CHAPTER-4 ANALYSIS

4.1 General

The analysis of the data was done on an Apple //e model personal computer as there were a large number of repetetive calculations.The following aspects were considered in the analysis.

(a) Determining a suitable runoff curvenumber.

(b) Computation of synthetic unit hydrographs.

(c) Computation of run off hydrographs using synthetic unit hydrographs.

4.2 Runoff curvenumber computed from observed hydrographs.

The SCS curvenumber for the Attanagalu Oya was calculated using some of the available rainfall and runoff data.The surface runoff was computed from the area of the observed hydrographs after seperating the baseflow.The base flow was assumed to be varying linearly.

4.2.1 Sample calculation for the runoff curvenumber

For the observed hydrograph of 01June1987.

Refer Figure 3.14

Data: Catchment area = 53.26SqKm (From fig 3.1)

Average total rainfall during the flood event = 236.9 mm (From table 3.5)

Area of the observed hydrograph = 25.5 Sqcm (From table 3.14)

Calculation of runoff

From the area of the surface runoff hydrograph.

Volume of surface runoff = $8342047.7 m^3$

Depth of runoff = Surface runoff volume/Catchment area

$$= \frac{8342047.7}{53.26 \times 10^6} = 156 mm$$

Calculation of the runoff curvenumber

Depth of rainfall = 236.9 mm

Using the basic equations

$$Q = \frac{(P - 0.2R)^2}{(P + 0.8R)} \quad \text{and} \quad R = \frac{25400}{CN} - 254$$

in which P= 236.9mm and Q = 156mm and R= Potential maximum retention

$$156 = (236.9 - .2R)^2/(236.9 + 0.8R)$$

$$R^2 - 5459R + 479130.25 = 0$$

R = 88.7 mm or 5400.2 mm

CN = 25400/(254 + R)

CN = 74.2 or CN = 4.49

But 0.2R = 17.7 or 1080

P > 0.2R condition should be satisfied to generate runoff

P > 0.2R only when .2R = 17.7

Therefore CN = 74.2

CN = 74 (on rounding off)

Table 4.1 shows computed runoff curvenumbers for all the flood events.

4.2.2 <u>Transformation of the runoff curvenumber to a common AMC</u>

The runoff curvenumbers computed above cannot be compared nor can they be averaged since these events belong to various antecedent moisture conditions.In order to arrive at a suitable curvenumber for the catchment, curvenumbers shown in table 4.1 have been categorised depending on the antecedent moisture conditions shown in table 4.2.The final set of transformed curvenumbers obtained by analysing the various flood events are presented in table 4.3 using the basic curvenumbers shown in table 2.4.The average curvenumbers are given at the end of table 4.3.

After estimating the runoff curvenumbers for the catchment it is now possible to develop the runoff hydrograph if the unit hydrograph is known.

4.3 Computation of the synthetic unit hydrographs for Attanagalla

4.3.1 SCS unit hydrograph

SCS unit hydrograph can be computed knowing the catchment properties and the time and discharge ratios for the unit hydrograph.

Sample calculation for the unit hydrograph

Based on the SCS unit hydrograph

Data:	Catchment area	=	53.26 Sqkm
	Catchment slope	=	0.025
	Mainstream length	=	8.6 km

Calculation of the time of concentration

Percentage slope = 0.025x100 = 2.5%

From Table 2.1 the average velocity = 0.924m/sec

$$\text{Time of concentration} = \frac{8.6\times1000}{0.924\times60} + 15$$

= 170.12minutes

= 2.82hrs

Calculation of time to peak, peakflow and unit rain duration

Time to peak $T_p = 0.7T_c$

$= 1.98\text{Hrs}$

Peak flow $$Q_p = \frac{0.208AQ}{T_p} = \frac{0.208\times53.26\times1}{1.98}$$

$= 5.59\ m^3/sec$

Q=1mm for the unit hydrograph.

Unit rainfall duration (T) = $0.25T_p$ = 0.5Hrs

Since the time to peak and the peakflow are known, using the time and discharge ratios given in table 2.2 the SCS unit hydrograph for 1mm rainfall excess can be calculated.

Table 4.4 shows the SCS (.5hour) unit hydrograph for Attanagalu Oya.

Figure 4.1 shows the plot of the SCS unit hydrograph.

4.3.2 Williams' instantaneous unit hydrograph

Data: (Fig3.1)

Catchment area(A) = 53.26 Sqkm

Catchment slope(s) = 0.025

Mainstream length(L) = 8.6 Km

Catchment width = Catchment area/Mainstream length

$= 53.26/8.6 = 6.19$

Time to peak

$$t_p = 0.06\, A^{0.422}\, s^{-0.46}\, (L/W)^{0.124}$$

$$= 0.06\,(53.26)^{0.422} \times (0.025)^{-0.46} \times (8.6/6.19)^{0.124}$$

$$= 1.83 \text{ Hrs}$$

Recession constant

$$k = 0.028 A^{0.231}\, s^{-0.777}\, (L/W)^{0.124}$$

$$= 0.028(53.26)^{0.231} \times (0.025)^{-0.777} \times (8.6/6.19)^{0.124}$$

$$= 1.28 \text{ Hrs}$$

The calculated time to inflexion point(t_0),shape constant (n) ,and the watershed parameter(B) are as follows.

$n = 5.2$, $t_0 = 2.7$ Hrs and $B = 455.4$

Calculation of peakflow

$$q_p = 0.00043 \times B \times A \times Q / t_p$$

$$= 0.00043 \times 455.4 \times 53.26 \times 1 / 1.83$$

$$= 5.7 \text{ cumecs}$$

Table 4.5 shows the Williams' instantaneous unit hydrograph for Attanagalu Oya.

Figure 4.2 shows the plot of the Williams' instantaneous unit hydrograph for Attanagalu Oya.

4.4 Computation of runoff hydrographs

4.4.1 General

Since the synthetic unit hydrographs for the catchment have been computed is possible to estimate the runoff hydrographs for the catchment corresponding to various storm events.

Runoff hydrographs are calculated using the proportional ordinate and concurrent flow propositions which come under unit hydrograph theory.To apply the unit hydrograph theory the storm is divided into sub-storms and the rainfall excess caused by these sub-storms should be estimated.This rainfall excess is estimated using the SCS method.An SCS curvenumber has to be applied for each flood event.

Figure 4.3 illustrates the procedure of obtaining the runoff hydrograph.

4.4.2 Adjusted runoff curvenumber to compute runoff hydrographs

It was seen that the average runoff curvenumbers presented in table 4.3 when used to compute runoff hydrographs,gave peakflows which do not tally with observed peakflows.This may be due to the changes in the curvenumber over the years owing to change in land use patterns.

For the events 19November1988,09November1988,01June1987 ,and 26 November 1982 an adjusted curvenumber was used to match the computed peakflow with the observed peakflow.These curvenumbers are presented in table 4.6.These too were transformed corresponding to three AMCs and presented in table 4.7.

4.4.3 Computation of runoff hydrograph based on SCS method

Sample calculation

For the flood event 09November1988.(Refer Fig 3.13)

Data

Duration of the rain	=	1	Hr (From fig 3.9)
Total rainfall in the pluviograph	=	91	mm (From fig 3.9)
Unit rainfall duration	=	0.5	Hrs(from section 4.3.1)
Adjusted curvenumber(CN)	=	66	(From table 4.6)
AMC	=	III	(from table 4.2)

No of sub hydrographs = Rain duration/Unit rain duration

= 1/0.5 = 2 Nos.

Rainfall intensity = Total rainfall/Rain duration

= 91/1 = 91 mm/hr

Total rainfall for the first hydrograph(P1) = 91x(1x0.5)

P1 = 45.5 mm

Total rainfall for the second hydrograph(P2) = 91x(2x0.5)

P2 = 91 mm

<u>Calculation of runoff</u>

Potential maximum retention(R) = 25400/CN - 254

= 25400/66 - 254

= 130.8 mm

0.2R = 26.61 and 0.8R = 104.64

P1 > 0.2R and P2 > 0.2R

Therefore both these rains generate runoff.

Initial runoff = 0 mm

Runoff upto(RO1) first rain $= \frac{(P1 - 0.2R)^2}{(P1 + 0.8R)} = \frac{(45.5 - 26.16)^2}{(45.5 + 104.64)}$

RO1 = 2.5 mm

Rainfall excess for the first hydrograph (IR1) = 2.5 - 0

IR1 = 2.5 mm

$$\text{Runoff upto (RO2) second rain} = \frac{(P2 - 0.2R)^2}{(P1 + 0.8R)} = \frac{(91 - 26.16)^2}{(91 + 104.64)}$$

$$RO2 = 21.5 \text{ mm}$$

Rainfall excess for the second hydrograph (IR2) = 21.5 - 2.5

IR2 = 19 mm

Calculation of the final runoff hydrograph

Using the proportional ordinate proposition

Ordinates of the first hydrograph = Ordinates of the unit hydrograph x IR1

Ordinates of the second hydrograph = Ordinates of the unit hydrograph x IR2

Using the concurrent flow proposition

Ordinates of the final runoff hydrograph = Ordinates of the first hydrograph + Ordinates of the second hydrograph lagged by rain duration.

Refer table 4.8 for the computed SCS runoff hydrograph for Attanagalu Oya.Refer figure 4.4 for the plot of SCS runoff hydrograph.

4.4.4 Computation of Williams' hydrograph

Using a procedure similar to above the Williams' runoff hydrograph can also be calculated.Since the Williams' hydrograph is an instantaneous unit hydrograph the storms can be divided to sub-storms of smaller durations.A 0.25hr unit rain duration was used in the Williams' method.

Refer table 4.9 for the computation of the Williams' runoff hydrograph for Attanagalu Oya.

Refer figure 4.5 for the plot of the Williams' runoff hydrograph for Attanagalu Oya.

After computation of the run off hydrograph for the catchment it is now possible to compare these computed runoff hydrographs with the observed hydrographs.This comparison is done in the next chapter.

Figure 4.1

SCS Unit Hydrograph for Attanagalu Oya

For 1mm rainfall excess

Unit rain duration = 0.5 Hrs.

Peak flow (Q_p) = 5.59 cumess

Time to peak (t_p) = 2.09 Hrs.

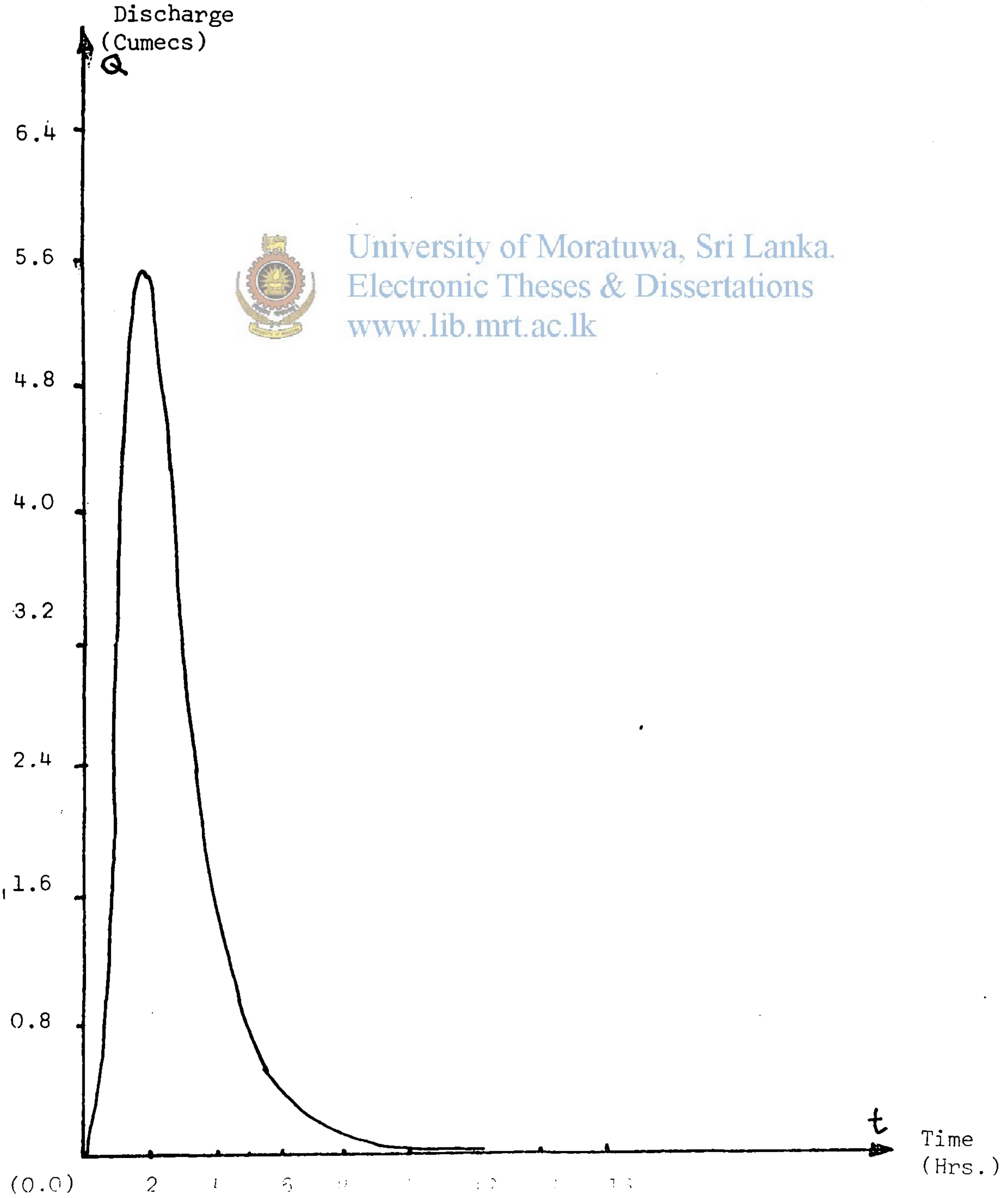


Figure 4.2

William's instantaneous unit hydrograph for Attanagalu Oya

For 1mm rainfall excess

Peak flow (Q_p) = 5.70(Cumecs)

shape constant (n) = 5.2

Watershed parameter (B) = 455.4

Time to inflexion point (t_p) = 2.71 Hrs.

Time to peak (t_p) = 1.83 Hrs.

Recession constant (k) = 1.28 Hrs.

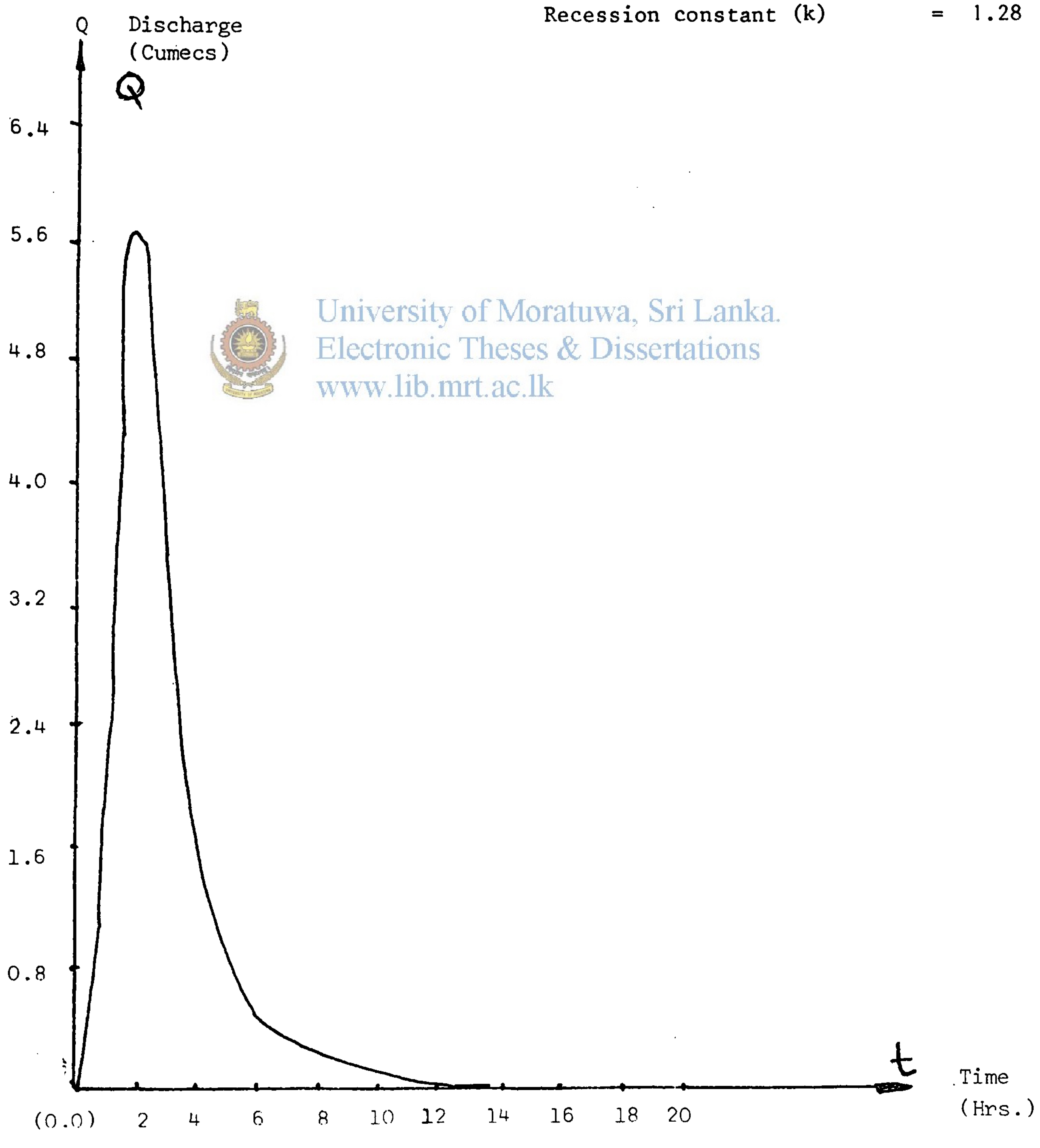
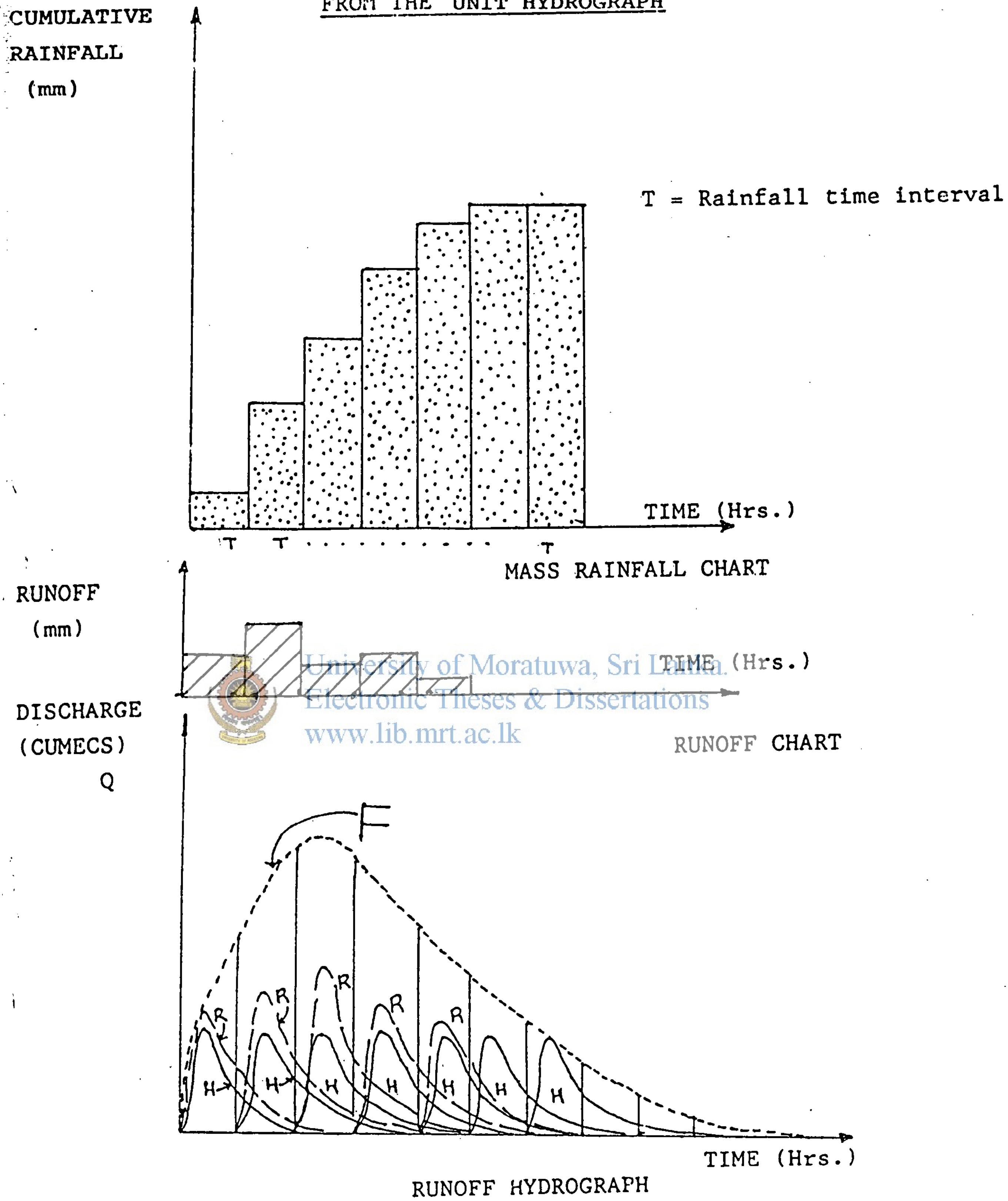


Figure 4.3 PROCESS OF OBTAINING THE RUN OFF HYDROGRAPH FROM THE UNIT HYDROGRAPH



H = The Unit Hydrograph

R = Hydrographs for rainfall excessess.

F = Final Storm Hydrograph

Figure 4.4.

SCS Runoff Hydrograph for Attanagalu Oya

For the flood event 09th November 1988

Rain duration = 1 Hr.

Peak flow = 118 cumecs

Depth of rainfall = 91 mm

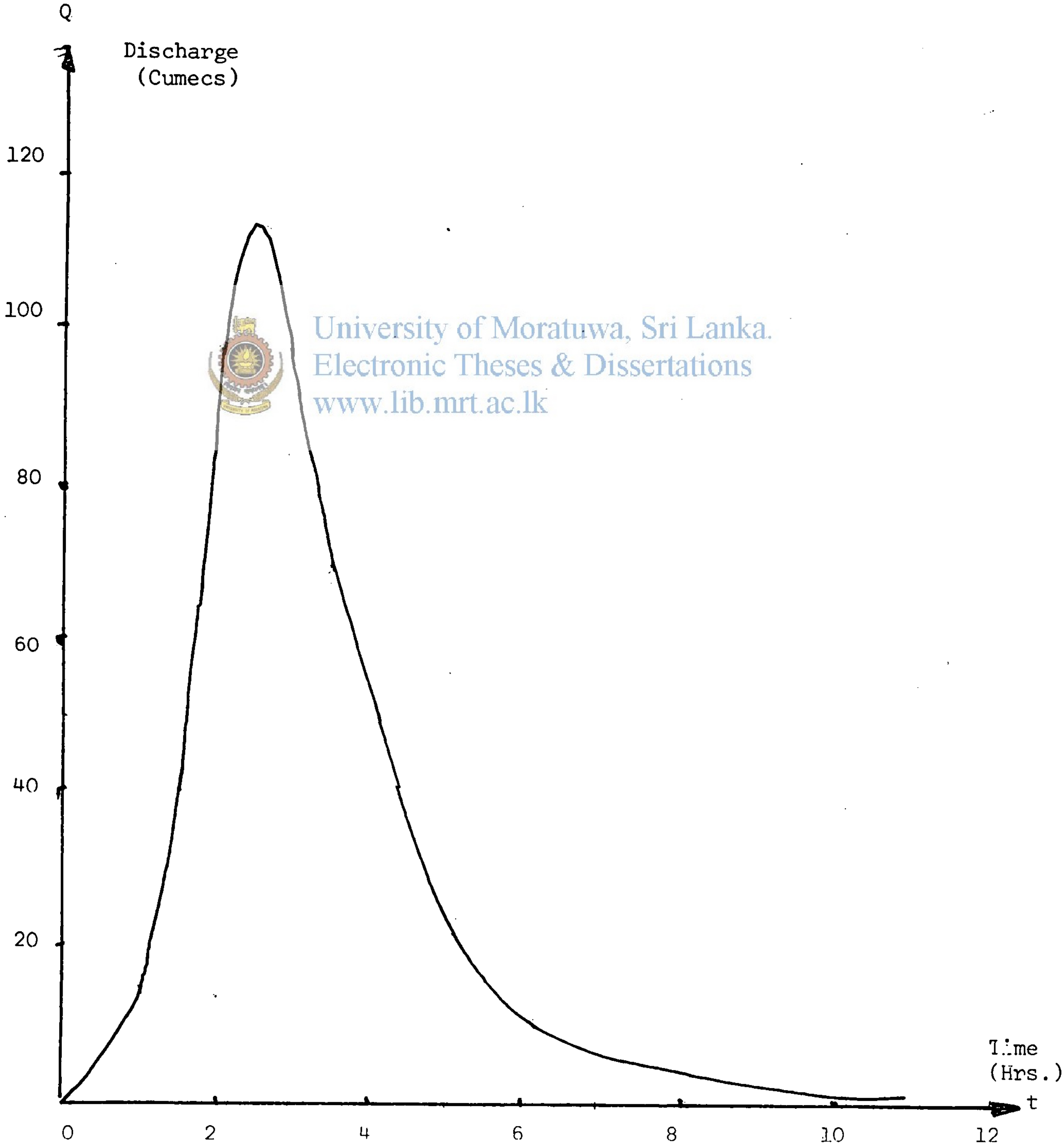


Figure 4.5 Williams' Runoff Hydrograph for Attanagalu Oya

For the flood event 09th November 1988.

Peak - 112 Cumecs

Rain duration - 1 Hr.

Depth of rainfall - 91 mm

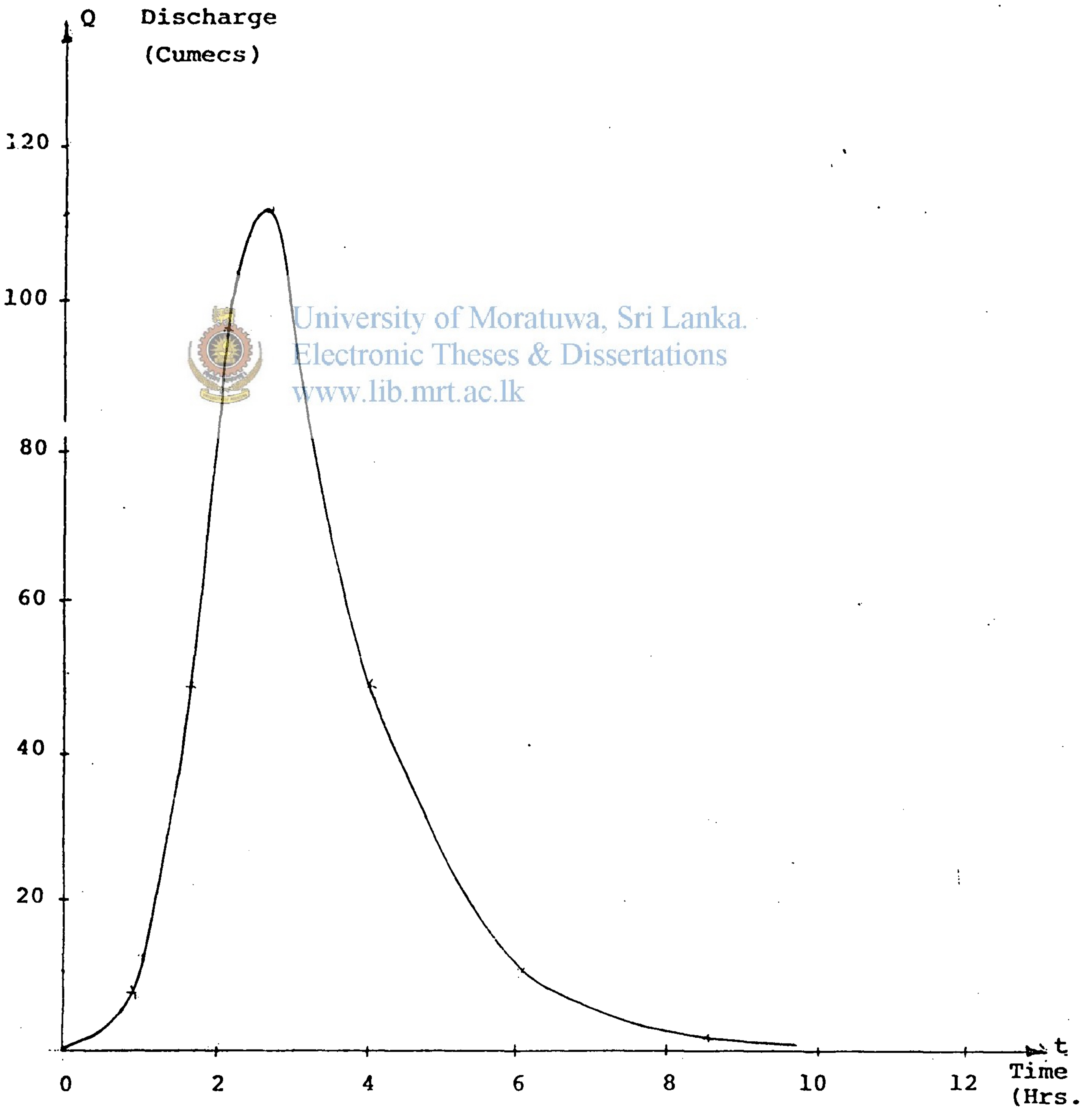


Table 4.1 SCS curvenumbers computed from runoff hydrographs

Flood event	Average total rainfall (mm) (From-table3.5)	Surface runoff (mm) (From-observed hydrographs)	Calculated Curvenumber CN
*19 November 1988	80.5	18.1	67
*09 November 1988	151.8	75.7	72
*01 June 1987	236.9	156.0	74
*26 November 1982	170.4	126.5	85
08 June 1982	186.4	152.2	88
29 May 1981	111.5	56.8	78
01 May 1980	182.5	78.2	69
13 September 1974	216.7	139.7	74
17 August 1971	276.0	216.0	80

*Flood events used to compute runoff hydrographs

Table 4.2 Determination of AMC

Flood event	Average total rainfall 05 days before a flood event (mm) (From-table3.3)	AMC (From-table2.3)	Runoff Curvenu-mber (From table 4.1)
*19 November 1988	2.54	I	67
*09 November 1988	259.5	III	72
*01 June 1987	106.7	III	74
*26 November 1982	84.0	III	85
08 June 1982	103.9	III	88
29 May 1981	109.7	III	78
01 May 1980	44.9	II	69
13 September 1974	93.0	III	74
17 August 1971	46.9	III	80

*Flood events used to compute runoff hydrographs

Table 4.3 Runoff curvenumbers obtained from table 4.2 after transformation.

Flood event	Transformed curvenumbers(using table2.5)		
	AMC I	AMC II	AMC III
*19 November 1988	67	83	93
*09 November 1988	33	53	72
*01 June 1987	35	55	74
*26 November 1982	51	70	85
08 June 1982	55	74	88
29 May 1981	40	60	78
01 May 1980	49	69	85
13 September 1974	35	55	74
17 August 1971	43	62	80
Rounded off average	45	64	81

*Flood events used to compute runoff hydrographs

Table 4.4 SCS unit hydrograph for Attanagalu Oya Catchment

For 1 mm rainfall excess

Unit rain duration 0.5 hours

Time (Hrs)	Discharge (Cumecs)
0.00	0.00
0.52	0.58
1.04	2.27
1.56	4.39
2.09	5.59
2.61	4.65
3.31	3.49
3.66	2.38
4.18	1.69
4.70	1.16
5.23	0.79
5.75	0.55
6.27	0.39
6.79	0.28
7.32	0.19
7.84	0.14
8.36	0.09
8.89	0.06
9.41	0.05
9.93	0.03
10.4	0.02

Table 4.5 William's instantaneous unit hydrograph for Attanagalu Oya

(For 1 mm rainfall excess)

Time to peak (t_p) = 2 hrs

Time to inflexion point (t_0) = 2.7 hrs

*Peakflow (q_0) = 5.7 cumecs

Shape constant (n) = 5.2

Recession constant(k) = 1.28 hrs

Time (Hrs)	Discharge (Cumecs)
0	0
0.5	0.47
1.0	2.80
1.5	5.03
2.0	*5.70
2.5	4.30
3.0	2.90
3.5	1.90
4.0	1.30
4.5	0.90
5.0	0.60
5.5	0.47
6.0	0.41
6.5	0.31
7.0	0.27
7.5	0.24
8.0	0.00

Table 4.6 Adjusted curvenumbers used for runoff hydrograph computation

Flood event	Antecedent moisture condition (From table 4.2)	Adjusted curvenumber to match the peak flow
19November1988	I	55
09November1988	III	66
01June 1987	III	85
26November1982	III	85

Table 4.7 Adjusted curvenumbers obtained from table 4.6 after transformation.

Flood event	Transformed curvenumbers (After adjustment)		
	AMC I	AMC II	AMC III
19 November 1988	55	74	88
09 November 1988	27	46	66
01 June 1987	51	70	85
26 November 1982	51	70	85
Rounded off average	46	65	81

Table 4.8 SCS runoff hydrograph (For the flood event 09 November 1988)

|IR1 = 2.5 mm|
|IR2 = 19.18 mm|

SCS Unit hydrograph (From table 4.4) Time (hrs) (i)	Discharge Q(I) (cumecs) (ii)	Ordinates of the first hydrograph. IR1xQ(I) (cumecs) (iii)	Ordinates of the second hydrograph IR2xQ(I) (cumecs) (iv)	Ordinates of the final runoff hydrograph v=iii+iv
0.00	0.00	0.0	-	0.0
0.52	0.58	1.4	0.0	1.4
1.04	2.27	1.2	11.1	12.3
1.56	4.39	11.1	43.5	54.6
2.09	5.59	14.1	84.2	98.3
2.61	4.65	11.8	107.4	118.8
3.31	3.49	8.8	89.1	98.0
3.66	2.38	6.0	66.9	72.9
4.18	1.69	4.2	45.6	49.9
4.70	1.16	8.9	32.4	35.3
5.23	0.79	2.0	22.2	24.2
5.75	0.55	1.3	15.1	16.5
6.27	0.39	0.9	10.5	11.5
6.79	0.28	0.7	7.4	8.1
7.32	0.19	0.4	5.3	5.8
7.84	0.14	0.3	3.6	3.9
8.36	0.09	0.2	2.6	2.9
8.89	0.06	0.1	1.0	1.1
9.41	0.05	0.1	1.0	1.0
9.93	0.03	0.0	0.0	0.0

Table 4.9 William's runoff hydrograph for Attanagalu Oya catchment

For the flood event 09 November 1988

*Peakflow (q_0) = 112.2 cumecs

Time (Hrs)	Discharge (Cumecs)
0.0	0.00
0.5	0.11
1.0	7.37
1.5	47.43
2.0	97.38
2.5	*112.20
3.0	98.29
3.5	70.32
4.0	47.46
4.5	32.03
5.0	21.62
5.5	14.59
6.0	10.46
6.5	8.50
7.0	4.20
7.5	2.20
8.0	0.00