 – H

(4) OPERATION MANUAL:

SEE PAGE 167

3-6. Some results of water requirement

NEXT PAGE

RESULTS OF IRRIGATION REQUIREMENT DETERMINED IN SOME ASIAN COUNTRIES

COUNTRY	AUTHOR	LOCATION	SEASON	PERIOD	TOTAL (AVERAGE DAILY AMOUNT) E	T	ET	P	IR
				day	mm	mm	mm	mm	mm
THAILAND	KUNG et. al,	CENTRAL PLAIN 15°N	MAIN SEASON 1964	151	294 (1.9)	591 (3.9)	885 (5.9)	97 (0.6)	983 (6.5)
			OFF SEASON 1965	91	364 (3.8)	348 (3.8)	695 (7.6)	48 (0.3)	748 (8.2)
	ROYAL IRRI. DEPT.	NORTHEAST 15°N	MAIN SEASON	94	233 (2.5)	255 (2.7)	488 (5.2)	278 (3.0)	766 (8.2)
CAMBODIA	HATTA	BATTAMBANG 13°N	DRY SEASON 1965/66	106	–	–	710 (6.7)	244 (2.3)	954 (9.0)
LAOS	KOTTER	VIENTIAN 18°N	WET SEASON 1967	102	270 (2.7)	245 (2.4)	515 (5.1)	742 (7.3)	1.257 (12.4)
EAST PAKISTAN	KUNG	KUSHTIA 24°N	WET SEASON 1959	78	382 (4.9)	733 (9.4)	1,115 (14.3)	78 (1.0)	1,193 (15.3)
			DRY SEASON 1958/59	101	436 (4.3)	515 (5.1)	951 (9.4)	54 (0.5)	1,095 (10.0)
CEYLON	MURAKAMI	DRY ZONE 8°N	DRY SEASON 1965	112	420 (3.8)	552 (4.9)	972 (8.7)	2,475 (22.1)	3,447 (30.8)
INDIA	VAMADEVAN et. al,	NEW DELHI 29°N	WET SEASON 1968	87	–	–	493 (5.7)	1,189 (13.7)	1,683 (19.3)
PHILIPPINES	IRRI	SOUTHERN RUZON 14°N	WET SEASON 1966	86	–	–	396 (4.6)	172 (2.0)	568 (6.6)
MALAYSIA		KELANTAN* 6°N	OFF SEASON 1982						
			OFF SEASON 1983						
	SUGIMOTO	KEDAH 6°N	MAIN SEASON 1967/69	97	226 (2.7)	262 (2.7)	527 (5.4)	61 (0.6)	588 (6.1)
			MAIN SEASON 1967/68	139	347 (2.5)	387 (2.8)	734 (5.3)	201 (1.4)	935 (6.7)
			OFF SEASON 1968	116	364 (8.1)	372 (3.2)	737 (6.4)	–19 (–0.2)	718 (6.2)
			MAIN SEASON 1968/69	110	336 (3.1)	312 (2.8)	649 (5.9)	37 (0.5)	705 (6.4)
			MAIN SEASON 1968/69	179	574 (3.2)	448 (2.5)	1,022 (5.7)	204 (1.1)	1,226 (6.8)
	NISHIO	KEDAH 6°N	MAIN SEASON 1970/71	102	–	–	542 (5.3)	371 (3.6)	913 (9.0)
			OFF SEASON 1971	122	–	–	834 (6.8)	618 (5.1)	1,452 (11.9)
		P. WELLESLEY 6°N	MAIN SEASON 1970/71	103	–	–	576 (5.6)	321 (8.1)	897 (8.7)
			OFF SEASON 1971	117	–	–	725 (6.2)	358 (3.1)	1,083 (9.3)

* NATIONAL WATER MANAGEMENT TRAINING CENTRE, KOTA BHARU.

SOURCE: – RICE CULTURE IN TROPICAL ASIA –

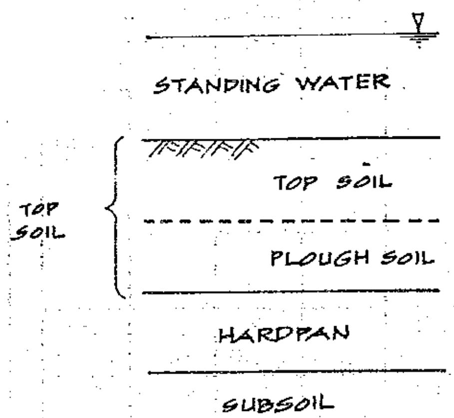
4. ON-FARM WATER MANAGEMENT EFFECT ON PADDY SOIL PHYSICOCHEMICAL CONDITION

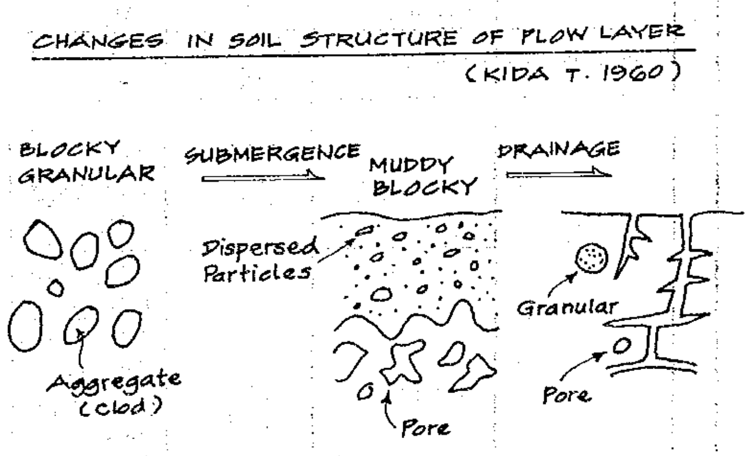
4-1. Physicochemical condition of paddy soil

4-1-1. Characteristics of paddy soil

Paddy soil has a different characteristics from upland field due to the standing water. Generally, paddy soil consists of three layers, top soil, hard pan and subsoil. Top soil is the layer of soil moved in cultivation and so called a horizon. In some cases, this top soil is sub-divided into two layers, top soil and plough soil. This plough soil is the layer of soil compacted by passage of plough. Hard pan is a formation which occurs by precipitation of dissolve materials, such as calcium carbonate or silica, at certain depths below the surface year after year. When this accumulation takes place, the subsoil is more or less firmly cemented and limits downward movement of water. This formation does not soften when wetted by water.

FIG. 20





The other way of classification of paddy soil is related to eluviation and illuviation. Typically, there are 4 horizon, A, B, G and C. A horizon is the uppermost eluvial layer of a soil profile. On the other, B horizon is the illuvial layer of a soil profile. In between B and C horizon, there may be G horizon (or Gley horizon)

This G horizon is the horizon containing soil having yellow and grey mottling produced by partial oxidation and reduction of iron caused by intermittent waterlogging. This condition is met with in poorly drained soil.

C horizon is the horizon of weathered rock material little affected by biological soil forming processes, it is usually referred to a parent material.

Each layer is sub-divided as shown in Fig. 21

<u>HORIZON OF PADDY SOIL:</u> (FIG. 21)

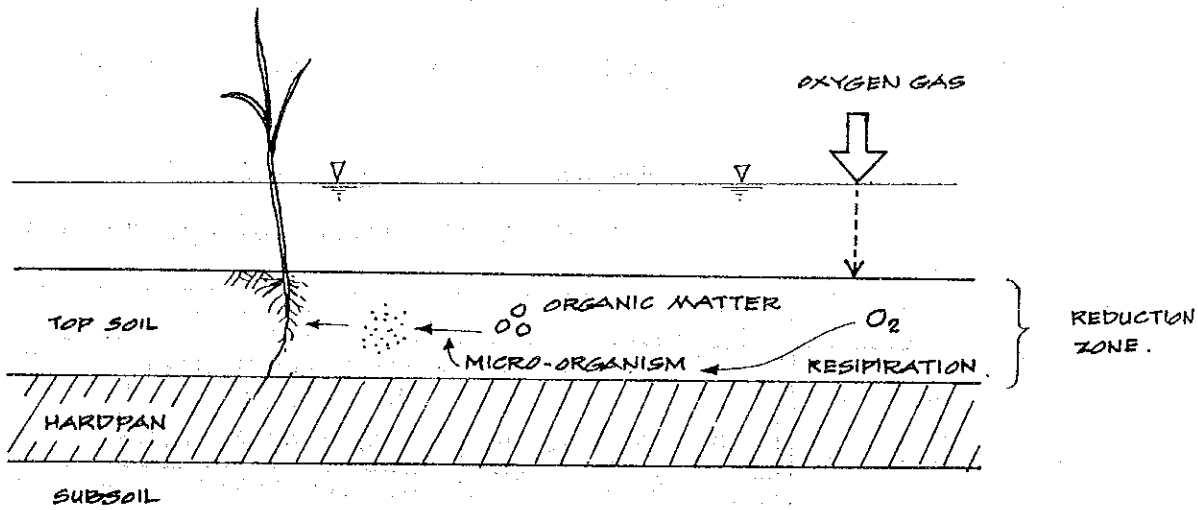
- IN RELATION TO ELUVIATION & ILLUVIATION

A HORIZON (ZONE OF ELUVIATION)	A1	ZONE OF MAXIMUM HUMUS ACCUMULATION (WITHOUT RUSTY MOTTLE)
	AB	TOP SOIL WHICH CONTAINS RUSTY MOTTLE
	A2	PLOUGH SOIL USUALLY ASH-COLORED EFFECTED BY ELUVIATION
B HORIZON (ZONE OF ILLUVIATION)	B1	THIS ZONE CONTAINS RUDDY BROWN RUSTY MOTTLE
	B2	THIS ZONE CONTAINS YELLOW RUSTY MOTTLE
	B3	THIS ZONE CONTAINS PARK PURPLE RUSTY MOTTLE
G HORIZON	G1	WITH RUSTY MOTTLE AND GROUNDWATER LEVEL FLUCTUATE DOWN TO THIS ZONE
	G2	WITHOUT RUSTY MOTTLE
C HORIZON	C	MINERAL HORIZON USUALLY UN-CONSOLIDATED.

4-1-2 Reduction and oxidation.

Naturally, or as applied fertilizer, there are many organic matters in the top soil. This organic matter will be disassembled by soil micro-organism, and these disassembled organic matter will be absorbed by plants. In this process, soil micro-organism will consume the oxygen in the top soil in respiration. Whereas oxygen gas supply from the atmosphere is very little due to standing water. Accordingly, the oxygen in the top soil will gradually be defficient.

(FIG. 22)



Some kind of soil micro-organism have ability to consume the oxygen in the chemical compound. According to the deficiency of oxygen in the top soil, this kind of micro-organism will consume the oxygen in the chemical compound. As a result, the oxide compound will be changed into oxygen-less or few oxygen compound. In other word, top soil layer will be changed into reduced layer.

Ex. $Fe2O3 \rightarrow FeO + Fe^{+} + O2$

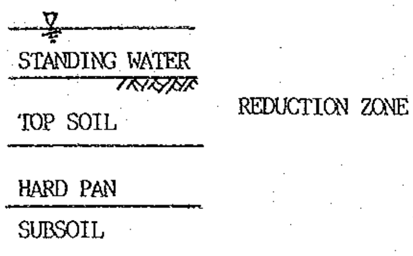
$O2 \downarrow$ RESPIRATION

$Fe^{+} \downarrow$ ELUVIATE BY PERCOLATION

In the hard pan, there are only few organic matters and activity of micro-organism is very low, therefore, they are generally oxidized.

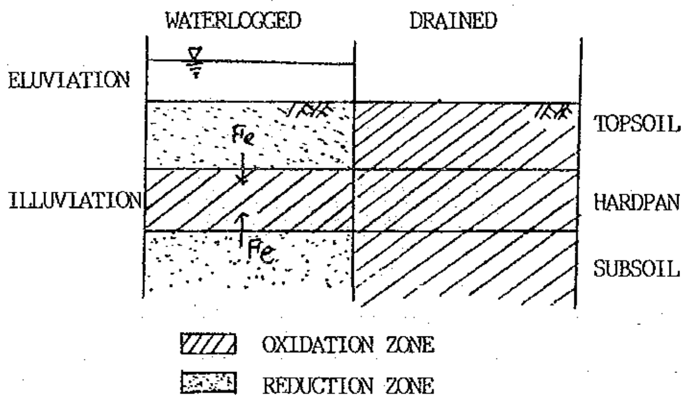
SCHEMATIC PRESENTATION OF PADDY SOIL. (F(G. 23)

(1) REDUCTION ZONE:



IN THIS ZONE, SOIL MICRO-ORGANISM CONSUME OXYGEN, BUT, OXYGEN IS EXCLUDED BY STANDING WATER. CONSEQUENTLY, REDUCTION OF THE OXIDED SUBSTANCE WILL TAKE PLACE (FOR EXAMPLE $Fe_2O_3 \rightarrow FeO$

(2) WATERLOGGED SOIL AND DRAINED SOIL:

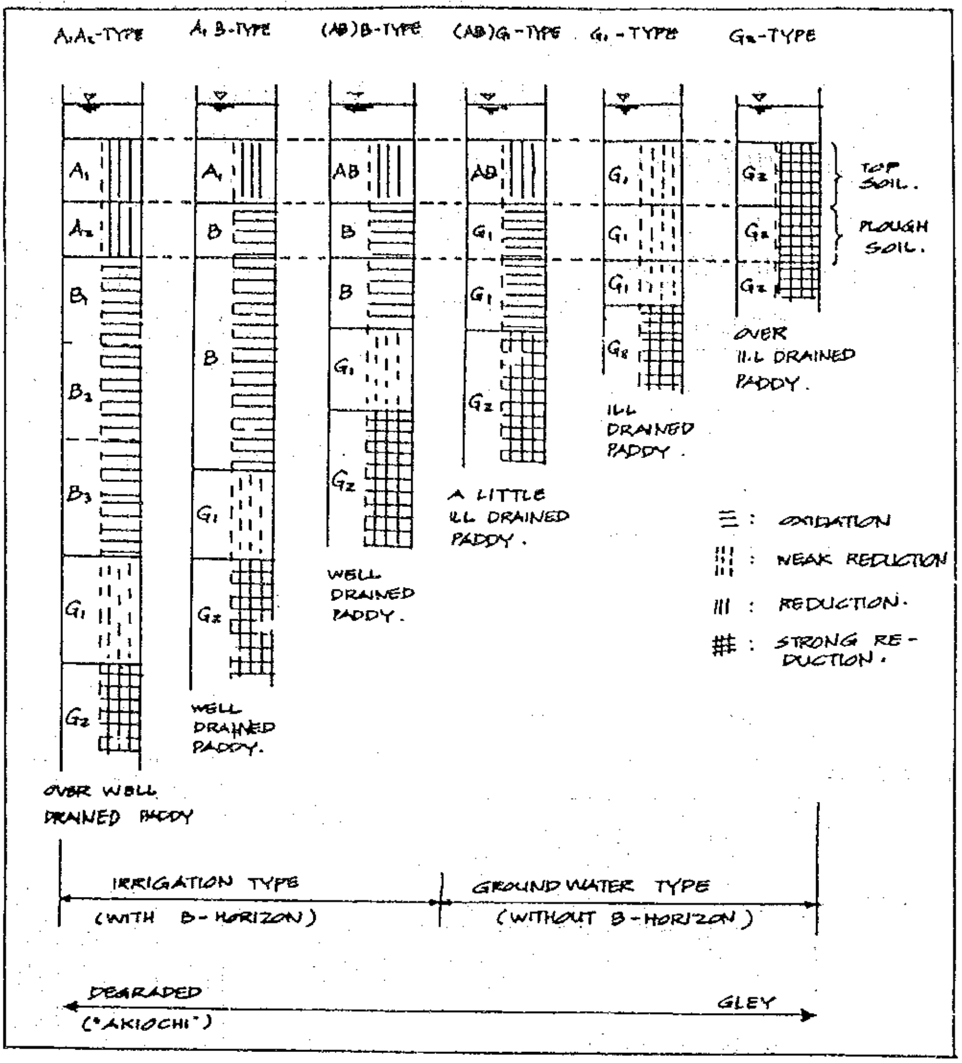


	COMPONENT	
	WATER-LOGGED	DRAINED
C	CH_4	CO_2
Fe	FeO	Fe_2O_3
Mn	Mn_2O_3	MnO_2
S	H_2S	M_2SO_4
N	NH_2	HNO_3

4-1-3. Well drained and ill drained paddy field.

Well drained field is defined as the field of which groundwater level will be decreased down to far below from surface of paddy field during fallow period after drain. In this case, soil condition of paddy after drain will be the same as the upland field. On the contrary, ill-drained paddy field's groundwater level is not so decreased even after drain and its moistrue contents is almost same as irrigation period.

TYPES OF PADDY (FIG. 24)



In the case ill-drained paddy, the movement of water through the soil surface into the soil body is very slow, therefore irrigation requirement is also very low. On the other hand, due to a strong reduction, growth of paddy roots is weak and toxic substance originated from disassembly of soil organic matter will not be washed away. At the same time, due to low percolation, available component is accumulative.

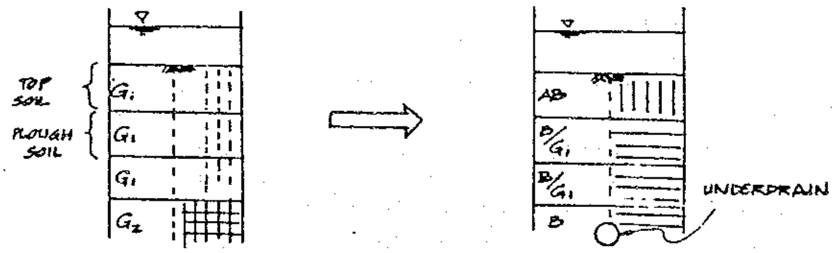
For the improvement of like this ill-drained condition, underdrain is effective. (See Fig. 26)

COMPARISON OF WELL DRAINAGE PADDY
& ILL DRAINED PADDY (FIG. 25)

ITEMS	ILL DRAINED PADDY	WELL DRAINED PADDY
WATER REQUIREMENT	LITTLE	LOT
GROWTH OF ROOTS	POOR & SMALL NUMBER OF ROOTS	ACTIVE & LARGE NUMBER OF ROOTS
COLOR OF ROOTS	RED: BECAUSE OF THE ILLUVIATION OF IRON	WHITE: BECAUSE OF THE ELUVIATION OF IRON AND OTHERS
TOXIC SUBSTANCE	CANNOT WASH AWAY	EASILY WASH AWAY
AVAILABLE COMPONENT (SOIL FERTILITY)	" (ACCUMULATIVE)	" (EXHAUSTED)

EFFECT OF UNDERDRAINAGE (FIG. 26)

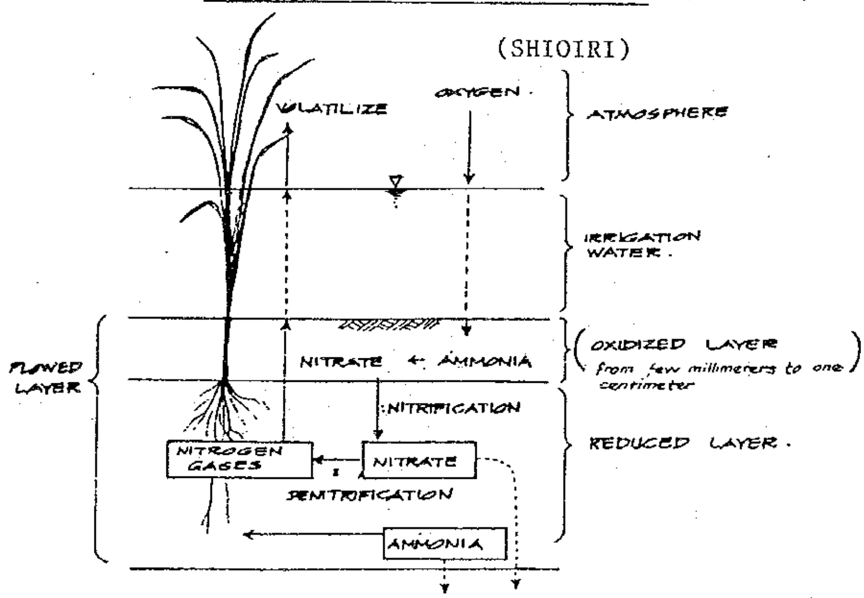
(IN CASE OF G1-TYPE)



4-1-4. Denitrification in paddy soil

DENITRIFICATION IN PADDY SOIL (FIG. 27)

(SHIOIRI)



Process of denitrification in paddy soil is;

1. Oxygen gas in the atmosphere is dissolved in the surface water of paddy soil.

2. Soil microbes consume far more oxygen in their respiration than can be supplied very rapidly in the soil.

3. A reduced condition is set up in the flooded soil.

4. With the progress of soil reduction after rapid decomposition of organic matter, the supply of oxygen from irrigation water comes to surpass the sonsumption by soil-microbes.

5. Consequently, the surface layer of paddy soil is eventually differentiated into two layers, oxidized layer and reduced layer.

6. In the reduced layer, obligate aerobic bacteria like nitrifiers may not thrive because of the anaerobic condition there, and ammonia stays very stable because it is not subjected to bio-chemical change.

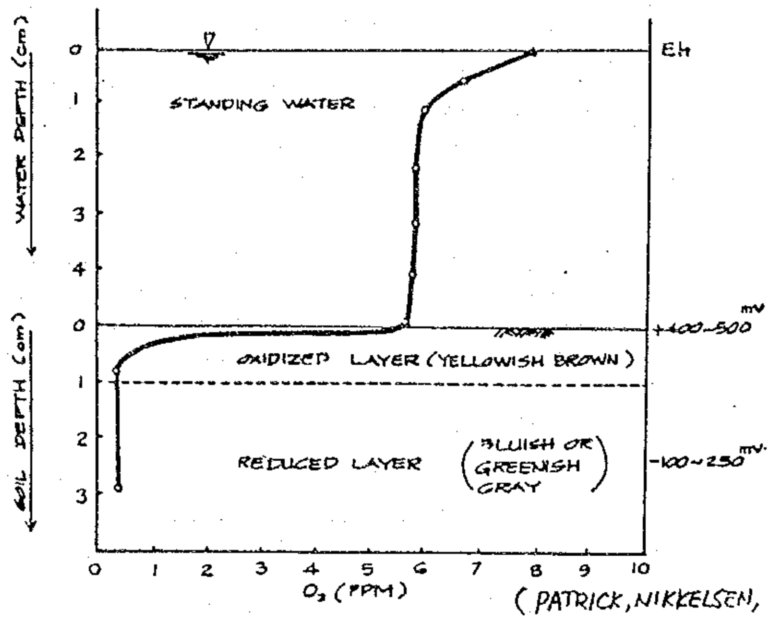
7. In the oxidized layer, nitrifier may be so active that ammonia may be oxidized to nitric-acid through nitrification. Nitric-acid produced in this manner may diffuse itself or be transported by percolation water into the reduced layer.

8. In the reduced layer or local reduced spots present in the oxidized layer, nitric-acid may be converted to nitrogen gas and/or oxides of nitrogen by a denitrifier to volatilize into the atmosphere.

9. In order to minimize possible loss of nitrogen from the soil, nitrogen fertilizer should be applied to the soil as deeply as possible.

10. Vertical distribution of oxygen content is as shown in Fig. 28.

VERTICAL DISTRIBUTION OF OXYGEN CONTENT OF THE WATERLOGGED SOIL (FIG. 28)

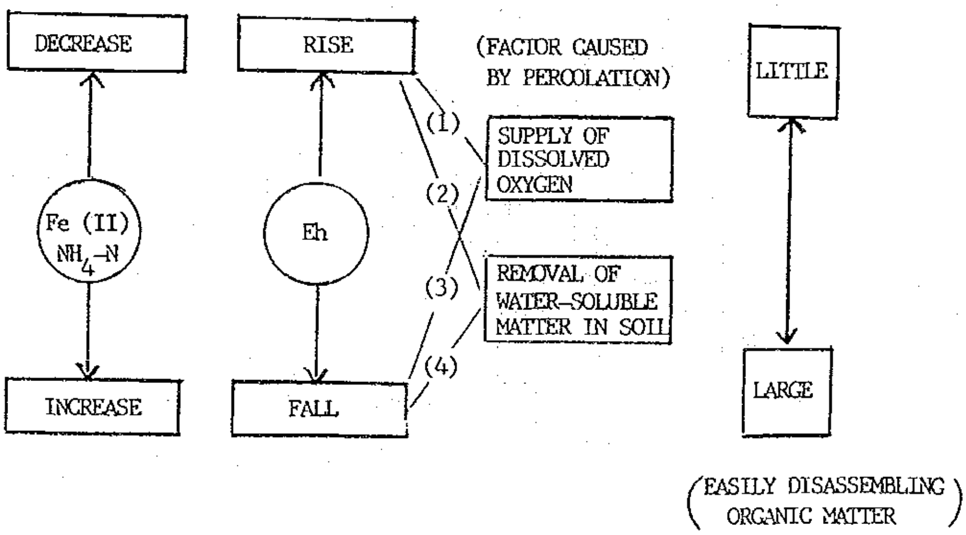


(PATRICK, NIKKELSEN, TAKAI)

4-1-5. Effect of percolation on rdeuction process in waterlogged soil.

Effect of percolation on reduction process depends on the amount of organic matters which is easily dis- assemble. If such an organic matter is enough, aerobic bacteris will be activated by dissolved oxygen in the percolation water and also due to washing away of toxic substance, the activity of soil micro-organism will be increased. Accordingly, reduction may be processed by the percolation.

Whereas, if such an organic matter is not enough, the supply of oxygen from percolation water comes to surpass and finally reduction process may controlled.



(1) Oxidation

(2) Lowering of microbial activities by removal of substance

(3) Stimulus to a growth of aerobic bacteria

(4) Increment of microbial activities by removal of toxic substance.

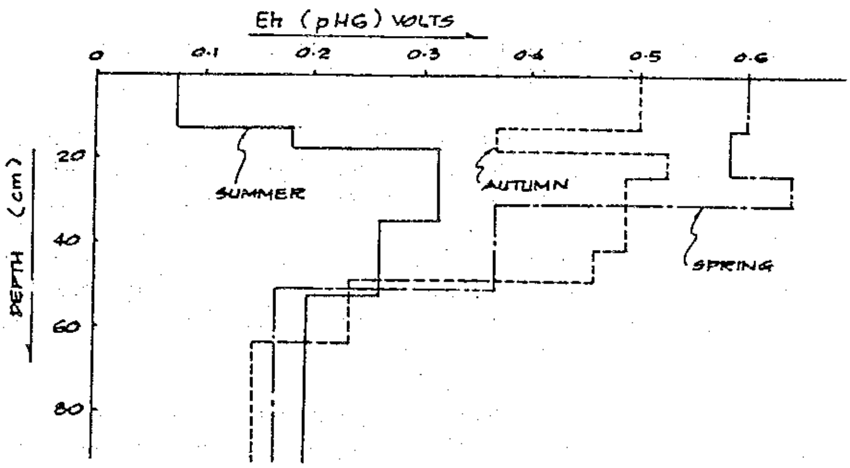
4-1-6. Redox potential

For the judgement of oxidation-reduction condition, we usually measure the oxidation-reduction (redox) potential. If this redox potential indicates more than 0.4 volts, the soil is roughly classified to be oxidation zone, on the contrary, if it is below 0.3 volts, the soil is judged to be reduction zone.

SEASONAL EXCHANGES OF REDOC POTENTIAL IN PADDY SOIL (IN JAPAN) (FIG. 29)

(AOMINE, 1949)

WELL DRAINED:



ILL DRAINED:

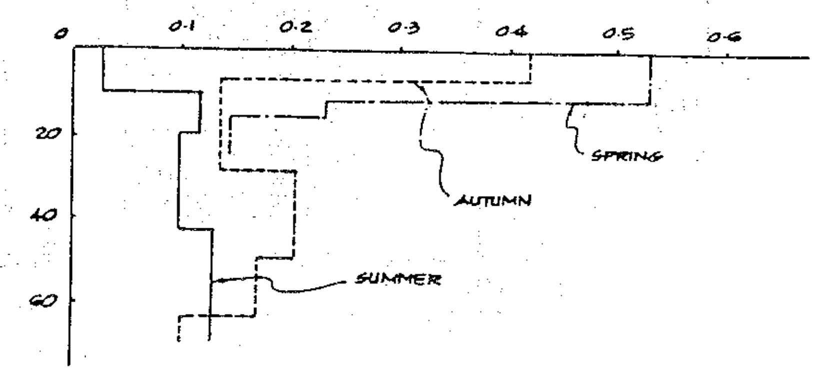


Fig. 29 shows the seasonal exchange of redox potential measured in Japan. In Japan, summer is the mid-season of rice cultivation and autumn is the harvesting time. Similarly, spring is just before presaturation. In the case of well drained paddy, the top soil (0-20 cm) was reduced in summer, but after drain, in autumn, they were oxidized. In spring time, just before presaturation, the soil was judged to be strongly oxidized. Regarding the hard-pan (30-50 cm), the soil was weakly reduced in summer but they were oxidized in autumn or in spring.

As for the ill-drained paddy, only the top soil was oxidized in autumn and in spring, because of the groundwater.

Fig. 30 shows the exchange of redox potential during cultivation period. As is evident from this graph, redox potential of high yield paddy was higher than that of low yield paddy at each growing stage.

EXCHANGES OF REDOX POTENTIAL DURING CULTIVATION PERIOD (FIG. 30)

(IN JAPAN, 1971)

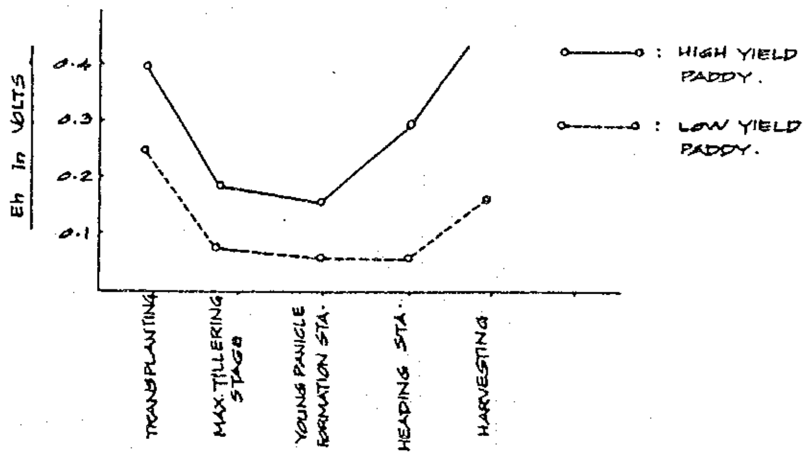
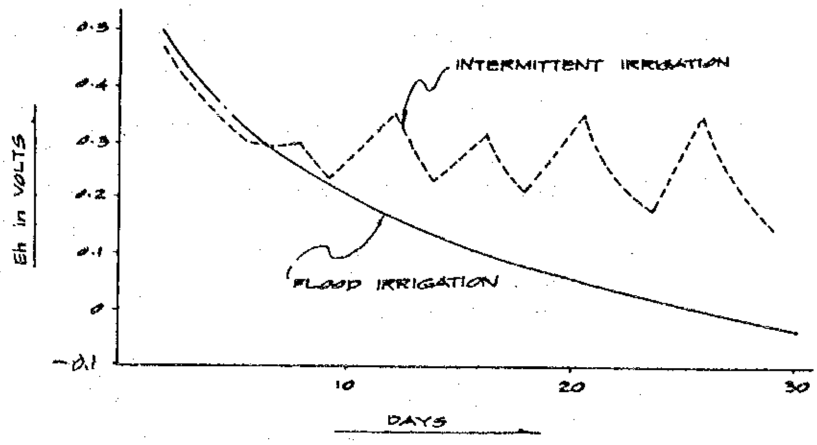


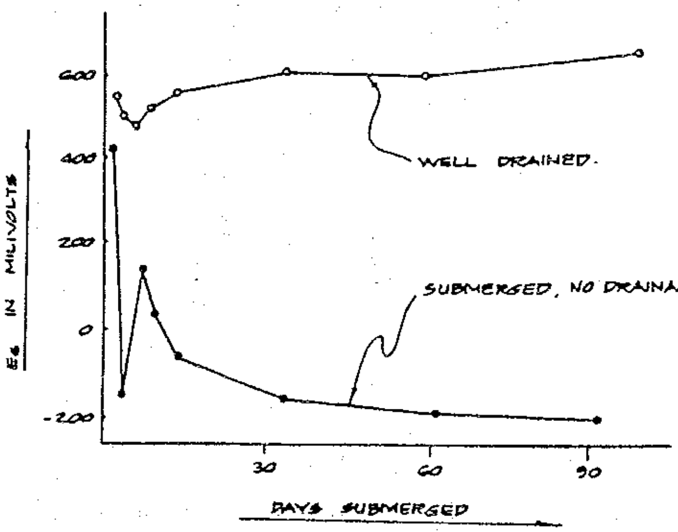
Fig. 31 shows the exchange of redox potential under different water management. In the case of intermittent irrigation, redox potential was fluctuating between reduction zone and weakly oxidized zone, but under the condition of flood irrigation, it was gradually reduced as shown by real line.

EXCHANGES OF REDOX POTENTIAL UNDER DIFFERENT WATER MANAGEMENT (FIG. 31)

(DEI, 1972)



CHANGES IN REDOX POTENTIAL (Eh) OF WELL DRAINED AND SUBMERGED SOIL WITH TIME (FROM: PONNAMPERUMA 1963)



E6 : REPRESENTS AND OXIDATION-REDUCTION POTENTIAL MEASUREMENT AT PH6.

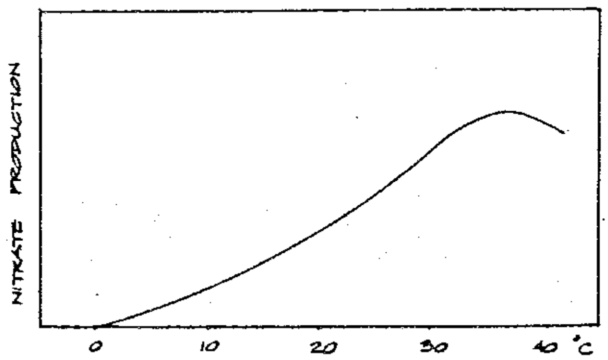
In colclusion, physicochemical condition of paddy soil is closely related to on-farm water management and redox potential is one of the most important indicator for judging its condition. At the same time high yield paddy is subject to appropriate percolation.

4-1-7. Soil temperature

According to the physiological studies on the inter-relationships between water, soil temperature and rice plant, the optimum temperature for plant growth is 30-32°C. This has been further confirmed by investigation on the photoplasmic streaming in the root-hair of rice crops in relation to temperature. Velocity of photo-plasmic streaming is at a maximum at 33°C and becomes zero at 40-45°C. Optimum temperature obviously varies with rice varieties. The critical temperature for varieties grown in tropical districts is higher than those in cool zone. (From "Irrigation in Japan").

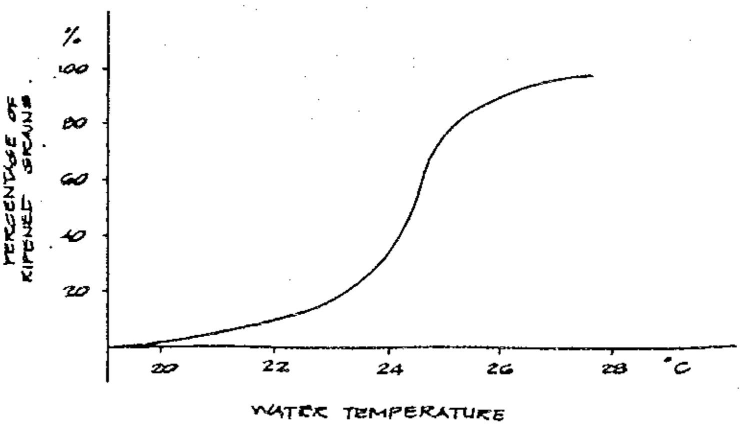
THE RELATION OF SOIL TEMPERATURE TO NITRATE PRODUCTION (FIG. 32)

(THOMPSON AND TROEH)

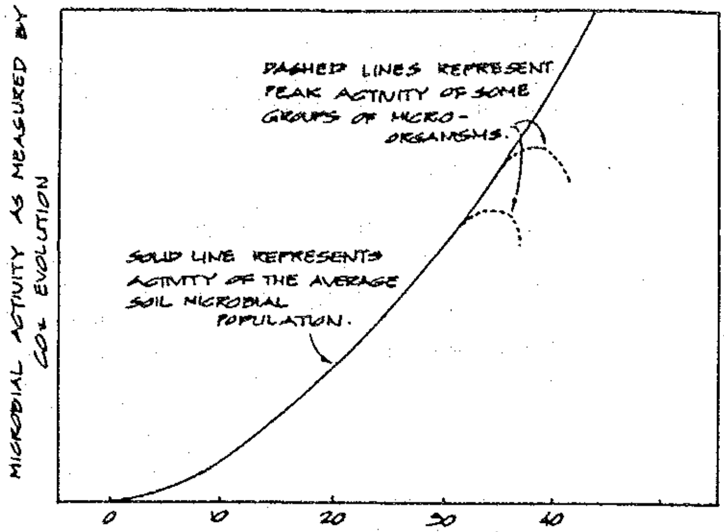


THE RELATION OF WATER TEMPERATURE TO RIPENING (FIG. 33)

(ONE EXAMPLE, IN JAPAN)



A SCHEMATIC DIAGRAM SHOWING THE RELATION OF CO_2 EVOLUTION TO SOIL TEMPERATURE (FIG. 34)

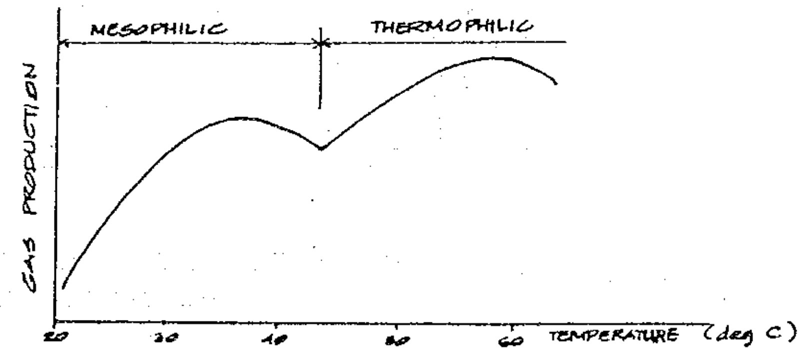


Note: * The peak in the biological range is about 50°C.

* CO_2 evolution continues to increase to a peak at about 70°C (Thompson, 1950), but the decomposition is probably more chemical than biological at temperature above 50°C.

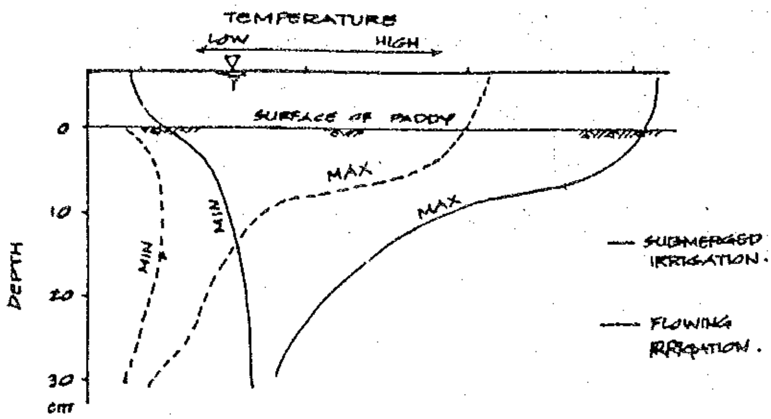
(THOMPSON AND TROEH)

GAS PRODUCTION BY ANAEROBIC OXIDATION AND TEMPERATURE (FIG. 35)



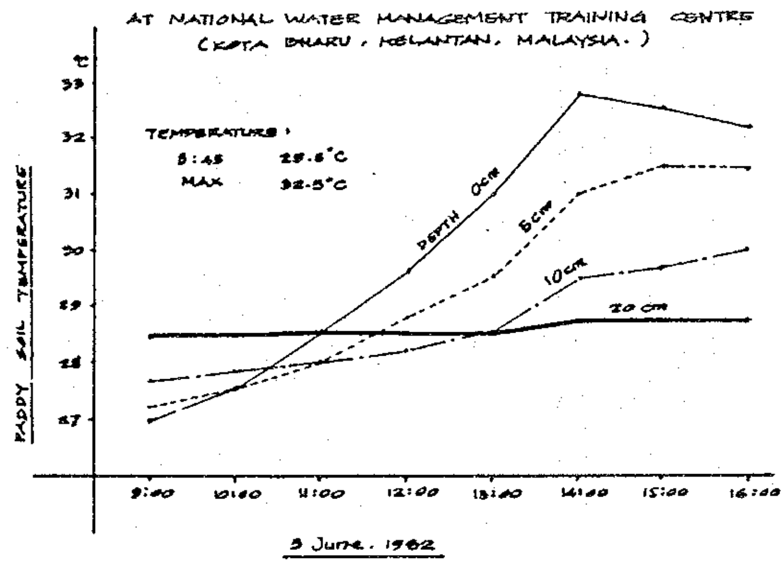
(SOURCE : PRINCIPLES OF WATER QUALITY CONTROL, T.H.Y. TEBBUTT.)

EFFECT ON WATER/SOIL TEMPERATURE BY
DIFFERENT IRRIGATION METHOD (FIG. 36)



DAILY CHANGES IN TEMPERATURE (FIG. 37)

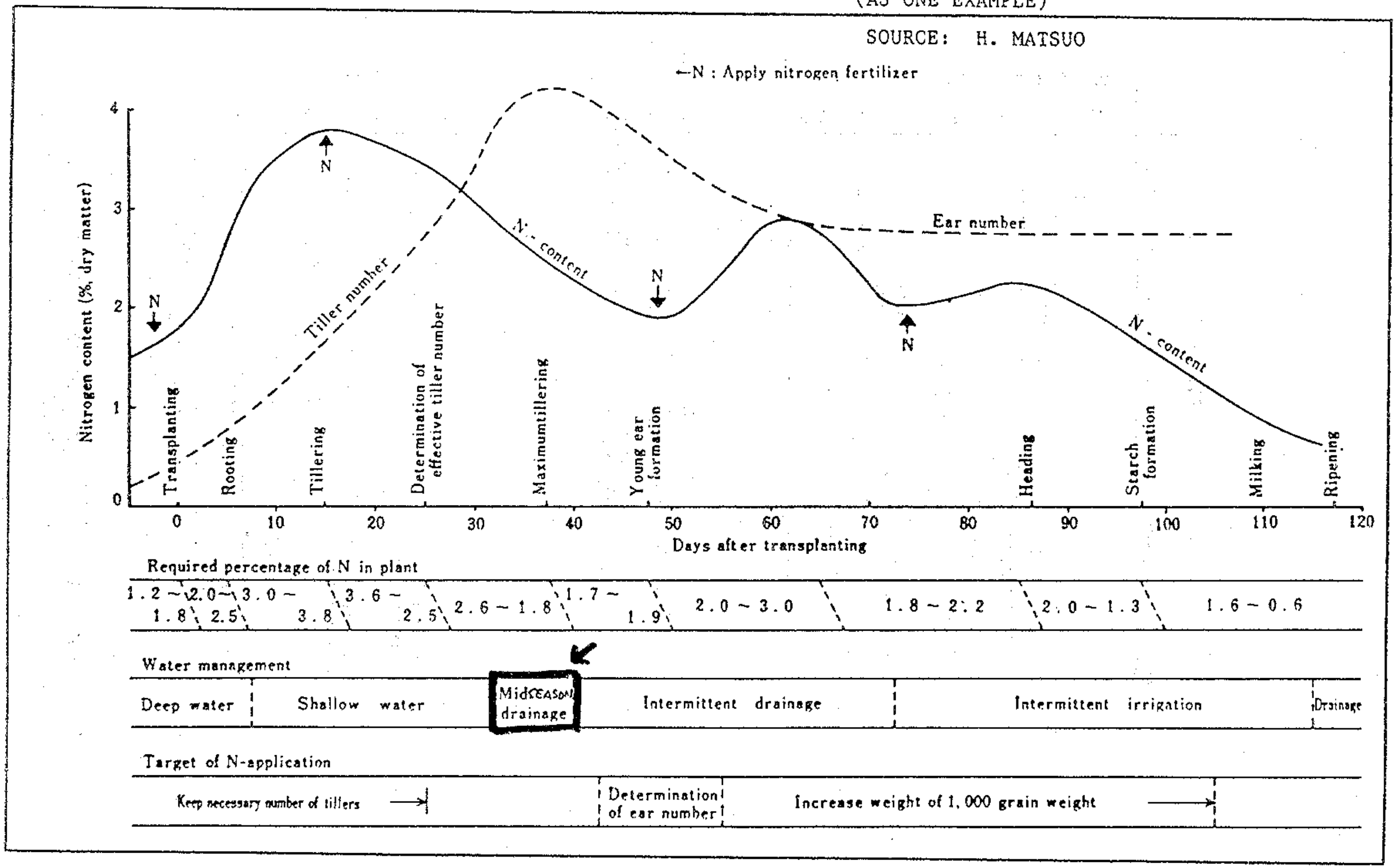
AT NATIONAL WATER MANAGEMENT TRAINING CENTRE
(KOTA BHARU, KELANTAN, MALAYSIA)



Nitrogen Content and Rice Growth and other Management Techniques (saga Exp. Sta.) (F(G. 38)

(AS ONE EXAMPLE)

SOURCE: H. MATSUO



4-1-8. Mid season drainage ("NAKABOSHI")

Mid-season drainage is carried out 30-40 days after transplanting.

Mid-season drainage has disadvantages as well as advantages, therefore, if the soil nutrient is not enough, this practise may be not successful.

(Disadvantages)

(1) To wash away available component.

(2) To require much labour.

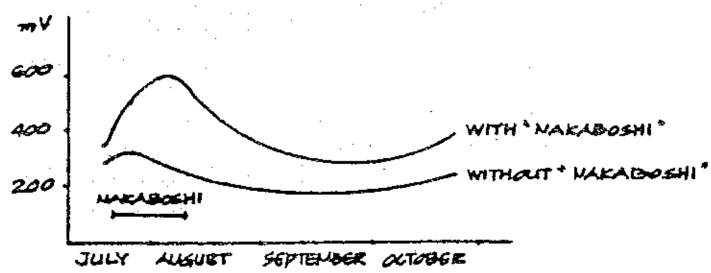
(3) Sometimes, it requires additional irrigation water.

(4) Generally, it requires on-farm water management facilities.

(5) Generally, it requires group water management.

(Advantages)

(1) To supply oxygen to root zone:



CHANGE OF OXIDATION-REDUCTION POTENTIAL BY "NAKABOSHI"

(2) To control non-effective tillers and to increase the ratio of effective tillers.

(3) To wash away toxic/detrimental substance from the root zone and to increase the absorbtion power of nutrients.

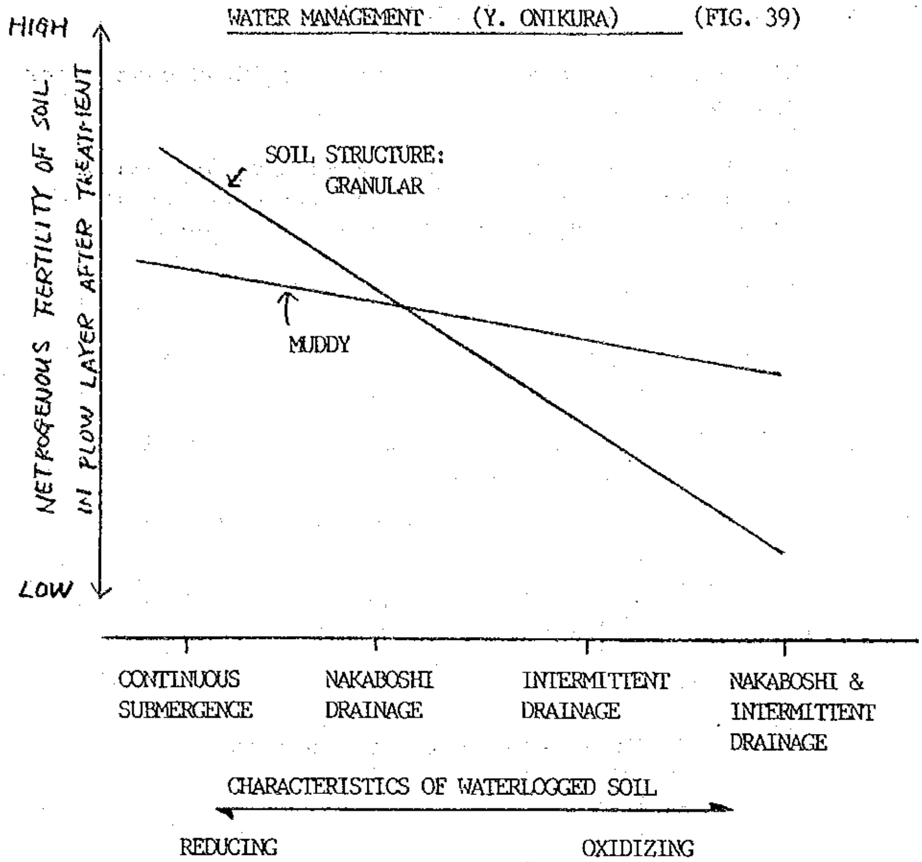
(4) To normalize the nitrogen concentration of the rice plant just before young panicle formation stage and to facilitate the application of top dressing.

(5) To set up straight rice plants and to increase light receiving coefficient.

(6) To prevent the rice from lodging and to facilitate cultivation work.

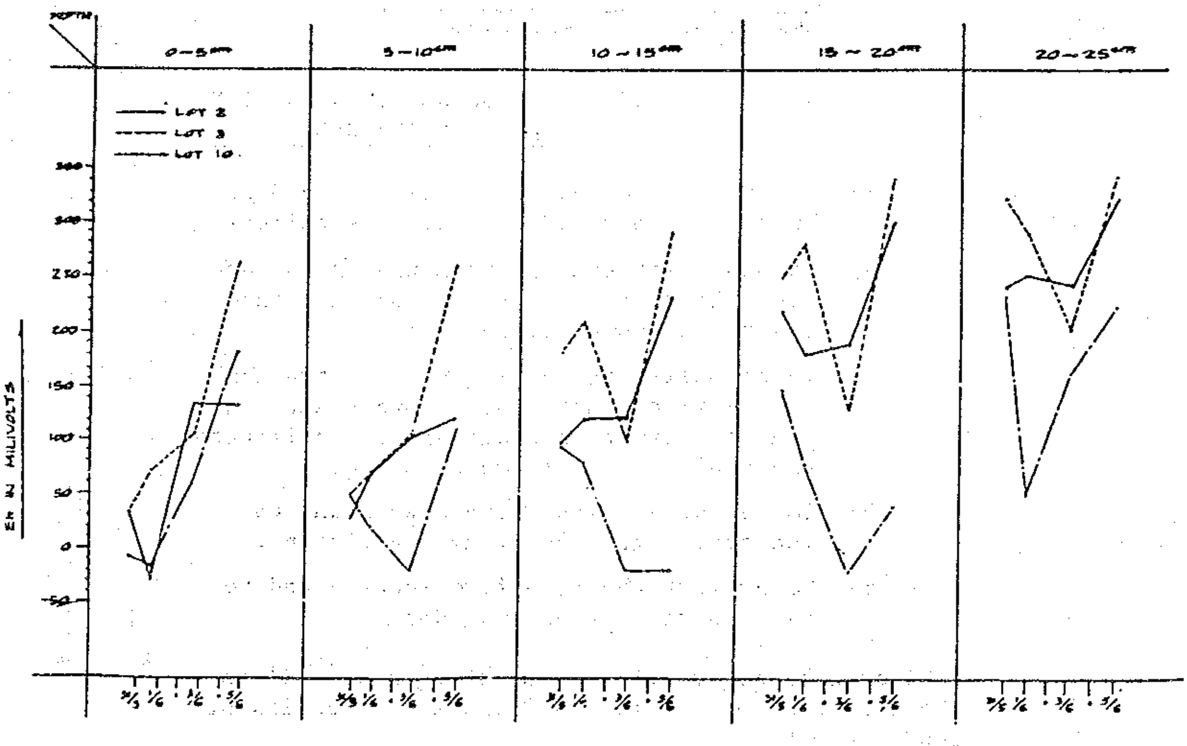
Schematic presentation for the changes of soil is as shown in Fig. 39. Fig. 40-42 shows the results of study in D/F.

SCHEMATIC PRESENTATION FOR THE CHANGES OF SOIL NITROGENOUS FERTILITY AFTER WATER MANAGEMENT (Y. ONIKURA) (FIG. 39)



CHANGES IN ODIXATION REDUCTION POTENTIAL WITH TIME AFTER "NAKABOSHI" (FIG. 40)

(NATIONAL WATER MANAGEMENT TRAINING CENTRE, KOTA BHARU, KELANTAN, MALAYSIA 1982)

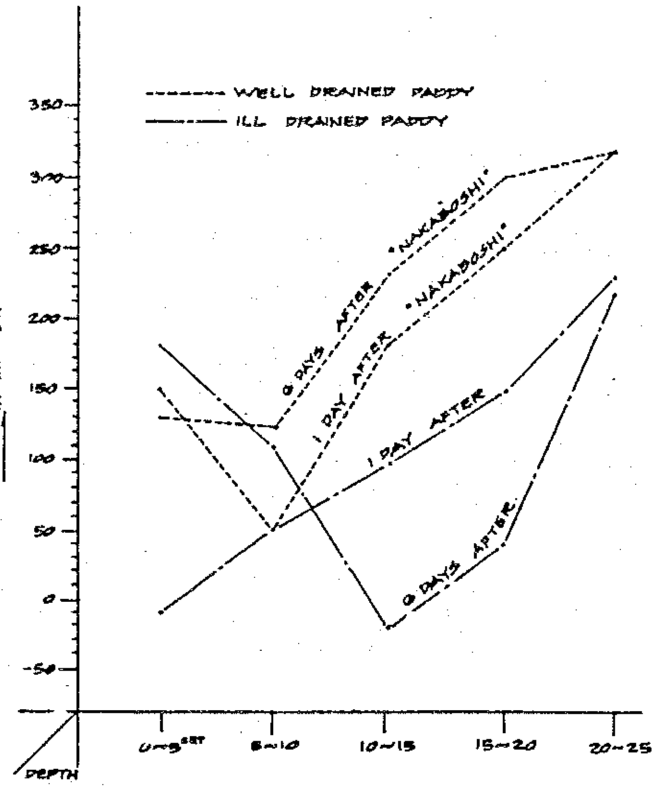


NOTE:

(1) LOT 2: UNDERDRAIN IS INSTALLED INTERVAL OF DRAINAGE IS 8m.
(2) LOT 3: UNDERDRAIN IS INSTALLED INTERVAL OF DRAINAGE IS 5m.
(3) LOT 10: WITHOUT UNDERDRAIN
(4) "NAKABOSHI" STARTED ON 30th. MAY.
(5) 1/643mm RAINFALL.

CHANGES IN REDOX POTENTIAL OF WELL DRAINED AND ILL DRAINED SOIL WITH TIME AFTER 'NAKABOSHI' (FIG. 41)

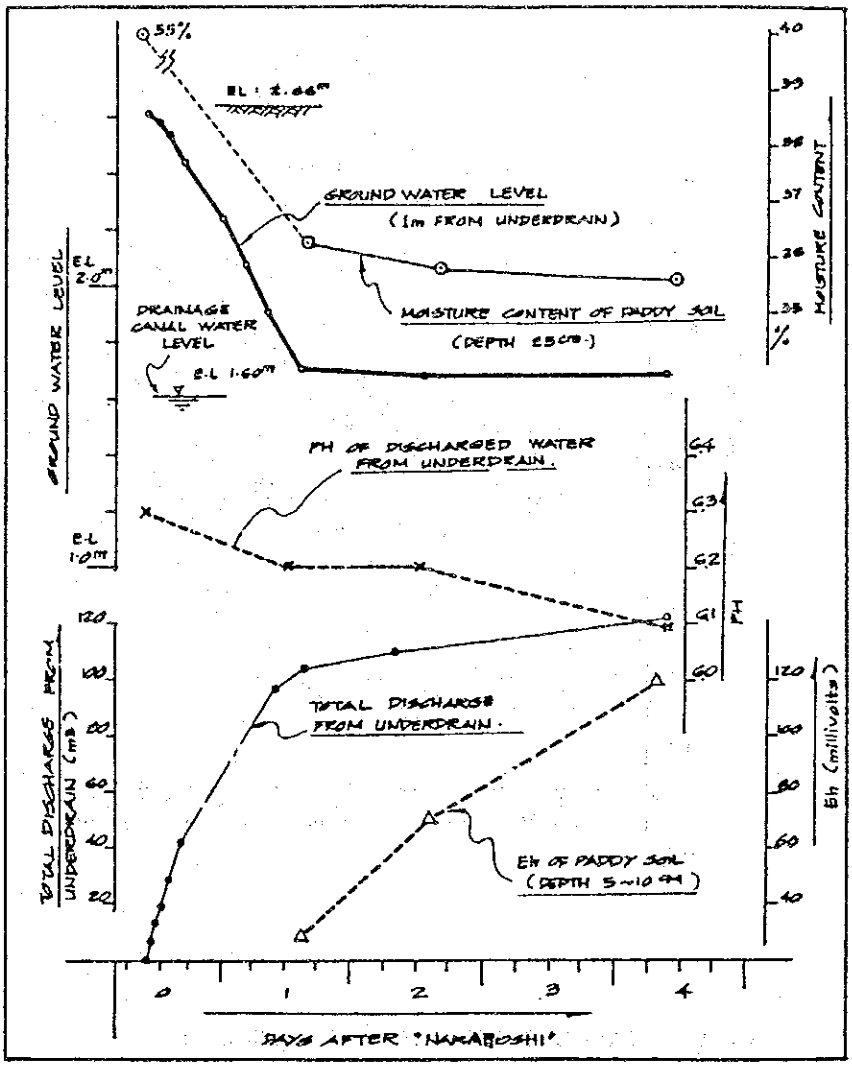
(NATIONAL WATER MANAGEMENT TRAINING CENTRE, KOTA BHARU)



(NOTE: 2 DAYS AFTER "NAKABOSHI", IT RAINED 43mm)

1982 OFF SEASON
(LOT 2)

(NATIONAL WATER MANAGEMENT
TRAINING CENTRE, KOTA BHARU)

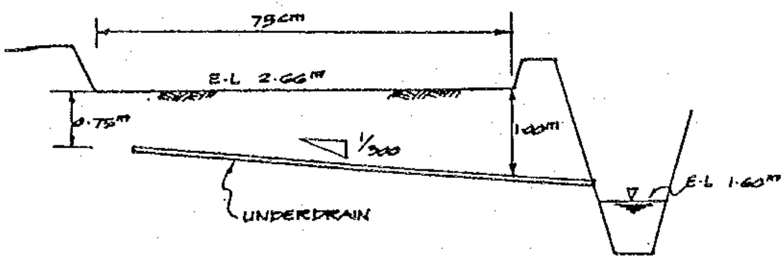


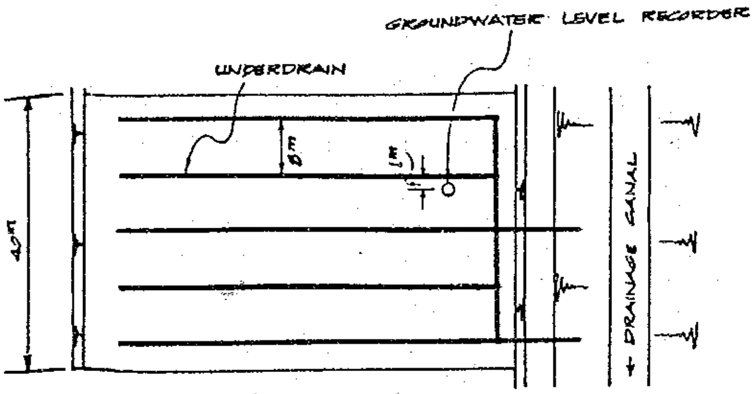
NOTE:

(1) UNDERDRAIN IS INSTALLED IN LOT 2:

(2) SOIL CONDITION:

- SANDY CLAYEY SILT (0 – 2.5m)
- γw = 1.80 kg/m^3 (0.3 – 0.9m)
- Gs = 2.68 (0.6 – 0.9m)





According to Dr. Sugimoto, effect of mid-season drainage on grain yield is as follows;

EFFECT OF MID-SEASON DRAINAGE ON GRAIN YIELD

VARIETY: IR8, MALAYSIA
(SUGIMOTO, 1979)

TREATMENT	NO. OF PANICLE PER m^2	NO. OF SPIKE-LETS PER m^2	WT. OF 1000 GRAINS	GRAINS YIELD	INDEX	
1. FLOOD IRRIGATION NON F.	213	2.0×10^4	28.3 g	2.76 t/ha	100%	100
2. " FERTILIZED	290	2.7	29.4	4.80	174	
3. 6 DAYS DRAIN NON F.	224	1.8	28.5	2.58	94	92
4. " FERTILIZED	288	2.6	29.3	4.42	161	
5. 12 DAYS DRAIN NON F.	213	2.0	28.8	2.99	109	109
6. " FERTILIZED	314	2.6	30.0	5.22	189	
7. 18 DAYS DRAIN NON F.	238	2.0	29.3	3.22	117	98
8. " FERTILIZED	318	2.7	29.5	4.73	172	
9. INTERMITTENT IRRI. NON F	221	2.1	28.3	2.70	98	99
10. " FERTILIZED	301	2.7	29.3	4.74	172	

(1) Mid-season drainage and intermittent irrigation clearly help to save irrigation water but their effect on yield increase may be up to about 10%. (There are many experimental results which shows no effects from them).

(2) Mid-season drainage and intermittent irrigation have two effect, that is, on the one hand. Both help to lighten the soil from heavy reduced conditions by means of drying, but on the other, both may cause loss of soil nutrients by denitrification.

(3) Both are promising technologies for high-yield varieties which have the weak point of susceptibility to root rot under worse condition.

(4) Both may help the soil giving durability for introduction of harvester or combine.

(5) In alluvial plain paddy fields, however, drainage is difficult in individual fields and large scale drainage facility covering a wide area is essential to adequate drainage.

4-1-9. Basic data for paddy soil study.

(1) WATER QUALITY OF RIVER. (WEST MALAYSIA):

(ANNUAL AVERAGE DATA, CITED FROM KOBAYASHI)

RIVER	SAMPLING SITES	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SiO_2	PH
		mg/l								
KELANTAN	PASIR MAS (KELANTAN)	4.7	0.8	2.8	1.3	26.4	1.1	0.1	16.2	6.7
TRENGGANU	KUALA TRENGGANU (TRENGGANU)	2.6	0.4	3.4	1.2	15.6	1.3	2.0	13.3	6.4
PAHANG TUA	PEKAN (PAHANG)	4.1	0.7	2.9	1.6	22.8	1.6	0	14.8	6.3
KESANG	MUAR (JOHOR)	9.9	7.1	11.4	4.5	6.1	102.8	16.5	14.8	4.4
TENGI	KUALA SELANGOR (SELANGOR)	1.2	0.2	2.3	1.1	0.7	2.7	2.3	5.3	4.3
MUDA	PINANG TUNGGAL (PENANG)	3.6	0.6	1.9	2.1	19.6	1.8	0.1	13.7	6.0
PADANG TERAP	PADANG TERAP (KEDAH)	4.3	0.9	2.2	1.9	21.2	1.7	1.7	13.0	6.1

(2) MEAN TOTAL CHEMICAL COMPOSITION (IN PERCENT)

COUNTRY	NO. OF SAMPLES	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	MnO_2	TiO_2	K_2O	P_2O_5
MALAYSIA	41	74.22	2.97	18.94	0.14	0.51	0.03	1.03	2.02	0.14
TROPICAL ASIA	410	72.16	5.94	16.34	1.42	0.92	0.12	1.14	1.33	0.13
(JAPAN)	155	71.77	6.00	16.26	1.86	0.75	0.13	0.88	2.14	0.22

(3) MEANS, STANDARD DEVIATION, MINIMUM AND MAXIMUM VALUES OF PADDY SOIL COMPONENTS IN WEST MALAYSIA

(NO. OF SAMPLES : 41)

	MEAN	STANDARD DEVIATION	MIN	MAX.	NOTE
PH	4.7	0.5	3.4	6.1	
TOTAL ORGANIC CARBON	3.36	2.53	0.60	11.40	AS PERCENTAGE OF AIR-DRY SOIL
TOTAL NITROGEN	0.28	0.21	0.05	0.92	"
CARBON/ NITROGEN RATIO	11.8	2.3	9.2	19.8	
AMMONIACAL NITROGEN PRODUCTION	14.9	9.9	3.8	40.3	IN Mg NH_3-N/100g AIR-DRY SOIL
TOTAL PHOSPHORUS	80.3	42.8	5.0	206.0	IN Mg P_2O_5/100g AIR-DRY SOIL
AVAILABLE PHOSPHORUS	3.7	4.2	0.3	20.0	"
CATION EX-CHANGE CAPA-CITY (CEC.)	15.9	8.6	2.9	33.2	IN ME/100 g AIR-DRY SOIL
EXCHANGEABLE CALCIUM	3.9	3.4	0.1	12.3	"
EXCHANGEABLE MAGNESIUM	5.2	6.4	0.4	28.7	"
AVAILABLE SILICA	10.4	10.0	1.0	53.5	IN Mg SiO_2/100 g AIR-DRY SOIL

SOURCE:- PADDY SOILS IN TROPICAL ASIA -

(4) CLASSIFICATION OF NUTRITIONAL DISORDERS IN ASIA

FROM TANAKA AND YOSHIDA (1970)

SOIL	SOIL CONDITION	DISORDER	LOCAL NAME
VERY LOW PH	(ACID SULFACE SOIL).	. IRON TOXICITY	BRONZING
LOW PH: HIGH IN ACTIVE IRON	LOW IN ORGANIC MATTER	. PHOSPHORUS DEFICIENCY	
	HIGH IN ORGANIC MATTER	. PHOSPHORUS DEFICIENCY COMBINED WITH IRON TOXICITY	
	HIGH IN IODINE	. IODINE TOXICITY COMBINED WITH PHOSPHORUS DEFICIENCY	AKAGARE TYPE III
	HIGH IN MANGANESE	. MANGANESE TOXICITY	
LOW PH: LOW IN ACTIVE IRON AND EXCHANGE-ABLE CATIONS	LOW IN POTASSIUM	. IRON TOXICITY INTERACTED WITH POTASSIUM DEFICIENCY	BRONZING AKAGARE TYPE I
	LOW IN BASES AND SILICA WITH SULFATE APPLICATION	. IMBALANCE OF NUTRIENTS ASSOCIATED WITH HYDROGEN SULFIDE TOXICITY	AKIOCHI
HIGH PH	HIGH IN CALCIUM	. PHOSPHORUS DEFICIENCY . IRON DEFICIENCY . ZINC DEFICIENCY	KHAIRA HADDA TAYA-TAYA AKAGARE TYPE II
	HIGH IN CALCIUM AND LOW IN POTASSIUM	. POTASSIUM DEFICIENCY ASSOCIATED WITH HIGH CALCIUM	
	HIGH IN SODIUM	. SALINITY PROBLEM . IRON DEFICIENCY . BORON TOXICITY (PROBABLY RARE)	

(5)

SUCCESSIVE PROCESSES OF MICROBIAL METABOLISM IN WATERLOGGED SOIL

(TAKAI, 1961)

DAYS AFTER WATERLOGGED	CHEMICAL TRANSFORMATION	RANGE OF Eh (VOLT)	ENERGY YIELDING METABOLISM	AMMONIUM FORMATION	CO_2 FORMATION	ORGANIC ACIDS FORMATION	STEP OF ORGANIC MATTER DE-COMPOSITION
EARLY	CONSUMPTION OF MOLECULAR OXYGEN	+0.5—+0.3	OXYGEN RESPIRATION	ACTIVELY PROCEED	ACTIVELY PROCEED	PRINCIPALLY NOT BE ACCUMULATED (BUT IN CASES OF DEGRADED SOILS OF OVER-DOSE OF GREEN MANURE, ACIDS ARE ACCUMULATED)	FIRST STEP:
	CONSUMPTION OF NITRATE	+0.4—+0.1	NITRATE REDUCTION				
	Mn^{2+} FORMATION	+0.4— -0.1	MANGANESE REDUCTION				
	Fe^{2+} FORMATION	(pH 6–7) +0.2— -0.2	IRON REDUCTION				
	SULPHIDE FORMATION	0 — -0.2	SULPHATE REDUCTION	SLOWLY PROCEED	SLOWLY PROCEED OR LITTLE DECREASE	MARKEDLY ACCUMULATED	SECOND STEP: ANAEROBIC PROCESS
	HYDROGEN FORMATION	-0.2— -0.42	FERMENTATION			OBVIOUSLY DECREASE IN ACCUMULATION WITH METHANE FERMENTATION	
LATE	METHANE FORMATION	-0.2— -0.3	METHANE FERMENTATION				

(b) CHARACTERIZATION OF WATERLOGGED SOIL

STATE OF REDUCTION	Eh	CHARACTERRISTICS OF WATERLOGGED SOIL
OXIDIZING CONDITIONS	(VOLT) 0.3	OXIDIZING ABILITY OF SOIL IS RELATIVELY HIGH. N AND P ARE LESS AVAILABLE N LIABLE TO BE LOST
ADEQUATE REDUCING CONDITIONS	0.3 - 0.05	ORGANIC MATTER IS DECOMPOSED BY SEMI-ANAEROBIC AND ANAEROBIC METABOLISM OF BACTERIA. STAGE OF IRON REDUCTION. THE BENEFECIAL CONDITION OF THE WATERLOGGED ENVIRONMENT. N AND P ARE MUCH AVAILABLE
EXTREME REDUCING CONDITIONS	-0.05	ORGANIC MATTER IS DECOMPOSED BY ANAEROBIC METABOLISM OF BACTERIA. STAGE OF SULFATE REDUCTION. THE CONCENTRATION OF REDUCED SUBSTANCES IN SOIL SOLUTION LIABLE TO BECOME TOO GREAT FOR THE RICE ROOTS.

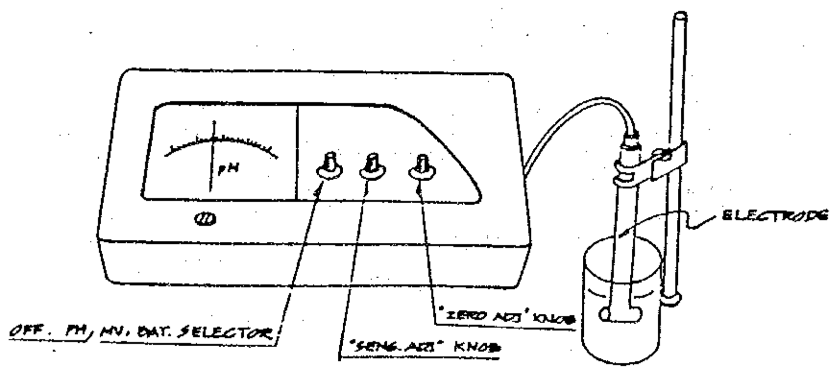
(Y. ONIKURA)

4-2. Measurement instruments of physicochemical condition

4-2-1. Ph meter (Model HM-7B)

<u>PH METER MODEL HM-7B:</u>

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

MEASURING RANGE	pH 0 – pH14, 0 – ± 700 mV
	0 – ± 1.400 mV BY DISPLACING ZERO
MINIMUM GRADUATION	0.1 pH, 10mV
ACCURACY	pH: ± 0.03 pH, ORP: ± 10mV
TEMPERATURE COMPENSATION	0 – + 100°C AUTOMATICALLY
OUTPUT	VOLTAGE 5mV/pH
POWER SOURCE	AC 220V, 50, $60H_2$ (0.6VA)
	DC UM-3 (3 PCS)
DIMENSIONS	APPROX. 310(w)x110(h)x180(d) mm
WEIGHT	APPROX. 2 kgs.

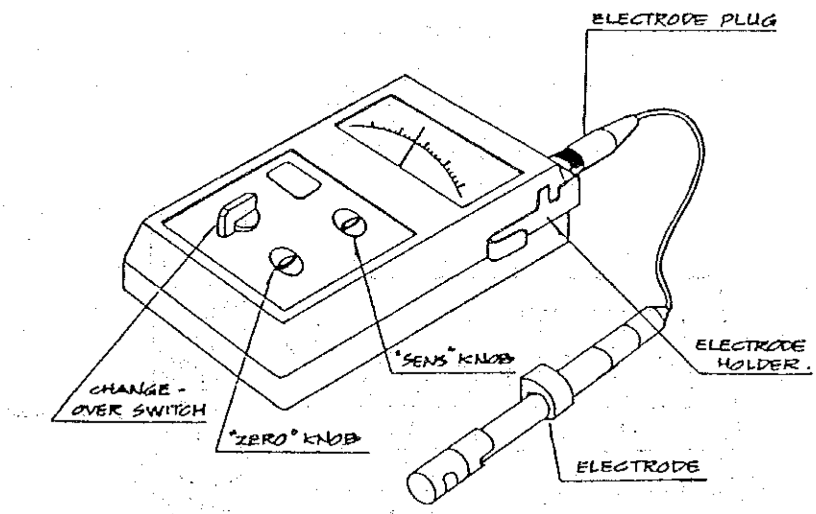
(3) OPERATION MANUAL

SEE: PAGE 173

4-2-2. Ph meter (Model HM-1K)

PH METER MODEL HM-1K

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

MEASURING RANGE	0 – 14 pH
MINIMUM GRADUATION	0.2 pH
ACCURACY	±0.1 pH
TEMPERATURE COMPENSATION	0 – 100°C, AUTOMATICALLY
POWER SOURCE	DRY CELL 006P (DC 9V) 1 PCE.
DIMENSIONS	APPROX. 176 (d)x104 (w)x44(h) mm
WEIGHT	APPROX. 500 g

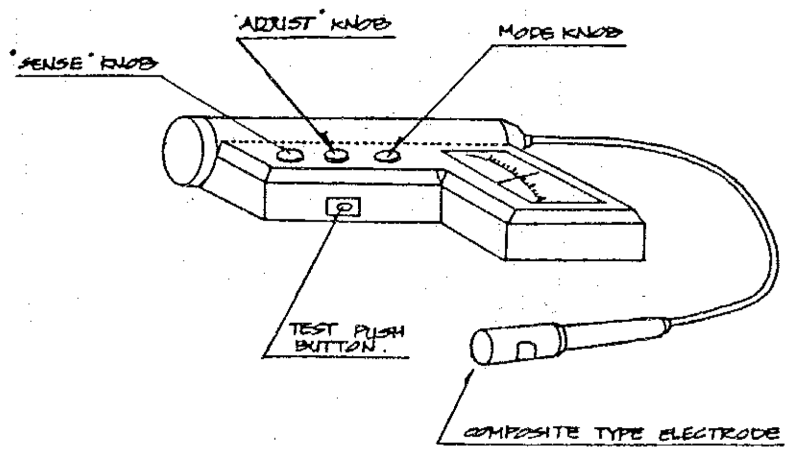
(3) OPERATION MANUAL:

SEE: PAGE 191

4-2-3. Ph meter (Model HM-1F)

PH METER MODEL HM-1F

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

MEASURING RANGE	1 - 13 pH
MINIMUM GRADUATIONS	0.2 pH
ACCURACY	± 0.1 pH
POWER SOURCE	DRY CELL 006P(DC9V) 1 PCE
DIMENSIONS	APPROX. 147(w)x179(d)x60(h)mm
WEIGHT	APPROX. 800 g

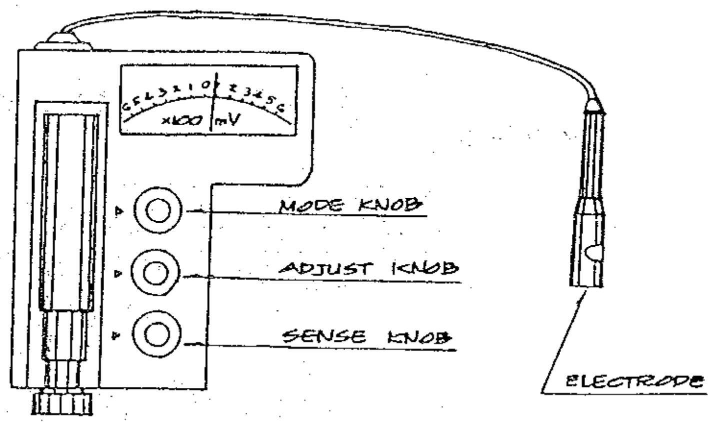
(3) OPERATION MANUAL:

SEE: PAGE 208

4-2-4. Redox potential meter (Model RM-1F)

REDOX POTENTIAL METER MODEL RM-1F:

(1) ILLUSTRATION (APPEARANCE IS SAME AS PH METER MODEL HM-1F)



(2) SPECIFICATIONS:

MEASURING RANGE	-600 mV – +600 mV
ACCURACY	± 3%
INDICATOR	FULL SCALE 70 mm (ARC LENGTH)
MINIMUM GRADUATION	20 mV
POWER SOURCE	DRY CELL 006P (DC9V) 1 PCE
DIMENSIONS	APPROX. 179(w)x60(h)x147(D) mm

(3) OPERATION MANUAL:

SEE: PAGE 224

5. On-farm water management effect on paddy soil physical condition.

5-1. Physical condition and trafficability

In order to introduce farm machine, paddy soil should have enough bearing capacity at the requested time in accordance with the type of machine. This bearing capacity is subject to paddy soil physical condition.

Generally, trafficability depends on following factors;

(1)	Soil condition:	grading of soil, apparent-specific gravity, hardness, soil structure, moisture content, unevenness of soil surface, etc.
(2)	Machine condition:	weight of machine, types of running device (wheel or caterpillar), etc.
(3)	Working condition:	types of machine, driving speed, etc.
(4)	Technical condition:	driving skill of farmer, etc.

However, from the view point of engineering, our subject is to improve soil condition.

Evidently, the softness of paddy soil is in direct proportion to the increment of moisture. Similarly, trafficability of machine is in direct proportion to the softness of paddy. Accordingly, prompt drainage from the paddy is required to secure the trafficability at a requested time.

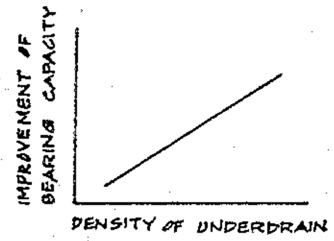
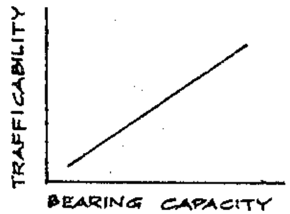
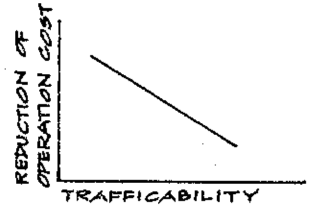
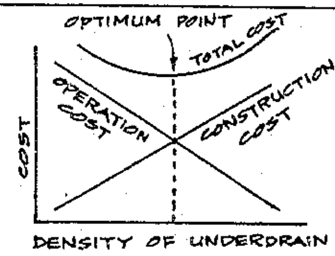
Trafficability is usually judged by bearing capacity measured by cone penetrometer. This method was developed by U.S. Army Corps of Engineers, Waterways Experimental Station (WES), for combat car.

Using the cone penetrometer, bearing capacity is described as kg/cm^2.

There are 4 steps to study by relationship between paddy field drainage capacity and trafficability. (Fig. 42)

GENERAL PROCEDURE TO STUDY THE RELATIONSHIP BETWEEN UNDERDRAIN AND TRAFFICABILITY.

(FIG. 42)

	1st. STEP	2nd. STEP	3rd. STEP	FINAL STEP
GRAPHS OBTAINED FROM EACH STEP				
NECESSARY STUDY, SURVEY OR MEASUREMENT ⇨	(1) FARM CONDITIONS: (WITH OR WITHOUT UNDER-DRAIN, DENSITY OF UNDER-DRAIN.) (2) DESIGN OF UNDERDRAIN. (3) IRRIGATION METHOD AND CULTIVATION METHOD. (4) BEARING CAPACITY OF PADDY SOIL. (5) GROUND WATER-LEVEL. (6) PHYSICAL CHARACTERISTICS OF SOILS.	(1) RELATIONSHIP BETWEEN BEARING CAPACITY AND TRAFFICABILITY OF FARM MACHINES, SUCH AS TRACTOR, ROTARY, RICE PLANTER, WEED HARROW, HARVESTER, COMBINE, ETC. (2) AVERAGE FIELD LEVELS AND THEIR STANDARD DEVIATIONS IN CM.	(1) OPERATION COSTS OF FARM MACHINES. (2) THE RATIO OF HIRED LABOUR AND FAMILY LABOUR. (3) LABOUR COST. (4) OPERATION HOUR OF FARM MACHINE DURING EACH CULTIVATION WORK (LAND PREPARATION, TRANS-PLANTING, HARVESTING, ETC.) (5) OPERATION HOUR AT EACH TRAFFICABILITY.	(1) OTHER RELATED STUDIES SUCH AS THE INCREASING OF LAND PRODUCTIVITY THROUGH UNDERDRAIN. (2) CONSTRUCTION COST OF UNDERDRAIN. (3) MAINTENANCE COST OF UNDERDRAIN.

First step is to study the relationship between paddy field drainage capacity and bearing capacity. As easily understand, the more the capacity of drainage system, the easier to get enough bearing capacity at a requested time.

Second step is to study the relationship between bearing capacity and trafficability. As mentioned before, trafficability depends on the weight of machine, types of running devices and so on. Therefore, the performance of the machine will be regarded as a given condition from the engineering aspect of view.

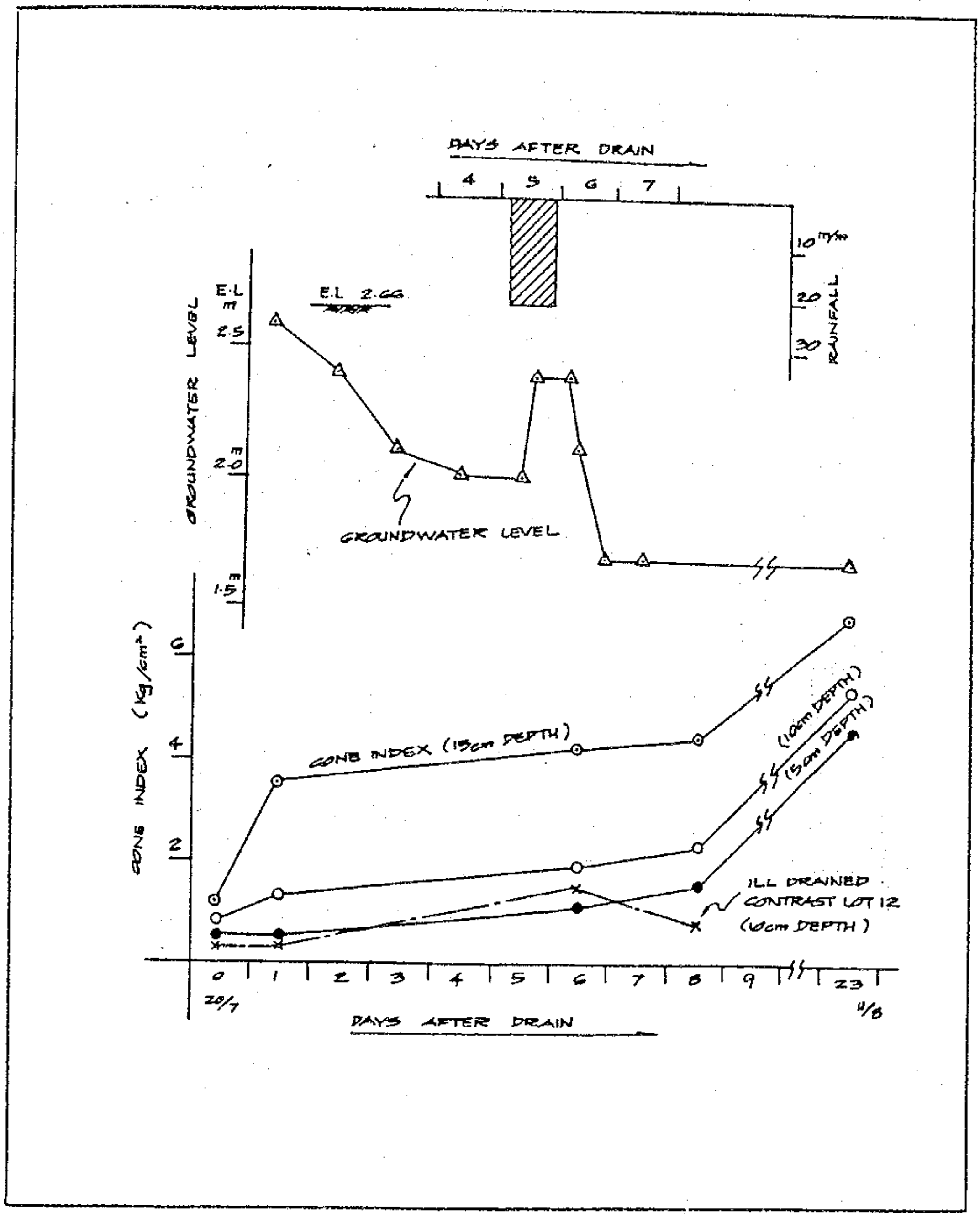
3rd. step is to study the relationship between trafficability and reduction of operation cost. The life of drainage facility is usually more than ten years, whereas the operation costs changes with time. Accordingly, carefull economical study is required at this stage.

Finally, we can get a graph which shows the relationship between density (capacity) of drainage facilities and total costs including operation cost and construction cost of facilities.

Fig. 43 & 44 shows some results studied in D/F.

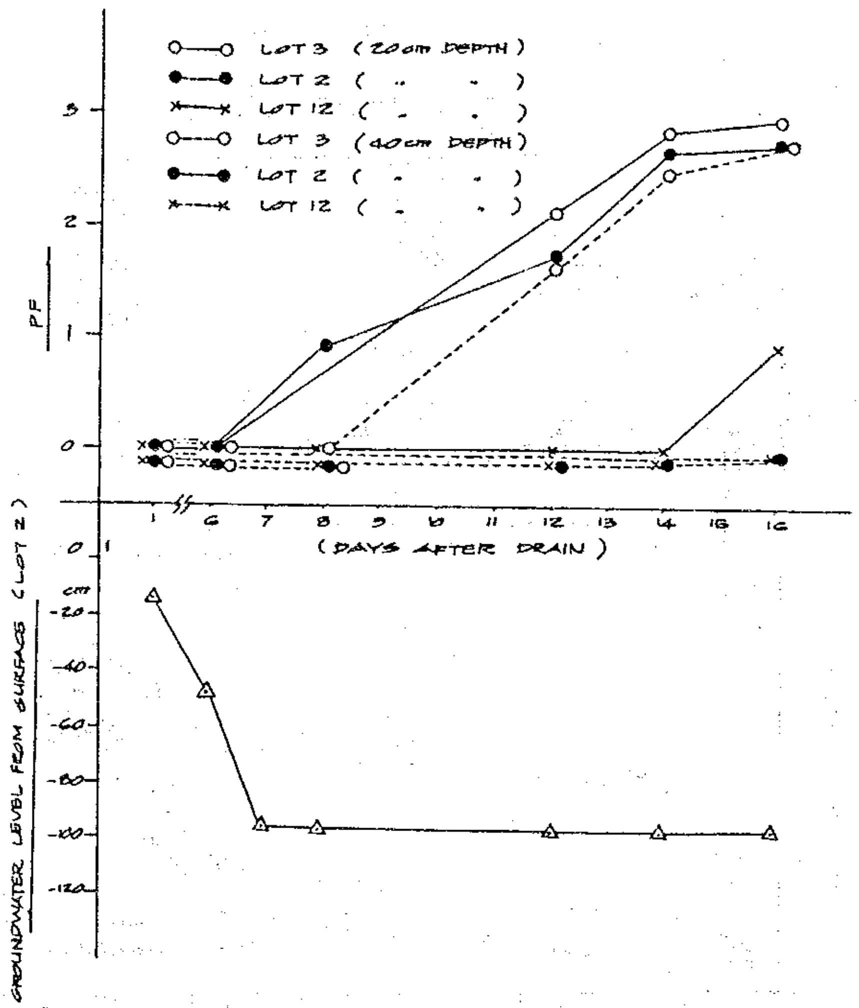
CHANGES IN CONE INDEX WITH TIME AFTER DRAIN (FIG. 43)

(NATIONAL WATER MANAGEMENT TRAINING CENTRE
D/F LOT.2 1982 OFF SEASON)



CHANGES IN PF WITH TIME AFTER DRAIN (FIG. 44)

(N.W.M.T.C. D/F LOT 2, 3, 12, 1982 OFF SEASON)

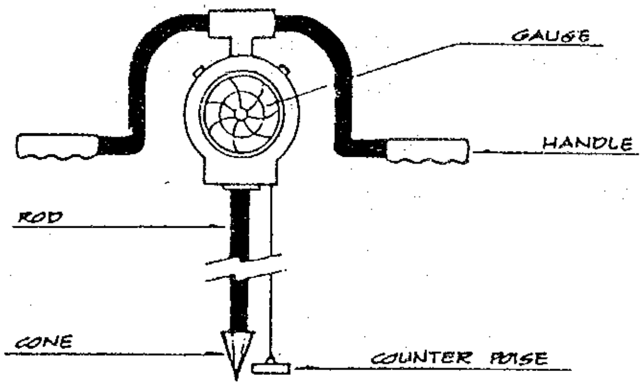


5-2. Measuring instruments of phusical condition

5-2-1. Bearing capacity (Self-recording cone penetrometer)

SELF-RECORDING CONE PENETROMETER:

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

MAXIMUM CAPACITY	100 kg.
RECORDING PAPER	CARBON-STAILESS PAPER
CONE BEARING CAPACITY	0 - 15 kg/cm^2 (IN CASE OF CONE AREA 6.45 cm^2)
	0 - 30 kg/cm^2 (IN CASE OF CONE AREA 3.23 cm^2)
MEASUREMENT DEPTH	0 - 100 cm, ONE GRADUATION 5 cm
CONE AREA	6.45 cm^2 AND 3.23 cm^2
CONE TOP ANGLE	30 DEGREE

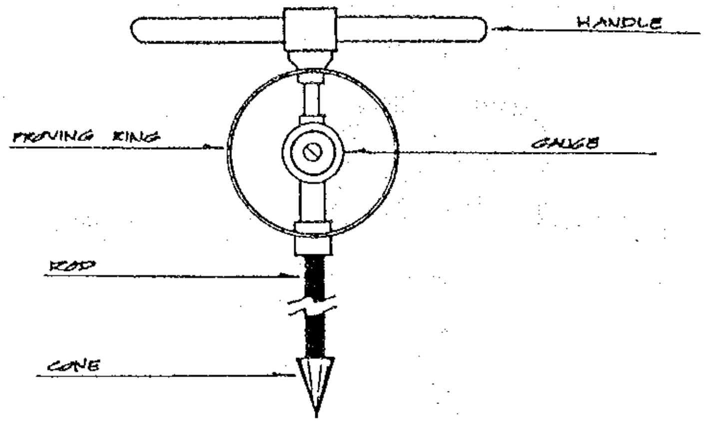
(3) OPERATION MANUAL:

SEE: PAGE 242

5-2-2. Bearing capacity (Cone penetrometer)

CONE PENETROMETER:

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

PROVING RING CAPACITY	100 kg
EXTENSION ROD	16 Ø x 500 mm, 10 PCS.
MEASUREMENT DEPTH	0 - 5 m
CONE AREA	6.45 cm^2 AND 3.23 cm^2
CONE TOP ANGLE	30 DEGREE

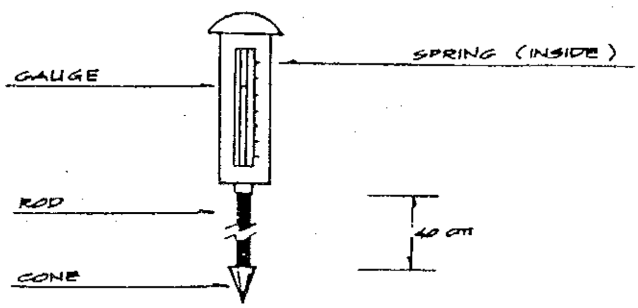
(3) OPERATION MANUAL:

SEE: PAGE 248

5-2-3. Bearing capacity (Soil resistance tester, SR-2)

SOIL RESISTANCE TESTER (SR-II)

(1) ILLUSTRATION:



(2) SPECIFICATION:

SPRING	25 & 50 Kg. (2 KINDS)
MEASURING DEPTH	400 mm
CONE AREA	CONE A : 2 cm^2 (TOP ANGLE 30^o)
	CONE B : 6 cm^2 (TOP ANGLE 30^o)

(3) PREDICTION OF TRAFFICABILITY:

INSTRUMENT	OPERATION	TRAFFICABILITY		
		EASY	POSSIBLE	IMPOSSIBLE
CONE INDEX (Kg/cm^2)	ROTARY TILLING	>5.0	2.5 - 5.0	< 2.5
	PLOWING	>6.5	4.0 - 6.5	< 4.5
	PLOWING (WITH GIRDLE)	>3.5	2.0 - 3.5	< 2.0

NOTE: CONE AREA 2 cm^2, MEAN VALUE IN 0 - 15 cm DEPTH.

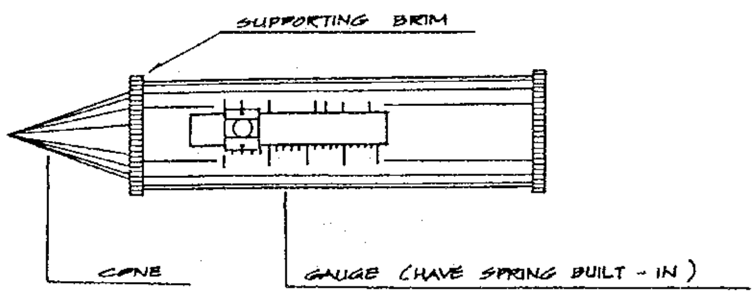
(4) OPERATION MANUAL:

SEE: PAGE 254

5-2-4. Soil hardness

SOIL HARDNESS TESTER

(1) ILLUSTRATION:



(2) SPECIFICATIONS:

HARDNESS INDEX RANGE	0 - 40 mm
GRADUATION	1 mm
BEARING CAPACITY RANGE	0 TO INFINITE Kg/cm^2
MAXIMUM LOAD	8 kg (TO 40 mm)
CONE SIZE	18 ∅ x 40 mm

(3) CALCULATION:

$$P = \frac{100X}{0.7952(40-X)^2}$$

WHERE:

P : BEARING CAPACITY

X : SHRINKAGE OF SPRING OR HARDNESS INDEX.

(4) OPERATION MANUAL:

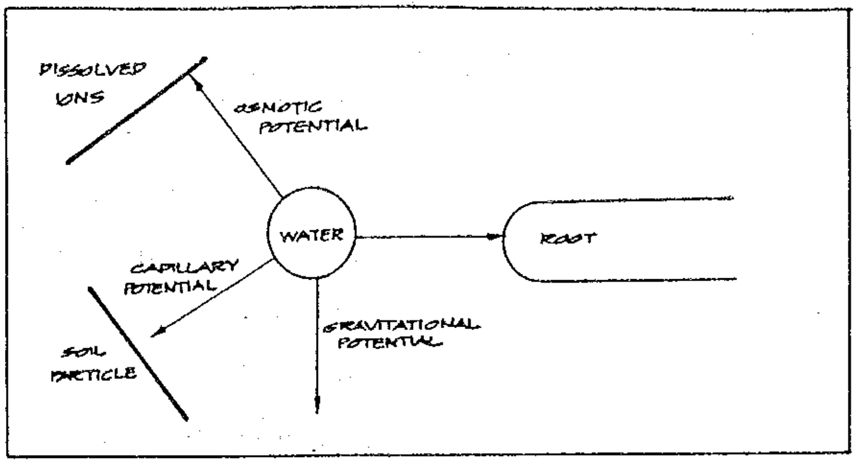
SEE: PAGE 265

5-2-5. Soil moisture

(1) SOIL MOISTURE:

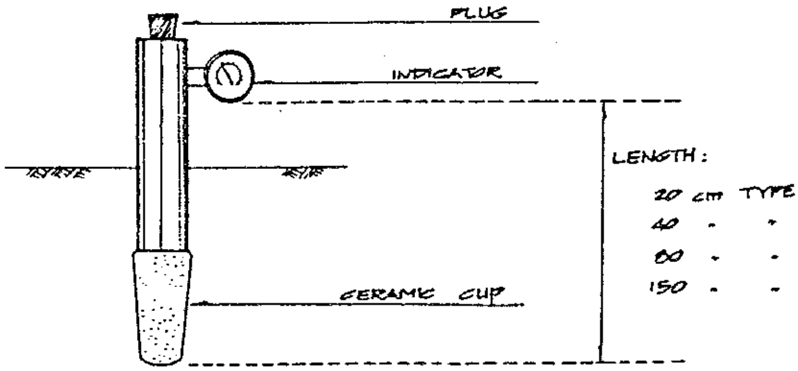
A SCHEMATIC ILLUSTRATION OF FORCES ACTING ON SOIL WATER

(THOMPSON & TROEH)



. THE SUM OF THE FORCES THE ROOT MUST OVERCOME TO ABSORB WATER IS CALLED THE SOIL MOISTURE POTENTIAL.

(2) ILLUSTRATION OF SOIL TENSIOMETER:



(3) SPECIFICATIONS:

MEASURING RANGE	:	0 - 76 cm Hg
GRADUATION	:	1 cm Hg
CERAMIC CUP	:	40 Ø x 100 m

(4) How to use:

(1) Remove the upper plug, then fill the cooled water which had been boiled before into the tube to drive the air out, then seal it tightly and leave it as it is.

(2) Indicator, at first will point to 0 of the gauge, however, as the water evaporates from the surface of the ceramic cup, the indicator rises gradually, and wait until the time when the indicator points to 35, then add the said water to fill the tube.

(3) Repeat this treatment, two or three times, then the air in the tube is completely driven out. Also every tiny crevice in the afore said cup is to be filled with water accordingly.

(4) Insert the meter into the soil.

(5) Detailed operation manual & conversion table.

See: Page 229

6. INTERIUM FINDINGS

6 - 1 INVESTIGATION OF OFF-SEASON, 1981

A. Investigations. (Off Season 1981)

1. Meteorological Data

See Table 3

2. Measurement of water consumption

See Table 4, 5, 6

devices	Objective
Stick gauge	To check water layer depth and measure of daily water consumption.
Ground water level recorder	i) To clarify the underdrainage work and its relation to ground water table. ii) To study the ground water table and its relation to percolation or infiltration. iii) To study the ground water level control and its relation to paddy yield.
Lysimeter (N-type. Box-type)	To measure, Evaporation, Traspiration and percolation.
Weir and Parshall Flume	To measure the quantity of water supply.

See Table

3. Investigation of soil

1) Investigation

Investigation of soil physical property had been made by DID Ampang Research Station on 7th. & 8th., 1981.

Result

Data No	depth	G s	W%	$\frac{wg}{cm^3}$	n%	L.L%	P.L%	P.I%
1.	0.61m to 0.91m	2.675	36.9	1.799	50.88	59.0	32.3	26.7
2.	1.52 to 1.83	2.646	34.1	1.783	49.72	56.5	31.4	25.1
3.	0.61 to 0.91	2.677	38.7	1.773	52.26	62.6	32.1	22.5
4.	1.52 to 1.83	2.664	37.1	1.798	50.77	55.2	32.5	22.7

Where Gs : specific gravity
w : natural bulk density
L.L : liquid limit
P.L : plastic index
w : natural moisture content
n : perosity
P.L : plastic limit

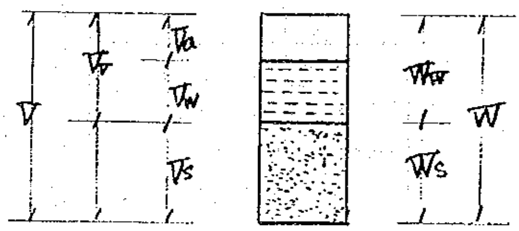
2) Study

i) Three phase of soil

From the figure of soil phisical property we can calculate three phase of soil such as Solid, Liquid, Vapour and S.

<u>Where</u>:

Vs : Solid volume (soil)
Vw : Liquid volume (water)
Va : Vapour volume (air)
Ws : Solid weight
Ww : Liquid weight
S : Vw/V x 100



Data No.	Depth	$\overline{V}s$ cm^3	$\overline{W}$ g	$\overline{W}$ (Wsxw) g	$\overline{W}$ cm^3	$\overline{W}$ (Ws + $\overline{W}s$) g	$\overline{V}$ $\overline{W}/rw$ cm^3	$\overline{V}v$ ($\overline{V}$–$\overline{V}s$)	Three phase (%)			S
									$\overline{V}s$	$\overline{V}w$	$\overline{V}a$	
1.	0.61 to 0.91	1000	2675	987	987	3662	2036	1036	49.1	48.5	2.4	92.3
2.	1.52 to 1.83	1000	2646	902	902	3548	1990	990	50.2	45.3	4.4	91.1
3.	0.61 to 0.91	1000	2677	1036	1036	3713	2094	1094	47.8	49.5	2.7	94.7
4.	1.52 to 1.83	1000	2664	988	988	3652	2031	1031	49.2	48.6	2.2	95.8

Where $\overline{V}s$: solid volume (soil)

$\overline{V}w$: liquid volume (water)

$\overline{V}a$: vapour volume (air)

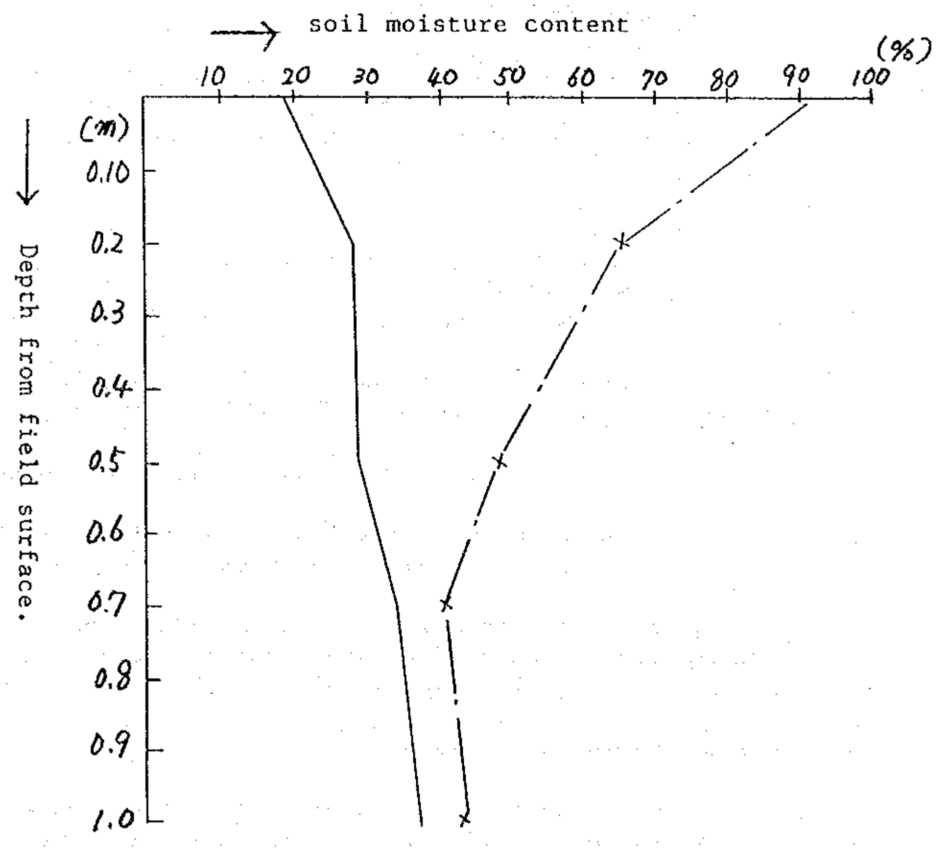
$\overline{W}s$: solid weight

$\overline{W}w$: liquid weight

S : $\overline{V}w/\overline{V} \times 100$

ii) Comparison of soil moisture content between before and after presaturation.

depth m	Soil moisture content		notes
	before pre.	after pre.	
0	18.8%	92.3%	date of survey:
0.10 - 0.30	27.7	64.9	before pre: 15 June, 1981
0.40 - 0.60	28.2	48.0	after pre: 18 July, 1981
0.60 - 0.80	33.7	41.0	
0.90 - 1.10	36.8	44.2	



B. Problems

1. Irrigation

1) Water requirement for presaturation

Usually the capacity of canal are decided by the amount of presaturation water requirement during off-season. Because before presaturation, the soil moisture in field come to a very dry condition and soil surface are made many cracks.

Accordingly, soil requires much value of water to bring the unsaturated soil to a saturated condition.

Water requirement for presaturation period: q

$q = Eu + (Es + p) + H + S$ ..... (1) this formula is

already mentioned. The figures pertaining to Eu, Es, and H have been accumulated by many studies. The figures for P and S are not yet clarified clearly but actually the figure of P is very little compared with S at this time of presaturation.

There are many factors affecting H, but major factors are a soil moisture content, cracks of soil surface, a soil layer to be saturated, groundwater table, humidity and temperature.

Making a formula integrated these factors will be a very important and urgent study for this P/F.

2) The optimum percolation: P

The study of the optimum percolation should be done in cooperation with Agronomist side.

3) The increase of water consumption by water management.

Control or making variation of water layer in field come to an increase of water consumption.

Accordingly, as a measure for an additional water consumption, a study of reusing system of drain water or storage water on low land should be done.

4) The management of drainage

In order to reduce a running cost of drainage pump, we have to make a criteria for drainage. As a measure for this matter, a study for allowable flooding depth corresponding to paddy growth stages should be done.

5) The management of pond

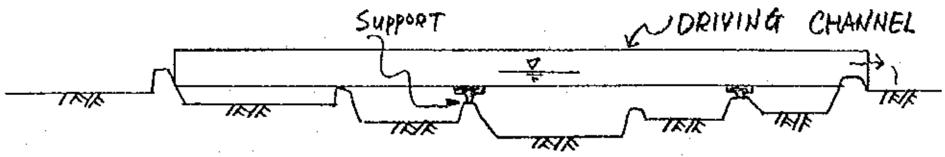
Before off-season starts, the pond must be filled up. A study regarding to a storage avoiding flood-drainage should be done.

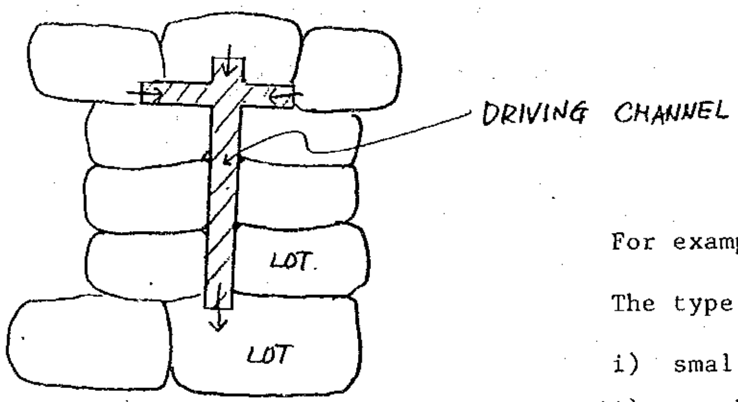
C. Water management under actual condition

1. Water management under a lot to lot irrigation system.

As for a lot to lot irrigation system, if there are some lower fields on the way of irrigation, the water is stored in those lower fields and not reach to the farther fields. Moreover the stored water will discharge to drainage canal as an exceeded water.

In this case, if we can set a driving channel which avoid storing water on lower fields, irrigation water will reaches to terminal fields faster and easily.





For example

The type of channel

i) small wooden bridge type

ii) earth bund "

iii) ready made flume "

As to actual water management there are many problems to resolve but there are many methods we may resolve in cooperation with farmers.

2. A measure for a water shortage at presaturation period.

There are two main causes for a irrigation water shortage. One is water shortage at water source and other is an insufficiency of irrigation channels capacity compare with irrigation requirement.

For former case we can do nothing, but in the case of the latter we may save the water shortage by water management.

For example

covered are	20 ha
Eu	5 mm
L	5 mm
F	150 mm

In this case, if we change presaturation period from 10-day to 20-day, the rate of flow come to down as following.

Presaturation period	Total water requirement per unit per(mm)	Total water requirement for 20 Ha(m^3)	The rate of flow per day
10-day	$q=\frac{(5+5)}{2}x10+150=200$	$\frac{200}{1000}x20x10^4=40,000$	$\frac{40,000}{10}=4000m^3$
20-day	$q=\frac{(5+5)}{2}x20+150=250$	$\frac{250}{1000}x20x10^4=50,000$	$\frac{50,000}{20}=2500m^3$

In such case as the amount of water source is sufficient and the capacity of irrigation devices are insufficient, the presaturation period should take a longer period matched to a covered area.

6-2. REPORT ON THE EFFECT OF UNDERDRAINAGE AT D/F

S. Imai
M. Mimoto

Report on the Effect of Underdrainage at D/F

I. Introduction

Underdrainage work was carried out a lots No. 2 and 3 of D/F in April, 1981. For the purpose of studying the effect of un :drainage, we have investigated the flooding water-level and underground water table at the condition of discharging underground water.

In this paper, the results of investigation and some comments are mentioned.

II. Condition of Underdrainage Work

1. Working diagram

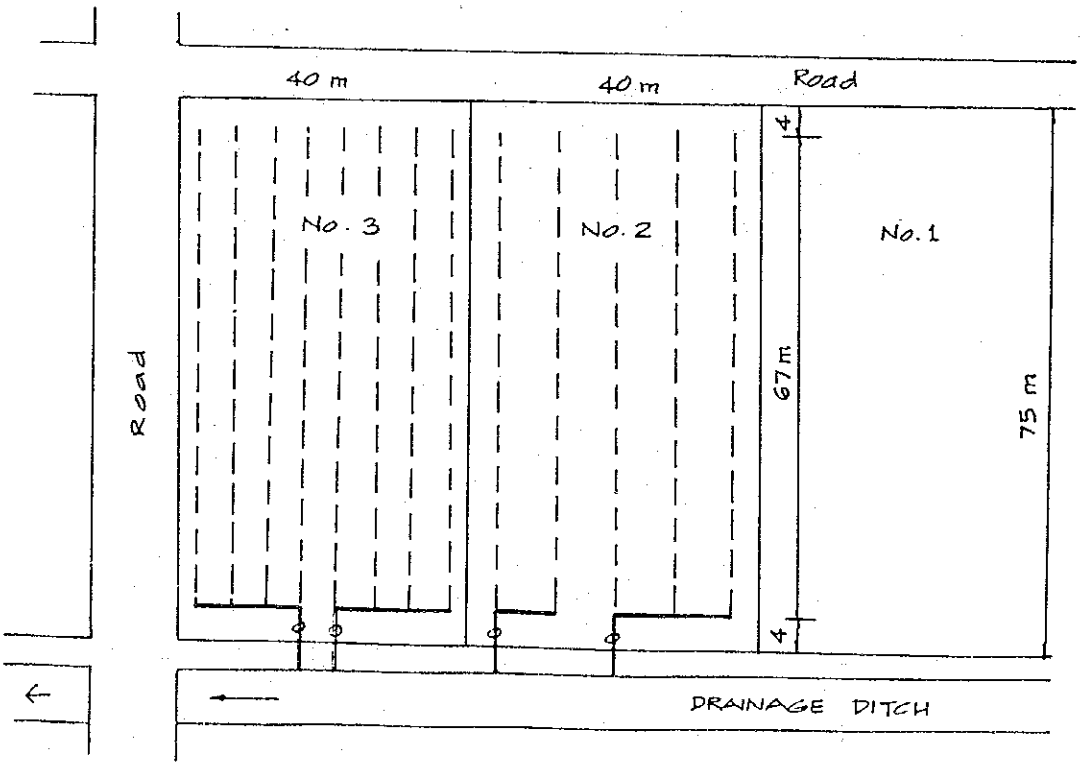
Depth of Lateral Pipe

0.75 - 1.00 m (from paddy field to bottom of trench)

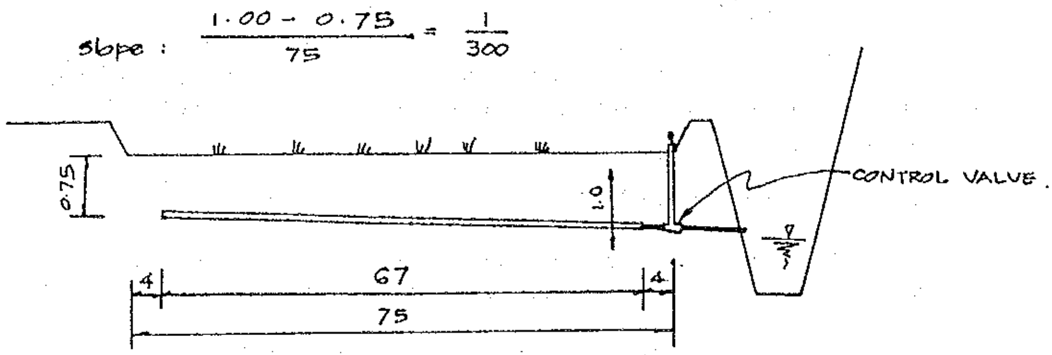
Interval

Lot No. 2 8m x 5 lines

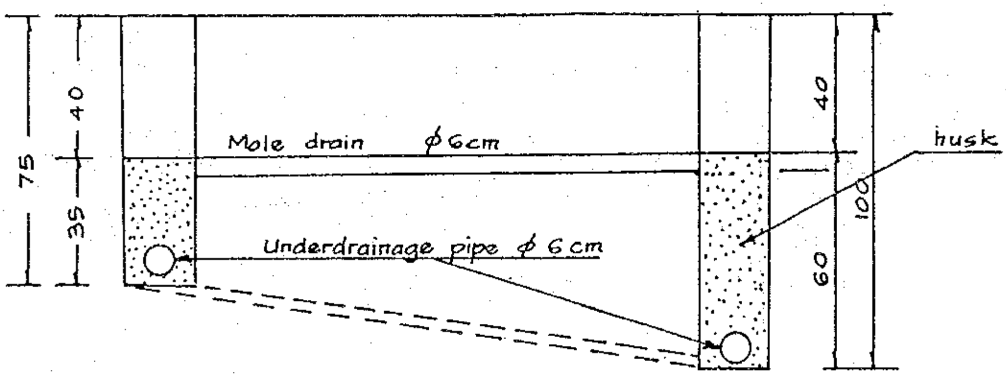
Lot No. 3 5m x 8 lines



LONGITUDINAL SECTION:



CROSS-SECTION:



(unit : cm)

III. Method of Investigation

Underground water is discharged by opening a control valve which is set at a terminal point of underdrainage pipe. Accordingly, opening the valve, the flooding water-level and ground water-table will fall down rapidly.

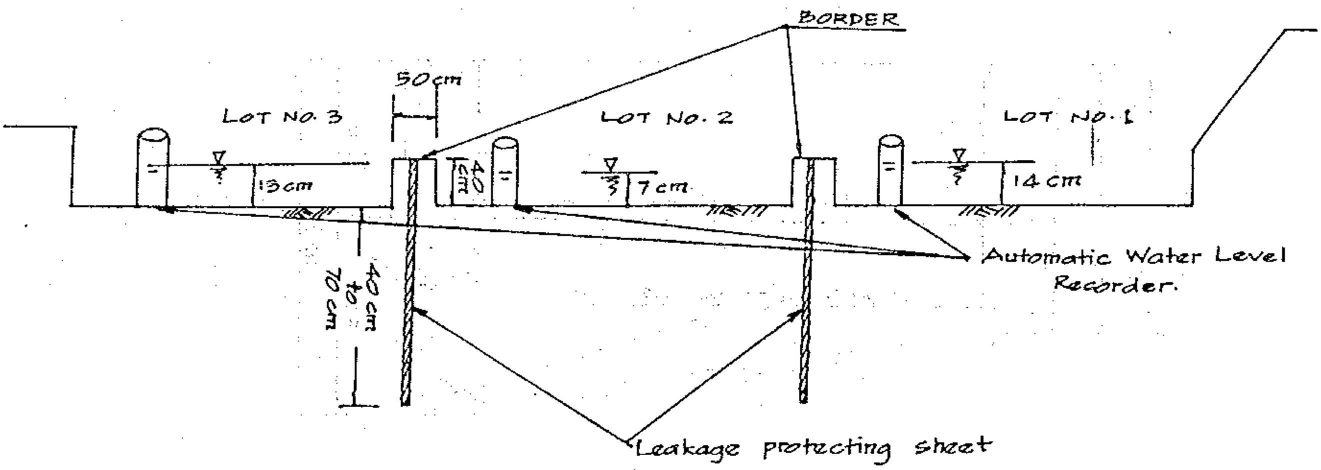
The effect on underdrainage may be judged with measurement of flooding water-level and ground water-table when valve is opened or closed.

1. The Flooding Water-Table

The level of flooding water are measured with automatic water-level recorder, which are set at lots No. 1, 2 and 3.

A condition of flooding is made before control valve is opened.

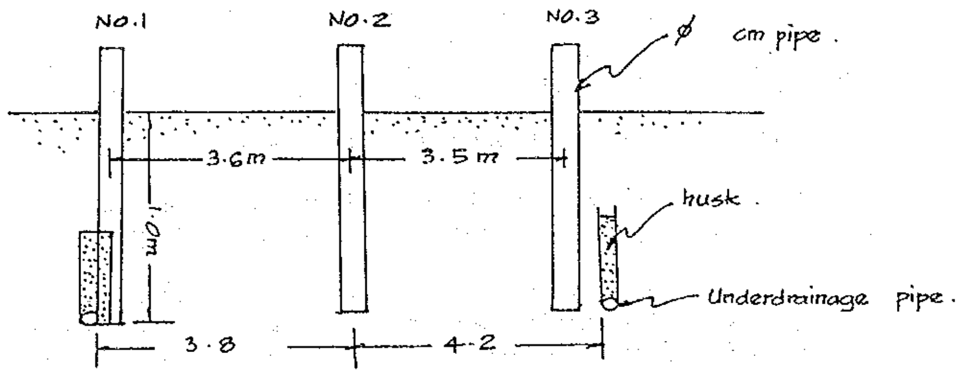
Flooding Condition



2. Ground water table

Three holes are excavated at lot No. 2 and underground water table is observed with automatic water level recorder.

Section



3. Investigation period

Recording period : From 23rd. to 29th. Feb., 1982

Underdrainage : Valves are opened at nine o'clock on 24th. and closed at nine o'clock on 25th. Feb.

IV. Results of Investigation

1. Flooding water-level

The variation of flooding water-level is shown in

Fig.-I. The decreasing speeds per day are shown below

Lot No. \ Date	Closed Valve	Opened Valve	Closed Valve		Note
	on 23rd.	on 24th.	on 25th. to 26th.	on 27th. to 1st.	
I	8.5	10.0	11.0	10.7	Unit:mm/day
2 and 3	8.6	160.0	16.1	16.6	

The water level at lots No. 2 and 3 are assumed to be varied jointly. It is supposed that the leakage protecting sheet is non effective, therefore, the calculated figures here are the average of these two.

2. Ground water table

The variation of ground water table is shown in Fig.-2.

V. Effect of Underdrainage

1. With reference to flooding water level.

From the result of investigation we may infer a specious permeability coefficient which is improved by underdrainage.

The decreasing speed of water level when valves are opened is 160 mm/day and the one before valves are opened is 8.6 mm/day, therefore, the figures which is increased by underdrainage is 160 minus 8.6.

On the other hand, the percolation loss when valves are closed is assumed as 1.0 mm/day (Ref. Appendix - I).

Accordingly the percolation loss during underdrainage may be estimated as 160 minus 8.6 plus I.

By using 1.0 mm/day and 152.4 (160 - 8.6 + 1), we may infer a specious permeability coefficient kl (without underdrainage) and k2 (with underdrainage).

$$1.0 = kl \times \frac{h}{L} \times 86400 \times 1000$$

$$kl = 1.16 \times 10^{-8} \text{ (m/sec.)}$$

$$152.4 = k2 \times \frac{h}{L} \times 86400 \times 1000$$

$$k2 = 1.76 \times 10^{-6} \text{ (m/sec)}$$

where

h : Distance from flooding water level to underground water table. (m)

L : Length of path of seepage flow (m)

Normally, $\frac{h}{L} = 1.0$ in this case

$$\frac{K2}{K1} = \frac{1.76 \times 10^{-6}}{1.16 \times 10^{-8}} = \underline{1.52 \times 10^{-2}}$$

Namely, the speed of percolation with underdrainage is as 1.52×10^{2} times that of without underdrainage.

2. With reference to underground water table.

There are a lot of formula pertaining to estimate the effect of underdrainage, but, in this paper, we adopt formula as shown below.

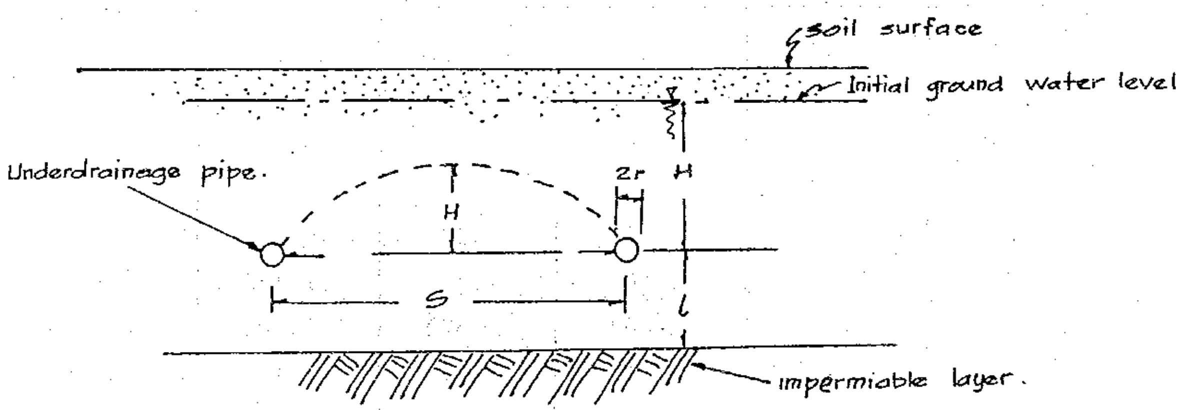
(1) Formula by Golve

$$\frac{H}{Ho} = \frac{1}{\frac{9}{2} \cdot \frac{k.Ho.t}{f.S^2} + 1} \qquad \text{............... (1)}$$

(2) Formula by Kerkham

$$\frac{H}{Ho} = \exp\left(- \frac{k}{f} \cdot \frac{t}{S.F} \right) \qquad \text{............... (2)}$$

Underdrainage Section



Where

Ho : Initial ground water-depth. (m)
H : Ground water-depth middle of S at a time of t. (m)
t : The time after valves are opened. (days)
S : Distance between underdrainage pipes. (m)
k : Permeability coefficient. (m/sec.)
f : Drainable porosity.
F : A coefficient.

F is functions of l/s and 2r/S, the figures are shown as under

Table - I   Figures of F

$\frac{l}{S}$	2r/S				
	0.0025	0.005	0.01	0.02	0.04
0.01	12.79	12.57	12.33	12.03	11.52
0.02	6.761	6.541	6.318	6.077	5.771
0.04	3.846	3.643	3.421	3.195	2.954
0.08	2.522	2.301	2.080	1.858	1.633
0.16	1.961	1.741	1.520	1.299	1.077
0.32	1.787	1.566	1.345	1.125	0.9040
0.64	1.764	1.543	1.323	1.102	0.8811
1.00	1.763	1.543	1.322	1.101	0.8808
∞	1.763	1.543	1.322	1.101	0.8808

The drainable porosity are varied from the condition of underdrainage, accordingly, the effect of underdrainage may be estimated by a comparision of function fs.

Drainable porosity, f, may be converted from formula (1) and (2) as follows.

$$f(G) = \frac{9.k.H.Ho.t}{2.S^2.(HO-H)} \quad \text{----------} \quad (4)$$

$$f(K) = \frac{k.t}{S.F.In(\frac{Ho}{H})} \quad \text{----------} \quad (5)$$

Where

f(G) : f by Golve's formula

f(K) : f by Kirkham's formula

The relationship between underground water table : H, and lapsed time : t, after valves are opened is shown below.

Relationship between t and H

Valves opened		Valves Closed		Note
t	H	t	H	The figures of valve closed are estimated as 0/mm/day.
(days)	(m)	(days)	(m)	
0	0.98	0	0.98	
1	0.56	10	0.97	

The figures of k, Ho and S are decided as follows previously.

$k = 10^{-6}$ m/sec. Ho = 0.98 m. S = 8 m.

The figure of F may be estimated as 12.45 from Table-1.

Namely 1/S = 0.01 2r/S = 0.0075

Therefore, F becomes 12.45.

f(G) and f(K) are calculated by using above mentioned figures, the results are shown below.

Formulae	Valve opened	Valve closed	f(c)/f(o)
	f (o)	f (c)	
Golve f(G)	$\frac{9\times10^{-6}\times0.98\times0.56\times1}{2\times8^2\times(0.98-0.57)}$ $=\frac{4.94\times10^{-6}}{53.76}$ $=\underline{9.2\times10^{-8}}$	$\frac{9\times10^{-6}\times0.98\times0.97\times10}{2\times8^2\times(0.98-0.97)}$ $=\frac{8.56\times10^{-5}}{1.28}$ $=\underline{6.7\times10^{-5}}$	$\underline{7.28\times10^2}$
Kerkham f(K)	$\frac{1\times10^{-6}\times1}{8\times12.45\times\ln(\frac{0.98}{0.50})}$ $=\frac{1\times10^{-6}}{67.02}$ $=\underline{1.8\times10^{-8}}$	$\frac{1\times10^{-6}\times10}{8\times12.45\times\ln(\frac{0.98}{0.97})}$ $=\frac{1\times10^{-5}}{1.02}$ $=\underline{9.8\times10^{-6}}$	$\underline{5.4\times10^2}$

Calculated results of the above shows that the efficiency of underdrainage becomes five or seven hundred times that of non underdrainage.

VI. Variation of Water Consumption

The increment of water consumption caused by underdrainage are shown below.

Period / Lot No	Just before (1)	After 1.5 days	After 3 days	Note
1	8.5	11.0	10.7	unit:mm/day
2 and 3	8.6	16.1	16.1	

Note.

Just before	:	Just before valves are opened.
After 1.5 days	:	After 1.5 days valves are closed.
After 3 days	:	After 3 days valves are closed.

Supposing the figures of just before is 1.0, the ratios of water consumption for just before are shown as follows.

Lot No. \ Period	Just before	After 1.5 days	After 3 day	During drainage	Note
1	1	1.29	1.25	1.41	
2 and 3	1	1.87	1.93	17.56	

The water consumption after underdrainage had been practiced and valves was closed becomes nearly two times that of just before for three days.

Supposing the figures of lot No. 1 are influenced by underdrainage, the figure of lots No. 2 and 3 will become more larger than that of shown here.

To study the tendency of increasing water consumption by underdrainage is important for future underdrainage works.

V. Conclusion

The results of investigation show that;

i) The effect of underdrainage is very large, the specious permeability coefficient is improved more than hundred times over that of non underdrainage, and underground water table falls down more than 40 cm per day.

ii) The analysis of investivation results shows only the tendency of effect by underdrainage, but in order to grasp the efficiency quantitatively, it is necessary to conduct more detail investigation.

iii) The difference of the figures between $\frac{k2}{k1} = 1.52 \times 10^{-2}$ and $f/B/fA = 7.28$ or 5.4×10^{-3} are not clear,

iv) The increment of water consumption by underdrainage should be investigated in more detail.

Fig. - 2 UNDERGROUND WATER TABLE

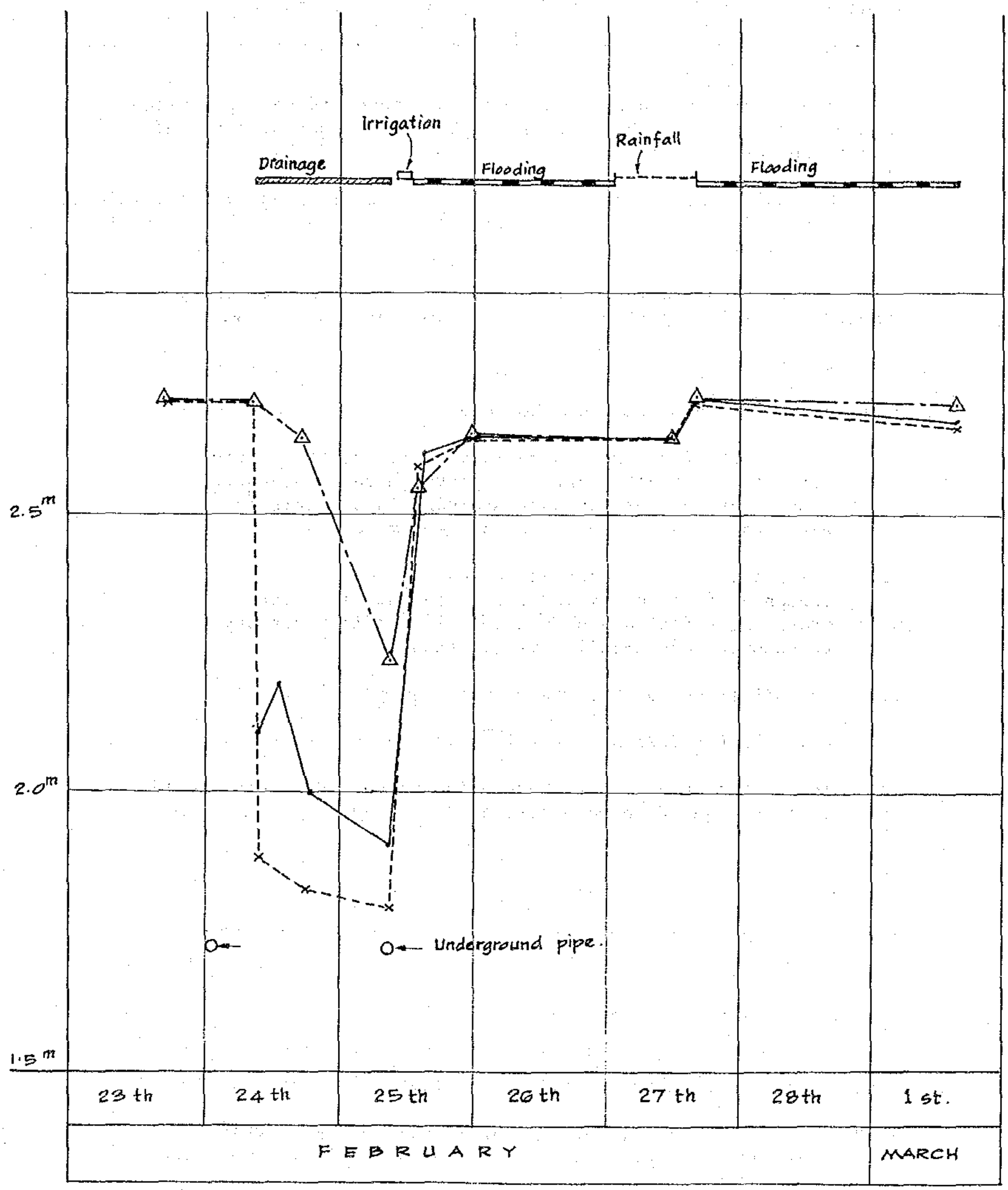


Fig. - 1 DEPTH OF FLOODING WATER