

RIVER LEE
FLOOD OF 5th/6th AUGUST 1986

Development Planning & Hydraulic Studies Division,
Civil Works Department

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RIVER LEE

REPORT ON FLOOD OF 6th AUGUST 1986

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Note: All levels given in this report refer to Poolbeg Ordnance Datum

1. INTRODUCTION

The largest peak inflow on record occurred on the River Lee catchment on the 6th August 1986. This flood was caused by a severe rainstorm which lasted for a total of 22 hours and affected the south-western part of the country worst.

This report outlines details of the rainstorm that occurred, the resultant flooding and how it was controlled at Inniscarra and Carrigadrohid Reservoirs. The downstream effects of the flood on Cork city and suburbs will also be examined.

The flood is compared with the design storms that have been selected in the re-assessment of safety of the Lee dams outlined in the report "River Lee - Flood Control and Dam Safety".

This review of safety involved the application of design rainstorms derived in accordance with the Flood Studies Report methods to the catchment. In order to do this a Flood Forecasting Model was developed for the Lee catchment. This model enables one to estimate the flood inflow hydrograph resulting from any rainstorm. Appendix F compares the recorded inflow hydrograph to Carrigadrohid with the inflow hydrograph derived applying the rainstorm of the 5th/6th August 1986 to the Flood Forecasting Model of the River Lee.

On the 25th and 26th August 1986 an exceptionally severe rainstorm occurred on the east coast on the Dodder and Dargle catchments. In Appendix G this rainstorm is applied to the Lee catchment and the flooding that would have resulted is presented.

2. RIVER LEE CATCHMENT

The River Lee rises near the Cork/Kerry border in the steep mountains which encircle Gougane Barra lake. It flows almost due east along a narrow valley for about 65km to Cork city, draining a total area of over 1,100 sq.km. The catchment is shown in Figure 1.

Hydro-electric development was carried out between 1953 and 1957. Two generating stations were constructed, at Carrigadrohid (8 MW) and at Inniscarra (19 MW).

Carrigadrohid dam is a concrete gravity dam 21.3m high, impounding a Reservoir of 9 sq.km. The catchment upstream of the dam has an area of 616 sq.km and is generally steep, apart from a stretch of the upper Lee which forms a narrow lake called Lough Allua. The long-term average flow at Carrigadrohid is 20.4 m³/s with an annual average rainfall of 1566mm.

Inniscarra dam is a concrete buttress dam 44m high, with a Reservoir approximately 5 sq.km in area. The catchment upstream of Inniscarra and downstream of Carrigadrohid has an area of approximately 177 sq.km. The long-term flow at Inniscarra is 25.7 m³/s and the annual average rainfall of the total area upstream is 1494mm.

3. METEOROLOGICAL CONDITIONS

The weather in August 1986 was similar to that which was experienced for the preceding summer months of 1986, i.e. cool and broken. There was heavy rain on the 1st, but an unusually severe rainstorm occurred on 5th/6th which caused flooding in many areas in West Cork and Kerry.

At mid-day on the 5th August a depression with its associated fronts approached the south-west of Ireland, and freshening south to south-west winds were accompanied by rain. By mid-night on the 6th, fronts over Ireland brought rain to all areas. At 12.00 hours on the 6th a depression centred near Shannon Airport moved slowly north-eastwards.

The Isohyetal Map for the 24 hour period 9.00 a.m. on 5th to 9.00 a.m. on 6th August, 1986 is shown on Figure 2. A list of the recorded rainfall amounts for the same period at all raingauges within the catchment and selected gauges outside is presented in Table 1. For comparison, the average monthly rainfall for each gauge estimated from the thirty year record 1951-1980 is given.

It is obvious that the worst of the storm was experienced in the western half of the catchment. The mean areal rainfall on the upper catchment to Carrigadrohid dam is estimated to have been 92mm, resulting in the highest inflow to Carrigadrohid Reservoir ever recorded. The rainstorm on the intermediate catchment was not as severe, the resultant peak inflow from the intermediate catchment being approximately 50 m³/sec. which has been exceeded on a number of occasions previously. However, the total inflow to Inniscarra Reservoir was the highest recorded since the station came into operation.

The hourly distribution of the rainfall for the duration of storm is given in Figure 3. The rainstorms used in estimating various return period floods in the recent flood studies work on the Lee are also given for comparison. The profile of the rainstorm was estimated from the charts recording rainfall continuously at Carrigadrohid Generating Station and Killarney (Muckcross) - Appendix A. The automatic gauge at Carrigadrohid was faulty, recording only 40mm of the total 60mm recorded on the daily check gauge. This error was corrected, taking cognisance of the profile at Inniscarra, Cork Airport and Killarney.

Table 1
Recorded Rainfall for 5th August, 1986

Raingauge Location	Observed Rainfall (mm)	Mean August Rainfall (mm)
1. Gauges used for estimation of mean areal rainfall on catchment:		
Gouganebarra	105.7 (U.C.)	152.0
Ballingeary V.S.	98.4 (U.C.)	120.0
Macroon (Curraleigh)	80.6 (U.C.)	125.0
Macroon (Renaniree)	93.7 (U.C.)	99.0
Ballyrowney (Clountycarty)	76.7 (U.C.)	101.0
		Contd./...

Table 1 (Contd.)

Raingauge Location	Observed Rainfall (mm)	Mean August Rainfall (mm)
Ballinagree (Mushera)	66.5 (U.C.)	123.0
Carrigadrohid (Gen. St.)	68.3 (U.C.)	80.0
Dunmanway (Inchardreen)	115.0 (U.C.)	124.0
Coachford G.S.	61.8 (M.C.)	77.0
Donoughmore	66.4 (M.C.)	92.0
Crookstown G.S.	73.0 (M.C.)	100.0
Inniscarra (Gen. St.)	59.3 (M.C.)	73.0
Cork (Univ. College)	54.0 (M.C.)	75.0
Cork Airport	60.9 (M.C.)	90.0
2. Daily totals exceeding 100mm in south/south-west Ireland:		
Glengarriff (Ilnacullin)	102.4	130.0
Durrrus G.S.	120.5	102.0
Bantry (St. Josephs Hosp.)	124.4	110.0
Kealkill	152.0	N/A
Kenmare (Derreen)	137.2	121.0
Kilgarvan (Gortnaboul)	124.2	107.0
Cummeragh No. 9	110.0	N/A
Glencar	119.1	N/A
Killarney (B.V.M. Park)	110.0	97.0
Gap of Dunloe	125.4	141.0
Beaufort G.S.	101.3	86.0
3. Caragh River Area:		
Dolagh	98.0	102.0
Glenvickee	128.0	N/A
Lyranes Upper	179.5	N/A
Cloone Lake	185.5	173.0
Tralee U.D.C.	106.0	88.0
Cloghane G.S.	125.5	164.0

Note: U.C. implies that the gauge is used in estimating rainfall for the catchment upstream of Carrigadrohid.

M.C. implies that the gauge is used in estimating rainfall for the intermediate catchment to Inniscarra.

4. FLOODING UPSTREAM OF CARRAIGADROHID DAM

The flood inflow hydrograph and the outflow hydrograph from Carrigadrohid Reservoir are shown on Fig. 4. The daily load report for the period of the flood is given in Appendix B; this indicates how the flood was controlled hour by hour. The level of the Reservoir was 64.67 m.O.D. at the beginning of the flood corresponding to a storage of $17.58 * 10^6 m^3$. The peak inflow was $574 m^3/s$; four hours after the peak inflow the Reservoir reached its peak level of 65.74 m.O.D. corresponding to a storage of $26.71 * 10^6 m^3$. The total volume of the flood inflow hydrograph was $40 * 10^6 m^3$. The total volume discharged through the turbine and gates was $36.5 * 10^6 m^3$. Spilling through the gates started when the Reservoir reached a level of 65.20 m.O.D.

The total discharge reached its maximum of $450 m^3/s$ when the Reservoir level reached 65.72 m.O.D., 0.22m above high water level of storage (65.50 m.O.D.). This is the highest discharge ever recorded at Carrigadrohid.

The inflow hydrograph to Carrigadrohid Reservoir is comprised of the flow from four tributaries:

1. The Sullane
2. The Upper Lee
3. The Laney
4. The Toon

The following is a description of the floods at each of these four tributaries.

4.1 Sullane

In the upper reaches, at Ballyvourney, there was extensive damage to three bridges. One of these bridges at "Pol na Bro" was almost demolished, see Photo 1.

Further downstream, before Macroom, Photo 2 shows that the Sullane used a second channel during the flood. Locals can recall only one other time when water flowed through this second channel. The water flowing in this second channel was very powerful; photo shows it was able to shift large boulders in an uphill direction. Also at this section the Sullane has changed its course permanently, as banks were eroded in places whereas in other places debris was deposited.

Downstream at Macroom severe flooding was encountered. An estimated £30,000 worth of damage was caused to a local bakery and a public house. The Riverside Inn is shown during the flood, in Photo 3. This public house is located immediately downstream of a bridge at Macroom.

Further downstream there is a mill which is approximately 200 years old. Over the past 100 years or so flood levels have been marked on a wall in the mill. The maximum flood level caused by the August 1986 flood was 890mm above the highest previous level marked.

The ESB automatic water level recorder downstream of the bridge at Macroom was inundated; see Photo 4. The red line on this photo shows the maximum level which the water reached. The water level recorder ceased to function at 01.00 hrs. on 6th August, 1986. The estimated time of the peak flood is 03.00 hrs. on 6th August, 1986. An estimate of the peak flow is 300 m³/sec.

4.2 Upper Lee (Fig. 5)

The Gouganebarra Lake reached its maximum level at 23.30 hrs. on 5th August 1986. Downstream at Dromcarra, the Lee reached its peak at 07.30 hrs. on 6th August 1986. Little damage was caused at this section of the River. The River overflowed its banks at locations and did some damage to crops.

4.3 Laney (Fig. 6)

The Laney reached its maximum water level at midnight on 6th August, 1986. It burst its banks and damaged some crops. It also flooded nearby roads making travel dangerous due to deposited debris on the roads. Photo 5 shows the height that the maximum water level attained. This level is indicated by a red line.

4.4 Toon

The Toon River at Toon Bridge reached its maximum level at 04.30 hrs. on 6th August 1986. The water rose above the arches of the bridge and flowed onto the road nearby. Fields along the banks were completely covered and travel along the road was made dangerous. Photo 6 shows the level the water rose to on the Toon Bridge. This level is also indicated by a red line.

5. FLOODING UPSTREAM OF INNISCARRA DAM

The flood inflow hydrograph and the outflow hydrograph from Inniscarra Reservoir are shown on Figure 7. The daily load report for the period of the flood is given in Appendix C; this shows how the flood was controlled hour by hour. The level of the Reservoir was 48.44 m.O.D. at the start of the flood, corresponding to a storage of $11.37 \text{ m}^3 * 10^6$. The peak inflow to Inniscarra Reservoir was 504 m³/s. This is composed of a discharge of 450 m³/s from Carrigadrohid and an intermediate catchment inflow from the area immediately upstream of Inniscarra of approximately 54 m³/s. Four hours after the peak inflow, the peak level of 50.45 m.O.D. was reached corresponding to a storage of $21.23 \text{ m}^3 * 10^6$. The total volume of the flood was $41.5 * 10^6 \text{ m}^3$. Spilling through the gates started when the Reservoir reached a level of 49.91 m.O.D.

The total discharge reached its maximum of 331 m³/s when the peak level of 50.45 was reached. This is 0.15m above the high water level of storage (50.30 m.O.D.). This discharge has been exceeded on two occasions previously, namely Dec. 1964 and Dec. 1978.

The inflow hydrograph to Inniscarra Reservoir comprises of the inflow from the Dripsey River as well as the discharge from Carrigadrohid.

5.1 Dripsey

The discharge hydrograph for the Dripsey is shown on Fig. 8.

6. DOWNSTREAM OF INNISCARRA TO CORK CITY

Immediately downstream of Inniscarra dam the maximum water level was 20.48 m.O.D. and the maximum discharge was 331 m³/sec. This occurred at 14.00 hrs. on 6th August, 1986. At the recorder station downstream of Leemount Bridge, the maximum water level recorded was 14.402 m.O.D. and the maximum discharge was estimated to be 445 m³/sec. This peak occurred at 17.00 hrs. on 6th August, 1986. At the Waterworks weir the maximum level recorded was 7.424 m.O.D. This level is subject to confirmation. Applying this level the maximum discharge was estimated to be 363m³/sec. This peak occurred at 18.00 hrs. on 6th August, 1986.

6.1 Shournagh

Fig. 10 shows the discharge hydrograph for the Shournagh. This hydrograph was developed from a synthetic unit hydrograph, which is obtained from catchment characteristics and the Flood Studies Report method. From Fig. 10 we see that the maximum discharge was 158 m³/sec. This is nearly 50% of the maximum discharge from the dam. Because the peak discharges from the Shournagh can be relatively large, it is desirable to avoid compounding the peak discharges from the Shournagh and the dam at Leemount Bridge. During this flood, at Leemount Bridge, the peak discharge from the Shournagh occurred 8 hours before the peak discharge, due to the dam, occurred on the Lee.

6.2 Bride

The water level recorder on the River Bride ceased to function correctly during this flood. Because of this, and the fact that the River is badly gauged it is difficult to estimate the peak discharge in the Bride during this flood. The area of the Bride catchment is 120 sq.km; this is 58% of the Shournagh catchment. This catchment is also flatter than the Shournagh catchment. The contribution to the flow in the main River during this flood from the Bride is thus considered to be small relative to the dam discharge.

Fig. 9 shows that the Lee overflowed its banks at several locations between Inniscarra and the Waterworks weir. The main damage caused was to crops and market gardens. Some houses were flooded, but no structural damage was caused. Many of the houses flooded had previously experienced flooding during heavy winter floods. Local people stated, however, that the water level had never been seen to rise so high before. No visible structural damage was apparent to bridges, roads or public buildings. Figure 9 shows that the Lee flowed onto roads and these roads acted as River channels during the flood. Many roads were impassible such as the Carraigrohane straight which was inundated and prevented vehicles entering or leaving Cork City from this direction.

The damage caused by flooding downstream of Inniscarra was considerably less than that which occurred upstream of Carrigadrohid at Macroom. The regulation of the flood through Carrigadrohid and Inniscarra Reservoirs prevented flooding of a more serious nature downstream to Cork City. Greater flooding would have occurred if there were no dams on the River. A comparison of flood levels with and without dams on the River is presented in Table 2. This shows that at the Waterworks Weir, which is located 13.1 km downstream of Inniscarra dam, the water level would have been 0.7m higher if there were no dams on the River. Similarly, we see that upstream of the Waterworks Weir as far as Inniscarra Dam the water levels would have been higher everywhere.

Table 2
Comparison of Flooding With and Without Dams

Location Downstream of Inniscarra Dam (km)	Max. Elevation During Flood (m)	Max. Elevation Assuming No Dams (m)
2.7	18.04	18.3
4.0	16.4	17.1
5.0	15.3	15.9
7.2	12.9	13.6
9.1	10.4	11.1
11.0	8.5	9.3
11.5	8.2	9.0
12.2	8.1	8.9
13.1	7.4	8.1

6.3 Effect of Removing Cork Waterworks Weir

The effect of removing the weir at the Cork Waterworks is to lower the maximum water level during this flood by 3 feet at this location. However, from 2 miles upstream of the weir to the dam at Inniscarra there is no difference in maximum water level due to the removal of the weir; thus there is no benefit afforded to the stretch of River where most flood damage occurs.

7. FLOOD FREQUENCY

7.1 Flood Frequency Analysis - High Water Periods

As mentioned previously, a re-assessment of the safety of the Lee dams has recently taken place. Floods with return periods ranging from 100 years to 10,000 years were derived in accordance with the procedures presented in the Flood Studies Report (NERC, 1975). Tables 3 and 4 list these return period floods at Carrigadrohid and Inniscarra, and also shown on each is the August 1986 flood. In the case of the return period floods, the water level at the start of the flood is assumed to be the high water level of storage (H.W.L.), whereas in the case of the August 1986 flood the level at the start of the flood was well below the H.W.L.

Table 3

Comparison with Return Period Floods

Upper Catchment to Carraigadrohid

Crest Level = 67.22 m.O.D.

Initial Reservoir Level = 65.00 m.O.D. with the exception of the August 1986 flood when it was 64.67 m.O.D.

RETURN PERIOD YEARS	PEAK INFLOW (m /s)	INFLOW VOLUME (m x 10)	PEAK DISCHARGE (m ³ /s)	RESERVOIR LEVEL (m.O.D.)	TAILWATER* LEVEL (m.O.D.)
10,000	1311	109	735	67.99**	
1,000	859	73	583	66.59	
500	691	58	574	66.18	
250	626	49	572	66.11	
150	594	47	401	66.06	
100	577	42	341	65.98	
August 1986	574	40	450	65.74	51.48

* Tailrace levels are not accurately estimated at this stage.

** Dam overtopped by 0.8m.

Table 4

Comparison with Return Period Floods

Overall Catchment to Inniscarra

Crest Level = 52.03 m.O.D.

Initial Reservoir Level = 50.30 m.O.D. with the exception of the
August 1986 flood when it was 48.47 m.O.D.

RETURN PERIOD YEARS	PEAK INFLOW (m ³ /s)	INFLOW VOLUME (m x 10 ⁶)	PEAK DISCHARGE (m ³ /s)	RESERVOIR LEVEL (m.O.D.)	TAILWATER LEVEL (m.O.D.)
10,000	1070	138	1,002	51.56	22.90
1,000	839	93	839	51.10	22.50
500	773	76	750	50.96	22.20
250	719	69	626	50.88	22.00
150	519	65	499	50.79	21.00
100	513	65	498	50.76	20.95
August 1986	504	41.5	331	50.45	20.48

7.2 Flood Frequency Analysis - Low Return Periods

The statistical model can be used to estimate Reservoir peak inflows up to a return period of 2N, where N years of records exist. However, in order to calculate estimates up to return periods of 5N, the regional growth curve for the country as a whole was applied. The statistical model used is the Annual Maximum Series Model, in which the maximum peak inflow for each year is listed and plotted against return period.

Hourly records of Carrigadrohid Reservoir levels and discharges are available since 1959. The peak inflows were calculated from these records. The return period of the floods in the flood frequency plot are estimated in accordance with the method outlined by Gringorten (see F.S.R. Vol. 1, Page 74). The maximum flood which occurred before the 1958-1986 record was in 1916 and was of the same order as the largest floods which occurred in 1957, 1975, 1978 and 1980. Prior to this 1916 flood a large flood occurred in 1853, which is referred to in Professor Walsh's paper entitled "Rainfall Intensity - Duration", published in Vol. LV (1928/29) of the Trans. Instn. Engineers in Ireland. It is reasonable to assume that the flood of August 1986 is the largest flood since this 1853 flood and therefore has a return period of approximately 250 years, see Fig. 11.

The annual maximum series of flood volumes are also listed in Appendix D. The duration of these floods range from three to seven days, and these durations were selected by including only the periods where the inflow was greater than the turbine discharge of 70 m³/s.

For Inniscarra, the peak inflows from the intermediate catchment of low return periods were estimated by reducing the region curve for Carrigadrohid in proportion to the area of the intermediate catchment to Inniscarra over the area of the catchment to Carrigadrohid. The area of the catchment to Carrigadrohid is 616 km² and to Inniscarra 177 km². The curve is shown on Fig. 12. The observed peak inflows to Inniscarra are listed in Appendix E.

8. SUMMARY AND RECOMMENDATIONS

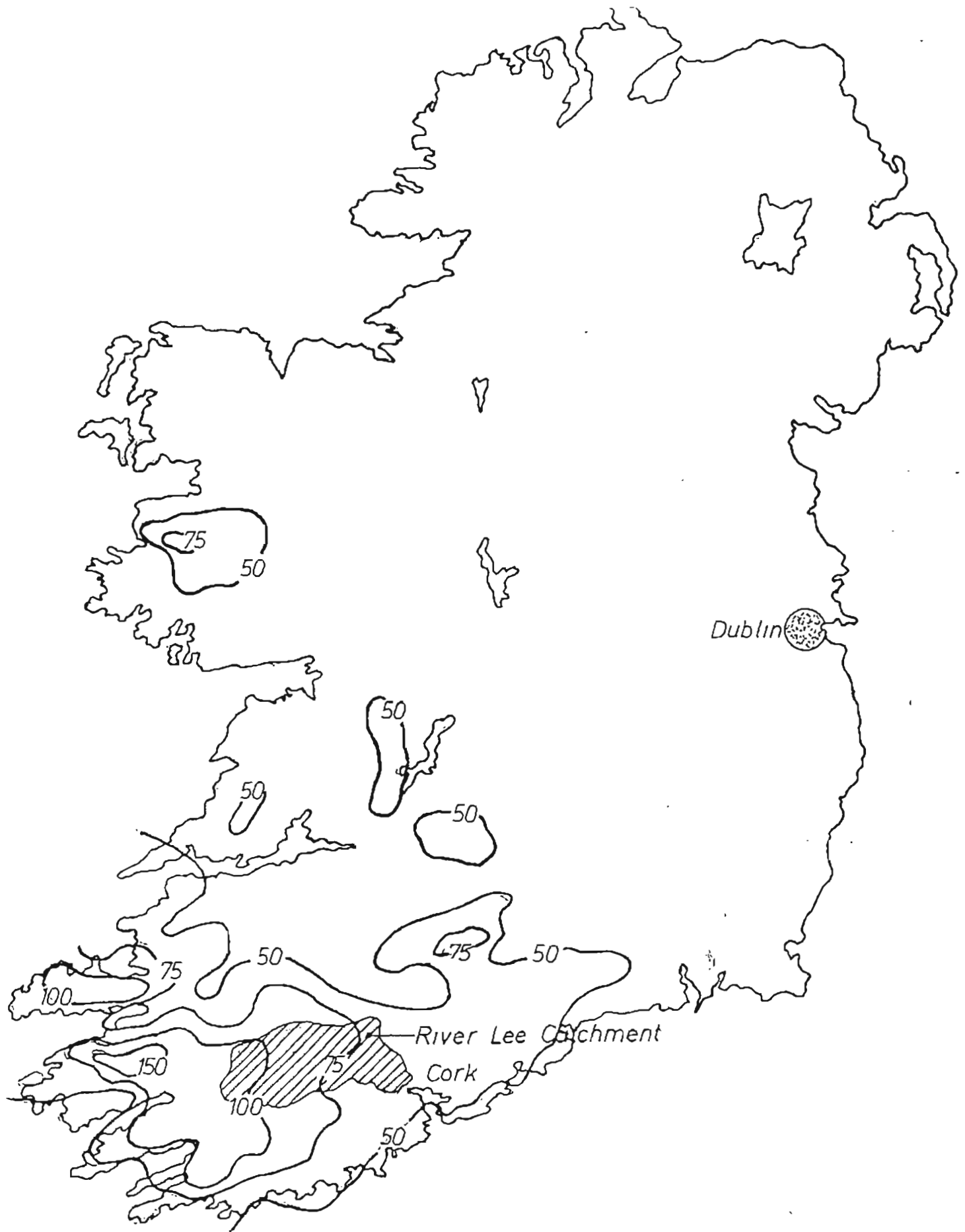
8.1 Summary

- . On the 6th August, 1986 the largest flood on record occurred on the River Lee catchment.
- . The 1984 Flood Control Regulations were adequate to handle this flood.
- . This flood has an estimated return period of 250 years. Serious flooding and moderate damage to property and structures were experienced upstream of Carrigadrohid Reservoir.
- . The maximum recorded discharge through Carrigadrohid dam occurred during this flood, but was less than the inflow to the reservoir.
- . Extensive flooding of land was experienced downstream of Inniscarra dam; however no structural damage occurred.
- . It is shown that the flooding would have been much more extensive had there not been dams on the River Lee.
- . The flood forecasting model has been verified for this flood, Appendix F.
- . Transposition of the severe rainstorm which occurred on the east coast during 25th/26th August 1986, to the Lee catchment results in a peak inflow with a return period of about 500 years, Appendix G.
- . It is clear that had the Dodder/Dargle storm occurred over the Lee catchment; peak discharge at Inniscarra would have been 50% higher and would have lasted several times longer than actually took place on August 5th/6th. This would have been long enough to coincide with high tides in Cork and would have provoked serious flooding both in the city and in the reach between the dam and the Waterworks Weir.

8.2 Recommendations

- . For legal and engineering reasons it is essential to monitor as accurately as possible large flood events on reservoirised catchments. If large overland flooding occurs it would be advantageous to photograph the area from the air as this would assist greatly with outlining the high water level profile. The profile of the high water level of future floods between Inniscarra dam and the Cork Waterworks Weir should be marked with pegs placed at regular intervals.

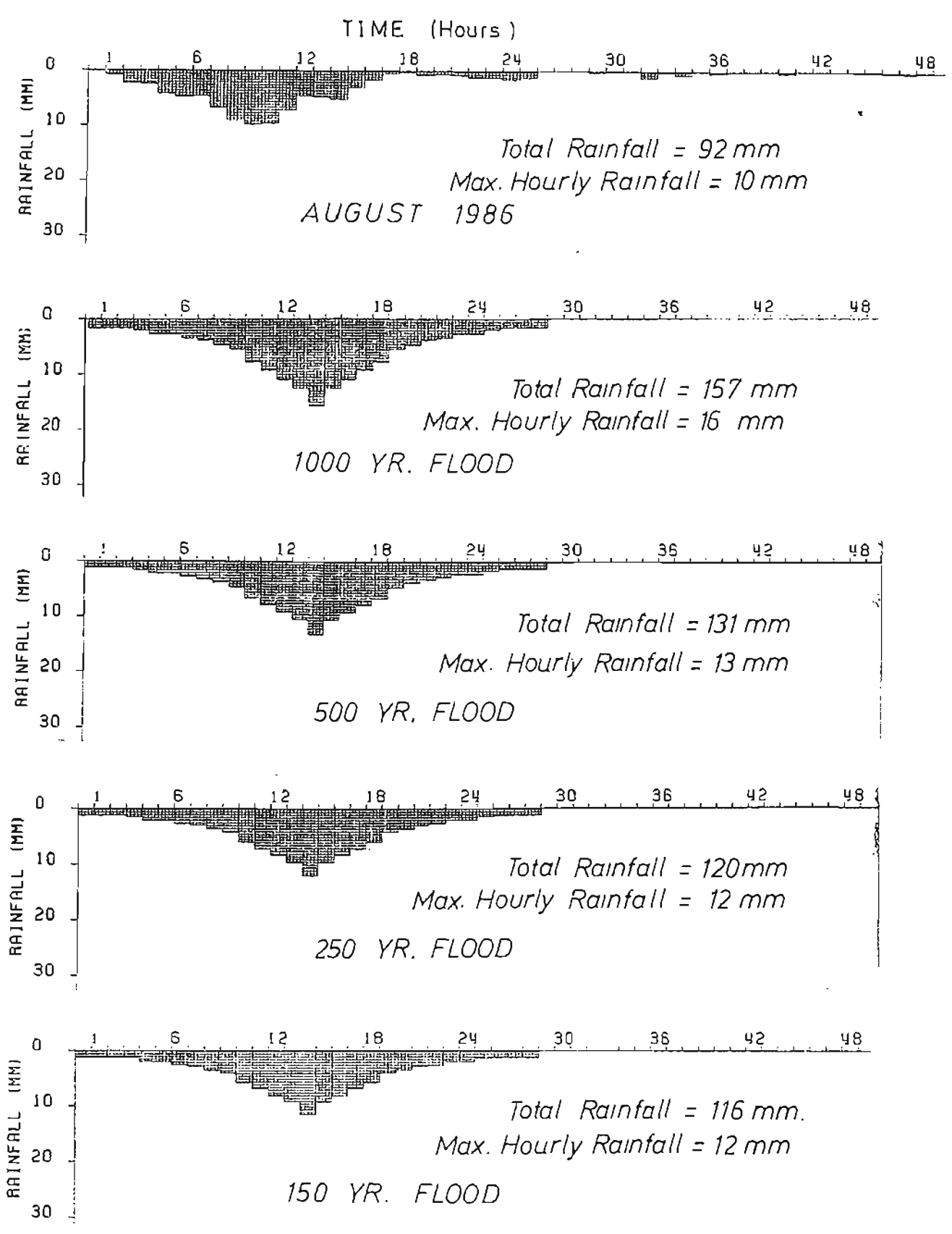
- . A person should be assigned locally to ensure all automatic flow recorders and rain gauges are in good working order during the flood. Experience has shown that these devices may cease operating due to swamping, debris or other reasons at the time they are needed most.
- . Improved arrangements are necessary so that hydro station staff can advise Development Planning and Hydraulics Division of their intention to spill and the estimated amount, as early as possible.
- . It is necessary to take advantage of large floods to build up the River rating curves by gauging at high water levels. This should be carried out systematically by estimating the time of peak flow at the gauges, using the flood forecasting model. Equipment for this purpose should be stored locally.
- . There is no particular reason why a flood similar to that on the Dodder/Dargle could not occur on the Lee catchment. This fact should be indicated to those responsible for planning developments etc. downstream.



ISOHYETAL MAP

24 Hr. Rainfall (mm) Ending 09.GMT 6.8.86

FIG. 2



STORM PROFILES

FIG. 3

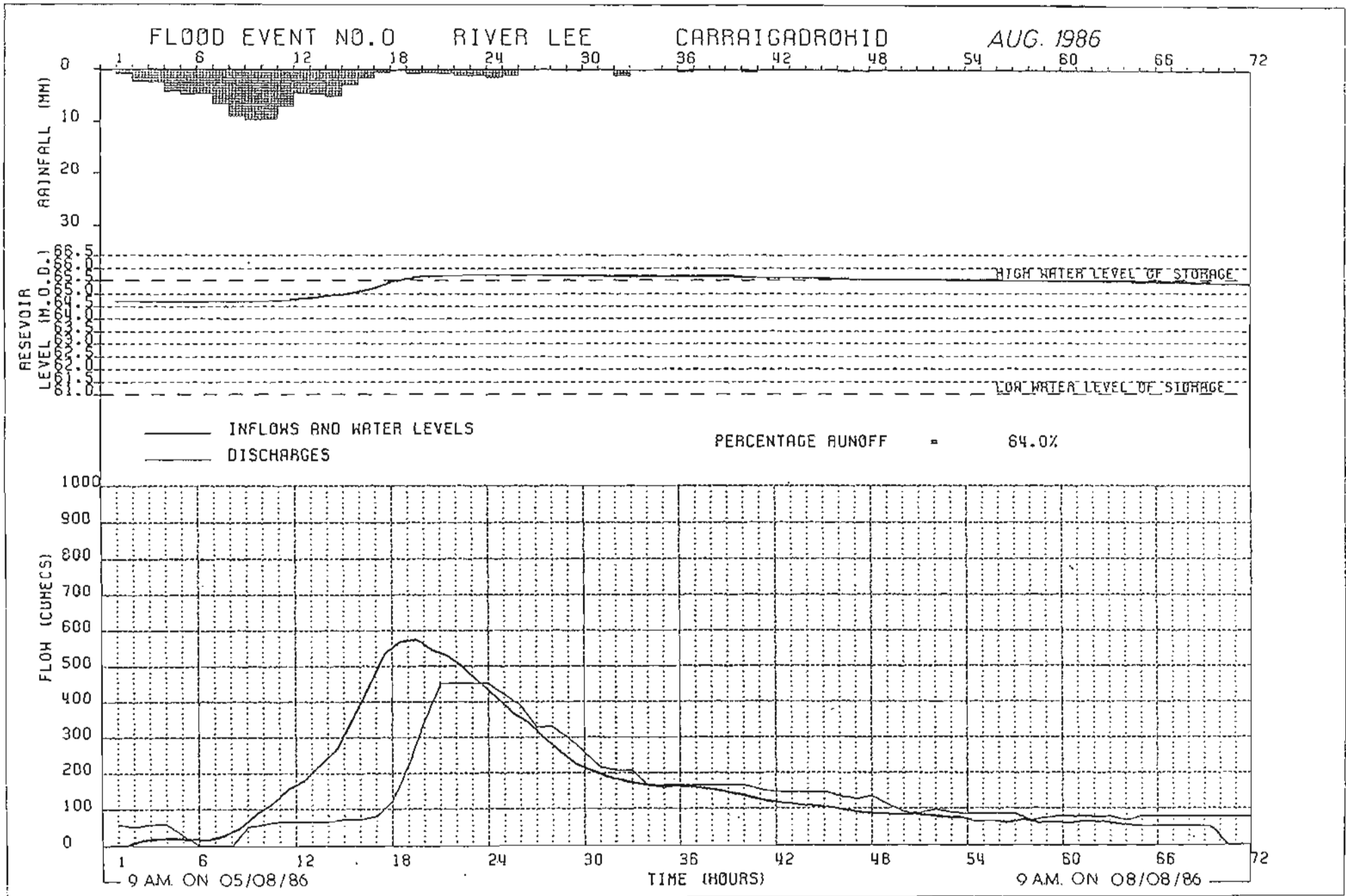


FIG 4

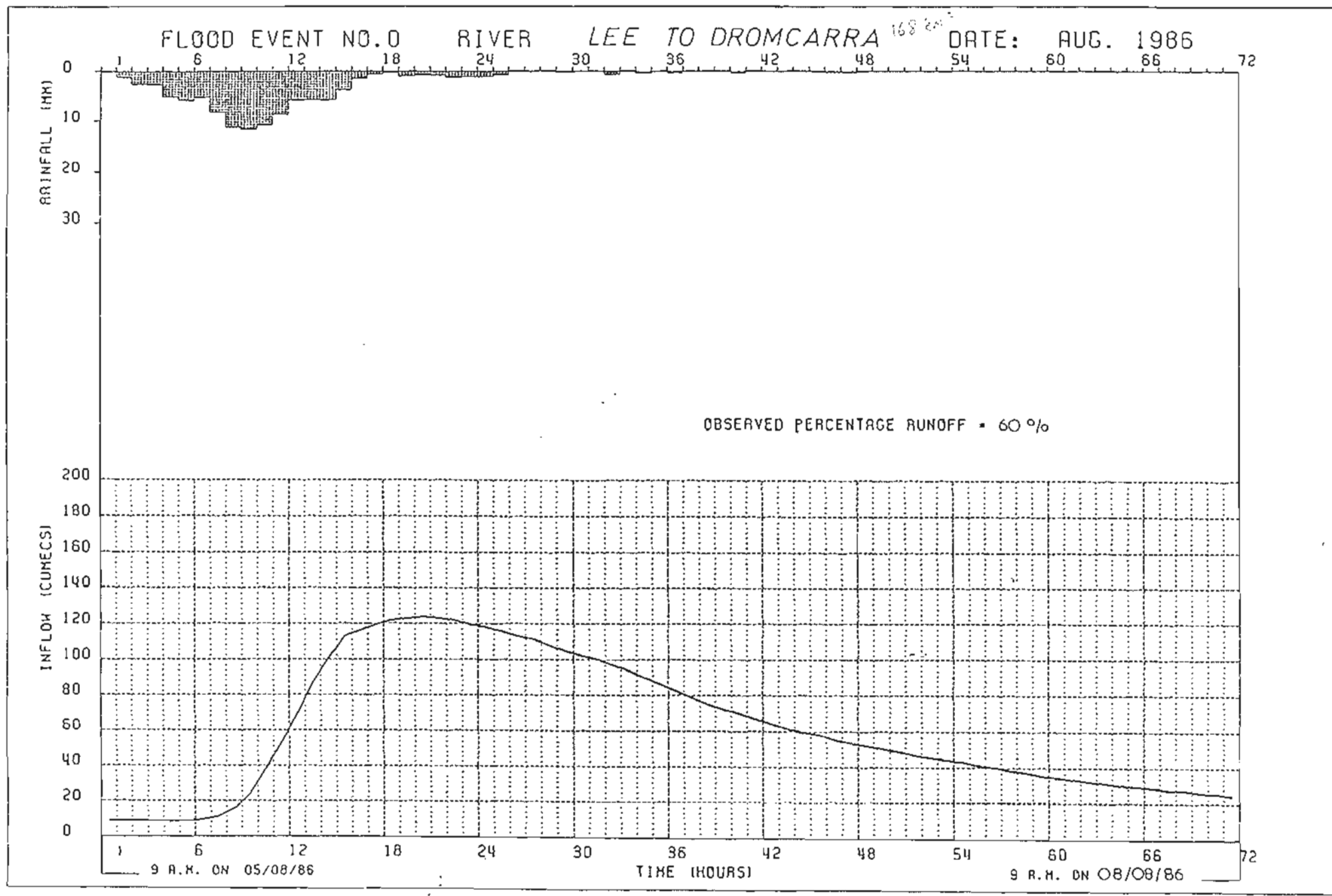


FIG 5

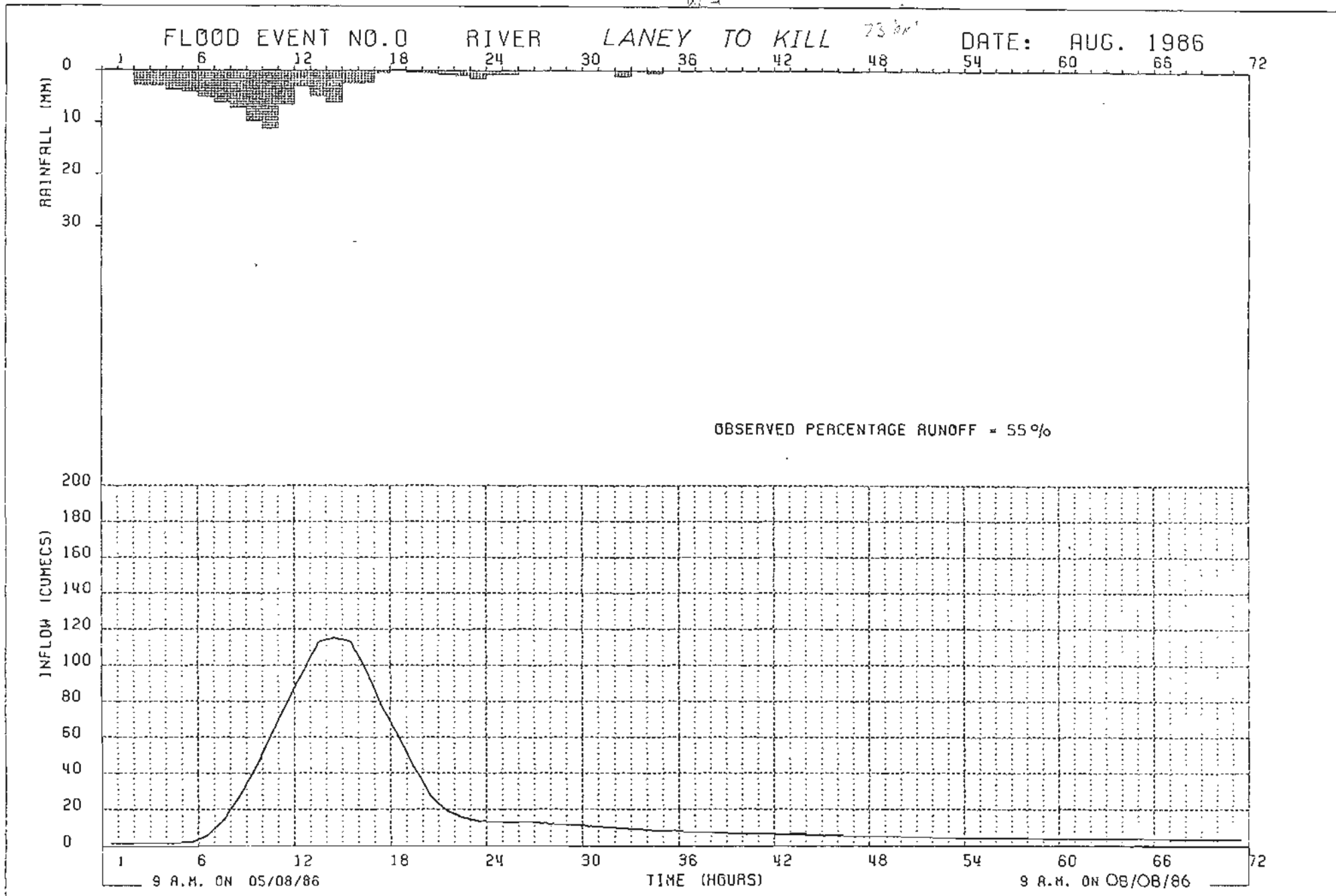


FIG. 6

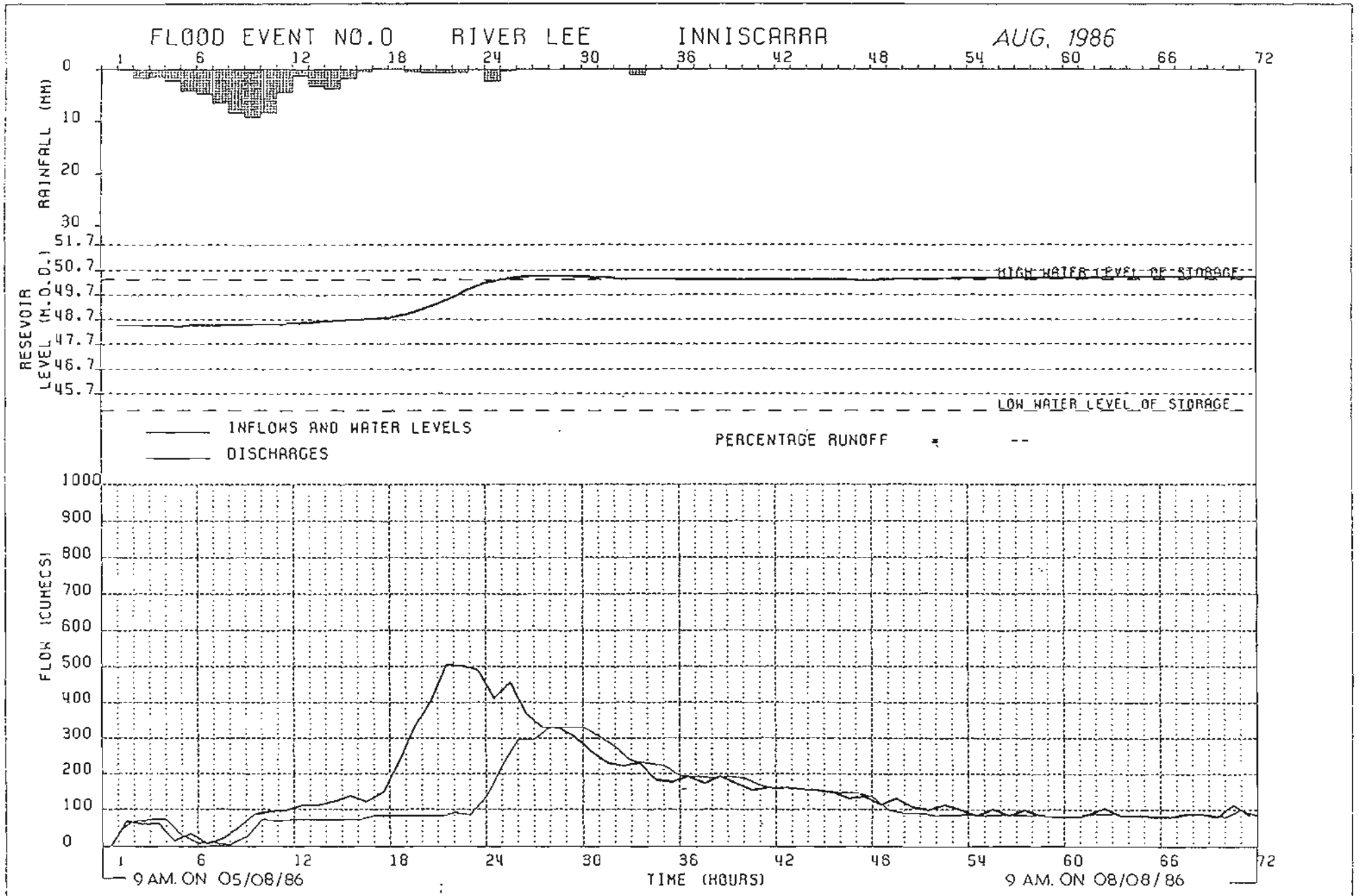


FIG 7

88 km²

FLOOD EVENT NO.0 RIVER DRIPSEY TO WOOLEN MILLS DATE: AUG. 1986

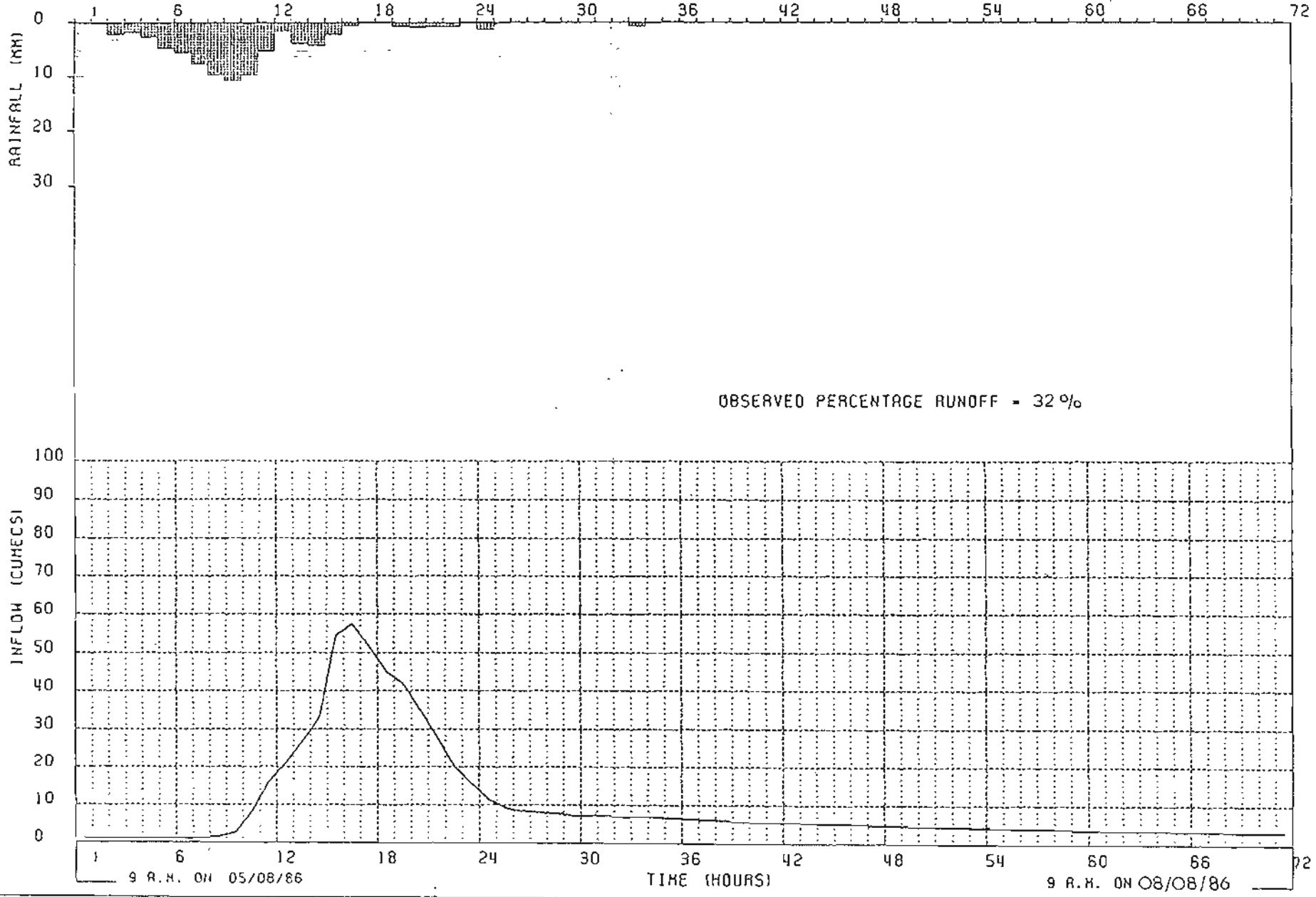
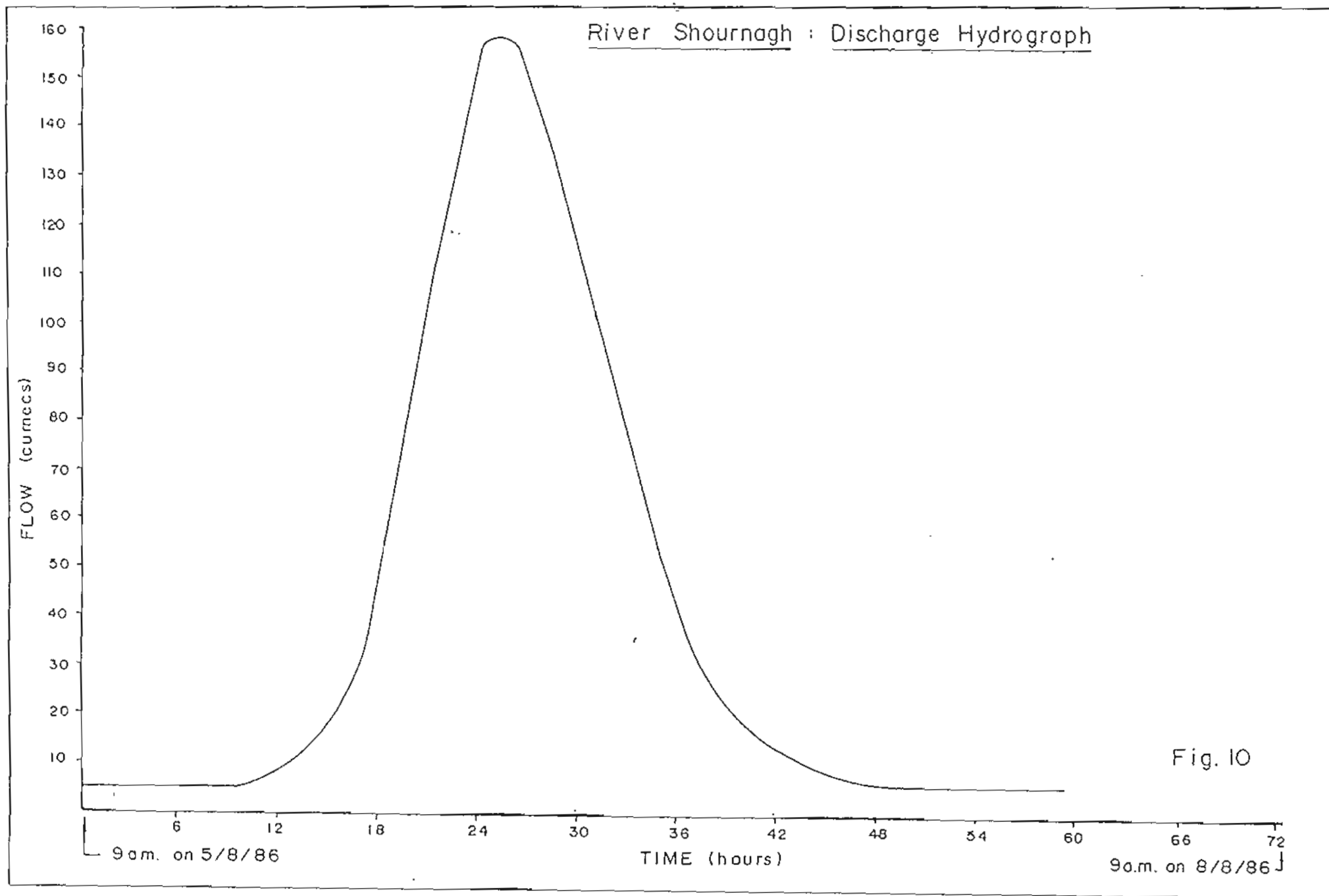


FIG 8





DESTRUCTION OF PŪL NA BRŌ BRIDGE
PHOTOGRAPH NO. 1



FLOOD RELIEF BRIDGE, UPSTREAM OF MACROOM
PHOTOGRAPH NO. 2



PUBLIC HOUSE DOWNSTREAM OF BRIDGE IN MACROOM TOWN

PHOTOGRAPH NO. 3



RECORDER HOUSE ON THE RIVER SULLANE

PHOTOGRAPH NO. 4



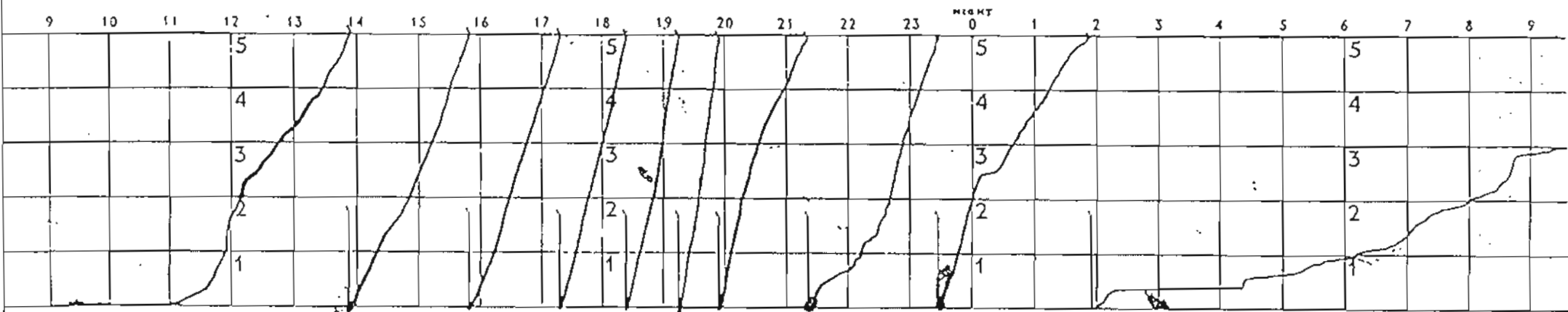
WATER LEVEL ON THE RIVER LANEY
PHOTOGRAPH NO. 5



WATER LEVEL ON THE RIVER TOWN
PHOTOGRAPH NO. 6

APPENDIX A

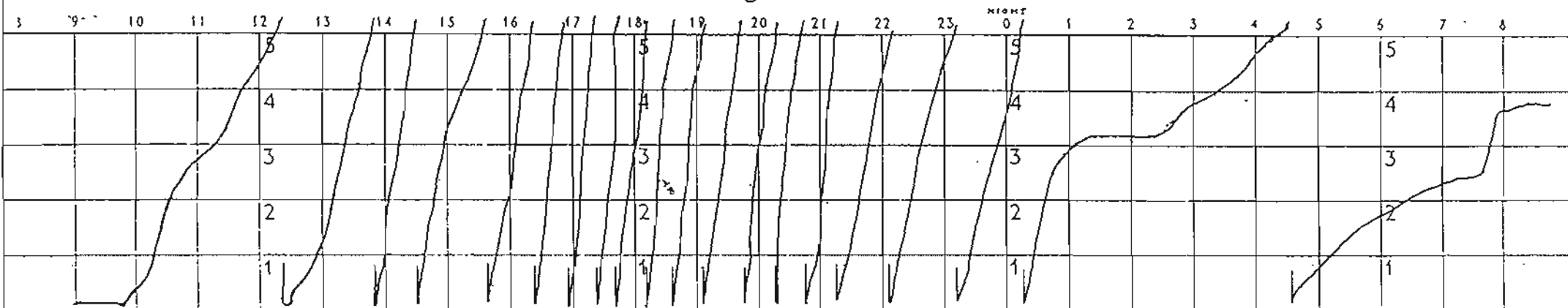
Station Carrigadrohid Lat Long H ft (M.S.L.) Month August Year 86 Time On 5 d 10 h. m Off 6 d. h. m Marks at 10th h. m A.M.T. Sheet No.



DURATION of RAINFALL h. TOTAL by RAIN RECORDER 48.0 mm. TOTAL by CHECK GAUGE 9h. to 9h. 68.3 mm.
 (rainfall at rate of 0.1 mm per hour or more)
 scales: 1 mm of rain = 10 mm. 1 hr = 11.4 mm. Size of chart 304 x 89 mm. Margins, Left 9 mm. Right, Nil. Upper, 21 mm. Lower, 18 mm.

DISTRIBUTION OF RAINFALL AT CARRIGADROHID 9 AM.-5th TO 9 AM.-6th AUG. 1986

Muckross Lat. Long H ft (M.S.L.) Month Aug Year '86 Time On 5 d 9 h 01 m Off 6 d 9 h 00 m Marks at h. m GMT. Sheet No.



DURATION of RAINFALL h. TOTAL by RAIN RECORDER mm. TOTAL by CHECK GAUGE 9h. to 9h. 101.2 mm.
 (Duration at rate of 0.1 mm per hour or more)
 Scales: - 1 mm of rain = 10 mm. 1 hr = 11.4 mm. Size of chart 304 x 89 mm. Margins. Left 9 mm. Right, Nil. Upper. 21 mm. Lower. 18 mm.

DISTRIBUTION OF RAINFALL AT MUCKROSS 9 A.M. - 5th. TO 9 A.M. - 6th AUG. 1986

APPENDIX B

DATE	TIME (HRS)	MEAN RAINFALL (MM)	AREAL ACTUAL INFLOW (M3/S)	SMOOTHED INFLOW (M3/S)	STATION (M3/S)	DISCHARGE		RESERVOIR		TAIL W.L. (M)
						DAM (M3/S)	TOTAL (M3/S)	HEAD W.L. (M)	STORAGE (10**6 M3)	
5 AUG	10.00	0.07	0.00	0.00	57.00	0.00	57.00	64.72	17.97	48.87
	11.00	0.85	27.77	0.00	50.00	0.00	50.00	64.71	17.89	48.84
	12.00	2.37	-8.55	14.39	57.00	0.00	57.00	64.68	17.65	48.83
	13.00	2.51	35.33	19.41	57.00	0.00	57.00	64.67	17.58	48.91
	14.00	4.26	29.00	18.98	29.00	0.00	29.00	64.67	17.58	48.46
	15.00	4.74	0.00	17.59	0.00	0.00	0.00	64.67	17.58	48.33
	16.00	4.64	21.67	16.00	0.00	0.00	0.00	64.68	17.55	48.39
	17.00	6.70	21.67	27.07	0.00	0.00	0.00	64.69	17.73	48.40
	18.00	8.94	6.66	46.25	50.00	0.00	50.00	64.67	17.58	48.85
	19.00	9.76	122.00	83.50	57.00	0.00	57.00	64.70	17.81	48.87
	20.00	9.56	87.23	113.16	65.00	0.00	65.00	64.71	17.39	48.95
	21.00	7.17	176.11	152.70	65.00	0.00	65.00	64.76	18.29	48.96
	22.00	4.45	153.89	179.44	65.00	0.00	65.00	64.80	18.61	48.99
	23.00	4.76	241.77	221.75	64.00	0.00	64.00	64.88	19.25	48.97
6 AUG	00.00	5.17	230.33	264.99	72.00	0.00	72.00	64.95	19.32	49.06
	1.00	3.02	325.89	349.21	72.00	0.00	72.00	65.06	20.73	49.07
	2.00	1.57	404.67	438.40	78.00	0.00	78.00	65.20	21.91	49.12
	3.00	0.50	653.44	533.89	79.00	45.00	124.00	65.42	23.82	49.53
	4.00	0.27	542.57	565.34	82.00	140.00	222.00	65.55	24.97	50.30
	5.00	0.70	624.34	573.84	76.00	270.00	346.00	65.66	25.97	50.65
	6.00	0.64	500.10	544.31	79.00	370.00	449.00	65.68	26.16	51.18
	7.00	0.76	552.78	526.24	80.00	370.00	450.00	65.72	26.53	51.29
	8.00	1.07	501.66	492.29	80.00	370.00	450.00	65.74	26.71	51.36
	9.00	1.08	450.00	450.84	80.00	370.00	450.00	65.74	26.71	51.48
6 AUG	10.00	1.47	420.00	409.91	80.00	340.00	420.00	65.74	26.71	51.39
	11.00	1.14	311.51	367.76	79.00	310.00	389.00	65.71	26.43	51.25
	12.00	0.00	404.49	339.39	77.00	250.00	327.00	65.74	26.71	50.96
	13.00	0.00	276.34	293.90	78.00	250.00	328.00	65.72	26.53	51.03
	14.00	0.00	245.33	257.44	77.00	220.00	297.00	65.70	26.34	50.77
	15.00	0.27	204.90	221.01	76.00	180.00	256.00	65.68	26.16	50.60
	16.00	0.15	214.00	203.94	84.00	130.00	214.00	65.68	26.16	50.49
	17.00	0.00	179.44	188.35	75.00	130.00	205.00	65.67	26.06	50.46
	18.00	1.09	179.46	177.36	75.00	130.00	205.00	65.66	25.97	50.46
	19.00	0.07	165.00	167.48	75.00	90.00	165.00	65.66	25.97	50.40
	20.00	0.58	155.00	162.94	75.00	80.00	155.00	65.66	25.97	50.36
	21.00	0.00	164.00	162.11	84.00	80.00	164.00	65.66	25.97	50.33
	22.00	0.40	164.00	160.16	84.00	80.00	164.00	65.66	25.97	50.33
	23.00	0.07	164.00	155.48	84.00	80.00	164.00	65.66	25.97	50.33
7 AUG	00.00	0.07	138.44	148.35	84.00	80.00	164.00	65.65	25.88	50.32
	1.00	0.00	138.44	139.01	84.00	80.00	164.00	65.64	25.79	50.33
	2.00	0.40	151.00	130.28	91.00	60.00	151.00	65.64	25.79	50.32
	3.00	0.00	92.90	119.38	84.00	60.00	144.00	65.62	25.60	50.31
	4.00	0.00	118.44	113.67	84.00	60.00	144.00	65.61	25.51	50.31
	5.00	0.00	118.44	109.12	84.00	60.00	144.00	65.60	25.42	50.31
	6.00	0.00	94.01	106.15	84.00	60.00	144.00	65.58	25.24	50.31
	7.00	0.00	108.99	99.16	84.00	50.00	134.00	65.57	25.15	50.26
	8.00	0.28	99.99	93.22	75.00	50.00	125.00	65.56	25.06	50.25
	9.00	0.28	59.00	85.44	84.00	50.00	134.00	65.53	24.79	50.26
7 AUG	10.00	0.00	109.00	84.44	84.00	25.00	109.00	65.53	24.79	50.26
	11.00	0.00	64.99	81.78	75.00	15.00	90.00	65.52	24.70	50.29
	12.00	0.00	85.00	82.44	75.00	10.00	85.00	65.52	24.70	50.30
	13.00	0.00	94.00	80.11	84.00	10.00	94.00	65.52	24.70	50.31
	14.00	0.00	60.01	75.56	75.00	10.00	85.00	65.51	24.61	50.31
	15.00	0.00	84.00	74.22	84.00	0.00	84.00	65.51	24.61	50.31
	16.00	0.00	58.99	64.85	84.00	0.00	84.00	65.50	24.52	50.30
	17.00	0.00	84.00	65.69	84.00	0.00	84.00	65.50	24.52	50.30
	18.00	0.00	10.67	60.15	84.00	0.00	84.00	65.47	24.26	50.32
	19.00	0.00	115.88	67.30	67.00	0.00	67.00	65.49	24.43	50.33
	20.00	0.00	50.57	60.98	75.00	0.00	75.00	65.48	24.34	50.33
	21.00	0.00	51.55	61.20	76.00	0.00	76.00	65.47	24.26	50.34
	22.00	0.00	51.55	59.59	76.00	0.00	76.00	65.46	24.17	50.34
	23.00	0.00	76.00	64.24	76.00	0.00	76.00	65.46	24.17	50.35
	24.00	0.00	76.00	63.36	76.00	0.00	76.00	65.46	24.17	50.35
	01.00	0.00	43.55	57.04	68.00	0.00	68.00	65.45	24.08	50.35
	02.00	0.00	51.57	52.50	76.00	0.00	76.00	65.44	23.99	50.33
	03.00	0.00	51.55	50.67	76.00	0.00	76.00	65.43	23.90	50.33
	04.00	0.00	51.55	51.56	76.00	0.00	76.00	65.42	23.82	50.34
	05.00	0.00	51.57	51.59	76.00	0.00	76.00	65.41	23.73	50.35
	06.00	0.00	51.55	51.65	76.00	0.00	76.00	65.40	23.64	50.35
	07.00	0.00	51.83	46.37	76.00	0.00	76.00	65.39	23.55	50.35
	08.00	0.00	51.83	0.00	76.00	0.00	76.00	65.38	23.47	50.35
	09.00	0.00	3.50	0.00	76.00	0.00	76.00	65.35	23.20	50.35

DATE 0.00 2 3 4 5 6 7 8 9
 0.00 IR MINOR LEE SULLANE LANEY TOON
 0.00 C'MENTS

APPENDIX C

DATE	TIME (HRS)	MEAN AREAL RAINFALL (MM)	ACTUAL INFLOW (M3/S)	SMOOTHED INFLOW (M3/S)	STATION (M3/S)	DISCHARGE		RESERVOIR		TAIL W.L. (M)
						DAM (M3/S)	TOTAL (M3/S)	HEAD W.L. (M)	STORAGE (10**6 M3)	
5 AUG	10.00	0.00	0.00	0.00	37.00	0.00	37.00	48.47	11.51	17.43
	11.00	0.16	67.00	67.00	67.00	0.00	67.00	48.47	11.51	17.87
	12.00	1.75	58.11	58.11	72.00	0.00	72.00	48.46	11.46	17.90
	13.00	1.46	60.89	60.89	72.00	0.00	72.00	48.45	11.42	17.87
	14.00	2.19	12.11	12.11	26.00	0.00	26.00	48.44	11.37	16.67
	15.00	4.07	32.00	32.00	7.00	0.00	7.00	48.46	11.46	16.47
	16.00	4.71	7.00	7.00	7.00	0.00	7.00	48.46	11.46	16.33
	17.00	6.53	17.89	17.89	4.00	0.00	4.00	48.47	11.51	16.29
	18.00	8.34	48.00	48.00	23.00	0.00	23.00	48.49	11.60	17.25
	19.00	9.17	84.89	84.89	71.00	0.00	71.00	48.50	11.65	17.82
	20.00	8.36	92.00	92.00	67.00	0.00	67.00	48.52	11.74	17.90
	21.00	4.50	96.00	96.00	71.00	0.00	71.00	48.54	11.83	17.97
	22.00	1.34	109.89	109.89	71.00	0.00	71.00	48.57	11.97	17.91
	23.00	3.33	109.89	109.89	71.00	0.00	71.00	48.60	12.11	17.91
6 AUG	0.00	3.73	122.00	122.00	72.00	0.00	72.00	48.64	12.29	17.97
	1.00	1.84	137.67	137.67	71.00	0.00	71.00	48.69	12.53	17.95
	2.00	0.44	121.89	121.89	83.00	0.00	83.00	48.72	12.67	18.09
	3.00	0.00	146.89	146.89	83.00	0.00	83.00	48.77	12.90	18.14
	4.00	0.03	230.22	230.22	83.00	0.00	83.00	48.88	13.43	18.14
	5.00	0.54	333.00	333.00	83.00	0.00	83.00	49.07	14.33	18.14
	6.00	0.75	399.67	399.67	83.00	0.00	83.00	49.31	15.47	18.14
	7.00	0.70	503.89	503.89	90.00	0.00	90.00	49.61	16.96	18.15
	8.00	0.64	501.67	501.67	85.00	0.00	85.00	49.91	18.46	18.12
	9.00	0.10	488.78	488.78	83.00	53.00	136.00	50.16	19.73	19.05
6 AUG	10.00	1.83	410.11	410.11	84.00	140.00	224.00	50.29	20.40	20.01
	11.00	0.28	453.33	453.33	85.00	210.00	295.00	50.40	20.97	20.31
	12.00	0.06	367.22	367.22	85.00	210.00	295.00	50.45	21.23	20.36
	13.00	0.03	331.00	331.00	85.00	246.00	331.00	50.45	21.23	20.48
	14.00	0.10	331.00	331.00	85.00	246.00	331.00	50.45	21.23	20.48
	15.00	0.00	303.22	303.22	85.00	246.00	331.00	50.43	21.13	20.42
	16.00	0.00	260.56	260.56	85.00	220.00	305.00	50.40	20.97	20.23
	17.00	0.03	230.56	230.56	85.00	190.00	275.00	50.37	20.81	20.22
	18.00	0.10	221.11	221.11	85.00	150.00	235.00	50.36	20.76	19.70
	19.00	0.96	229.00	229.00	84.00	145.00	229.00	50.36	20.76	19.63
	20.00	0.06	182.33	182.33	84.00	140.00	224.00	50.33	20.61	19.61
	21.00	0.00	176.33	176.33	83.00	110.00	193.00	50.32	20.55	19.24
	22.00	0.00	191.00	191.00	91.00	100.00	191.00	50.32	20.55	19.20
	23.00	0.00	173.11	173.11	87.00	100.00	187.00	50.31	20.50	19.19
7 AUG	0.00	0.00	191.00	191.00	91.00	100.00	191.00	50.31	20.50	19.19
	1.00	0.00	173.11	173.11	87.00	100.00	187.00	50.30	20.45	19.16
	2.00	0.00	153.11	153.11	87.00	80.00	167.00	50.29	20.40	19.07
	3.00	0.07	161.00	161.00	91.00	70.00	161.00	50.29	20.40	18.91
	4.00	0.00	161.00	161.00	91.00	70.00	161.00	50.29	20.40	18.90
	5.00	0.00	157.00	157.00	87.00	70.00	157.00	50.29	20.40	18.90
	6.00	0.07	153.00	153.00	83.00	70.00	153.00	50.29	20.40	18.89
	7.00	0.03	146.00	146.00	86.00	60.00	146.00	50.29	20.40	18.83
	8.00	0.00	132.11	132.11	86.00	60.00	146.00	50.28	20.35	18.83
	9.00	0.00	136.00	136.00	86.00	50.00	136.00	50.28	20.35	18.73
7 AUG	10.00	0.00	111.89	111.89	85.00	13.00	98.00	50.29	20.40	18.12
	11.00	0.00	130.67	130.67	89.00	0.00	89.00	50.32	20.55	17.98
	12.00	0.00	105.67	105.67	89.00	0.00	89.00	50.33	20.61	17.92
	13.00	0.00	97.89	97.89	84.00	0.00	84.00	50.34	20.66	17.89
	14.00	0.00	111.78	111.78	84.00	0.00	84.00	50.36	20.76	17.90
	15.00	0.00	98.89	98.89	85.00	0.00	85.00	50.37	20.81	18.06
	16.00	0.00	84.00	84.00	84.00	0.00	84.00	50.37	20.81	17.91
	17.00	0.00	100.67	100.67	84.00	0.00	84.00	50.38	20.87	17.92
	18.00	0.00	84.00	84.00	84.00	0.00	84.00	50.38	20.87	17.92
	19.00	0.00	97.89	97.89	84.00	0.00	84.00	50.39	20.92	17.89
	20.00	0.00	84.00	84.00	84.00	0.00	84.00	50.39	20.92	17.89
	21.00	0.00	80.00	80.00	80.00	0.00	80.00	50.39	20.92	17.90
	22.00	0.00	80.00	80.00	80.00	0.00	80.00	50.39	20.92	17.90
	23.00	0.00	88.00	88.00	88.00	0.00	88.00	50.39	20.92	17.90
	24.00	0.00	101.89	101.89	88.00	0.00	88.00	50.40	20.97	17.89
	01.00	0.00	84.00	84.00	84.00	0.00	84.00	50.40	20.97	17.89
	02.00	0.00	84.00	84.00	84.00	0.00	84.00	50.40	20.97	17.90
	03.00	0.00	80.00	80.00	80.00	0.00	80.00	50.40	20.97	17.89
	04.00	0.00	80.00	80.00	80.00	0.00	80.00	50.40	20.97	17.89
	05.00	0.00	88.00	88.00	88.00	0.00	88.00	50.40	20.97	17.89
	06.00	0.00	88.00	88.00	88.00	0.00	88.00	50.40	20.97	17.90
	07.00	0.00	80.00	80.00	80.00	0.00	80.00	50.40	20.97	17.89
	08.00	0.00	112.89	112.89	99.00	0.00	99.00	50.41	21.02	17.90
	09.00	0.00	84.00	84.00	84.00	0.00	84.00	50.41	21.02	17.88
		1	2	3	4	5	6	7	8	9
DATE		RESEVOIR	MINOR	LEE	SULLANE	LANEY	TOON			
			C'MENTS							

APPENDIX D

APPENDIX D

RIVER LEE - CARRIGADROHID

ANNUAL MAXIMUM FLOOD VOLUMES

Volumes are listed in the Hydrometric Year, 1st October - 30th September

Volumes are estimated from records of Average Daily Inflow.

Each flood was assumed to extend over the number of days where the average daily inflow exceeded $70\text{m}^3/\text{s}$ (i.e. the turbine discharge).

YEAR	DATE	VOLUME ($\text{m} \times 10^6$)	DURATION (days)
1958/'59	19/12/'58	26.13	3
1959/'60	30/01/'60	71.27	6
1960/'61	27/01/'61	78.99	6
1961/'62	16/01/'62	28.70	3
1962/'63	14/03/'63	54.14	5
1963/'64	19/03/'64	46.66	4
1964/'65	13/12/'64	40.50	3
1965/'66	15/02/'66	70.64	7
1966/'67	27/02/'67	21.43	2
1967/'68	23/03/'68	9.69	1
1968/'69	10/01/'69	26.68	2
1969/'70	21/01/'70	38.85	4
1970/'71	24/11/'70	39.22	4
1971/'72	02/02/'72	26.21	3
1972/'73	12/12/'72	26.00	3
1973/'74	30/01/'74	67.21	6
1974/'75	25/01/'75	18.95	2
1975/'76	23/10/'75	53.93	3
1976/'77	20/01/'77	23.28	2
1977/'78	31/10/'77	43.71	4
1978/'79	07/12/'78	102.57	7
1979/'80	15/12/'79	42.51	5
1980/'81	02/11/'80	29.64	2
1981/'82	21/02/'82	19.95	1
1982/'83	17/10/'82	32.27	3
1983/'84	16/12/'83	13.25	1
1984/'85	08/02/'85	28.18	3
1985/'86	06/08/'86	40.00	3

APPENDIX E

APPENDIX E

INNISCARRA - OBSERVED PEAK INFLOWS

Year	Month	Peak Inflow (m ³ /s)	Peak Discharge (m ³ /s)	Intermediate Catchment Peak Inflow (m ³ /s)	Discharge from Carraigadrohid (m ³ /s)
1957	Sept.	487	N/A	69	418
1962	Jan.	170	81	25	145
1964	Dec.	433	422	31	401
1966	Feb. (3-12)	285	258	29	256
1966	Feb. (12-17)	329	312	33	296
1975	Oct.	398	225	173	275
1978	Dec.	408	372	51	357
1980	Oct./Nov.	305	223	71	234
1982	June	203	156	24	180
1986	August	504	331	54	450