drought, water with an EC upto 4000 micromhos may be admitted. In the flowering stage water with an EC of less than 4000 micromhos may be safely used. In case of extreme drought when crop failure is probable water with an EC upto 6000 micromhos may be admitted for a short period. However, it should be born in mind that in case of an Aman crop, the conditions are in general such that not much rain can be expected and that the salinity of the riverwater in this period is increasing. This means that no water of lower conductivity for subsequent leaching might be expected.

In the beginning of a rice crop, preceeded by a dry fallow period, river water should be admitted when the conductivity of the paddy water is greater than that of the river to hasten the removal of salts which have been accumulated in the dry season.

For non-rice crops with intermittent irrigation, the water should be evaluated according to

- electrical conductivity of the distilled water extract from saturated soil (ECe)
- electrical conductivity of irrigation water (ECw)

Besides the previously mentioned dependance upon the irrigation frequency, the suitability of the irrigation water also depends on the nature of the soils. This aspect is illustrated in Table IV - 3.8. Salts do not accumulate as rapidly in well drained sandy soils as they do in heavy clay soils with poor internal drainage.

Table IV - 3.8 Irrigation water salinity in relation to soil and ECe level

Electrical conductivity of saturation extract (ECe), micromhos/cm		Maximum conductivity of irrigation water (ECw), micromhos/cm				
		sand	sandy loam	loam	clay loam	clay
Low, ECe	<4000	2500	1600	1000	800	400
Medium ECe		6500	4000	3000	2000	1000
High, ECe	>10,000	10000	6000	4500	3000	1600

Crops vary widely in salt tolerance. In Table IV - 3.9 several crops in Bangladesh are classified according to their salt tolerance in three groups. Within each group the species are listed as much as possible in the order of decreasing tolerance (ref.11).

Table IV - 3.9 Salt tolerance of crops

Highly tolerant (ECe > 6000 micromhos)	Moderately tolerant (2000 < ECe < 6000)	Sensitive (ECe < 2000)
Barley	Soybean	Peas
Sugarbeet	Sorghum	Sugarcane
	Rice	Onion
Most grasses	Wheat	Carrot
Cotton	Groundnuts	Bean
Date palm	Tomato	
	Cucumber, Corn, Orange, Cabage, Broadbean, Pepper	

- Sodium hazard

Sodium (Na) is unique among the cations in its effect upon the soil. When present in the soil in exchangeable form, even at low concentrations compared with the other cations, it causes adverse chemical and physical conditions to develop. Exchangeable sodium tends to make a moist soil impermeable to air and water, and on drying out this soil is hard and difficult to till. The most commonly used index for the sodium hazard, of the irrigation water is the sodium-absorption-ratio (SAR). It is defined as :

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

where the concentrations are expressed in meq/liter.

The classification of water according to the SAR is also related to the water's salt concentration. This relation is shown in Figure IV - 3.2.

In Irrigation and Drainage Paper No. 29 (ref. 11), a refinement, called the adjusted SAR, is suggested. Since it involves a rather, complicated operation to calculate a certain theoretical pH value, this method is not included in this manual. For the evaluation of critical conditions reference is made to this publication.

- Toxities

Too high quantities of Boron may be very toxic to certain plant species. The occurence of Boron in toxic concentrations in irrigation water makes it necessary to take this element into account when assessing the water quality. In Table IV - 3.10 some crops are classified on the basis of their tolerance to boron.

Table IV - 3.10 Limits of Boron in irrigation waters for crops and different degrees of Boron tolerance

Tolerant	Semi Tolerant	Sensitive
4.0 ppm	2.0 ppm	1.0 ppm
coconut	potato	most fruit trees
sugarcane	cotton	
broad bean	tomato	
onion	peas	
cabbage	wheat	
carrots		

The tolerance of rice is being investigated, in particular at IRRI.

Chapter 4. Irrigation Water Supply

4.1 Ground Water

Although in some parts of the south western deltaic area a well defined continuous fresh water aquifer exists between 200 - 300 m depth, (for instance in the Patuakhali and Barisal districts) these deep groundwater-layers will not be considered for irrigation purposes.

In the shallow aquifers to depths of 60 m, the salinity is extremely variable in the south-west deltaic area and changes rapidly over short distances (ref. 15). Generally the shallow groundwaters are too saline for domestic and irrigation use due either to connate salts or to estuarine flooding. However, land flooding by saline water is prevented by the Coastal Embankment Project and polder development activities. As a result the shallow groundwater quality will gradually improve.

Whenever there is fresh groundwater in deltaic areas it usually floats over highly saline water due to density differences. When this fresh water layer is skimmed by pumping from the groundwater, the interface freshwater - saline water will rise approximately 40 m for every 1 meter draw-down of the fresh groundwater level. In addition the groundwater level will be for a longer time below the level of the saline estuaries and saline water may flow into the polder through permeable layers.

It can be concluded that in the deltaic area groundwater can not be used for irrigation purposes.

4.2 Surface water

The main source of irrigation water in the deltaic area is surface water. Supplement E of the Southwest Regional Plan (ref. 6) contains data of the salinity of the major estuaries and rivers. In part of the area the water is suitable throughout the year, viz. the area that is bounded by the Lohalia River to the east and the Baleswar River to the west. In the rest of the area the water can be used for (supplemental) irrigation only in part of

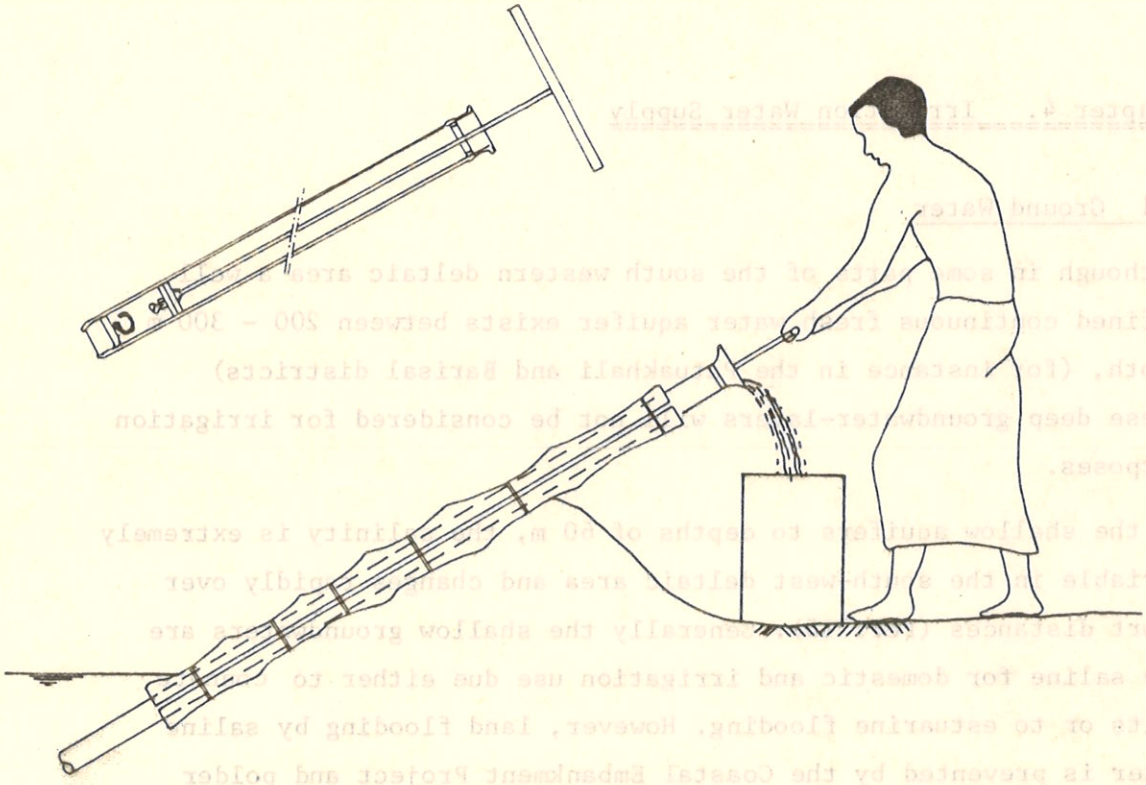
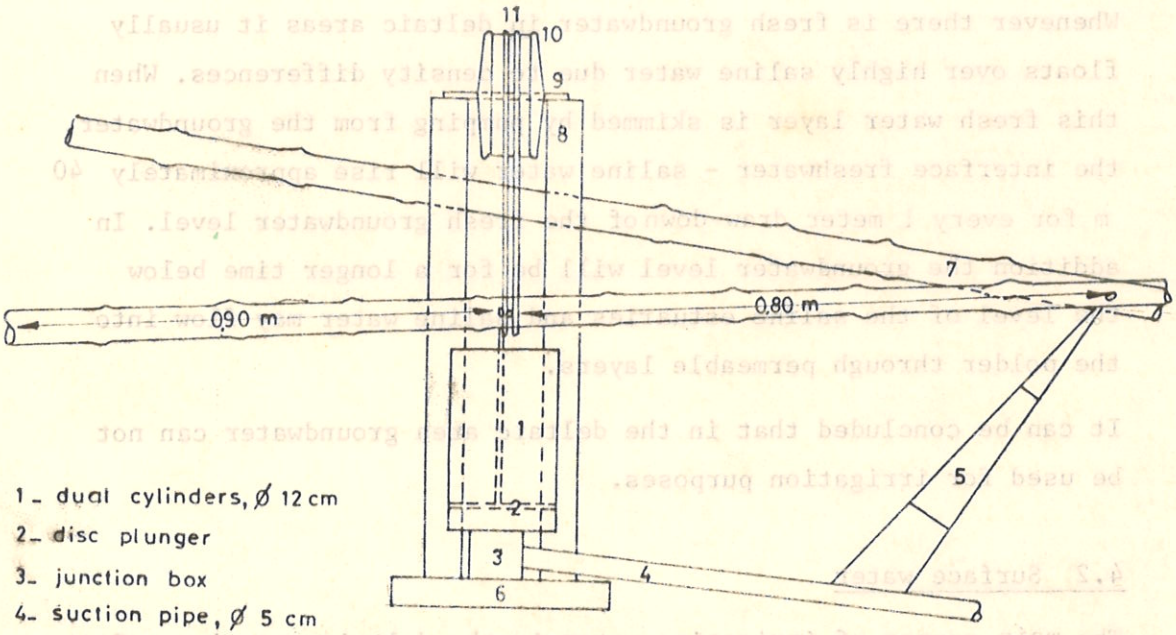


Figure IV - 4.1. Rower pump.



1 - dual cylinders, Ø 12 cm
2 - disc plunger
3 - junction box
4 - suction pipe, Ø 5 cm
5 - treadle support
6 - foot
7 - treadles bamboo
8 - pulley stand, 5x5 cm
9 - pulley axle, 12mm M.S.
10 - hard wood pulley
11 - rope (jute, nylon)

CAPACITY : at medium lift : max 150 - 200 litre/minute

SUITABLE LIFT RANGE : 1.5 - 3.0 m

Figure IV - 4.2. Low lift threadle pump.

the monsoon and sometime thereafter. The length of this period varies from place to place and more detailed data are required to determine the length of this period for each location.

4.3 Water lifting devices

In the preceding section it was seen that pumping from groundwater is generally not feasible. Low lift handpumps however may be very usefull where small plots can not be irrigated by gravity because:

- the groundlevel is too high in relation to the outside river-level
- or it concerns an isolated plot that requires the construction of too long or too high bunds to convey the water to the plot.

In such cases the plots may be irrigated by pumps. However, in case of supplemental irrigation of these small plots, mechanised low-lift pumps are often not feasible. The most suitable manual devices which are presently used in Bangladesh are:

- The Rower Pump, developed by the Mennonite Central Committee and manufactured by the Mirpur Agricultural Workshop and Training School, Mirpur Section 12, Dhaka. For lifting surface water, a 3" simplified version of the shallow tubewell Rower pump (without the vertical part and the suction surge chamber) has been developed. Price (1982) Tk. 450.- It consists mainly of a PVC cylinder with a piston and a foot valve. The operator pushes and pulls directly on the T - handle at the end of the piston rod. A split bamboo is tied around the PVC pipe for sunlight protection (see Figure IV - 4.1).
- Threadle pump (Twin pump, RDRS pump), developed by the Rangpur Dinajpur Rehabilitation Project of the Lutheran World Federation. The pistons in the two mild steel cylinders are connected with bamboo threadles that are moved by the legs of the operator. The surface water type is manufactured with cylinders of 4 $^{3}/4$" or 6" diameter. The price (1982) is about Tk. 350.- without the bamboo threadles. (see Figure IV - 4.2).

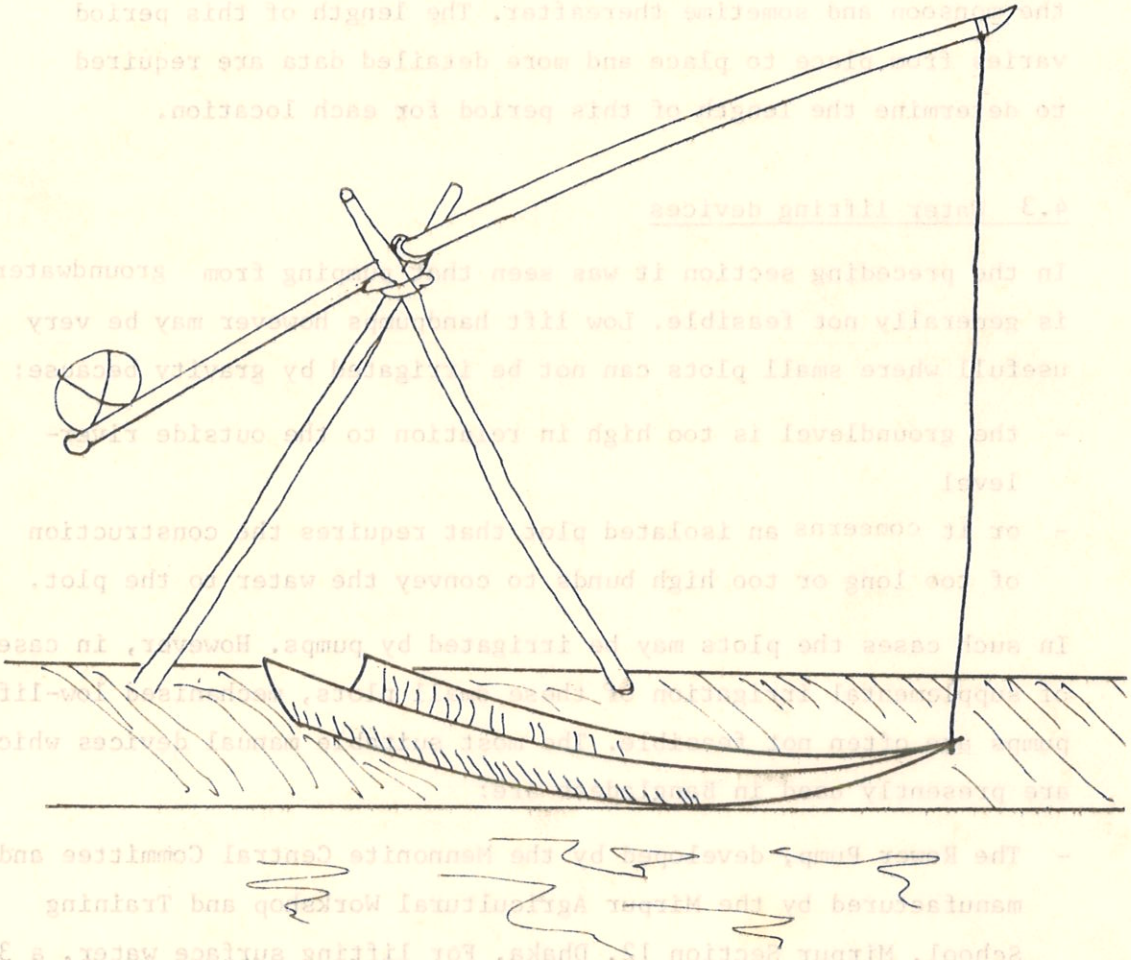


Figure IV - 4.3. Dhone.

- Dhone

  This consists of a lever in the form of a pole pivoted like a see saw. At one end is a canoe shaped through made of a hollowed log (a modernised version is made of sheet steel). One end of the log is fixed on the side of a field and acts as a pivot. The other end, which is closed off, is lowered in the water and filled. This end is then raised with the help of a counter-poised weight to a level slightly above that of the field. The water then flows down the log to the field (see Figure IV - 4.3).

Chapter 5. Seperate Irrigation and Drainage Systems or Irrigation-cum-Drainage Systems

The required waterdepth in the paddy field at different stages of growth is shown in Figure IV - 5.1.

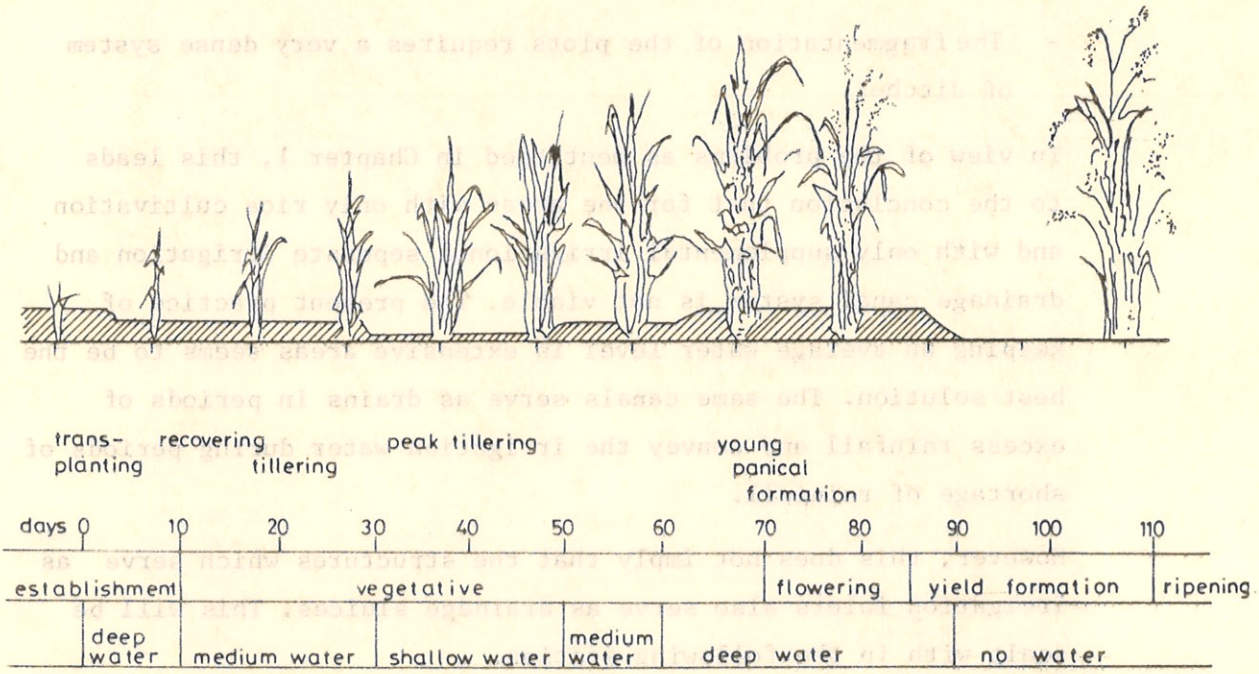


Figure IV - 5.1. Controlled waterdepth in paddy field.

The rice is cultivated by individual farmers with various farm sizes, labour force, etc. This means that no fixed cultivation schedule with fixed dates for soil preparations and transplanting can be made for large units. Differences in required water depths in adjoining plots imply that an optimal watermanagement requires a separate irrigation and drainage system so that every plot can be irrigated or drained at any moment during the irrigation period.

If a multiple of crops is grown in the same area, with greater differences in planting schedules, irrigation requirements, etc., the need for a seperate irrigation and drainage canal system

increases. However, there are factors which limit the possibilities for the implementation of a seperate irrigation and drainage canal system.

- For areas with rice cultivation, bunds have to be made along the entire drainage system to keep the water in the field.
- The fragmentation of the plots requires a very dense system of ditches.

In view of the problems as mentioned in Chapter 1, this leads to the conclusion that for the areas with only rice cultivation and with only supplemental irrigation, a seperate irrigation and drainage canal system is not viable. The present practice of keeping an average water level in extensive areas seems to be the best solution. The same canals serve as drains in periods of excess rainfall and convey the irrigation water during periods of shortage of rainfall.

However, this does not imply that the structures which serve as irrigation inlets also serve as drainage sluices. This will be dealt with in the following section.

Only in areas where a variation of crops are grown, a seperate irrigation and drainage canal system is required. These are normally the areas which can be irrigated in the dry season.

Chapter 6. Drainage and Irrigation Units

6.1 General

A drainage unit is the area that evacuates through the same drainage sluice; an irrigation unit is the area with its own intake for irrigation water. Although in a previous section it has been described that in general it is not viable to make a seperate irrigation and drainage canal system and that the channels will serve both for the drainage of excess rainfall as well as for the conveyance of irrigation water, this does not mean that the irrigation units correspond with the drainage units and that the irrigation inlets also serve as drainage sluices.

In general the polders are slightly saucer-shaped, somewhat higher around the edges and a depression in the centre. A system of natural creeks and channels cris-crosses the polder area. Before the construction of the embankments these channels debouched directly into the surrounding estuaries and rivers. Water flowed into the system and flooded the land at each high tide and was evacuated again at each low tide. The construction of the embankments closed the channels and prevented the inflow of water and flooding of the land. Only a few drainage sluices serve as evacuation points of the excess rainfall. This is schematically shown in Figure IV - 6.1.

The network of channels with many interconnecting channels conveys the drainage water to the drainage sluices. In principle these drainage sluices should be located near the lowest parts of a polder. In many cases the boundary between the drainage units is not well defined. With the many interconnecting channels the drainage flow just in between two sluices may be in either direction, whichever water level is lowest that moment.

It is possible to divide a drainage unit in many irrigation units, each served by its own intake. The water is taken in above groundlevel and can be distributed either via channel or as an overland flow. If in existing canal intake can be below groundlevel. If ditches are not existing they can be made.

The reasons to divide a drainage unit in many more irrigation units will be dealt with in the following section.

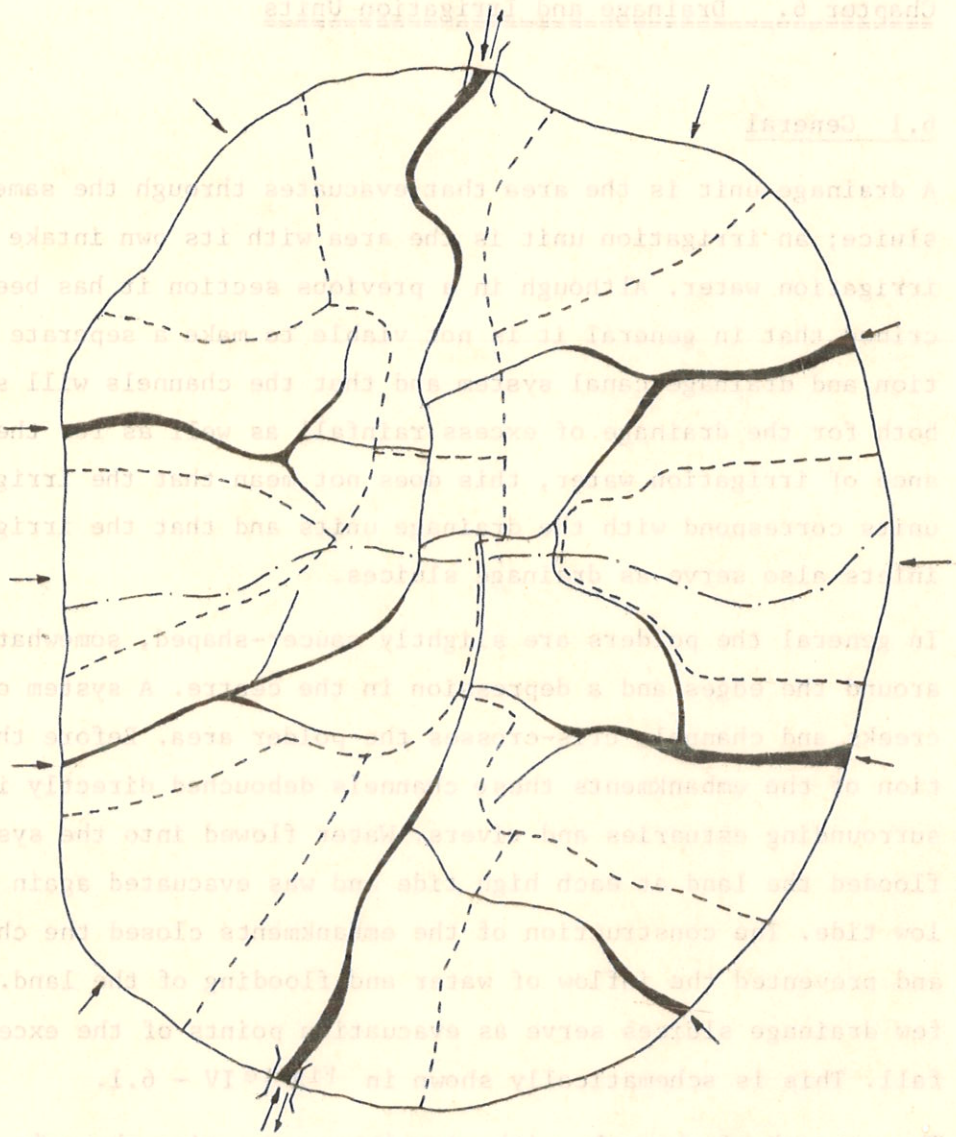


Figure IV - 6.1. Schematic presentation of irrigation and drainage units in a polder.

6.2 Size of irrigation units

In this section the components which determine the size of an irrigation unit are being discussed. Only the case of supplemental irrigation of a rice crop is considered. In this case the rice fields act as a reservoir that should be supplemented. In case of irrigation of other crops, the time required for the irrigation water to reach the end of the unit plays an important role but with rice irrigation this is not important.

Surface relief

Although the polders are relatively flat, elevation differences in the range of 0.3-1m exist.

In case of a gentle general slope in one direction, fairly large irrigation units can be created.

In case of a rather ondulating surface, however, with scattered higher parts, high bunds are required along the irrigation canal sections that convey the water through the depressions between the higher parts (see Figure IV - 6.2).

The larger the size of the irrigation unit, the more bunds are required. With many (small) inlets, each serving only a small unit, the elevation differences within the units are smaller and less and lower bunds are required.

In view of the former mentioned problem, that people are not willing to sacrifice land for the benefit of other people, a reduction of the size of an irrigation unit should be pursued. It might although be more economical to reduce the number of intakes and construct higher bunds along part of the system. The implementation of such a system with only a few inlets might be impossible because the farmers who have to provide the land for the bunds will refuse to do so.

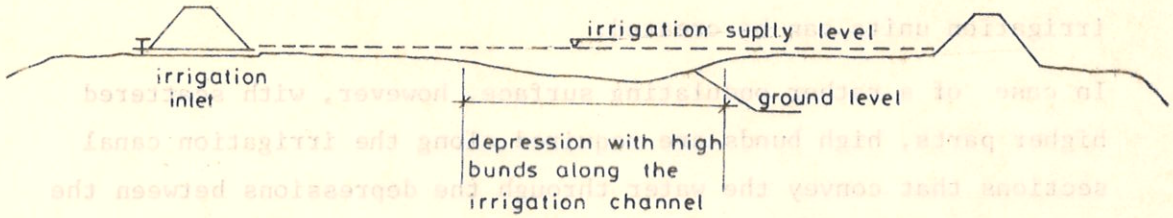
Cooperation of farmers

The individual behaviour of farmers (or small groups of farmers) will complicate the successful introduction of large water manage-

ment units; a successful watermanagement system will be enhanced by the formation of relatively small units, each unit with its own intake, which can operate independently and without interference of farmers who do not cultivate land within the unit.

These two factors imply that a straight forward economical solution is not possible. A comparison of the reduction in costs by reducing the number of inlets and the increased costs of the higher bunds will lead to irrigation units which will be too large for organizing the users. From the experience in Polder 22 an irrigation unit of about 40-50 ha is recommended, averaging 40 farmers.

A: one inlet with high bunds in depressions.



B : two inlets with checks.

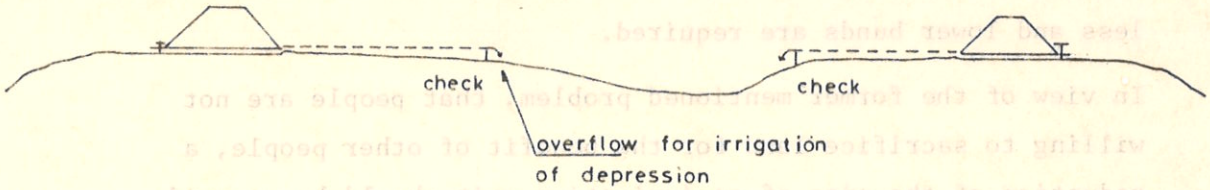


Figure IV - 6.2. Area with one or two irrigation inlets.

6.3 Size of drainage unit

In the coastal zone most of the embankments and drainage sluices have been constructed already and therefore the size of the drainage units have already been fixed.

The same factors that determine the size of an irrigation unit also have a bearing on the size of a drainage unit. In general the drainage sluice will be located near the lowest part of the area.

Increasing the size of the drainage unit may bring on that the drainage will include more low parts that are scattered over the area with higher parts in between. These low parts have to be connected with the drainage sluice. This implies the deepening of channels or digging of new channels through the higher parts (see Figure IV - 6.3).

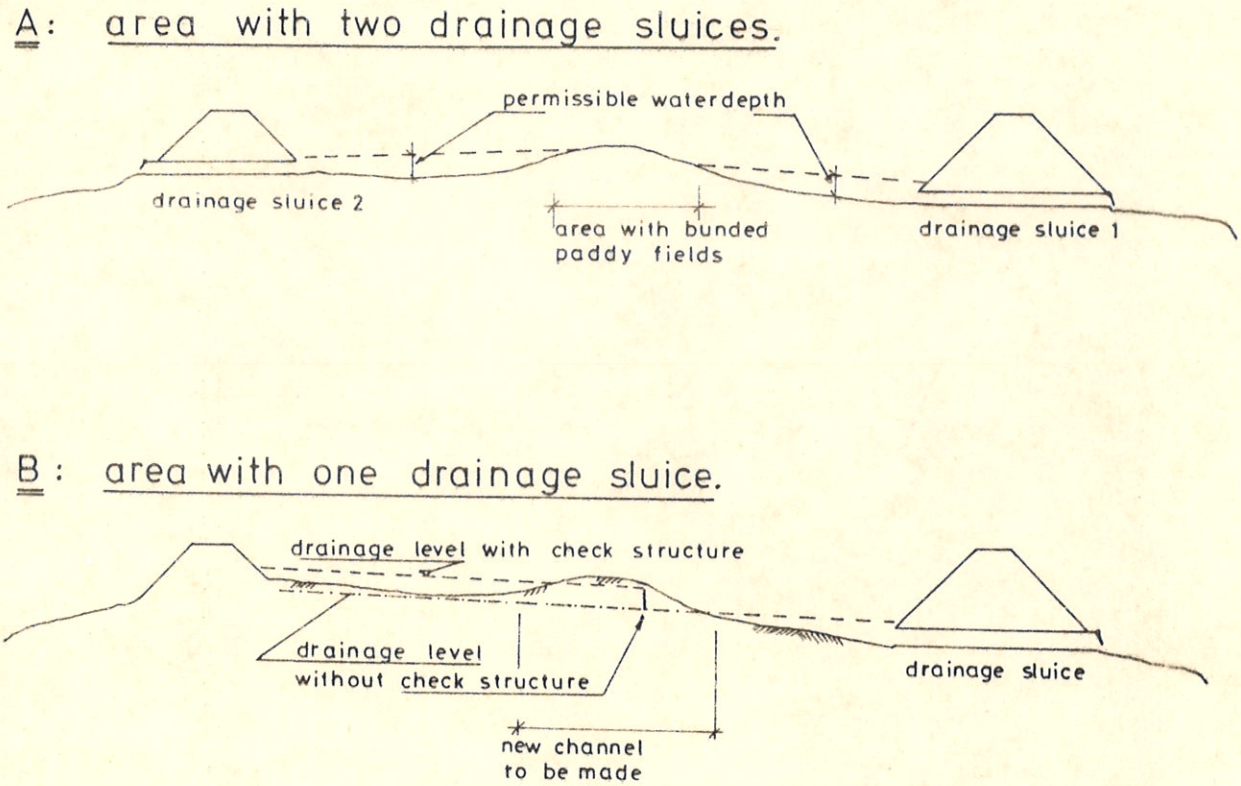


Figure IV - 6.3. Area with one or two drainage sluices.

The various low parts will not have the same groundlevel. The drainage level should be low enough to keep the water level in the lowest part below the permissible depth. This implies a lowering of the drainage level in other parts. This is schemati-

cally shown in Figure IV - 6.3.(a), where the area is divided in two drainage units, each with its own drainage sluice and its own drainage level. In Figure IV - 6.3.(b) the two drainage units are joined to one unit. This will lower the water level in the area that in Figure IV - 6.3.(a) drained through sluice 2. Maintaining a water layer in the paddy fields in this part requires a check structure at the boundary of this part.

Chapter 7. Drainage and Irrigation Design Requirements

7.1 General

After an embankment has been constructed for the purpose to control the water level in the enclosed area, drainage facilities and irrigation facilities are required to resp. evacuate excess water and provide necessary fresh water.
The locations, the type and the size of such a drainage c.q. irrigation regulator depends on:

- the characteristics of the area to be drained
- the quantity of water to be drained / admitted
- the levels and fluctuations of water level inside and outside the embankment.

Before any design work on the drainage and irrigation facility or facilities can start, the following basic data have to be co-llected.

- topography
- volume of water to be drained / admitted
- hydrograph and salinity conditions of outer water
- characteristics of main khals that might be considered as future main drainage canal or feeder canal

In the next paragraphs these items will be elaborated.

7.2 Data collection

7.2.1 Topography

From a detailed topographic map of sufficient large scale (i.e. 1:5000, 1:10,000), on which contour lines are shown every half foot or foot, the area elevation curve of the polder can be constructed (see Figure IV - 7.1). The curve starts from the deepest point in the polder and ends at the highest point, equalling then the total area enclosed by the embankment. For accurate plotting of the curve, all contour lines have to be planimetered.

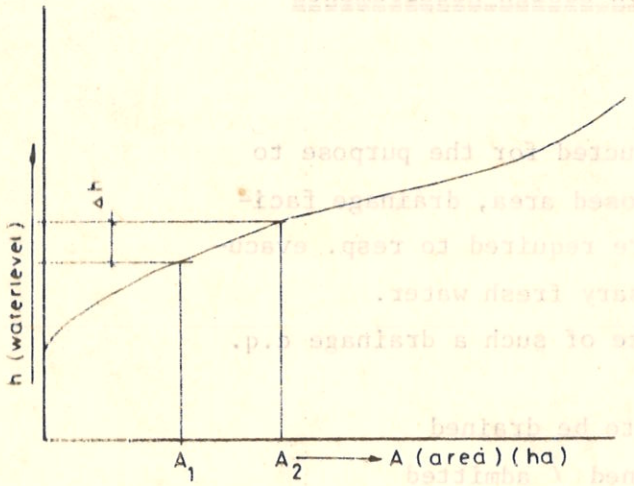


Figure IV - 7.1. Area elevation curve.

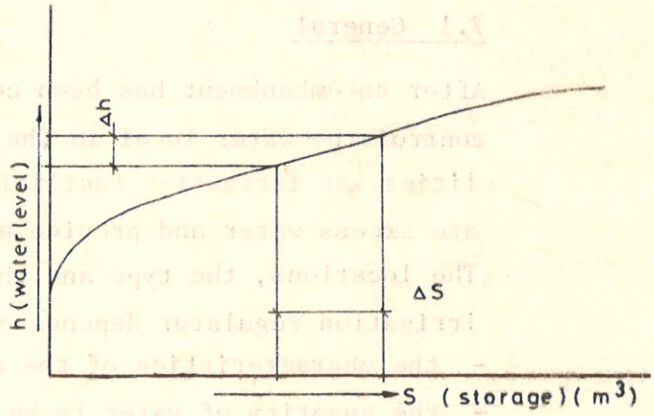


Figure IV - 7.2. Elevation-storage capacity curve.

From the area-elevation curve, the elevation - storage capacity curve can be constructed by integrating the area elevation curve h = f (A). Storage capacity is then expressed as :

$$S = \int A.\ d(h)$$

or simplified $\Delta S = \Delta h \times \left[\frac{A_2 + A_1}{2}\right]$

in which ΔS = increase in storage capacity

Δh = increase in water level

A_1 = area submerged before water level increase

A_2 = area submerged after water level increase.

An example of a elevation - storage capacity curve is shown in Figure IV - 7.2.

7.2.2 Volume of water to be drained / to be admitted

The excess rainwater which has to be evacuated through the drainage sluice(s) is determined as outlined in Chapter 2.4 of this volume. The drainage module as mentioned there reflects the drainage capacity in mm/day which is necessary to avoid flooding above a certain

level in the rice fields during the period of the year that drainage will be critical. It also takes into account the duration of flooding, which may be limited by the type of crop grown. The drainage module has to be re-worked from mm/day to m^3/s for the sluice to be designed, taking account of area size, tidal movement of the outer water and polder water level. The irrigation water requirements are calculated as indicated in Chapter 3. These calculations show an irrigation water requirement during a certain month, expressed in mm/month for the area under consideration. The water needs have to be re-worked to m^3/s for the inlet structure to be designed, taking account of area size, tide and salinity conditions of the outer water and the required intake level of the irrigation water.

7.2.3 Hydrograph of the outer water

In order to design a drainage sluice, the characteristics of the outer water have to be analysed for the period of the year that the functioning of the sluice is critical. When this period will be, depends on meteorolgical and agricultural conditions (cropping patterns and crops) in the considered area. *)

Water level data at the future sluice site are only available of a few months prior to construction from a specially erected gauge. These limited gaugereadings have to be related to more extensive data from neighbouring permanent gauge stations. For this purpose the gaugereadings at site and the gaugereadings from the neighbouring permanent gauge stations have to be correlated.

Water levels in tidal rivers are influenced by the upland discharge, which is subject to seasonal variation, and by the tides of the sea.

*) The same applies for an irrigation inlet.

In order to eliminate the tidal effect, a fortnightly mean water level (F.M.L.) is calculated for the station over the period of interest. F.M.L. can be approximated by taking the mean of the high water (M.H.W.) and low water (M.L.W.) readings during a period of 15 days.

Once F.M.L. has been establish for the considered stations and for the considered period of the year, a curve can be drawn, representing the hydrograph of the station in which the tidal effect is excluded and only true seasonal variation is shown. For every year of record such a hydrograph can be made, but it is more convenient to draw only one hydrograph for each station, representing the water level which is exceeded by 50% of the years of record. Thus only the curve representing F.M.L. (50%) will be drawn for each station.

The calculation of M.L.W., M.H.W. and F.M.L. can be made according to Table IV - 7.1 for each year of record. In Table IV - 7.2 the calculated F.M.L. for the record-years are summarised and F.M.L. (50%) can be determined for every fortnightly period. The same is done for M.H.W. and M.L.W. in Table IV - 7.3. It should now be indicated which fortnightly period is to be used as determinant for sluice discharge calculations and for maximum irrigation flow well as maximum drainage flow.*) For this period the H.H.W. and L.L.W. of the years of record are then summarised in Table IV - 7.4 and HHW (50%), LLW (50%) (exceeded by 50% of the records) are determined. Thus, the boundary conditions for the hydraulic calculation are established :

---

*) Maximum flow through the sluice, if used for letting in water, will not occur during the same time of the year as maximum drainage flow. It is however assumed, for simplification reasons, that the maximum velocities calculated for this period will not be exceeded in other times of the year. For instance, a big design drainage at favourable tidal conditions might be less critical than a moderate drainage discharge at unfavourable tidal conditions.

F.M.L. (50%) = average water level

M.L.W. (50%) = average low water

M.H.W. (50%) = average high water

Since already the critical drainage discharge has been based on a rainfall frequency and duration of once in five years, it is felt unrealistic to base the hydraulic design again on most unfavourable conditions (i.e. spring-tide). It is considered more appropriate to take average tide conditions.

The design water levels as established according to above procedures are determined for a nearby permanent gauge station and should be re-worked to waterlevels at the construction's site by correlating water level readings from the permanent gauge with the temporary gauge at site.

Table IV - 7.1. F.M.L. per year

Year 19..	nbr.of H.W.	sum H.W.	mean H.W.	nbr.of L.W.	sum L.W.	mean L.W.	nbr.of peaks	F.M.L.
fortnightly period:								
1. May 17 - 31								
2. June 1 -15								
3. June 16 - 30								
4. July 1 - 15								
5. July 16 - 30								
6. July 31 - Aug 14								

Table IV - 7.2. Summary of F.M.L.'s

fortnightly period	1	2	3	4	5	6
year 19..						
19..						
19..						
19..						
F.M.L. (50%)						

Table IV - 7.3. Mean High Water, Mean Low Water.

fortnightly period	M.H.W.						M.L.W.					
	1	2	3	4	5	6	1	2	3	4	5	6
19..												
19..												
19..												
19..												
19..												
.												
.												
.												
.												
M.H.W./M.L.W.50%												

Table IV - 7.4. M.H.W., M.L.W. summarized for the specific period.

Year	M.H.W.	M.L.W.
19..		
19..		
19..		
19..		
19..		
19..		
.		
.		
.		
.		
50%		

note:

1. For every year of record prepare Table IV-7.1.
2. Summarize the yearly average F.M.L.,M.H.W. and M.L.W. for the different 15-days periods in Table IV-7.2 and -7.3 resp.
3. Summarize the H.H.W. and L.L.W. for the specific 15-day period in Table IV-7.4.

REFERENCES of Volume IV

1 ILRI (International Institute for Land Reclamation and Improvement), Drainage Principles and Applications, Publication 16, Wageningen, the Netherlands, 1973.

2 Fukuda, H. Tsutsui, H, Rice Irrigation in Japan, FAO Rome, 1968.

3 IBRD, Bangladesh Land and Water Resources Sector Study, Vol. VII, Water, 1972.

. Technical Report No. 23, Rainfall Analysis

. Technical Report No. 20, Overall Water Potential

4 IECO, EPWAPDA, Master Plan, Supplement A, Climate and Hydrology, 1964.

5 Leedshil - de Leuw Engineers, EPWAPDA, Coastal Embankment Project, Engineering and Economic Evaluation, 1968.

6 IECO, BWDB, Southwest Regional Plan, 1980.

7 BWDB, Hydrologic and Hydraulic Design Procedures for Drainage Structures.

8 Irrigation, Drainage and Salinity, an International Source Book, FAO/UNESCO, 1973.

9 BRRI (Bangladesh Rice Research Institute), Agro Climatic Survey of Bangladesh.

10 FAO, Crop Water Requirements, FAO Irrigation and Drainage Paper No. 24, revised, 1977.

11 FAO, Water quality for agriculture, FAO Irrigation and Drainage Paper No. 29, 1976.

12 BRRI, Annual Report 1974-75.

13 ACRES/ILACO, Draft Technical Guidelines, Rainfall analysis, East Pakistan, 1971.

14 U.S. Salinity Laboratory Staff, Diagnosis and Improvement of Saline and Alkoline Soils, USDA agriculture handbook No. 60, 1954.

15 BWDB, Water Supply Paper, 416, Morton and Khan, 1979.

16 FAO, Irrigation and Drainage Paper 33 : Yield response to water, Rome, 1979. J. Doorenbos and A.H. Kassem.

17 ILACO, Agricultural compendium for rural development in the tropics and subtropics. Elsevier Scientific Publishing Company, 1981.

18 ILRI publication 14, Irrigation requirements for double cropping of low land rice in Malaya, Wageningen, 1968.

*) The drainage modulus method as presented in paragraph IV-2.3 is applicable for rice polders in low laying tidal areas. The method assumes that evaporation and percolation losses are compensated for by any runoff from adjacent areas or any irrigation water entering the drainage system.

ANNEX IV - 1

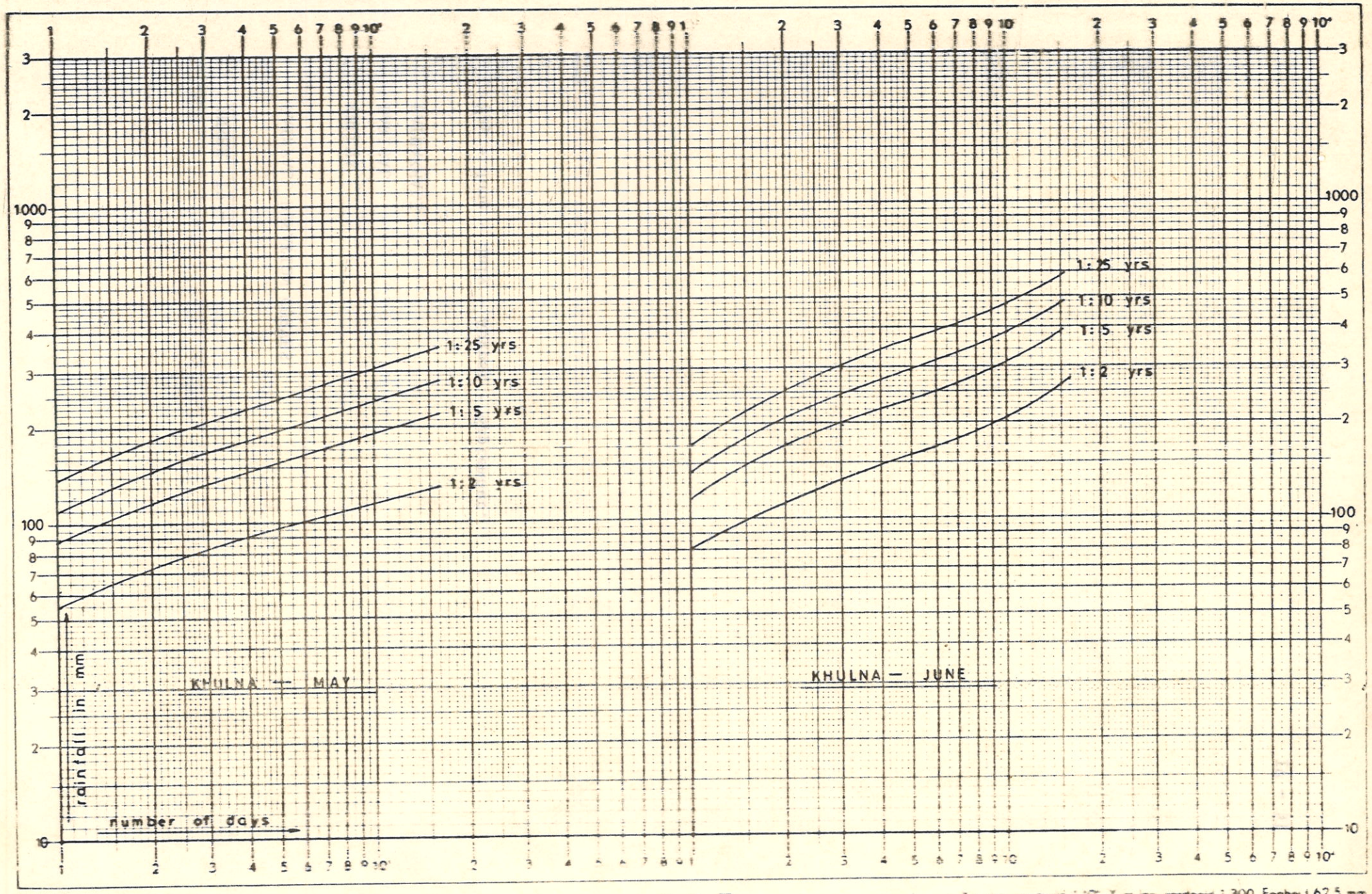
RAINFALL DURATION CURVES.

KHULNA

BARISAL

PATUAKHALI

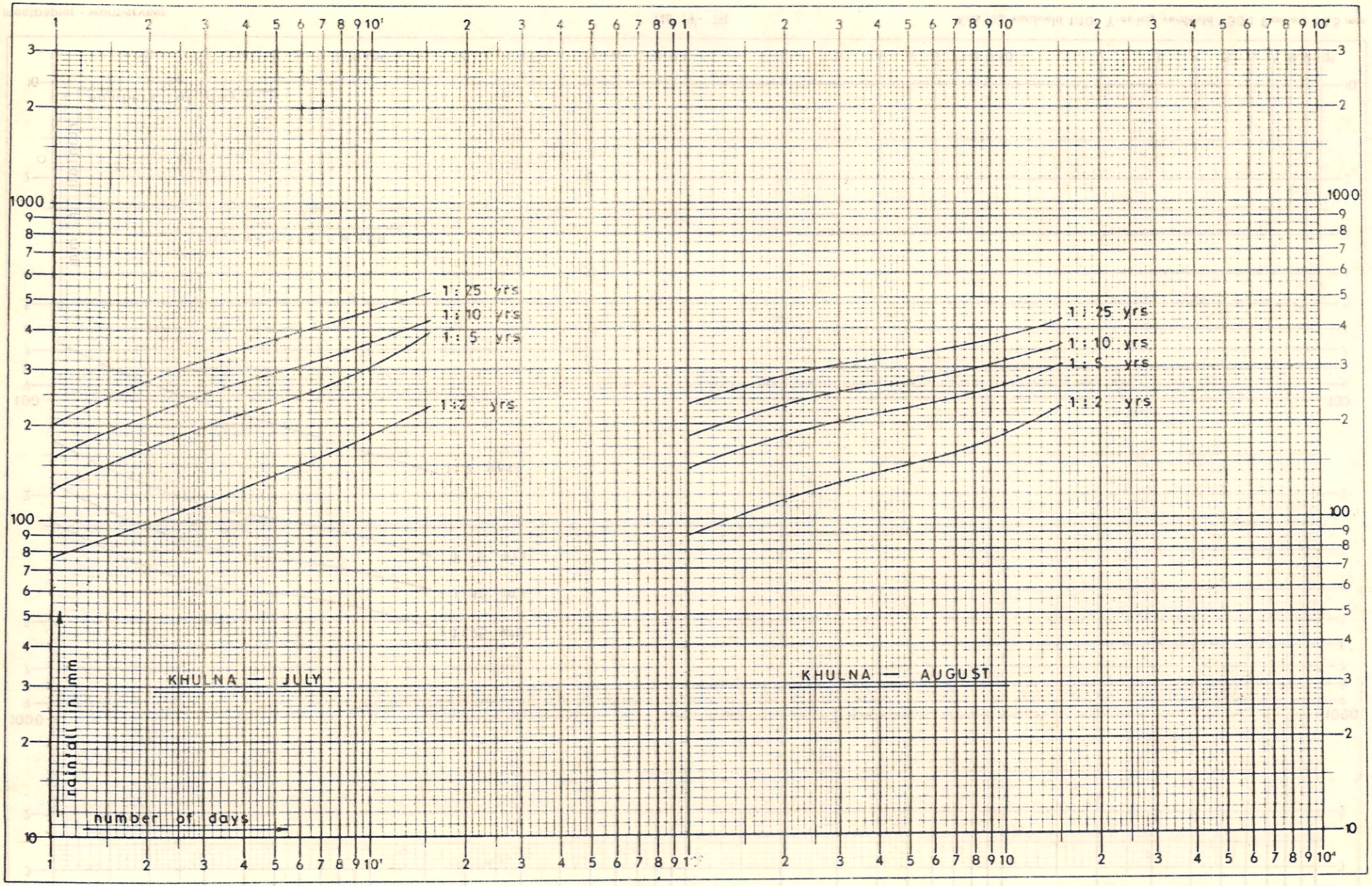
May - June - July - August - September.



meetpapier - wormerveer

No 19 TE

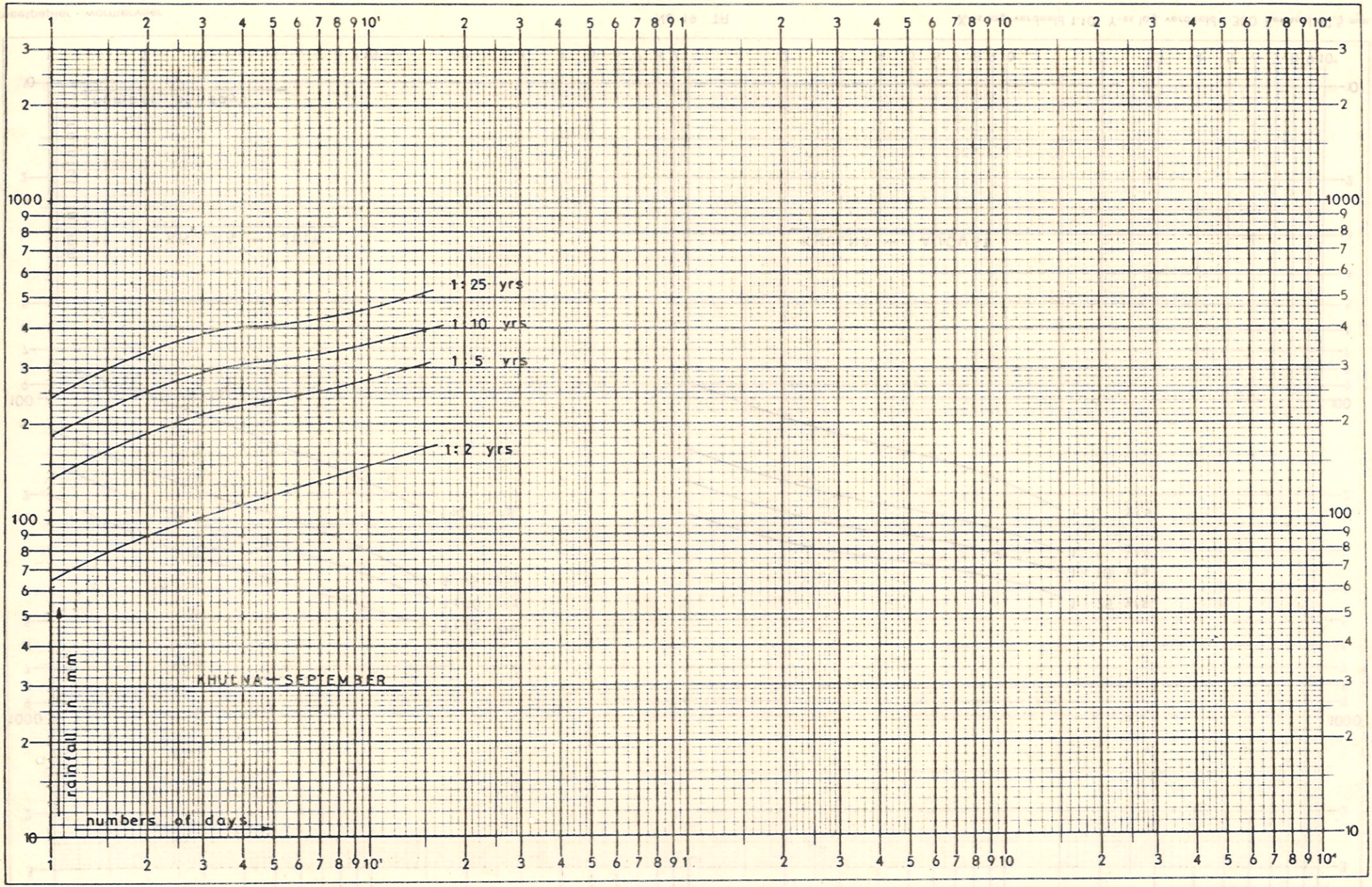
X-as log verdeeld 1:10 Y as log verdeeld 1:300 Eenheid 62.5 mm



meetpapier - wormerveer

No. 19 TR

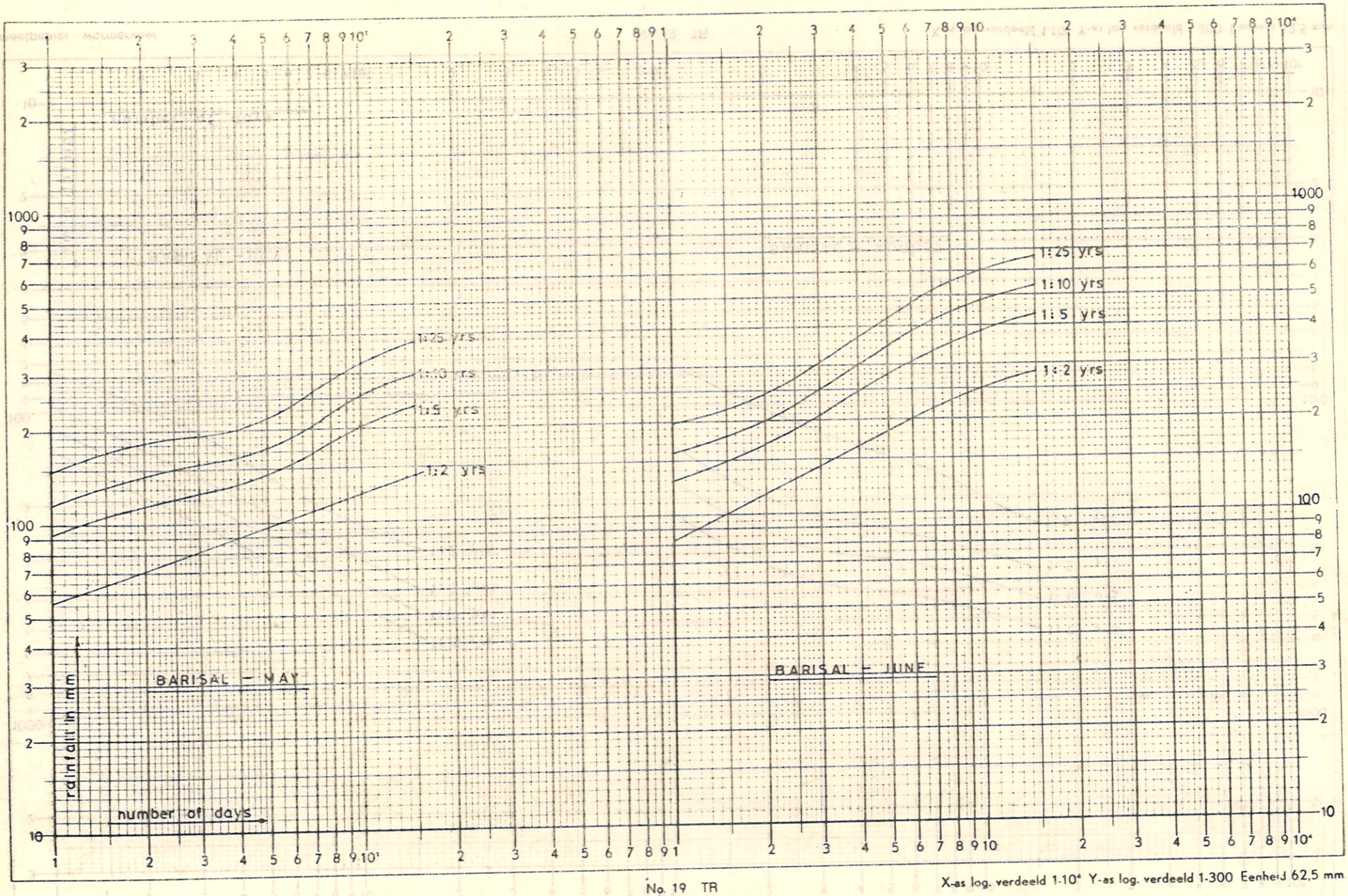
X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.



meetpapier - wormerveer

No. 19 TR

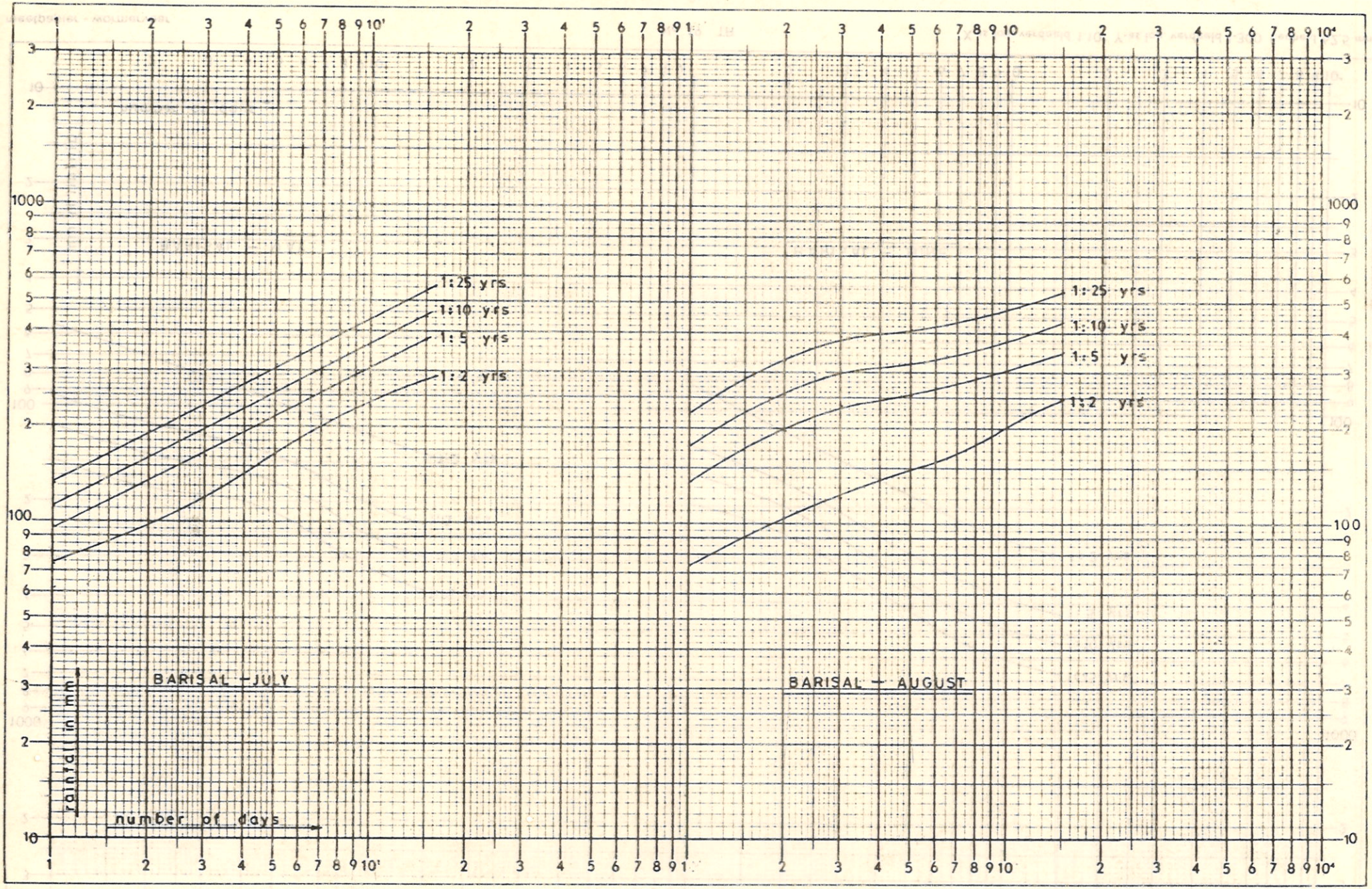
X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.



No. 19 TR

X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm

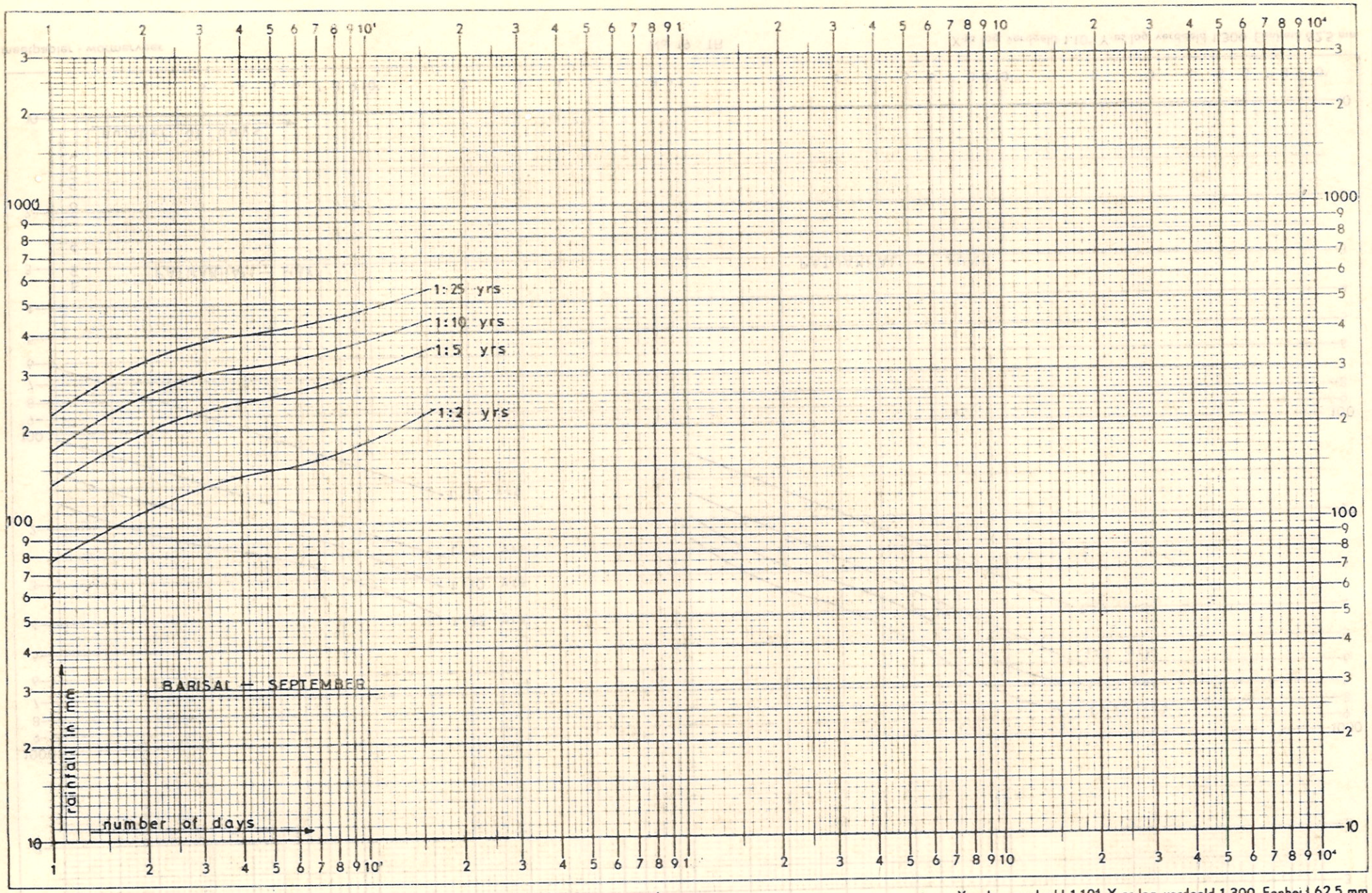
meetpapier - wormerveer



meetpapier - wormerveer

No. 19 TR

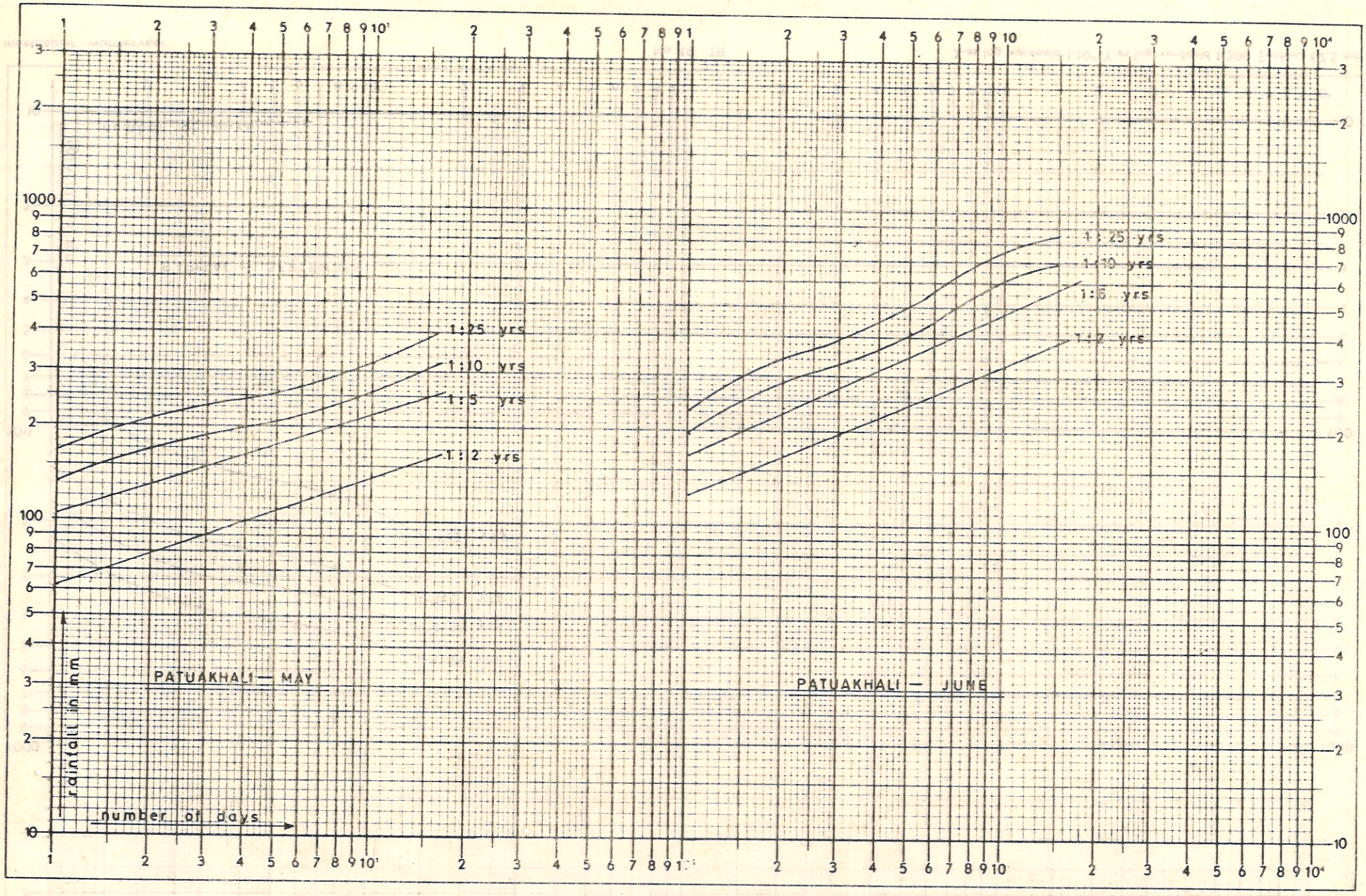
X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.



No. 19 TR

X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm

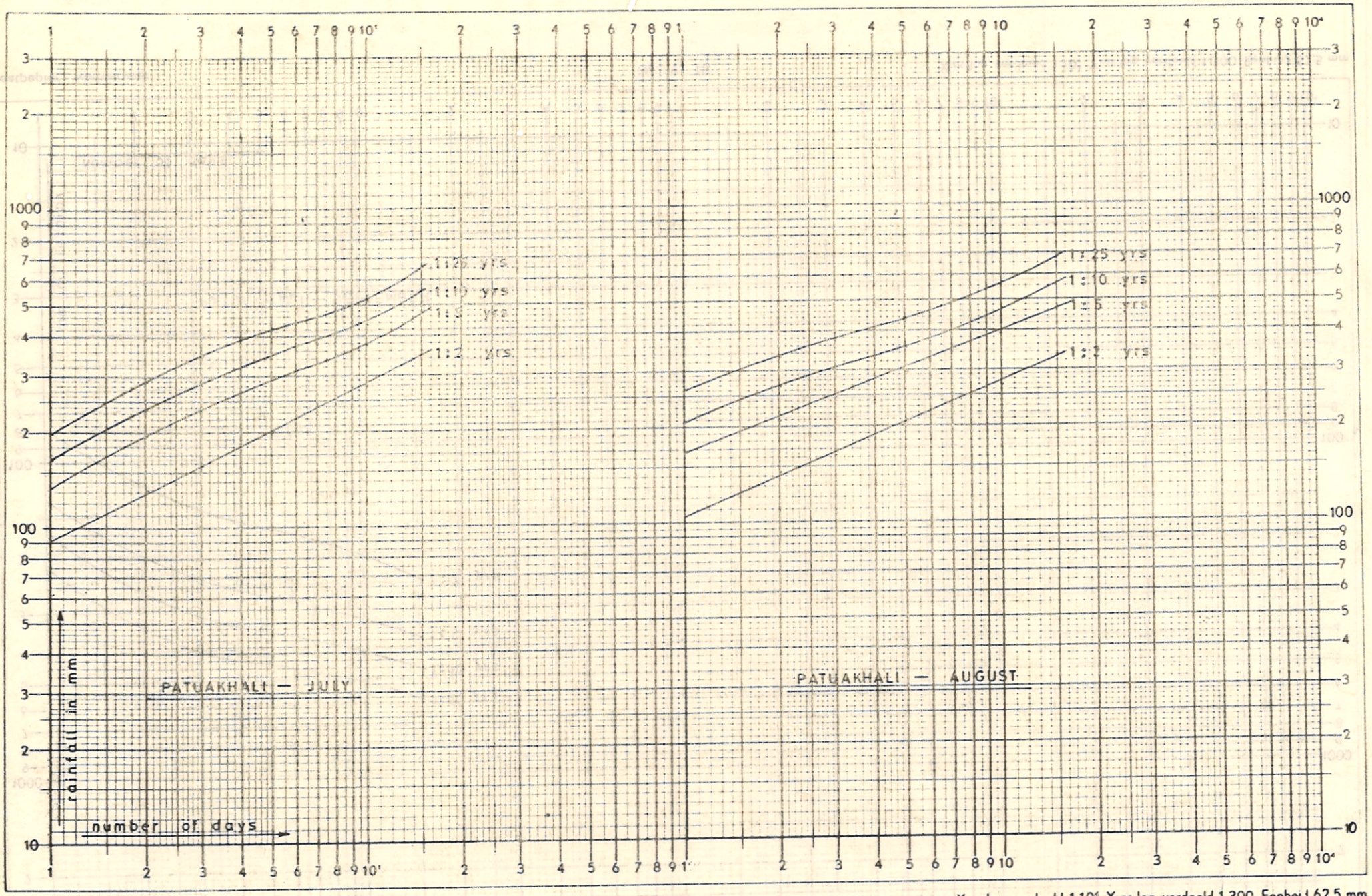
meetpapier - wormerveer



meetpapier - wormerveer

No. 19 TR

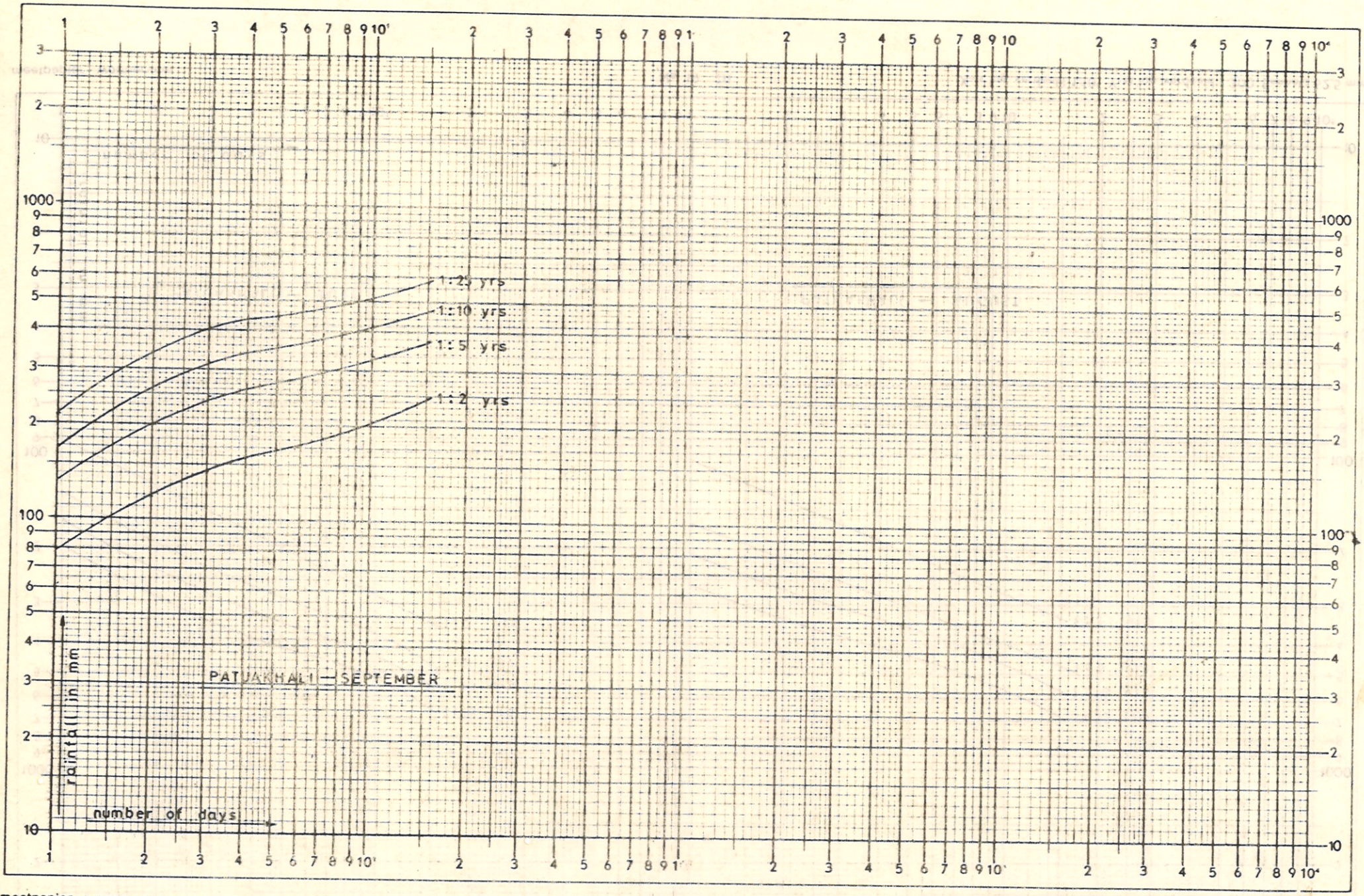
X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.



meetpapier - wormerveer

No. 19 TR

X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.



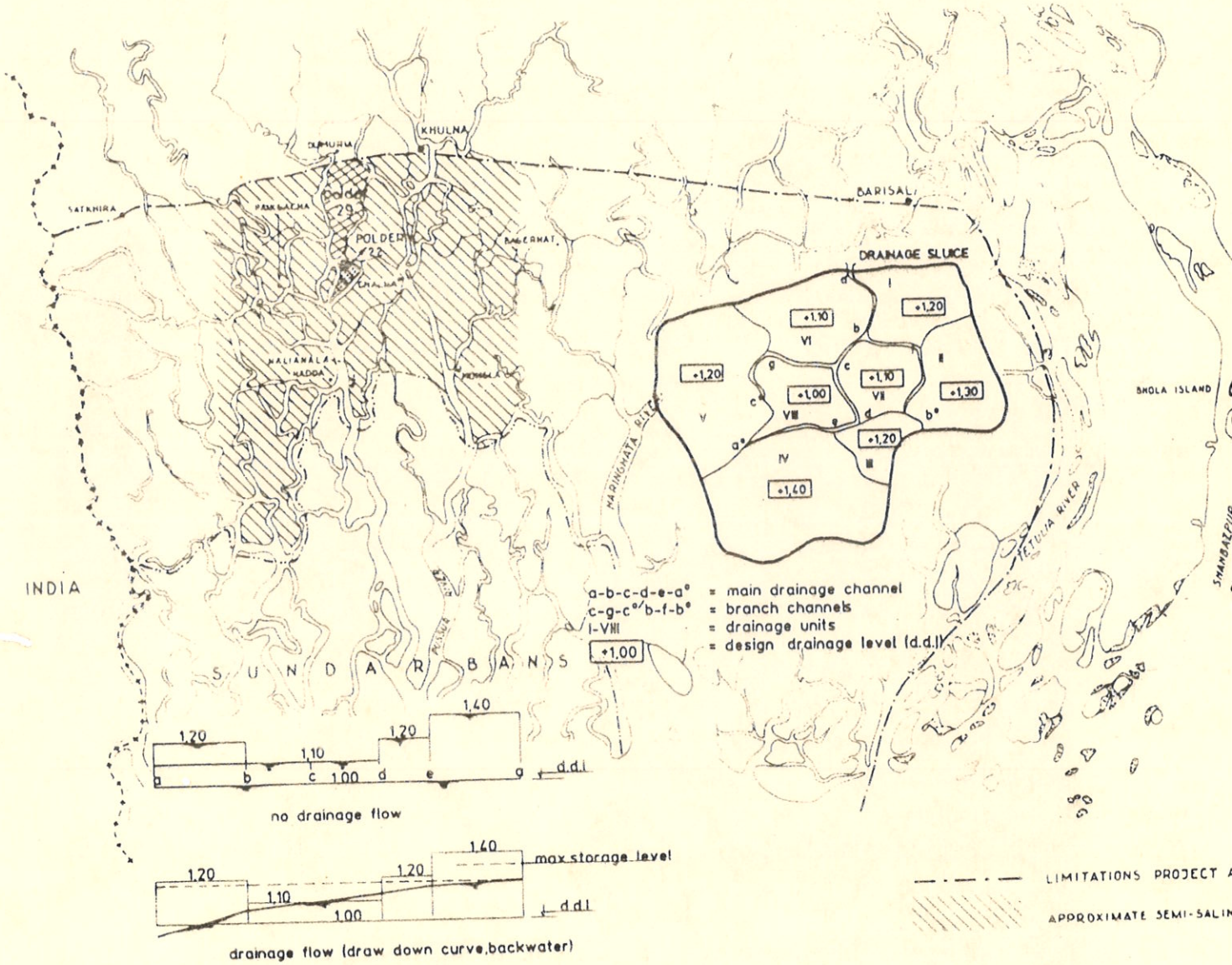
meetpapier - wormerveer

No. 19 TR

X-as log. verdeeld 1-10⁴ Y-as log. verdeeld 1-300 Eenheid 62,5 mm.

DESIGN MANUAL

FOR POLDERS IN SOUTH-WEST BANGLADESH



ANNEX PART 1

DELTA DEVELOPMENT PROJECT
BANGLADESH-NETHERLANDS JOINT PROGRAMME
UNDER BWDB

DHAKA
NOVEMBER 1985

DESIGN MANUAL

FOR POLDERS IN SOUTH-WEST BANGLADESH

ANNEX PART 1

DELTA DEVELOPMENT PROJECT
BANGLADESH-NETHERLANDS JOINT PROGRAMME
UNDER BWDB

DHAKA
NOVEMBER 1985

ANNEX PART I - COMMENTS ON REMARKS OF DESIGN CIRCLE-I.

Introduction

Late September and early October 1985 the project sent the final draft version of this manual to the Chief Engineer, Design. The remarks received back are given below along with the project's comments. The main part concerns drainage modulus. Other subjects are use of peat soil for construction of embankment, split crest embankment and free board height.

Remarks of Design Circle-I on Design manual Vol-II, III & IV submitted by D.D.P. & communicated vide Chief Engineer, Design's U.O. No. 852 dated 25.9.1985.

1. It appears that the concept of finding drainage modulus and adopting them in estimating flood discharge provides only one maximum discharge of designed storm. A drainage structure designed from that discharge is capable to drain the discharges at any time of the inflow hydrograph of the basin without accepting any storage volume. This provides an excess drainage provision while concept of unit hydrograph as followed in the design office makes the provision of forming expected hydrograph of designed storm and creats the scope of routing through regulator to fix an exact size of regulators under acceptable inundation of the basin. So concept of finding discharge from drainage modulus is only the peak & can only be used when data are not adequately available for hydrograph routing. Therefore it is suggested that the manual should also provide the scope of routing concept of designed hydrograph of a basin generated from the unit hydrograph.

2. In Fig. IV-2.1 a procedure has been described to find out drainage modulus from the depth duration frequency relation curve. Following observations are made for clarification.

a) The procedure is missing to count losses due to percolation, transpiration, evaporation, interception etc. & thus recommend excess drainage modulus. The concept appears to have not excluded rainfall losses correctly & generates exergerated drainage modulus.

b) Shape (in respect of contour) of the basin have not been counted in the concept. A deep saucer type & flat type basins generate same drainage modulus under this concept.

3. It is noted that 1:25 years curve generate 85 mm/day run-off modulus at field storage of 100 mm. And a field storage of 200 mm generates a run-off modulus of about 35 mm/day from the same curve. According to the calculation shown in page IV-II a flat area of 1 ha with field storage between 100 mm to 200 mm may originate drainage modulus of about 12 mm/day. So the difference should have been 12 mm/day or close to it. Such big difference is confusing & invites clarification. On the other way around the objection can be made more observations considering the basin to be flat & embanked from the all sides. The 1:25 years curve with field storage 100 mm generates drainage modulus 80 mm/day, 150 mm storage generates 50 mm/day & 200 mm storage generates 35 mm/day. Though the storage difference from 100 mm to 150 and 150 mm to 200 mm is more or less same, difference of run off modulus is significant.

4. It is stated that the above method of estimation of discharge & drainage modulus has been adopted from the publication 16 of the institute of land reclamation & improvement (Ref.1). From the above three observations it appears to us that there are certain limitations for the approach which have not been totally incorporated in this manual.

5. In Fig. No. IV-2.5 of draft manual submitted by the same consultant routing concept was included. An objection was given on adoptibility of the concept in the meeting with Chief Engineer, Design during last month. It was decided that the consultant will design one regulator from the concept & that will be compared with the result calculated from the procedure described in the manual of WDB. But without making the concept clear and comparing the result the chapter has been excluded from this manual. The reason therefore initiate scope of discussion & clarification. More over post monsoon routing concept has not been dealt with at all.

6. In page III-17 of Vol. III provision of shrinkage and settlement of the embankment has been recommended. Allowances for settlement of

the peat sub-base has been suggested as 50%. But it has not been stated as to whether the peat soil can be used for construction of the embankment itself. If yes, under what condition & with what percentage of shrinkage allowance the embankment should be constructed.

7. Page III-20 Art. 4.2 of Vol. III. The recommendation of the technical team of WDB during visit to polder 22 on March'84 was to use normal embankment section instead of split crest embankment as shown in Fig. III 4.2 vide no. 331 (13) dated 25.3.84 of Director, Design-I. The technical team apprehended that the narrow crest of the embankment may be damaged due to walking of cattle & man specially during rainy season thereby endangering the safety of the embankment.

8. In page-III-8, for fixing the height of the embankment. 1 m safety margin i.e. free board has been suggested over design flood level plus wind set up plus wave run up. It is practice here to adopt free board of 3' or 5' (considering different types of rivers) which includes every of these provisions over designed flood level. As such, it appears that the scope of re-thinking & discussion is available to reduce the safety margin of the embankment in many cases.

Comments on Remarks of Design Circle I on the Design Manual Volumes II, III & IV

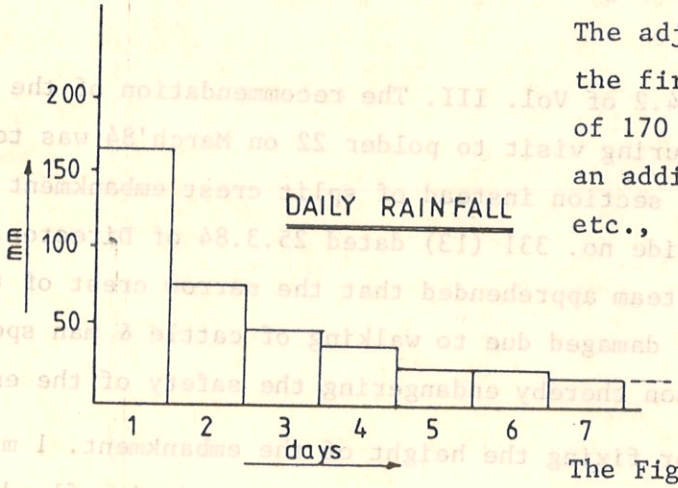
1. The question put forward under point 1 is whether the method of determination of design drainage discharge as presented in the manual does not give too high values in comparison with the unit hydrograph method. Especially the aspect of storage is also mentioned in this respect.

   An additional explanation and justification of the method adopted in the manual seems therefore appropriate.

   The concpet for determination of the design drainage discharge as presented in the manual is based on the inflow hydrograph obtained via statistical analysis of rainfall data of the specific area as explained in paragraph IV-2.3 of the manual.

   Annex IV-1 of the manual show rainfall duration curves for various months for three main stations. The information in these curves can

be re-plotted as shown in Figure IV-2.1 of the manual. The thus obtained depth-duration frequency relation could also have been plotted as shown below.



The adjacent graphs shows during the first day an in-flow (rainfall) of 170 mm, during the second day an additional rainfall of 80 mm, etc.,

The Figure IV-2.1 of the manual should be seen as a cumulative graph of this in-flow hydrograph.

This "inflow" - hydrograph could be used both for the determination of the outflow discharge via unit hydrograph method and the drainage modulus concept.

In de Unit Hydrograph concept, a discharge hydrograph for the drainage channel-cum-drainage sluice is determined, yielding a certain maximum discharge to which the drainage channel and sluice are dimensioned.

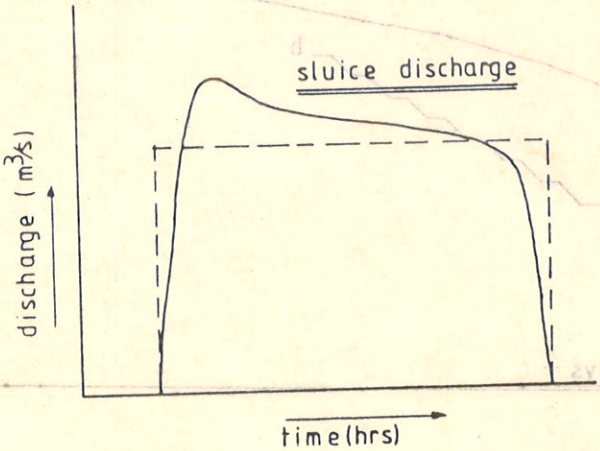
The Unit Hydrograph concept results in a discharge hydrograph which, depending on the conditions, has a lower peak and a broader base than the inflow hydrograph. But the discharge itself is not the critical issue in the drainage design.

For rice polders, the criteria is the maximum permissible water layer in the fields during a design rainstorm period.

The other important aspect is the fact that the drainage discharge in the main drainage channel is restricted by the tidal lockage of the drainage sluice. Therefore, a clock-shaped drainage hydrograph with a base of several days cannot develope. Furthermore, it should be realised that the design drainage level in the polder is a farily stagnant water level in the drainage channels. Only during the

tidal drainage period of a few hours, a gradient will develop towards the sluice, but this gradient flattens very quickly after the sluice is locked by the tide. Because of the above features the "unit hydrograph concept" has been replaced by a method which corresponds much closer with the actual physical features in polders in the Bangladesh Delta where predominantly rice is cultivated.

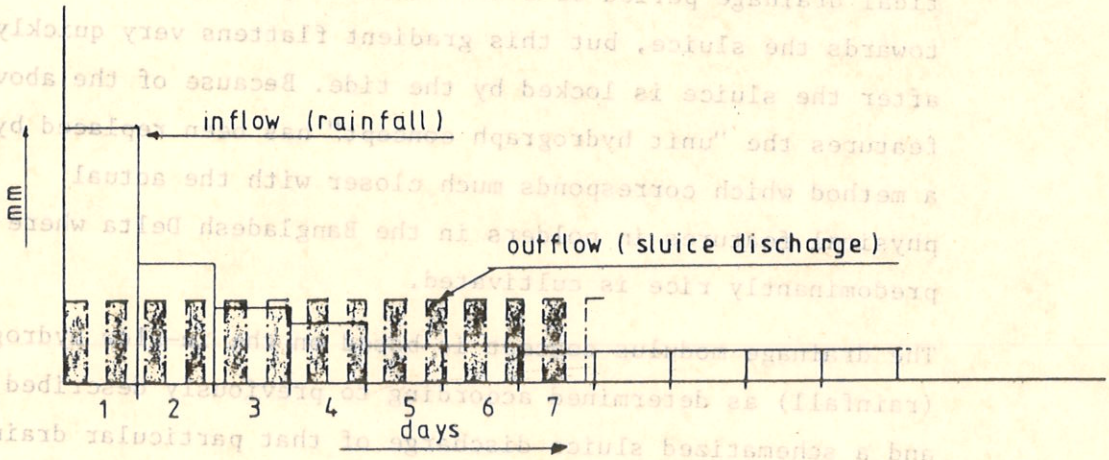
The drainage modulus concept is based on the in-flow hydrograph (rainfall) as determined according to previously described methods and a schematized sluice discharge of that particular drainage area. The sluice discharge during a tidal cycle is shown in the next figure.



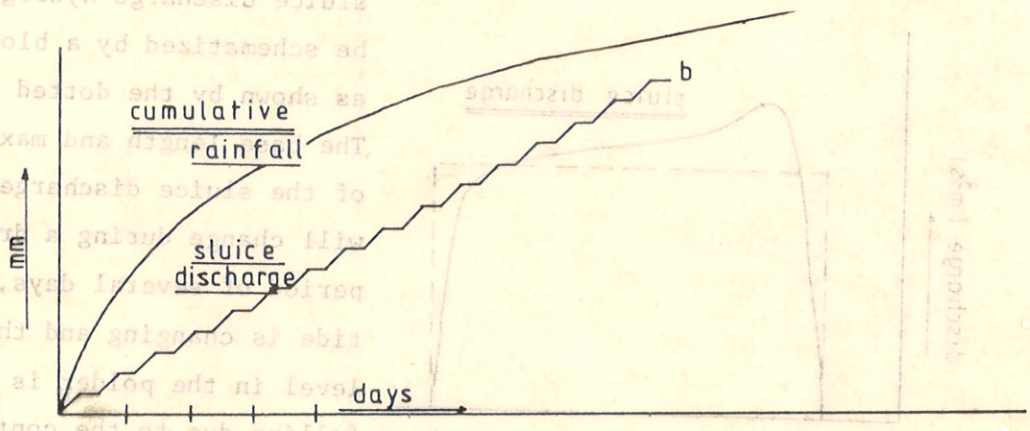
It's shape is nearly uniform for all tidal drainage sluices. The sluice discharge hydrograph can be schematized by a block-shape as shown by the dotted line. The base length and maximum value of the sluice discharge hydrograph will change during a drainage period of several days, since the tide is changing and the water level in the polder is rising and falling due to the continuous inflow of excess rainwater and intermittant outflow during the tidal drainage hours.

However the change in duration and discharge is only marginal.

For simplification reasons, the sluice discharge is therefore schematized to this block shape with a constant height and base. The polder in-flow hydrograph (rainfall) is now plotted in the same graph as the sluice discharge, yielding the following graph.



If this graph is plotted in a cumulative way, the result will look very much like Figure IV-2.1 of the manual.



In Figure IV-2.1 of the manual the dented line b of the above graph has further been schematized to a straight line a*.

The difference between the inflow-line and the outflow-line is the amount of water stored, expressed in mm. The storage takes place over the whole polder area, including fields, ditches, channels. The drainage criteria is that the flooding caused by this storage may not exceed a certain level (100-300 mm, depending on the cultivated varieties) and/or may not exceed a certain duration.

To meet the criteria the sluice discharge line (b) gradient may be changed to a convenient value, after which the average sluice discharge for the drainage period can be determined.

The gradient of the sluice discharge line is the drainage modulus (expressed in mm/day).

Excessive drainage modulus can only result if the criteria were taken too conservative i.e. :

- frequency of rainstorms
- initial field storage
- maximum permissible water level in the fields
- duration of flooding above a certain depth
- evacuation time of a certain flooding.

The routing of a designed discharge hydrograph according to the Unit Hydrograph concept through the drainage sluice is not appropriate because of the tidal restriction at the sluice. However, a complete routing of the tidal drainage period with the polder water level and the tide as boundary conditions, has been included in the design manual as ANNEX V-5.3-D.

2. a) The procedure for determination of the drainage modulus in rice fields as applied in this manual (ref. ILRI) assumes that any percolation losses and evaporations during the drainage period are compensated by run-off from adjacent fields.
It may be remarked that generally the percolation is low in comparison with the amount of excess water to be evacuated.
Moreover, harmful inundations mostly occur in low areas, where percolation is very low. The assumption does not generate exaggerated drainage modulus values.

b) The statement made here is correct. Per definition the drainage modulus will be the same for any shape of the area.
In general, the slope of a drainage area will affect the storage capacity and the shape of the discharge hydrograph.
But the drainage modulus is something different than a discharge hydrograph of a drainage channel.
In non tidal conditions the discharge hydrograph of a drainage channel has a clock shape. In tidal areas, this discharge is an intermittant block shape. The average gradient of the comulative block discharges is the drainage modulus.

3. The calculation shown on Page IV-11 only demonstrates how the

quantity (mm/day) is transferred to (liters per second per hectare).

1 mm/day over an area of 1 ha. means:
10.000 m^2 x 0,001 m/day = 10 m^3/day per hectare
= 0,12 liter per second per ha.

The difference between drainage modulus 85 mm/day and 35 mm/day for fieldstorage of 100 and 200 mm respectively has no relation at all to the above transfer calculation.

Also the differences between fieldstorage levels of 100, 150 and 200 mm in relation to the differences in corresponding drainage modulus of 80, 50 and 35 mm/day are not correlated linearly.
If a certain rainstorm hits a rice field with short straw varieties and an initial water layer of 100 mm, then additionally 100 mm can be stored on the fields resulting in a drainage modulus of 80 mm/day. If the initial water layer in the fields was only 50 mm, an additional 150 mm could have been stored, requiring a drainage modulus of only 50 mm/day. If no water was on the fields, then 200 mm could be stored, requiring a drainage modulus of 35 mm/day.

Because the gradient of the rainfall duration curve is at first very steap and then gradually decreases, the relation between the drainage moduli and the increasing storage levels is not linear.

4. Limitation of the drainage modulus concept have been incorporated in above comments. The most important are summaized hereunder:

- The method applies to rice polders where undesirable flooding by excess rainfall during critical phases of the rice growth has to be prevented.

- In the method presented in the manual it is assumed that any run-off from adjacent areas or any irrigation water entering the drainage system are compensated for by evaporation and percolation losses.

5. With the above additional clarifications it is hoped that the drainage modulus concept will be clear to the user of the manual. A worked out example of the complete design of a drainage sluice,

including the determination of drainage modulus is included in the manual as VOLUME IX in which also the drainage modulus determination is extensively treated. A comparison with the Unit Hydrograph method and the post monsoon routing concept have not been included.

6. Peat soils should not be used for embankment construction.

7. Whether the application of split level crests on embankments will be introduced on a larger scale is a matter of evaluating construction costs and maintenance costs to keep the embankment up to its design dimensions. The experiences in Polder 22 with the crest bund indicate that maintenance of this type of embankment is not likely to cost more than the maintenance of conventional embankments.

8. The freeboard adopted by the BWDB Design Department is said to include any provisions for wave run up and wind set up and a safety margin. In the new concept, a split up has been made in which the formerly applied freeboard of 3-5 ft is replaced by a safety margin of 1 m and additional calculated or estimated height for wave run-up and wind set up.

   The safety margin of 1 m is not only to cover any uncertainties in the calculation process of the design crest level, but also to have a margin for maintenance works. Further reduction of the 1 m safety margin would make the maintenance work more critical.