DESIGN OF SMALL SCALE WATER CONTROL STRUCTURES

VOLUME II

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DESIGN OF SMALL SCALE WATER CONTROL STRUCTURES.

CONTENTS

VOLUME I

CHAPTER I	Basic Hydraulics Design Data Checklist
CHAPTER II	Hydologic Design A. Simple Method - Using Graphs & Tables B. Elaborate Method - Using Unit Hydrograph Method - Using Richard's Method - Using SCS Method
CHAPTER III	Hydraulic Design
CHAPTER IV	Structural Design
CHAPTER V	Foundation Design

VOLUME II

CHAPTER VI	Design of Bidirpur and Jublee Khal Regulator in Rajshahi
CHAPTER VII	Design of Drainage Sluice (Tidal) at Bamandanga in Khulna
CHAPTER VIII	Design of Flushing Regulator (2-5'x6') at Sharia in Tangail

CHAPTER VI

HYDROLOGIC AND HYDRAULIC DESIGN
OF
BIDIRPUR AND JUBLEE KHAL REGULATOR

CONTENTS

HYDROLOGICAL DESIGN PROCEDURE 1

HYDROLOGICAL DESIGN OF BIDIRPUR KHAL AND JUBLEE KHAL REGULATOR

A. Develop of Design Storm
1. Point Rainfall 5
2. Equivalent Uniform Depth of Rainfall 11
3. Rainfall Sequence of Uniform Equivalent Depth 20

B. Agricultural Land Classification 25

C. Rainfall Excess (Runoff Distribution)
1. Paddy Land Rainfall Excess 25
2. Non-paddy Land Rainfall Excess 26
3. Rainfall Excess - Weighted Basin Average 27

D. Development of Unit Hydrograph 29

E. The Runoff Hydrograph 35

F. Flood Routing
1. Elevation - Area - Capacity curve 39
2. Stage - Discharge Curve 41
3. 2s/t + D Curve 46
4. Pre-monsoon Flood Routing Procedure 49
Flood Routing for 1-vent 52
Flood Routing for 2-vents 54
Flood Routing for 4-vents 56
Flood Routing for 5-vents 58
Flood Routing for 6-vents 60
Post-monsoon Flood Routing 62

DISCUSSION AND CONCLUSION 65

HYDRAULIC DESIGN OF JUBLEE KHAL 68

REFERENCES 86

HYDROLOGIC DESIGN

DRAINAGE REGULATOR

DATA REQUIRED FOR HYDROLOGIC DESIGN

1. Project Description

2. Topographic map

   - area of the drainage basin
   - length of the principal drainage channel
   - map of the basin area with its geographical center
   - contour area of the respective ground elevations

3. Rainfall data (taken from Master Plan - prepared by IECO)

   - 4-months period rainfall index
   - ratio of index rainfall for a given time interval to index rainfall for 4 months
   - rainfall for selected recurrence intervals
   - isohyetal maps for total rainfall of required period of 10-years recurrence interval
   - rainfall variability
   - 24 hours point rainfall time-distribution

4. River hydrograph

   - hourly tide levels (for coastal areas only)
   - stage and discharge records of outfall channel
   - maximum and minimum water levels on river side during peak discharge period and also during the period when flushing is required
   - minimum discharge record (only required if structure used for dry season irrigation)

5. Cross-sections and Long-sections of drainage channel

   - channel slope
   - channel roughness factor

6. C_t vs. C_p graph (C_p, C_t - Snyder's co-efficient)

DATA REQUIRED FOR HYDRAULIC DESIGN

1. Design discharge (from flood routing)

2. No. of vents (from flood routing)

3. Tail water depth (from river hydrograph)

4. Graph - L/d_2 vs. Froude number (L-length of hydraulic jump, d_2 -tailwater depth)

5. Average grain size diameter (from sieve analysis)

6. Top width of embankment (from x-sections of the embankment)

7. Exit Gradient (for uplift pressure)

8. Khosla's chart (1/a vs. P_D & P_E where P_D, P_E are water pressures)

9. Water level data (for frequency analysis)

DESIGN PROCEDURE

A. Develop a Design Storm

1. Point Rainfall

a) Locate basin on Fig.1 and find the 4-month rainfall index.

b) Determine from Fig.2, the ratio to apply to the four-month index to compute the index rainfall for the selected time interval. (Table 1).

c) Determine from Fig.3, the ratio to apply to the index rainfall for the selected time period to determine the rainfall for the selected recurrence interval. (Table 2).

d) Multiply the index rainfall for the selected time period in Table 1 determined by step A.1.b by the ratio in Table 2 determined by step A.1.c. The calculation is in Table 3.

e) Multiply the 4-month index by the daily combined indices in Table 3. This gives the accumulated point rainfall volume in inches for storms of 1,2,3,4 & 5 days duration. Table 4 shows the computation.

2. Equivalent Uniform Depth of Rainfall.

a) Compute the reduction factor for rainfall variability. Computation in Table 5 and Table 6.

b) Multiply the point rainfall volumes by the rainfall reduction factor. Separate accumulative totals into daily increments. Computation in Table 7.

3. Rainfall Time Distribution

a) Arrange the daily increments in an order giving the worst flood condition. For a 3-day storm use the sequence 3,2,1. For a 5-day storm use 3,2,1,4,5. For a 6-day storm use 6,3,2,1,4,5 and so on.

b) Locate the gauging station closest to the basin being investigated. Convert the indicated gaging station rainfall during multiples of the unit duration to rainfall at the basin by using a ratio of the respective 4-month indices.

c) Convert unit duration point rainfall to equivalent uniform depth using the reduction factor. Table 9 shows the computation.

d) Arrange the unit durations for the maximum day into sequence. Use the same sequences given in step 3-a.

e) Compute the volumes and arrange the unit durations for the remaining days into sequence (Table 10).

B. <u>Determine percentage of paddy and non-paddy land</u>

Determine land classification as percentages of area in paddy land and non-paddy land. Whenever possible these percentages should be determined by field inspection. This is particularly important for small basins where the proportion of paddy land is disproportionately high. In absence of a survey the percentages on Table 13 can be used as an average.

C. <u>Determine Rainfall Excess (Runoff Distribution)</u>

1. Paddy land:

   Separate the rainfall losses from the rainfall time distribution determined in Table 10 by assuming the entire basin area consists of paddy land. (Table 12).

2. Non-paddy land:

   Separate the rainfall losses from the rainfall time distribution determined in Table 10 by assuming the entire basin area consists of non-paddy land. (Table 13).

3. Compute the weighted basin runoff distribution by multiplying the net runoff obtained in steps D-1 and D-2 by the respective land classification percentage as in Table 11. Computation shown in Table 14.

D. Develop a Unit Hydrograph

E. Prepare the Runoff Hydrograph

F. Flood Routing through the sluice

1. Prepare Basin Elevation-Area-Capacity curves (Fig.13)
2. Prepare stage-discharge curves for different flow conditions
3. Prepare 2s/t + D Curve
4. Route the flood through the structure
5. From the flood routing computations plot basin storage water surface elevation vs. time
6. Make assessment of flood damage
7. From the level of flooding and the extent of crop damage, make a judgement whether the capacity of the structure is adequate. If necessary repeat routing procedure using a revised sluice discharge capacity.

A. Develop a Design Storm

1. Point Rainfall

Point rainfall is the quantity of rain falling at a specific point, usually as measured at a rain gauging station. The point rainfall can be defined as the center of a storm, equal to the product of the four-month rainfall index (45") and the combined rainfall indices from Table 3.

a) Determine the four-month index rainfall for the desired location from the isohyetal map (fig.1).

In this case, the rainfall index for four-month period for the project area is 45".

b) Determine from fig.2, the ratio to apply to the four-month index to compute the index rainfall for the selected time interval. A rainfall duration of 5 days is required for our study.

Days	Ratio
1	0.085
2	0.13
3	0.158
4	0.176
5	0.189

Ratio of Index Rainfall
Table - 1

c) Determine from fig.3, the ratio to apply to the index rainfall for the selected time period to determine the rainfall for the selected recurrence interval.

	Ratio	
Days	10 yr.frequency	25 yr.frequency
1	1.51	1.80
2	1.48	1.76
3	1.47	1.727
4	1.465	1.725
5	1.46	1.72

Ratio of Rainfall for 10 yr & 25 yr Recurrence Interval
Table - 2

d) Multiply the index rainfall for the selected time period determined in step B-1-b by the ratio determined in step B-1-c.

Days	Storm Frequencies	
	10 years	25 years
1	0.128	0.153
2	0.192	0.288
3	0.230	0.272
4	0.257	0.303
5	0.276	0.326

Combined Rainfall Index for Selected Frequency
Table-3

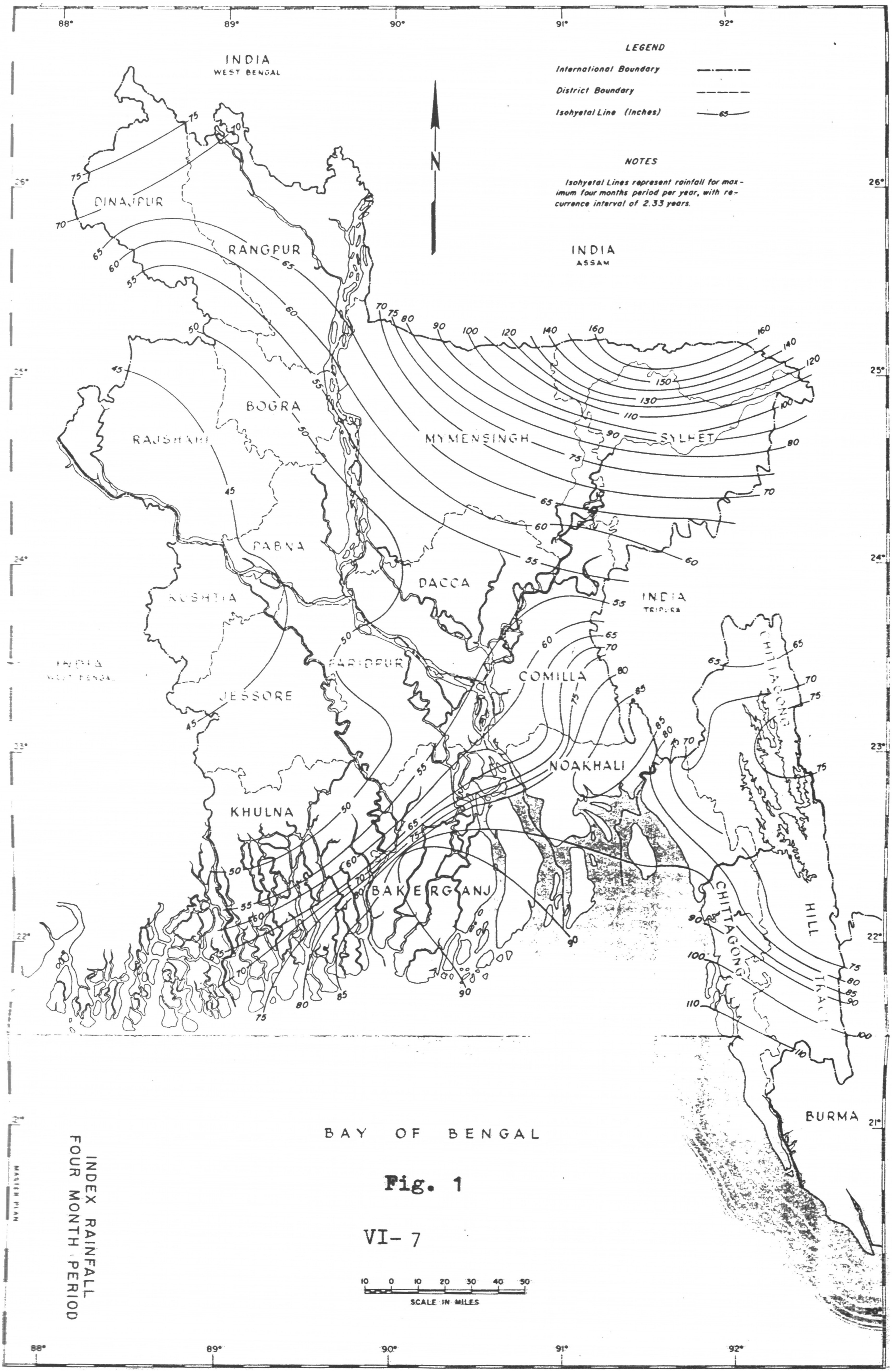
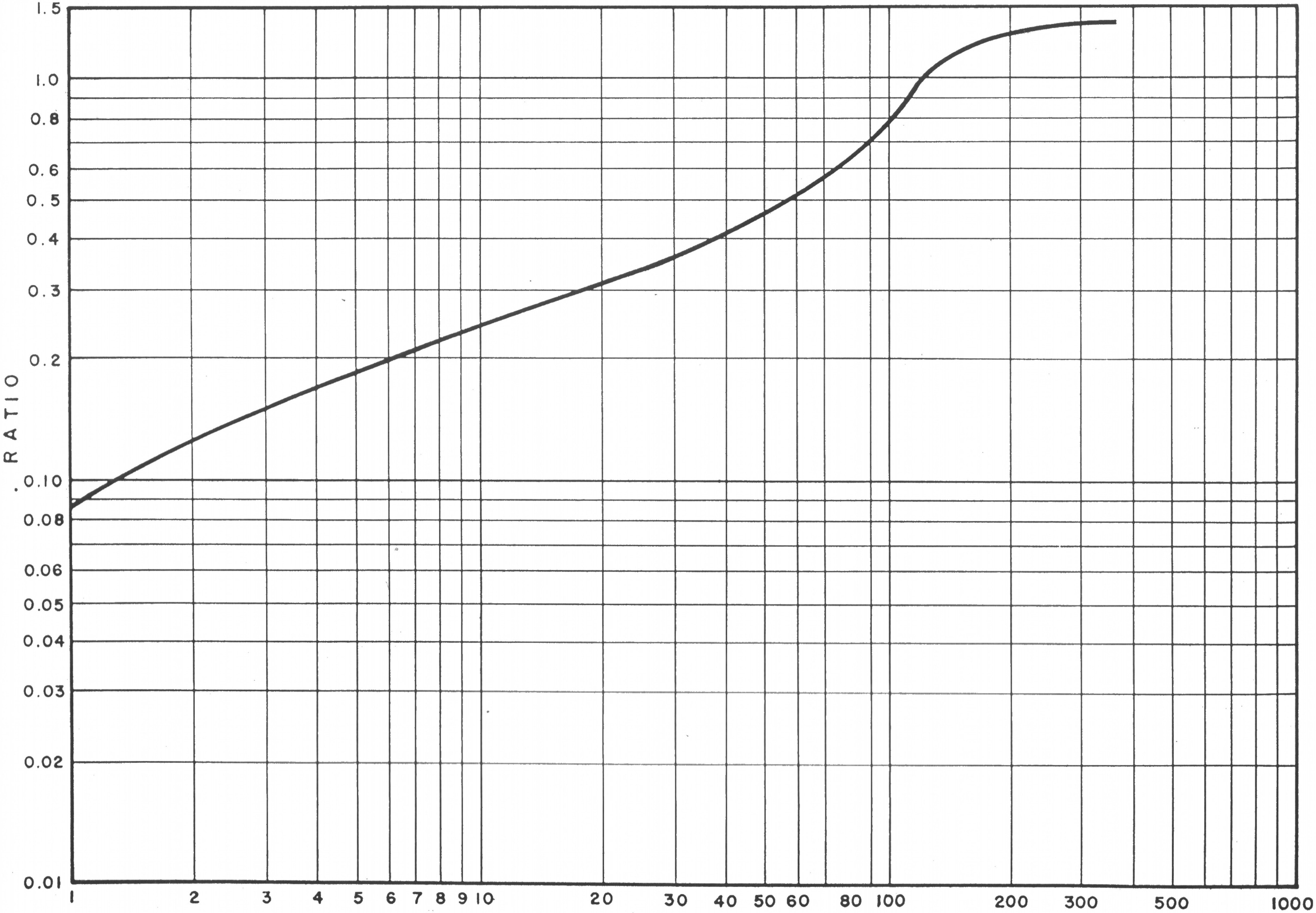


Fig. 1

VI- 7

INDEX RAINFALL
FOUR MONTH PERIOD

RATIO OF INDEX RAINFALL FOR A GIVEN TIME INTERVAL TO INDEX RAINFALL FOR FOUR MONTHS



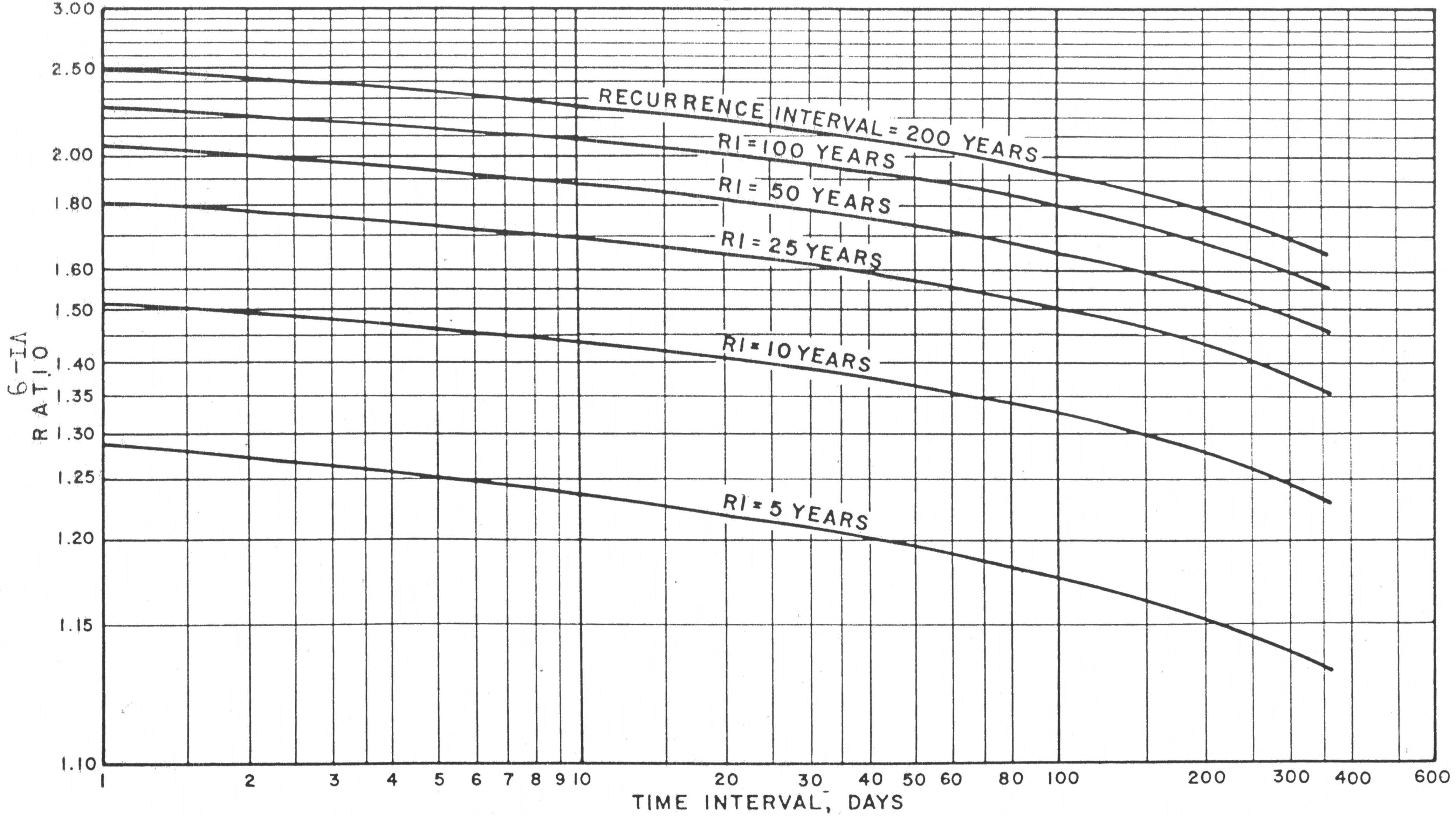
TIME INTERVAL, DAYS

Fig. 2

8-IA

RATIO OF RAINFALL FOR SELECTED RECURRENCE INTERVALS
TO INDEX RAINFALL FOR INDICATED TIME INTERVAL

Fig. 3



e) Rainfall index for four months for the project area = 45"

Accumulated point rainfall for 10 years frequency is as follows:

Days	Accumulated point rainfall for 10 yrs. frequency
1	5.8" (45"x0.128)
2	8.6" (45"x0.192)
3	10.4" (45"x0.23)
4	11.6" (45"x0.257)
5	12.4" (45"x0.276)

Accumulated Point Rainfall
Table-4

If point rainfall were used as the basis for designing a structure the computed volume of water would be unrealistically large. Rainfall intensity decreases as the distance from the storm center increases until at the storm edge it is zero.

Therefore it is necessary to determine an average or equivalent uniform depth of rainfall.

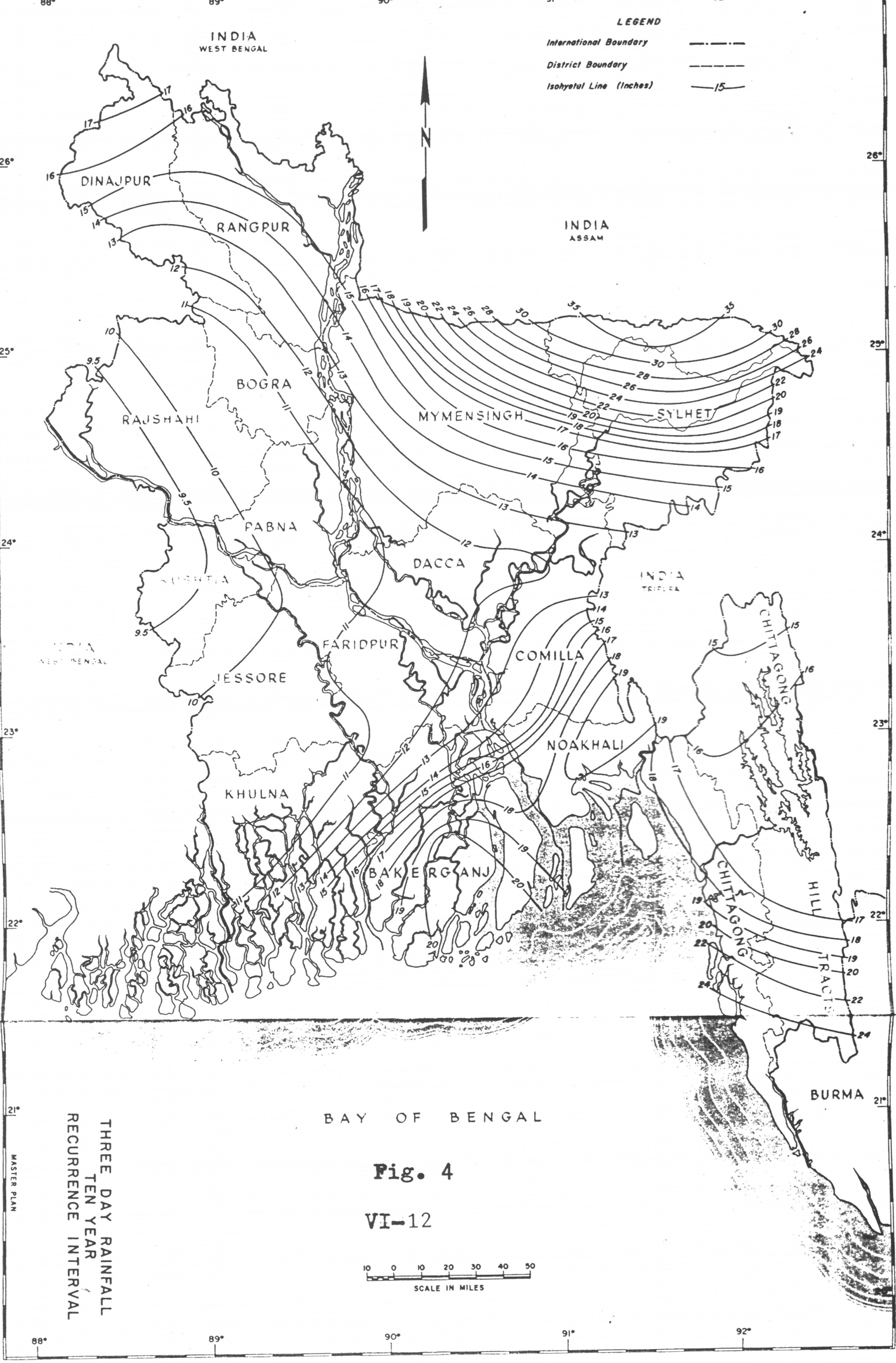
Equivalent Uniform Depth of Rainfall

The equivalent uniform depth of rainfall is defined as the depth of water which results from spreading the total volume of basin rainfall uniformly over the total basin area.

The storm center may occur at any point over the basin or may move along any path across the basin. We assume the storm center is stationary over the geographical center of the basin.

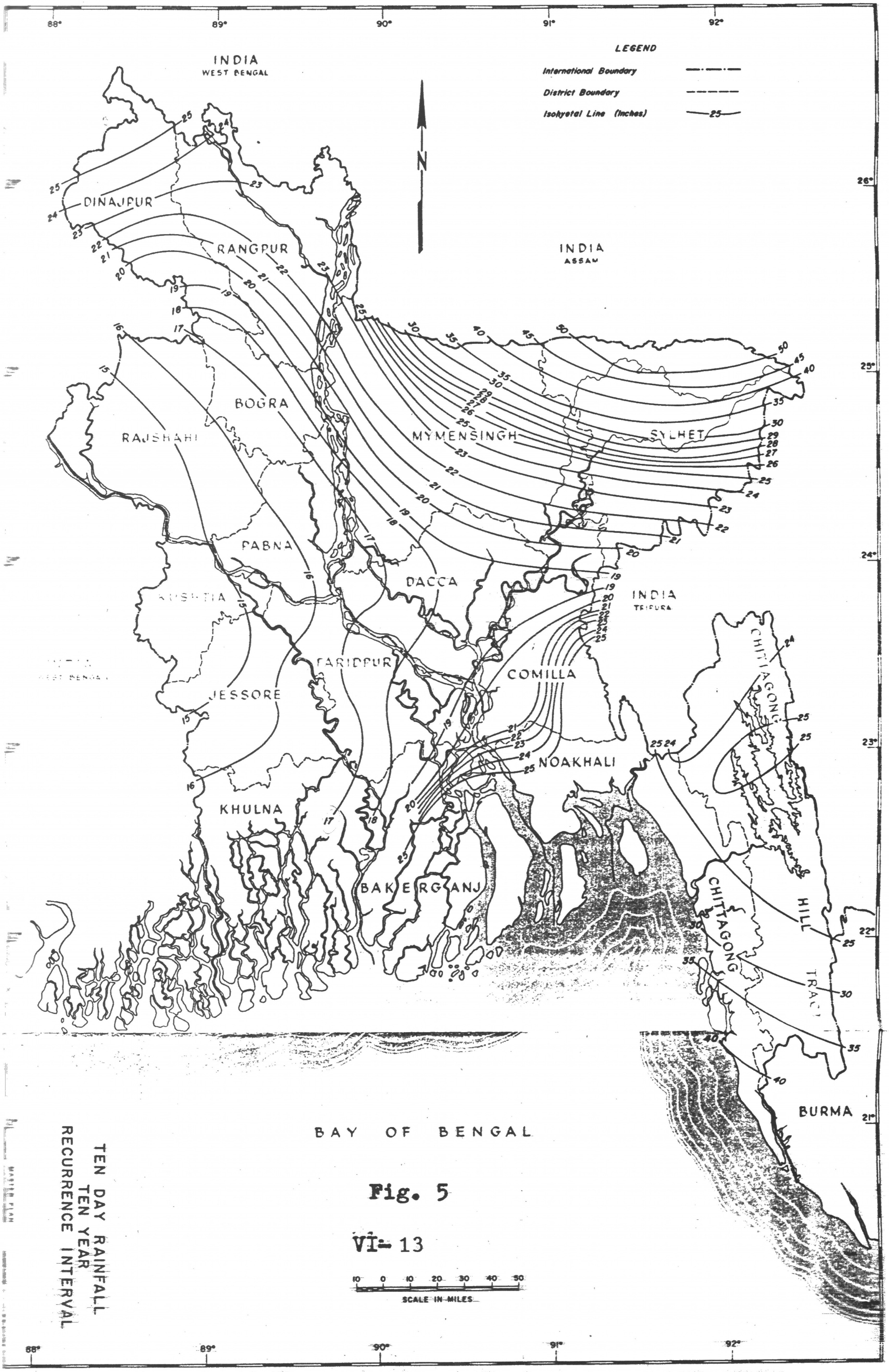
The rate of decrease of a storm's intensity away from its center has been studied by the General Consultants the IECO Master Plan states that studies of storm in Bangladesh indicate, that a fairly good relationship exists between depth of rain and distance from storm center.

Isohyetal maps for total rainfall in periods of 3-days, 5-days, 1-month and 4-months of 10-year recurrence interval are shown in figures 4,5,6,7 respectively. Fig.8 shows the relationship plotted as percent of the rainfall of 10-years recurrence interval against distance from the storm center. Table 5 shows the relationship in tabular form for 5-day storm.



LEGEND
International Boundary
District Boundary
Isohyetal Line (Inches)
INDIA
WEST BENGAL
INDIA
ASSAM
INDIA
TRIPURA
DINAJPUR
RANGPUR
BOGRA
RAJSHAHI
MYMENSINGH
SYLHET
PABNA
DACCA
FARIDPUR
COMILLA
JESSORE
KHULNA
NOAKHALI
BAKERGANJ
CHITTAGONG
CHITTAGONG HILL TRACTS
BURMA
BAY OF BENGAL
THREE DAY RAINFALL
TEN YEAR
RECURRENCE INTERVAL
MASTER PLAN
SCALE IN MILES

Fig. 4


LEGEND
International Boundary
District Boundary
Isohyetal Line (Inches)
INDIA
WEST BENGAL
INDIA
ASSAM
INDIA
TRIPURA
DINAJPUR
RANGPUR
BOGRA
RAJSHAHI
MYMENSINGH
SYLHET
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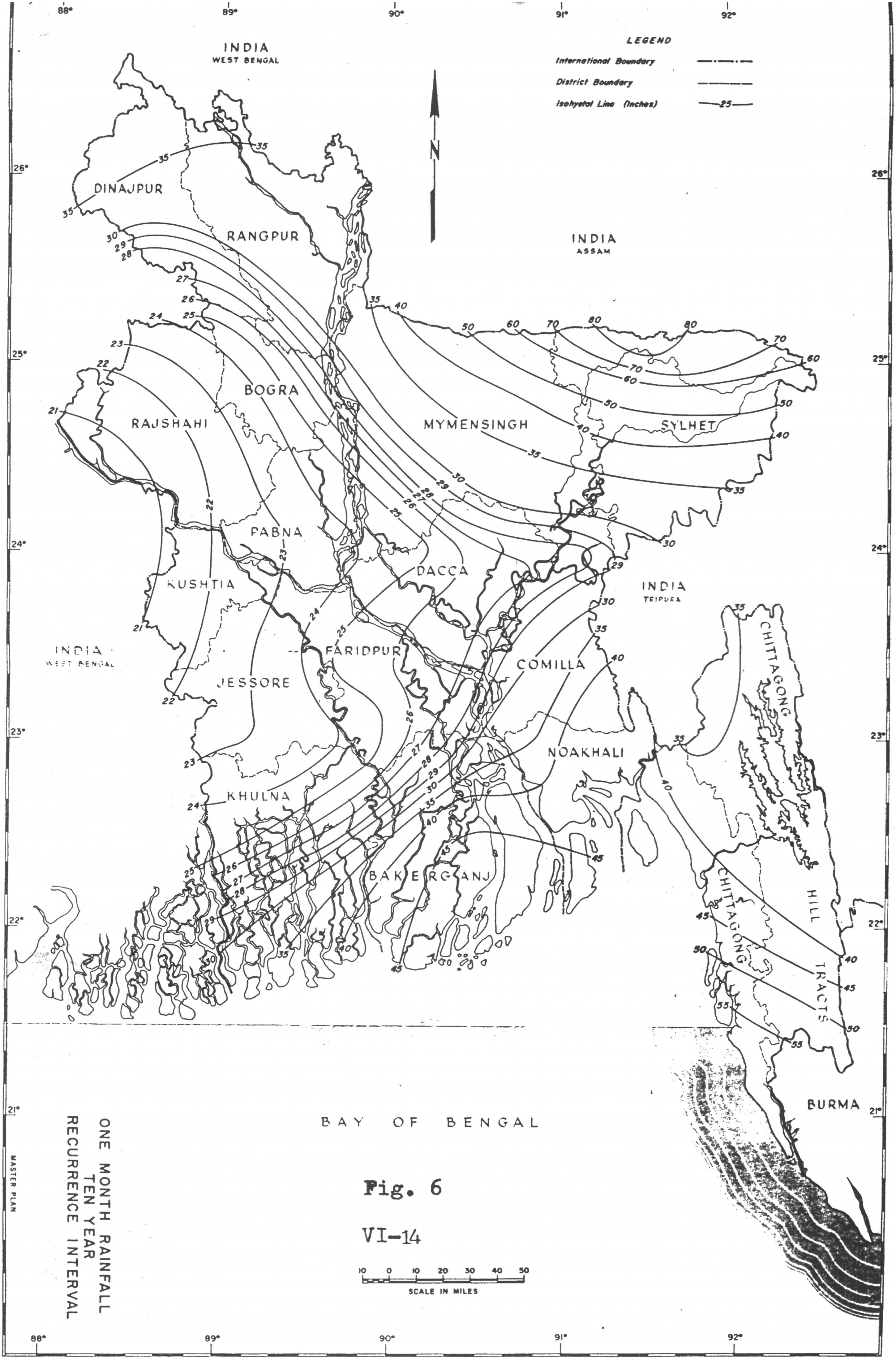
FARIDPUR
JESSORE
COMILLA
NOAKHALI
KHULNA
BAKERGANJ
CHITTAGONG
CHITTAGONG HILL TRACT
BURMA
BAY OF BENGAL
SCALE IN MILES
TEN DAY RAINFALL
TEN YEAR
RECURRENCE INTERVAL

Fig. 5


INDIA
WEST BENGAL
LEGEND
International Boundary
District Boundary
Isohyetal Line (Inches)
25
N
DINAJPUR
RANGPUR
INDIA
ASSAM
BOGRA
RAJSHAHI
MYMENSINGH
SYLHET
PABNA
DACCA
KUSHTIA
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TRIPURA
INDIA
WEST BENGAL
FARIDPUR
COMILLA
JESSORE
CHITTAGONG
NOAKHALI
KHULNA
BAKERGANJ
CHITTAGONG HILL TRACTS
BURMA
BAY OF BENGAL
MASTER PLAN
ONE MONTH RAINFALL
TEN YEAR
RECURRENCE INTERVAL
10 0 10 20 30 40 50
SCALE IN MILES

Fig. 6

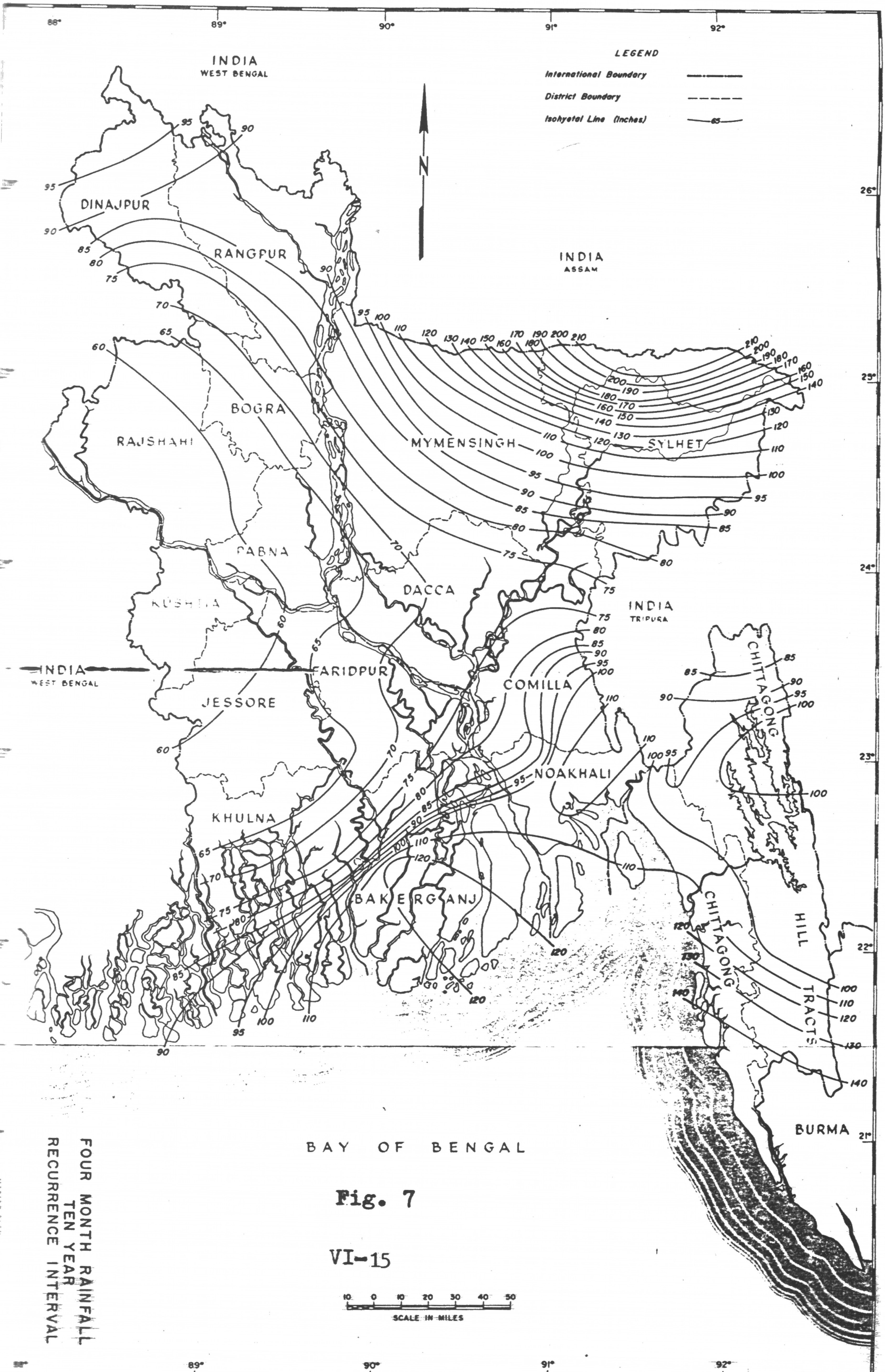

FOUR MONTH RAINFALL
TEN YEAR
RECURRENCE INTERVAL
LEGEND
International Boundary
District Boundary
Isohyetal Line (Inches)
INDIA
WEST BENGAL
INDIA
ASSAM
INDIA
TRIPURA
BURMA
DINAJPUR
RANGPUR
BOGRA
RAJSHAHI
MYMENSINGH
SYLHET
PABNA
KUSHTIA
DACCA
FARIDPUR
JESSORE
COMILLA
NOAKHALI
KHULNA
BAKERGANJ
CHITTAGONG
CHITTAGONG HILL TRACTS
BAY OF BENGAL
SCALE IN MILES

Fig. 7

RAINFALL VARIABILITY

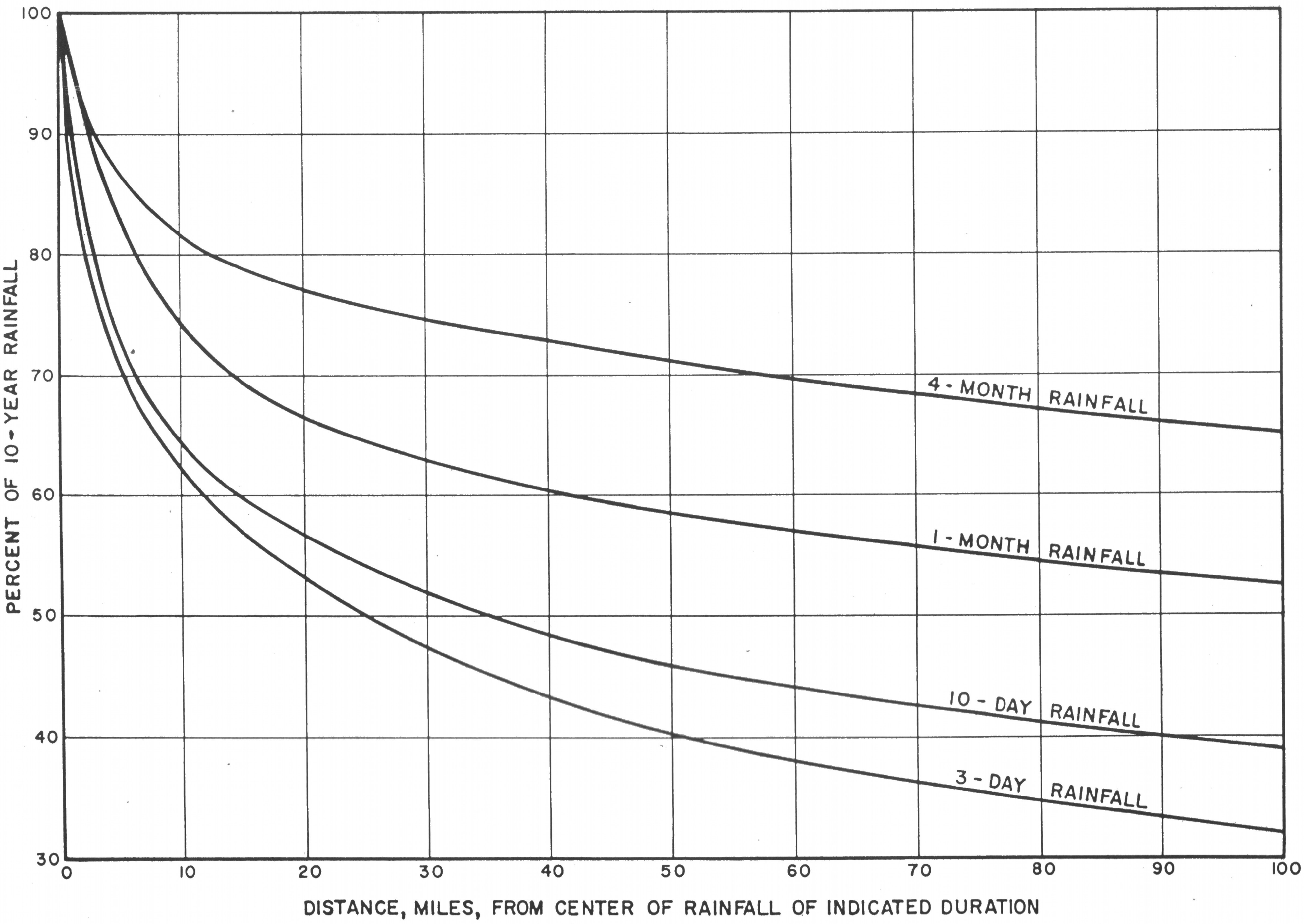


Fig. 8

a) Rainfall Variability

Distance from storm center	5-day Storm Percentage of point rainfall
1/4	100
1	88
2	81.7
3	77.5
4	74.2
5	72.0
6	69.8
7	67.8
8	66.0
9	64.5
10	63.1

Rainfall Variability
Table-5

The equivalent uniform depth of rainfall can be determined by the following way:

Step 1. Locate the geographical center of the basin area. The basin centroid can be found by the following way:
Cut a hardboard identical to the catchment area. Fix three or four points on the hard board. Hang the board with a thread through these fixed points at one end, one by one having a piece of weight on

the other end of the thread. Draw straight lines along the thread at each time. The point of intersection of these lines gives the centroid of the basin.

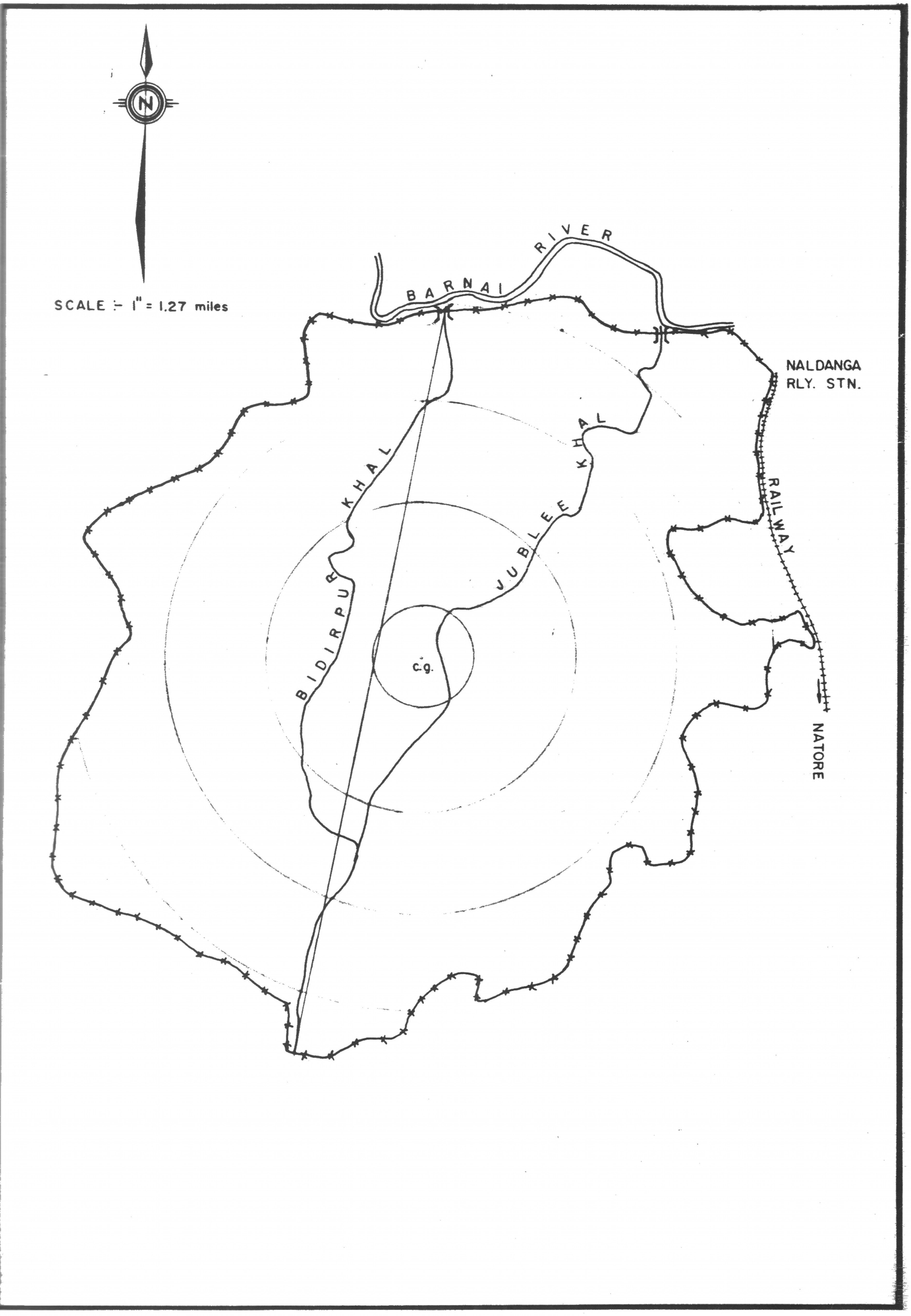
Step 2. Draw concentric circles or isohyetals at even mile intervals around the center. Fig.9 is a map of the basin area with its geographical center located and isohyetals drawn at one mile interval starting one-half mile from the center.

Step 3. Plainmeter the areas between the respective isohyetals within the basin area.

Step 4. Multiply the area by the proper percentage from Table 5 and make a summation of the values.

Average distance from Storm Center	5-day storm percentage of point rainfall	Area [sq.miles]	Area times Percentage
1/4	100	0.79	0.79
1	88	6.21	5.46
2	81.7	12.63	10.32
3	77.5	14.32	11.10
4	74.2	3.05	2.26
		37.00	29.93

Percentage of Point Rainfall
Table - 6



N
SCALE :- 1" = 1.27 miles
BARNAI RIVER
NALDANGA
RLY. STN.
RAILWAY
NATORE
BIDIRPUR KHAL
JUBLEE KHAL
c.g.

Figure - 9

Step 5. Compute the percentage of point rainfall that forms the uniform equivalent depth of rainfall.

$$\frac{29.33}{37.00} \times 100 \approx 81\%$$

b) Convert accumulative point rainfall to daily uniform depth equivalents by multiplying Table-4 values by 81%.

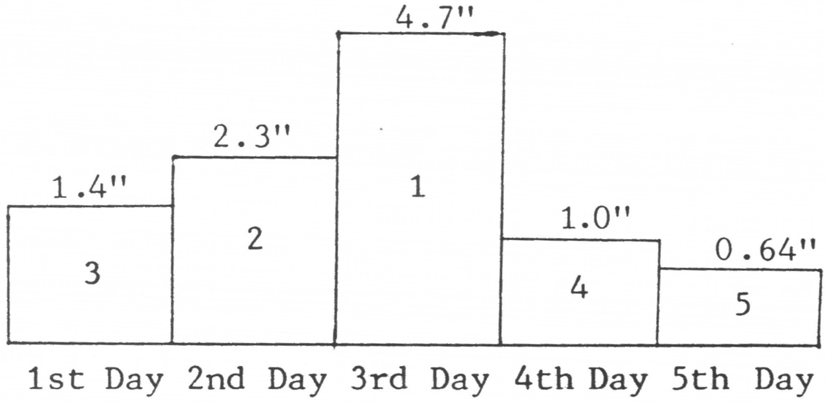
Days	Equivalent Uniform Depth	
	Accumulative total [inch]	Daily Increments [inch]
1	4.7	4.7
2	7.0	2.3
3	8.4	1.4
4	9.4	1.0
5	10.04	0.64

Equivalent Uniform Depth
Table 7

3. <u>Rainfall Sequence of Uniform Equivalent Depth</u>

a) The above supposition says, in effect, a maximum one-day storm forms part of a maximum 2-day storm, which in turn forms part of a maximum 3-day storm etc. And as stated, these daily increments can occur in any order i.e. will arbitarily arrange a sequence of 3,2,1,4,5 in order to satisfy the losses that will take place early in the storm.

A graphical arrangement of this sequence looks like this:



Daily rainfall sequence of Equivalent Uniform Depth =(OK)

b) Now we want to know the quantity of rain falling during certain hourly intervals. Table 8 has been prepared from Master Plan rainfall data for breaking down rainfall time-distribution into intervals less than 24-hours.

Districts	4-Month Index	Storm Duration in Hours / Accumulated rainfall in Inches						
		1	2	3	6	12	18	24
Barisal	65	2.33	2.77	3.11	3.82	5.36	6.85	8.35
Jessore	46	2.37	3.00	3.35	3.80	4.43	5.15	5.90
Cox's Bazar	115	2.33	2.88	3.30	4.40	6.65	10.50	14.10
Chittagong	86	2.43	3.07	3.58	4.56	6.67	9.00	11.00
Dhaka	55	3.10	4.00	5.50	5.25	6.10	6.60	7.06
Bogra	58	3.40	4.23	4.50	5.47	6.30	6.90	7.40
Sylhet	120	2.85	4.15	5.00	6.16	6.20	12.00	15.30

24-hour Point Rainfall Time-Distribution
Table 8

c) The smallest time interval to be used will depend on the length of the main drainage course within the basin. The following intervals are recommended:

1. Less than 2 miles; one hour
2. 2 to 6 miles; 3 hours
3. Over 6 miles; 6 hours

The length of the Bidirpur khal is 8.78 miles (fig.9). So we will use a unit interval of 6-hours. The rainfall data located closest to Rajshahi District is Bogra, with a 24-hour point rainfall of 7.40 inches.

After the adjustment made on the basis of the ratio of the 4-month rainfall indices between Bogra and the project area that is, 45/58 (=0.775). The adjusted maximum accumulative point rainfall of the project area are shown in Table 9.

Stations	Storm Duration Accumulative Rainfall			
	6 hours	12 hours	18 hours	24 hours
Bogra Maximum Accumulative Point Rainfall	5.47" x.775 =	6.30" x0.775 =	6.90" x0.775 =	7.40" x0.775 =
Project Area Maximum Accumulative Point Rainfall	4.24"	4.88"	5.35"	5.74"
Project Area Maximum Incremental Point Rainfall	4.24" x0.81 =	0.64" x0.81 =	0.47" x0.81 =	0.39" x0.81 =
Uniform Equipment Depth	3.43"	0.52"	0.38"	0.32"

24 - hour Rainfall Time Distribution
Table 9

d) As pointed out for rainfall time-distribution with 24-hour increments the increments within a 24-hour period also cannot be predicted. Therefore, we will arbitrarily arrange a sequence of 3,4,1,2.

Thus during the maximum 24-hour rainfall period the 6-hour incremental rainfall is 0.38", 0.32", 3.43" and 0.52". So, the rainfall sequence for the peak 24-hour period is established.

Now, to determine a sequence for the other 24-hour periods we will use two arbitary assumptions to assist in the distribution.

1. In as much as possible, use the same increments and sequence as was used with the maximum 24-hour period.

2. Use the entire time period for distribution.

3) The procedure for calculation of design storm is as follows :

1. Referring to table 10, we have established the sequence for the 3rd day.
2. Moving to the 2nd day, use the same increments for the 1st, 2nd and 4th periods as were used for the 3rd day.
3. For the 3rd period of the 2nd day we will assign the remainder of the total 2nd day rainfall or 1.08 inches.
4. The 1st day is similarly handled with the remainder of 0.18 inches in the 3rd period.
5. The 4th and 5th days are similarly handled and the design storm is complete.

Day	6-hour Increments
1	0.38"
	0.32"
	0.18"
	0.52"
2	0.38"
	0.32"
	1.08"
	0.52"
3	0.38"
	0.32"
	3.43"
	0.52"
4	0.38"
	0.32"
	0.00"
	0.30"
5	0.38"
	0.00"
	0.00"
	0.26"

Design Storm
Table 10

E. Agricultural Land Classification

District	Available for Cultivation	Cultivated as Paddy Land
Dhaka	70	33
Mymensingh	75	40
Faridpur	84	50
Bakerganj	69	57
Chittagong	42	39
Noakhali	66	41
Comilla	79	61
Sylhet	56	35
Rajshahi	74	45
Dinajpur	69	46
Rangpur	66	42
Bogra	84	56
Pabna	81	37
Kushtia	75	26
Jessore	73	35
Khulna	36	25

Percentage of Total Land Area
Table 11

C. Rainfall Excess (Runoff Distribution)

1. Paddy Land Rainfall Excess

We will assume the following paddy land losses for the basin.

1. Initial soil-moisture loss is nil.

   (Paddy land assumed to be saturated)

2. Subsequent soil-moisture loss is assumed to be at the constant infiltration rate of 0.04 inch/hour or 0.25 inch each 6-hour interval.

3. Initial paddy depression storage assumed to be 4 inches.

Days	Hours	Rainfall in Inches	Losses in Inches: Soil Moisture: Initial	Losses in Inches: Soil Moisture: Subsequent	Losses in Inches: Depression Storage [inches]	Available Paddy Storage [inches]	Net Runoff [inches]
1	0-6	0.38	0	-0.25	-4.00	-3.87	0
	6-12	0.32		-0.25		-3.80	0
	12-18	0.18		-0.25		-3.87	0
	18-24	0.52		-0.25		-3.60	0
2	0-6	0.38		-0.25		-3.47	0
	6-12	0.32		-0.25		-3.40	0
	12-18	1.08		-0.25		-2.57	0
	18-24	0.52		-0.25		-2.30	0
3	0-6	0.38		-0.25		-2.17	0
	6-12	0.32		-0.25		-2.10	0
	12-18	3.43		-0.25		0	1.08
	18-24	0.52		-0.25		0	0.27
4	0-6	0.38		-0.25		0	0.13
	6-12	0.32		-0.25		0	0.07
	12-18	0.00		-0.25		-0.25	0
	18-24	0.30		-0.25		-0.20	0
5	0-6	0.38		-0.25		-0.07	0
	6-12	0.00		-0.25		-0.32	0
	12-18	0.00		-0.25		-0.57	0
	18-24	0.26		-0.25		-0.56	0

Rainfall Excess
Paddy Land
Table 12

2. Non-paddy Land Rainfall Excess

We will assume the following non-paddy land losses for the basin:

1. Initial soil-moisture loss is 0.50 inch.

2. Subsequent soil-moisture loss is 0.25 inch/6 hour interval.

3. Depression storage at a maximum constant rate of 0.033 inch/hour or 0.20 inch/6-hour interval, provided the rainfall is available, until a total of 1.00 is stored.

Days	Hours	Rainfall in Inches	Losses in Inches: Soil Moisture Initial	Losses in Inches: Soil Moisture Subsequent	Losses in Inches: Depression Storage [inches]	Available Non-Paddy Storage [inches]	Net Runoff [inches]
1	0-6	0.38	-0.50	-	-	-0.12	0
	6-12	0.32		-0.25	0	-0.05	0
	12-18	0.18		-0.25	0	-0.12	0
	18-24	0.52		-0.25	-0.15	0	0
2	0-6	0.38		-0.25	-0.13	0	0
	6-12	0.32		-0.25	-0.07	0	0
	12-18	1.08		-0.25	-0.20	0	0.63
	18-24	0.52		-0.25	-0.20	0	0.07
3	0-6	0.38		-0.25	-0.13	0	0
	6-12	0.32		-0.25	-0.07	0	0
	12-18	3.43		-0.25	-0.05	0	3.13
	18-24	0.52		-0.25	0	0	0.27
4	0-6	0.38		-0.25	0	0	0.13
	6-12	0.32		-0.25	0	0	0.07
	12-18	0.00		-0.25	0	-0.25	0
	18-24	0.30		-0.25	0	-0.20	0
5	0-6	0.38		-0.25	0	-0.07	0
	6-12	0.00		-0.25	0	-0.32	0
	12-18	0.00		-0.25	0	-0.57	0
	18-24	0.26		-0.25	0	-0.56	0

Rainfall Excess
Non-paddy Land
Table 13

3. Rainfall Excess - Weighted Basin Average

The project area is in Rajshahi District. Referring to Table 11 we find that 45% of the total land area is paddy land, leaving 55% as non-paddy land.

Table 14 shows our computation for a weighted average. The net runoff columns are taken from table 12 and table 13 respectively.

The weighted runoff columns are obtained by multiplying paddy land runoff by 45% and non-paddy land runoff by 55%. The basin weighted runoff is the sum of the paddy and non-paddy weighted runoff.

Day	Hours	Paddy Land Net Runoff	Paddy Land Weighted Runoff	Non-Paddy Land Net Runoff	Non-Paddy Land Weighted Runoff	Basin Weighted Runoff
1	0-6	0	0	0	0	0
	6-12	0	0	0	0	0
	12-18	0	0	0	0	0
	18-24	0	0	0	0	0
2	0-6	0	0	0	0	0
	6-12	0	0	0	0	0
	12-18	0	0	0.63	0.35	0.35
	18-24	0	0	0.07	0.04	0.04
3	0-6	0	0	0	0	0
	6-12	0	0	0	0	0
	12-18	1.08	0.49	3.13	1.72	2.21
	18-24	0.27	0.12	0.27	0.15	0.27
4	0-6	0.13	0.06	0.13	0.07	0.13
	6-12	0.07	0.03	0.07	0.04	0.07
	12-18	0	0	0	0	0
	18-24	0	0	0	0	0
5	0-6	0	0	0	0	0
	6-12	0	0	0	0	0
	12-18	0	0	0	0	0
	18-24	0	0	0	0	0
TOTAL			0.70		2.37	3.07"

Rainfall Excess
Weighted Basin Average
Table 14

Paddy Land = 45%

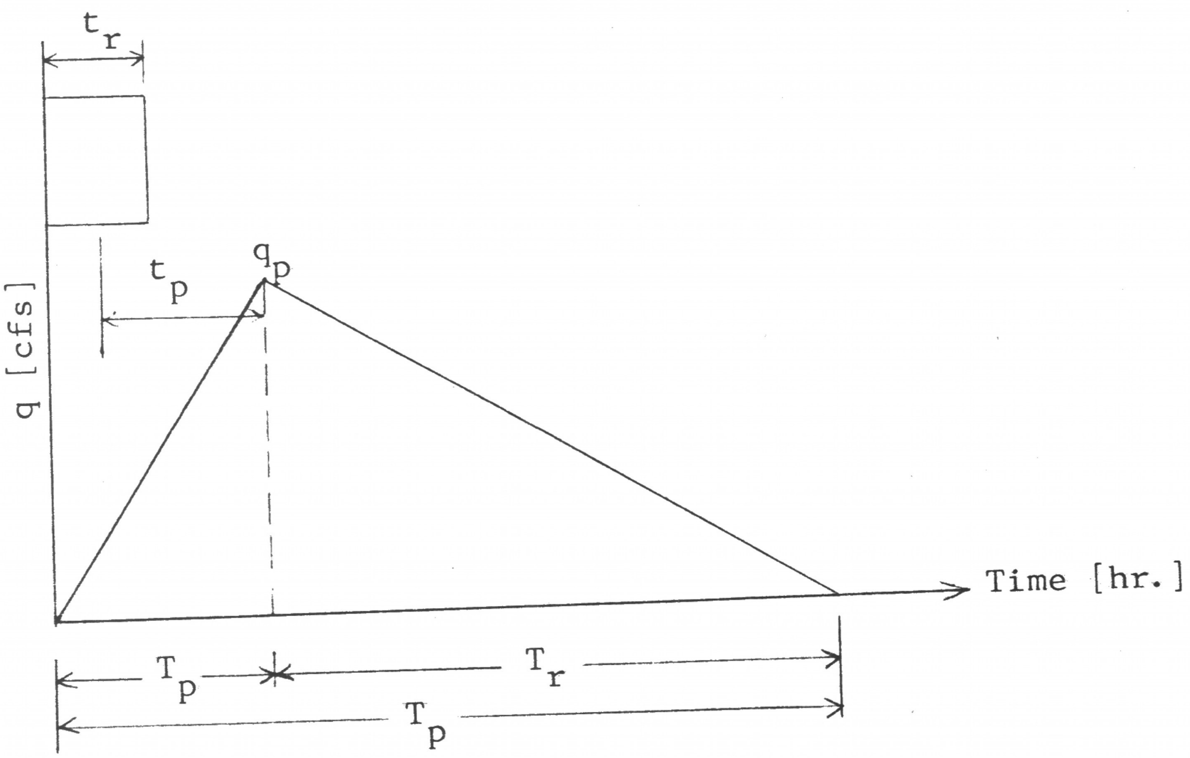
Non-paddy Land = 55%

D. Development of Unit Hydrograph

The hydrograph is a graphical presentation of discharge with respect to time at the drainage basin outlet. The unit hydrograph may be defined as the hydrograph of a unit volume of storm runoff produced by a uniform intensity storm of unit duration. The unit volume corresponds to one inch of rainfall excess spread uniformly over the total basin area.

Synthetic Unit Hydrograph (Snyder's Method)

Unit hydrographs can be derived only if sufficient records are available. But synthetic unit hydrographs can be derived for ungauged basins. This requires a relation between the physical geometry of the basin and resulting hydrographs. For ungauged basins with lack of hydrological data available, triangular synthetic hydrograph can be developed as follows :



q_p = peak rate of runoff in cfs

T_p = time of rise from beginning of rainfall excess to peak rate in hours

T_r = time of recession from peak rate to end of hydrograph in hours

T_b = time base of hydrograph in hours

t_r = duration of rainfall excess in hours

t_p = lag time in hours from center of rainfall excess to peak

T_c = time of concentration in hours, travel time of water from hydraulically most distant point to point of interest.

Steps:

1. To calculate basin area from topographic maps:

   $A = 37$ sq.miles

   $= 23680$ acres

2. Length of the principle drainage channel (Fig.9):

   $L = 8.78$ miles

3. To find out the centroid of the basin (Fig.9):

4. Distance from the outlet to a point on the stream nearest to the basin centroid (Fig.9):

   $L_c = 4.44$ miles

5. Average overland slope of the basin measured between contours:

0.85 ft/mile (from topographic map)

6. Straight length of the basin (Fig.9):

7.49 miles

7. Average channel slope :

$$S = \frac{0.85 \times 7.49}{8.78} = 0.72 \quad \text{ft/mile}$$

8. Channel roughness factor (assumed) :

$n = 0.055$

9. Time of concentration :

$$T_c = 31 \left(\frac{L^2 n^2}{S}\right)^{0.3} = 31\left(\frac{8.78^2 \times 0.055^2}{0.72}\right)^{0.3} = 22.10 \text{ hours}$$

10. Lag time to peak:

$$t_p = 0.6 \; T_c = 0.6 \times 22.1 = 13.26 \quad 14 \text{ hours.}$$

11. Time of rise :

$$T_p = t_p + 1/2 \; t_r = 14 + (1/2 \times 6) = 17 \text{ hours}$$

where, t = time considered for developing the design storm, in this case, 6 hours.

12. Co-efficient C_t :

$$C_t = \frac{t_p}{(LL_c)^{0.3}} = \frac{14}{(8.78 \times 4.44)^{0.3}} = 4.66$$

13. From the graph C_p vs C_t : (Fig.10)

$$C_p = 0.445$$

14. Base length of Unit Hydrograph :

$$T_b = \frac{1.2 \quad T_c}{C_p} = \frac{1.2 \times 22.1}{0.445} = 60 \text{ hours}$$

15. Peak discharge :

$$q_p = \frac{2A}{T_b} = \frac{2 \times 23680}{60} \approx 790 \text{ cfs}$$

16. Draw the unit hydrograph on the basis of the calculation from step 1 to 15 above. (Fig.11).

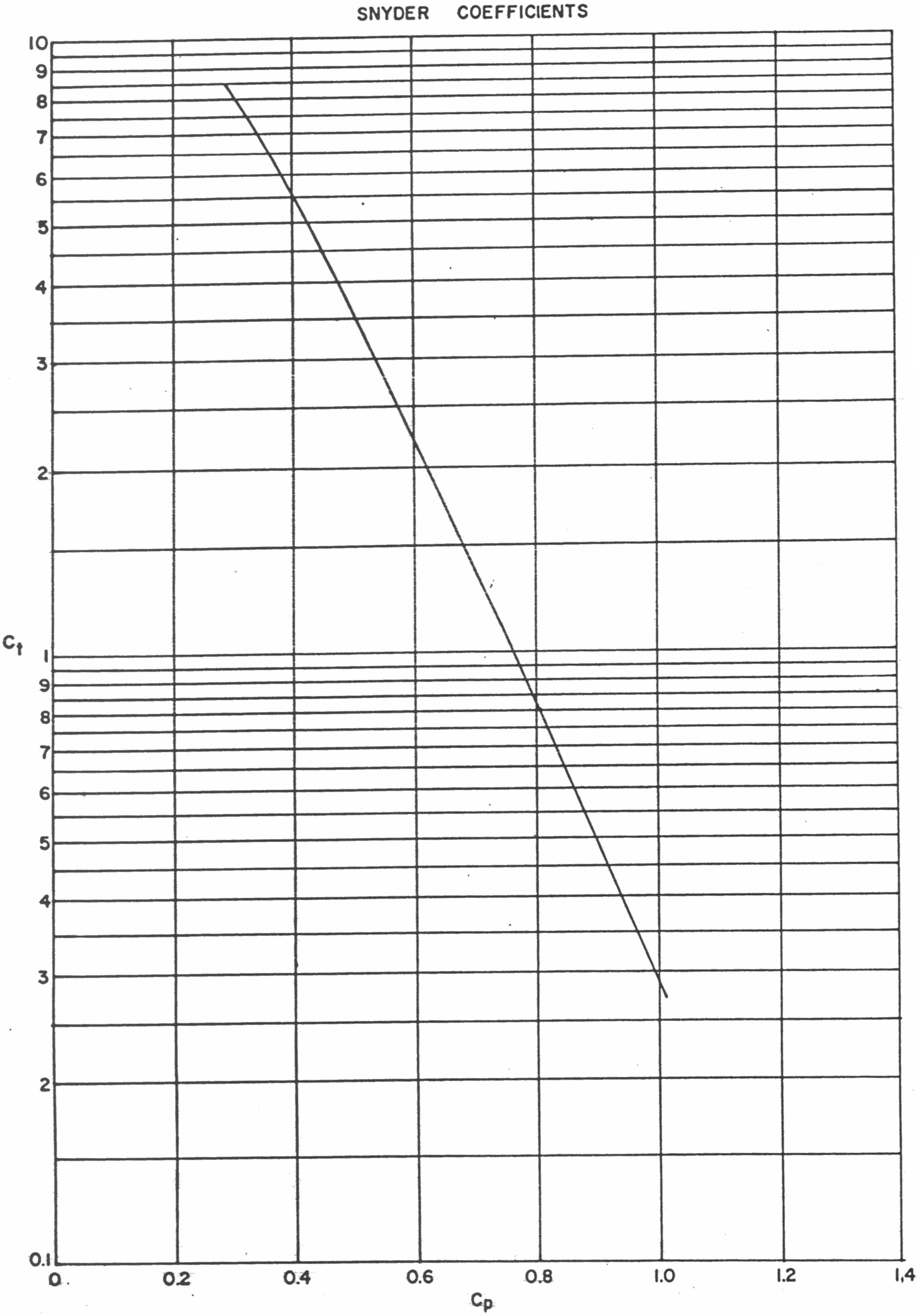

SNYDER COEFFICIENTS
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
0.1
C_t
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
C_p

FIGURE - 10

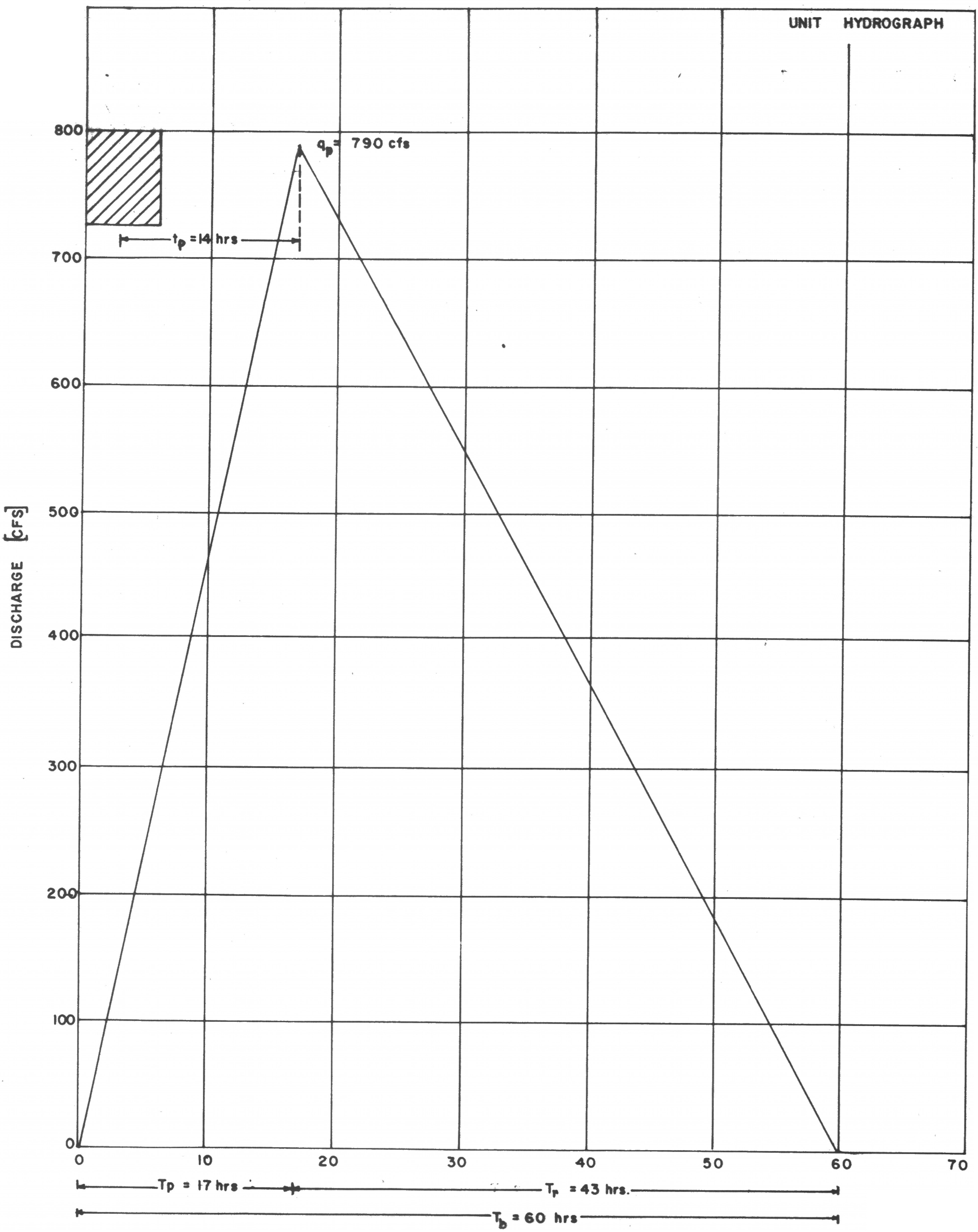

UNIT HYDROGRAPH
DISCHARGE [CFS]
q_p = 790 cfs
t_p = 14 hrs
Tp = 17 hrs
T_r = 43 hrs.
T_b = 60 hrs
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70

Figure - 11

E. The Runoff Hydrograph

The runoff hydrograph represents the time-dicharge relationship of the total design storm runoff at the basin outlet. The preparation of the storm runoff hydrograph involves treating each 6-hour period as a separate storm, multiplying the unitgraph vertical ordinates by the depth of rainfall excess, relating each hydrograph in time to the other hydrographs and summing up their combined ordinates.

The computations are shown on Table 15. Column 1 are values of the unitgraph vertical ordinates at 6-hour intervals. The intervals are started from the peak rather than from the beginning of the time of rise.

Columns 2 and 3 are 6-hour intervals and days of the storm runoff period respectively.

Columns 4 to 9 are the hydrographs for each 6-hour period of rainfall excess. The values are computed by multiplying the unitgraph values by the amount of rainfall excess at the column head. The zero value of each hydrograph coincides with the first hour of the 6-hour rainfall period.

Column 10 is the summation of values for each 6-hour increment. These values represent the discharge ordinates of the runoff hydrograph and are shown on Fig. 12.

Unitgraph [cfs]	Hours	Day	Rainfall Excess - 6 hour duration						Runoff Hydrograph
			0.35"	0.04"	2.21"	0.27"	0.13"	0.07"	3.07"
1	2	3	4	5	6	7	8	9	10
0	18	1	0						0
225	24		79	0					79
505	6		177	9	0				186
790	12	2	277	20	497	0			794
675	18		236	32	1116	61	0		1445
570	24		200	27	1746	136	29	0	2138
460	6		161	23	1492	213	66	16	1971
350	12	3	123	18	1260	182	103	35	1721
240	18		84	14	1017	154	88	55	1412
130	24		46	10	774	124	74	47	1075
20	6		7	5	530	95	60	40	737
0	12	4	0	1	287	65	46	32	431
	18			0	44	35	31	25	135
	24				0	5	17	17	39
	6	5				0	3	9	12
	12						0	2	2
	18							0	0
	24								
									1217

Table 15

A check on the computations of Runoff Hydrograph in Table 15 can be made using the following formulae:

1. Total volume of water under the hydrograph:

$$V = \frac{It}{12}, \qquad I = \text{from column 10}, \quad t = \text{6-hour time interval}$$

$$V = \frac{12177 \times 6}{12} = 6089 \text{ acre ft.}$$

2. Total rainfall excess, i

$$i = \frac{12V}{A}, \quad A = \text{basin area in acres}$$

$$= \frac{12 \times 6089}{23680} = 3.086''$$

This should equal the summation of weighted rainfall excess in Table 14 or 3.07".

Figure - 12

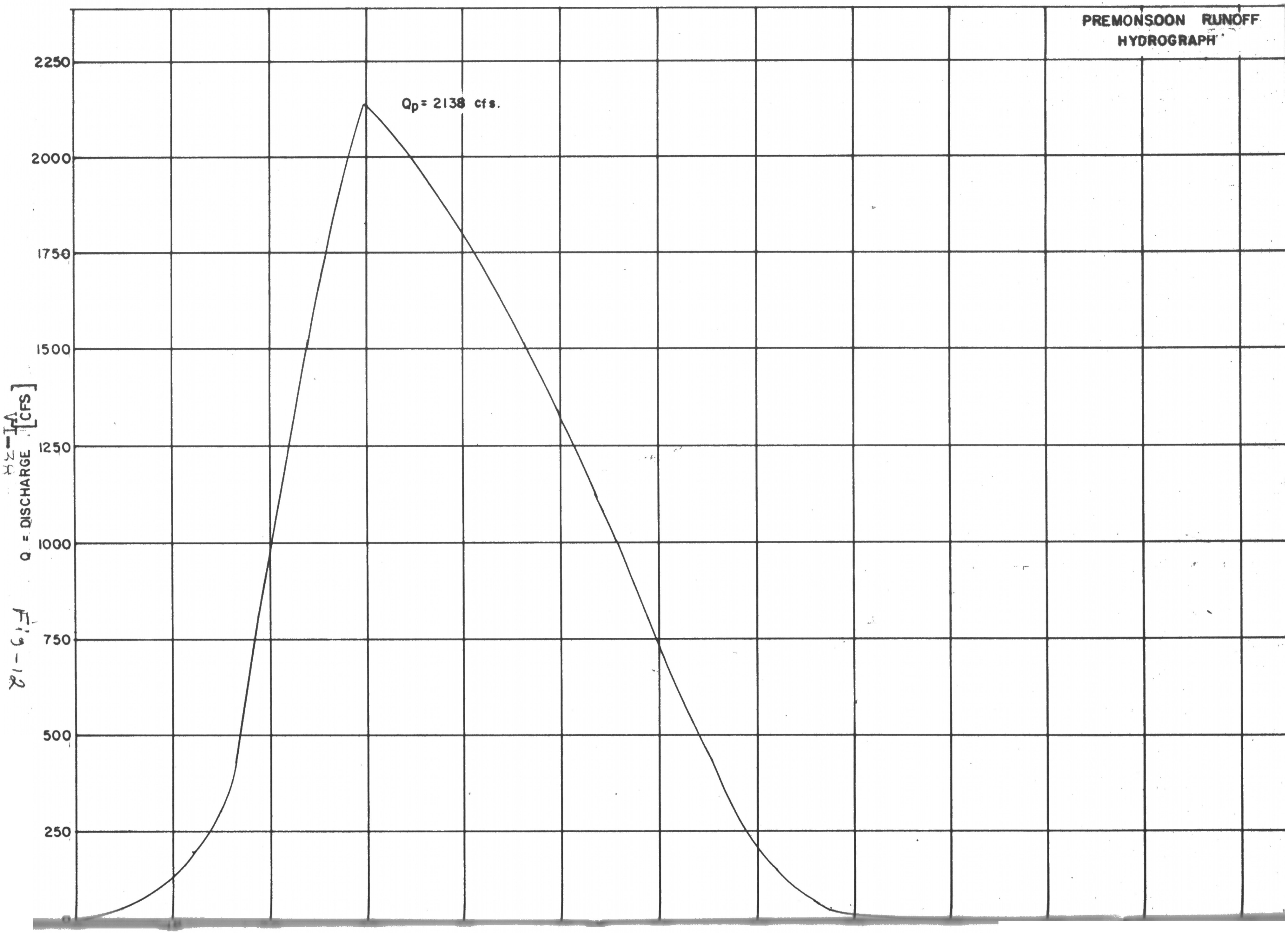


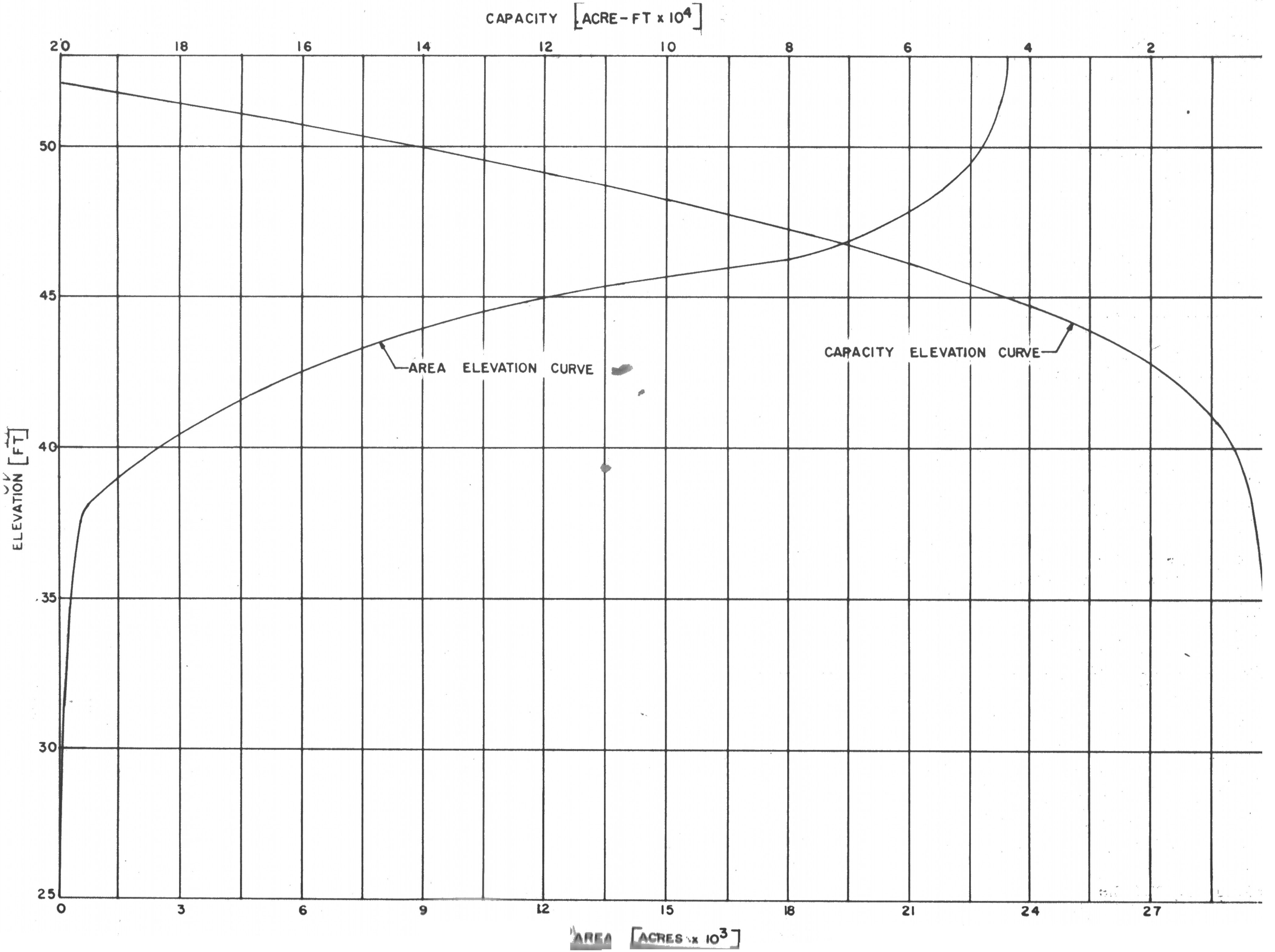
Fig - 12

VI-38

F.1 Calculation for Elevation Area Capacity

Ground El. [ft.PWD]	Area [acres]	Σ Area [acres]	Volume [acre ft]	Σ Volume [acre ft]
1	2	3	4	5
25	0	0	0	0
			8.51	8.51
26	17.02	17.02		
			68.10	76.61
28	34.05	51.07		
			153.22	229.83
30	51.07	102.14		
			272.38	502.21
32	68.10	170.24		
			425.62	927.83
34	85.13	255.37		
			595.88	1523.71
36	85.13	340.5		
			1011.10	2534.81
38	330.10	670.6		
			3098.30	5633.11
40	1757.10	2427.7		
			8211.90	13845.01
42	3356.50	5784.2		
			16387.60	30232.61
44	4819.20	10603.4		
			26882.20	57114.81
46	5675.40	16278.8		
			37635.60	94750.41
48	5078.00	21356.8		
			44399.90	139150.31
50	1686.30	23043.1		
			46723.10	185873.41
Above 50	636.90	23680 =37 sq miles		

Elevation Area Capacity Table
Table 16


CAPACITY [ACRE - FT x 10^4]
20
18
16
14
12
10
8
6
4
2
50
45
40
35
30
25
ELEVATION [FT]
AREA ELEVATION CURVE
CAPACITY ELEVATION CURVE
0
3
6
9
12
15
18
21
24
27
AREA [ACRES x 10^3]

2. <u>Stage-Discharge Curve</u>

During a typical drainage cycle the storage level will at first be low and discharge will begin under flow condition 5. In this condition, it is assumed that there will be a properly designed stilling basin as part of the structure and a critical depth will control at the outlet.

As the storage level rises the entrance to the sluice may become submerged and the dischare will under flow condition 3. After the flood crest passes, the storage level will drop, the entrance will no longer be submerged and discharge will again take place under flow condition 5.

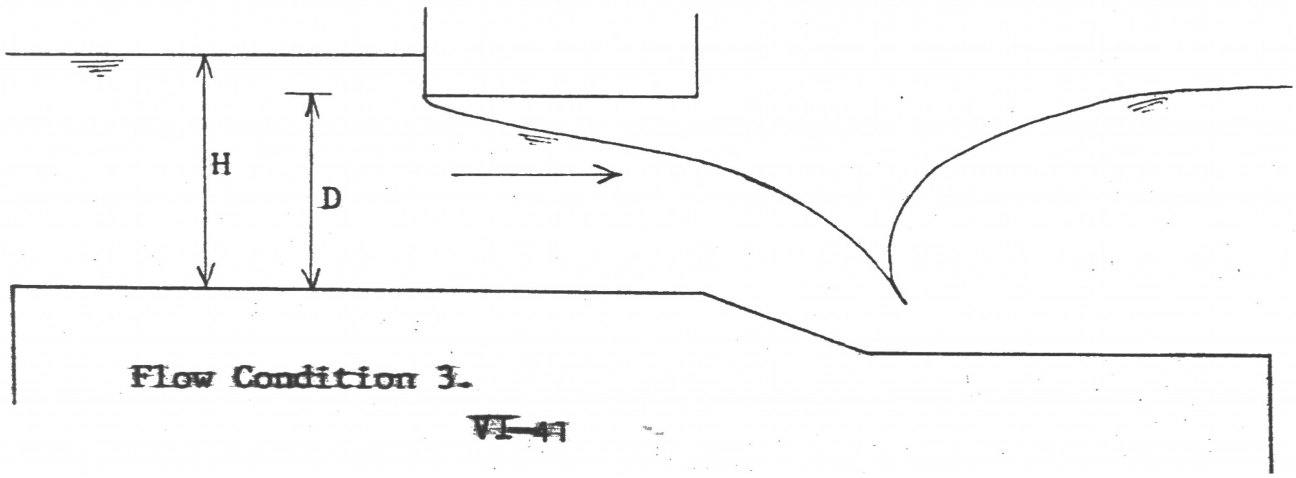
<u>Flow Condition 3</u>

In order for the entrance to be submerged H must be greater than the critical value of 1.2 to 1.5 D. However, in this range the flow is unsteady, so for design purposes 1.5D will be used as limit.

For H > 1.5 D, $q = C_q D \sqrt{2gH}$ [Ref: Fluid Mechanics for Hydrualic Engineers-Rouse]

where, q =unit discharge, cfs/unit width

C_q = co-efficient of discharge (taken from Fig.14)



Flow Condition 3.

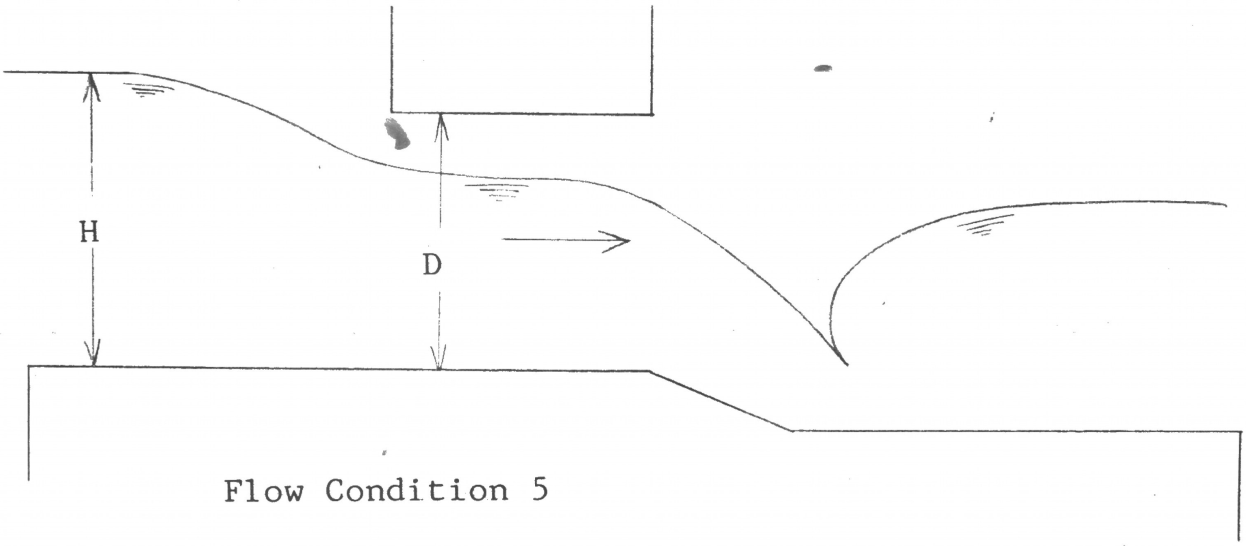
Flow condition 5

This condition will usually occur when a stilling basin with glacis is attached to the sluice, or, when the flow downstream of the vents is able to spread laterally sufficiently to pass through critical depth. In this condition

For $H < 1.5 D$

$$q = C H^{3/2}$$ [Ref: Hydrologic Design Procedure for Drainage Structures - BWDB]

where C = co-efficient of discharge (Ref. Table 17)



Flow Condition 5

Co-efficient of Discharge
Sluice flowing partially full

Type of entrance	C
Cylinder quadrant	2.86
Simplified straight line	2.80
Straight line transition	2.68
Square ended transition	2.45
Well rounded entrance	2.68
Square entrance	2.45

Co-efficient of Discharge
Table 17

At the beginning, the discharge will follow the flow condition 5. [H $\leqslant$ 1.5 D = 9 ft.]. After that the discharge will be under flow condition 3 [H $\geqslant$ 1.5 D = 9 ft]. Computation of discharge with different flow conditions for different no. of vents are shown in Table 18.

Discharge with different elevations and ventages

Condition 5

El.	H[ft]	$q=2.68\ H^{3/2}$	Discharge [cfs] Ventages 1	2	3	4	5	6
25	0	0	0	0	0	0	0	0
26	1	2.68	13.4	27	40	54	67	80
28	3	14	70	140	210	280	350	420
30	5	30	150	300	450	600	750	900
32	7	50	250	500	750	1000	1250	1500
34	9	72.4	362	724	1086	1448	1810	2172

Condition 3

El.	H	D/H	Cq (from graph)	$q=CqD\sqrt{2gH}$ [cfs/unit width]	Discharge [cfs] Ventages 1	2	3	4	5	6
35	10	0.60	0.495	75.37	377	754	1131	1507	1884	2261
36	11	0.54	0.497	79.37	397	794	1191	1587	1984	2381
38	13	0.46	0.506	87.84	439	878	1318	1757	2195	2635
40	15	0.40	0.513	95.67	478	957	1435	1913	2392	2870
42	17	0.35	0.520	103.23	516	1032	1549	2065	2581	3097
44	19	0.31	0.525	110.19	551	1102	1653	2204	2755	3306
46	21	0.28	0.530	116.94	585	1169	1754	2339	2924	3508

Stage-Discharge Table
Table - 18

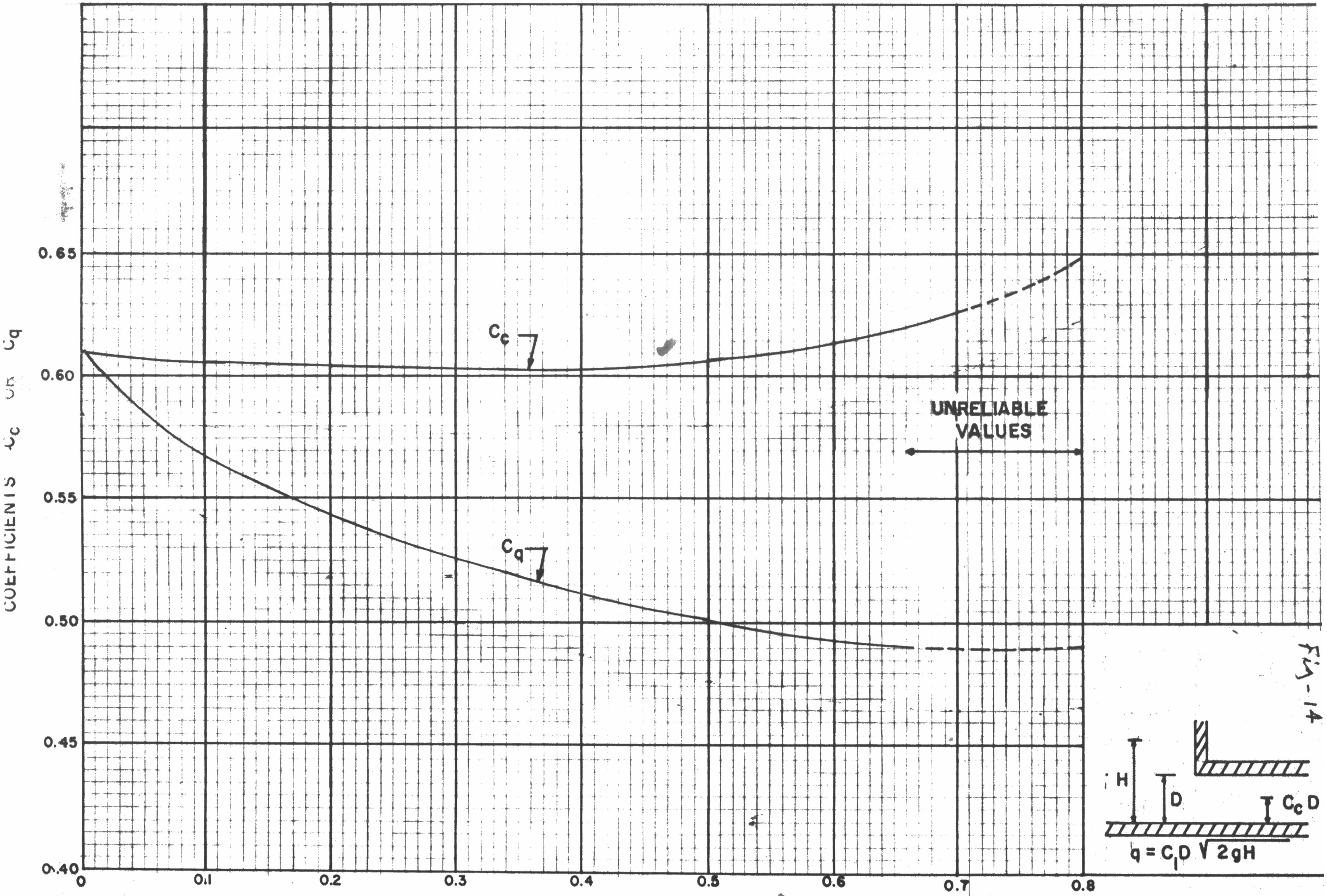
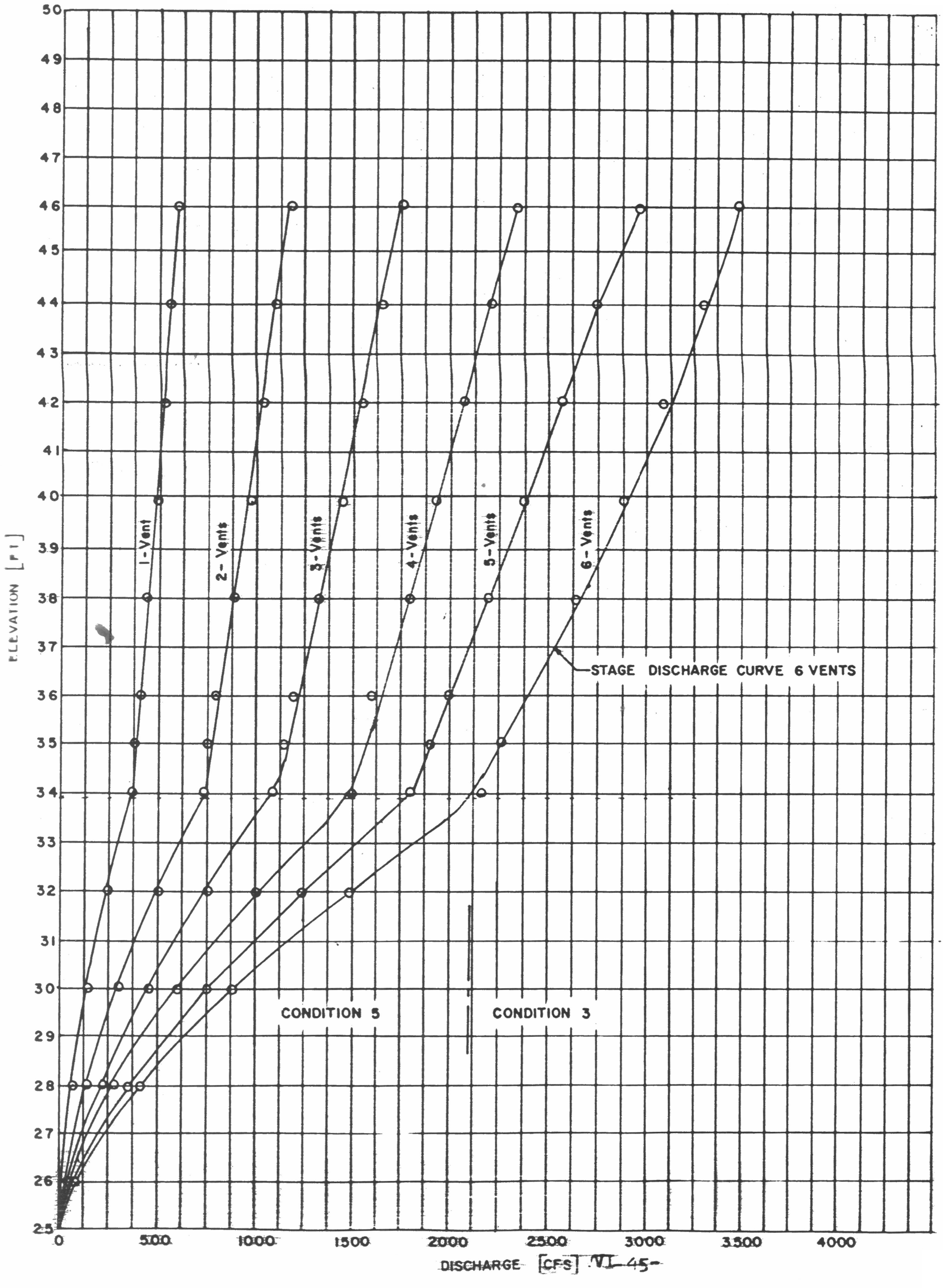


Fig-14
COEFFICIENTS Cc OR Cq
0.65
0.60
0.55
0.50
0.45
0.40
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Cc
Cq
UNRELIABLE VALUES
H
D
Cc D
q = Cq D √2gH
D/H



ELEVATION [FT]
DISCHARGE [CFS]
1-Vent
2- Vents
3- Vents
4- Vents
5- Vents
6- Vents
STAGE DISCHARGE CURVE 6 VENTS
CONDITION 5
CONDITION 3

VI-45-

3. $2s/t \pm D$ Curve

The computations for this curve are shown in Table 19 and Table 20. Column 2 is the storage capacity in acre-feet taken from Fig.13. Column 3 is 2s/t in cfs where S is the storage in cubic feet and t is a selected time interval of 21,600 seconds (6-hours). Column 4 of Table 19 is taken from the stage-discharge curve, Figure 15. Column 5 is the summation of Column 3 and Column 4. Column 4 vs Column 5 is plotted in Figure 15 to get 2S/t +D curve for 1 vent. Similarly 2S/t +D curve for two and three vents are drawn in Figure 16 and that of four, five and six vents are drawn in Fig. 17.

2S/t +D Vs. D Curve for 1 vent, 2 vents & 3 vents

El.	Storage Volume(S) [acre-ft]	2S/t [cfs]	1 vent		2 vents		3 vents	
			D	2S/t +D	D	2S/t +D	D	2S/t +D
1	2	3	4	5	6	7	8	9
25	0	0	0	0	0	0	0	0
26	9	36	13.4	49.4	27	63	40	76
27	30	121	25	146	75	196	125	246
28	77	311	70	381	140	451	210	521
29	125	504	87	591	200	704	325	829
30	230	928	150	1078	300	1228	450	1378
31	380	1533	175	1708	387	1920	587	2120
32	502	2025	250	2275	500	2525	750	2775
33	720	2904	287	3191	600	3504	900	3804
34	928	3743	362	4105	724	4467	1086	4829
35	1000	4033	378	4411	757	4790	1135	5168
36	1524	6147	398	6545	797	6944	1195	7342
37	2000	8067	425	8492	837	8904	1265	9332
38	2535	10225	440	10665	880	11105	1320	11545
39	4000	16133	450	16583	906	17039	1375	17508
40	5633	22720	480	23200	960	23680	1440	24160
41	9300	37510	500	38010	975	38485	1475	38985
42	13845	55842	515	56357	1030	56872	1545	57387
43	21000	84700	525	85225	1050	85750	1575	86275
44	30233	121940	550	122490	1100	123040	1650	123590
45	43000	173433	562	173995	1125	174558	1675	175108
46	57115	230364	583	230947	1167	231531	1751	232115
47	74700	301290						
48	94750	382158						
49	116000	467867						
50	139150	561238						

2 s/t + D Vs D Table
Table-19

2S/t ±D Vs. D Curve for 4 vents, 5 vents & 6 vents

El.	Storage Volume(S) [acre-ft]	2S/t [cfs]	4 vents		5 vents		6 vents	
			D	2S/t +D	D	2S/t +D	D	2S/t +D
1	2	3	4	5	6	7	8	9
25	0	0	0	0	0	0	0	0
26	9	36	54	90	67	103	80	116
27	30	121	150	271	200	321	238	359
28	77	311	275	586	350	661	418	729
29	125	504	400	904	544	1048	638	1142
30	230	928	587	1515	750	1678	899	1827
31	380	1533	800	2333	1000	2533	1175	2708
32	502	2025	1000	3025	1250	3275	1489	3514
33	720	2904	1250	4154	1525	4429	1813	4717
34	928	3743	1450	5193	1800	5543	2171	5914
35	1000	4033	1575	5608	1892	5925	2268	6301
36	1524	6147	1650	7797	1992	8139	2388	8535
37	2000	8067	1725	9792	2100	10167	2525	10592
38	2535	10225	1760	11985	2200	12425	2638	12863
39	4000	16133	1850	17983	2281	18414	2781	18914
40	5633	22720	1921	24641	2401	25121	2879	25599
41	9300	37510	2000	39510	2475	39985	3013	40523
42	13845	55842	2061	57903	2576	58418	3088	58930
43	21000	84700	2125	86825	2650	87350	3238	87938
44	30233	121940	2200	124140	2750	124690	3310	125250
45	43000	173433	2250	175683	2875	176308	3413	176846
46	57115	230364	2334	232698	2918	233282	3499	233863
47	74700	301290						
48	94750	382158						
49	116000	467867						
50	139150	561238						

Table 20

4. <u>Flood Routing Procedure</u>

The computations are shown in Table 21. The procedure is as follows:

1. The first values in Column 6 and 8 are known or assume.
2. The first value in Column 5 is the value of 2s/t+D taken from Figure 16 &17 corresponding to the known value of D, in this case zero.
3. In subsequent lines Column 5 is Column 4 plus Column 7 from the line above.
4. Column 7 is Column 5 minus twice Column 6 in each case throughout the computations.
5. After the first line, values of D in Column 6 are taken from Figure 16 & 17 corresponding to the value of 2s/t +D on the same line.
6. Column 8 is the basin water surface elevation taken from Figure 15 for the corresponding value of D in Column 6.

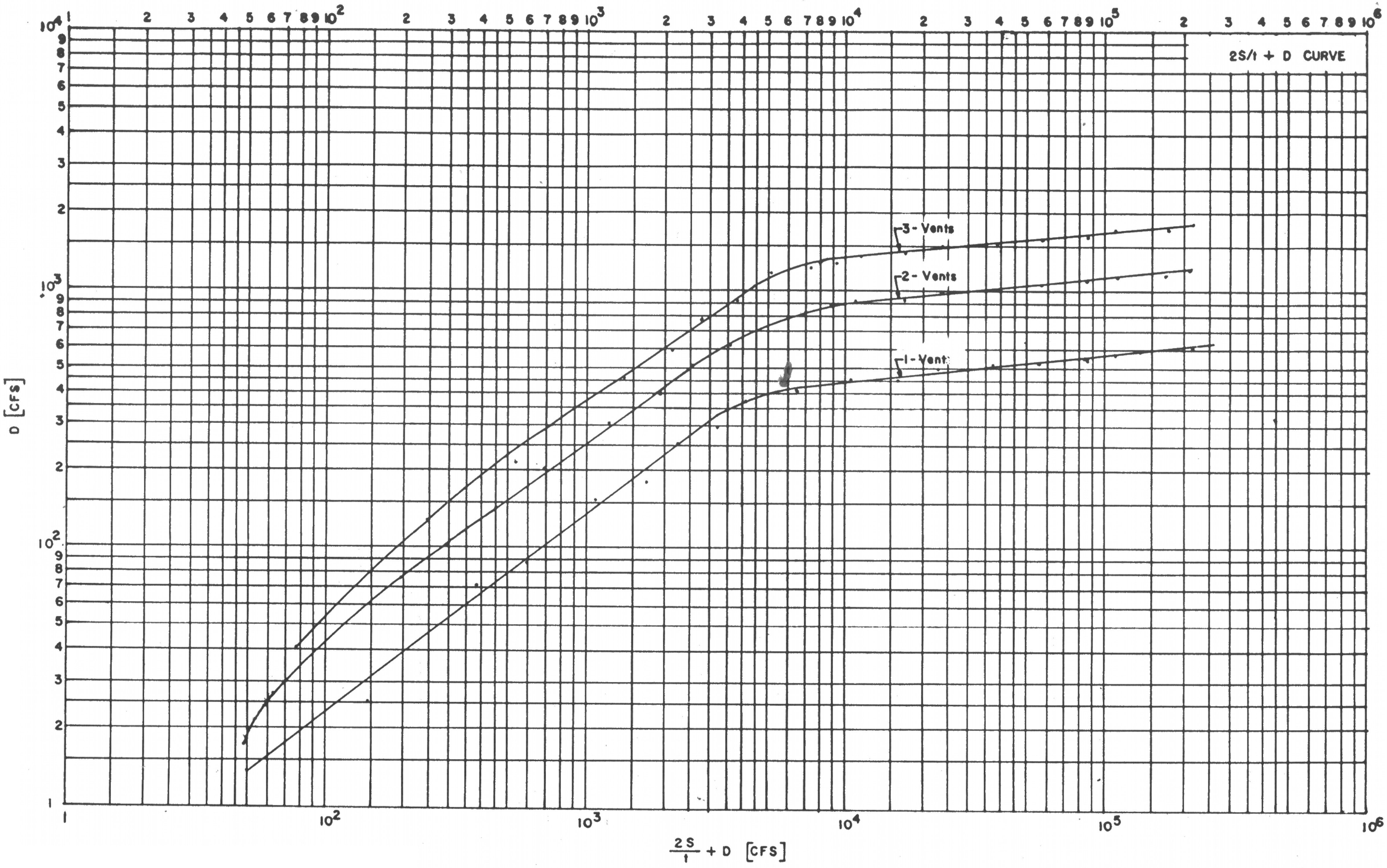


Figure – 16

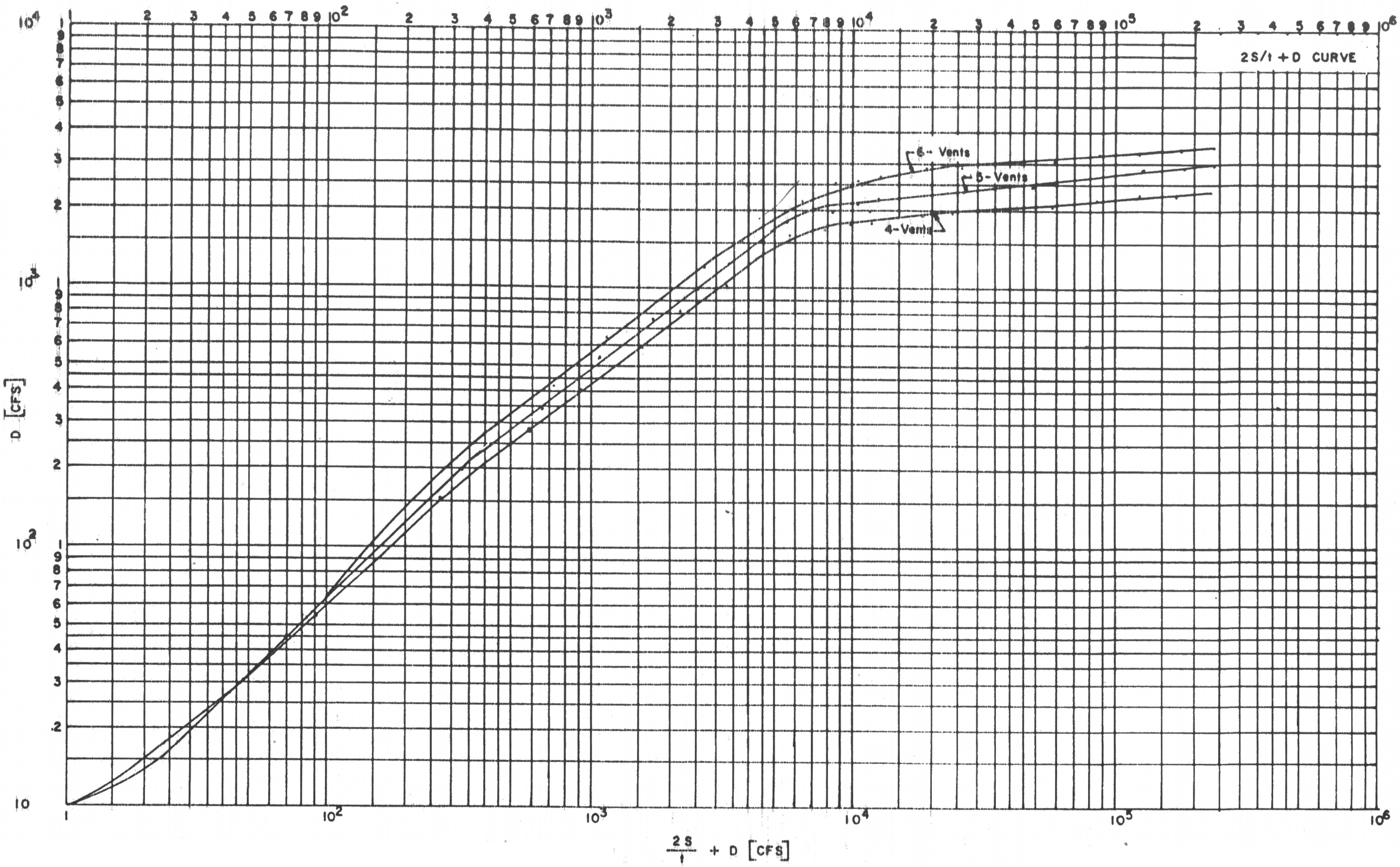


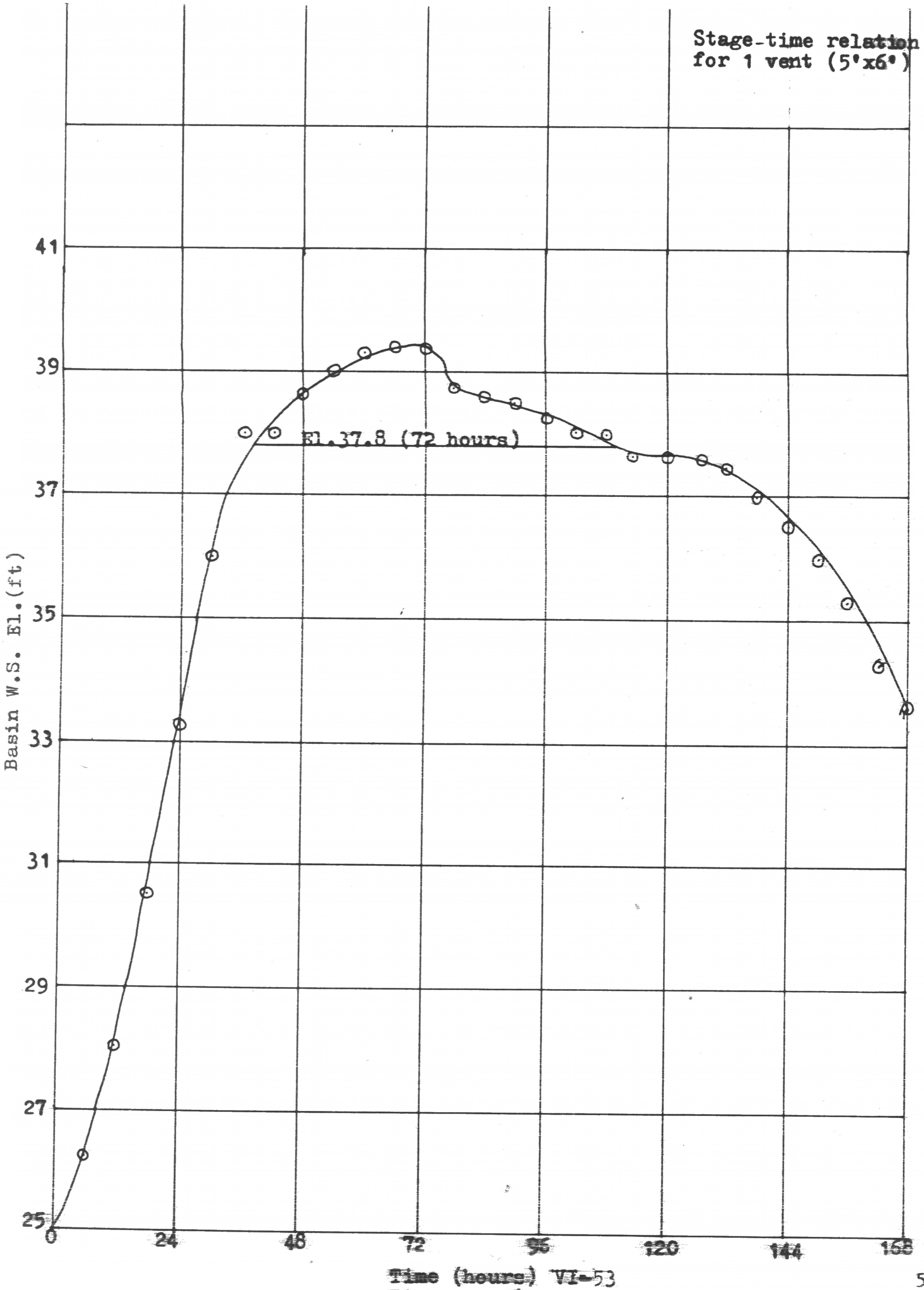
Figure - 17

Flood Routing for 1-vent

Day	Hour	I [cfs]	I 1 + 2	2 s/t + D (4)+(7)	D	2 s/t - D (5)-2x(6)	Basin W.S.El.
1	2	3	4	5	6	7	8
1	18	0	0	0	0	0	25.0
	24	79	79	79	19	41	26.0
	6	186	265	306	52	202	28.0
2	12	794	980	1182	150	882	30.5
	18	1445	2239	3121	315	2491	33.4
	24	2138	3583	6074	400	5274	36.0
	6	1971	4109	9383	430	8523	37.9
3	12	1721	3692	12215	435	11345	38.0
	18	1412	3133	14478	450	13578	38.6
	24	1075	2487	16065	455	15155	39.1
	6	737	1812	16967	460	16047	39.5
4	12	431	1168	17215	462	16291	39.55
	18	135	566	16857	459	15939	39.3
	24	39	174	16113	452	15209	38.7
	6	12	51	15260	450	14360	38.6
5	12	2	14	14374	448	13478	38.5
	18	0	2	13480	445	12590	38.2
	24	0	0	12590	437	11716	38.0
	6	0	0	11716	435	10846	37.9
6	12	0	0	10846	432	9982	37.8
	18	0	0	9982	430	9122	37.8
	24	0	0	9122	428	8266	37.8
	6	0	0	8266	418	7430	37.5
	12	0	0	7430	415	6600	37.0
7	18	0	0	6600	410	5780	36.5
	24	0	0	5780	400	4980	36.0
	6	0	0	4980	385	4210	35.2
8	12	0	0	4210	365	3480	34.3
	18	0	0	3480	335	2810	33.7

Pre-monsoon Flood Routing Table (1 vent 5'x6')
Table 21

To determine the crop damage, a basin water surface elevation vs. time curve is plotted in Figure 17 to 25. This completes the flood routing procedure.



Stage-time relation
for 1 vent (5'x6')
El. 37.8 (72 hours)
Basin W.S. El. (ft)
41
39
37
35
33
31
29
27
25
0
24
48
72
96
120
144
168
Time (hours)

VI-53

Flood Routing for 2-vents

Day	Hour	I [cfs]	I_1+I_2	2s/t +D (4) +(7)	D	2s/t -D (5)- 2x(6)	Basin W.S.El.
1	2	3	4	5	6	7	8
1	18	0	0	0	0	0	25.0
	24	79	79	79	34	11	25.7
	6	186	265	276	96	84	27.4
2	12	794	980	1064	260	544	29.7
	18	1445	2239	2783	520	1743	32.3
	24	2138	3583	5326	720	3886	34.0
	6	1971	4109	7995	830	6335	35.9
3	12	1721	3692	10027	870	8287	37.9
	18	1412	3133	11420	880	9660	38.2
	24	1075	2487	11472	880	9712	38.2
	6	737	1812	11524	880	9764	38.2
4	12	431	1168	10932	875	9182	38.0
	18	135	566	9748	860	8028	37.7
	24	39	174	8202	830	6542	36.8
	6	12	51	6593	780	5023	35.4
5	12	2	14	5037	710	3617	33.8
	18	0	2	3619	610	2399	32.9
	24	0	0	2399	470	1459	31.7
	6	0	0	1459	330	799	30.5
6	12	0	0	799	210	379	29.0
	18	0	0	379	130	119	28.0
	24	0	0	119	73	-27	27.0

Pre-monsoon Flood Routing Table (2 vents 5'x6')
Table 22

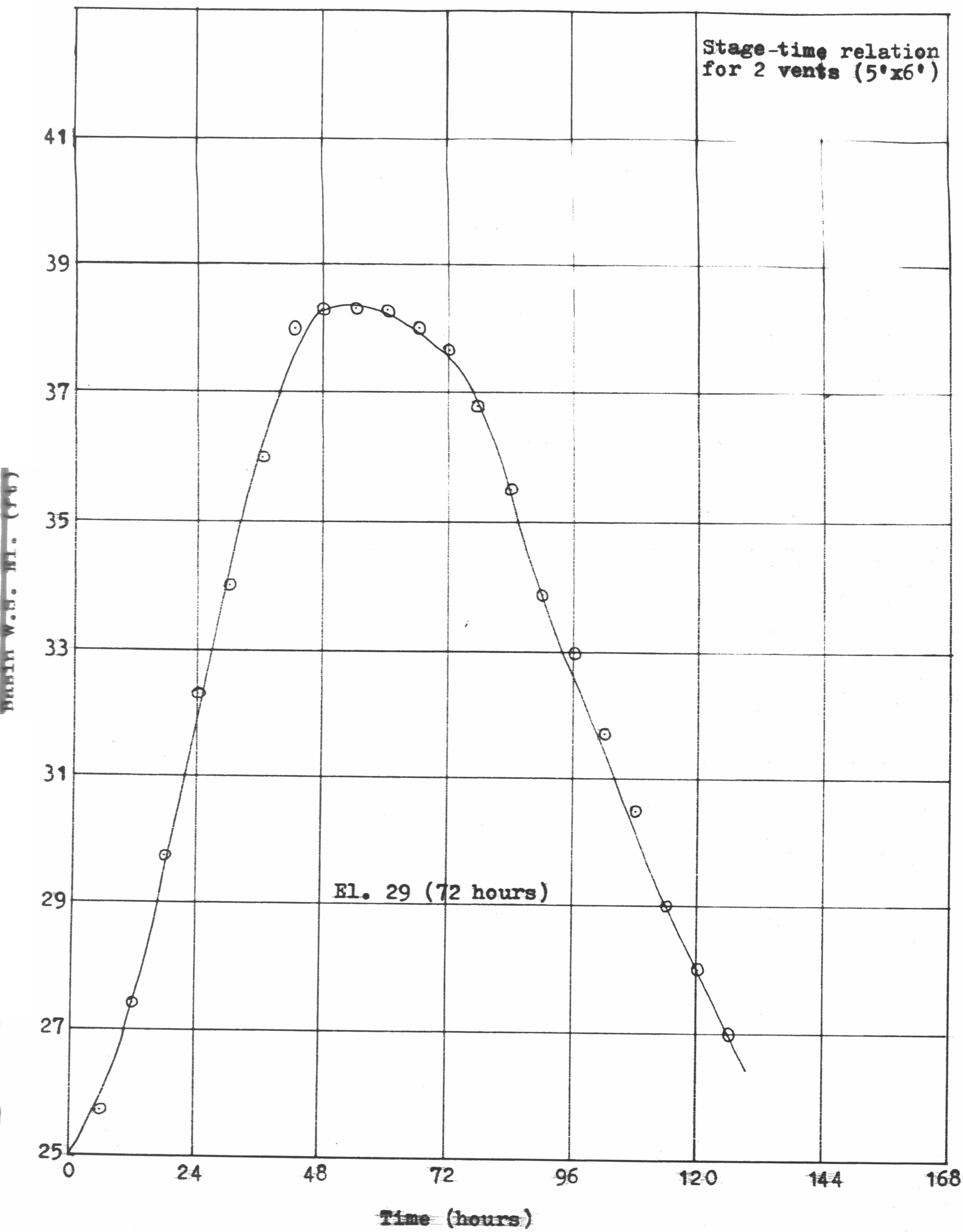

Stage-time relation
for 2 vents (5'x6')
41
39
37
35
33
31
29
27
25
0
24
48
72
96
120
144
168
El. 29 (72 hours)
Time (hours)

Figure - 19

Flood Routing for 4-vents

Day	Hour	I [cfs]	$I_1 + I_2$	2s/t +D (4)+(7)	D	2s/t -D (5)- 2x(6)	Basin W.S.El
1	2	3	4	5	6	7	8
1	18	0	0	0	0	0	25.0
	24	79	79	79	48	-17	25.9
	6	186	265	248	140	-32	26.9
2	12	794	980	948	400	148	28.6
	18	1445	2239	2327	800	727	30.8
	24	2138	3583	4310	1280	1750	33.2
	6	1971	4109	5859	1500	2859	34.2
3	12	1721	3692	6551	1580	3391	34.7
	18	1412	3133	6524	1600	3324	35.4
	24	1075	2487	5811	1500	2811	34.2
	6	737	1812	4623	1450	1723	33.8
4	12	431	1168	2891	940	1011	31.6
	18	135	566	1577	600	377	30.1
	24	39	174	551	270	11	29.2
	6	12	51	62	38	-14	25.7
5	12	2	14	0			
	18	0	2				
	24	0	0				

Pre-monsoon Flood Routing Table (4 vents 5'x6')
Table 24

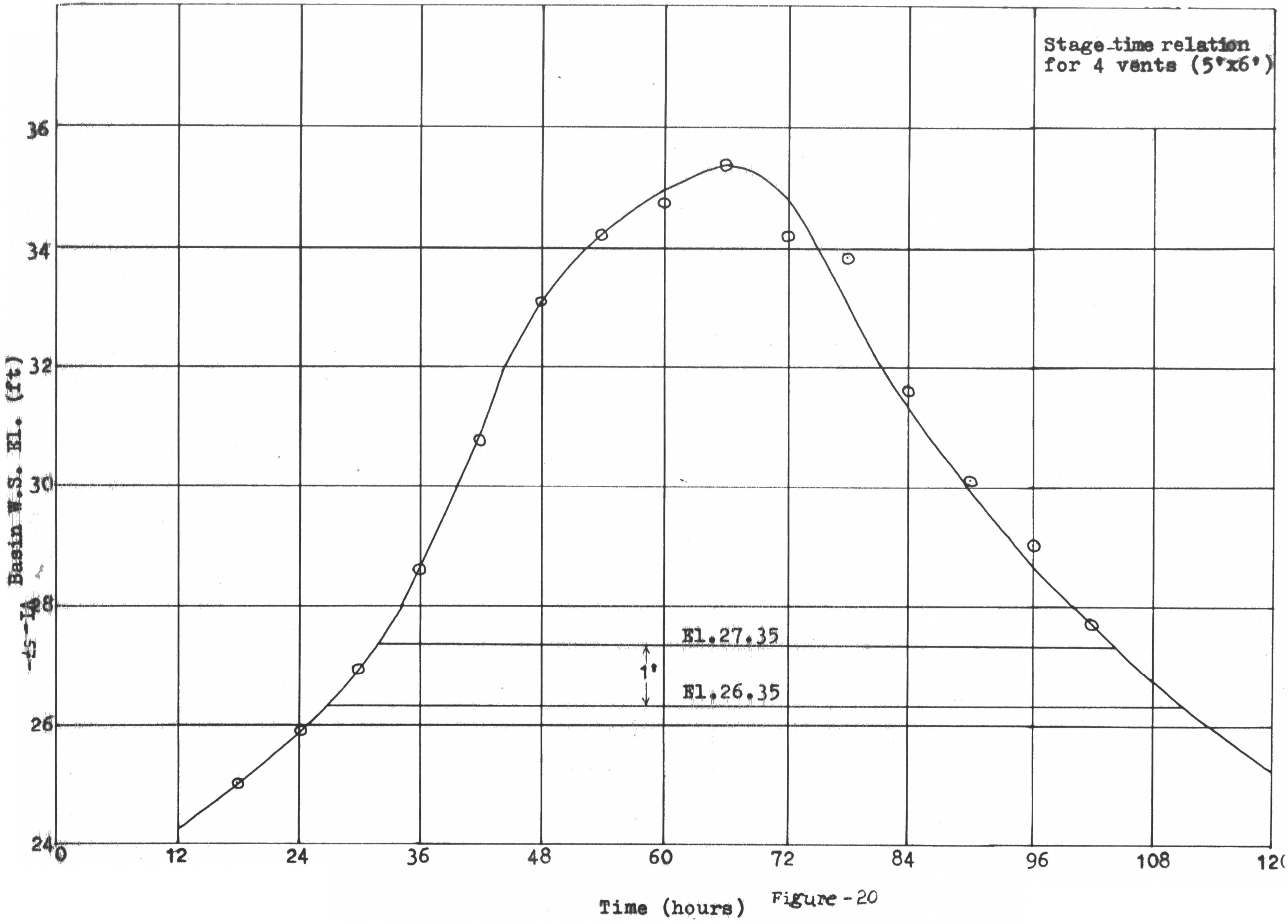
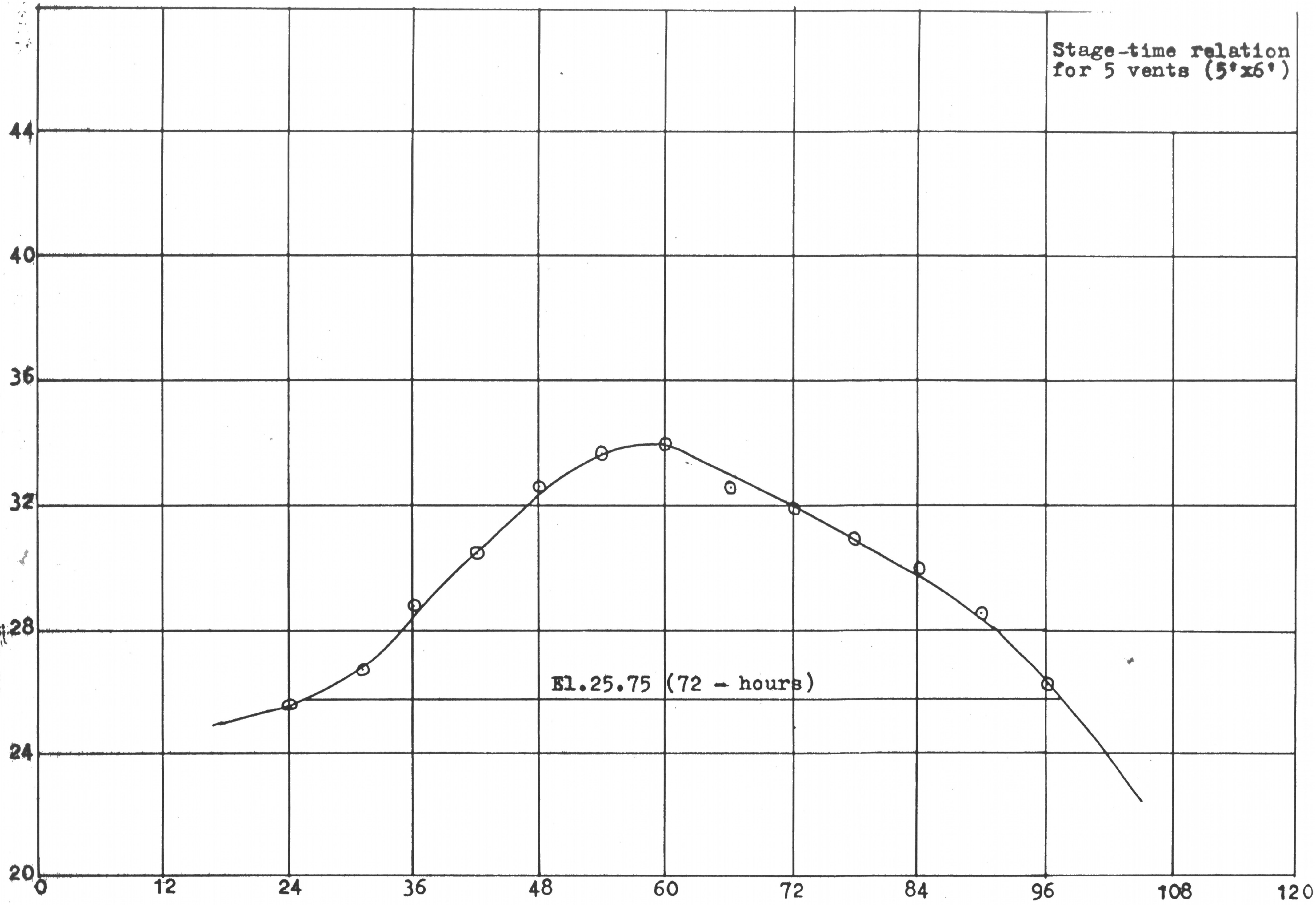

Stage-time relation
for 4 vents (5'x6')
Basin W.S. El. (ft)
36
34
32
30
28
26
24
0
12
24
36
48
60
72
84
96
108
120
El.27.35
El.26.35
1'
Time (hours)

Figure - 20

Flood Routing for 5-vents

Day	Hour	I [cfs]	$I_1 + I_2$	2s/t +D (4) +(7)	D	2s/t -D (5)-2x(6)	Basin W.S.El.
1	2	3	4	5	6	7	8
1	18	0	0	0	0	0	25.0
	24	79	79	79	52	-25	25.5
	6	186	265	240	155	-70	26.7
2	12	794	980	910	470	-30	28.7
	18	1445	2239	2209	910	389	30.6
	24	2138	3583	3972	1425	1122	32.6
	6	1971	4109	5231	1750	1731	33.8
3	12	1721	3692	5423	1800	1823	34.0
	18	1412	3133	4956	1700	1556	35.6
	24	1075	2487	4043	1450	1143	31.9
	6	737	1812	2955	1150	655	30.9
4	12	431	1168	1823	780	263	30.1
	18	135	566	829	430	-31	28.4
	24	39	174	143	92	-41	26.2
	6	12	51	10			
5	12	2	14				
	18	0	2				
	24	0	0				

Pre-monsoon Flood Routing (5 vents 5'x6')
Table 25



Time (hours) Figure - 21

Flood Routing for 6 vents

Day	Hour	I [cfs]	$I_1 + I_2$	2s/t +D (4) +(7)	D	2s/t -D (5) -2x(6)	Basin W.S.El.
1	2	3	4	5	6	7	8
1	18	0	0	0	0	0	25
	24	79	79	79	47	-15	25.5
	6	186	265	250	170	-90	26.5
2	12	794	980	890	500	-110	28.4
	18	1445	2239	2129	990	-149	30.4
	24	2138	3583	3434	1400	634	31.7
	6	1971	4109	4743	1800	1143	32.9
3	12	1721	3692	4835	1825	1185	33.0
	18	1412	3133	4318	1700	918	32.6
	24	1075	2487	3405	1420	565	31.6
	6	737	1812	2377	1075	227	30.7
4	12	431	1168	1395	715	35	29.4
	18	135	566	601	370	-139	27.7
	24	39	174	35	18	-1	25.1
	6	12	51				
5	12	2	14				
	18	0	2				
	24						

Pre-monsoon Flood Routing Table (6 vents 5'x6')
Table 26

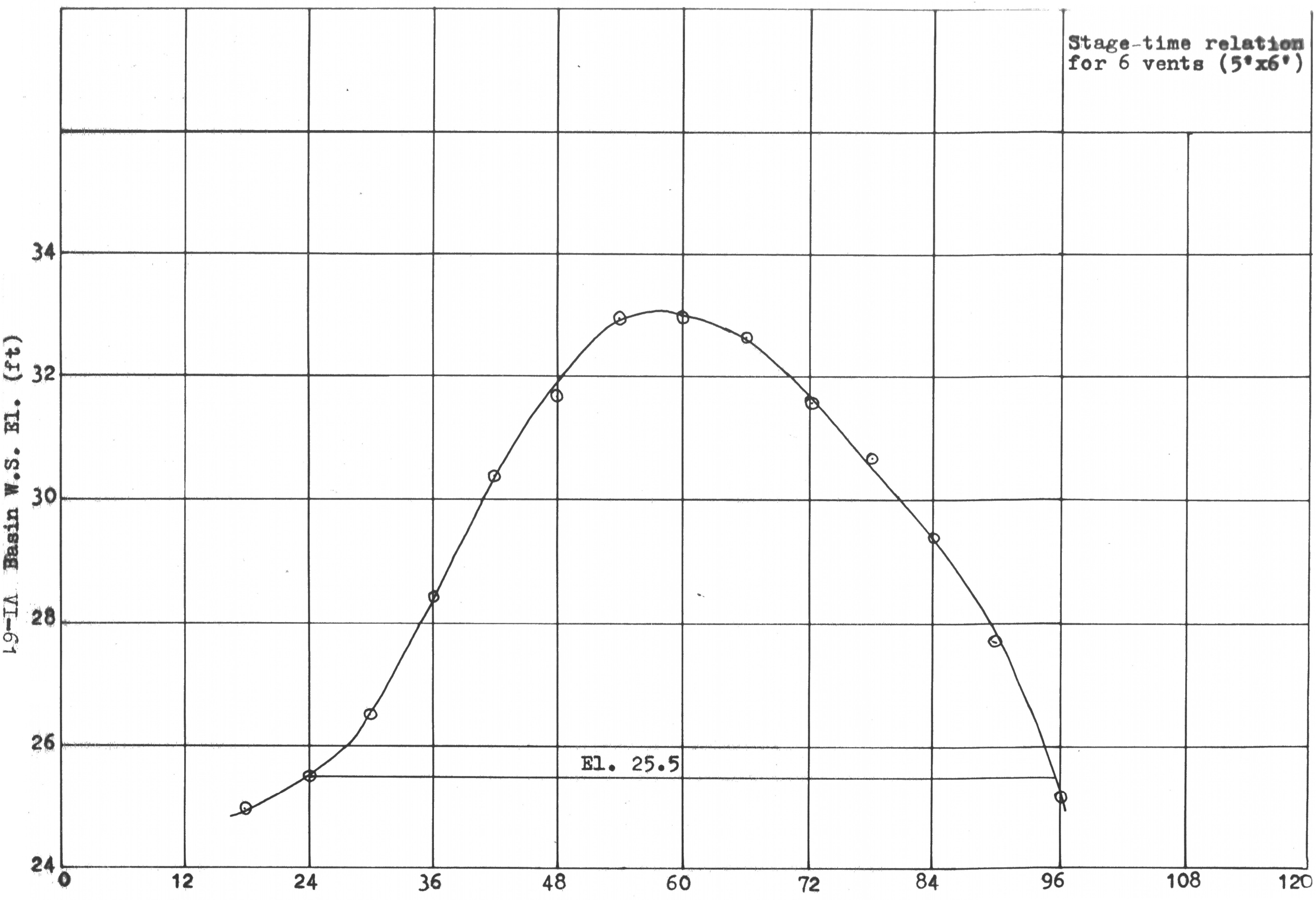

Stage-time relation
for 6 vents (5'x6')
El. 25.5
VI-61 Basin W.S. El. (ft)
34
32
30
28
26
24
0
12
24
36
48
60
72
84
96
108
120
Time (hours)

Figure-22

Post Monsoon Routing (5 vents 5'x6')

Computation of Runoff Volume

Month	Monthly Rainfall (inch)	Monthly Evapotranspiration (inch)	Initial soil Moisture loss (inch)	Depression Storage (inch)	Runoff (inch)	Runoff Volume (Acre ft)
July	12.06	4.2	0.5	1.0	6.36	12550
August	13.04	4.1	-	-	8.94	17642
Sept	8.08	3.8	-	-	4.28	8446
Oct	4.93	3.6	-	-	1.33	2625

Rainfall runoff volume (non paddy land)
Table 27

Month	Monthly Rainfall (inch)	Monthly Evapotranspiration (inch)	Initial soil Moisture loss (inch)	Depression Storage (inch)	Runoff (inch)	Runoff Volume (Acre ft)
July	12.06	5.6	-	4.0	2.46	4855
August	13.04	5.3	-	-	7.74	15273
Sept	8.08	5.1	-	-	2.98	5881
Oct	4.93	5.2	-	-	-	-

Rainfall runoff volume (paddy land)
Table 28

Computation of runoff volume

Month	Non paddy land (55%)		Paddy land (45%)		Basin Weighted Runoff (Acre-ft)
	Net Runoff	Weighted Runoff	Net Runoff	Weighted Runoff	
July	12550	5648	4855	2670	8318
August	17642	7939	15273	8400	16339
Sept	8446	3801	5881	3235	7036
Oct	2625	1181	-	-	1181

Rainfall runoff volume (Weighted Basin Average)
Table 29

Date	River W/L (in ft pwd)	Runoff Volume (Acre-ft)	Gate position	Inside	
				Storage (Acre-ft)	W.L. (in ft pwd)
13th July	39.00	7182	Gate closed	7182	39.00
31st July	43.20	4830		12012	41.55
31st August	44.0	16339		28351	43.77
5th Sept	43.90	1173	Gate opened	29524	43.90

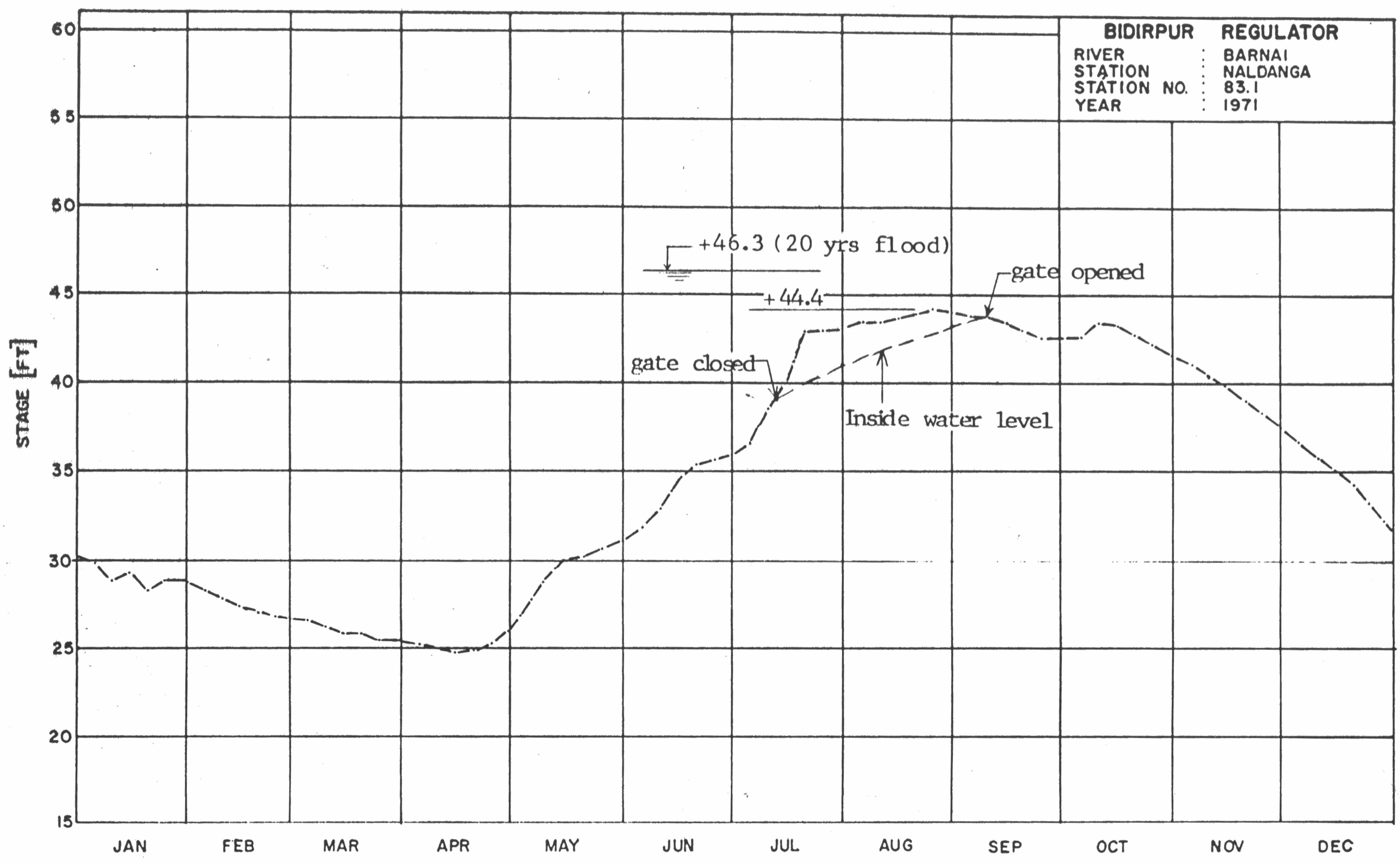
Computation of Inside storage & water level
Table 30

Post Monsoon Flood Routing

5 vents 5'x6'

Date	C/s Water level W1	R/s Water level W2	(W1 - W2) (ft)	Total discharge Q (Acre ft)	Residual storage (Acre ft)	Corresponding C/s Water level
Sept 5	43.9	43.9	0	0	29524	43.9
6	43.9	43.74	0.16	783.07	28740.93	43.82
7	43.82	43.58	0.24	999.06	27781.87	43.70
8	43.70	43.42	0.28	1037.58	26744.29	43.57
9	43.57	43.26	0.31	1089.99	25654.30	43.44
10	43.44	43.10	0.34	1141.52	24512.78	43.30
11	43.30	42.94	0.36	1174.61	23338.17	43.16
12	43.16	42.78	0.38	1206.80	22131.37	43.01
13	43.01	42.62	0.39	1222.57	20908.80	42.86
14	42.86	42.46	0.40	1238.15	19670.65	42.71
15	42.71	42.30	0.41	1253.53	18417.12	42.56
16	42.56	42.14	0.42	1268.73	17148.39	42.40
17	42.40	41.98	0.42	1268.73	15879.66	42.25
18	42.25	41.82	0.43	1283.74	14595.92	42.09
19	42.09	41.66	0.43	1283.74	13312.18	41.87
20	41.87	41.50	0.37			

Table 31


BIDIRPUR REGULATOR
RIVER : BARNAI
STATION : NALDANGA
STATION NO. : 83.1
YEAR : 1971
+46.3 (20 yrs flood)
+44.4
gate opened
gate closed
Inside water level
STAGE [FT]
60
55
50
45
40
35
30
25
20
15
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

DISCUSSION & CONCLUSION

Jublee Khal & Bidirpur are two defined channels draining a common catchment area of about 37 sq.mile to Barnai river. Bidirpur khal takeoff from the Jublee khal at about 6.5 mile from its offtake & flows almost parallel with the Jublee khal near its offtake. The topography of the catchment area is such that it is rather impossible to identify the individual catchment area for Jublee khal & Bidirpur khal. Attempt has therefore been made to complete the flood routing procedure assuming a single channel for the whole catchment area & then distributing the number of vents between the two khals according to their existing carrying capacity. From the results of the premonsoon routing the extent of crop damage or the percentage of total area that will remain submerged for more than 72 hours for different ventages are presented in Table below.

Number of vents	% of total area submerged more than 72 hours
1 vent 5'x6'	2.7%
2 vents 5'x6	0.33
4 vents 5'x6'	0.2%
6 vents 5'x6'	0.04%

From the above Table it may be observed that even with 1 vent of size 5'x6' there is no appreciable damage. But to satisfy other hydraulic conditions like tolerable velocity a minimum of 5 vents of size 5'x6' is required.

From the study of the existing x-sections of Jublee Khal and Bidirpur Khal it is observed that 75% of the runoff volume of the catchment area drains through Jublee Khal and rest 25% through Bidirpur Khal. By proportioning the number of vents according to the carrying capacities of these khals a regulator of 3.75 vents and another 1.25 vents of size 5'x6' are required respectively at the outfall of Jublee Khal and Bidirpur Khal. For convenient a 4 vent regulator is selected at the outfall of Jublee Khal a 2 vent at the outfall of Bidirpur Khal. For hydraulic design the design discharge is also proportioned according to the number of vents selected for the khals.

HYDRAULIC DESIGN