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TECHNICAL NOTE

NO. 5

A DRAINAGE COEFFICIENT FOR THE DESIGN OF TERTIARY DRAINS AT LAM NAM OON

SAKON NAKHON, THAILAND

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(REVISED)

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INTRODUCTION

Paddy fields do not require drainage of excess rain water in the same way as fields planted to other crops. Rainfall filling the paddies flows from one paddy to the next lower paddy until the surplus water accumulates in a depression. Large areas of paddy fields may be submerged in such depressions. The yields of rice are effectively reduced by submergence for extended periods. Therefore it is imperative to reduce the period of submergence to tolerable limits.

Drains should be constructed with sufficient capacity to remove the excess water within the time limits. The time of submergence tolerated by the rice varies with the variety and the turbidity of the water.

The rate of runoff from paddy fields depends on the frequency, the intensity and duration of the rainfall and a drainage coefficient or modulus is used to describe the rainfall relationship to the drainage area. Two methods for estimating the drain capacity are described in the following pages. These are applied to the Lam Nam Oon irrigation area in Sakon Nakhon province, Northeastern Thailand. Rainfall analysis for rainfall patterns specific to the area also comprises a part of the foregoing application, this, too, is described in the following pages.

PART I

BACKGROUND

A. Review of the Methodology

The drain design capacity criteria used by the Royal Irrigation Department (RID) at Lam Nam Oon is given in the following table based on information provided by the Design Section of RID in Bangkok.

Drain Design Capacities

1. For Drain Channel Capacity

Non-Cultivated areas;	0.7 m^3/s per Km^2
Cultivated areas (paddy);	0.5 m^3/s per Km^2

2. For Structures

All kinds of land;	1.0 to 1.5 m^3/s per Km^2

In addition, for the Lam Nam Oon Project area a table for drainage ditch capacity is based on a drainage modulus of 0.0004 m^3/s per rai, (4 lps/rai).

Neither the technical basis for nor the source of these data has been discovered by the author.

The former consultants at Lam Nam Oon, E.C.I.* proposed a drainage modulus of 0.944 litres per sec. per rai, based on a 10 year rainfall design frequency and a 3 day duration based on rainfall records from the Sakon Nakhon Meteorological Station. The equation used to obtain this modulus will be given later in this paper.

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* Memorandum "Lam Nam Oon-Reclamation Problem Areas and Preliminary Drainage Modulus." April 25, 1974. Engineering Consultants, Inc.

In general, there are two methods of estimating the drainage coefficient (which is the same as the drainage modulus). The first, is a graphic method based on a plot of the rainfall-duration frequency curves, and the second, from estimates based on calculations from the periodic frequency values for reoccurring rainfall. All these data are based on local station rainfall data. Both these methods are used in this paper to provide comparative values for a drainage coefficient for the Lam Nam Oon area.

An alternative method of estimating the drainage coefficient is based on the ratio of the area submerged to the total area of the contributing catchment. This method is widely used for drainage design of paddy fields in Indonesia.* This procedure is applicable to the Northeast region and to other parts of Thailand too. An example of this method is included in this paper and it is recommended that this procedure should be used for the design of tertiary drains on the Lam Nam Oon project.

The Array of Drainage Coefficient's

1. Data

A review of the technical literature reveals that very little data is available concerning paddy field drainage in Thailand. Various data on drainage coefficients are available for other countries in Southeast Asia and these may be useful for comparison with data derived for the Lam Nam Oon Project area.

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* "Irrigation Rehabilitation Project." Series B. Final Report 1974. NEDECO. page 96.

The data in Table 2a, is given in two parts; the first, for 5 day rainfall reoccurring once in 5 years and the second, for 5 day rainfall reoccurring once in 10 years. Two drainage coefficients were chosen, 20 mm. per day, or 0.37 l.p.s. per rai, and 25 mm. per day, or 0.46 l.p.s. per rai. The normal water depth in the paddy is 50 mm. and the total depth of submergence is given in the last two columns. Suppression of yield occurred when the submergence depth exceeded 150 mm. for more than 5 days in the first month after planting. The last two columns in Table 2a show that submergence exceeds the safe limit for the 5 days rainfall, once in 10 years for both the drainage coefficients used. Table 2b shows that a safe coefficient of 30 mm. per (0.56 lps per rai) day will provide the required safety for the 10 years rainfall, draining the excess water off in 120 hrs. or 5 days.

These two Tables indicate a procedure for estimating the effectiveness of a drainage coefficient.

Drainage coefficients used in other neighboring countries with similar climatic conditions, namely Java and Malaysia, (Table 3a and Table 3b) indicate coefficients corresponding closely to those, estimated for the Lam Nam Oon area, in Table 9, for the 2 and 5 year return period, namely 0.23 l.p.s/rai for 100 mm. submergence for 5 days and 0.27 l.p.s/rai for 150 mm. respectively.

Data gathered in the Chao Phaya Delta* indicates that the 3-day rainfall ranged from 110 mm. once in 2 years up to 175 mm. once in 10 years and on the basis of those data a coefficient of 46 mm. or 0.85 l.p.s. per rai could be used for tertiary drain design. The rainfall tends to decrease over extended areas and on the basis of the data in Table 4 and a coefficient for that area could be reduced to 30.25 mm.

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* "Design criteria for drainage at the farm level in Asia and the Far East". ECAFE, Secretariat Bankgok 1970.

or 0.56 l.p.s. per rai. However, this value should not be used as a universal drainage coefficient for the whole of Thailand and further research should be conducted to derive drainage coefficients for each of the irrigation projects in Thailand.

2. The Submergence of Rice and Yield Reductions

Conclusive research evidence has shown that the yield of most rice varieties, other than "swamp" rice, are reduced by excessive submergence. Furthermore, tall varieties are more adapted to areas with less dependable water control.* Traditional varieties are generally taller and High Yielding Varieties (H.Y.V.) are shorter. Grain yields of a rice crop decrease with increased water depth. The effect of submergence on yield is shown in Figure 1.

The optimum depth of water for high yield varieties are 50 mm. and depths greater than this will suppress yields, while at depths of 150 mm. to 200 mm. yield will be considerably reduced if the plants are submerged for periods in excess of 3 days.

Observations at Suphan Buri, Thailand indicate; "in the dry season, average water depth was about 100 mm. ranging from 2.4 mm. to 394 mm. there are a 50 mm. difference between shallow, moderate and deep locations. Water was deepest in the middle of the growing season and shallowest between flowering and harvest. In the wet season, average water depth was about 120 mm., varying from 185 mm. to 381.8 mm. Water

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* Tropical Climate and Its Influence on Rice." Shouichi Yoshido. I.R.R.I. Research Series No. 20., July 1978.

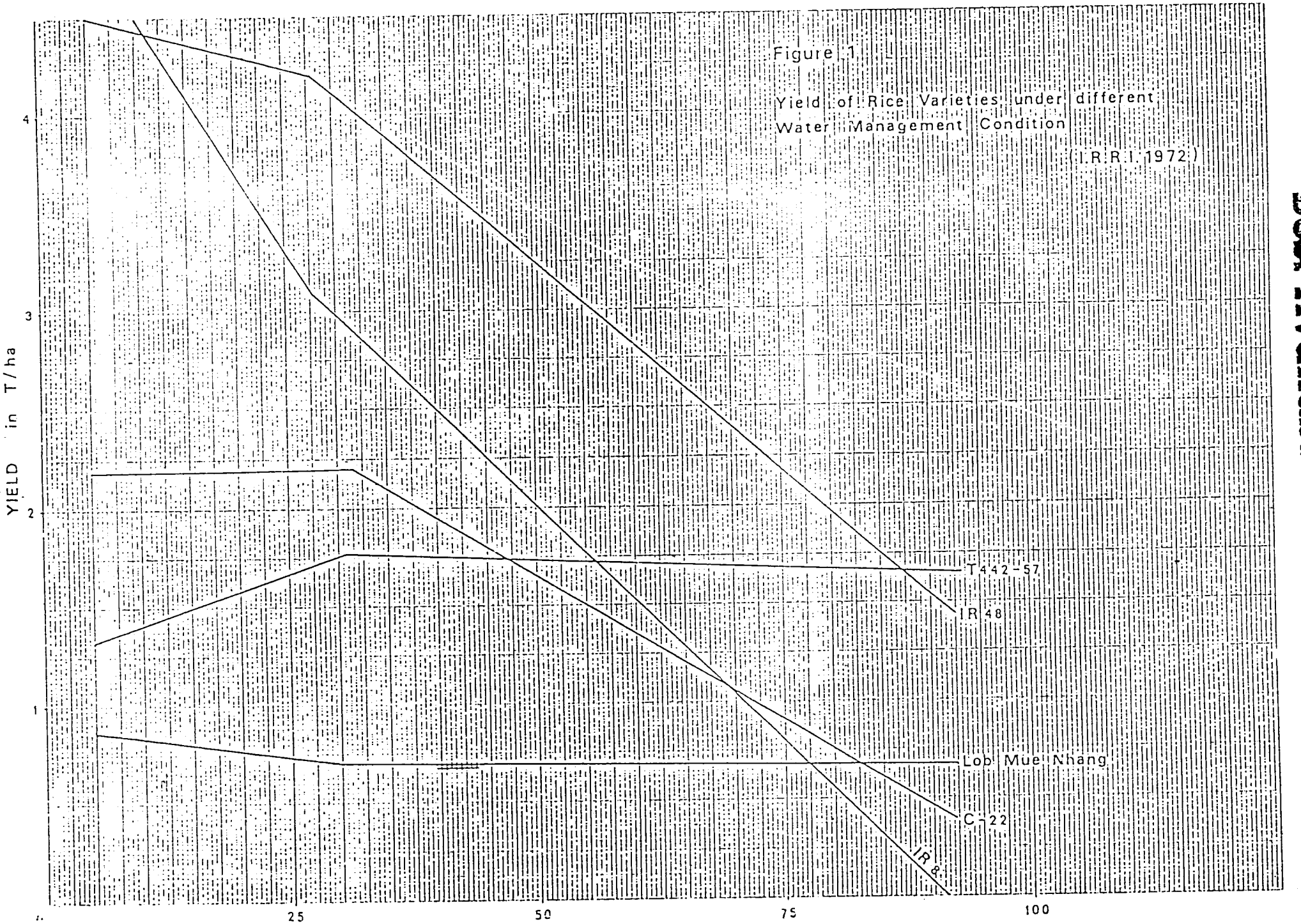

Figure 1

Yield of Rice Varieties under different Water Management Condition

(I.R.R.I. 1972)

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was deepest between flowering and harvesting".* From these observations it is possible to note that there is a relation between water depth and the growing period, as well as between the seasons. The water depths and corresponding yields in Table 5 indicate that better yields are obtained at shallower water depth in the wet season, while the converse appears to be true for the dry season. Significance of this may be attributed to higher fertilizer application rather than water depth (see Table 5).

However, in the Northeast of Thailand more glutinous rice is grown than non-glutinous varieties. The glutinous rice comprise primarily very tall local varieties adapted to deeper water than normal and it is not uncommon to find depths of 300 to 350 mm. and yields do not seem to be affected. This may be the case as glutinous rice is traditionally grown under rainfall conditions in this region. Paddy bunds are higher, ranging from 400 mm. to as much as 600 mm. and deeper water layers are maintained to conserve erratic rainfall besides controlling weeds. With the advent of irrigation at Lam Nam Oon in the near future assuring a reliable supply of water the paddy bunds can be made lower; high bunds constitute quite an investment in labour, for construction and for maintenance, besides harbouring weeds and pests. Shallower water layers may will be adapted but weed control by weedicides may have to be introduced.

In time the farmers of the Lam Nam Oon project area may change to better yielding non-glutinous rice varieties responsive to fertilizer but this will only occur once the reliability of the water supply has been established and the risk of flooding has been minimized. Moreover, the extensive cropping of non-glutinous rice will solely depend on an established, reliable market.

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* "Farm-Level Constraints to High Rice Yields in Asia." 1974-1977. I.R.R.I. 1979, page 315, Tables 23 and 24.

The better-yielding glutinous varieties tend to be shorter than the traditional varieties and in the absence of established local data a maximum water layer depth of 100 mm. can be used as a basis for design, though 200 mm. should never be exceeded.

The period of submergence, from all available evidence, should not exceed three days and five days is an absolute maximum. Submergence in clear water could be tolerated for the longer period but turbid, muddy water should be drained away rapidly.

Furthermore, the critical growing stages of the rice plant, when submergence may cause the greatest suppression of yield, are at transplanting, at tillering and at the panicle initiation stage.

At Lam Nam Oon the paddy fields range in area from 0.20 rai up to 0.6 rai. The smaller paddies tend to occur on the steeper, upper slopes while the longer paddies occur on the flat valley floors.

The height of the bunds appear to be consistently between 0.40 to 0.60 metres, usually the higher bunds occur more frequently. Gaps in the bunds, used as spillways, have not been observed in the project area. In Southeast Asia simple bamboo spiles are used for maintaining the water levels in the paddies and these are commonly used at Lam Nam Oon.

The overall effect of paddy size and bund height on drainage is that the paddy system is capable of storing most of the rainfall that occurs in any protracted period of rainfall, within the "normal" season; say, for rainfall that may occur once in 2 years. However, this system would overflow when capacity of the paddies are exceeded on the occasion of

more intensive rainfall or rainfall occurring for long periods. Under these conditions the lower-lying valley floor will be flooded to depths submerging the rice plants for periods that may induce yield reduction.

Based on observation of drainage conditions at Lam Nam Oon during the wet season of 1980, it would appear that much of the flooding of paddies is caused by an inadequate main drainage system which inhibits proper drainage of the tertiary areas. Another problem arises from the effect of back-flooding from the main river systems in the vacinity of the project. This problem should be investigated in the wet seasons of 1982 and 1983.

B. The Land Form of the Project Area at Lam Nam Oon

The land form has a specific bearing on the drainage of the paddy fields. The whole area at Lam Nam Oon is generally a terrace system with low ridges and valleys with the ridges no more than two to three metres above the valley floor, over distances of 1000 to 1500 metres, and average land slopes range from 1 in 300 to 1 in 500.

The natural drainage channels meander across the flat valley floors. The bed slopes in the upper reaches tend to be steeper, about 1 in 800; the intermediate slopes, about 1500 and the slope toward the main drainage system - the Huai Pla Hang stream, flatten out again to about 1 in 1100.

The Nam Oon river water slope is in the region of 1 in 10,000 m. and Huai Pla Hang is of the same order.

C. Analysis of Rainfall Data

Only three rainfall stations, with extensive records are located within or close to the project area.

The rainfall station at Sakon Nakhon is a first order station operated by the Meteorological Department. The other two stations, at Phanna Nikhom and Waritchiphum are located at the Changwat offices, and they are only third order rainfall stations.

There are two other stations at the Lam Nam Oon project. One is at the Sakon Nakhon Rice Experiment Station and the other at the Lam Nam Oon Project Office. Data from these two stations have not been used in this study.

The rainfall and climatic data have been reviewed elsewhere* and a detailed discussion of the meteorology and hydrology of the project area is available in the Feasibility Report Supplement.**

A duration frequency analysis of the maximum cumulative daily rainfall done by the Author is based on computer print-outs of daily rainfall records from 1952 to 1980 provided by the Royal Irrigation Department (R.I.D.) for the three Stations. Only the Sakon Nakhon Station was used to derive the drainage coefficients. The reason for using the one station is partly that the reliability of the Sakon Nakhon station is of a higher order than the other two and it is also generally representative of the whole project area.

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* Technical Note No. 6 "Estimates for Irrigation Water Requirement - Lam Nam Oon" September, 1982.

** "Lam Nam Oon Irrigation Project Feasibility Report Supplement". E.C.I. June 1970.

The maximum daily total rainfall for 1, 2, 3, 4, 5 and 6 days were derived from these data, covering a period of 29 years for the Sakon Nakhon Station.

The duration frequency curves in Figure 2 area based on the Type III, limited extreme value distribution. These data are shown in Table 6.

Tables 6a, 6b and 6c give maximum daily rainfall data for Sakon Nakhon, Phanna Nikhom and Waritchaphum. These data should be used for determining the drainage coefficient.

Tables 7a to 7f show maximum daily rainfall for the months April to September for the Sakon Nakhon Nation and these data are plotted in Figures 4 to 10.

FIGURE 2

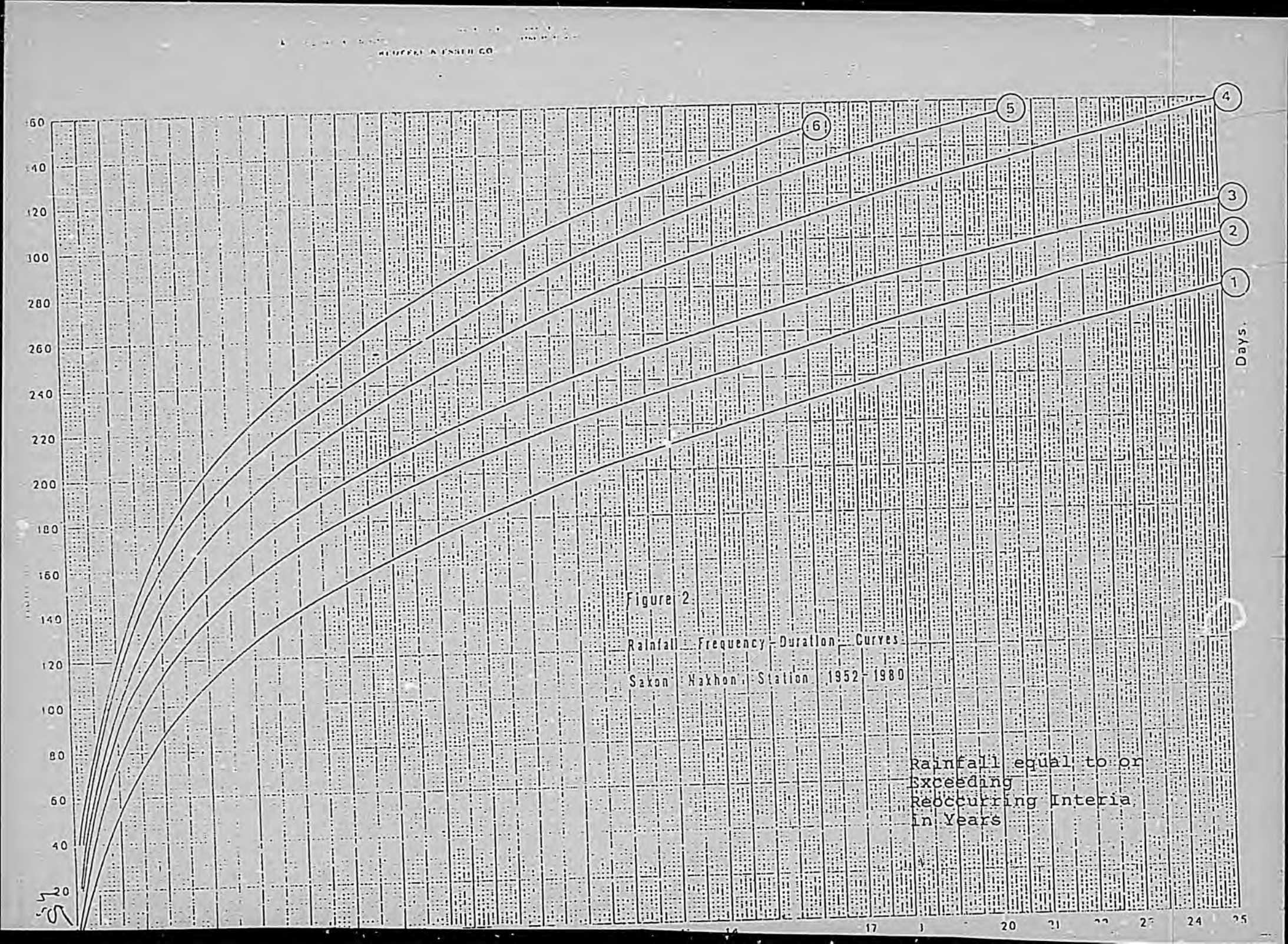

Figure 2.

Rainfall - Frequency - Duration - Curves

Saxon Haxhon Station 1952 - 1980

PART II

DETERMINING THE DRAINAGE COEFFICIENT

A. ECI Method

A method for estimating a drainage coefficient (or drainage modulus) is given in an E.C.I. memorandum.* The equation used to express the drainage coefficient is,

$$Dc = Pn + In - \Delta Sn - Cu(n) - If(n) \ldots\ldots 1$$

where,

Dc = surface drainage runoff in m.m., in a time period of n days

Pn = precipitation in m.m. in the same period of n days

In = irrigation supply in m.m. in the same period of n days

Δ Sn = difference in storage of water in m.m. on farm fields between beginning and end of the same period of n days

Cu(n) = crop water use in m.m. during the same period of n days

Ifn = infiltration or deep perculation in the period of n days

In applying this equation it was assumed that the value of the term, If(n), would be zero; the irrigation supply, In, and change in storage, ΔSn, would cancel each other out, therefore,

$$Dc = Pn - Cu(n)$$

* E.C.I. Memorandum. April 25, 1974, file No. 1084/188/B 273/74. "Lam Nam Oon - Reclamation Problem Areas and Preliminary Drainage Modulus."

A 3 day period was used to calculate the relevant drainage coefficient. If water used by the crop during the 3 day period was calculated to be 29 m.m. and the rainfall for the 10 year return period is 182 m.m., then

$$Dc = 1/3\ (182-29)^{*}$$
$$= 51.0 \text{ m.m./day}$$

and, convert this value by 1/54, gives,

$$= 0.944 \text{ l.p.s. per rai}$$

B. The ILACO (Indonesia) Method

A similar equation based on the water balance procedure is widely used in Indonesia.** The drainage coefficient is based on the following criteria.

a. Area of submergence

Excess water concentrates in depressions which occupy between one fifth (0.2) to one third (0.33) of the total catchment area in flat areas and one fifteenth (0.7) in steeply sloping areas. (For most of the Lam Nam Oon area a value of 0.25 to 0.3 may apply but the ratio should be measured from the contour maps.)

b. Rainfall Return Period

The economic criteria chosen is that on an average of once every 2 or 5 years damage may result from too high a water level in the paddy fields. (Here again, observations to determine this fact will have to be made for Lam Nam Oon; but it would appear that these values are applicable).

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* The factor 1/3 does not appear in the other equations above.

** "Rehabilitation of Drainage System facilities". Part I and II. Proyek Irigasi I.D.A. Series A. July 1972.

c. Depth of Submergence

Yield reduction will occur if the rise in water level exceeds 100 m.m. for a period exceeding 3 days and if the average rise in this period is more than 200 m.m. (These values are strictly applicable to short straw, non-glutinous varieties, however, it must be assumed that shorter strawed, high yield varieties will be grown on the Lam Nam Oon project in the future and excessive submergence will depress yield of those varieties, therefore, these submergence values will be used for design on the Lam Nam Oon project).

The following equation is used to estimate the drainage coefficient, based on the above criteria,*

$$Dc = 1/3\ R(1, max)\ T + 1/3\ R(2, max)\ T - 400/3A - Cu(n) \ldots\ldots 2$$

Dc = drainage coefficient, in m.m. per day

R(n, max) T = maximum rainfall, in m.m. during n days, equal or exceeded on an average of once in T years. (For example, the 2 day rainfall once in 3 years and the 3 day rainfall once in 3 years, are taken together).

$\frac{400}{3A}$ = The value of A, the lower part of the area on which water is allowed to collect and rise to more than 100 m.m. during 3 days, can be measured from contour maps. However, once a ratio for a particular land form has been established, such as for specific land forms which prevail within the project area then the value of A may be adjusted accordingly. A value of A = 4 should be used.

* See Appendix I for the derivation of this equation.

While a higher value may have to be selected at some later time this value should suffice for the present.

Cu(n) = crop water use, in m.m. for the period n days. This value can be approximated by using a mean daily value of 5.00 or 6.00 m.m. or an exact value can be derived from the crop water use study for the period of the anticipated maximum rainfall.*

The return period used for estimating the drainage coefficient for tertiary and other structures are outlined below.

T = 2 years, for small structures and tertiary drains.

T = 5 years; for tertiary, secondary and primary drains where the F.S.L. of the drains should remain below the field levels (this excludes back flooding from the main drainage system)

T = 10 years; for river or natural drains where the F.S.L. should remain below dyke crest levels.

T = 50 years; for freeboards of primary structures, drains etc which protect roads, villages and permanent property.

The above mentioned criteria are generally applicable for any method of ascertaining the drainage coefficient for any climatic situation.

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* See Appendix I.

A modification of this foregoing equation is also widely used and similar to equation 1,

$$Dc = R(n, max)\ T + n\ (In - Cu(n) - If(n)) - A.\ \Delta Sn \quad .....3$$

where,

Dc	=	drainage coefficient
n	=	number of consecutive days
R(n, max) T	=	rainfall during n consecutive days with an average return period of T years, m.m.
In	=	irrigation water supply in n days, m.m.
Cu(n)	=	Crop water use, m.m.
If(n)	=	infiltration in n days, m.m.
Δ Sn	=	storage differential, n days, m.m.
A	=	the size of the area of depression as a percentage of the whole catchment area, %.

The calculation of the drainage coefficient based on equations 2 and 3 for the Sakon Nakhon rainfall data are given in Table 8.

C. The "Depth - Duration - Frequency Curve" Method

The final procedure for estimating the drainage coefficient is based on indices derived from the "Depth-Duration-Frequency" curves derived from rainfall data from the main meteorological station. The curves for Sakon Nakhon are shown in Figure 2. The drainage coefficients for various submergence depths have been derived from the curves on Figure 3 and shown in Table 7. The principles of the derivation and the method of deriving the drainage coefficient are given in Appendix II.

FIGURE 3

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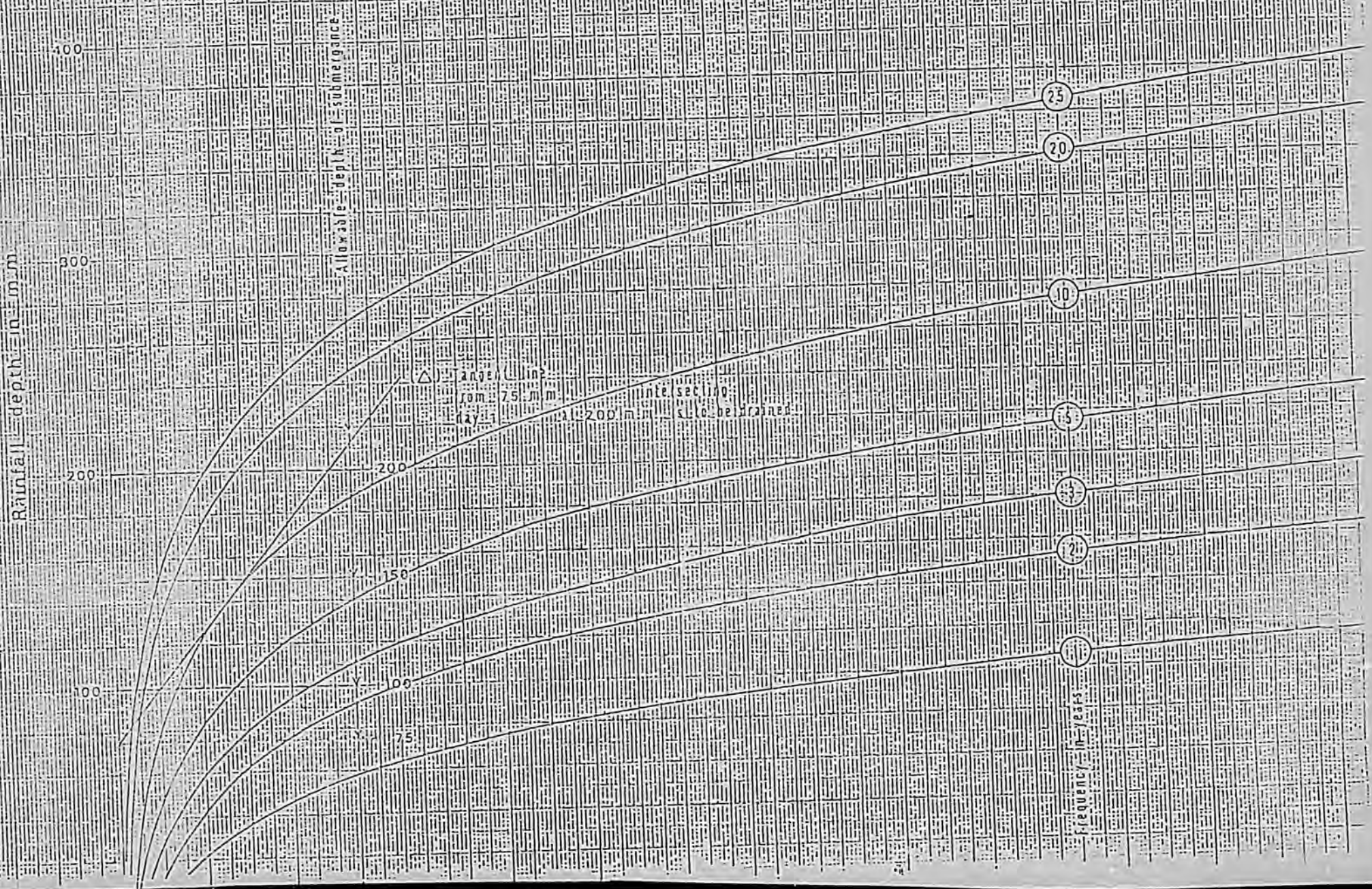
Figure 3

Depth - Duration - Frequency Curves for Sakon Nakon Rainfall Data



D. The Drainage Coefficient

Drainage coefficients, have been calculated using equations 2 and 3 and values derived from the curves in Figure 3.

A comparison of the the values of the drainage coefficients obtained by these different methods are given in Table 11.

The coefficients taken from Table 4 and Table 9 are comparable, being based on the premises that the values represent discharge from a flat unit area and represents the run off of surplus water when the paddy overflows, flowing into a drain. These values do not apply to ponded conditions. The values derived from the curves in Figure 3 tend to be higher than those in Table 9, because the values are derived from an integrated time base rather than from a linear time base; though the coefficient is greater it provides a higher degree of safety and should be used for critical structures and high value property, roads etc. The coefficients given in Table 9 may be used for tertiary drain design in non-ponded areas. These values will give less costly drain dimensions with a high degree of reliability.

A comparison of the coefficients in Table's 7 and 10, the values obtained from using equation 2 are greater than those of equation 3. Observations have shown where rainfall is more extensive, for example, in Malaysia, Sulawesi and Java and possibility in Southern Thailand, this equation gives very safe drainage protection; however, equation 3 and the derived values in Table 10, should be used for ponded conditions on the Lam Nam Oon project.

PART III

USE OF THE DRAINAGE COEFFICIENTS FOR DESIGN

A. Tertiary Drains

1. Non-Ponded Conditions

For tertiary drains on flat terrain; usually farms bordering drains on the upper slopes; the drainage coefficients recommended are taken from Table 9, for

i. a return period of 2 years,

ii. maximum submergence of 50 m.m.,

iii. for a 3-day period

the value of the coefficient is 0.53 lps. per rai.

2. Ponded Conditions

Ponded conditions occur frequently on the Lam Nam Oon project. (A notable example occurs on Pilot Area 2 Unit II). The area of the whole contributing catchment is measured - by means of a plenimeter - and the area within contour of the anticipated inundation. The ratio of the areas is expressed as a percentage and the recommended coefficient can be either calculated by means of equation 3 or obtained from Table 10, for,

i. a return period of 5 years,

ii. maximum submergence of 100 m.m.

iii. for a period of 3 days

This method should be used to estimate the size of drains discharging from a closed basin although other subsidary drains are used within that basin.

B. Tertiary Structures

It is recommended that the capacity of tertiary structures should be based on a more critical drainage coefficient using values taken from Table 9 for,

i. a return period of 5 years,

ii. zero submergence,

iii. for a period of 3 days

For culverts under canals a 10 year return period may be used, however, it would be advisable to use the coefficient in Table 7. The appropriate return periods are outlined following equation 2.

APPENDIX I

A RATIONAL DRAINAGE EQUATION FOR PADDY FIELDS

1. The Drainage Mechanism

The discharge of excess water from paddy fields can be discribed as follows:

a. After a heavy rainfall water flows from higher paddies to lower paddies, bunds behave as small weirs.

b. In sloping areas, these small weirs behave as a broad-crested weir and the discharge is dependent on the up stream water level, while in flat areas the discharge is dependent on downstream water levels.

c. In both sloping and flat areas free discharge from paddy to paddy will not create submergence. The rapid rise and fall of the water level in paddies will not cause yield reduction.

d. However, the lowest paddy fields do not have the opportunity to discharge freely and facilities will be needed to drain off the water.

e. In fairly steeply sloping areas fair to satisfactory drainage occurs while in very flat areas drainage has to be provided. (In the case of the Lam Nam Oon project area, in this terraced land form the valley sides slope from 1 in 300 to 1 in 500 and the flat valley floors, from 1 in 1500 up to 1 in 2000 or more).

2. The Derivation of the Drainage Coefficient Equation

The drainage equation development here is based on the expectation of yield reductions resulting from excessive submergence. The yield reduction is determined by the average rise in water level - submergence - during some period when the water level had risen more than 100 m.m. and for the duration

for that period. Though it is not necessary to know what actually happens to the water levels in the low lying paddy fields, it is sufficient to know that flooding to a depth of 100 m.m., or more, does occur within reoccurring intervals. The measurement of this phenomenon, will be the objective of investigation on the Lam Nam Oon project in the future.*

The drainage coefficient equation is based on the following assumption.

a. Excess water from higher paddies immediately flows to lower paddies after rainfall.

b. The excess water - from rainfall-concentrates in depressions which occupy a fractional part (1/A), part of the total catchment area.

c. Irrigation water supply does not occur during this period; therefore, the rise of the water level, in the low-lying area, after n days can be calculated, using,

$$D = A(R(n, max)\ T - n\ (Dc + Cu) \quad \ldots\ldots 1$$

where

D = rise of water level after n days in m.m.

A = total catchment area

R(n, max)T = maximum rainfall during n days reoccurring once every T years

Dc = drainage coefficient in m.m./day

Cu = crop water use in m.m./day

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* "Project Planning Note No. 1 A Water Efficiency Measurement and Training Work Plan for Pilot Areas 2 and 3A" September 9, 1981.

The following observations apply to conditions prevailing in rice paddy areas.

d. In most irrigated rice growing areas where flooding occurs the depressions occupy between one fifth to one third of the total area, however, greater or lesser values may occur on the Lam Nam Oon project. Therefore A will range from 3 to 5, a value of 4 may be used as a first approximation at Lam Nam Oon. By using $A < 4$, it will mean that for a smaller relative value of A yield reduction, on an average, will be greater on larger areas that are flooded and conversely, for $A > 4$, yield reduction will be less on larger areas and greater on smaller areas. The use of 4 will tend to even out the losses over a long period.

e. As an economical criterium a return period of 2 or 5 years in used, assuming that yield reductions will occur because of submergence within these periods.

f. Generally, no yield reduction will occur if the period during which the rise of the water level exceeds 100 m.m. is less than 3 days and the average rise during this period is less than 200 m.m. Observation of rainfall in the tropics indicates that most of the rainfalls during the first 2 days of an extended rainfall period, viz a 3-day period. Therefore, the first 2 days of rainfall will contribute to the average rise of the water level which is equal to or less than 200 m.m.

Taking all the foregoing factors into account the follow equations can be derived from the equation 1 in (c) above;

$$D_1 = A\ (R(1, max)\ T - Dc - Cu) \quad .....2$$

and

$$D_2 = A\ (R(2, max)\ T - 2Dc - 2Cu) \quad .....3$$

therefore, combining,

$$\frac{D_1 + D_2}{2} = 1/2\ A\ ((R\ (1, max)\ T + R\ (2, max)\ T - 3\ Dc - 3\ Cu)); \quad .....4$$

where

where D < 200. Rearranging and solving for Dc, the following equation is obtained:

$$Dc = 1/3\ R\ (1, max)\ T + 1/3\ R\ (2, max)\ T - \frac{400}{3\ A} - Cu(n) \quad .....5$$

It should be noted that R (1, max) T, means that the one day rainfall is used for a reoccurring interval of say, 2 years and then the 2 day rainfall for that same reoccurring interval. The reoccurring interval is chosen according to the degree of protection needed, as discussed in the main part of the paper.

APPENDIX II

THE DERIVATION OF DRAINAGE COEFFICIENTS, FROM DEPTH-DURATION-FREQUENCY CURVES

The statistical analysis of the maximum cumulative daily rainfall is plotted on square graph paper, Figure 3, for the required return period, in years.

To obtain the required drainage coefficient (or design discharge) for each return period, tangent lines are drawn from the intersection, on the vertical ordinate, of the "Allowable Submergence Depth", from 75 m.m. to the 10 year return period. Therefore, the intersect on the ordinate is 200 minus 75 m.m. which is equal to 125 m.m. or 2.315 lps. per rai. This procedure is repeated for the other return periods and for different depths of submergence.

A mathematical analysis and the validity of the derivation of this procedure may be found in standard references on meteorology and hydrology, viz- "Handbook of Applied Hydrology" Ven Te Chow, 1964 and " Short Duration Rainfall Intensity Estimates and Other Design Aids for Regions of Space Data:. B.M. Reich, 1963. J. of Hydrology.

Table 1

The Effect of Submergence on Rice Yields at Various Stages of Growth.

Crop Growth Stages	Clear Water				Turbid Water			
	Days Submerged							
	1 - 2	3 - 4	5 - 7	+7	1 - 2	3 - 4	5 - 7	+7
	% Reduction in Yield							
20 days after Transplanting	10	20	30	35	-	-	-	-
Young panicle formation partly inundated*	10	30	65	90/100	20	50	85	90/100
Young panicle formation, completely inundated.**	25	45	80	80/100	70	80	85	90/100
Heading Stage	15	25	30	70	30	80	90	90/100
Ripening Stage	0	15	20	20	5	20	30	30

Apter H. Fukuda and H. Toutoui (1968)
"Rice Irrigation in Japan" F.A.O. Rome.

Table 2 (a)

Cumulative Rainfall and Drainage Factors in the Setjanggang Area, Sumatra, Indonesia 1971.

Day	Cumulative Rainfall	Cumulative Drainage Coefficient 20mm/day (a)	Cumulative Drainage Coefficient 25mm/day (b)	Excess water in Field m.m. a	Excess water in Field m.m. b	Water level m.m. Normal height m.m.	Water level m.m. Total Depth a	Water level m.m. Total Depth b
Once in 5 years, 5 day Rainfall.								
1	110	20	25	90	85	50	140	135
2	130	40	50	90	80	50	140	130
3	150	60	75	90	75	50	140	125
4	165	80	100	85	65	50	135	115
5	180	100	125	80	55	50	130	105
6	180	120	150	60	30	50	110	80
7	180	140	175	40	5	50	90	55
Once in 10 years, 5 day Rainfall.								
1	120	20	25	100	95	50	150	145
2	150	40	50	110	100	50	160	150
3	170	60	75	110	95	50	160	145
4	190	80	100	110	90	50	160	140
5	210	100	125	110	85	50	160	135
6	210	120	150	90	60	50	140	110
7	210	140	175	70	35	50	120	85
8	210	160	200	50	10	50	100	60
9	210	180	225	30	-	50	80	50
10	210	200	250	10	-	50	60	50

Table 2 (b)

Time Required to Drain the Indicated Rainfall in hours.

Rainfall Duration	Daily Periodic Rainfall m.m.				Water level excedence m.m.	Drainage Coefficient m.m./24 hrs.				
	1st day	2nd day	3rd day	4th day		30	40	50	60	70
						(time in hrs.)				
1 in 2 yrs.	49	69	82	-	40	60	32	21	17	14
1 in 5 yrs.	63	91	107	-	55	108	58	37	26	21
1 in 10 yrs.	74	112	130	-	65	>120	83	57	40	31

Note These are the conversion factors: l.p.s. per ha $= \frac{\text{m.m.}}{8.64}$

l.p.s. per rai $= \frac{\text{m.m.}}{54}$

(ILACO Report to Government of Indonesia, 1971).

Table 3 (a)

Drainage Modules according to rainfall reoccurence in Java, Indonesia. Harza, 1968.

Reoccurence Years	m.m./day Range					Average	l.p.s./ha. Range					Average	l.p.s./rai
2	19	26	32	46	65	37	2.3	3	3.7	5.3	7.5	4.3	0.69
5	31	39	59	79	110	63	3.6	4.5	6.8	8.7	12.7	7.3	1.17

Table 3 (b)

Drainage Modules according to rainfall reoccurence in Kelantan, Malaysia.

Reoccurence Years	Drainage Module acres / cusec.	Equivalent Water Depth m.m.	Equivalent l.p.s./ha.	l.p.s./rai
2	20	31	3.6	.576
5	11	57	6.5	1.04
10	7.5	83	9.6	1.54

Table 3b. from "Progress Report, Kemuba Rice Project", Malaysia, 1970.

Table 4

Maximum Rainfall/Total Area relationship during 10 days period in Chao Phya Delta.

Return Period	1 Station		2 Stations		10 Stations		18 Stations	
	m.m.	lps/rai	m.m.	lps/rai	m.m.	lps/rai	m.m.	lps/rai
2	160	.296	140	.259	135	.250	135	.250
5	250	.463	230	.426	200	.37	200	.37
10	320	.59	280	.519	250	.463	250	.463

Note: The area covered by each station are as follows.

2 Stations 10,000 ha.
10 Stations 220,000 ha.
18 Stations 700,000 ha.

From: "Design Criteria for Drainage at the Farm level in Asia and the Far East", ECAFE, 1970

Table 5

Use of Inputs by farms with different Average Depth of water standing in their Rice paddies; Suphan Buri (1976).

Water depth cm.	Fertilizer ฿/rai	HYV. %	Herbicides %	Insecticides %	Yield kg/rai
		Wet Season			
0 - 5	119	67	0	33	630
5 - 10	94	73	36	27	567
10 - 15	85	29	29	29	536
> 15	73	75	12	25	500
		Dry Season			
0 - 5	78	100	0	33	496
5 - 10	126	100	29	54	604
10 - 15	130	100	39	50	636
> 15	108	100	50	75	651

From: "Farm-Level Constraints to High Rice Yields in Asia, 1974 - 77", I.R.R.I. 1979 pp. 315, Table 24.

Table 6

Sakon Nakhon 1952 to 1980
Maximum Cumulative Daily Rainfalls in m.m.

Cumulative Rainfall	Return Period - years						
	1	2	3	5	10	20	25
1 Day	56.5	90.9	112.3	142.0	190.9	253.5	277.4
2 Days	76.6	114.9	137.9	168.6	217.2	276.9	299.1
3 Days	89.4	130.2	154.1	185.6	234.7	293.9	315.7
4 Days	99.5	146.0	173.3	209.4	265.9	334.4	359.7
5 Days	111.9	161.3	189.8	223.4	285.4	354.9	380.3
6 Days	120.5	172.7	202.7	242.2	303.1	375.7	402.2

Note: These values have been calculated by means of the Limited Extreme Value Distribution using the Type II evaluation for fitting the data.

Table 6a

Sakon Nakhon 1952-1980

Cumulative Maximum Daily Rainfall (Period)

Maximum Daily Rainfall mm							
Cumulative Probability	Return Period in years	1 day	2 day	3 day	4 day	5 day	6 day
.01	1	56.5	76.6	89.4	99.5	111.9	120.5
.50	2	90.9	114.9	130.2	146.0	161.3	172.7
.67	3	112.3	137.9	154.1	173.3	189.8	202.7
.80	5	142.0	168.6	185.6	209.4	223.4	242.2
.90	10	190.9	217.2	234.7	265.9	285.4	303.1
.96	25	277.4	299.1	315.7	359.7	380.3	402.2

See Table No. 6. Technical Note No. 5

Table 6b

Phanna Nikhom

Cumulative Maximum Daily Rainfall (Period)

Cumulative Pro-bability	Return Period in years	Maximum Daily Rainfall (Period) mm					
		1 day	2 day	3 day	4 day	5 day	6 day
.01	1	74.10	78.63	95.41	101.79	115.92	127.04
.50	2	95.05	119.17	139.49	152.64	169.13	183.71
.67	3	106.21	134.42	155.71	171.65	188.70	204.42
.80	5	120.13	152.83	175.09	194.54	212.05	229.08
.90	10	140.29	180.21	203.52	228.42	246.30	265.13
.96	25	170.65	221.91	246.15	279.81	297.60	318.90
.98	50	188.36	258.97	283.44	325.26	342.43	365.72

Table 6c

Waritchaphum

Cumulative Maximum Daily Rainfall (Period)

Maximum Daily Rainfall mm							
Cumulative Probability	Return Period in years	1 day	2 day	3 day	4 day	5 day	6 day
.01	1	61.91	88.17	103,22	118.22	130.83	141.74
.50	2	99.73	137.94	163.92	179.37	195.32	214.15
.67	3	114.51	157.04	187.43	202.39	219.36	241.35
.80	5	132.68	180.31	216.21	230.21	248.26	274.16
.90	10	160.27	215.3	259.71	271.56	290.99	322.87
.96	25	203.49	269.38	327.39	334.6	355.64	396.98
.98	50	242.92	318.10	388.76	390.65	412.72	462.75

Table 7

Drainage Coefficients derived from the Depth - Duration - Frequency Curves in Figure 3 in l.p.s. per rai.

Allowable Submergence depth m.m.	Return Period - years				
	1	2	3	5	10
75	.139	.426	.667	1.148	2.315
100		.241	.407	.722	1.556
150				.287	.695
200					-

Note: This Table is derived from the curves in Figure 3.. by the method described in Appendix II.

Table 7a

Sakon Nakhon

Cumulative Maximum Daily Rainfall

Maximum Daily Rainfall mm							
Cumulative Probability	Return Period in years	April					
		1 day	2 day	3 day	4 day	5 day	6 day
0.01	1.01	-	-	-	-	-	-
.02	1.02	-	-	-	-	-	-
.04	1.04	3.92	4.38	3.98	1.32	-	-
.05	1.05	5.79	6.54	6.31	3.93	2.27	3.58
.10	1.11	11.92	13.60	13.96	12.47	11.36	13.9
.20	1.25	19.41	22.24	23.30	22.90	22.46	25.15
.50	2.0	33.71	38.73	41.13	42.82	43.67	47.79
.67	3.0	41.20	47.36	50.47	53.26	54.78	59.65
.80	5.0	48.01	55.22	58.96	62.74	55.79	70.43
.90	10.0	55.50	63.85	68.31	73.18	75.98	82.29
.95	20.0	61.62	70.92	75.95	81.71	85.07	91.99
.96	25.0	62.50	73.08	78.28	84.32	87.85	94.95
.98	50.0	68.60	78.97	84.65	91.44	95.42	103.04
.99	100.0	73.37	84.46	90.60	98.08	102.49	110.59

Table 7b

Sakon Nakhon
Cumulative Maximum Daily Rainfall

Cumulative Probability	Return Period in years	May Maximum Daily Rainfall mm 1 day	2 day	3 day	4 day	5 day	6 day
.01	1.01	-	-	-	-	-	-
.02	1.02	-	-	-	-	-	1.34
.04	1.04	-	1.74	8.77	9.03	14.14	16.73
.05	1.05	-	6.22	13.56	15.00	19.52	22.38
.10	1.11	13.48	28.88	29.24	31.92	37.13	40.85
.20	1.25	30.02	38.80	48.40	52.60	58.65	63.42
.50	2.0	61.60	73.00	84.99	92.08	99.74	106.52
.67	3.0	78.14	90.92	104.15	112.76	121.26	129.09
.80	5.0	93.17	107.20	121.57	131.57	140.83	149.61
.90	10.0	109.71	125.12	140.74	152.25	162.35	172.19
.95	20.0	123.24	139.78	156.42	169.17	179.96	190.66
.96	25.0	127.38	144.26	161.20	174.34	185.34	196.30
.98	50.0	138.66	156.48	174.28	188.44	200.02	211.69
.99	100.0	148.18	167.88	186.47	201.60	213.71	226.06

Table 7c

Sakon Nakhon

Cumulative Maximum Daily Rainfall

Maximum Daily Rainfall							
Cumulative Probability	Return Period in years	June 1 day	2 day	3 day	4 day	5 day	6 day
.01	1.01	8.81	4.32	5.59	6.79	2.17	-2.71
.02	1.02	14.59	13.30	14.82	15.12	15.01	11.32
.04	1.04	20.78	22.93	25.90	30.31	28.76	26.36
.05	1.05	23.06	26.45	29.96	34.77	33.81	31.87
.10	1.11	30.49	38.00	43.26	49.36	50.31	49.91
.20	1.25	39.57	52.11	59.51	67.21	70.48	71.96
.50	2.0	56.91	79.05	90.53	101.27	108.99	114.05
.67	3.0	65.99	93.16	106.78	119.11	129.16	136.10
.80	5.0	74.25	105.99	121.55	135.33	147.50	156.14
.90	10.0	83.33	120.10	137.00	153.17	167.67	178.19
.95	20.0	90.77	131.65	151.10	167.76	184.17	196.23
.96	25.0	93.04	135.18	158.85	172.22	189.22	201.75
.98	50.0	99.23	144.80	166.24	184.39	202.97	216.78
.99	100.0	105.01	153.78	176.58	195.74	215.81	230.81

Table 7d

Sakon Nakhon

Cumulative Maximum Daily Rainfall

Maximum Daily Rainfall							
Cumulative Pro-bability	Return Period in years	July					
		1 day	2 day	3 day	4 day	5 day	6 day
.01	1.01	-	-	-	-	-	-
.02	1.02	-	-	-	-	1.81	-
.04	1.04	-	-	2.81	8.70	14.20	13.81
.05	1.05	-	-	6.96	12.99	18.75	18.76
.10	1.11	5.44	10.35	20.52	27.03	33.62	34.95
.20	1.25	20.40	27.18	37.11	44.19	51.80	54.73
.50	2	48.97	59.31	68.76	76.94	86.50	92.51
.67	3	63.94	76.14	85.34	94.10	104.68	112.29
.80	5	77.54	91.43	100.41	109.70	121.21	130.28
.90	10	92.51	108.26	116.99	126.85	139.39	150.07
.95	20	104.75	122.03	131.69	140.89	154.26	166.26
.96	25	108.49	126.24	134.70	145.18	158.80	171.20
.98	50	118.70	137.71	146.01	156.88	171.28	184.69
.99	100	128.22	149.42	156.56	167.79	182.77	197.28

Table 7e

Sakon Nakhon

Cumulative Maximum Daily Rainfall

Cumulative Probability	Return Period in years	Maximum Daily Rainfall mm August 1 day	2 day	3 day	4 day	5 day	6 day
.01	1.01	-	-	-	-	-	-
.02	1.02	-	-	-	-	-	-
.04	1.04	-	-	-	-	-	-
.05	1.05	-	-	-	-	-	-
.10	1.11	-	-	-	-	-	5.44
.20	1.25	11.41	21.11	35.89	36.56	41.83	54.09
.50	2	78.39	96.62	114.17	126.78	135.46	146.97
.67	3	113.48	136.18	155.16	174.04	184.50	195.62
.80	5	145.38	172.14	192.44	217.00	229.08	239.85
.90	10	180.47	211.69	233.44	264.26	278.13	288.50
.95	20	209.17	244.05	266.98	302.96	318.25	328.31
.96	25	217.95	253.94	277.23	314.74	330.51	340.47
.98	50	241.87	280.91	305.19	346.96	363.95	373.64
.99	100	264.20	306.08	331.28	377.03	395.16	404.60

Table 7f

Sakon Nakhon

Cumulative Maximum Daily Rainfall

Cumulative Probability	Return Period in years	Maximum Daily Rainfall mm September 1 day	2 day	3 day	4 day	5 day	6 day
.01	1.01	-	-	-	-	-	-
.02	1.02	-	-	10.94	3.97	7.91	3.14
.04	1.04	-	13.32	23.74	19.27	24.55	22.30
.05	1.05	-	17.78	28.43	24.89	30.66	29.33
.10	1.11	15.37	32.37	43.78	43.26	50.63	52.32
.20	1.25	33.03	50 20	62.55	65.71	75.05	80.42
.50	2	66.74	84.24	98.38	108.57	121.66	134.07
.67	3	84.41	102.07	117.15	131.02	146.07	162.17
.80	5	100.46	118.28	134.21	151.42	168.26	187.71
.90	10	118.12	136.11	152.97	173.88	192.68	215.81
.95	20	132.57	150.7	168.33	192.24	212.65	238.80
.96	25	136.99	155.16	173.02	197.86	218.76	245.83
.98	50	149.03	167.32	185.82	213.16	235.40	264.99
.99	100	160.27	178.67	197.76	227.45	250.94	282.87

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Figure 4

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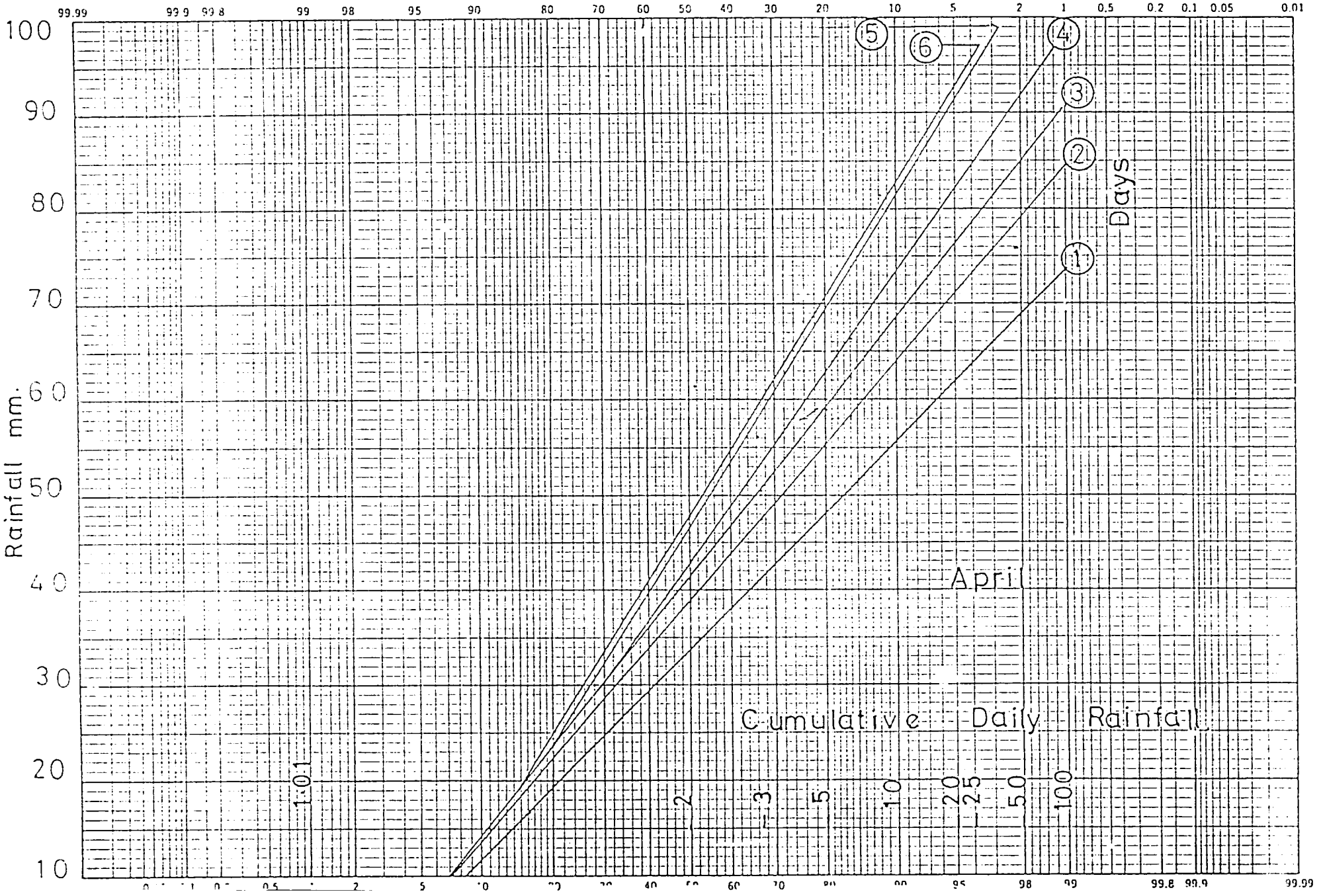

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Figure 5

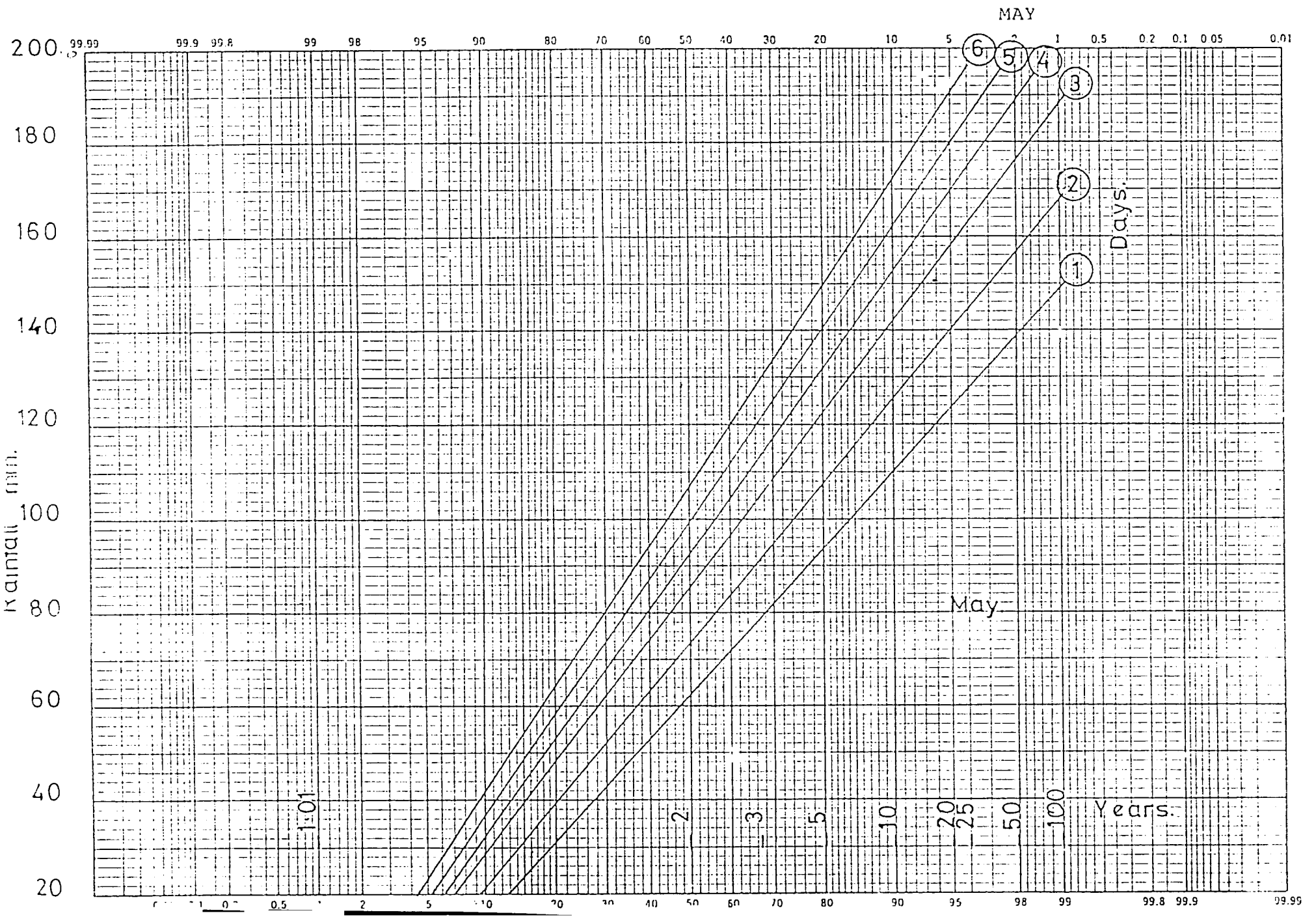

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Figure 6

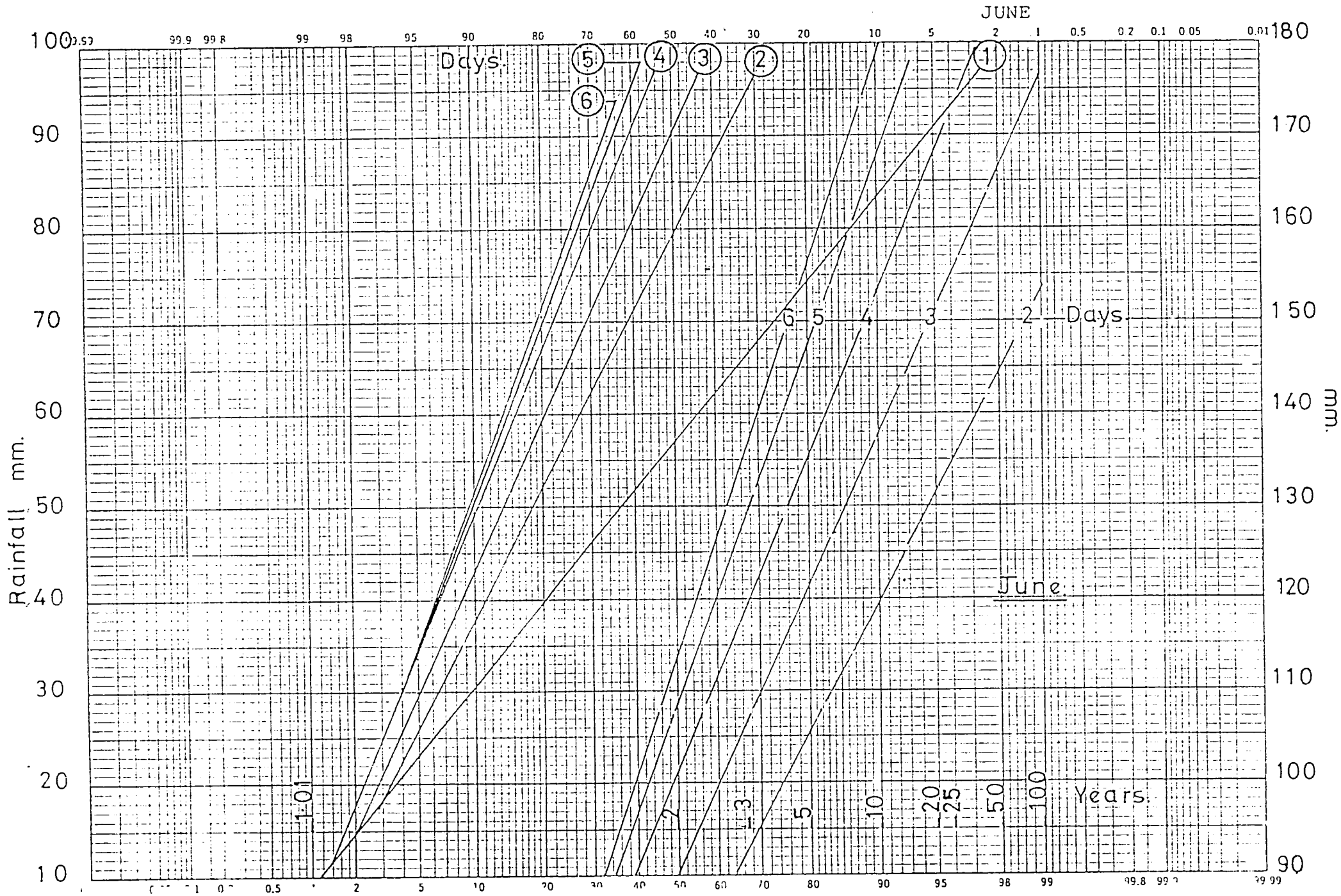

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Figure 7

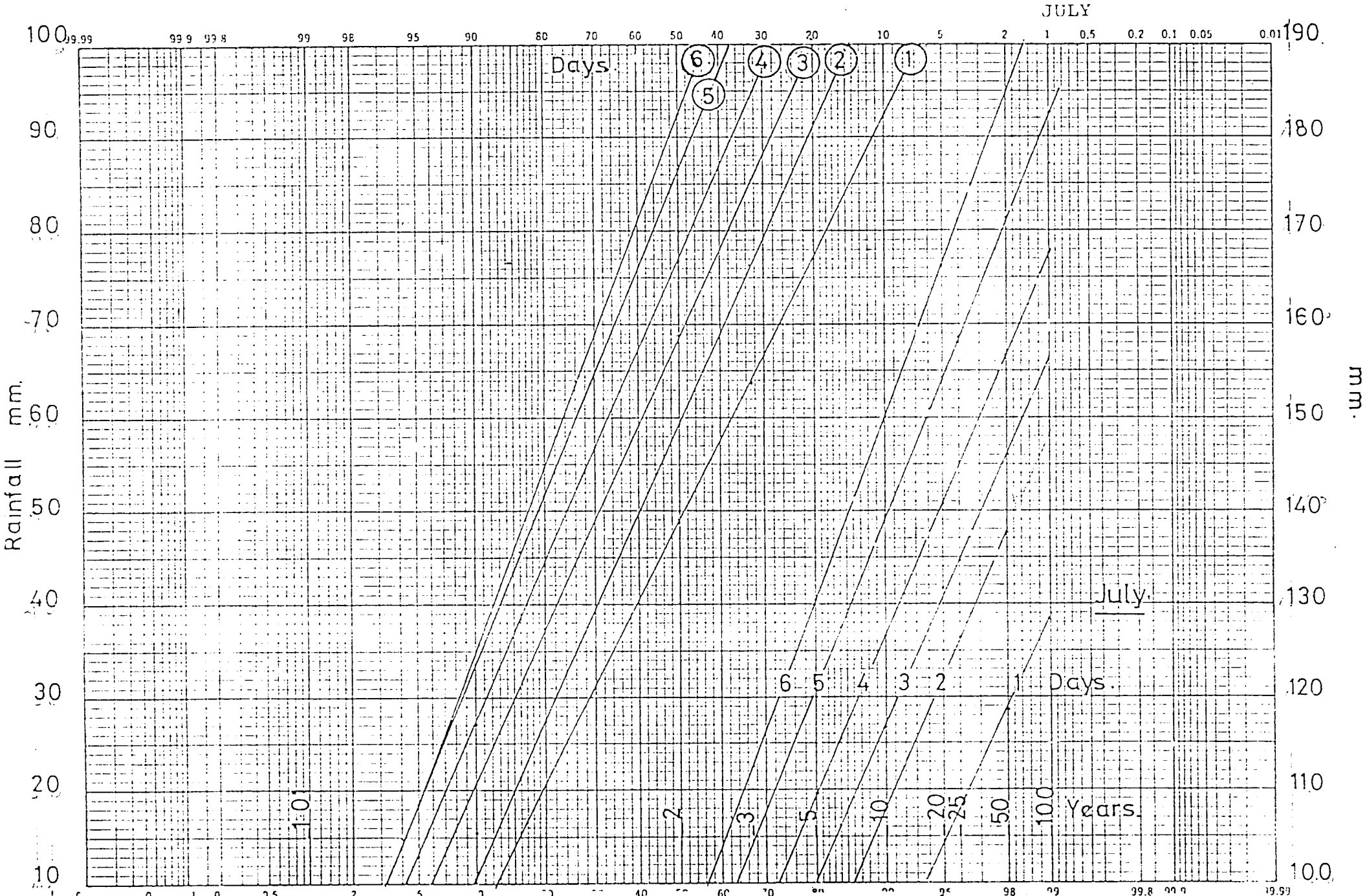

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Figure 8

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AUGUST

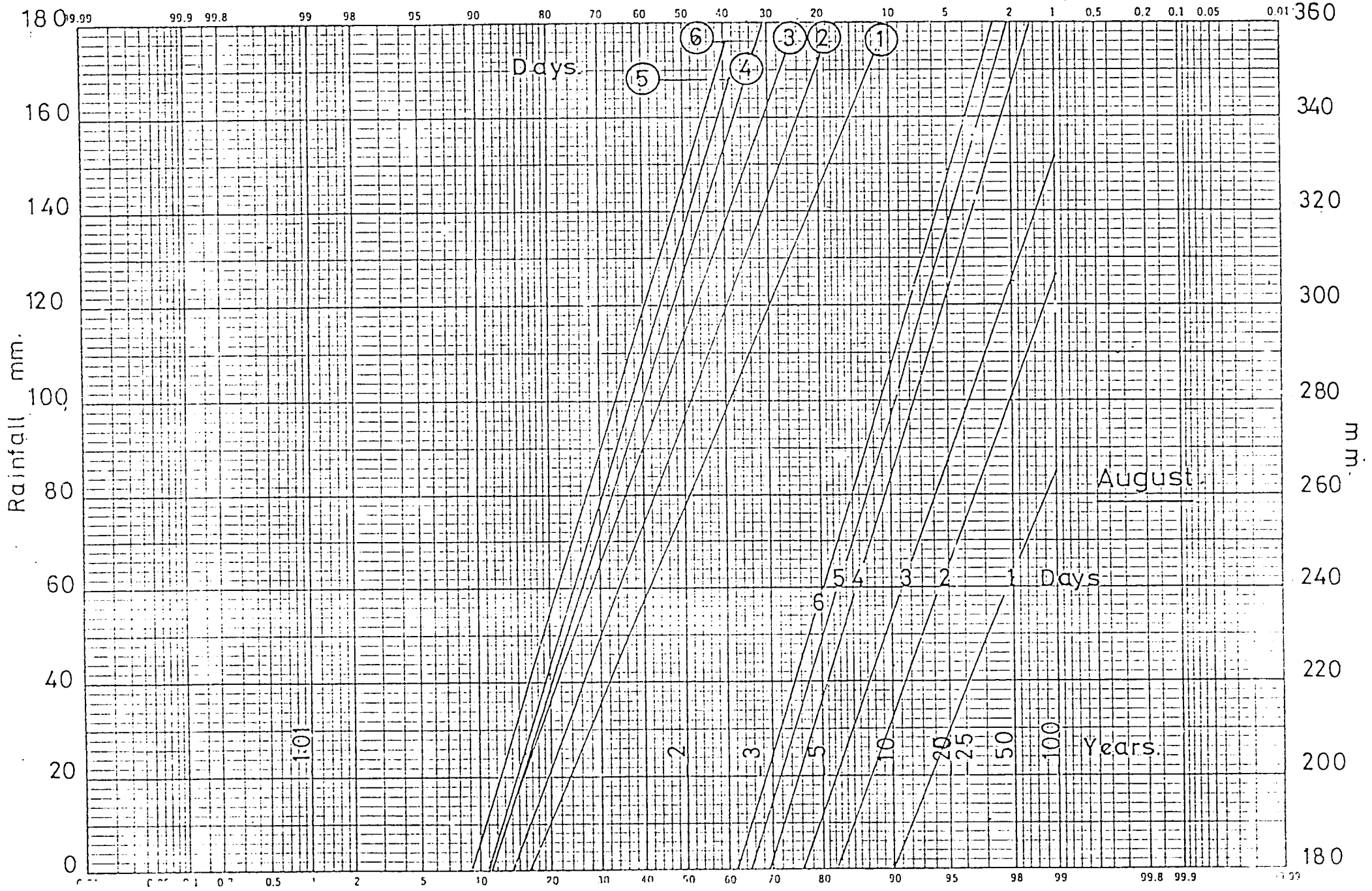

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Figure 9

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SEPTEMBER

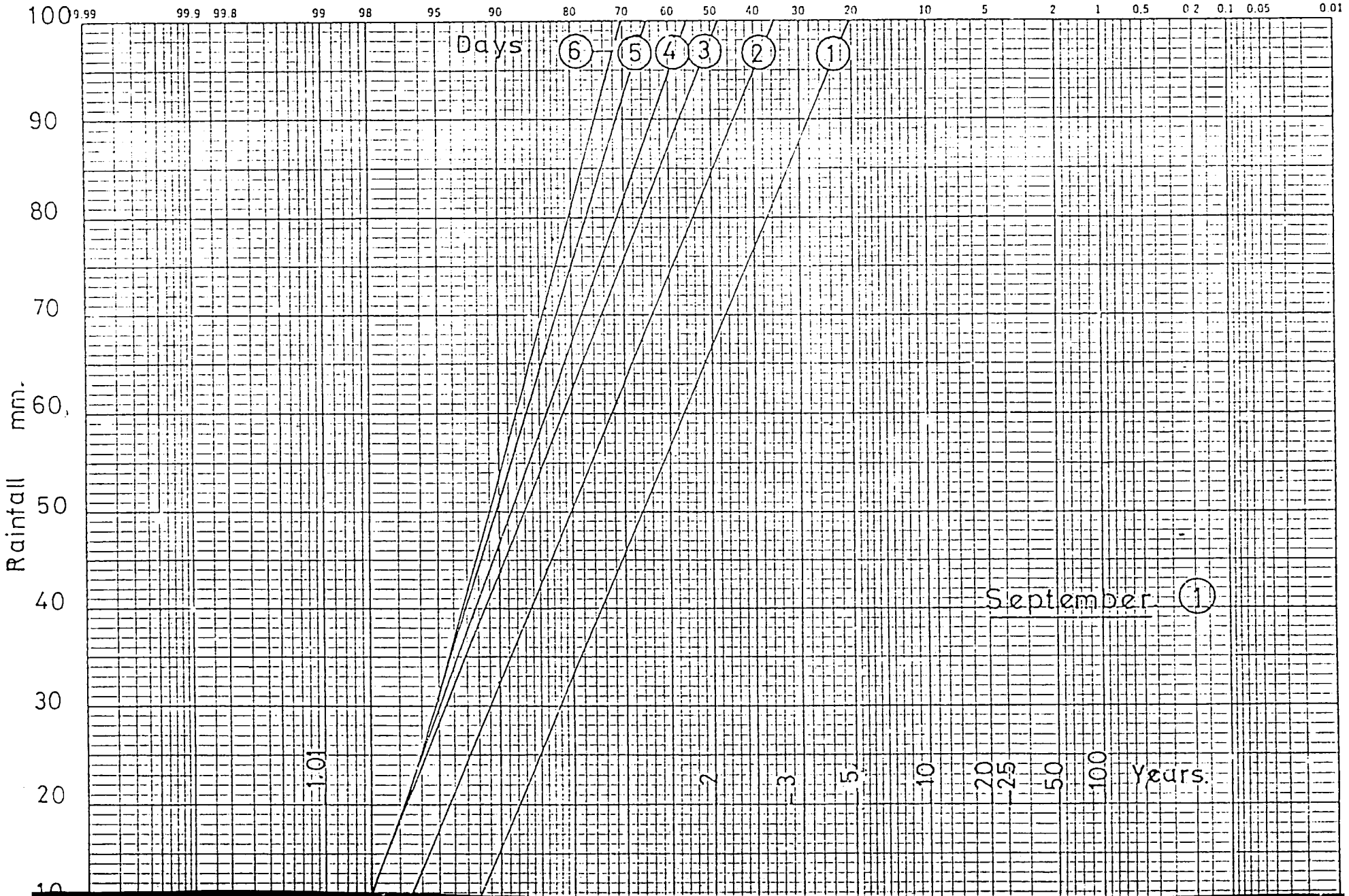

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FIGURE 10

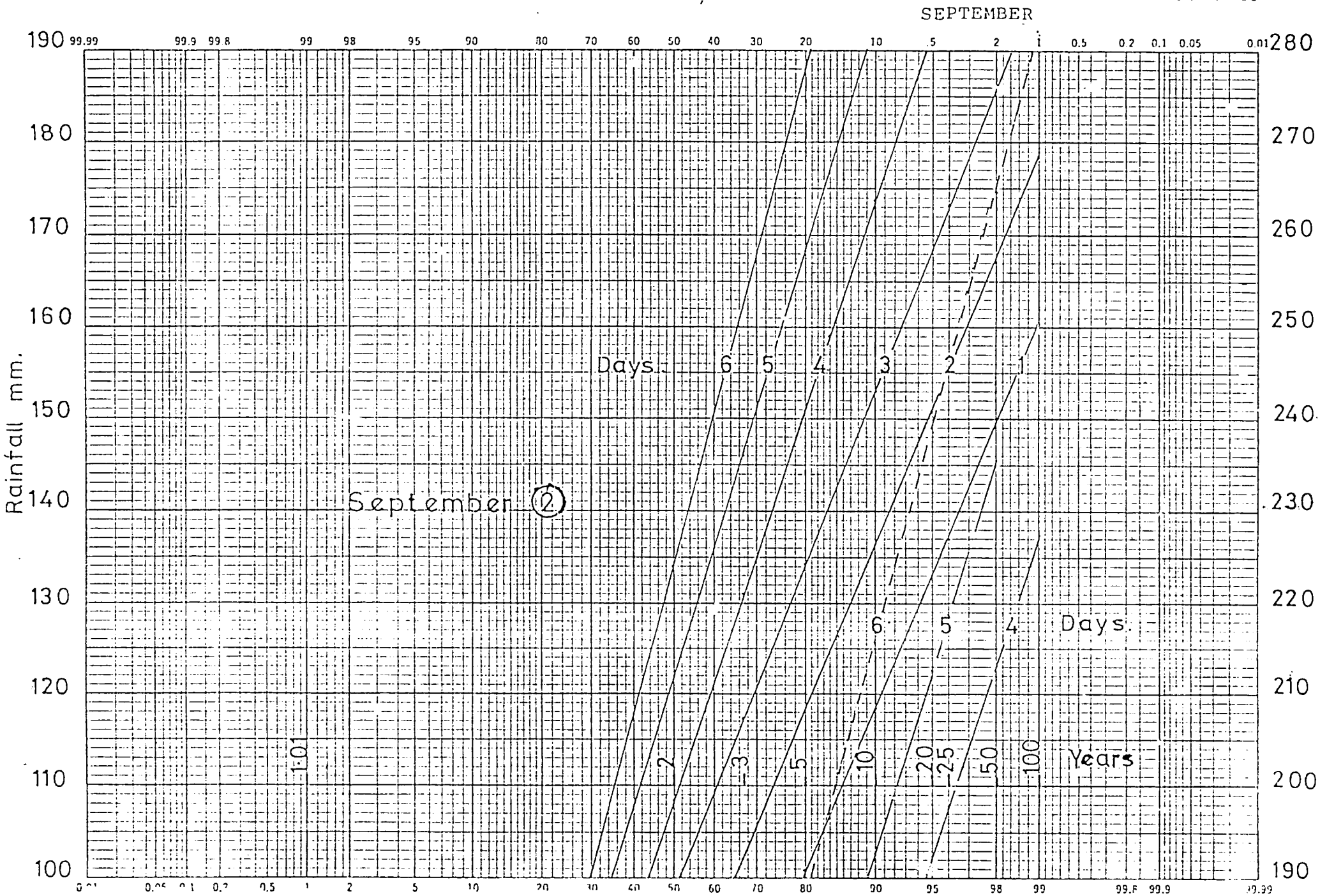

Table 8

The Drainage Coefficient obtained by using Equation 2 in l.p.s. per rai.

	Return Period - years		
	2	5	10
Cumulative days	2 and 3	2 and 3	2 and 3
A = 4	.641	1.315	1.918
Cumulative days	3 & 4	3 & 4	3 & 4
A = 4	0.731	1.465	2.117

Note: 1, an average value of 5.5 m.m./day is used for the Cu(n);

for 2 + 3 days $\overline{Cu}$ = 13.75 and

for 3 + 4 days $\overline{Cu}$ = 19.25

2, 400/3A = 33.33 and A = 4

3, Assuming that submergence does not exceed 200 m.m.

Table 9

Drainage Coefficient, at Different Submergence Depths, on Flat Areas (No ponding), in l.p.s. per rai.

Return Period Years	Maximum Submergence m.m.	Cumulative Period - days					
		1	2	3	4	5	6
2	0	1.68	1.06	.81	.68	.60	.53
	75	.29	.33	.35	.33	.32	.30
	100	-	.14	.19	.21	.23	.22
	150	-	-	-	-	.04	.07
	200	-	-	-	-	-	-
5	0	2.63	1.56	1.15	.97	.83	.75
	75	1.24	.87	.68	.62	.55	.52
	100	.78	.64	.53	.51	.46	.44
	150	-	.17	.22	.28	.27	.29
	200	-	-	-	.04	.09	.13
10	0	3.54	2.01	1.45	1.23	1.06	.94
	75	2.15	1.32	.99	.88	.78	.70
	100	1.68	1.09	.83	.77	.69	.63
	150	.76	.622	.52	.54	.50	.47
	200	-	.16	.21	.31	.32	.32

Note: This Table is based on the rainfall data in Table 6 and converted by $R(n)T - \Delta S(n) - Cu(n)$.

Table 10

Drainage Coefficients for Catchments with Proportional Areas of Ponding, in l.p.s. per rai, by using Equation 3.

Return Period Years	Maximum Submergence m.m.	Ratio of Ponded Area %	Cumulative Period - days					
			1	2	3	4	5	6
2	0	100	1.68	1.06	.81	.68	.60	.53
		75	.64	.54	.46	.42	.39	.36
	75	50	1.00	.72	.57	.50	.46	.42
		25	1.34	.89	.69	.59	.53	.48
		10	1.55	.99	.76	.64	.57	.51
	100	75	.29	.36	.35	.33	.32	.30
		50	.76	.60	.50	.44	.41	.38
		25	1.22	.83	.65	.56	.51	.46
		10	1.50	.97	.75	.63	.56	.50
	150	75	-	.02	.11	.16	.18	.19
		50	.29	.37	.34	.33	.32	.30
		25	.99	.72	.57	.50	.46	.42
		10	1.41	.93	.71	.61	.54	.49
	200	75	-	-	-	-	.04	.07
		50	-	.14	.19	.21	.23	.22
		25	.76	.60	.49	.44	.41	.38
		10	1.31	.88	.68	.56	.52	.47
	0	100	2.63	1.56	1.15	.97	.83	.75
	75	75	1.59	1.04	.80	.71	.62	.57
		50	1.94	1.21	.91	.80	.69	.63
		25	2.28	1.39	1.03	.88	.76	.69
		10	2.49	1.49	1.10	.93	.80	.72

Table 10 (cont'd)

Return Period	Maximum Submergence m.m.	Ratio of Ponded Area %	Cumulative Period - days					
			1	2	3	4	5	6
5	100	75	1.24	.87	.68	.62	.55	.52
		50	1.70	1.10	.84	.74	.64	.59
		25	2.17	1.33	.99	.85	.73	.67
		10	2.44	1.47	1.08	.92	.79	.72
	150	75	.55	.52	.68	.45	.41	.40
		50	1.24	.87	.84	.62	.55	.52
		25	1.94	1.21	.99	.80	.69	.63
		10	2.35	1.42	1.08	.90	.77	.70
	200	75	-	.17	.22	.28	.27	.28
		50	.78	.64	.53	.51	.46	.44
		25	1.70	1.10	.84	.74	.64	.59
		10	2.26	1.38	1.02	.88	.75	.69
10	0	100	3.54	2.01	1.45	1.23	1.06	.94
	75	75	2.49	1.49	1.10	.97	.85	.76
		50	2.84	1.66	1.22	1.06	.92	.82
		25	3.19	1.84	1.33	1.44	.99	.88
		10	3.40	1.94	1.40	1.20	1.03	.91
	00	75	2.15	1.32	.99	.88	.78	.70
		50	2.61	1.55	1.14	.99	.87	.78
		25	3.07	1.78	1.29	1.12	.96	.86
		10	3.35	1.92	1.39	1.18	1.02	.90
	200	75	1.45	.97	.75	.71	.64	.59
		50	2.15	1.32	.99	.88	.78	.70
		25	2.89	1.66	1.22	1.06	.92	.82
		10	3.26	1.87	1.36	1.16	1.00	.89
		75	.76	.62	.53	.54	.50	.47
		50	1.68	1.09	.83	.77	.69	.63
		25	2.61	1.55	1.14	.99	.87	.78
		10	3.17	1.83	1.33	1.14	.98	.88

Table 11

Drainage Coefficients derived from the Three methods assumming 100 m.m. Submergence for 3 days (except column 2, which is for one day) in l.p.s. per rai.

1 Return Period	2 Table 7	3 Table 8 (1)		4 Table 9	5 Table 10 (2)
		2 + 3 days	3 + 4 days		
2	0.241	.641	.731	0.19	0.65
5	0.722	1.315	1.465	0.53	0.99
10	1.556	1.918	2.117	0.83	1.29

Note: 1 & 2. These values are based on 25 percent ponding within the catchment area.

APPENDIX III

AN EXAMPLE OF THE APPLICATION OF THE DRAINAGE COEFFICIENT IN DRAIN DESIGN (PILOT AREA 2)

(LAM NAM OON)

1. The Purpose of this Example

The example given here is to demonstrate the calculation of the drainage discharge from two kinds of catchment areas;

i. a large catchment area, the size of a whole tertiary unit, with a ponded area, and,

ii. a minor, quaternary catchment area.
The drainage discharge will be calculated by means of the equations explained in the text.

2. Catchment Areas

A catchment area is defined as an area of land sloping toward a natural channel bound along the higher ground by a crest line or ridge line; however, such a ridge line may be some artificial obstacle restricting the runoff from rainfall reaching the channel.

i. Tertiary catchments; are mostly bound by canals or roads, but in some cases natural boundaries may occur.

ii. Quaternary catchments, are restricted to areas bound by minor canals roads and drains.

3. Ponded Conditions.

Ponded areas occur within tertiary catchments in the form of natural depressions such as "nongs". But by superimposing a transparent overlay, with the contours of the area, on an aerial photograph the flooded area can be easily demarcated. However, the area should be carefully examined in the field and if possible, with observation during the rainy season. Once the area has been drawn in on the tertiary map, the area is measured by planimeter.

4. Some Basic Assumptions.

In applying the foregoing equations to the conditions at Lam Nam Oon, the following assumptions will apply.

1. Ponded Conditions

i. The greatest amount of rainfall tends to occur an the second day of a storm of long duration of three days or more.

ii. Draining the accumulated, or ponded, water in three days; this assume, of course that no other storm occurs within that period which seems valid from rainfall records.

iii. Only a minor portion of the catchment will be flooded - ponded, unless the area is very flat, that is the long slope is less than 150 to 200 mm per 1000 m.

iv. The maximum rainfall is based on annual maximum cumulative daily rainfalls for the Sakon Nakhon Station and these values are representative for the whole project area, which seems to be the case. The rainfall values are taken from Table No. 6.

v. Maximum submergence should not exceed 100 mm.

2. Non-Ponded Conditions

The preceding conditions apply to non-ponded situations including the following.

i. Assuming that the paddy fields retain all the excess rainfall and discharge the water simultaneously over the 3 day period, thereby providing 100% retention.

ii. Assuming 100 mm. water depth in paddies planted to local rice varieties and 50 to 75 mm. for HYV and maximum rise in paddy water level is 50 mm for the Storage depth. Wherever possible these values should be checked in the field or obtained from the farmer.

5. The Calculation of the Drain Discharge for Pilot Area 2 (II)

1. Location

i. The catchment area's bound by the canal R-15L, and the minor canals along lower slope as shown on the map (enclosed). The area measured by planimeter is 876 rai.

ii. The ponded area is enclosed by the contour 167.5 although this may be a little above the actual "ponded line" it is good enough for this example. The ponded area "D" on the map is 115 rai.

iii. Water from the adjacent tertiary area P.A.2 (I) enters the area at point "A" through a culvert under R-15L. The discharge from this area will have to be added to the discharge being calculated to obtain the total drain capacity at "C". A culvert at "B" has been observed to be inadequate in lowering the ponded water in area "D" but the capacity of this culvert, at maximum capacity should be deducted from the capacity of "C".

2. Calculation.

i. Areas.

Total Catchment Area = 876 rai
Ponded area = 115 rai

Ratio, A = 115/876 = 0.1312
1/A = 1/o.1312 = 7.622

ii. Drainage Coefficient for the Ponded Area.

Use equation 2

$$Dc = 1/3 . R(1, max)t + 1/3 . R(2,max)t. - 400/3A - CU(n).$$

Use; A = 0.1312
CU = 5.5 mm/day
n = 3 days;

∴ CU = 5.5 x 3
= 16.5 mm

Referring to Table 6, for a return period of T = 2 years and n = 1 day,

R = 90.6 mm

and,

n = 2 days, T = 2 years

R = 114.9 mm

Dc = (1/3.90.6) + (1/3.114.9) -
- 400/3 x 7.622 - 16.5
= 68.5 - 17.49 - 16.5
= 34.51 mm/day
= 34.51 x .01852
= 0.6391 lps/rai

For, T = 5 years, n = 1 day

R = 142.0 mm

T = 5 years, n = 2 days

R = 168.6 mm

Dc = (1/3/142) + (1/3.168.6)
- 400/3 x 7.622 - 16.5
= 103.53 - 17.49 - 16.5
= 69.54 mm/day
= 1.288 lps/rai

The total discharge for the return periods of 2 years and 5 years are as follows.

T = 2 years

Discharge = Dc x Area
= 0.6391 x 115 rai
= 73.5 lps

T = 5 years

Discharge = 1.288 x 115 rai
= 148.1 lps

The total discharge through point "C" will be the discharge through the culvert at point "A" plus that at point "C" less that at point "B",

Discharge at "C" = 148.1 + "A" - "B".

In the case of a major outlet the T = 5 years discharge should be used.

iii. <u>Drainage Coefficient for the Non-ponded Area</u>

Use equation 3,

$Dc = R(n, max)\ t + (n(In-CU(n) - If(n)) - \Delta A.\ \Delta S(n)./3.$

The parameters $n(In-CU(n) - If(n)$ are usually assumed to be compensated during the height of the rainy season, then,

$Dc = R(n, max)t - \Delta A.\ \Delta S(n)$

Where,

$\Delta S(n)$ = Storage depth = 50 mm.
n = 2 days
T = 2 years,
R = 114.9 mm. (Table 6)
ΔA = 100% retention area
Dc = (114.9 - 100% x 50)/3
= 21.63 mm/day
= 0.401 lps/rai

Compare this value with
T = 5 years
n = 2 days
R = 168.6 mm
Dc = (168.6 - 100% x 50)/3
= 39.53 mm/day
= 0.732 lps/rai

The discharge from the catchment "E" of 164 rai.

for,

T = 2 years

Discharge = 0.401 x 164

= 65.76 lps

For T = 5 years

Discharge = 0.732 x 164

= 120 lps

The decision to use the 2 year return period will depend on the possibility of damage that will occur to structures and yield reduction to crops and kind of crop grown (Local rice varieties or HYV's). Normally, T = 2 years is used for quaternary structures.

6. Step-by-Step Methodology

1. Demarcate drainage lines on the map.
2. Demarcate catchment area of the tertiary unit.
3. Demarcate ponded area using contour lines and aereal photographs.
4. Demarcate quaternary drainage areas.
5. Measure the respective areas using a planimeter.
6. Obtain rainfall values for the return periods.
7. Calculate drainage coefficient for the ponded area using equation 3.
8. Calculate drainage coefficient for all the quaternary areas, using equation 2.
9. Calculate the discharge from each catchment.
10. Design structures and drain channel using the above discharges.
11. Note that the discharge at "C" will be the sum of all the discharges from the whole tentiary catchment plus the discharge from the ponded area, plus the discharge through "A" thus, the total discharge at "C" will be,

$$D = (876 \times .401) + (115 \times 1.288) + (\text{discharge "A"}) - (\text{discharge "B"})$$

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