HYDROLOGY AND STREAM SEDIMENTS
IN A MOUNTAIN CATCHMENT

VOLUME III (of three volumes)
THE DATA AND APPENDICES

A dissertation presented to the University of Canterbury
in fulfilment of the requirements for the degree
Doctor of Philosophy.

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HYDROLOGY AND STREAM SEDIMENTS
IN A MOUNTAIN CATCHMENT

VOLUME III

(being volume III of three volumes)

THE APPENDICES

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APPENDIX I

CLIMATIC INFORMATION RECORDED IN THE TORLESSE STREAM CATCHMENT

1972 - 1977

The following climatic data have been recorded in the Torlesse stream catchment and are held at the Tussock Grasslands and Mountain Lands Institute, Lincoln College.

(i)	Daily rainfall	8.9.72	-	31.5.77
(ii)	Solar radiation	18.3.73	-	31.5.77
(iii)	Wind run	1.5.73	-	31.5.77
	Wind run and wind direction	17.10.74	-	10.12.74
		19.12.74	-	5.5.75
		9.5.75	-	8.7.75
		16.7.75	-	19.8.75
		30.8.75	-	22.12.75
		25.12.75	-	24.1.76
		9.2.76	-	19.3.76
		5.5.76	-	31.5.76

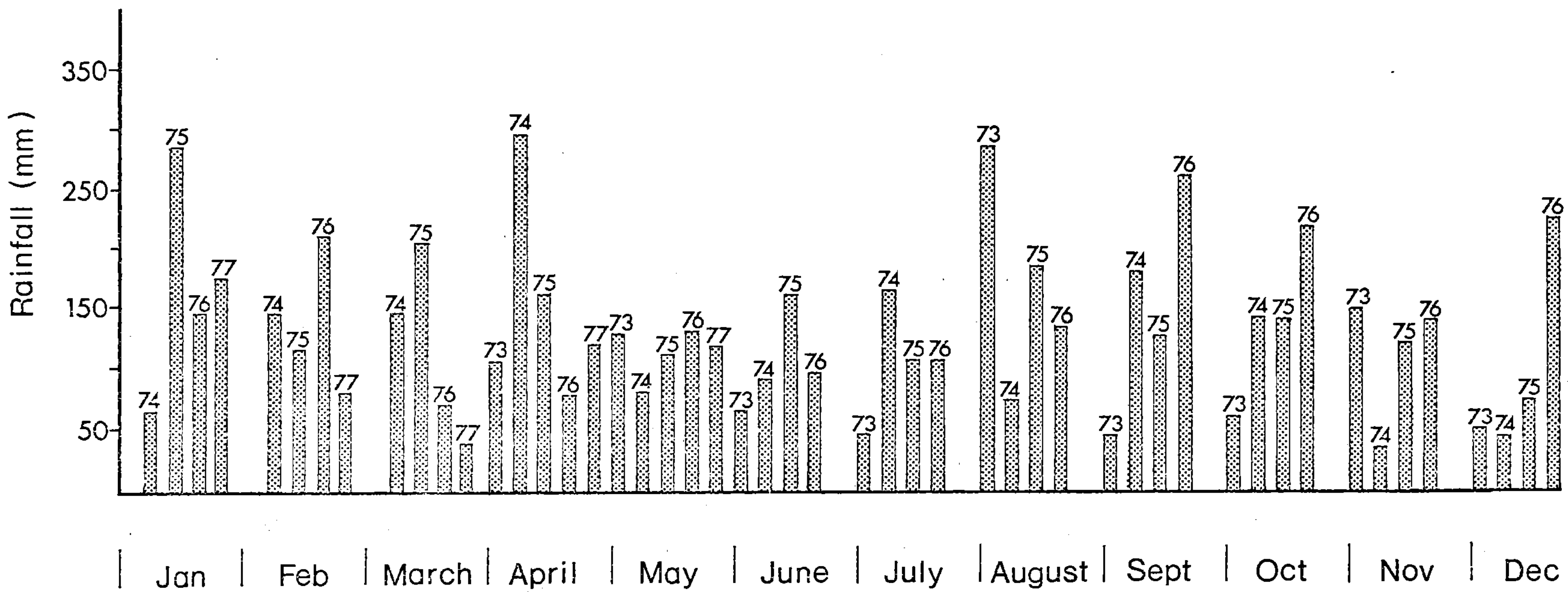
(iv) Temperature:

Monthly minimum and maximum temperatures October 73 - May 77

with selected means for those months with more than 10 days data.

FIGURE 1.1.

Monthly precipitation, Torlesse Stream Catchment, 1973 - 1977.



Rainfall (mm)
350
250
150
50
74
75
76
77
74
75
76
77
74
75
76
77
73
74
75
76
77
73
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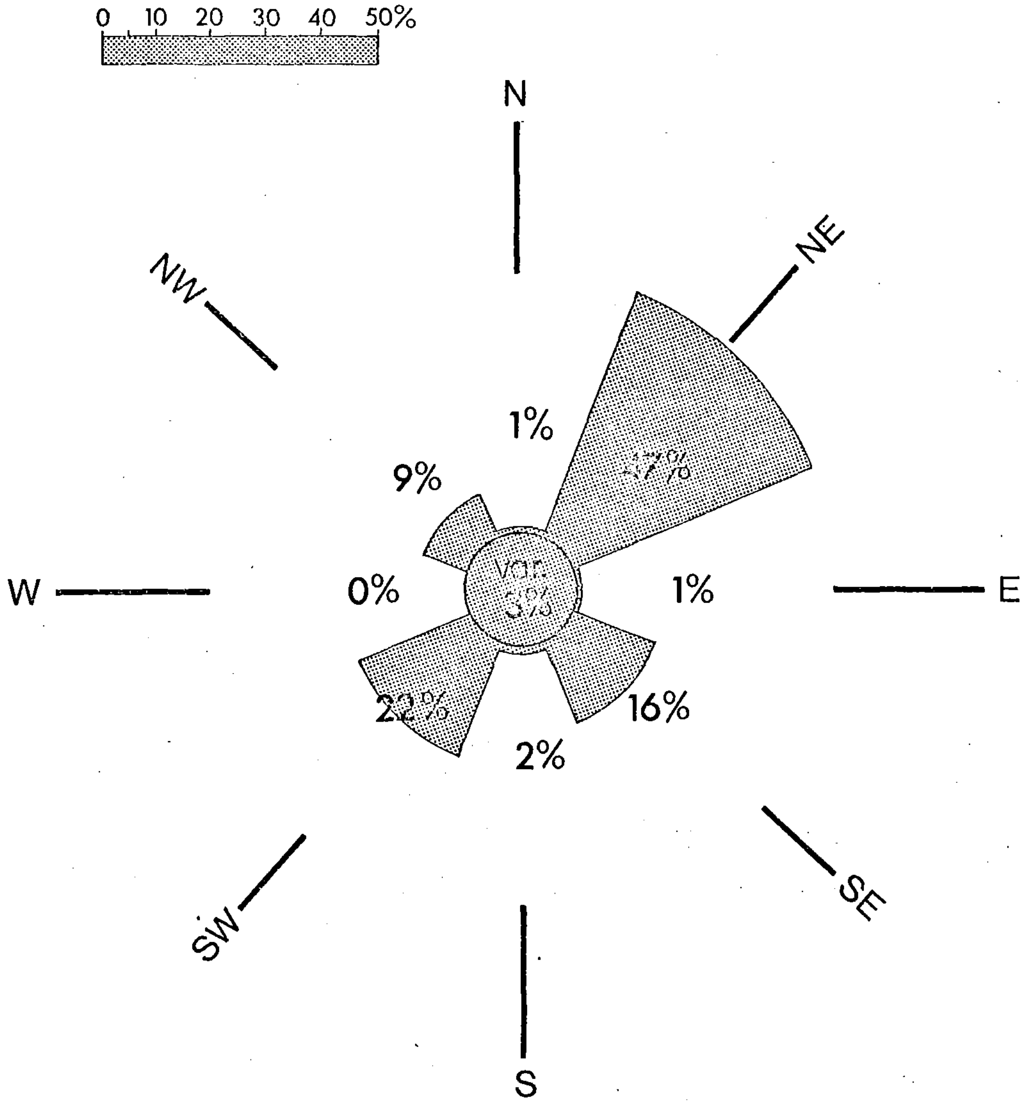
76
73
74
75
76
73
74
75
76
Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec

FIGURE 1.2.

A summary of wind direction for Torlesse stream catchment, 1974 - 1976.



0 10 20 30 40 50%
N
NE
E
SE
S
SW
W
NW
1%
47%
9%
var. 3%
0%
1%
22%
16%
2%

TABLE 1.1.

Daily rainfalls (midnight to midnight), Torlesse stream catchment, 1973 - 1977.

1973

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1				22.7					8.3	3.5		
2								3.5	3.5			2.3
3					0.2			5.2		2.0	28.7	0.1
4					4.7	23.1					5.7	
5						0.2		170.0			1.5	
6					0.8	0.1	5.8				1.0	
7					5.5		1.6		1.9	1.3		
8					6.2	16.6			6.4			
9					8.7	0.7					5.4	0.7
10							4.6	9.7				
11					0.3		4.6	5.2				2.6
12					14.5			15.85			13.4	
13				21.0	33.8			4.85		0.6	0.7	
14				0.7	16.0	2.2		4.3	0.6		63.2	1.8
15				3.4				2.3	2.8		14.8	
16				1.0	2.3			11.15				
17				0.7				8.0				
18					7.4			6.8			0.5	
19				0.2				1.1				
20					0.8			15.4		0.3	0.3	
21				8.3	10.9			4.2	0.4	9.0	11.6	
22				6.2	0.8			0.1	15.5	5.2		
23				37.1				12.6	2.6	32.4		
24				5.2						2.0		10.3
25							25.4		0.1			8.0
26						20.3						
27				0.2								
28				0.2			1.5		0.3			
29					15.8	1.0	0.5					
30									0.1		0.3	8.8
31								3.8		4.3		13.5
					128.7	64.2	44.0	284.1	42.5	60.6	147.1	48.1

Table 1.1 continues...

Table 1.1 contd.

1974

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1			0.6				0.8	1.5				
2			0.1			3.3	24.7					
3	2.4	1.2	24.6	1.2	13.2		10.2		24.3			
4		15.0		2.0			3.0		65.0			
5		4.5		29.3			2.3	2.1	20.3			
6				48.8			7.3	16.7				
7				0.1	0.3			4.3		4.4	1.3	1.5
8			1.2	2.7	0.3		0.2			26.5	2.8	20.0
9	0.5			10.2			2.5		9.5	15.4	15.2	0.3
10	15.2	3.0		0.6			↑	0.4		25.7		7.2
11	2.8	0.1				10.7	|	0.6				
12		0.1				9.7	9.0	0.1		0.7		
13	0.9	0.1				6.5	|	7.4				
14					0.8	9.3	|	1.0			13.2	7.5
15		64.0	30.5	15.1		1.8	|				0.7	0.2
16	23.7	9.6	5.2	107.1		1.8	↓			0.5	0.4	
17		0.2	43.6	1.2		0.1						
18		0.1	28.2		0.5	0.3	2.8	13.5	2.5			
19			11.2		9.0	0.1	20.2	3.0	28.1			0.1
20		15.5	0.4	41.9	0.4		3.3			1.9		
21		19.7		5.2				0.3		16.7		5.4
22		0.6		12.8		25.8	30.3	17.7		8.8		
23	1.0	0.4		3.8	8.4	12.9				0.7		
24	16.5				0.6		4.5	0.1		1.2		
25	1.7			0.1			7.8			0.6		
26		0.7	0.3	5.7			7.1	3.1	5.0	11.8		
27				6.3		5.2		1.0	15.5			
28		10.8			21.4	2.2	18.0		10.0	2.0		
29					21.0		2.2			18.2		
30	0.2				3.6					6.4		
31							7.1					
	64.9	145.6	145.9	294.1	79.5	89.7	163.3	72.8	180.2	141.5	33.6	42.20

An. total = 1453

Table 1.1 continues...

Table 1.1 contd. 1975

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1				7.4				46.8				
2				7.2			2.1				22.4	0.3
3		0.3		0.3	12.4		1.9			3.8	8.2	
4			1.2		3.1	0.1	3.7		25.5	34.7	3.8	0.7
5		14.6	0.5				?		16.8			6.3
6		0.2	5.8		8.3	79.2				1.5	0.2	
7	1.1			26.5	0.1	10.3		5.3	0.7		2.0	
8	9.4		0.7			3.6		7.0		2.1	20.1	
9										0.4	1.8	
10			2.3			12.7	0.5				0.2	
11			40.4	0.1	8.4				8.1			2.6
12			102.8	9.5					1.8			0.2
13			40.6	7.4		11.7		1.1		0.5		
14	2.7	9.1	0.2	0.7		5.2	30.8	0.2		13.5	9.8	
15	0.2	0.2			10.3	8.7	9.9	24.6	0.1			
16	49.4	2.0				10.8	7.1	0.3	2.2		0.3	
17	13.8	0.4			9.4	4.7	5.5	5.3			14.0	
18					21.6	8.3		1.2	0.6	11.7		5.5
19					15.8			50.2	1.0	10.7	11.9	
20	105.5	0.1			1.7		0.2	5.3	25.7		2.8	
21	1.5	1.9			6.7	3.7	1.2	0.3	8.4		1.1	
22	2.2	24.6			1.5	0.4	1.4	5.9	2.9	0.9		
23					0.1			0.1	7.0			
24		24.4	0.2					7.9	22.2(+)			13.2
25	0.4	1.6		24.8					3.2	0.8		13.7
26	8.2		6.8	4.3	4.5	0.2	15.9	0.4		9.0	8.8	0.5
27		5.3			7.1	0.2				32.5	12.2	
28	17.3	31.9			0.1			5.7		1.7		30.3
29	60.5			25.5			4.6	17.3			0.1	
30	7.5			46.7			18.2			15.8		
31	5.1		4.2									
	284.8	116.6	205.7	160.4	111.1	159.8	103.0	184.9	126.2	139.6	119.7	73.3

An. total = 1785.1

Table 1.1 continues...

Table 1.1 contd. 1976

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	5.5			6.9			0.5		0.6	0.1	1.9	9.5
2	3.1		0.3			4.5			0.4	7.9	0.2	6.2
3			0.1			25.4				4.0	0.9	3.8
4			9.1			1.3		0.5		6.9	1.0	0.1
5			5.8			1.0		4.9			12.1	8.1
6	1.1	0.1			0.2			2.9	33.1			8.5
7		49.1					9.3		93.9			
8	1.8	66.1			28.1		0.2		31.6	0.4		
9	0.1	11.3	14.4	29.4	8.9	15.5	0.0	8.1	2.4	22.0	3.8	40.8
10	1.7				7.5	28.4	2.9	45.6	6.6	0.3	2.6	1.2
11		3.0			0.1		2.4	13.1	0.3	44.5	10.2	
12		1.4			9.2		6.9	3.0	1.8	13.9	6.1	
13	11.4	16.7			9.8				9.2	0.1	3.0	1.6
14	20.6	31.6					0.1		13.6	9.8	0.2	13.9
15	2.4	1.3					51.9	11.4	10.9	0.2		0.1
16	0.2					0.1		6.9	5.0			
17	0.9						8.9	0.1	1.4	2.3		
18	0.7					0.5	0.1			42.8		
19	0.1				54.5		5.8		0.8	5.9		31.1
20		3.8		5.6	4.6	3.9*	3.8			0.2		9.8
21		0.3		0.2		0.8*	8.8					4.4
22			1.1		3.7	3.8*			6.1			22.7
23	29.8			2.7				0.9	0.5	19.2		27.0
24	0.1								0.6		27.4	0.7
25	0.7	1.9			2.4			22.4	23.8	15.4	27.6	
26	10.9	20.7	1.2		0.3			3.9	14.7	15.7	4.6	
27	4.8	1.0	1.8	0.1		1.3		4.6		2.0	0.1	0.2
28	29.5		1.1	1.1		1.1	0.7	2.5			0.3	15.8
29			3.6					2.0			3.4	1.0
30	2.0		8.8	31.1		5.8	0.6	0.9	3.2		32.3	0.9
31	19.8		20.7				2.3	0.1		4.1		15.8
	147.2	208.3	68.0	77.1	129.3	93.4	105.2	133.8	260.5	217.7	137.7	223.2

An. total = 1801.4

Table 1.1 continues...

Table 1.1 contd. 1977

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	1.9		0.3		1.4							
2	1.5	9.6	2.0	1.7	19.9							
3	26.1				35.9							
4	15.3				4.4							
5	6.0				0.3							
6	5.7				1.5							
7		16.4	0.5									
8	3.5											
9	23.6											
10	0.1	10.7		6.3								
11	1.7	6.3		22.2								
12												
13	3.4											
14												
15												
16			3.0		3.2							
17	2.5		6.2	0.1	0.1							
18	62.8			5.5	2.1							
19	14.4		3.6	4.0	0.5							
20	0.9		0.6	13.0								
21	1.6	32.3		1.4								
22		2.0			0.1							
23												
24		0.6	21.7	4.7	2.1							
25				10.8	31.4							
26				12.8	2.8							
27	1.8			2.6								
28												
29				29.6	0.2							
30				5.5	10.4							
31	4.2											
	177.0	77.9	37.9	120.2	116.3							

TABLE 1.2.

Monthly wind run (hrs) and direction, Torlesse stream catchment, 1974 - 1976.

Month	Days of record	N	E	S	W	NE	SE	SW	NW	Var.
10/74	15	3	6	3	0	123	88	81	32	24
11/74	30	10	5	17	0	249	169	164	65	41
12/74	23	2	1	9	0	261	71	128	53	27
1/75	31	2	4	6	0	245	201	191	46	51
2/75	28	1	7	5	0	230	158	195	65	12
3/75	31	14	0	17	0	318	119	189	75	13
4/75	30	3	4	17	0	392	83	125	85	12
5/75	28	7	0	38	0	360	52	109	72	37
6/75	30	8	2	4	0	488	53	108	41	16
7/75	24	7	2	8	0	353	63	77	60	6
8/75	21	5	2	10	3	230	42	135	51	22
9/75	30	12	11	23	1	358	79	143	83	8
10/75	31	2	16	17	0	337	105	177	62	28
11/75	30	9	15	25	0	271	126	158	90	26
12/75	29	4	15	31	0	237	131	198	60	14
1/76	24	2	8	26	0	161	149	183	39	8
2/76	20	1	2	12	0	216	70	106	50	11
3/76	19	0	15	16	0	225	50	114	29	7
4/76										
5/76	27	1	2	13	0	418	56	85	70	3
6/76	15	0	2	0	0	225	32	62	37	1
7/76	3	0	0	0	0	38	15	10	9	-
8/76	20	1	7	10	0	279	61	66	53	1
9/76	21	0	1	8	0	292	58	106	33	7
10/76	26	3	4	12	0	316	88	152	50	3
11/76	20	0	1	1	0	181	142	132	22	1
12/76	7	0	1	3	0	63	29	46	26	-
	613									
	Totals	97	133	331	4	6866	2290	3240	1358	379 = 14,698 hrs
% of total		1%	1%	2%		47%	16%	22%	9%	3%
	87.6									

TABLE 1.3.

Monthly minimum and maximum recorded temperatures, Torlesse stream catchment.

		1973	1974		1975	1976	1977
January	max.		33.5		34.5	30.0	28.0
	min.		6.0		4.0	2.0	0.5
	mean				(14.5)	(14.5)	
February	max.		26.0		32.0	27.0	31.0
	min.		8.0		1.0	-1.0	0.5
	mean				(15.5)	(13.0)	
March	max.		25.5	* 12 days data	29.0	27.5	26.0
	min.		-1.5		5.0	1.0	1.5
	mean		(13.0)			(14.5)	
April	max.		24.0	* 16 days data	21.0	23.0	26.0
	min.		-2.0		-3.5	-3.0	-4.0
	mean		(11.0)			(10.5)	
May	max.		17.5	* 9 days data	16.0	19.0	15.0
	min.		-3.0		-3.0	-5.5	-7.5
	mean						
June	max.		12.5		13.5	22.0	13.0
	min.		-8.0		-7.0	-9.0	-6.0
	mean						
July	max.		13.5		11.0	12.5	
	min.		-6.0		-1.0	-8.0	
	mean						
August	max.		15.0		14.0	15.0	
	min.		-7.0		-7.0	-5.5	
	mean						
September	max.		17.0		25.0	15.0	
	min.		-6.0		-5.0	-6.0	
	mean						
October	max.	26.5	25.0		23.0	21.0	
	min.	-3.0	-2.0		-5.0	-6.0	
	mean						
November	max.	23.5	26.0		27.0	22.0	
	min.	0.0	0.0		-2.0	-8.0	
	mean						
December	max.	31.0	30.0	* 9 days data	32.0	25.5	
	min.	3.5	2.0		-3.0	0.0	
	mean				(13.6)		

APPENDIX II

A SUMMARY OF RAINFALL OBSERVATIONS

MT. TORLESSE STATION 1909 - 1975

(Derived from records held by N.Z. Meteorological Service)

TABLE II.1.

Annual precipitation Mt. Torlesse Station 1909 - 1975.

Year	Precipitation	Year	Precipitation
1909	1030	1942	1141
1910	1065	1943	956
1911	1255	1944	1214
1912	1118	1945	1341
1913	947	1946	1038
1914	919	1947	866
1915	668	1948	865
1916	1033	1949	834
1917	1081	1950	1038
1918	1022	1951	1400
1919	1040	1952	1019
1920	967	1953	1143
1921	893	1954	951
1922	798	1955	884
1923	1038	1956	1105
1924	1090	1957	1288
1925	1346	1958	1006
1926	1055	1959	1237
1927	1118	1960	926
1928	1159	1961	1179
1929	1239	1962	1077
1930	1024	1963	1235
1931	948	1964	789
1932	876	1965	1043
1933	828	1966	912
1934	925	1967	957
1935	1002	1968	980
1936	1194	1969	561
1937	986	1970	870
1938	1215	1971	684
1939	674	1972	1057
1940	1015	1973	838
1941	1083	1974	1200
		1975	1383

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mean	98.4	79.7	76.3	89.0	85.5	71.1	78.9	76.6	80.7	96.9	92.9	102.0	1025.1
Standard deviation	51.2	43.2	41.0	60.3	55.2	38.8	54.8	51.0	45.1	53.4	43.7	54.9	173.2

TABLE II.2.

Mean monthly precipitation Mt. Torlesse Station 1909 - 1975.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	2.6	2.2	2.1	2.1	2.1	1.9	1.9	2.1	2.2	2.4	2.7	2.9
Standard deviation	1.2	1.3	1.2	0.9	1.1	1.2	1.2	1.4	1.3	1.3	1.3	1.7

TABLE II.3.

Storm events* per month (mean(Mt. Torlesse Station 1909 - 1975.

* precipitation in excess of 10 mm.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	8.7	8.1	9.1	9.8	9.6	10.8	10.2	11.1	9.6	8.2	8.4	8.2
Standard deviation	4.6	3.5	4.1	4.5	4.2	4.5	3.7	5.1	4.5	3.3	3.7	3.8

TABLE II.4.

Longest period without rain (mean) Mt. Torlesse Station 1909 - 1975.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	10.7	9.0	9.0	9.2	9.8	8.1	8.4	8.3	9.1	10.4	10.3	10.9
Standard deviation	4.0	2.7	3.3	3.7	4.1	3.1	3.6	3.4	3.6	3.5	3.5	4.5

TABLE II.5.

Number of raindays* per month (mean) Mt. Torlesse Station 1909 - 1975.

* precipitation in excess of 0.0 mm.

APPENDIX III

MEAN DAILY STREAM FLOWS (MIDNIGHT TO MIDNIGHT)
TORLESSE STREAM CATCHMENT 1973 - 1977. ($m^3 sec^{-1}$)

Note ( ) = flow estimated

1973.

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1					.130	.150	.115	.075	.217	.135	.098	.085
2					.123	.147	.113	.080	.195	.125	.095	.085
3					.115	.138	.105	.077	.178	.108	.131	.083
4					.115	.155	.100	.077	.156	.115	.151	.082
5					.112	.170	.097	.080	.144	.108	.138	.083
6					.103	.157	.093	.115	.130	.110	.128	.085
7					.100	.148	.090	.115	.123	.125	.123	.085
8					.103	.148	.090	.080	.113	.129	.120	.085
9					.110	.153	.089	.090	.103	.134	.120	.085
10					.120	.155	.086	.110	.099	.150	.115	.083
11					DATA	.135	.085	.140	.099	.165	.105	.080
12						.130	.085	.265	.098	.180	.113	.080
13					MISSING	.127	.085	.398	.094	.190	.113	.083
14				DATA		.127	.084	.352	.111	.185	.238	.085
15						.124	.083	.253	.120	.168	.335	.085
16				MISSING		.123	.083	.230	.103	.153	.270	.083
17						.122	.083	.200	.098	.140	.250	.080
18						.117	.082	.170	.098	.130	.185	.100
19					.280	.098	.081	.155	.090	.130	.140	.105
20				.098	.270	.090	.081	.171	.090	.128	.128	.090
21				.108	.255	.097	.087	.160	.089	.133	.128	.090
22				.118	.253	.097	.088	.145	.088	.135	.128	.090
23				.180	.257	.100	.083	.137	.087	.174	.125	.090
24				.177	.235	.103	.080	.140	.083	.156	.123	.095
25				.155	.205	.103	.095	.147	.082	.133	.105	.100
26				.148	.185	.115	.100	.150	.083	.124	.090	.095
27				.133	.175	.125	.090	.140	.087	.122	.090	DATA
28				.130	.160	.120	.087	.175	.092	.120	.089	MISSING
29				.130	.153	.120	.084	.536	.095	.115	.088	
30				.130	.153	.119	.076	.596	.108	.105	.087	
31					.150		.070	.369		.100		
Monthly Mean				.137	.168	.127	.089	.191	.112	.136	.138	.087

Appendix III continues...

Appendix III contd. 1974

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	DATA MISSING	.078	.125	.150	.185	.140	.175	.170	.150	.200	.320	.145
2		.078	.120	.150	.175	.148	.250	.155	.200	.195	.293	.133
3		.080	.140	.150	.165	.150	.250	.150	.210	.195	.258	.130
4	.083	.083	.160	.150	.158	.150	.180	.145	.289	.195	.245	.130
5	.075	.088	.153	.168	.153	.148	.180	.133	.895	.190	.230	.128
6	.070	.090	.143	.444	.150	.145	.180	.140	.418	.205	.215	.125
7	.070	.085	.140	.333	.150	.143	.178	.148	.275	.250	.210	.125
8	.075	.080	.140	.259	.148	.143	.178	.130	.280	.380	.220	.128
9	.088	.080	.143	.255	.140	.150	.180	.130	.270	.407	.255	.130
10	.090	.080	.148	.245	.133	.203	.175	.130	.210	.339	.280	.128
11	.083	.080	.150	.225	.130	.225	.170	.130	.190	.375	.273	.125
12	.080	.080	.150	.210	.130	.195	.165	.130	.168	.390	.260	.125
13	.080	.080	.150	.195	.130	.190	.158	.130	.153	.335	.248	.123
14	.080	.080	.150	.205	.130	.195	.155	.128	.145	.295	.255	.120
15	.080	.125	.190	.225	.128	.195	.155	.123	.145	.255	.275	.120
16	.100	DATA MISSING	.188	1.130	.123	.185	.153	.120	.150	.230	.260	.120
17	.110		.332	.745	.120	.180	.148	.120	.153	.215	.230	.120
18	.100		.362	.297	.120	.178	.145	.120	.153	.205	.215	.118
19	.098		.248	.237	.135	.168	.396	.120	.175	.200	.210	.108
20	.093		.197	.275	.140	.160	.326	.118	.185	.200	.195	.100
21	.090	.190	.185	.289	.130	.185	.250	.108	.165	.215	.180	.098
22	.088	.210	.185	.374	.128	.303	.255	.100	.165	.225	.170	.093
23	.085	.185	.185	.336	.125	.344	.265	.100	.170	.220	.158	.090
24	.108	.170	.175	.291	.130	.349	.240	.100	.165	.220	.158	.088
25	.115	.155	.165	.268	.133	.273	.210	.100	.158	.220	.160	.085
26	.098	.145	.155	.250	.130	.248	.190	.100	.163	.235	.160	.085
27	.093	.135	.150	.235	.130	.240	.175	.100	.180	.245	.158	.085
28	.088	.130	.150	.225	.130	.230	.205	.100	.180	.235	.158	.085
29	.085		.150	.210	.140	.195	.235	.100	.175	.240	.158	.085
30	.085		.150	.195	.145	.175	.215	.110	.190	.255	.155	.083
31	.083		.150		.140		.190	.120		.290		.080
Monthly mean	.088	.112	.172	.291	.139	.198	.204	.123	.218	.253	.229	.111

Appendix III continues...

Appendix III contd. 1975

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	.080	.240	.260	.175	.467	.150	.135	Data Missing	.160	.140	.220	.160
2	.075	.205	.210	.195	.306	.150	.125	.240	.160	.125	.349	.180
3	.070	.170	.185	.145	.268	.140	.125	.150	.150	.130	.280	.160
4	.080	.148	.165	.138	.220	.130	.130	.130	.209	.228	.280	.155
5	.078	.148	.150	.133	.190	.120	.125	.120	.240	.220	.260	.150
6	.073	.145	.135	.125	.180	.300	.125	.110	.250	.220	.250	.150
7	.070	.133	.125	.155	.160	.280	.125	.110	.200	.200	.220	.140
8	.080	.125	.120	.175	.170	.184	.125	.125	.180	.180	.257	.130
9	.088	.122	.120	.150	.160	.160	.125	.110	.160	.170	.230	.125
10	.085	.117	.123	.135	.160	.150	.130	.100	.160	.170	.220	.125
11	.085	.110	.186	.128	.160	.150	.130	.098	.190	.165	.220	.120
12	.085	.105	1.385	.128	.160	.150	.130	.095	.190	.165	.200	.110
13	.085	.105	2.078	.135	.160	.150	.130	.090	.160	.175	.180	.100
14	.088	.113	.468	.130	.158	.160	.211	.095	.155	.190	.155	.090
15	.093	.115	.300	.120	.180	.160	.320	.110	.150	.200	.155	.085
16	.164	.110	.240	.120	.160	.150	.240	.125	.155	.180	.155	.090
17	.202	.110	.210	.120	.160	.145	.180	.120	.150	.165	.155	
18	.173	.108	.195	.120	.237	.140	.160	.120	.155	.160	.155	
19	.153	.103	.180	.120	.289	.130	.150	.281	.190	.170	.145	
20	.780	.095	.165	.120	.260	.125	.140	.377	.265	.180	.160	DATA MISSING
21	.645	.093	.158	.120	.230	.155	.130	.209	.200	.160	.140	
22	.323	.113	.153	.120	.220	.140	.125	.160	.170	.160	.140	
23	.233	.118	.150	.120	.190	.135	.110	.155	.170	.160	.140	
24	.190	.119	.150	.120	.180	.140	.100	.155	.280	.150	.140	.085
25	.160	.161	.138	.140	.160	.140	.095	.155	.260	.160	.140	.085
26	.155	.143	.125	.155	.160	.140	.145	.155	.240	.180	.140	.090
27	.150	.140	.123	.153	.170	.140	.130	.150	.230	.209	.163	.100
28	.150	.220	.120	.153	.160	.140	.120	.140	.210	.190	.150	.159
29	.533		.115	.207	.158	.135	.110	.150	.190	.210	.155	.160
30	.443		.110	.992	.155	.135	Data Missing	.160	.170	.250	.160	.160
31	.302		.110		.150			.170		.240		.160
Monthly mean	.193	.133	.273	.168	.198	.154	.142	.149	.192	.181	.191	.128

Appendix III continues...

Appendix III contd. 1976

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	.160	.140	.120	.111	.111	.110	.100	.115	.170	.220	.370	.340
2	.160	.130	.115	.085	.09	.110	.095	.110	.160	.235	.340	.300
3	.155	.125	.115	.08	.09	.160	.090	.100	.155	.240	.345	.270
4	.150	.125	.115	.11	.09	.150	.090	.100	.150	.240	.390	.240
5	.150	.130	.130	.1	.09	.140	.085	.100	.150	.240	.420	.210
6	.130	.130	.130	.1	.09	.140	.080	.095	.223	.250	.440	(.210)
7	.135	.189	.130	.1	.09	.135	.070	.090	.650	.325	.380	(.200)
8	.130	.212	.130	.1	.08	.130	.070	.085	.670	.400	.360	(.190)
9	.125	.250	.150	.135	(.10)	.131	.070	.088	.288	.460	.340	.265
10	.120	.320	.140	.105	(.095)	.240	.070	.210	.260	.550	.330	.310
11	.120	.430	.120	.105	.09	.210	.080	.298	.270	.663	.340	.285
12	.110	.270	.115	.110	.09	.160	.085	.280	.250	.980	.330	.245
13	.110	.210	.110	.120	.085	.130	.080	.215	.220	.590	.335	.200
14	.145	.275	.100	.120	.09	.130	.080	.200	.210	.495	.330	.200
15	.150	.270	.09	.125	.10	(.125)	.35	.170	.220	.425	.320	.180
16	.150	.235	.085	.125	.09	(.120)	.173	.155	.230	.380	.320	.190
17	.145	.170	.085	.120	.100	(.115)	.130	.155	.205	.350	.310	.180
18	.140	.165	.08	.120	.110	(.110)	.125	.150	.180	.435	.270	.175
19	.150	.130	.08	.120	.40	(.100)	.120	.140	.170	.590	.265	.219
20	.150	.125	.07	.120	.30	(.095)	.115	.125	.155	.540	.250	.265
21	.150	.125	.07	.125	.18	(.090)	.115	.125	.155	.480	.245	.265
22	.140	.120	.07	.130	.155	(.085)	.115	.125	.160	.405	.240	.280
23	.153	.120	.107	DATA	.155	.085	.110	.125	.160	.410	.235	.371
24	.150	.120	.107		.14	.080	.100	.125	.155	.370	.240	.360
25	.120	.120	.07		.125	.080	.095	.176	.183	.420	.308	.290
26	.110	.140	.07	MISSING	.120	.075	.090	.190	.225	.460	.380	.240
27	.130	.130	.07		.120	.090	.100	.180	.225	.410	.300	.230
28	.160	.125	.07		.115	.100	.120	.180	.225	.410	.245	(.220)
29	.130	.120	.07	.08	.110	.095	.125	.180	.255	.410	.210	(.210)
30	.120		.089	.116	.110	.100	.120	.180	.235	.405	.284	(.205)
31	.120		.097		.110		.120	.180		.390		(.200)
Monthly mean	.138	.178	.098	.111	.123	.121	.109	.153	.232	.425	.315	.243

Appendix III continues...

Appendix III contd. 1977

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	.195	(.130)	.100	.080	.180							
2	.190	(.140)	.100	.080	(.175)							
3	.235	.140	.095	.080	(.224)							
4	.285	.135	.095	.085	(.440)							
5	.270	.130	.095	.080	.280							
6	.255	.125	.090	.080	.210							
7	.235	.131	.090	.080	.170							
8	.205	.130	.085	.075	.160							
9	.270	.120	.095	.075	.145							
10	.285	.109	.085	.085	.140							
11	.260	.134	.085	(.100)	.135							
12	.230	.115	.080	(.090)	.120							
13	.200	.100	.080	(.085)	.120							
14	.175	.095	.080	.090	.120							
15	.170	.100	.080	.090	.130							
16	.165	.100	.085	.090	.135							
17	.160	.095	.095	.090	.130							
18	.266	.090	(.090)	.100	.125							
19	.330	.090	(.095)	.105	.120							
20	.270	.090	(.095)	.110	.115							
21	.220	.132	(.090)	.119	.105							
22	.190	.150	(.090)	.100	.100							
23	.170	.125	.090	.090	.100							
24	.160	.110	.103	.085	.100							
25	.160	.100	.113	.095	(.116)							
26	.155	.095	.095	.120	.140							
27	.150	.095	.090	.125	.110							
28	.145	.095	.085	.110	.100							
29	.140		.085	.104	.135							
30	.135		.085	.233	.176							
31	(.130)		.085		.165							
	.207	.114	.091	.098	.152	Monthly mean						

APPENDIX IV

DOUBLE RING INFILTRATION RATES, TORLESSE STREAM CATCHMENT.

DOUBLE RING INFILTRATION RATES, TORLESSE STREAM CATCHMENT.

LEGEND

f_{0-10} = Average infiltration rate for the first 10 minutes ($mm\ h^{-1}$)

f = Average infiltration rate ($mm\ h^{-1}$)

f_{30} = Infiltration rate after 30 minutes

* = infiltration trial terminated before 30 minutes because a steady rate of infiltration had been attained

DRY = Dry run trials

WET = Wet run trials 18 - 25 hours after dry run

$\overline{x}$ = Mean value

SD = Standard deviation

INFILTRATION PLOTS - SITE DESCRIPTIONS

PLOT 1

Vegetation	-	short tussock grassland, including *Celmisia* sp.
Aspect	-	south 192°
Slope	-	1°
Soils	-	Cass hill soil, slightly stony silt loams, stony silt loams, bouldery silt loams.

	DRY			WET		
Site	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 2	1,182	986	900			
Site 3	1,218	1,148	1,020	240	228	180
Site 4	1,080	998	960	678	628	510
$\overline{X}$	1,160	1,044	960	459	428	345
SD	72	90	60	310	283	233

PLOT 2

Vegetation	-	short tussock grassland including clovers and sweet vernal grass
Aspect	-	north-east 55°
Slope	-	26°
Soils	-	Tekoa steepland soils, very stony silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	213	154	120	40.5	32.4	15
Site 2	816	752	780	798	736	720
Site 3	1,920	1,754	1,380	309	283	240
Site 4	390	322	300	25.5	10.2	10
$\overline{X}$	835	745	645	293	265	244
SD	767	718	564	361	337	336

PLOT 3 Vegetation - Short tussock grassland including *Celmisia* spp. and sweet vernal grass.

Aspect - S.S.W. 205°

Slope - 9°

Soils - Cass silt loam, slightly stony silt loams.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	810	696	660	582	498	420
Site 2	402	334	300	159	130	60
Site 3	396	348	360	270	216	120
Site 4	516	464	420	258	195	200
$\overline{X}$	531	461	435	317	260	200
SD	194	168	159	183	163	158

PLOT 4 Vegetation - short tussock grassland including sweet vernal grass.

Aspect - S.S.E. 150°

Slope - 12°

Soils - moderately gravelly silt loams.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	378	276	210	192	155	150
Site 2	224	134	90	125	76	30
Site 3	515	318	210	258	170	120
Site 4	332	227	195	201	154	105
$\overline{X}$	362	239	176	194	139	101
SD	121	79	58	55	43	51

PLOT 5 Vegetation - short tussock grassland including significant sweet vernal,

Aspect - south-east 135°

Slope - 18°

Soils - Cass hill soils, slightly gravelly to slightly stony silt loams.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	462	313	240	266	194	180
Site 2	537	407	330	378	308	240
Site 3	656	558	450	624	527	465
Site 4	1,404	1,294	1,080	1,158	1,108	1,110
$\overline{X}$	765	643	525	566	534	499
SD	434	446	380	362	407	426

PLOT 6 Vegetation - Short tussock grassland including significant sweet vernal grass

Aspect - south 195°

Slope - 29°

Soils - Stony silt loams

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	5,400	5,400	5,120	4,800	4,800	4,000
Site 2	1,510	1,504	1,320	2,000	2,000	1,980
Site 3	220	205	195	225	173	200
Site 4	3,396	3,205	2,600	3,396	3,205	2,600
$\overline{X}$	2,632	2,579	2,309	2,605	2,545	2,195
SD	2,260	2,247	2,116	1,956	1,953	1,576

PLOT 7

Vegetation - Manuka and Discaria scrub, with tussock (Bare plot).

Aspect - north-west 295°

Slope - 25°

Soils - Tekoa steepland eroded phase, very gravelly silt loams.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	333	319	300	140	141	150
Site 2	1,425	1,132	950	426	426	420
Site 3	141	111	80	82	64	45
Site 4	192	173	135	198	172	120
$\overline{X}$	523	434	366	212	201	184
SD	607	474	400	151	157	164

PLOT 8

Vegetation - Matt shrub (*Hymenanthra* sp.) and *Chinochloa*. otherwise bare ground.

Aspect - south-east 150°

Slope - 31°

Soils - stony silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	1,230	1,192	1,000			
Site 2	576	529	400	738	712	660
Site 3	70	64	30			
Site 4	2,820	2,820	2,700			
Site 5	684	625	510			
$\overline{X}$	1,076	1,046	928			
SD	1,058	1,070	1,049			

PLOT 9 Vegetation - short tussock grassland

Aspect - south-west 235°

Slope - 24°

Soils - Cass hill soil. Slightly stony to stony silt loam

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	744	692	540*	720	649	540*
Site 2	3,864	3,727	3,480*			
Site 3	510	432	270	498	420	300*
Site 4	2,466	2,316	1,980*			
$\overline{X}$	1,896	1,791.75	1,567.5	609	534.5	420
SD	1,575	1,183	1,480	157	162	170

PLOT 10 Vegetation - short tussock grassland with Discaria. (Bare Plot)

Aspect - north-west 310°

Slope - 20°

Soils - Cass hill soil, eroded phase. Very gravelly silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	708	260	160	179	160	135
Site 2	215	168	120	138	127	110
Site 3	359	301	175	257	251	240
Site 4	348	315	270	113	100	90
$\overline{X}$	408	261	181	172	160	144
SD	211	66	64	63	66	67

* denotes run stopped before full time.

PLOT 11 Vegetation - mixed *Dracophyllum* and *Chinochloa* (Bare plot)

Aspect - south 170°

Slope - 10°

Soils - Tekoa hill soil, eroded phase. Slightly stony to very stony silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	90	43.4	45*	61.5	38.4	30*
Site 2		NO		DATA		
Site 3	71.25	52.5	30*	70.5	58	30*
Site 4	70.7	20.7	30	84	67	30*
$\overline{X}$	77.3	38.9	35	72	54.5	30
SD	11	16	9	11	15	0

PLOT 12 Vegetation - *Dracophyllum* scrub

Aspect - south 195°

Slope - 35°

Soils - No information.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	492	507	525	342	333	330
Site 2	627	564	500	540	472	390
Site 3	980	896	820	744	660	600
Site 4	675	613	600	1,026	974	980
$\overline{X}$	694	645	611	663	610	575
SD	206	173	146	292	277	294

* denotes run stopped before full time.

PLOT 13 Vegetation - short tussock grassland, some matagouri

Aspect - west 250°

Slope - 22°

Soils - cass hill soil, very gravelly to stony silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	2,268	2,070	1,800*			
Site 2	432	400.5	360*	870	828	720*
Site 3	2,532	2,270.6	1,680*			
Site 4	2,070	1,859.5	1,860*			
$\overline{X}$	1,825.5	1,650.2	1,425			
SD	949	850	714			

PLOT 14 Vegetation - manuka scrub

Aspect - west 240°

Slope - 26°

Soils - no information.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	1,917	1,615	750	1,998	1,877	1,840
Site 2	359	269	225	222	182	180
Site 3	396	264	210	434	299	225
Site 4	3,936	3,576	3,120			
$\overline{X}$	1,652	1,431	1,076	885	786	748
SD	1,687	1,565	1,385	970	947	946

* denotes run stopped before full time.

PLOT 15 Vegetation - snow totara

Aspect - no information

Slope - no information

Soils - very stony, silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1						
Site 2	1,086	994	750			
Site 3	1,320	1,320	1,300			
Site 4	2,625	2,625	2,400			
$\overline{X}$	1,677	1,646	2,363			
SD	829	863	1,887			

PLOT 16 Vegetation - short tussock grassland

Aspect - west 240°

Slope - 25°

Soils - Tekoa hill soil, slightly stony to very stony silt loam.

	DRY			WET		
	f_{0-10}	f	f_{30}	f_{0-10}	f	f_{30}
Site 1	1,200	1,110	840*			
Site 2	372	324	240*	270	233.3	210*
Site 3	447	352	135*	279	198	120*
Site 4	1,500	1,472.7	1,200*			
$\overline{X}$	879.75	814.7	603.75	274.5	215.7	165
SD	558	570	504	6	25	64

* denotes run stopped before full time.

APPENDIX V

THE SEISMIC REFRACTION METHOD USED IN THE DETERMINATION OF SUBSURFACE DISCONTINUITIES. (Chapter 4 Vol II)

by R.W. Lewandowsky

INTRODUCTION

Seismic refraction surveys have long been used in petroleum exploration. With the advent of relatively cheap, portable seismographs the method became applicable to site investigation for other purposes such as engineering works. Using the same equipment, the techniques can be applied to a number of problems other than engineering site investigations. In this study the depth to bedrock was determined in several areas of eroded land in the Torlesse stream catchment.

Seismic Refraction Theory.

A refraction seismograph consists of three basic components:

- i) A source of seismic energy, in this case a hand operated hammer.
- ii) A geophone.
- iii) An electronic counter to measure time.

The mode of operation is as follows: at the instant the hammer hits the ground a signal is sent to the counter to start measuring time; seismic waves travel through the ground and are picked up by the geophone and the counter is stopped by the first wave arrival.

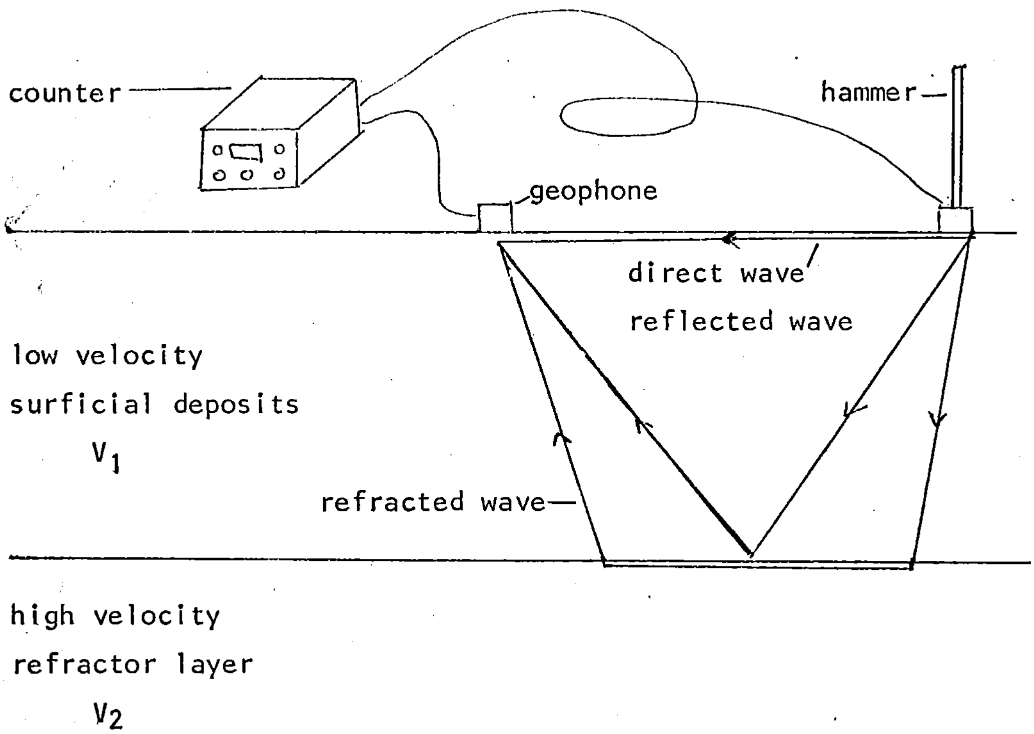
Three different paths can be followed by the seismic wave: as a direct wave, as a reflected wave or as a refracted wave (Figure V.1). Seismic waves obey the laws of optical physics.

In a seismic refraction survey only the direct and refracted waves are used. If the seismic wave is initiated close to the geophone the direct wave will reach the geophone first, followed by the refracted wave. If the seismic wave is initiated at some distance from the geophone, the refracted wave will reach the geophone first followed by the direct wave.

Figure V.1. follows

FIGURE V.1.

Seismic wave paths.


counter
hammer
geophone
direct wave
reflected wave
low velocity
surficial deposits
V_1
refracted wave
high velocity
refractor layer
V_2

If seismic waves are initiated at a number of points of known distance from the geophone, a graph of time of travel against distance can be drawn (Fig. V.2.) - this is the field information obtained during a survey.

FIELD METHOD

A "Bison 1501" engineering seismograph was used. This instrument has a digital readout in milliseconds (1 second = 1,000 milliseconds). A tape was laid out along the direction of traverse and the geophone was set at one end. Travel-time readings were taken at 1 m intervals for the first 5-10 m of the traverse and at 3 m intervals thereafter to a total length of 40-50 m. At the conclusion of this forward traverse the geophone was moved to the other end of the traverse and the procedure repeated in the opposite direction.

INTERPRETATION

The reciprocal method of Hawkins (1961) was used to interpret the time-distance graphs. This method gives a profile of refractor depth as well as seismic velocities within the refractor. The seismic velocities of the surface layer were determined directly from the time-distance graphs. A worked example for one traverse can be seen in Table V.1.

RESULTS

In general, velocity contrasts between the colluvium and the Torlesse Group rocks were good; the colluvium having velocities between 200-500 m sec^{-1}, and the Torlesse Group rocks between 1,000-3,600 m sec^{-1}. A few velocities between 500-1,000 m sec^{-1} were found. These could be ascribed to highly crushed shear-zones in the Torlesse Group, water-logged and compacted surficial deposits, or to a layer of intermediate velocity between the Torlesse Group and the colluvium. Fig. V.3 shows the three possible interpretations: more sophisticated instruments or test pits and bores would be required to define the alternative.

Figures V.2, V.3 Table V.1 follow

FIGURE V.2.

The time distance graph.

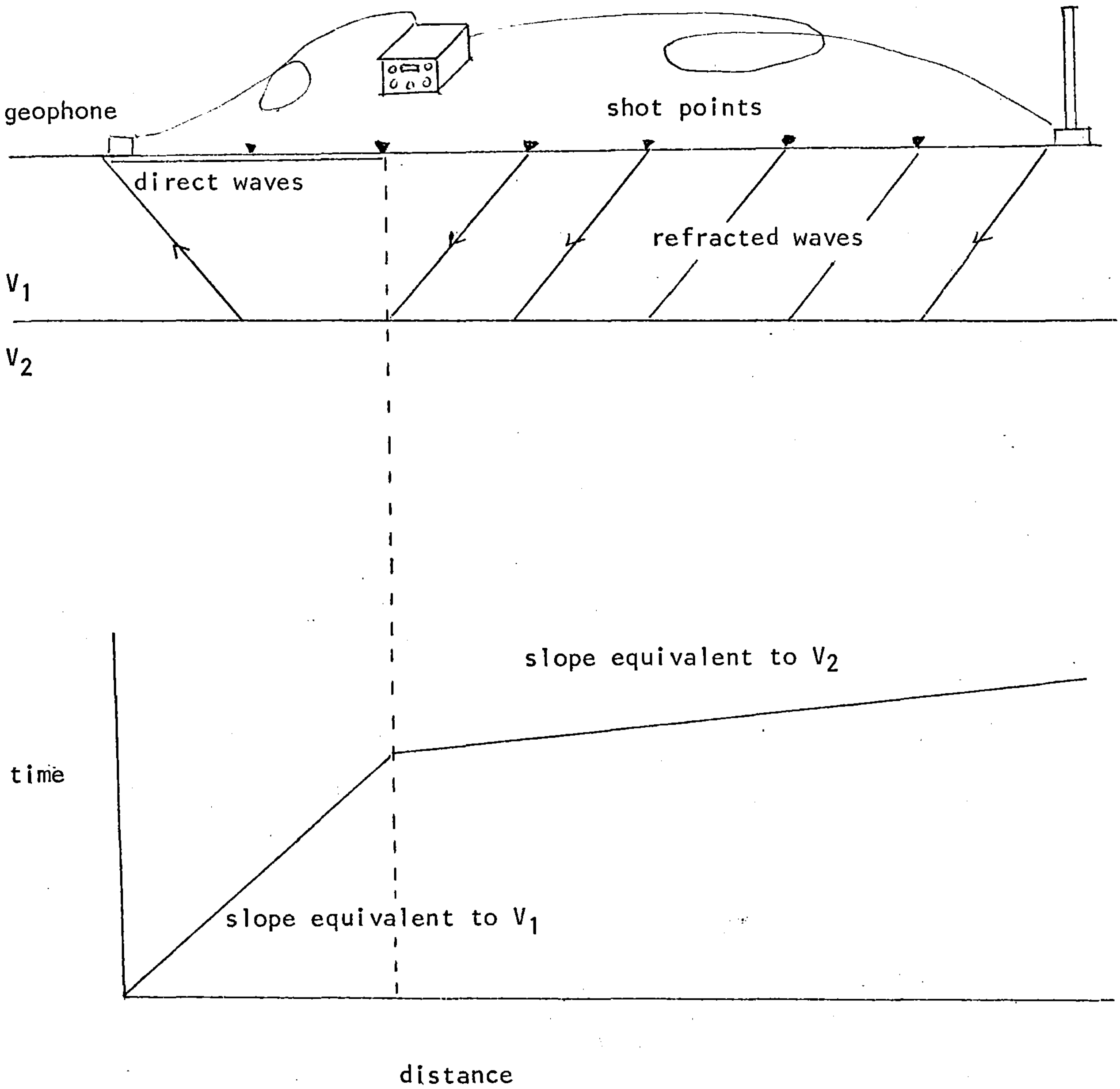
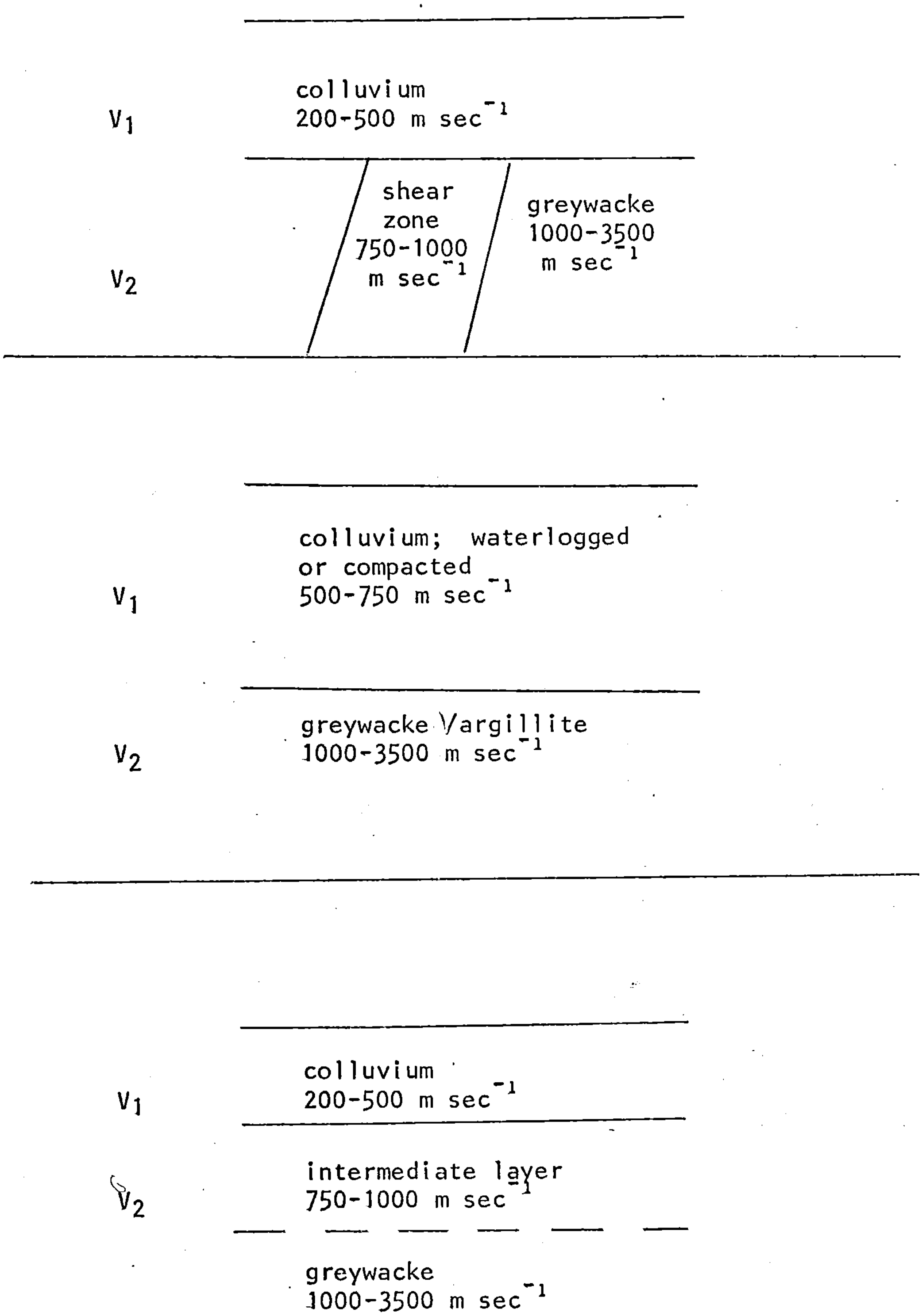

geophone
shot points
direct waves
refracted waves
V_1
V_2
slope equivalent to V_2
time
slope equivalent to V_1
distance

FIGURE V.3.

Possible interpretation of profiles.



colluvium
200-500 m sec⁻¹
V1
shear zone 750-1000 m sec⁻¹
greywacke 1000-3500 m sec⁻¹
V2
colluvium; waterlogged or compacted
500-750 m sec⁻¹
V1
greywacke /argillite
1000-3500 m sec⁻¹
V2
colluvium
200-500 m sec⁻¹
V1
intermediate layer
750-1000 m sec⁻¹
V2
greywacke
1000-3500 m sec⁻¹

TABLE V.1.

A worked example of the determination of surface depths from seismic velocities.

Page 1 (of 3 pages) Calculation sheet

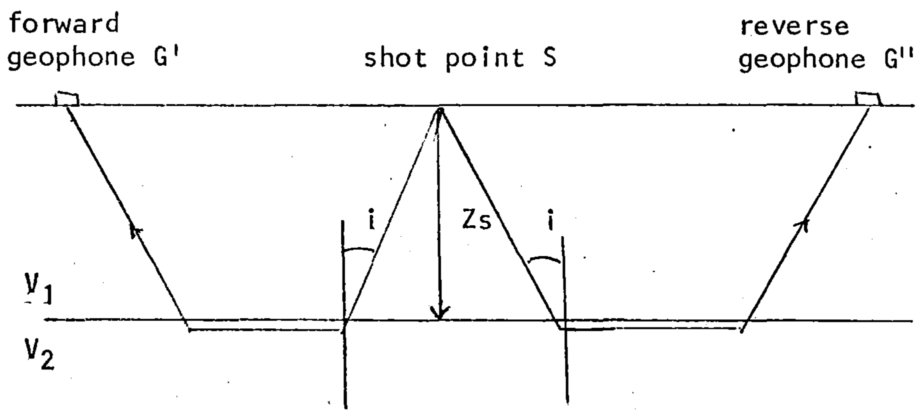
Dist m	Forward time ms	Reverse time ms	Time depth td	Corrected fwd. time	Corrected rev. time	V_2 m/s	F *	Ftd m *
0		43.5						
1								
2	1.6	40.5						
3	4.5							
4	7.8							
5	11.4	40.1						
8	20.5	33.5						
11	24.7	39.3						
14	24.7	39.7	10.2	14.5	29.5	769	0.53	5.4
17	30.6	32.0	9.3	21.3	22.7	769	0.53	4.9
20	34.2	27.8	9.0	25.2	18.8	769	0.53	4.7
23	33.4	26.4	7.9	25.5	18.5	3529	0.44	3.5
26	34.6	29.4	9.9	24.4	19.5	3529	0.44	4.4
29	37.0	26.6	9.8	27.2	16.8	3529	0.44	4.3
32	39.0	24.3	9.7	29.3	14.6	2045	0.45	4.4
35	37.6	20.2	6.9	30.7	13.3	2045	0.45	3.1
38	39.5	19.3	7.4	32.1	11.9	2045	0.45	3.3
41	39.0	15.5	5.3	33.7	10.2	2045	0.45	2.4
44	40.4	14.4						
45		10.3						
46		10.7						
47	42.5	6.5						
48		2.5						
49		2.0						
50	44.5							

Explanation and legend for Table V.1. continues...

Table V.1. contd.

(page 2 of 3 pages)

Legend.



Time depth td.

$$td = \frac{1}{2}\,(TG'S + TG''S - TG'G'')$$

where T is the time between the indicated sections.

The distance from S to the refractor normal to the refractor (Zs) is given by the equation:

$$Zs = td.V_1/\text{Cos } i$$

the term $V_1/\text{Cos } i$ may be regarded as a depth conversion factor F, and by using Snell's law may be written as:

$$F = V_1\sqrt{\frac{V_2}{V_1}^2 - 1}$$

Therefore

$$Zs = F.td$$

Table V.1. continues...

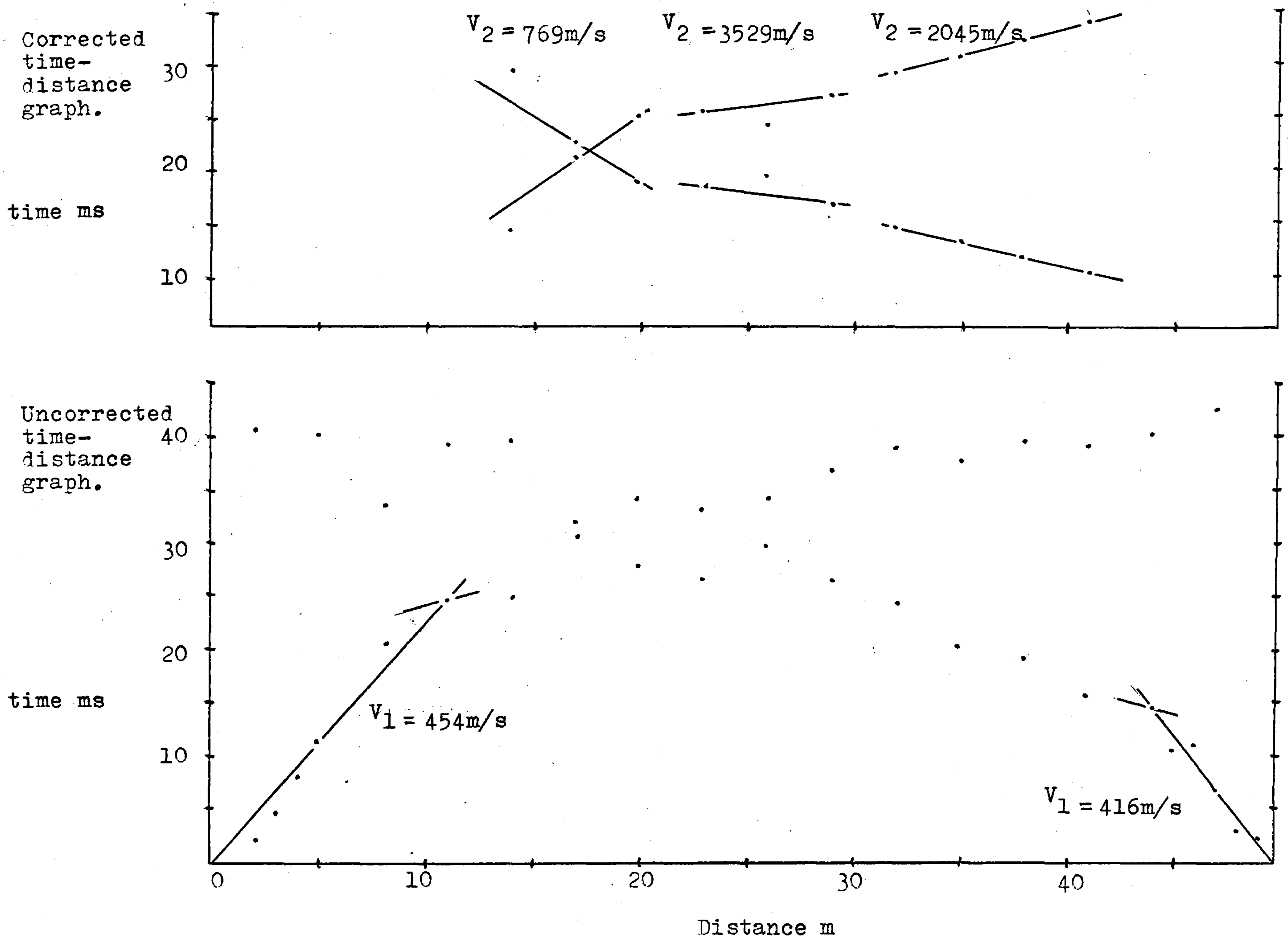


Table V.1. contd.
(page 3 of 3 pages)

TIME DISTANCE GRAPHS

As a tentative classification the velocity variations could be ascribed to the following conditions:

200-350 m sec^{-1}. Debris from debris avalanches, deep humus layers, screes.
350-500 m sec^{-1}. Typical colluvium of angular particles in a fine matrix with a thin humus layer on the surface.
500-750 m sec^{-1}. Short grazed ground, waterlogged ground, or surfaces with the humus layer completely removed.
750-1000 m sec^{-1}. Highly fractured shear-zones, or a consolidated weathering layer.
1000-2000 m sec^{-1}. Interbedded greywacke and argillite with many joints.
2000-3000 m sec^{-1}. Interbedded greywacke and argillite with few joints.
Above 3500 m sec^{-1}. Thick greywacke beds with little argillite and few joints.

The derived profiles from the traverses are shown in Figs. V.4, V.5, V.6.

DISCUSSION

The accuracy of seismic refraction surveys to a large degree depends on the control available to test the results. In this study the control was limited to a few surface exposures. The problem of lack of control is exemplified in the two sets of overlapping traverses on Gingerbread spur (Fig. V.4.) that do not give coinciding refractor profiles. Variable velocities in the colluvium layer probably account for much of this error. A very irregular refractor surface or a bedrock surface that is intensely jointed can affect the accuracy of the derived profile; these conditions are probably common in the area of study. For this study however, the magnitude of the variation of depth between individual traverses is probably more important than the absolute depth under each point on the traverses.

Figures V.4, V.5, V.6 follow

FIGURE V.4.

Composite profile Gingerbread spur.

Torlesse Seismic Survey

Composite profile - 'Gingerbread Spur'

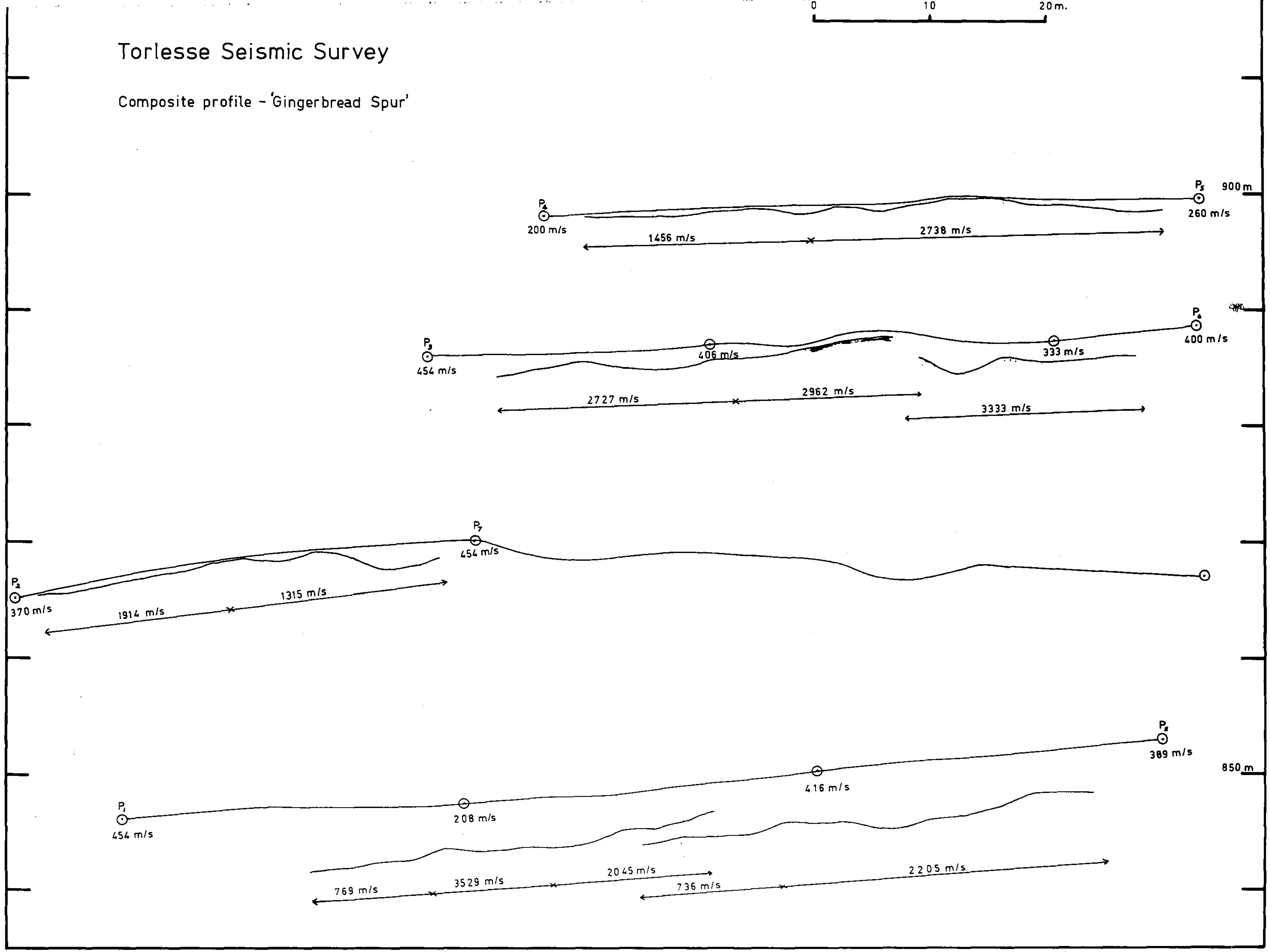


FIGURE V.5.

Composite profile true right face of Helen stream.

Torlesse Seismic Survey

Composite profile - 'Fryers Face'

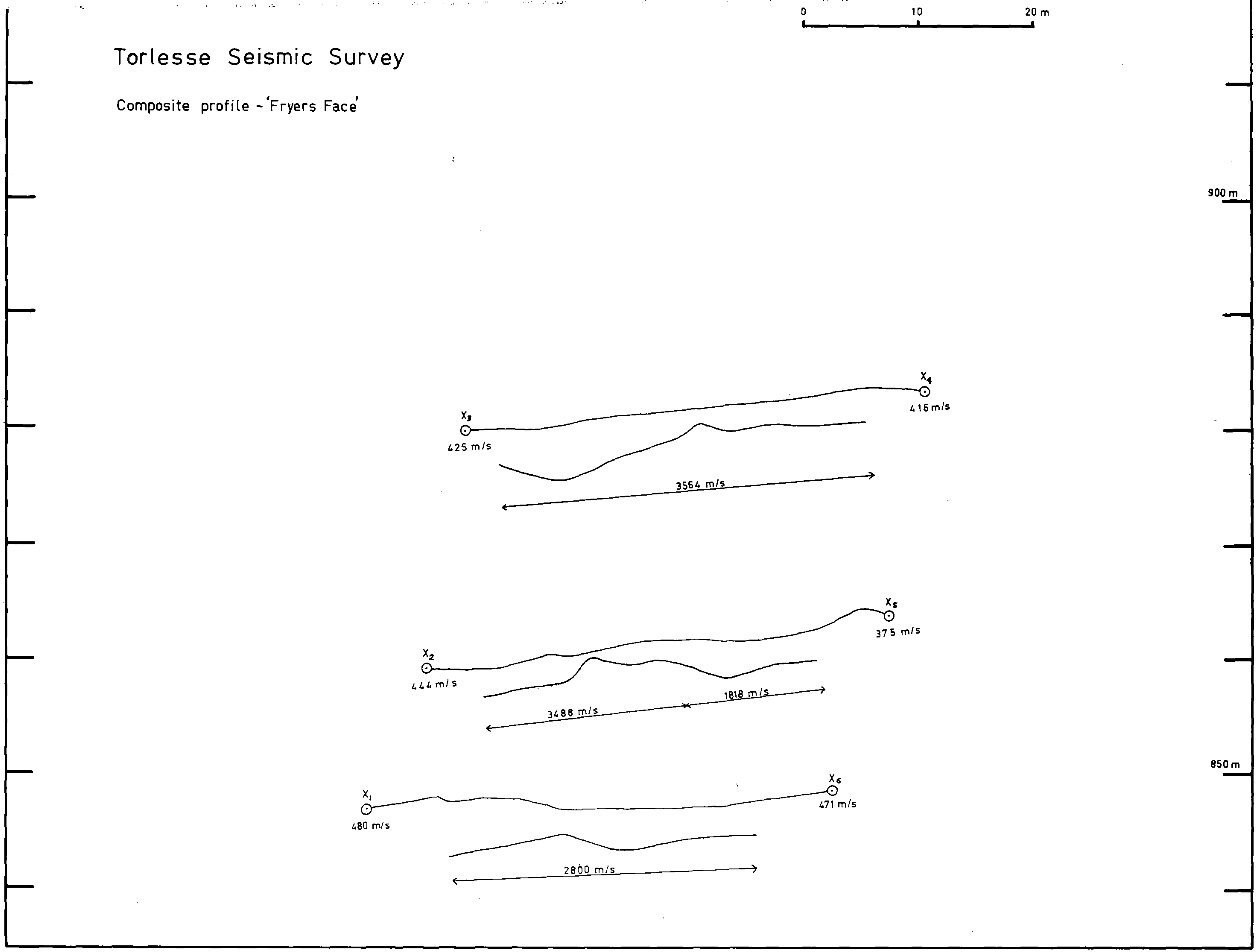
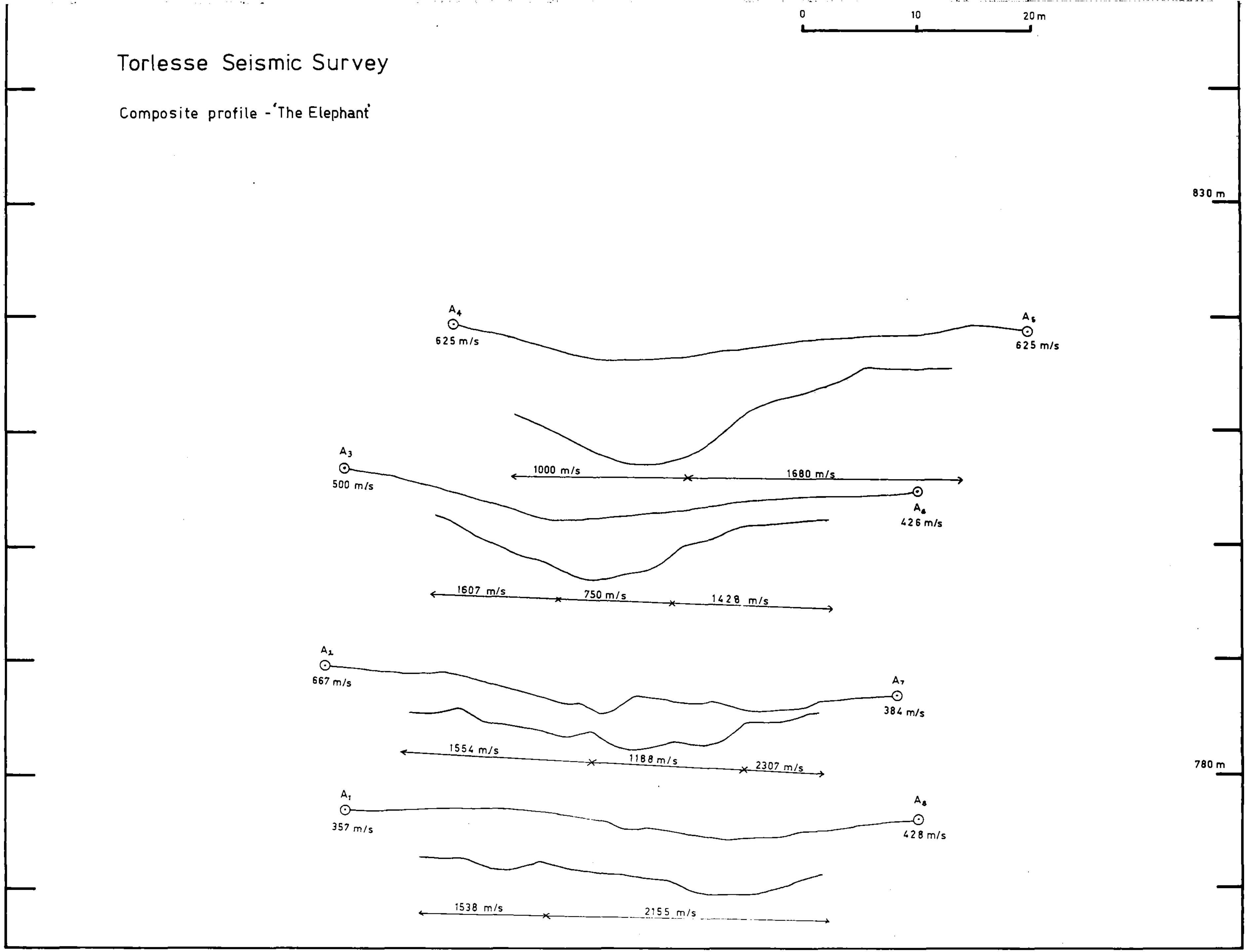


FIGURE V.6.

Composite profile of a site opposite the Kowai river, Torlesse stream confluence.



Torlesse Seismic Survey
Composite profile - 'The Elephant'
0
10
20 m
830 m
780 m
A4
625 m/s
A5
625 m/s
1000 m/s
1680 m/s
A3
500 m/s
A6
426 m/s
1607 m/s
750 m/s
1428 m/s
A2
667 m/s
A7
384 m/s
1554 m/s
1188 m/s
2307 m/s
A1
357 m/s
A8
428 m/s
1538 m/s
2155 m/s

Again because of the lack of control the interpretation given to the velocities found in the colluvium and refractor materials must, at best, be regarded as tentative.

Despite these uncertainties the results confirm that the three erosion features were associated with areas where the refractor came close to the surface.

REFERENCES

Anon, 1969: Instruction Manual - Bison Instruments Engineering Seismograph Model 1501: Bison Instruments Inc. 25 p

Hawkins, L.V. 1961: The reciprocal method of routine shallow seismic refraction investigations. *Geophysics Vol. 26:* 806-19.

APPENDIX VI

HYDROGRAPHS, HYETOGRAPHS, SEDIMENT YIELDS AND SEDIMENT TRANSPORT RATES, TORLESSE STREAM CATCHMENT 1972 - 1977

EVENTS

1972

14 July
8 Sept
9 Sept
13 Sept
8 Oct

1973

23 Apr
9 May
29 May
4 June
6 Aug
10 Aug
12 - 15 Aug
20 Aug
29 - 31 Aug
23 Oct
3 Nov
14 - 15 Nov
21 Nov

1974

16 Jan
15 Feb
3 Mar
15 Mar
17 - 18 Mar
5 - 7 Apr
16 - 18 Apr
22 June
24 June
2 July
19 July
28 July
6 Aug
4 - 6 Sept
7 - 8 Sept
19 - 20 Sept
8 Oct
11 Oct

1975

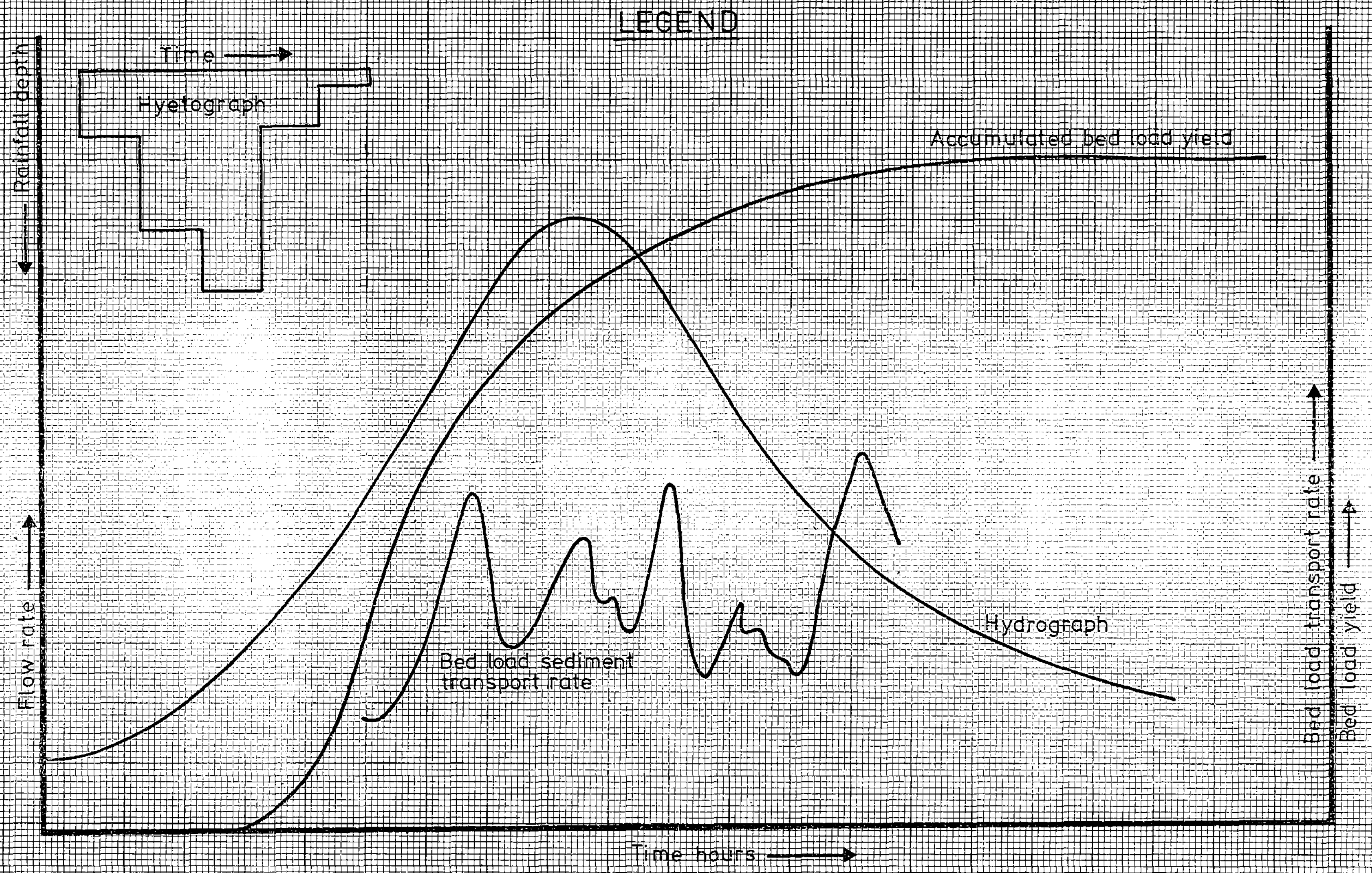
16 Jan
20 - 21 Jan
25 Jan
24 Feb
28 Feb
12 - 13 Mar
1 Apr
7 Apr
30 Apr
19 May
6 June
14 July
26 July
1 Aug
19 Aug
30 Aug
4 Sept
20 Sept
24 Sept
4 Oct
2 Nov
8 Nov
27 Nov
24 Dec
28 Dec

1976

14 Jan
23 Jan
28 Jan
7 Feb
9 - 10 Feb
11 Feb
14 - 15 Feb
19 May
10 June
15 July
10 Aug
7 - 8 Sept
11 - 12 Oct
18 - 19 Oct
24 Nov
25 - 26 Nov
30 Nov
9 Dec
19 Dec

1977

3 Jan
18 - 19 Jan
7 Feb
10 Feb
21 - 22 Feb
24 - 25 Mar



LEGEND
Time
Hyetograph
Rainfall depth
Accumulated bed load yield
Hydrograph
Bed load sediment transport rate
Flow rate
Bed load transport rate
Bed load yield
Time hours

Torlesse Stream Catchment

14 July 1972

Precipitation ?

Peak flow rate 0·240 m^3/sec

Bed load yield 0·145 tonnes

Torlesse Stream Catchment

8 Sept 1972

Precipitation 0 (snow melt)

Peak flow rate 0·380 m^3/sec

Bed load yield 0·405 tonnes

Torlesse Stream Catchment

9 Sept 1972

Precipitation 25·5 mm

Peak flow rate 0·200 m^3/sec

Bed load yield 0

Torlesse Stream Catchment

13 Sept 1972

Precipitation ?

Peak flow rate 0·270 m^3/sec

Bed load yield 0·042 tonnes

Torlesse Stream Catchment
8 Oct 1972

Precipitation 190 mm (approx)

Peak flow rate 1·300 m^3/sec

Bed load yield large - 50 tonnes?

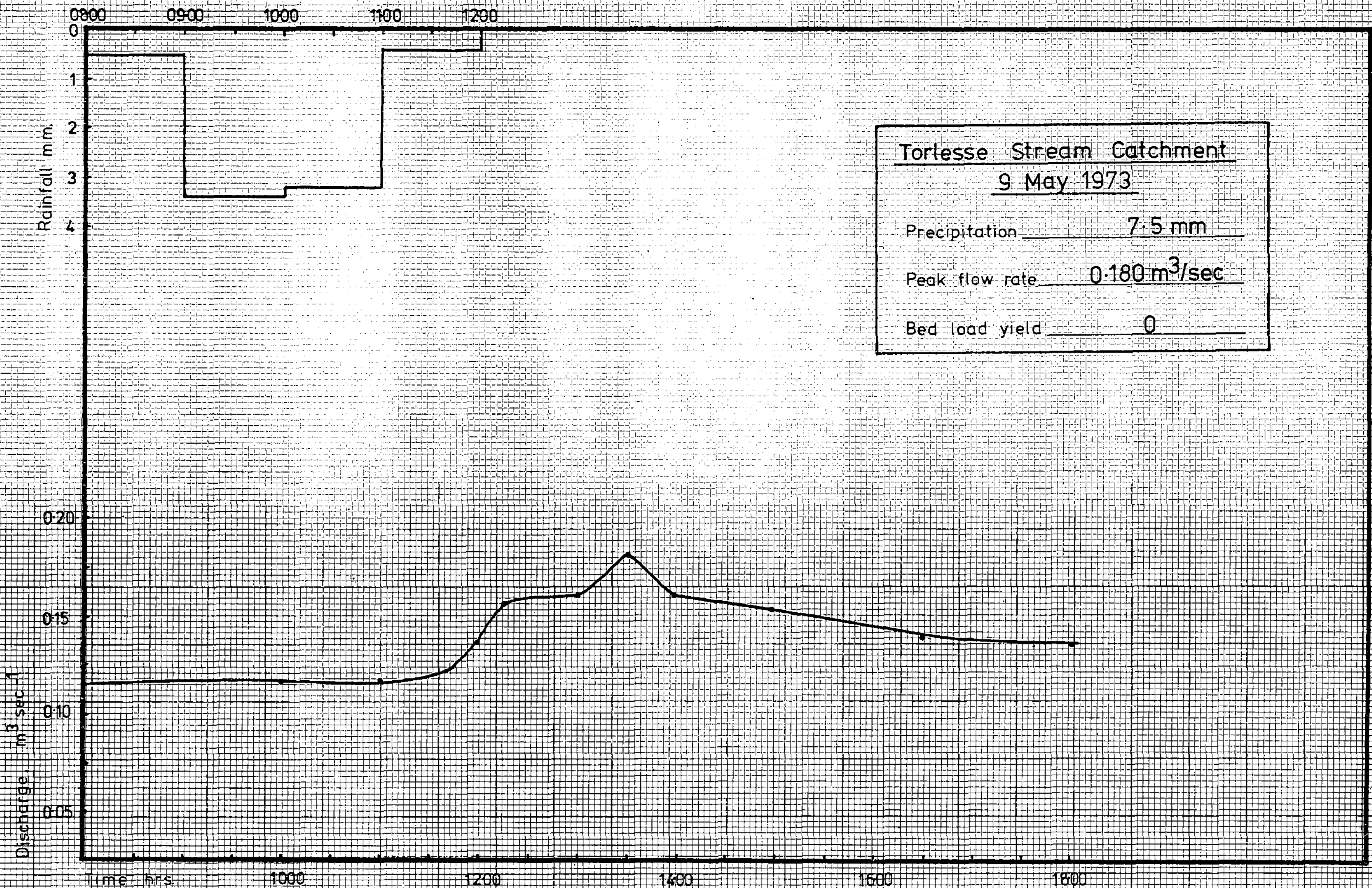
Torlesse Stream Catchment

23 April 1973

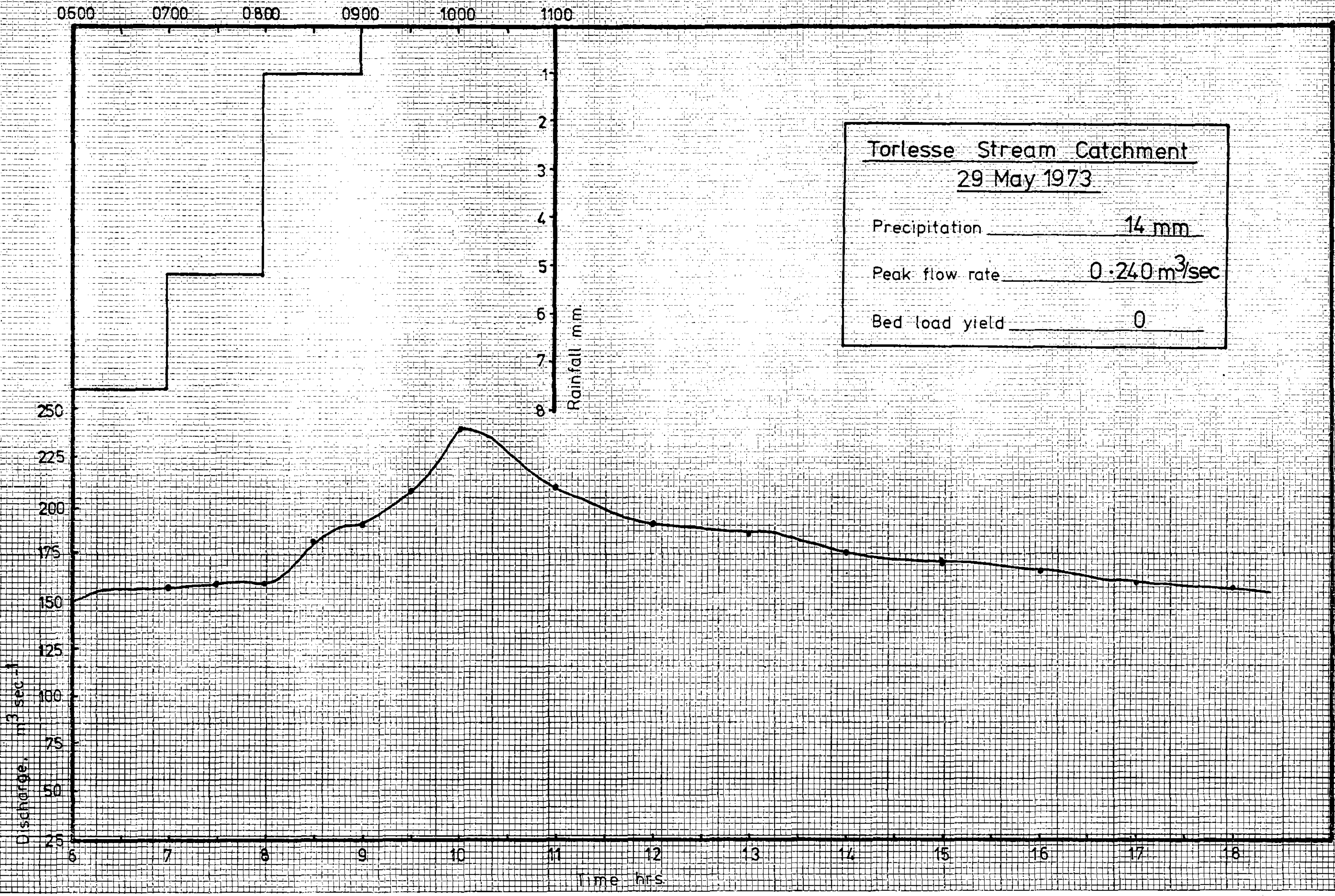
Precipitation 36·6 mm

Peak flow rate 0·180 m^3/sec

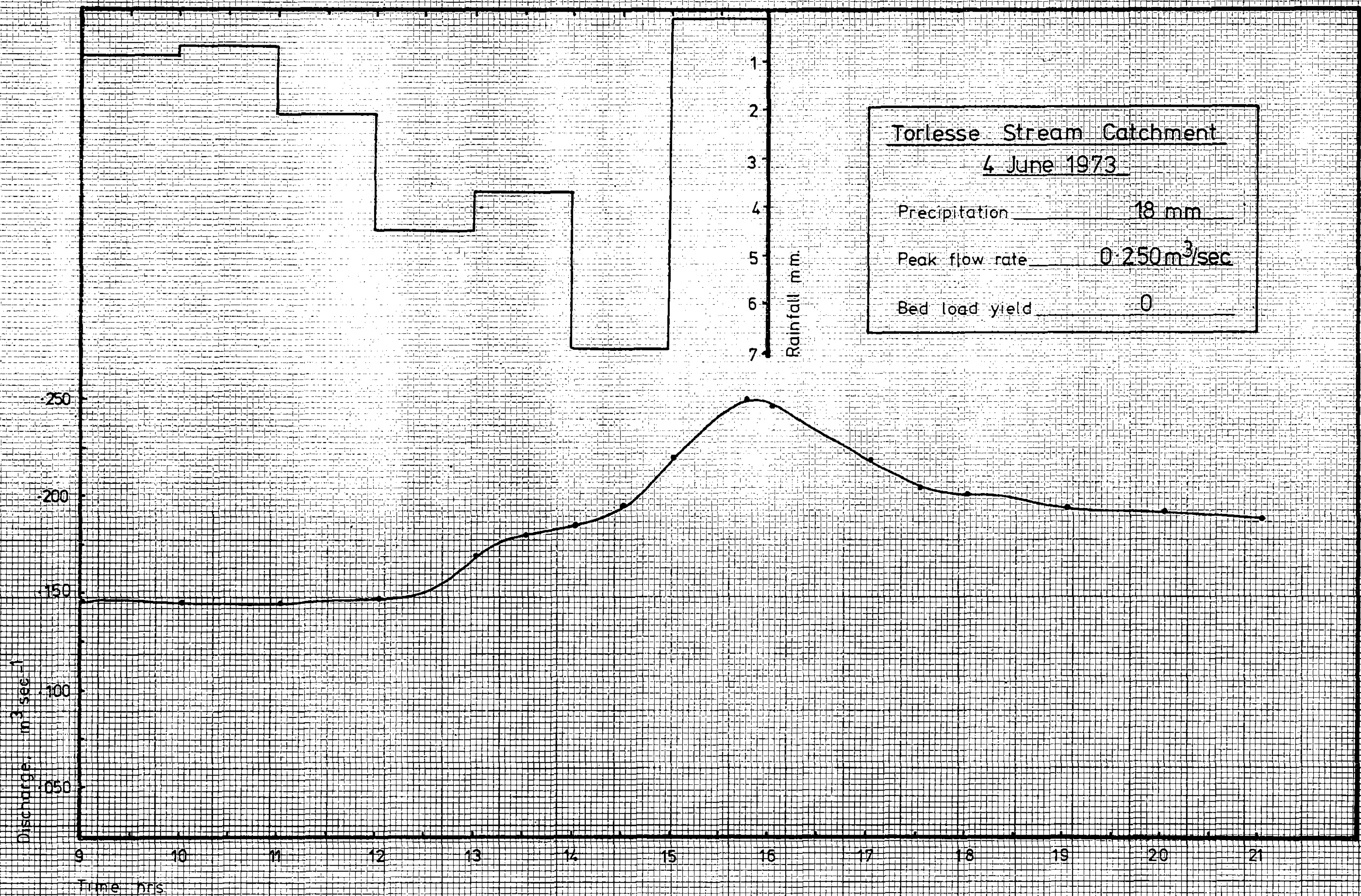
Bed load yield 0



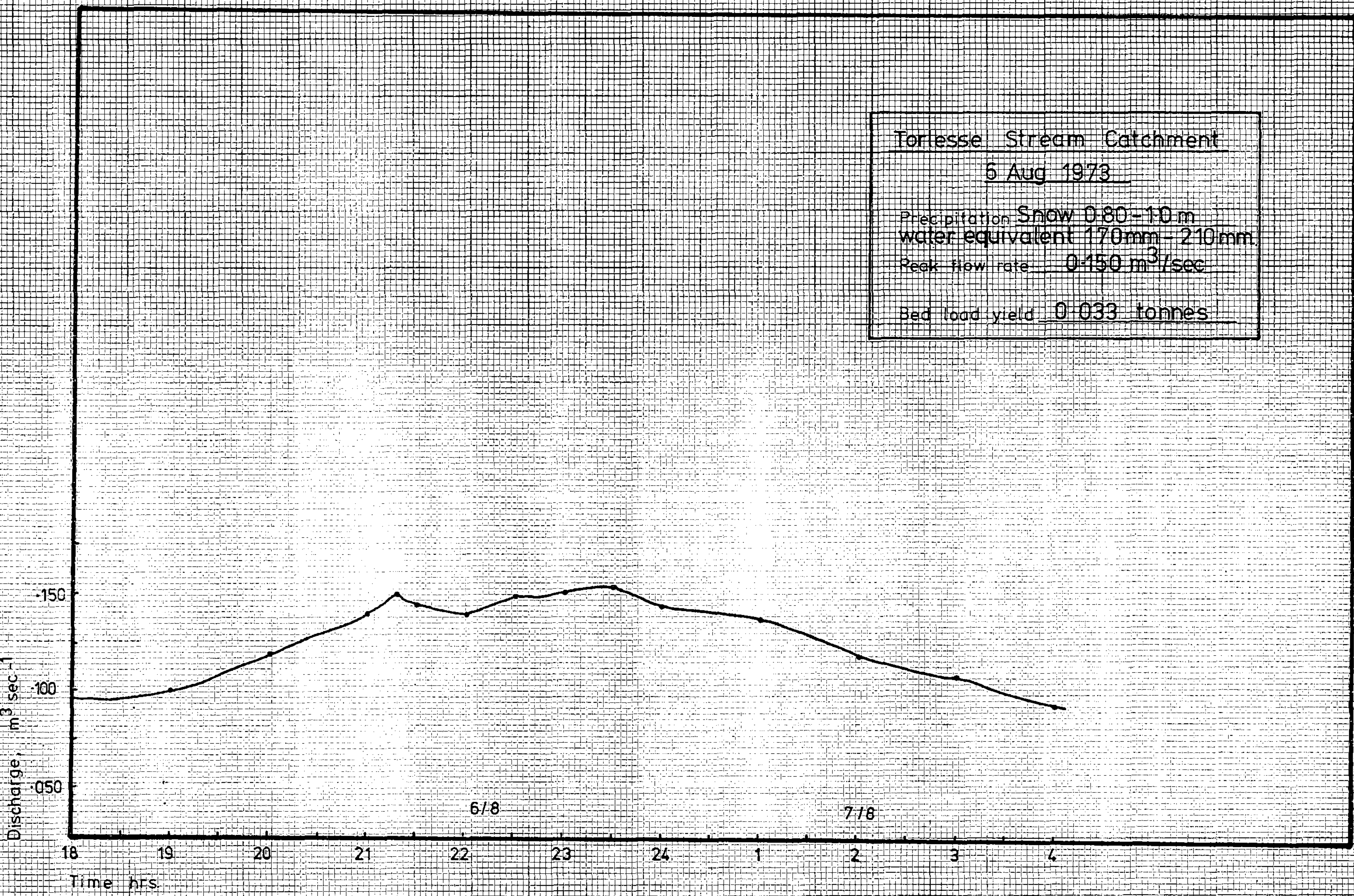
0800
0900
1000
1100
1200
Rainfall mm.
0
1
2
3
4
Torlesse Stream Catchment
9 May 1973
Precipitation 7·5 mm
Peak flow rate 0·180 m3/sec
Bed load yield 0
Discharge m3 sec-1
0·20
0·15
0·10
0·05
Time hrs.
1000
1200
1400
1600
1800

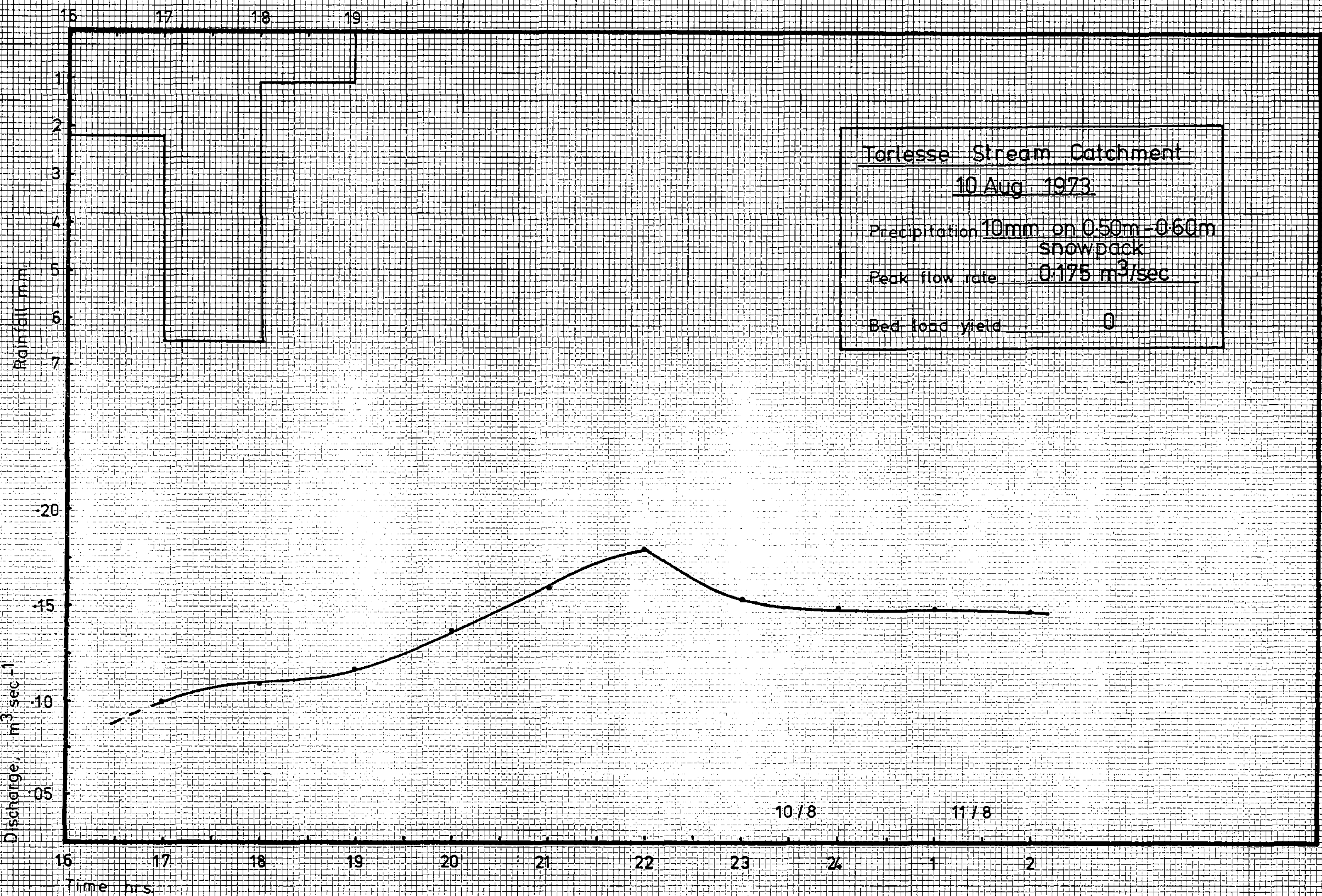


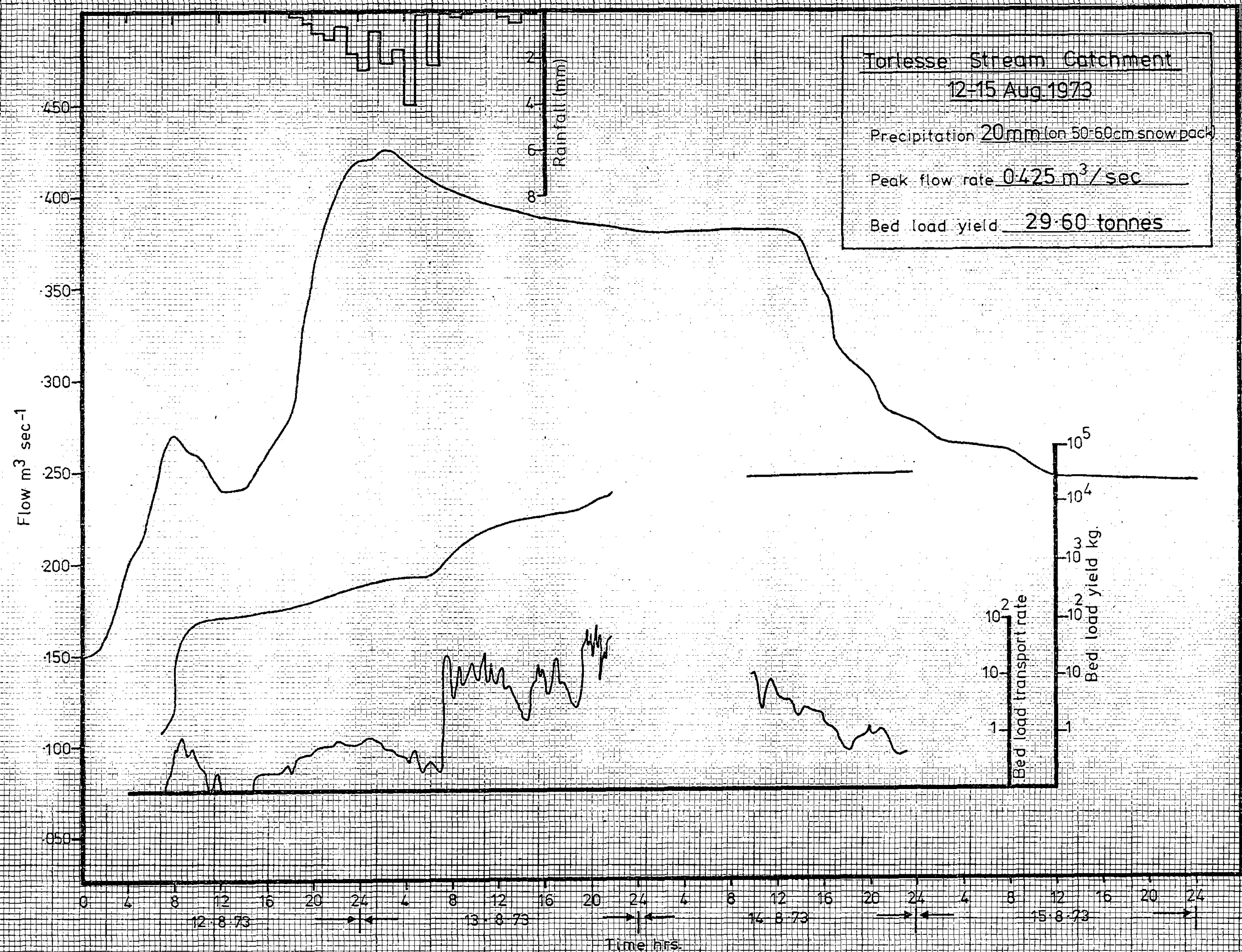
0600
0700
0800
0900
1000
1100
Torlesse Stream Catchment
29 May 1973
Precipitation 14 mm
Peak flow rate 0·240 m³/sec
Bed load yield 0
Rainfall mm
1
2
3
4
5
6
7
8
250
225
200
175
150
125
100
75
50
25
Discharge, m³ sec⁻¹
6
7
8
9
10
11
12
13
14
15
16
17
18
Time hrs



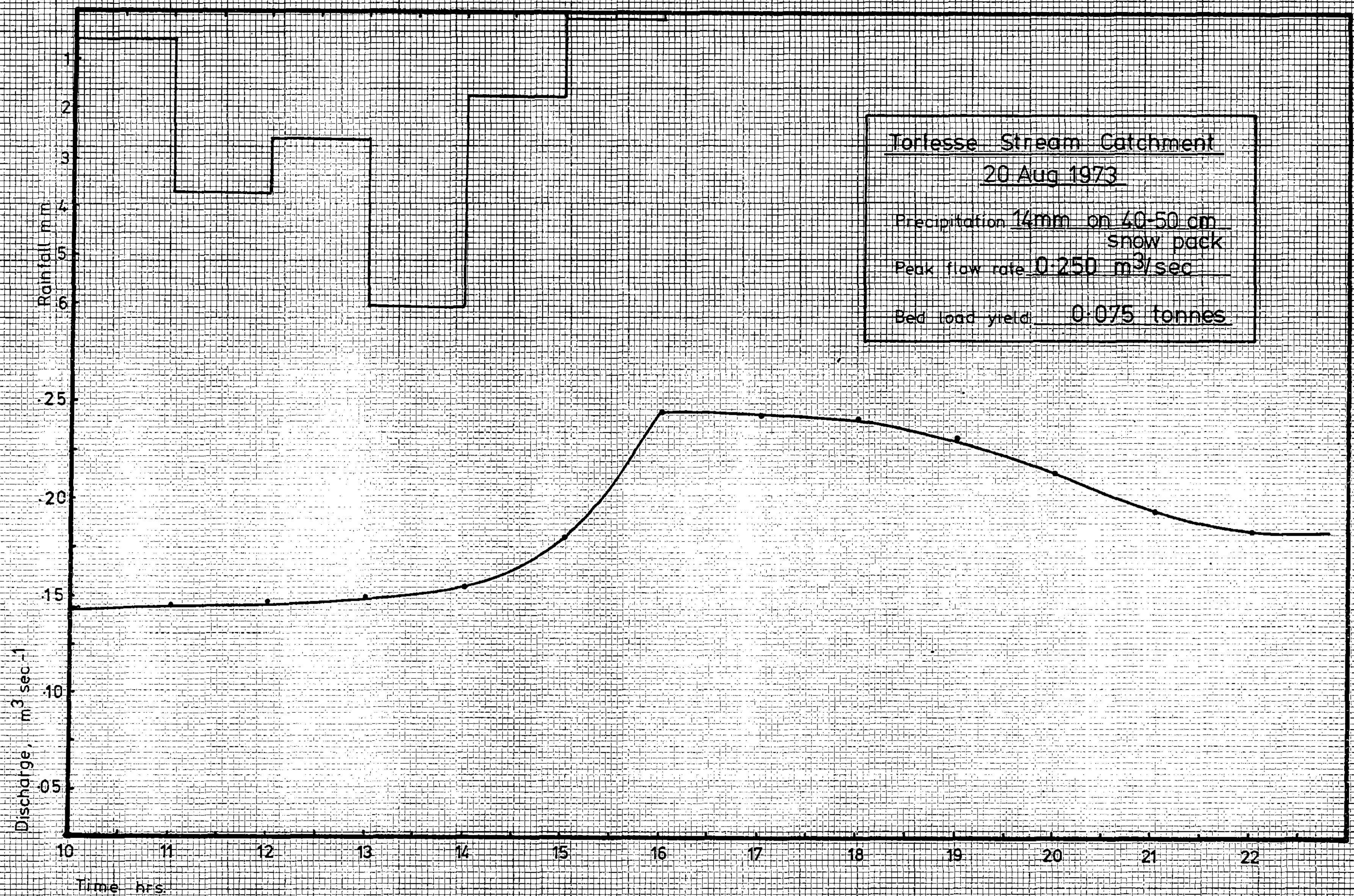
Torlesse Stream Catchment
4 June 1973
Precipitation 18 mm
Peak flow rate 0·250 m3/sec
Bed load yield 0
Rainfall mm
1
2
3
4
5
6
7
Discharge m3 sec-1
·250
·200
·150
·100
·050
9
10
11
12
13
14
15
16
17
18
19
20
21
Time hrs


Torlesse Stream Catchment
6 Aug 1973
Precipitation Snow 0·80-1·0 m
water equivalent 170mm - 210mm
Peak flow rate 0·150 m3/sec
Bed load yield 0·033 tonnes
Discharge, m3 sec-1
·150
·100
·050
6/8
7/8
18
19
20
21
22
23
24
1
2
3
4
Time hrs

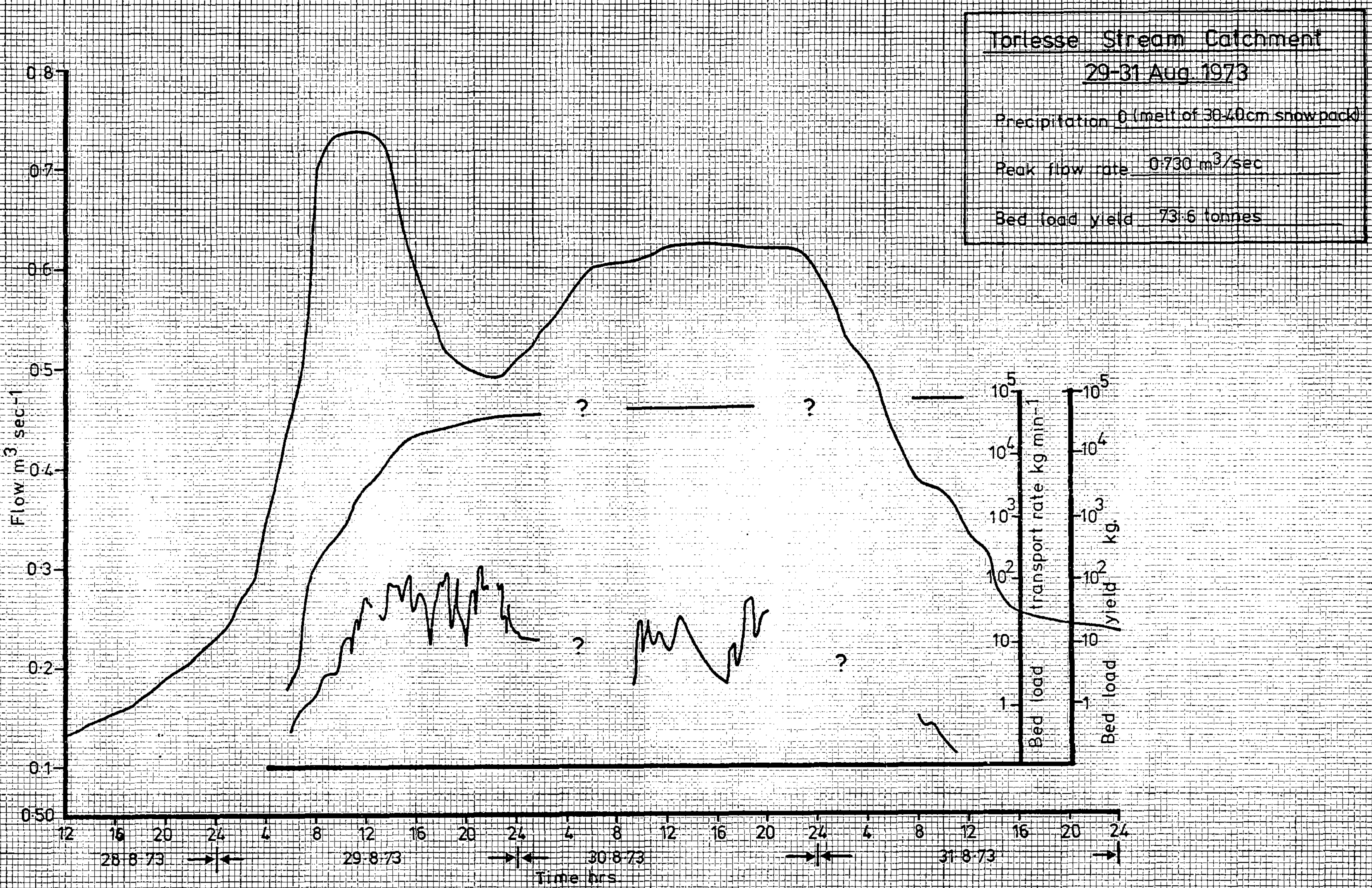

Tarlesse Stream Catchment
10 Aug 1973
Precipitation 10mm on 0·50m - 0·60m snowpack
Peak flow rate 0·175 m³/sec
Bed load yield 0
Rainfall mm.
Discharge, m³ sec -1
Time hrs.
10 / 8
11 / 8
16
17
18
19
20
21
22
23
24
1
2
·05
·10
·15
·20
1
2
3
4
5
6
7



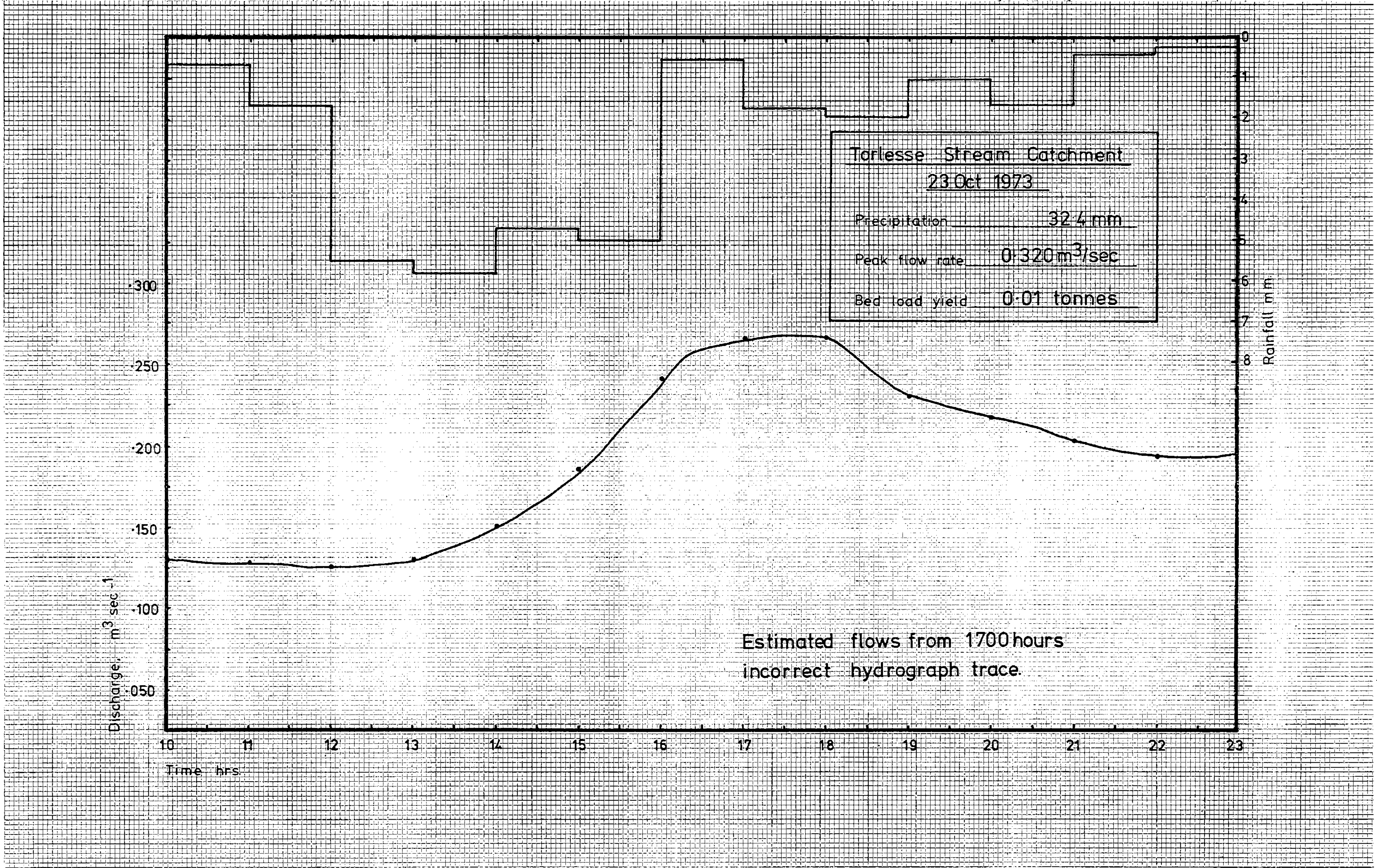
Torlesse Stream Catchment
12-15 Aug. 1973
Precipitation 20mm (on 50-60cm snow pack)
Peak flow rate 0·425 m³/sec
Bed load yield 29·60 tonnes
Rainfall (mm)
Flow m³ sec-1
Bed load transport rate
Bed load yield kg.
12·8·73
13·8·73
14·8·73
15·8·73
Time hrs.



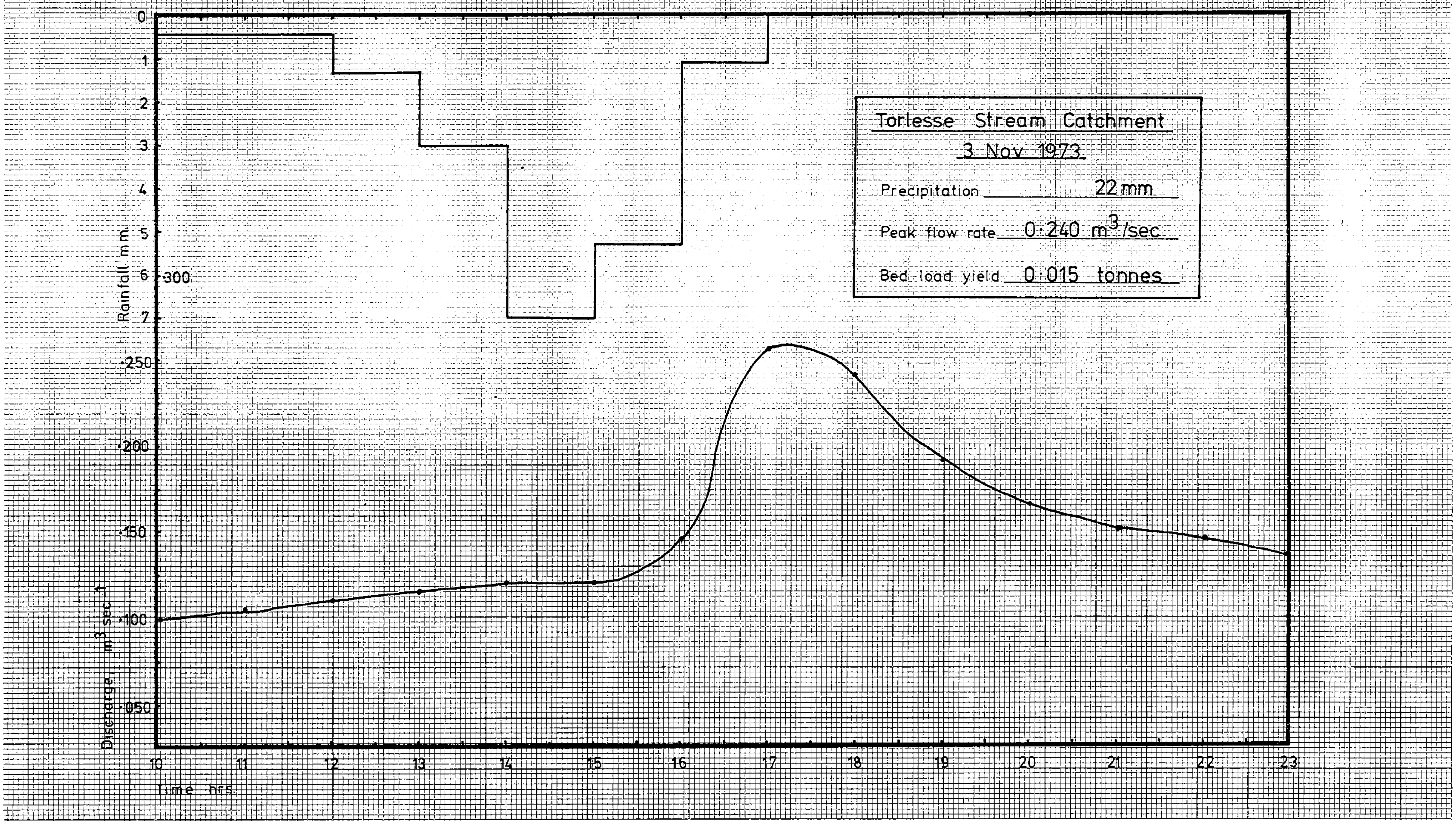
Torlesse Stream Catchment
20 Aug 1973
Precipitation 14mm on 40-50 cm snow pack
Peak flow rate 0·250 m3/sec
Bed load yield 0·075 tonnes
Rainfall mm
1
2
3
4
5
6
·25
·20
·15
·10
·05
Discharge, m3 sec-1
10
11
12
13
14
15
16
17
18
19
20
21
22
Time hrs.



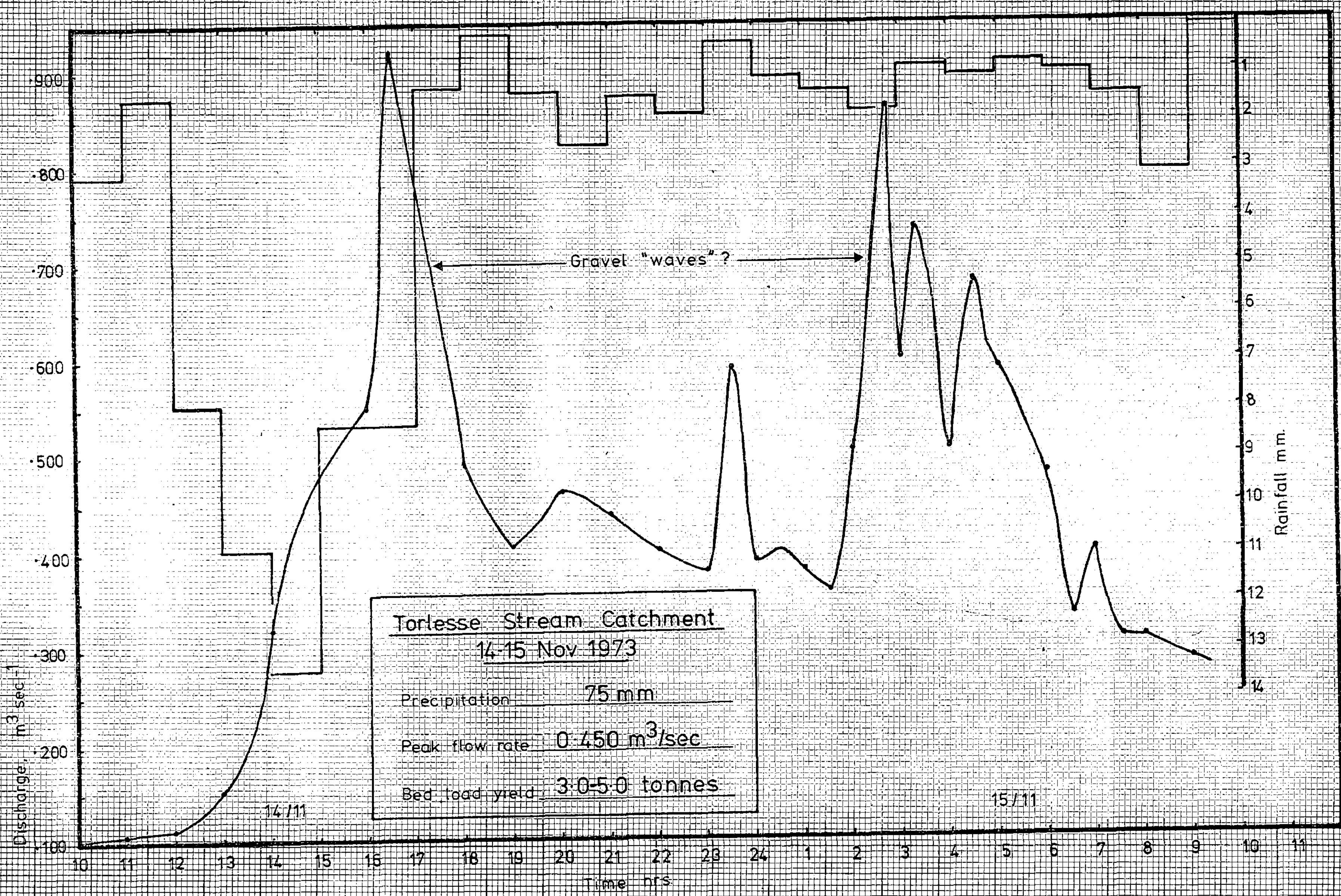
Torlesse Stream Catchment
29-31 Aug. 1973
Precipitation 0 (melt of 30-40cm snowpack)
Peak flow rate 0.730 m3/sec
Bed load yield 73.6 tonnes
Flow m3 sec-1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.50
Bed load transport rate kg min-1
Bed load yield kg.
10^5
10^4
10^3
10^2
10
1
?
12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24
28.8.73
29.8.73
30.8.73
31.8.73
Time hrs



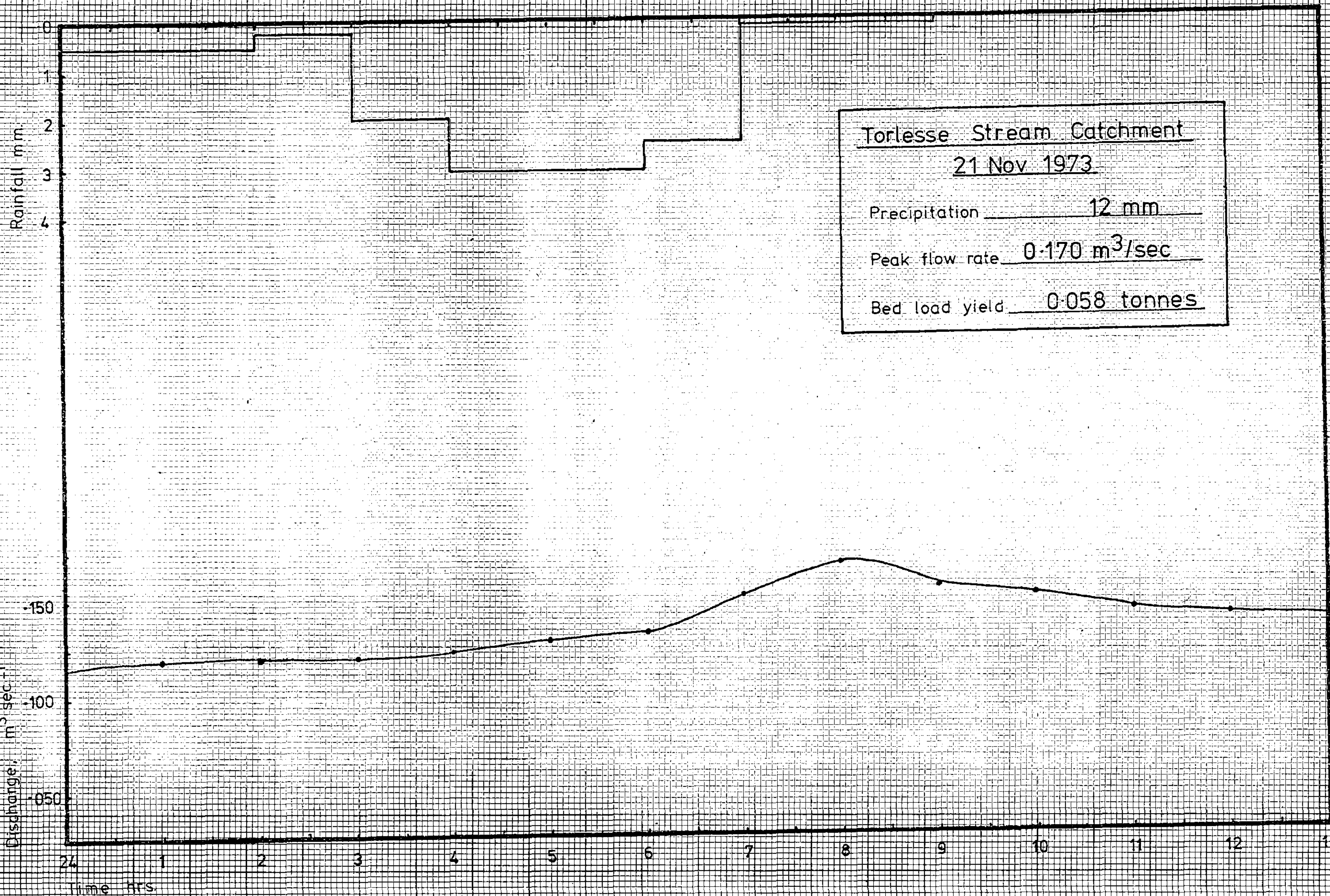
Torlesse Stream Catchment
23 Oct 1973
Precipitation 32·4 mm
Peak flow rate 0·320 m3/sec
Bed load yield 0·01 tonnes
Estimated flows from 1700 hours
incorrect hydrograph trace.
Discharge, m3 sec-1
·300
·250
·200
·150
·100
·050
Rainfall mm
0
1
2
3
4
5
6
7
8
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Time hrs



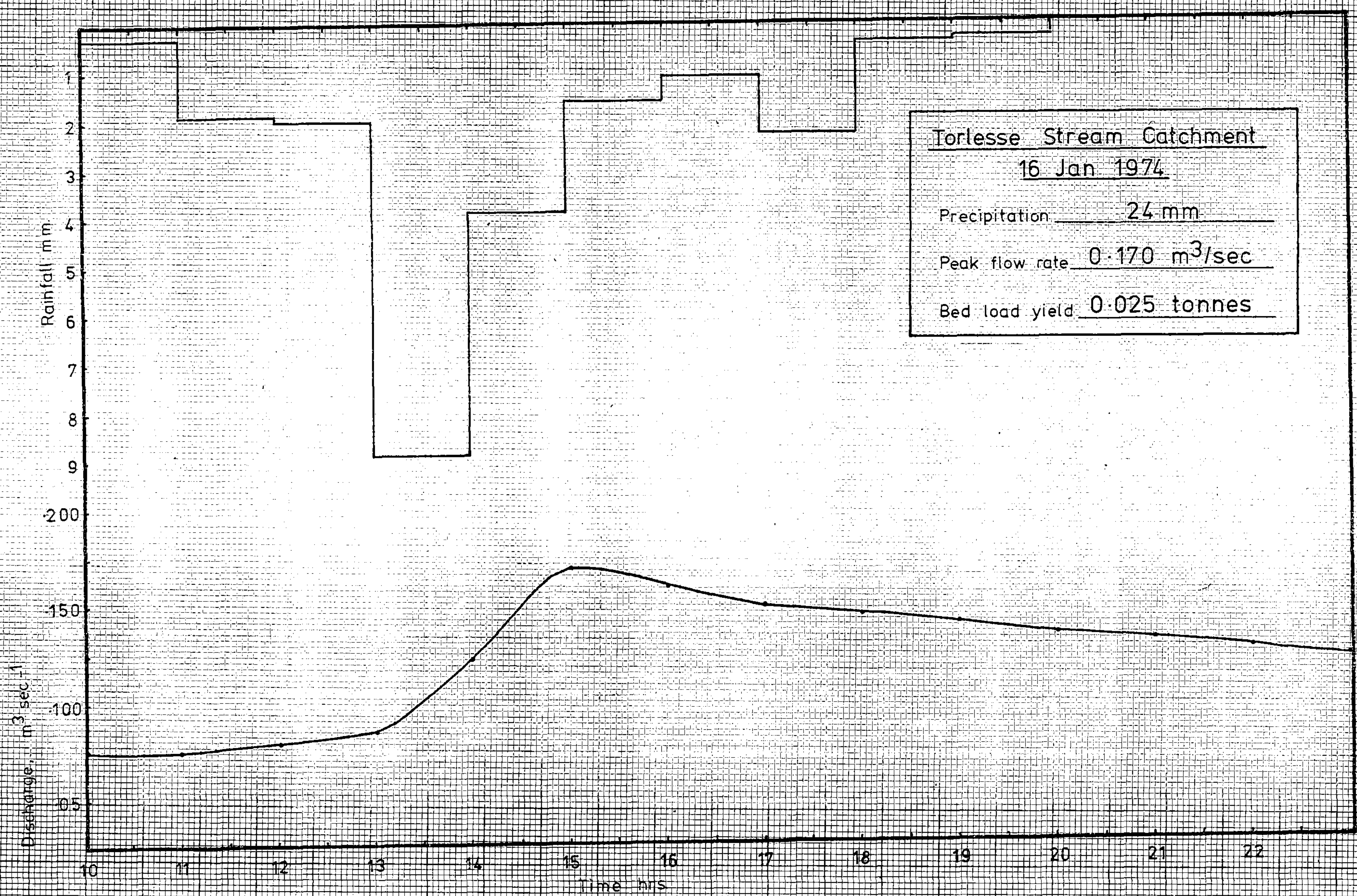
Torlesse Stream Catchment
3 Nov 1973
Precipitation 22 mm
Peak flow rate 0·240 m3/sec
Bed load yield 0·015 tonnes
Rainfall mm.
0
1
2
3
4
5
6
7
·300
·250
·200
·150
·100
·050
Discharge, m3 sec-1
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Time hrs.

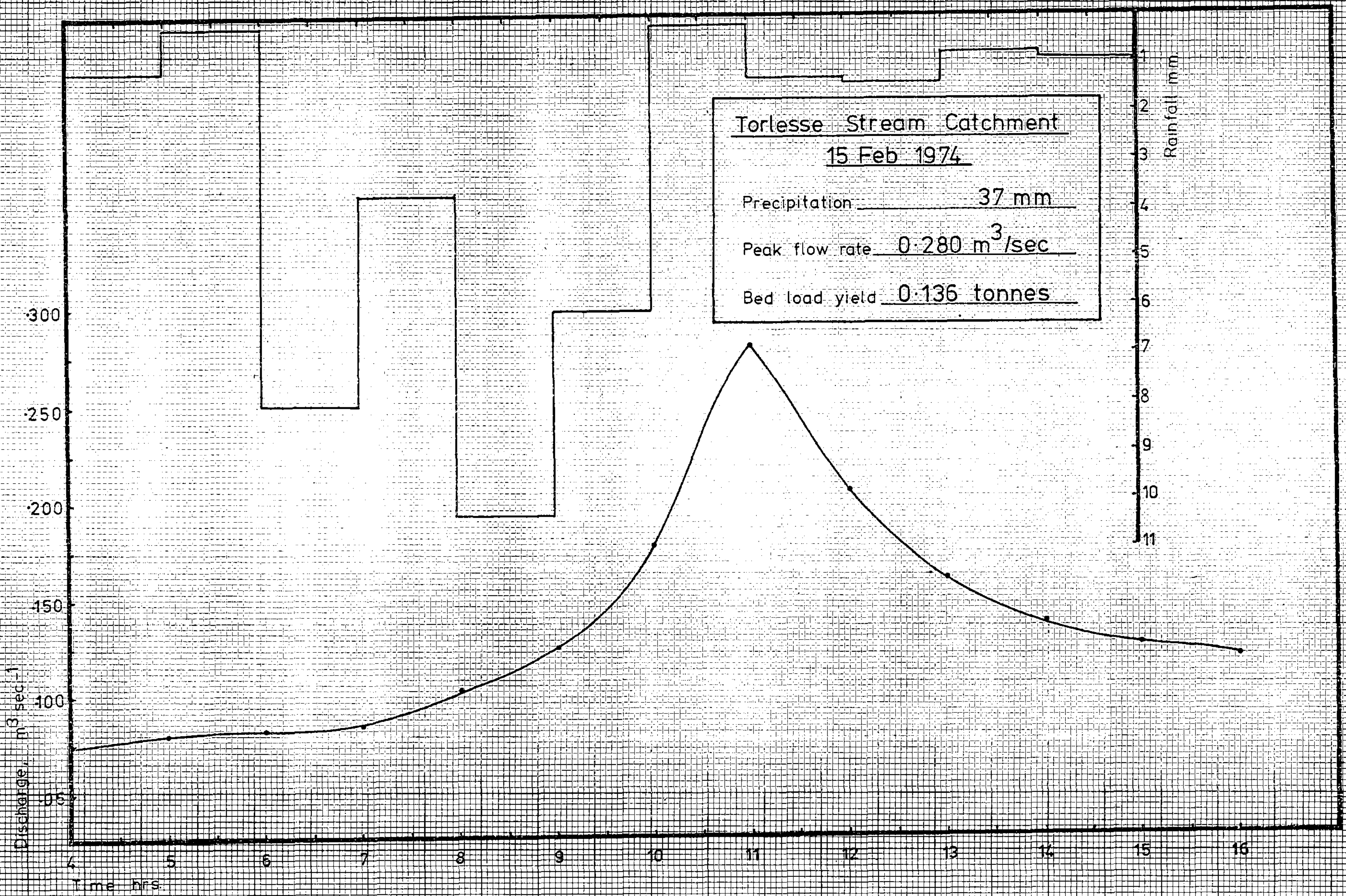


Torlesse Stream Catchment
14-15 Nov 1973
Precipitation 75 mm
Peak flow rate 0·450 m3/sec
Bed load yield 3·0-5·0 tonnes
Gravel "waves"?
Discharge m3 sec-1
Rainfall mm.
Time hrs
14/11
15/11

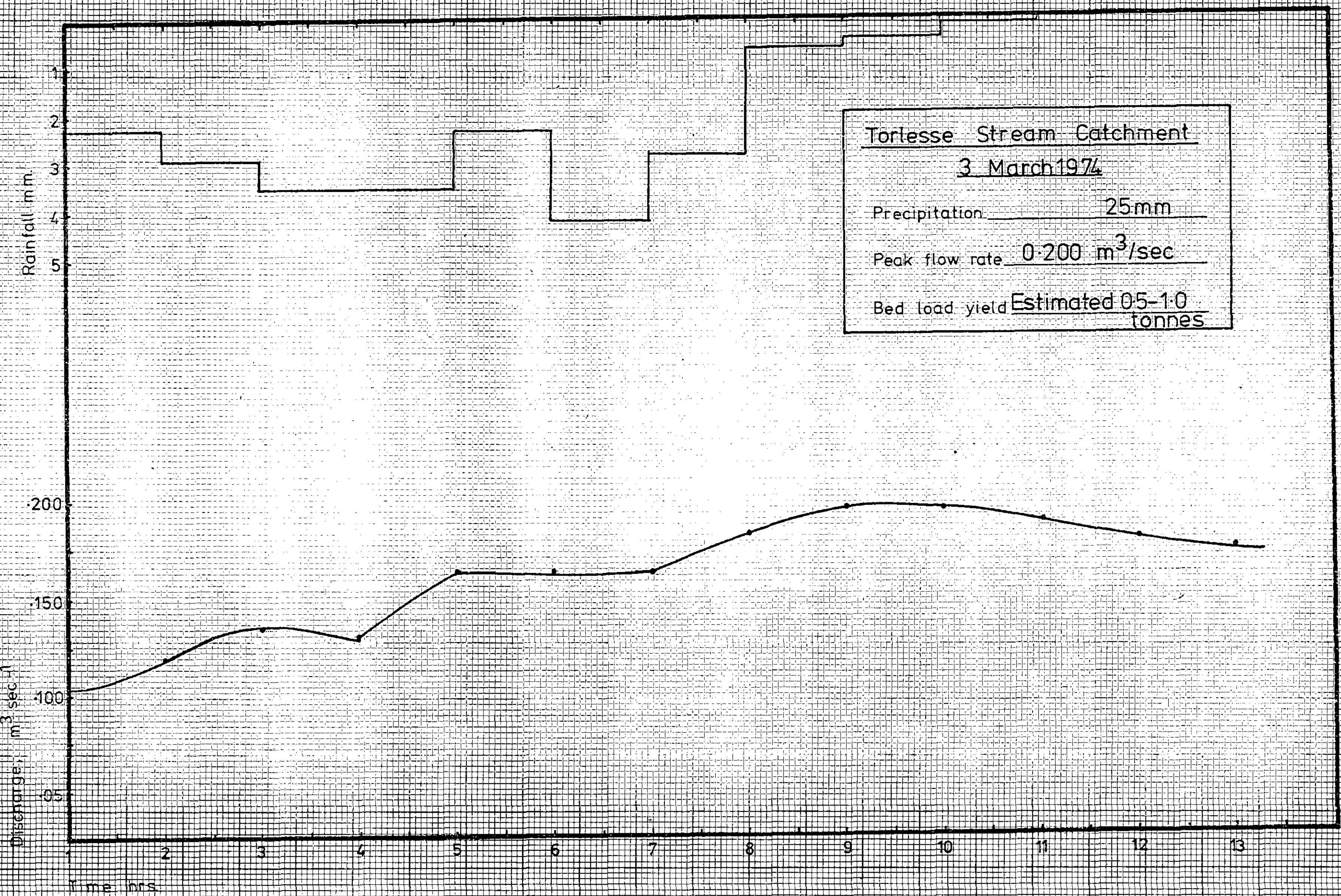


Torlesse Stream Catchment
21 Nov 1973
Precipitation 12 mm
Peak flow rate 0·170 m3/sec
Bed load yield 0·058 tonnes
Rainfall mm
0
1
2
3
4
Discharge, m3 sec-1
·150
·100
·050
24
1
2
3
4
5
6
7
8
9
10
11
12
13
Time hrs.

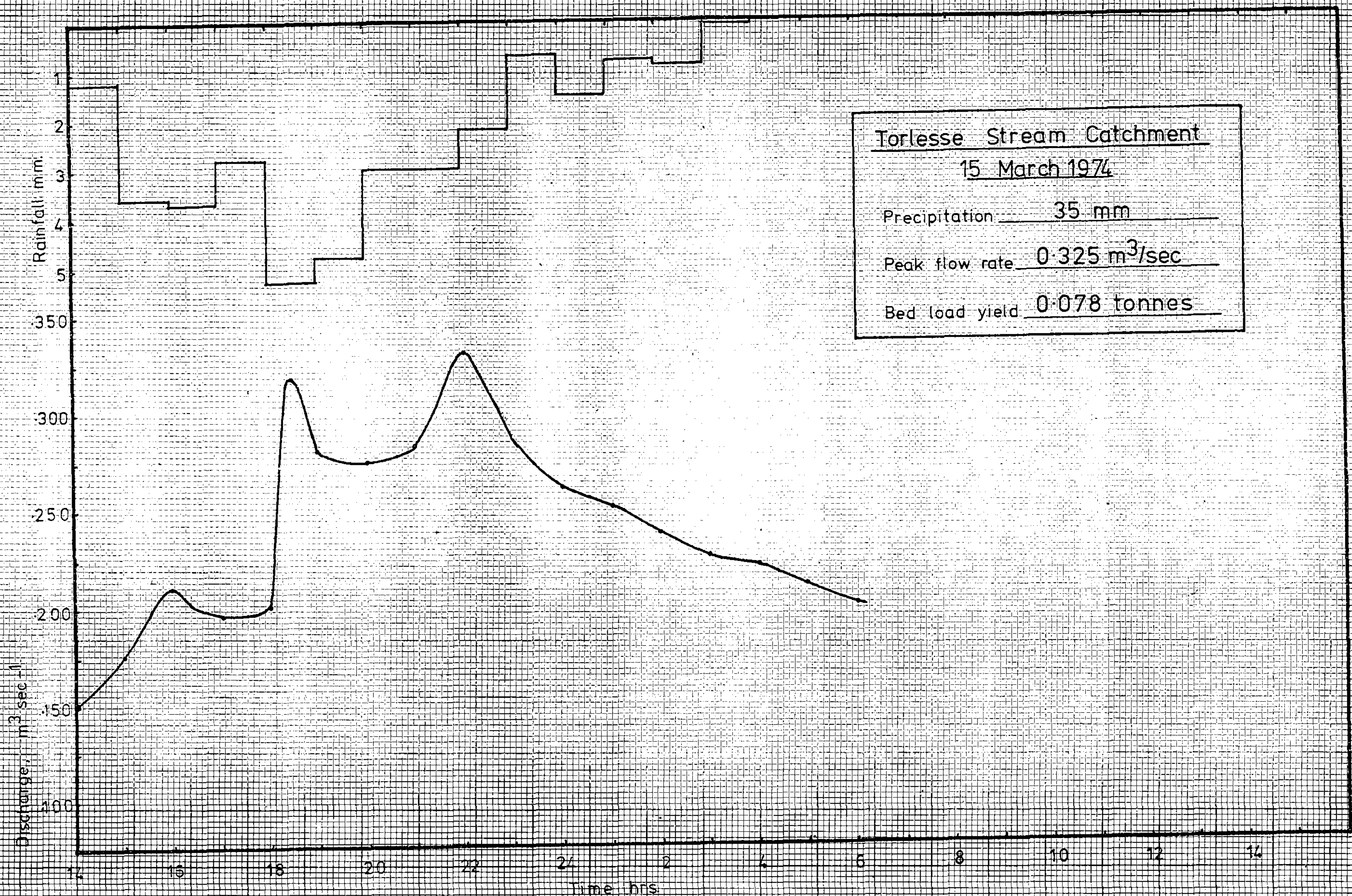

Torlesse Stream Catchment
16 Jan 1974
Precipitation 24 mm
Peak flow rate 0·170 m3/sec
Bed load yield 0·025 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
9
·200
·150
·100
0·5
Discharge, m3 sec-1
10
11
12
13
14
15
16
17
18
19
20
21
22
Time hrs



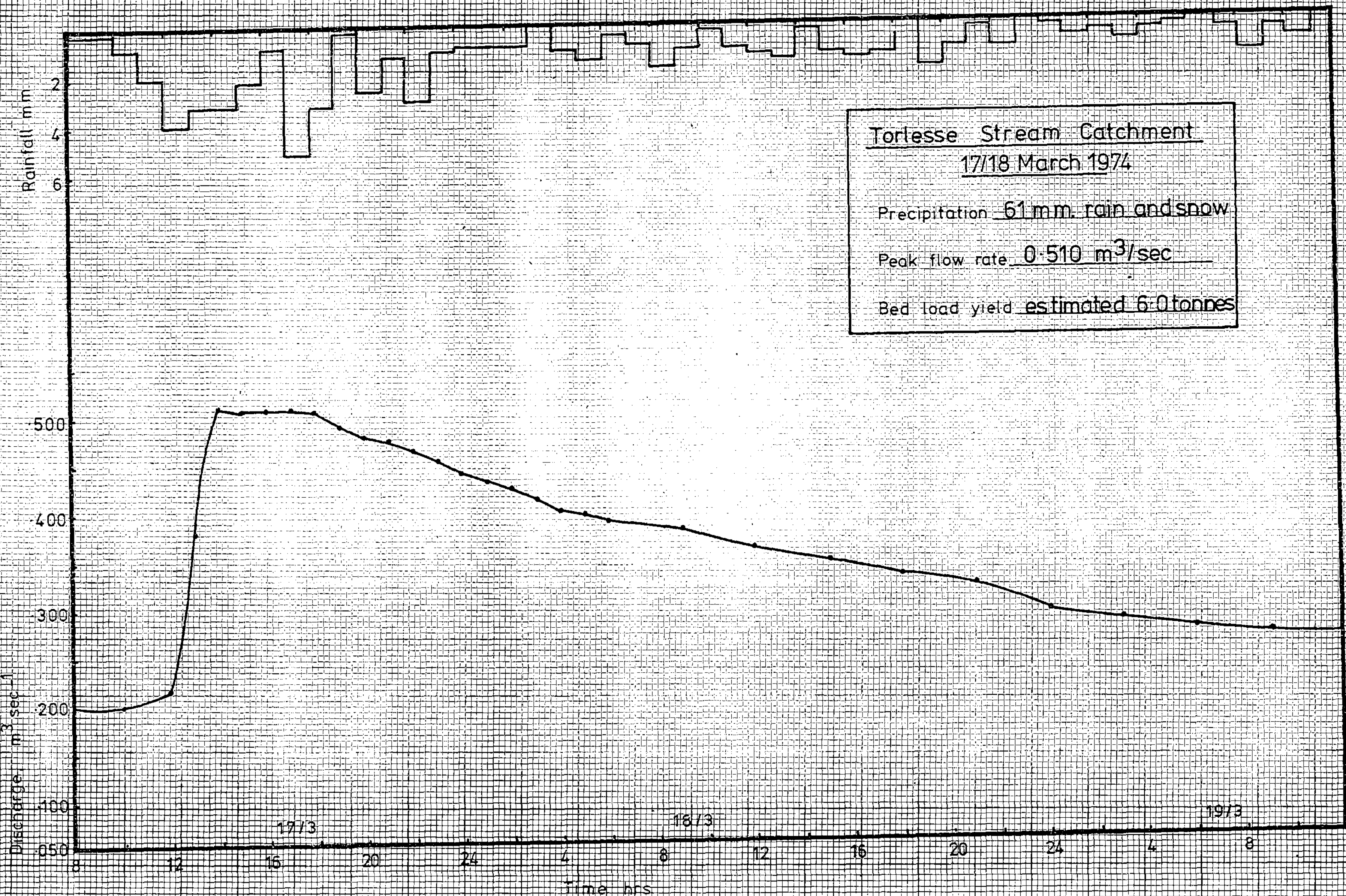
Torlesse Stream Catchment
15 Feb 1974
Precipitation 37 mm
Peak flow rate 0·280 m3/sec
Bed load yield 0·136 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
9
10
11
·300
·250
·200
·150
·100
·050
Discharge, m3 sec-1
4
5
6
7
8
9
10
11
12
13
14
15
16
Time hrs.



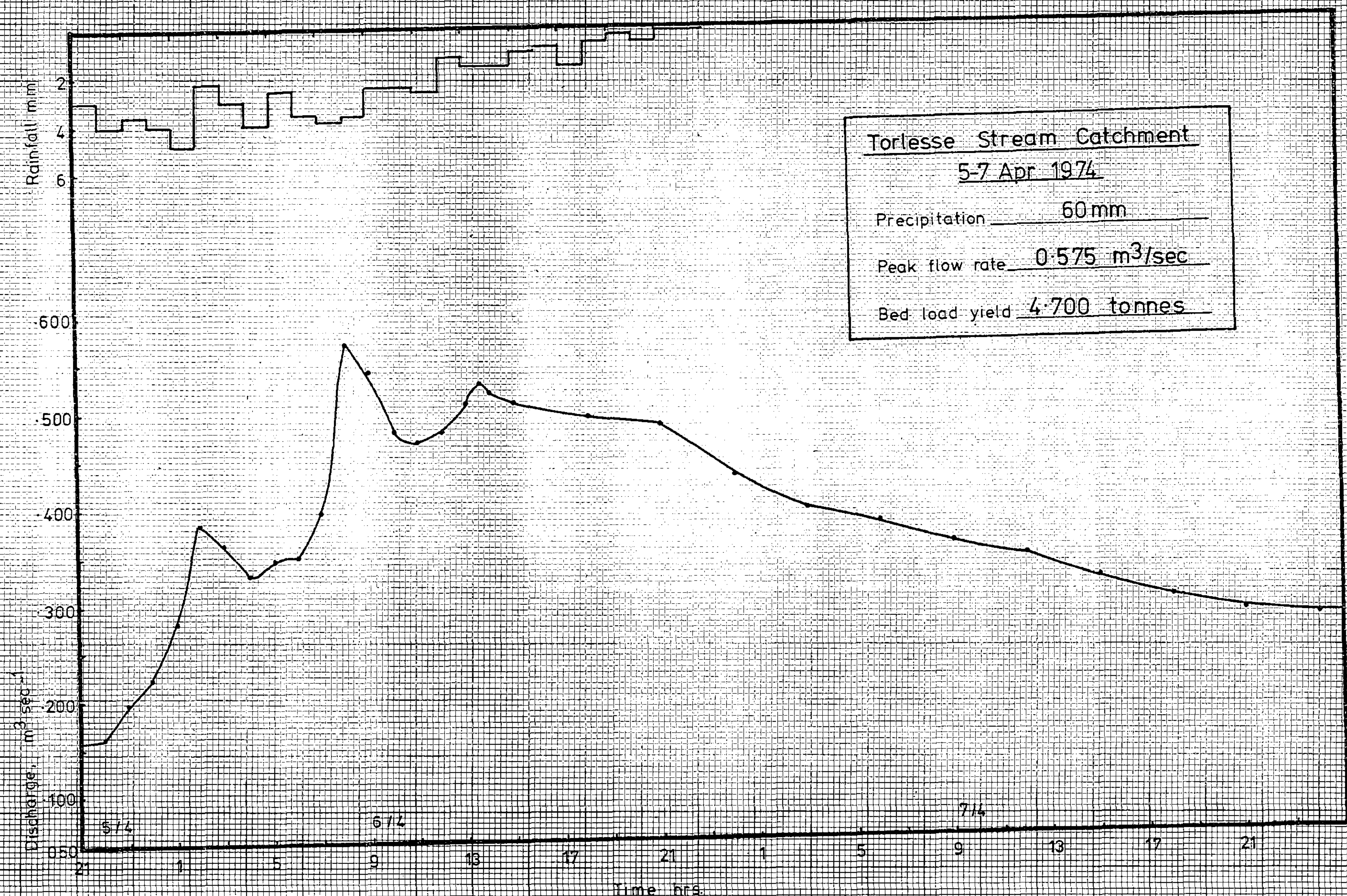
Torlesse Stream Catchment
3 March 1974
Precipitation 25mm
Peak flow rate 0·200 m3/sec
Bed load yield Estimated 0·5–1·0 tonnes
Rainfall mm.
1
2
3
4
5
Discharge, m3 sec-1
·200
·150
·100
·05
1
2
3
4
5
6
7
8
9
10
11
12
13
Time hrs.



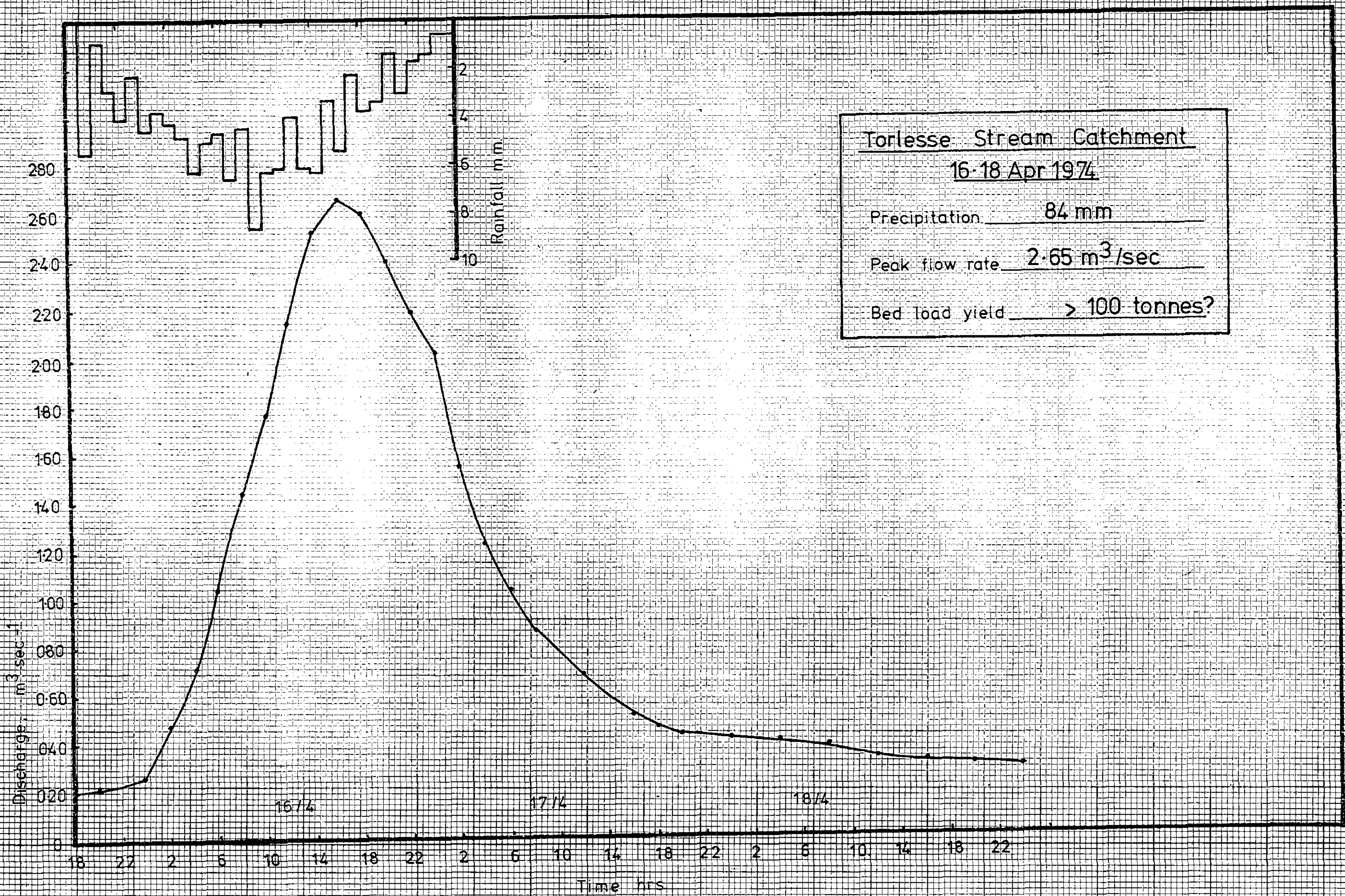
Torlesse Stream Catchment
15 March 1974
Precipitation 35 mm
Peak flow rate 0·325 m3/sec
Bed load yield 0·078 tonnes
Rainfall mm.
1
2
3
4
5
·350
·300
·250
·200
·150
·100
Discharge, m3 sec-1
14
16
18
20
22
24
2
4
6
8
10
12
14
Time hrs



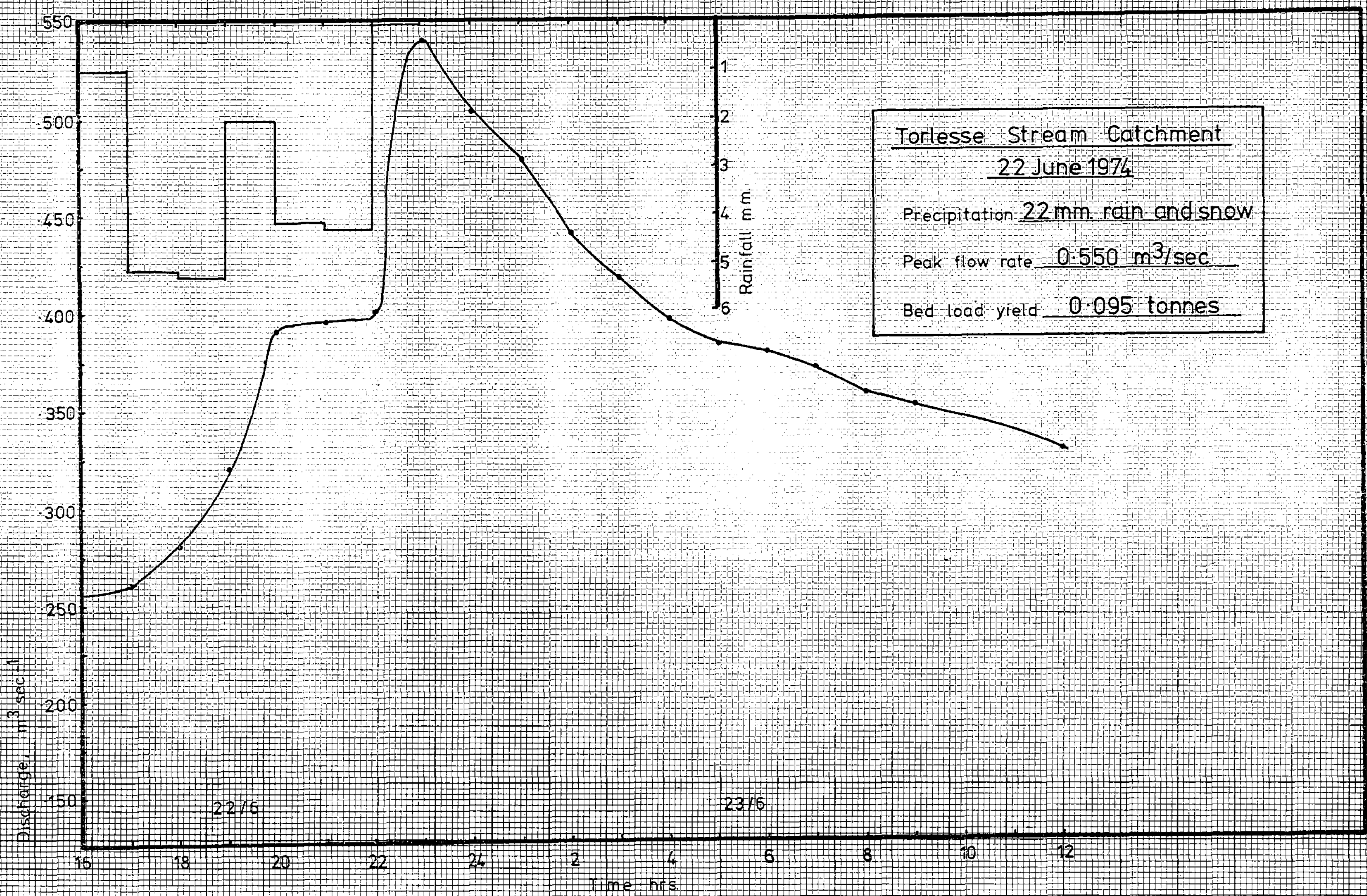
Torlesse Stream Catchment
17/18 March 1974
Precipitation 61 mm. rain and snow
Peak flow rate 0·510 m³/sec
Bed load yield estimated 6·0 tonnes
Rainfall mm
2
4
6
Discharge, m³ sec-1
·500
·400
·300
·200
·100
·050
17/3
18/3
19/3
8
12
16
20
24
4
8
12
16
20
24
4
8
Time hrs

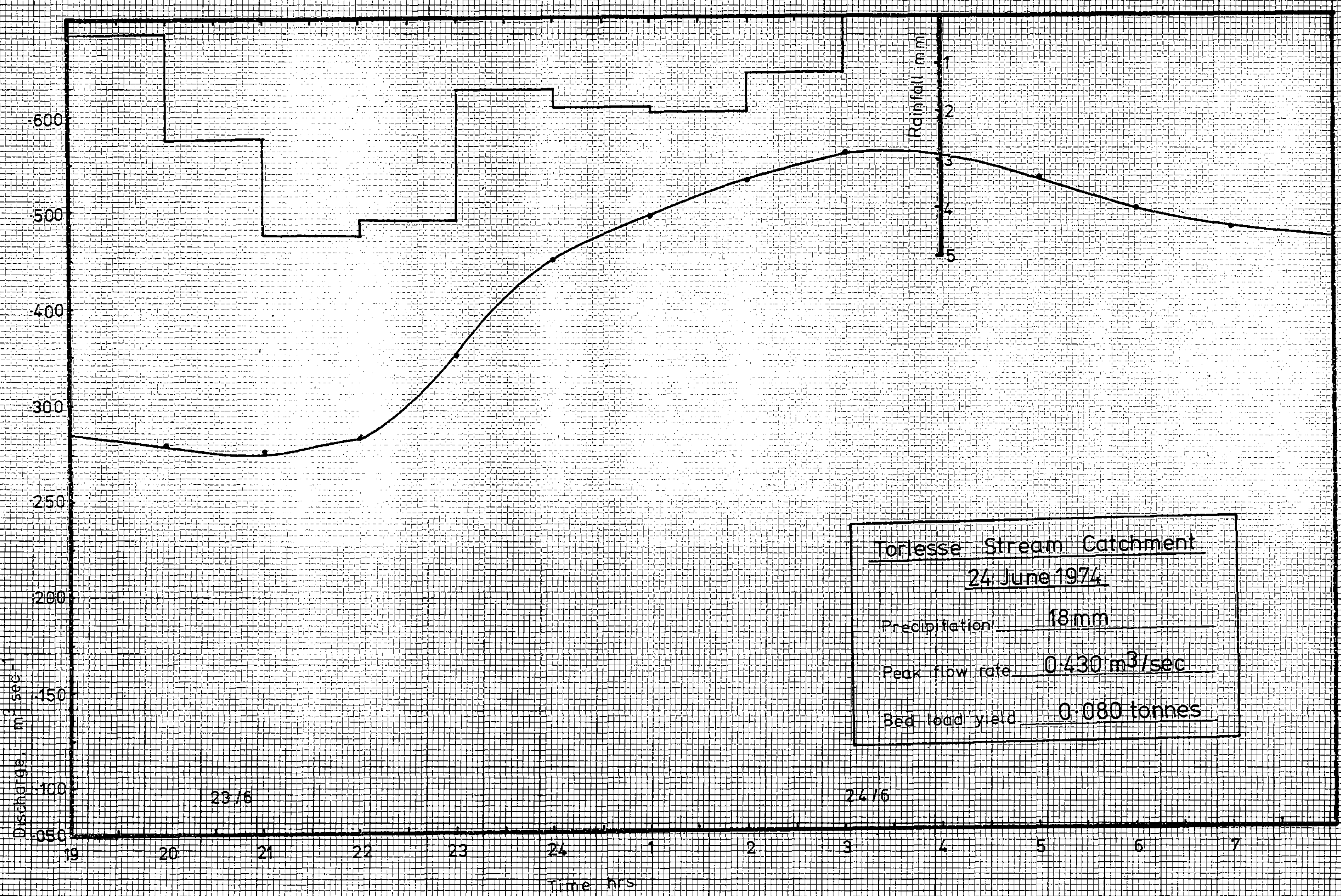


Torlesse Stream Catchment
5-7 Apr 1974
Precipitation 60 mm
Peak flow rate 0·575 m3/sec
Bed load yield 4·700 tonnes
Rainfall mm
2
4
6
Discharge, m3 sec-1
·600
·500
·400
·300
·200
·100
·050
5/4
6/4
7/4
21
1
5
9
13
17
21
1
5
9
13
17
21
Time hrs.

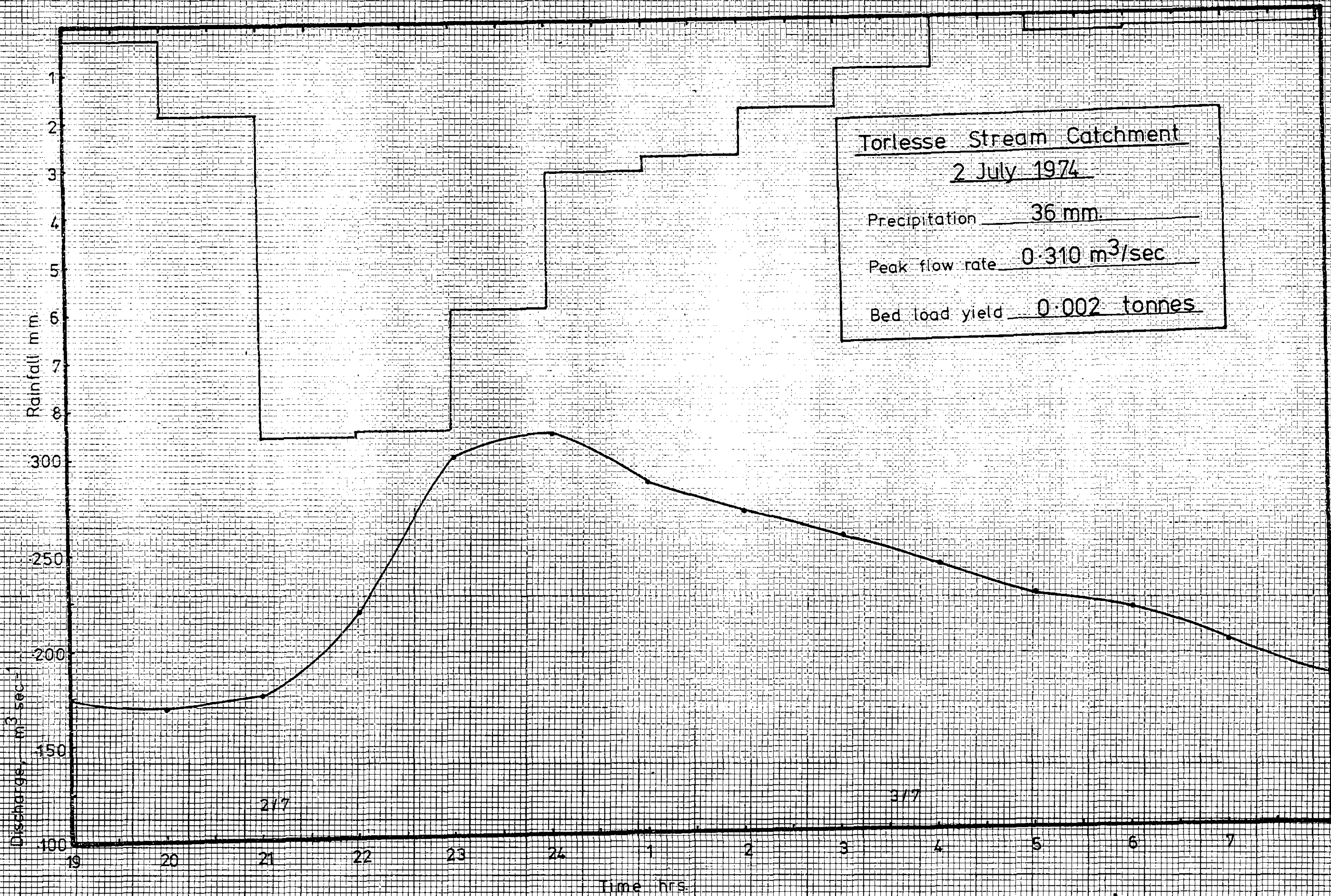


Torlesse Stream Catchment
16-18 Apr 1974
Precipitation 84 mm
Peak flow rate 2·65 m3/sec
Bed load yield > 100 tonnes?
Rainfall mm
2
4
6
8
10
Discharge, m3 sec-1
2·80
2·60
2·40
2·20
2·00
1·80
1·60
1·40
1·20
1·00
0·80
0·60
0·40
0·20
0
16/4
17/4
18/4
18 22 2 6 10 14 18 22 2 6 10 14 18 22 2 6 10 14 18 22
Time hrs

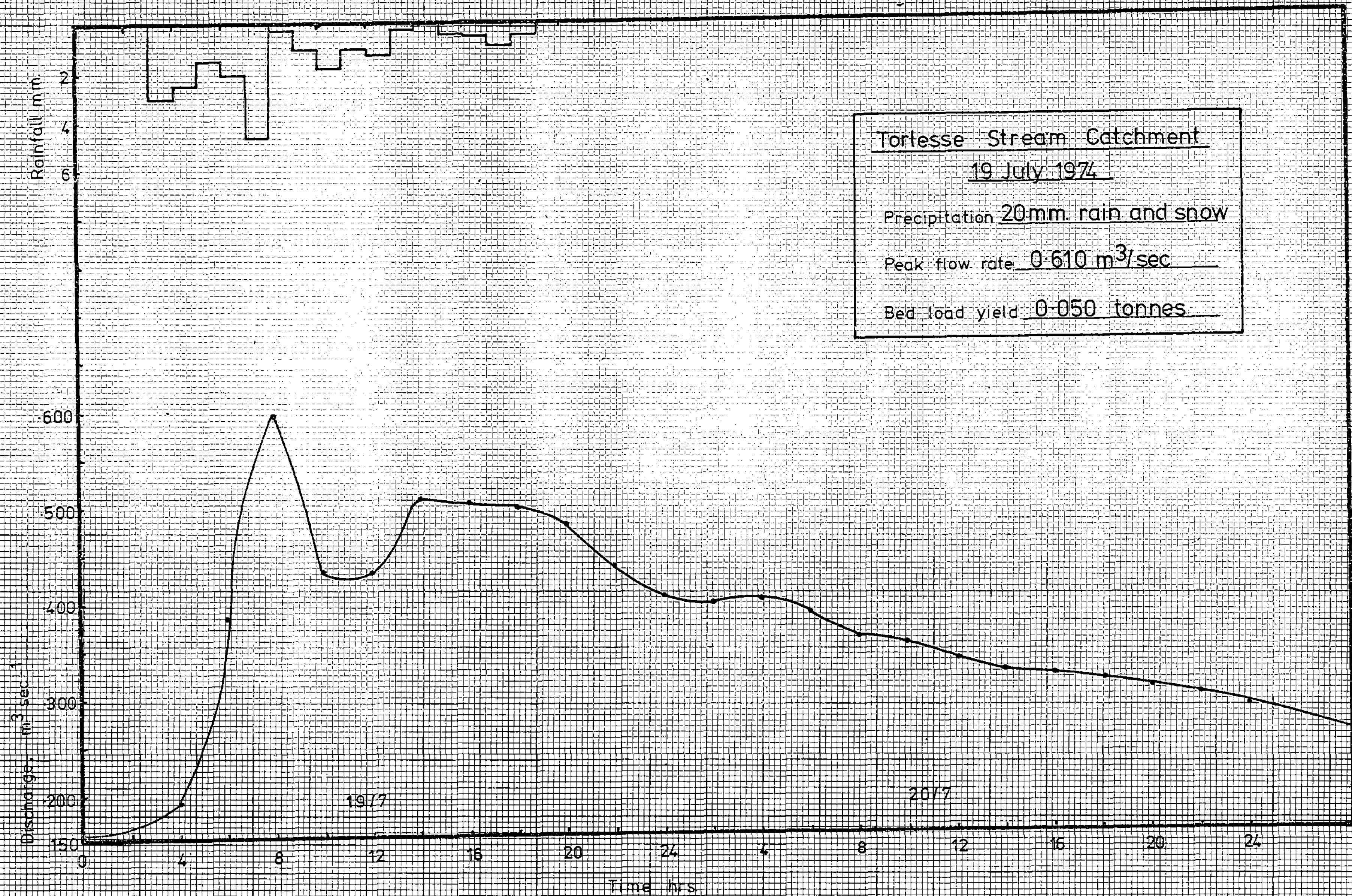

Torlesse Stream Catchment
22 June 1974
Precipitation 22 mm. rain and snow
Peak flow rate 0·550 m3/sec
Bed load yield 0·095 tonnes
Rainfall mm.
1
2
3
4
5
6
Discharge, m3 sec-1
550
500
450
400
350
300
250
200
150
22/6
23/6
16
18
20
22
24
2
4
6
8
10
12
Time hrs.



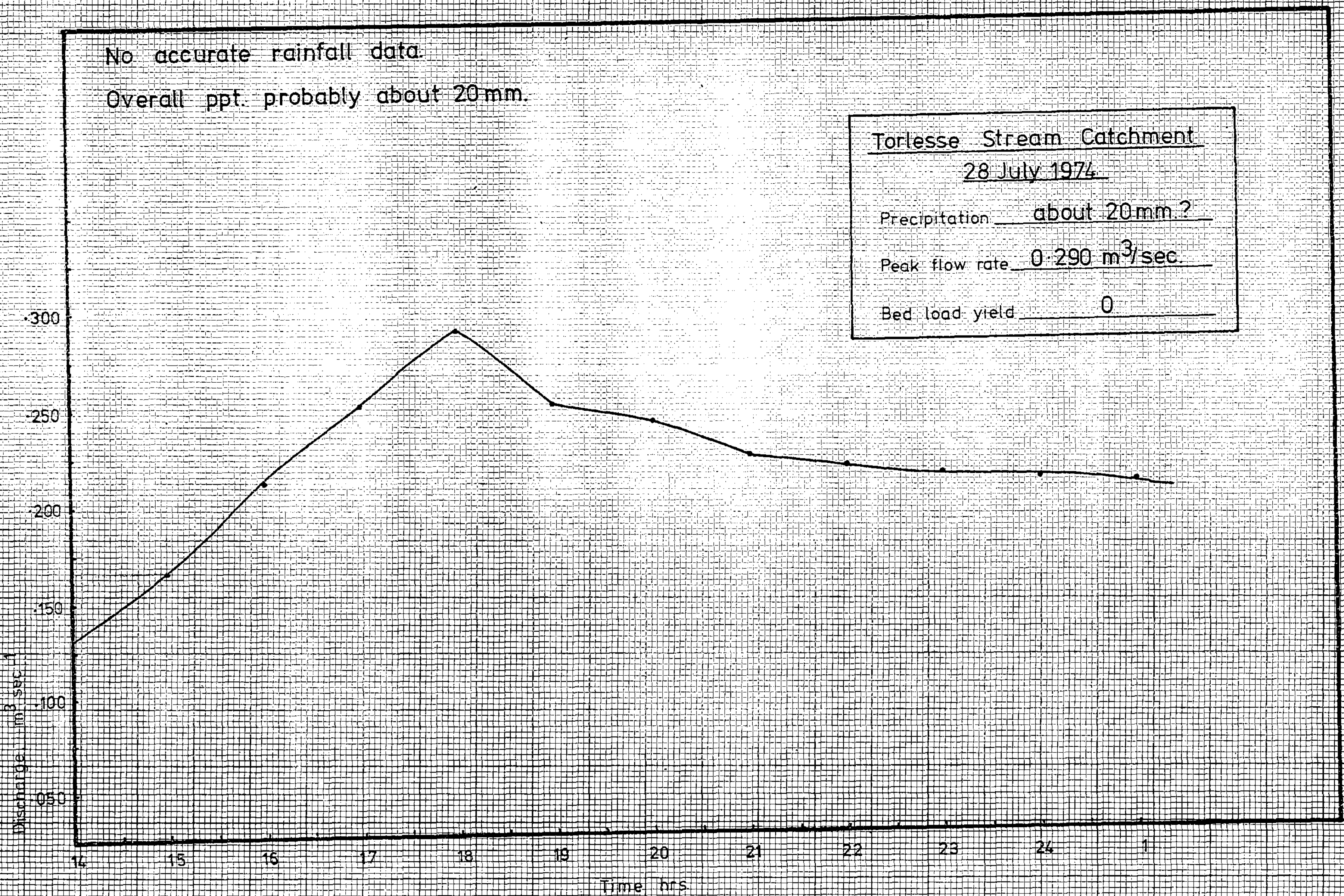
Torlesse Stream Catchment
24 June 1974
Precipitation 18 mm
Peak flow rate 0·430 m3/sec
Bed load yield 0·080 tonnes
Rainfall mm
1
2
3
4
5
Discharge, m3 sec-1
·600
·500
·400
·300
·250
·200
·150
·100
·050
23/6
24/6
19
20
21
22
23
24
1
2
3
4
5
6
7
Time hrs



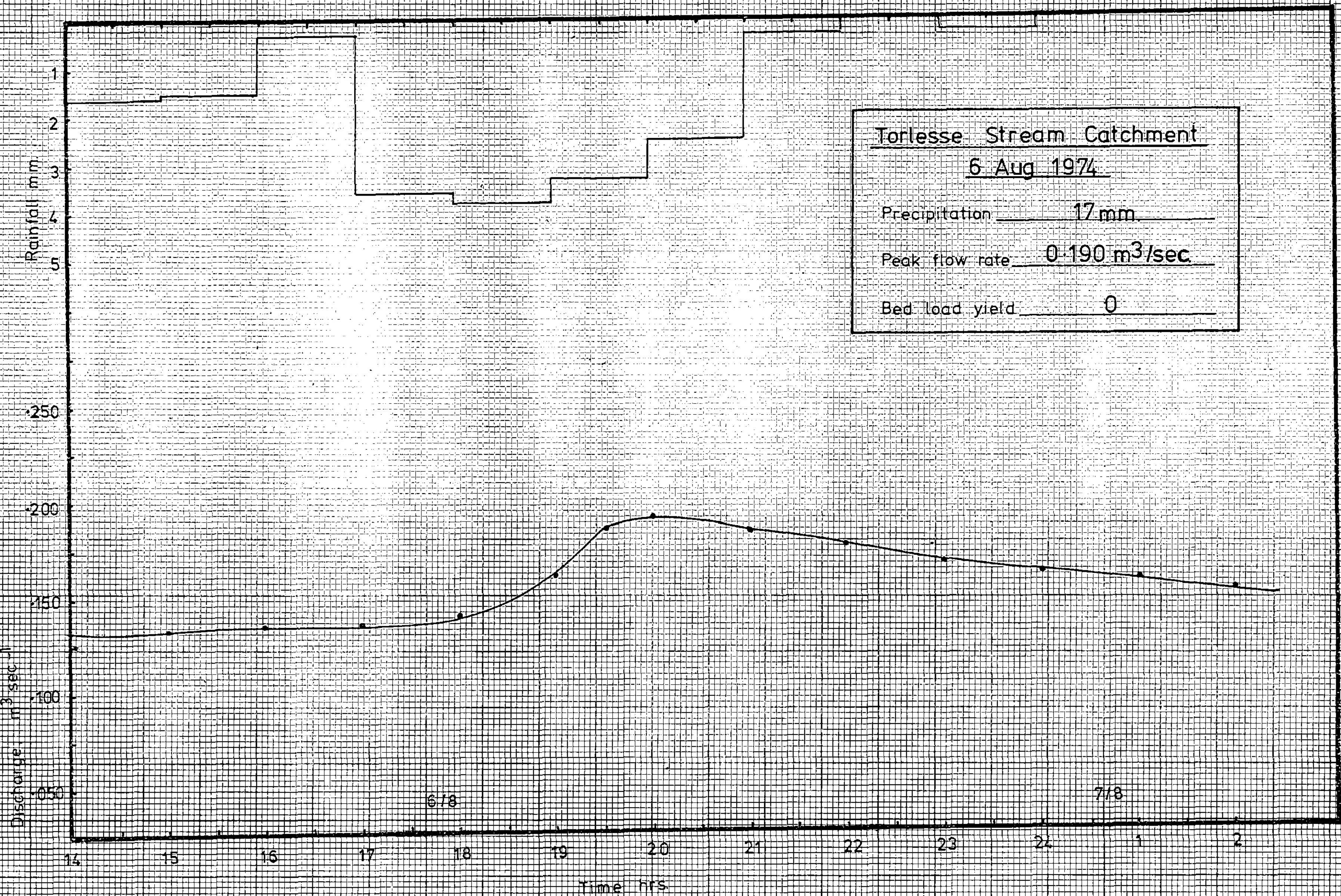
Torlesse Stream Catchment
2 July 1974
Precipitation 36 mm.
Peak flow rate 0·310 m3/sec
Bed load yield 0·002 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
Discharge, m3 sec-1
300
250
200
150
100
19
20
21
22
23
24
1
2
3
4
5
6
7
2/7
3/7
Time hrs.



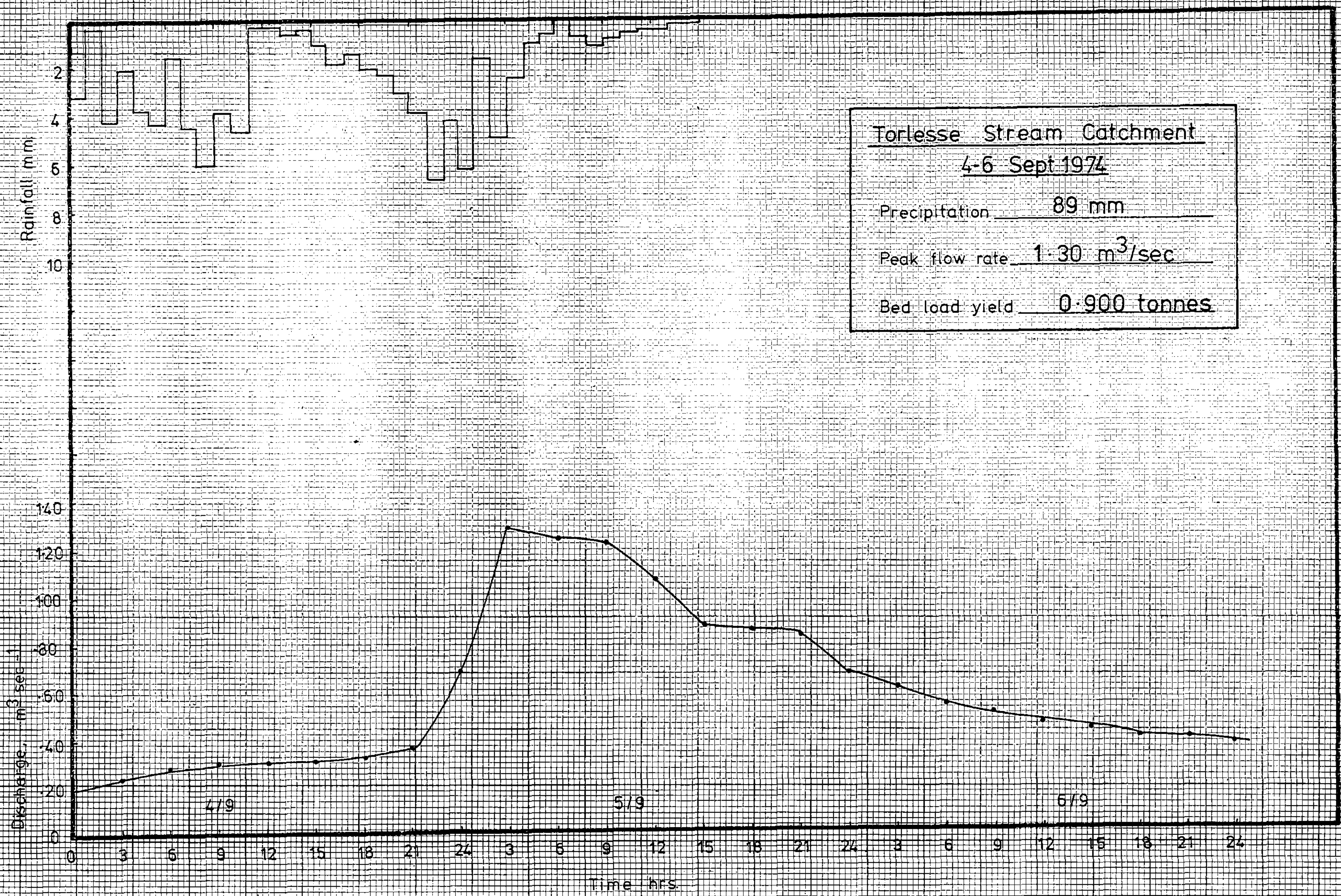
Torlesse Stream Catchment
19 July 1974
Precipitation 20mm. rain and snow
Peak flow rate 0·610 m3/sec
Bed load yield 0·050 tonnes
Rainfall mm
2
4
6
Discharge m3 sec-1
600
500
400
300
200
150
0
4
8
12
16
20
24
4
8
12
16
20
24
19/7
20/7
Time hrs

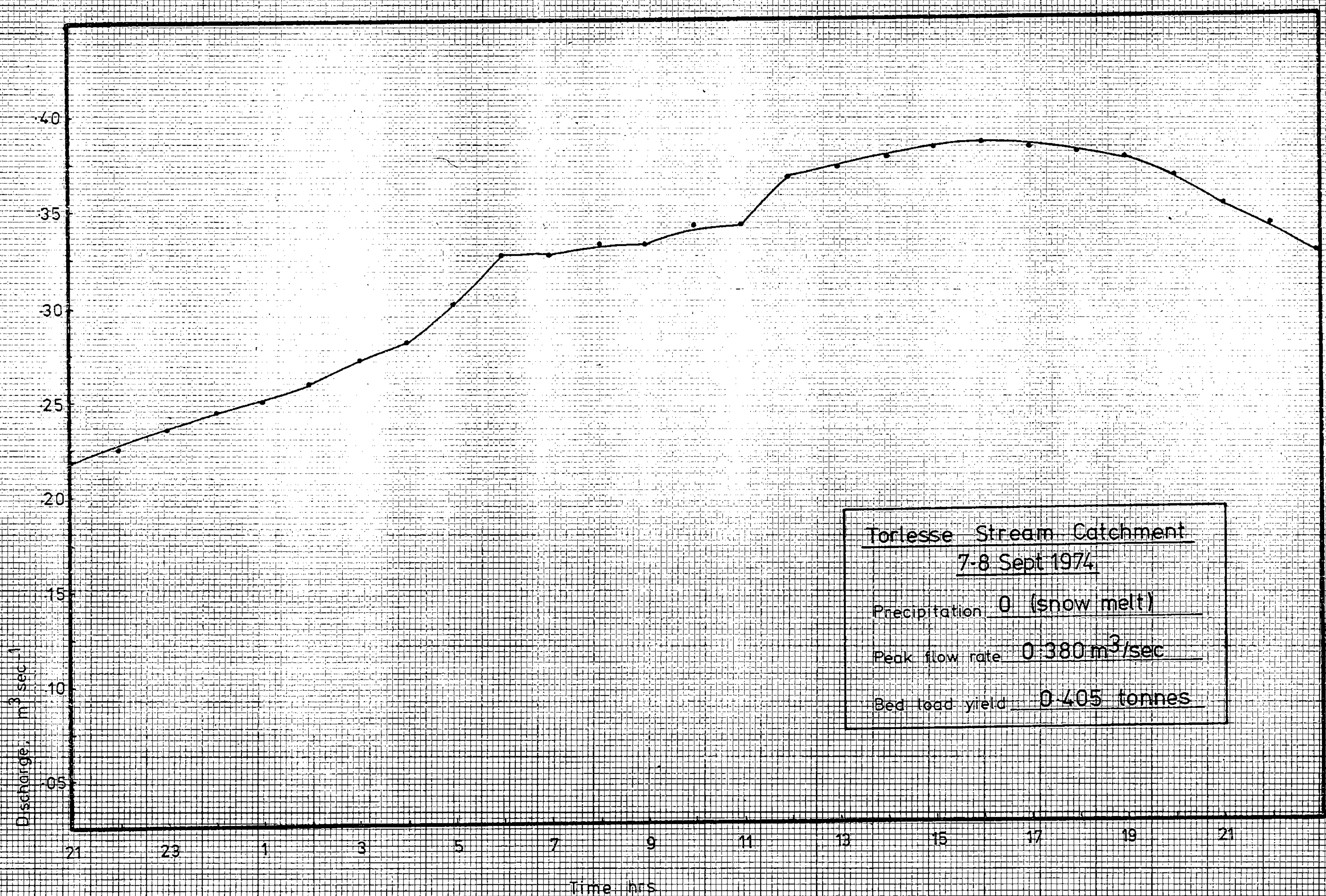


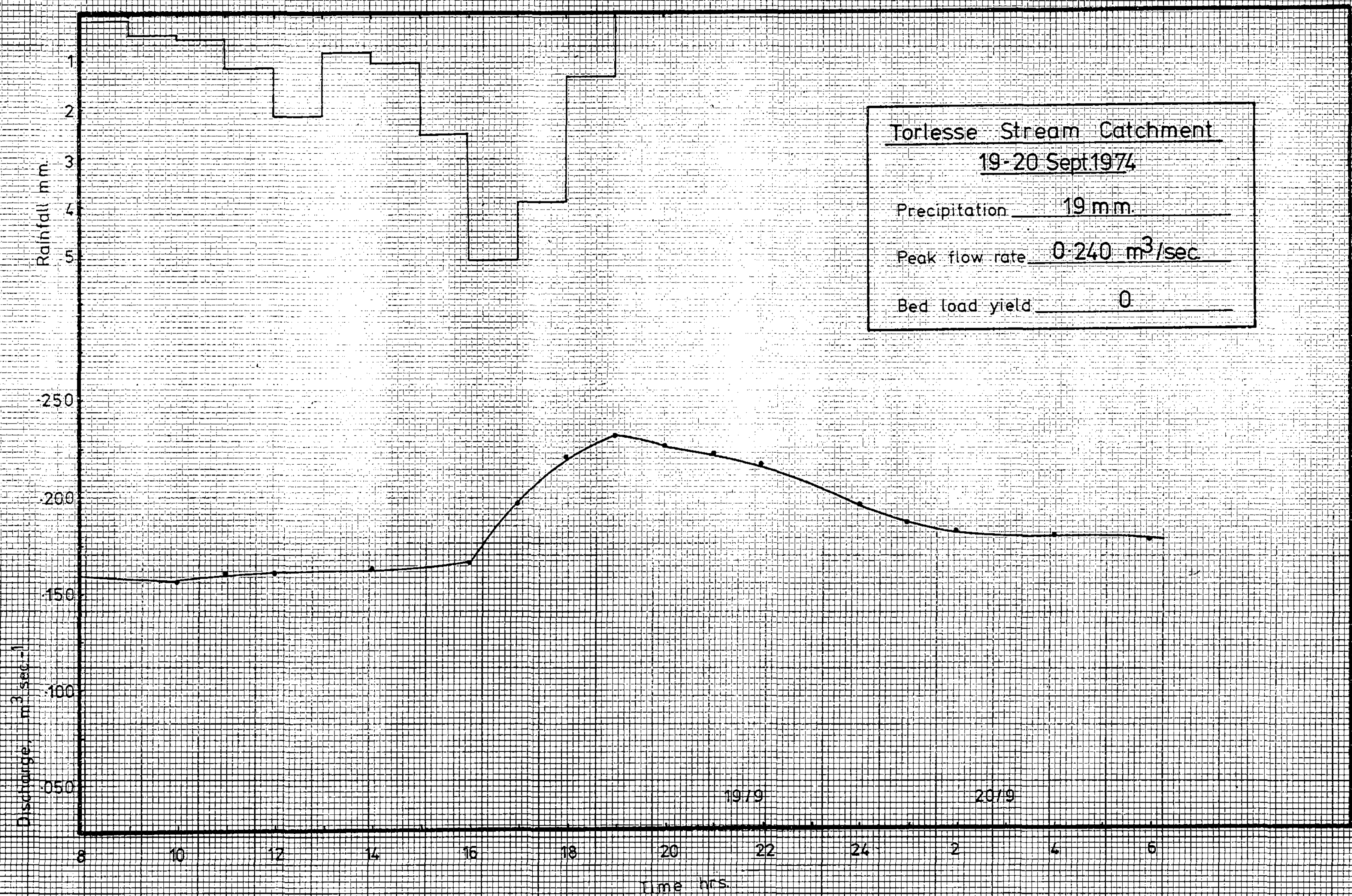
No accurate rainfall data.
Overall ppt. probably about 20 mm.
Torlesse Stream Catchment
28 July 1974
Precipitation about 20 mm ?
Peak flow rate 0·290 m3/sec.
Bed load yield 0
·300
·250
·200
·150
·100
·050
Discharge m3 sec-1
14
15
16
17
18
19
20
21
22
23
24
1
Time hrs



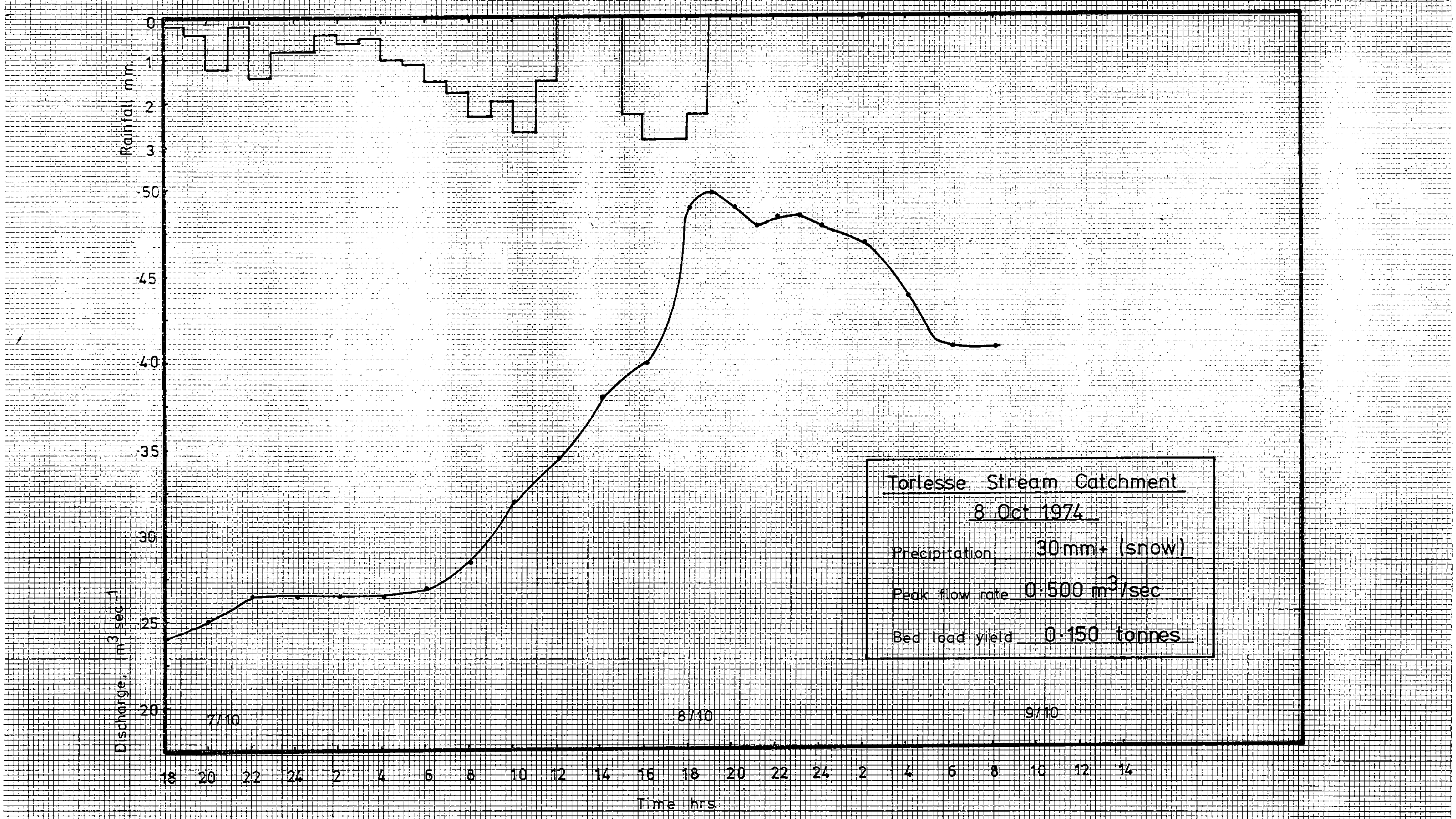
Torlesse Stream Catchment
6 Aug 1974
Precipitation 17 mm
Peak flow rate 0·190 m3/sec
Bed load yield 0
Rainfall mm
1
2
3
4
5
·250
·200
·150
·100
·050
Discharge m3 sec-1
6/8
7/8
14
15
16
17
18
19
20
21
22
23
24
1
2
Time hrs


Torlesse Stream Catchment
4-6 Sept 1974
Precipitation 89 mm
Peak flow rate 1·30 m3/sec
Bed load yield 0·900 tonnes
Rainfall mm
2
4
6
8
10
Discharge, m3 sec-1
·140
·120
·100
·80
·60
·40
·20
0
4/9
5/9
6/9
0 3 6 9 12 15 18 21 24 3 6 9 12 15 18 21 24 3 6 9 12 15 18 21 24
Time hrs.

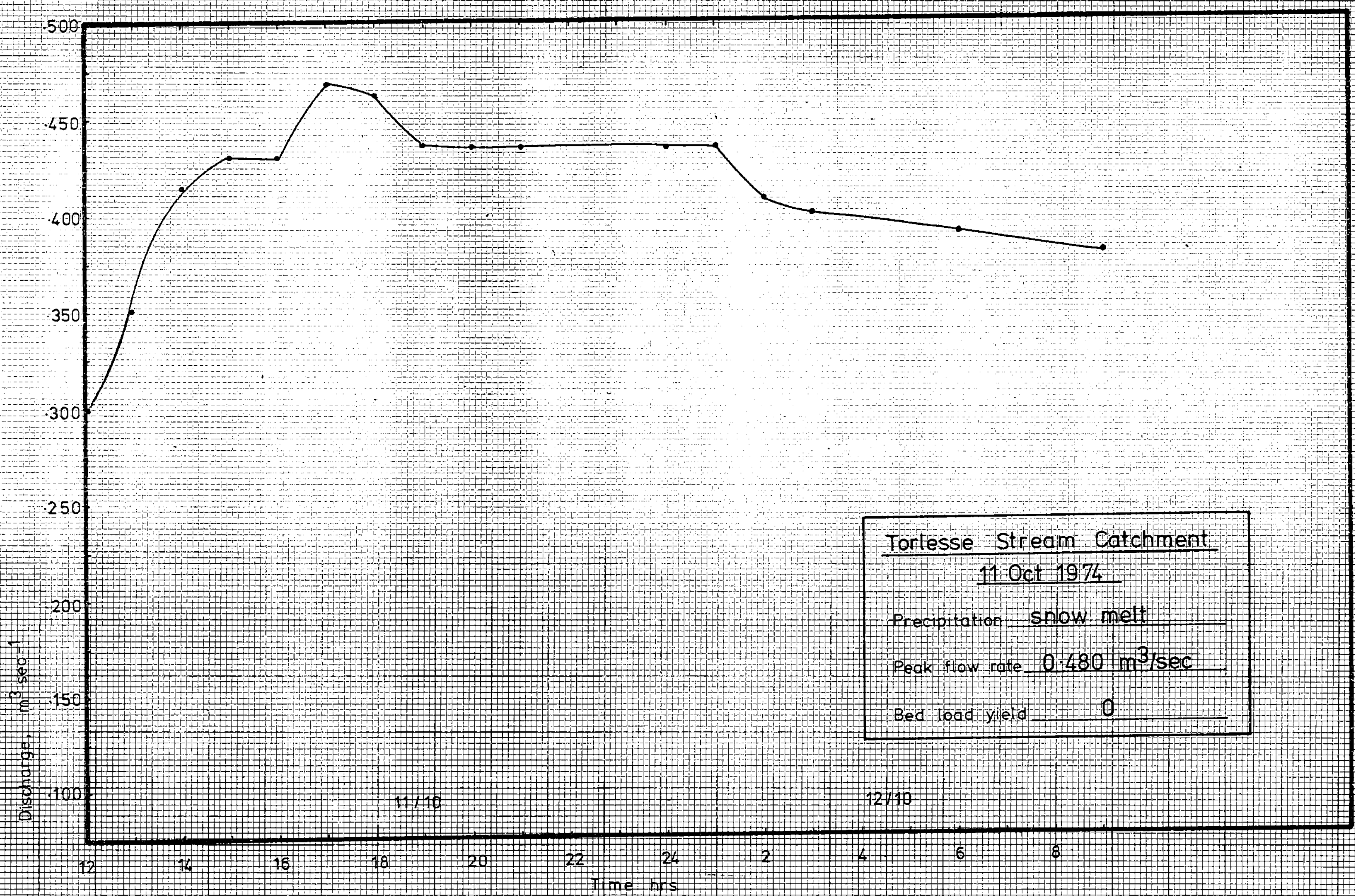

Torlesse Stream Catchment
7-8 Sept 1974
Precipitation 0 (snow melt)
Peak flow rate 0·380 m3/sec
Bed load yield 0·405 tonnes
Discharge, m3 sec-1
·40
·35
·30
·25
·20
·15
·10
·05
21
23
1
3
5
7
9
11
13
15
17
19
21
Time hrs



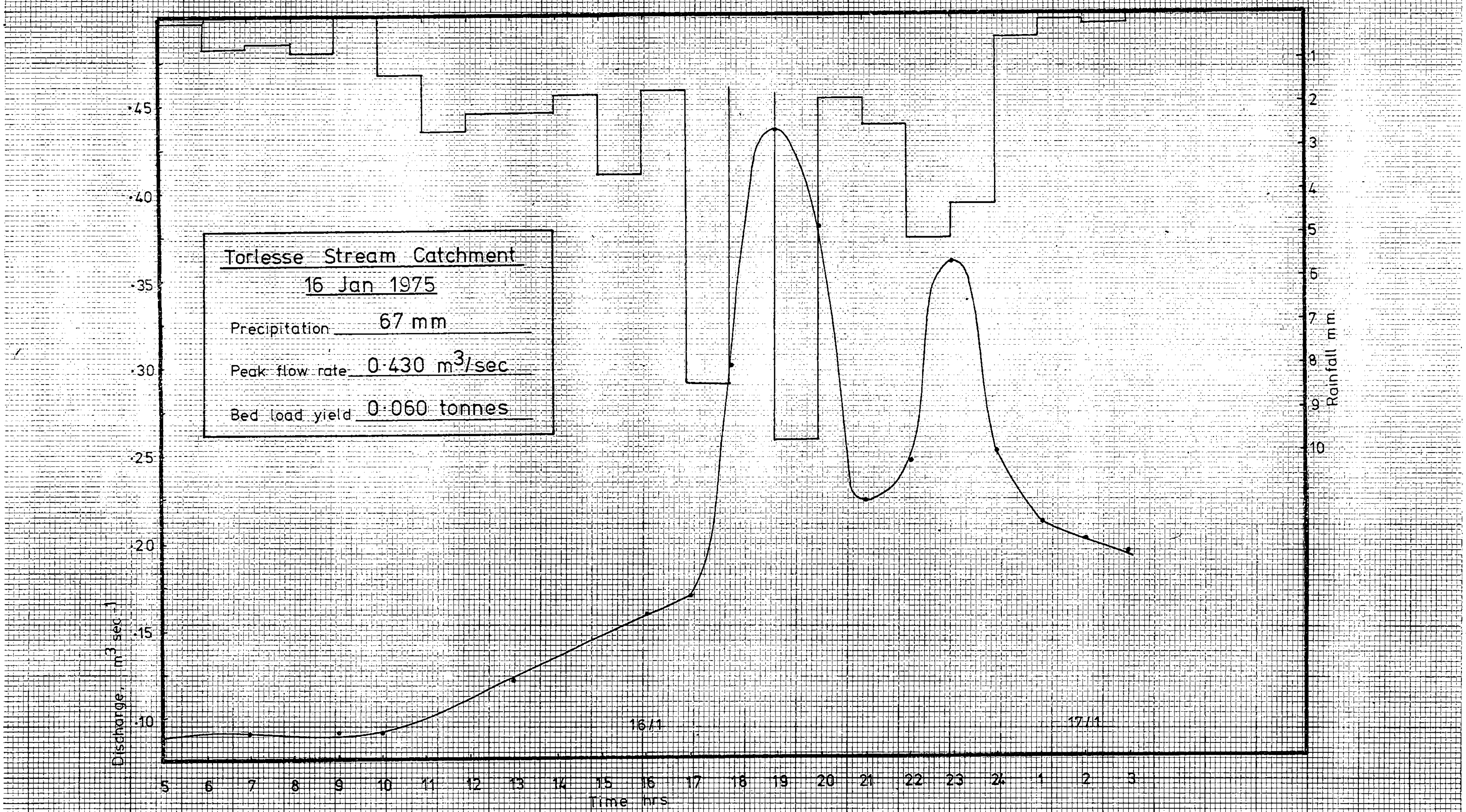
Torlesse Stream Catchment
19-20 Sept.1974
Precipitation 19 mm.
Peak flow rate 0·240 m3/sec.
Bed load yield 0
Rainfall mm.
1
2
3
4
5
Discharge, m3 sec-1
·250
·200
·150
·100
·050
19/9
20/9
8
10
12
14
16
18
20
22
24
2
4
6
Time hrs.



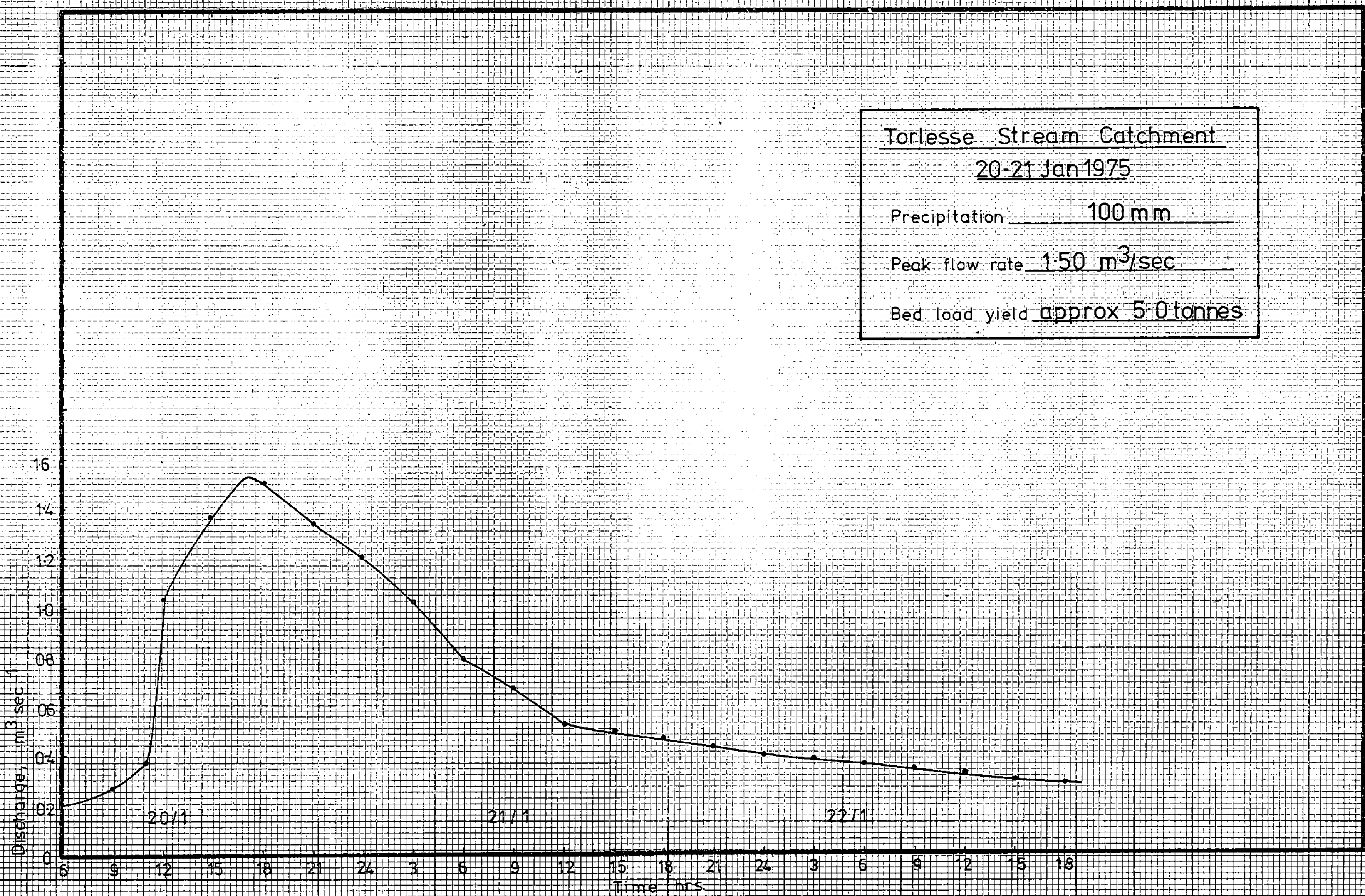
Rainfall mm.
0
1
2
3
50
45
40
35
30
25
20
Discharge, m3 sec-1
7/10
8/10
9/10
18
20
22
24
2
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
Time hrs.
Torlesse Stream Catchment
8 Oct 1974
Precipitation 30mm+ (snow)
Peak flow rate 0·500 m3/sec
Bed load yield 0·150 tonnes



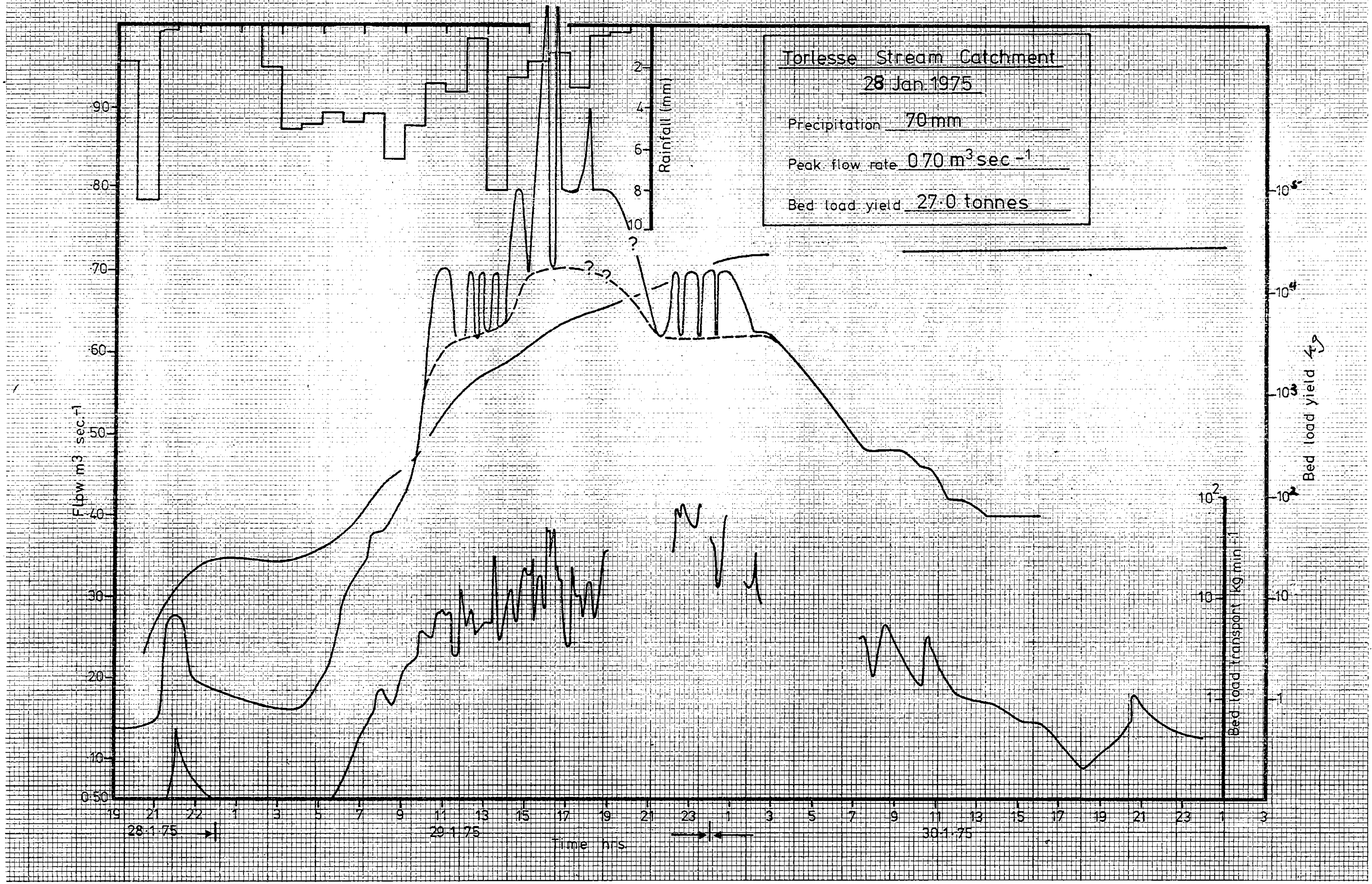
Tortesse Stream Catchment
11 Oct 1974
Precipitation snow melt
Peak flow rate 0·480 m³/sec
Bed load yield 0
·500
·450
·400
·350
·300
·250
·200
·150
·100
Discharge, m³ sec⁻¹
11/10
12/10
12
14
16
18
20
22
24
2
4
6
8
Time hrs



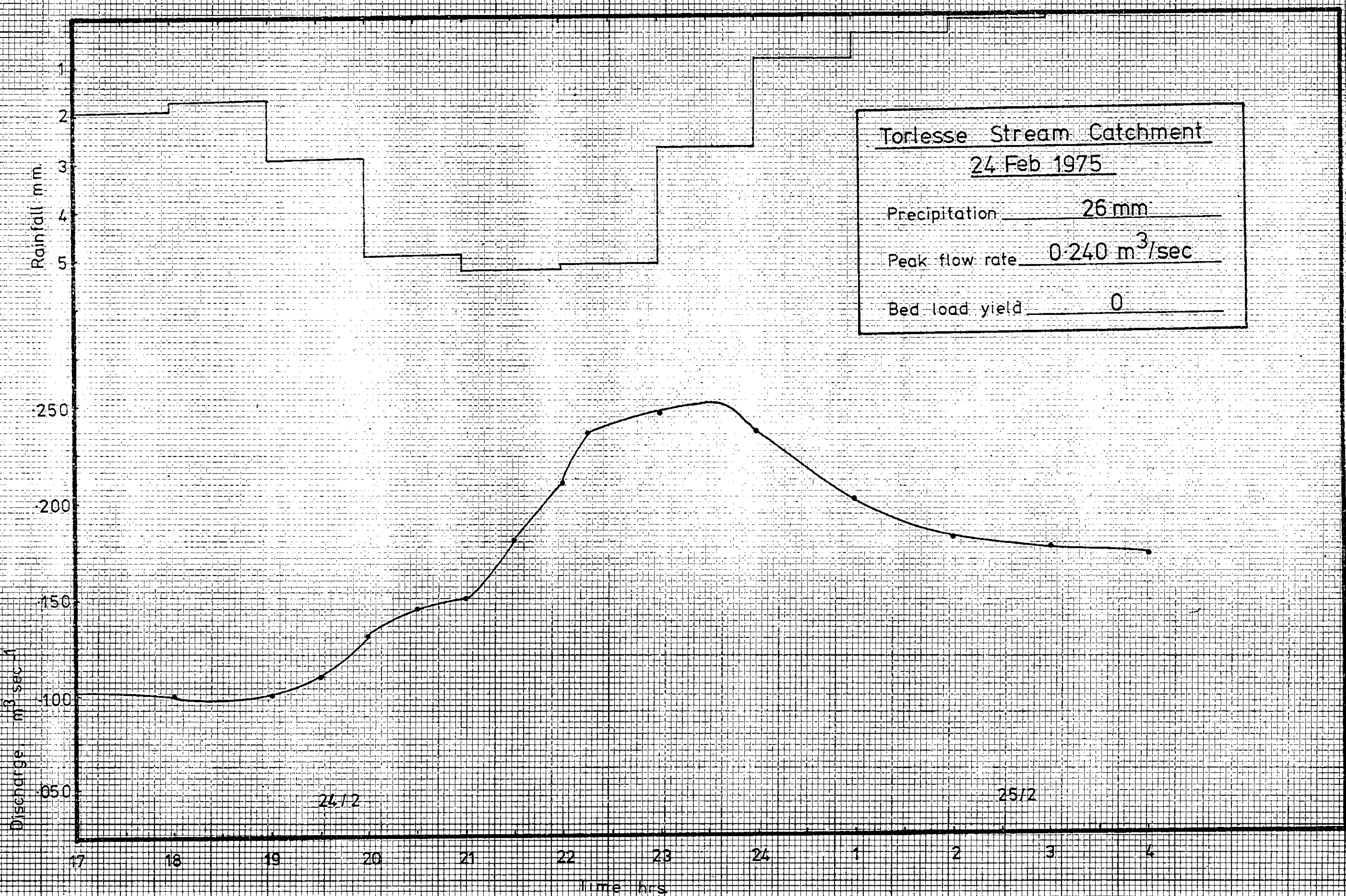
Torlesse Stream Catchment
16 Jan 1975
Precipitation 67 mm
Peak flow rate 0·430 m3/sec
Bed load yield 0·060 tonnes
Discharge, m3 sec-1
Rainfall mm
Time hrs
16/1
17/1
·45
·40
·35
·30
·25
·20
·15
·10
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 1 2 3
1 2 3 4 5 6 7 8 9 10



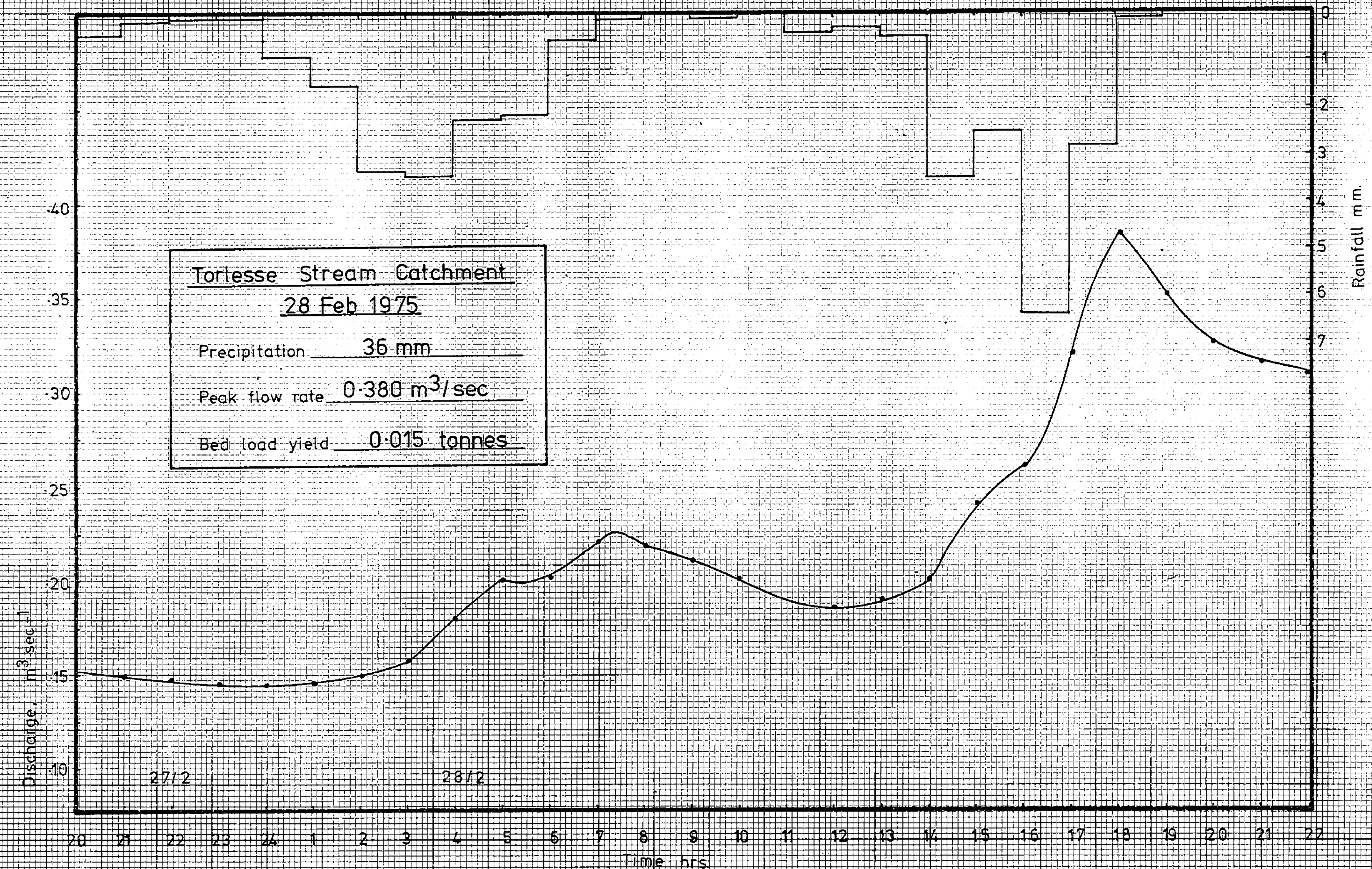
Torlesse Stream Catchment
20-21 Jan 1975
Precipitation 100 mm
Peak flow rate 1·50 m3/sec
Bed load yield approx 5·0 tonnes
Discharge, m3 sec-1
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
20/1
21/1
22/1
6 9 12 15 18 21 24 3 6 9 12 15 18 21 24 3 6 9 12 15 18
Time hrs



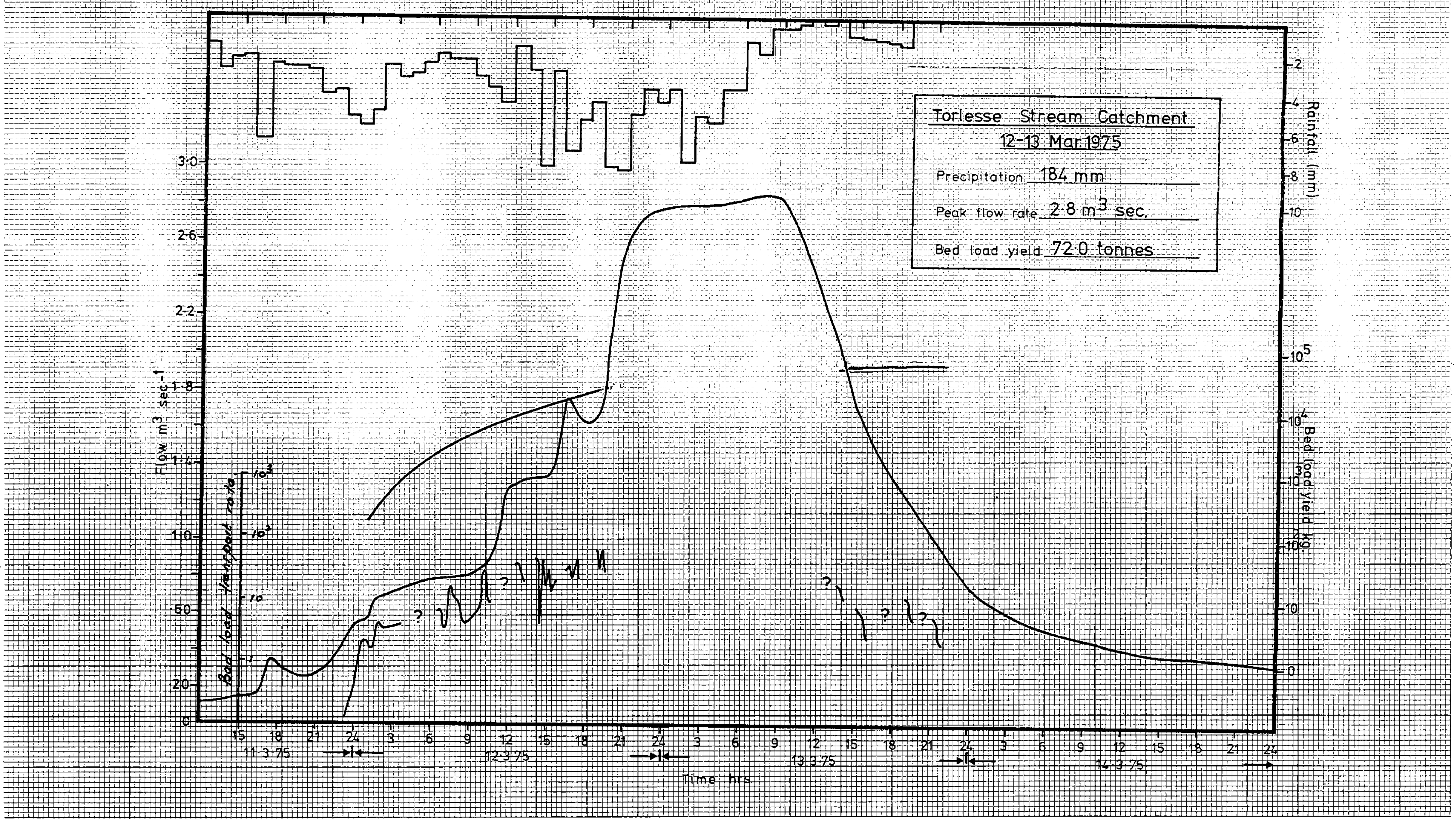
Torlesse Stream Catchment
28 Jan 1975
Precipitation 70 mm
Peak flow rate 0 70 m3 sec -1
Bed load yield 27·0 tonnes
Rainfall (mm)
Flow m3 sec -1
Bed load yield kg
Bed load transport kg min -1
Time hrs
28·1·75
29·1·75
30·1·75



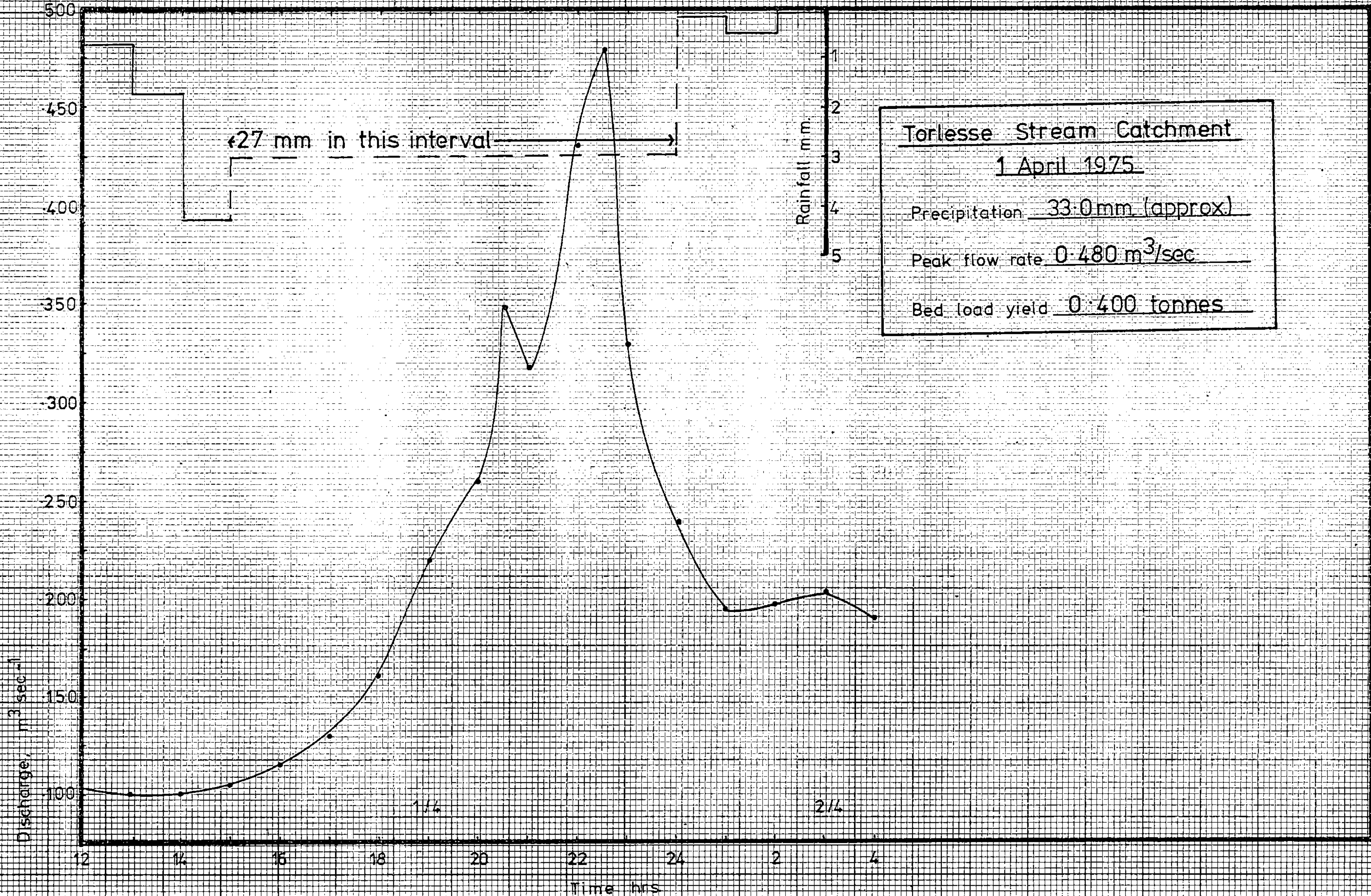
Torlesse Stream Catchment
24 Feb 1975
Precipitation 26 mm
Peak flow rate 0·240 m3/sec
Bed load yield 0
Rainfall mm.
1
2
3
4
5
·250
·200
·150
·100
·050
Discharge m3 sec-1
24/2
25/2
17
18
19
20
21
22
23
24
1
2
3
4
Time hrs



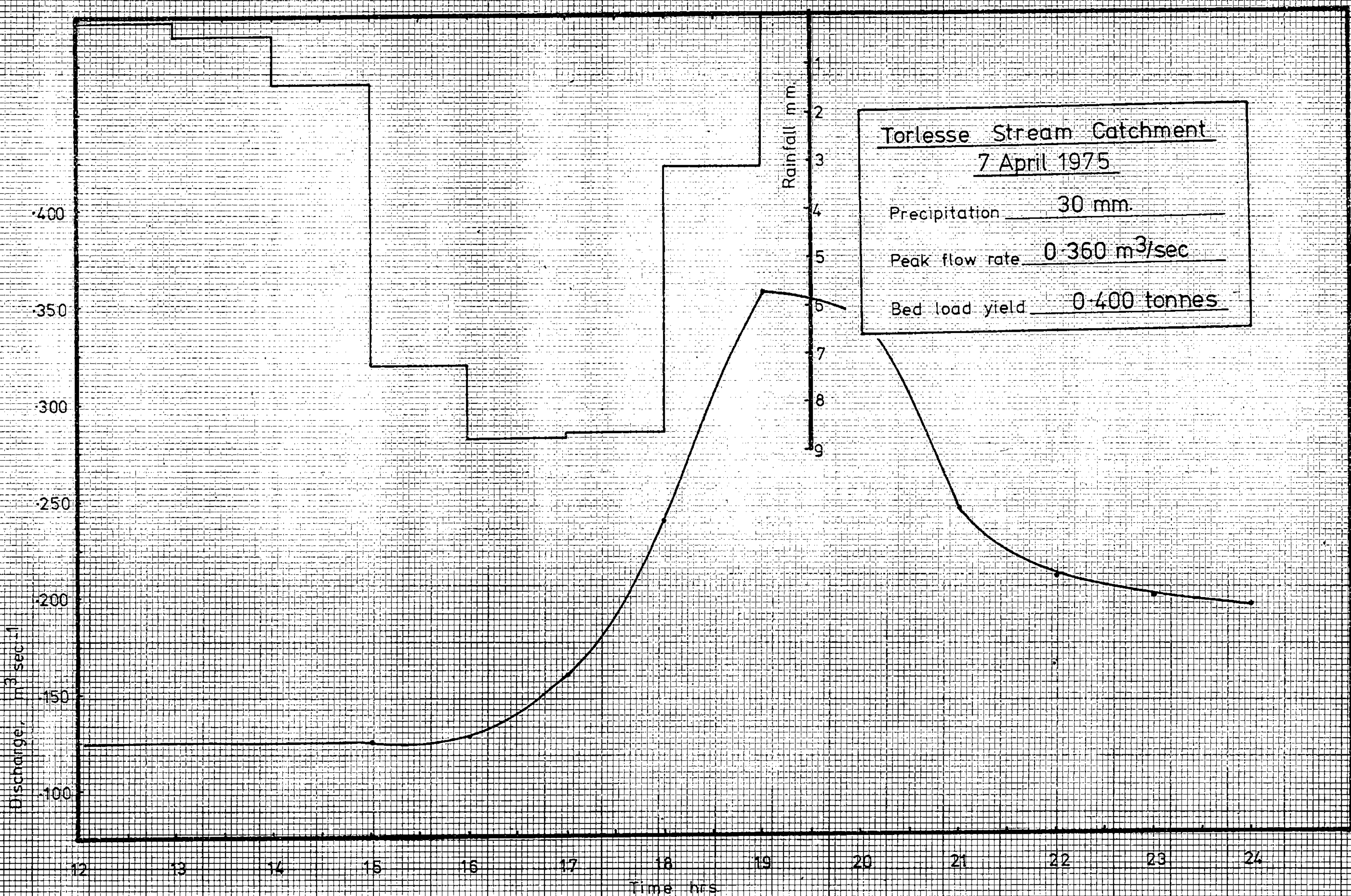
Torlesse Stream Catchment
28 Feb 1975
Precipitation 36 mm
Peak flow rate 0·380 m3/sec
Bed load yield 0·015 tonnes
Discharge, m3 sec-1
10
15
20
25
30
35
40
Rainfall mm.
0
1
2
3
4
5
6
7
27/2
28/2
20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Time hrs

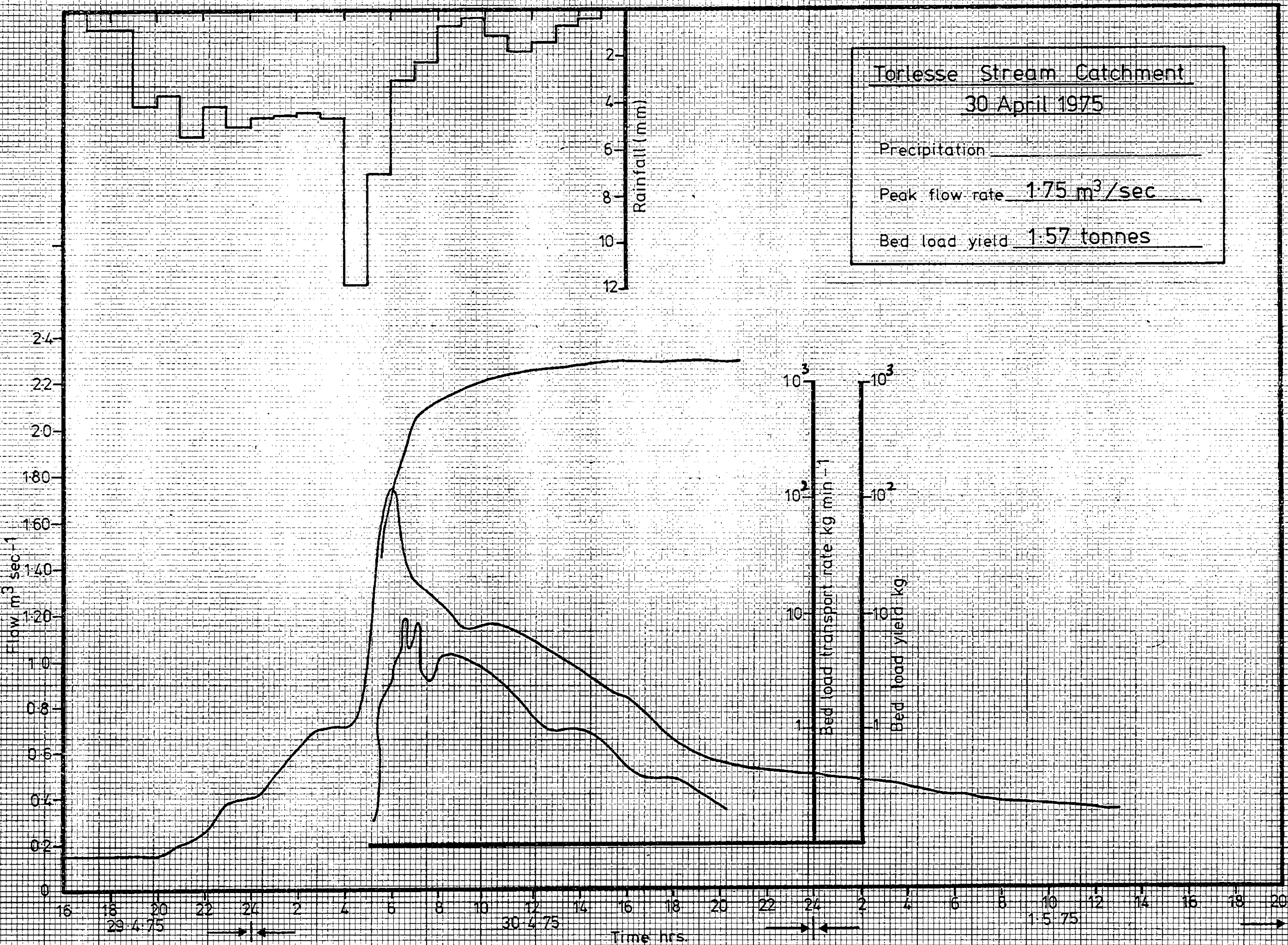


Torlesse Stream Catchment
12-13 Mar 1975
Precipitation 184 mm
Peak flow rate 2·8 m3 sec.
Bed load yield 72·0 tonnes
Rainfall (mm)
Flow m3 sec-1
Bed load transport rate
Bed load yield kg.
Time hrs
11·3·75
12·3·75
13·3·75
14·3·75

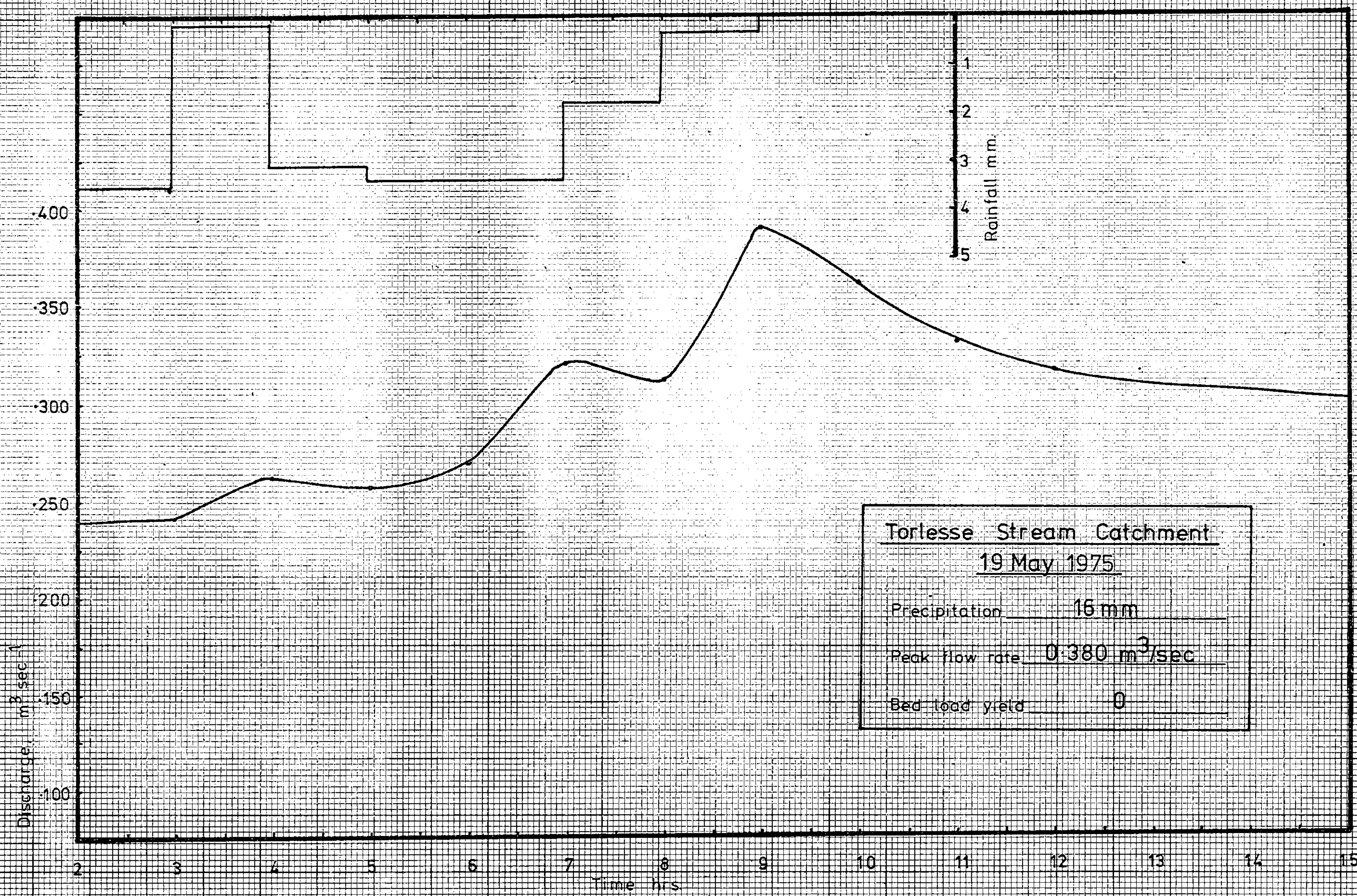


Torlesse Stream Catchment
1 April 1975
Precipitation 33·0 mm (approx)
Peak flow rate 0·480 m3/sec
Bed load yield 0·400 tonnes
27 mm in this interval
Rainfall mm
1
2
3
4
5
500
450
400
350
300
250
200
150
100
Discharge, m3 sec-1
12
14
16
18
20
22
24
2
4
1/4
2/4
Time hrs

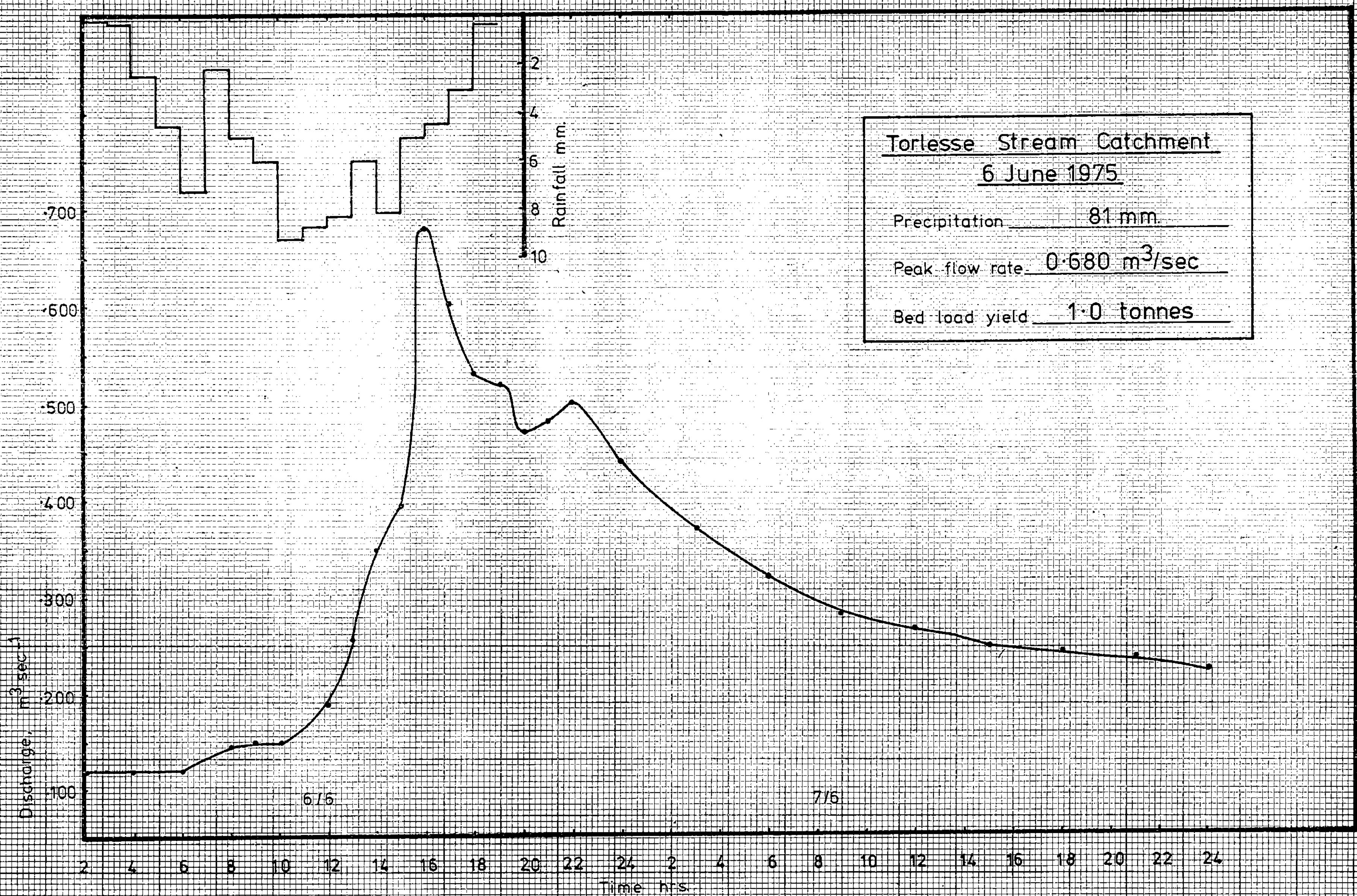

Torlesse Stream Catchment
7 April 1975
Precipitation 30 mm.
Peak flow rate 0·360 m3/sec
Bed load yield 0·400 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
9
Discharge, m3 sec-1
·400
·350
·300
·250
·200
·150
·100
12
13
14
15
16
17
18
19
20
21
22
23
24
Time hrs



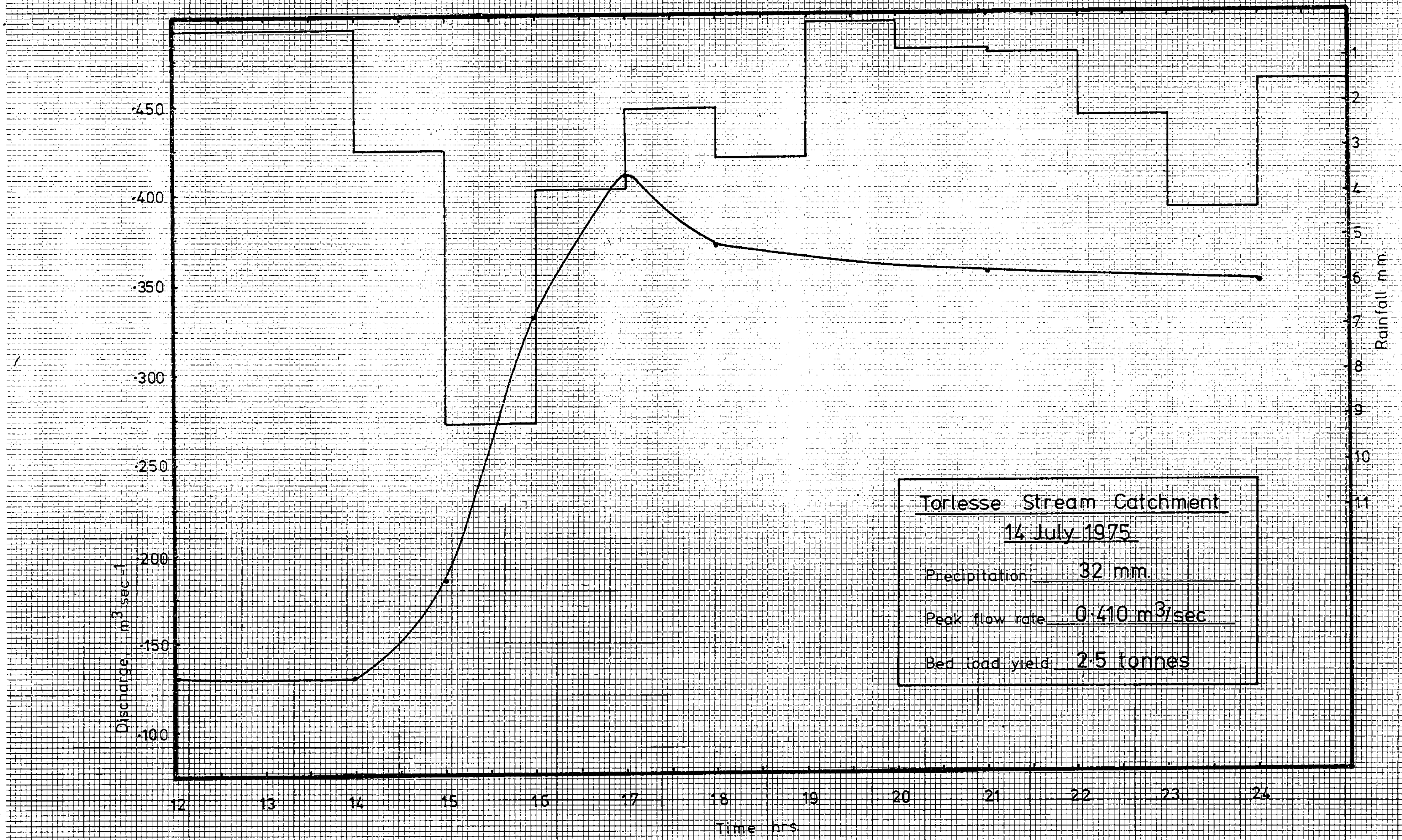
Torlesse Stream Catchment
30 April 1975
Precipitation
Peak flow rate 1·75 m3/sec
Bed load yield 1·57 tonnes
Rainfall (mm)
2
4
6
8
10
12
Flow m3 sec-1
0
0·2
0·4
0·6
0·8
1·0
1·20
1·40
1·60
1·80
2·0
2·2
2·4
Bed load transport rate kg min-1
Bed load yield kg
1
10
10²
10³
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
29 4 75
30 4 75
1 5 75
Time hrs.



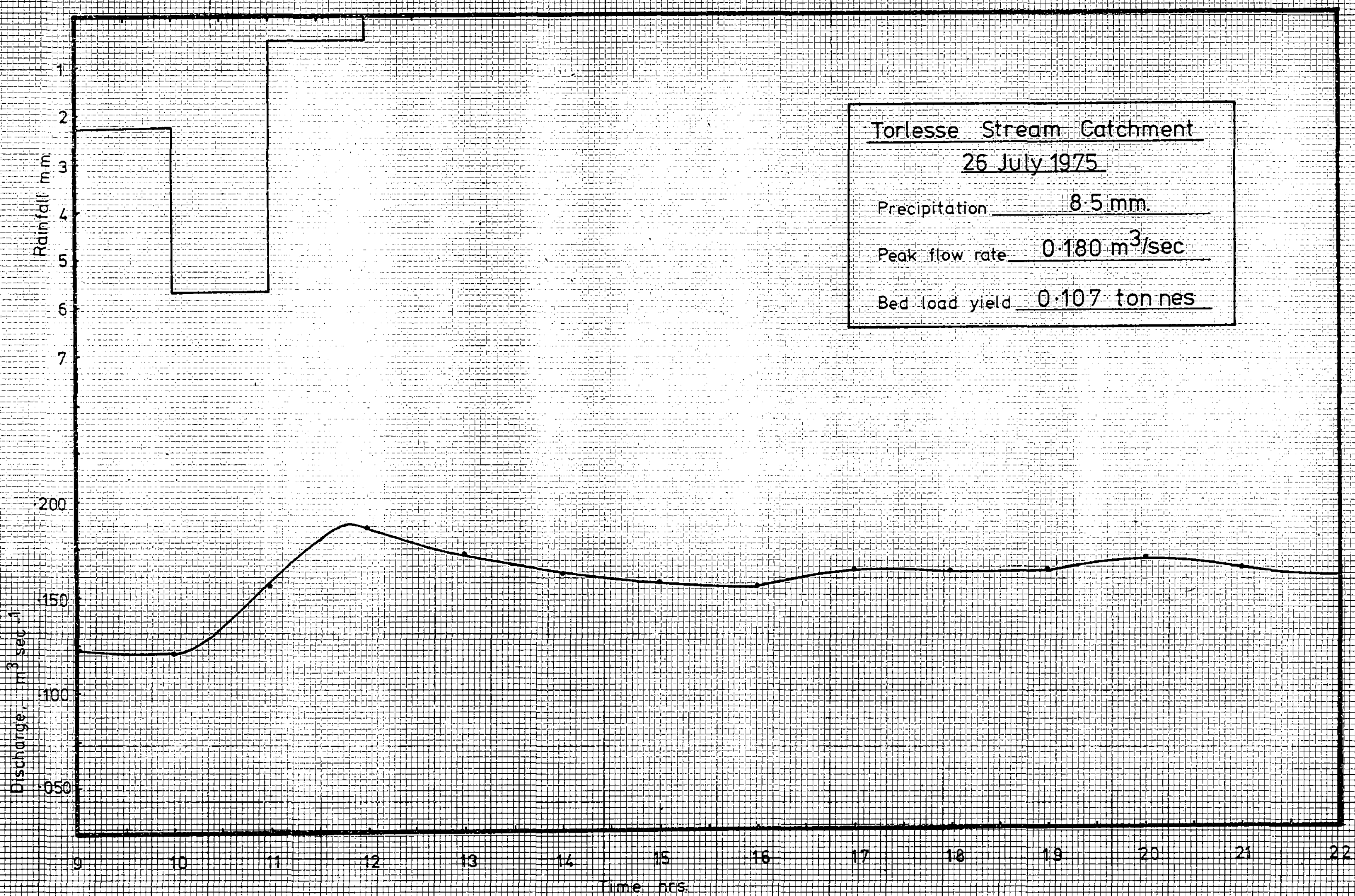
Torlesse Stream Catchment
19 May 1975
Precipitation 16 mm
Peak flow rate 0·380 m³/sec
Bed load yield 0
Rainfall mm.
1
2
3
4
5
·400
·350
·300
·250
·200
·150
·100
Discharge m³ sec⁻¹
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time hrs



Torlesse Stream Catchment
6 June 1975
Precipitation 81 mm.
Peak flow rate 0·680 m3/sec
Bed load yield 1·0 tonnes
Rainfall mm.
2
4
6
8
10
·700
·600
·500
·400
·300
·200
100
Discharge, m3 sec-1
6/6
7/6
2 4 6 8 10 12 14 16 18 20 22 24 2 4 6 8 10 12 14 16 18 20 22 24
Time hrs.



Torlesse Stream Catchment
14 July 1975
Precipitation 32 mm.
Peak flow rate 0·410 m3/sec
Bed load yield 2·5 tonnes
Discharge m3 sec-1
·100
·150
·200
·250
·300
·350
·400
·450
Rainfall mm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time hrs


Torlesse Stream Catchment
26 July 1975
Precipitation 8·5 mm.
Peak flow rate 0·180 m3/sec
Bed load yield 0·107 ton nes
Rainfall m.m.
1
2
3
4
5
6
7
Discharge, m3 sec-1
·200
·150
·100
·050
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Time hrs.

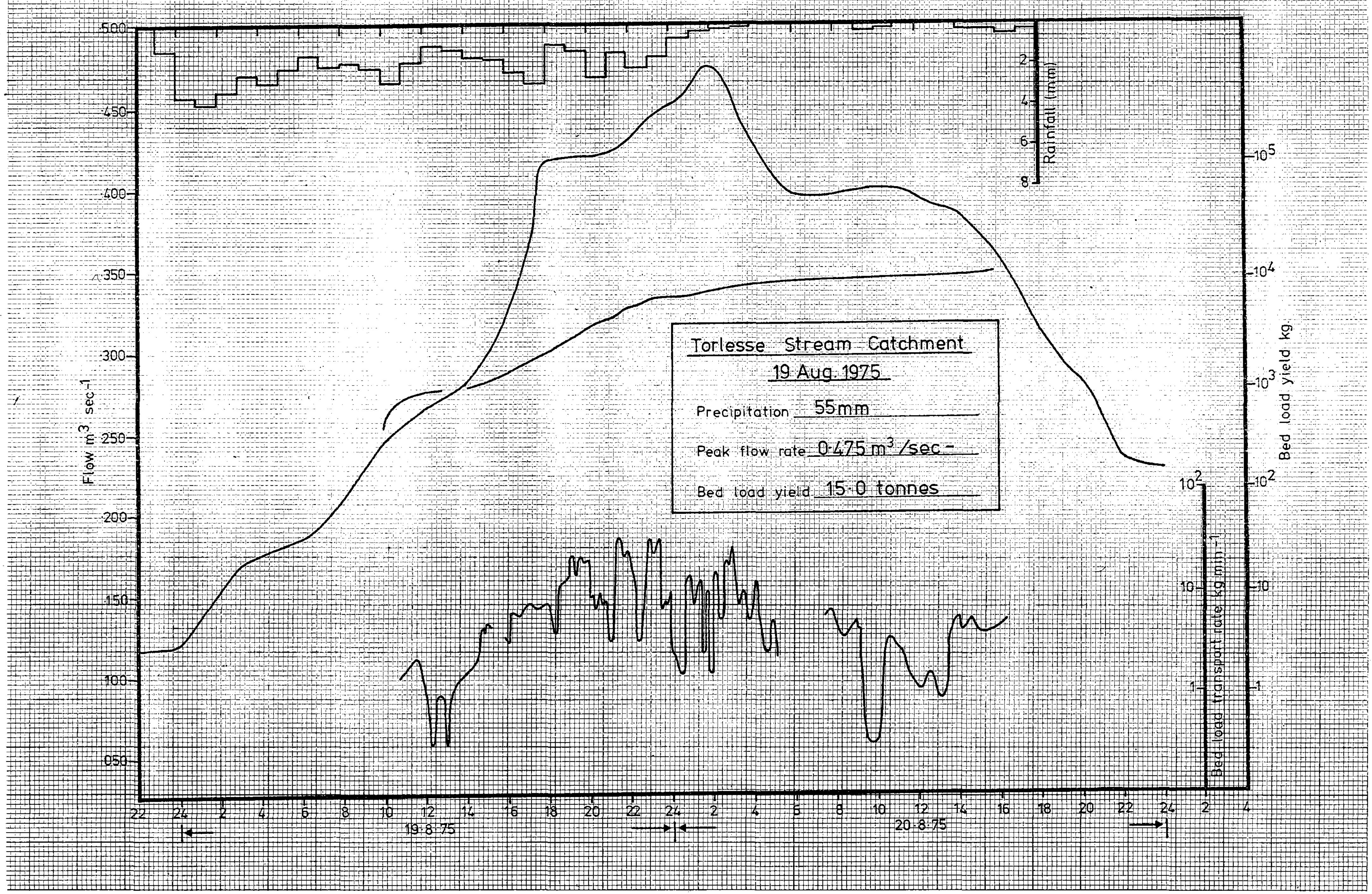
Torlesse Stream Catchment

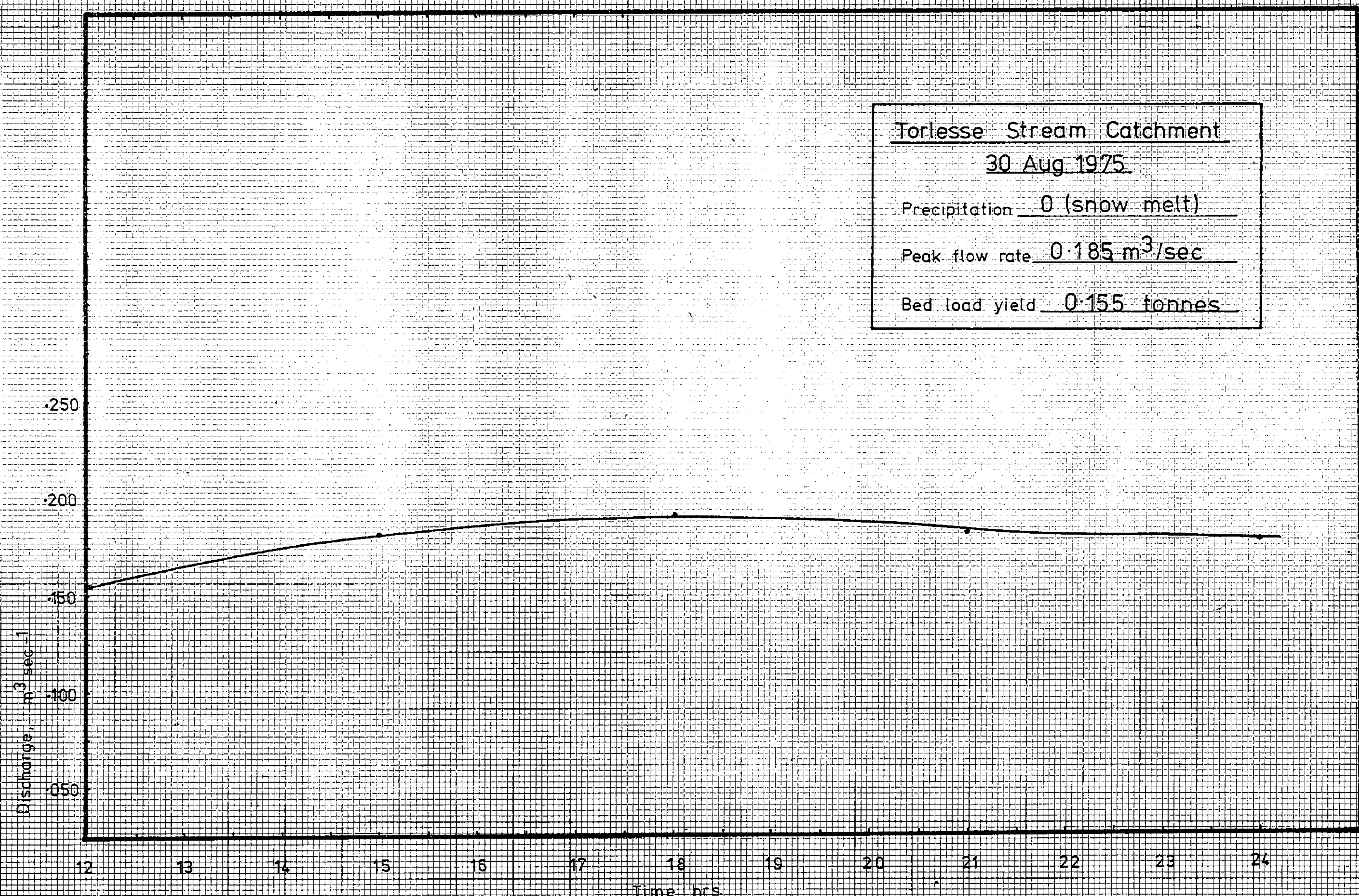
1 Aug 1975

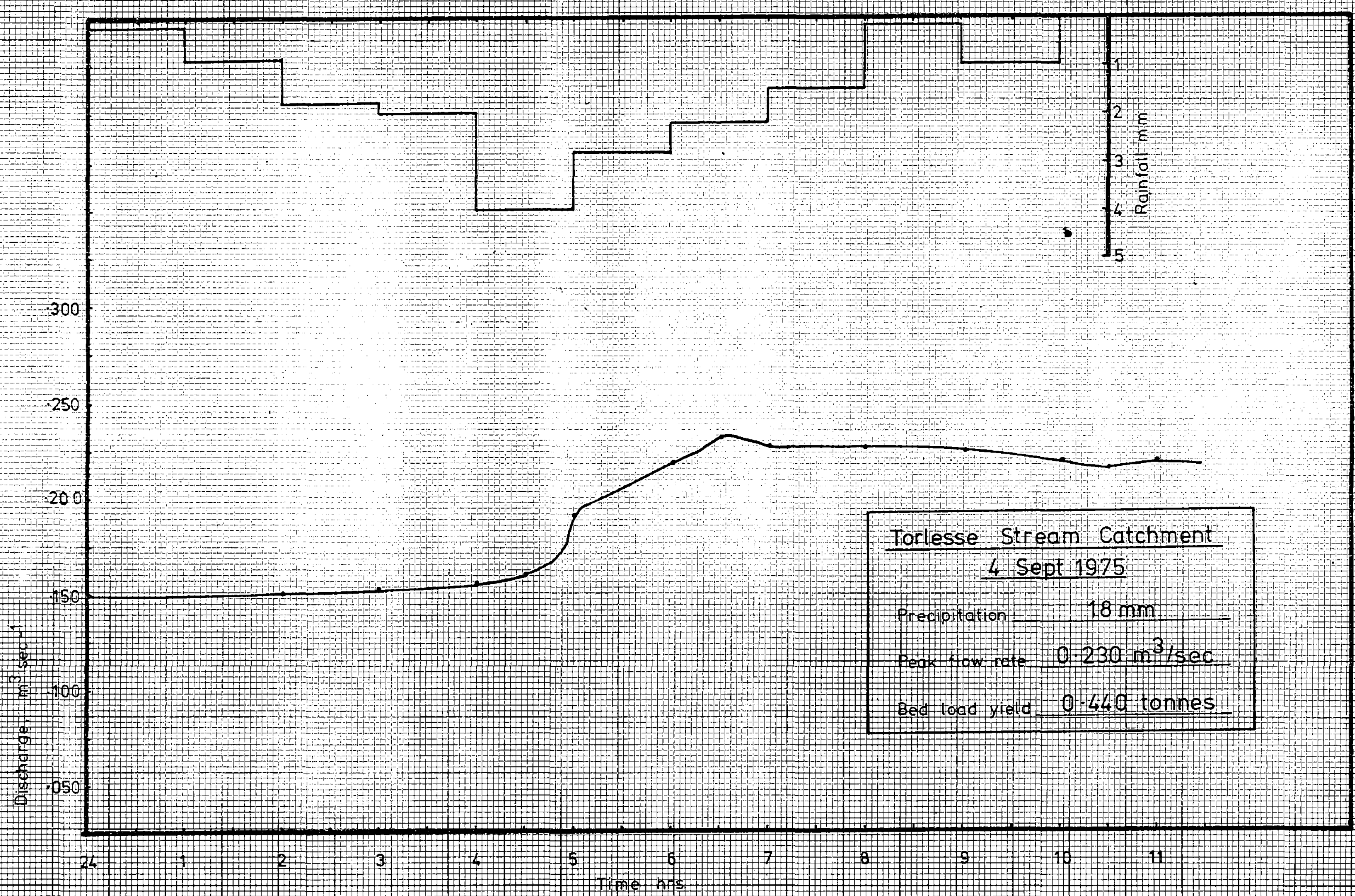
Precipitation 41 mm (rain and snow melt)

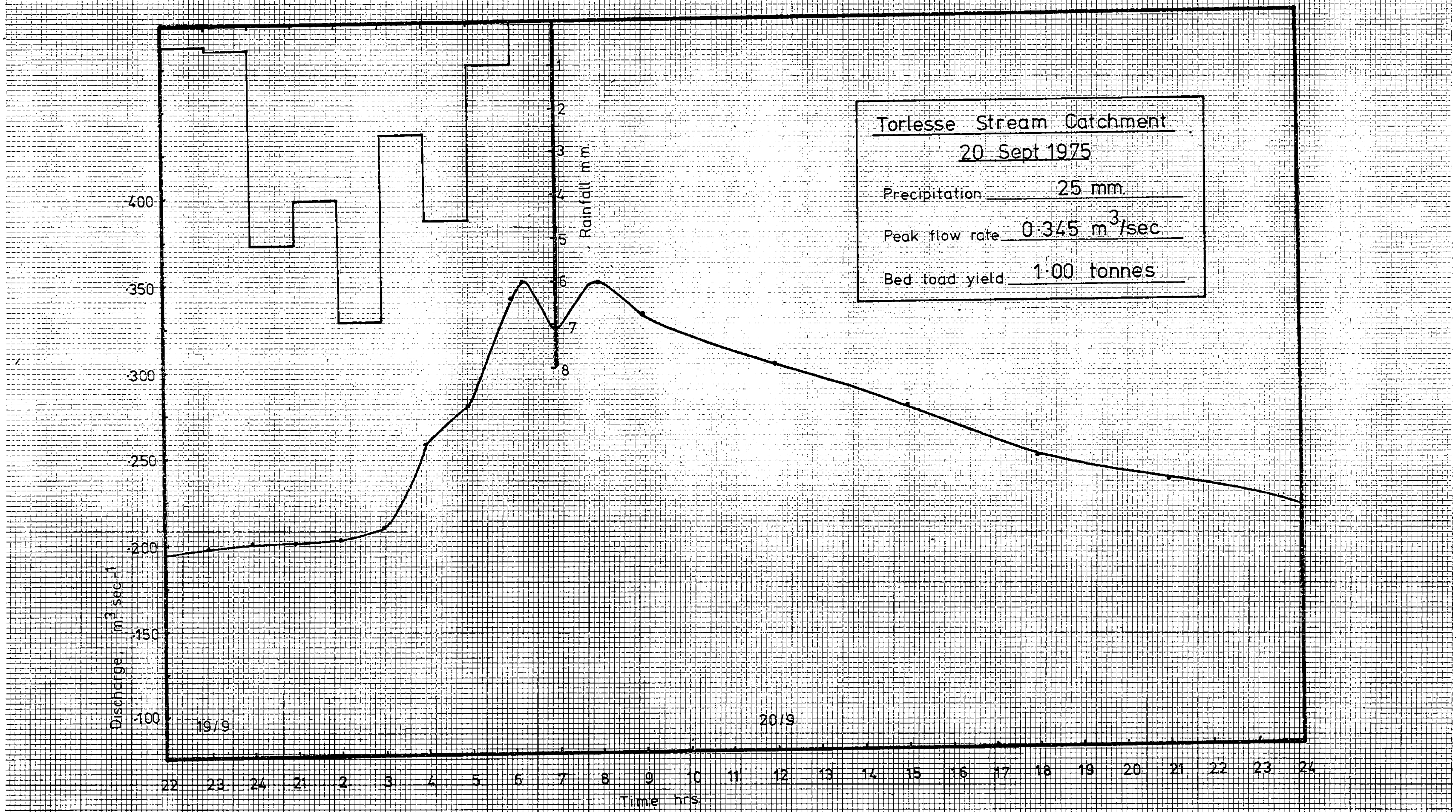
Peak flow rate 0·500 m^3/sec (approx)

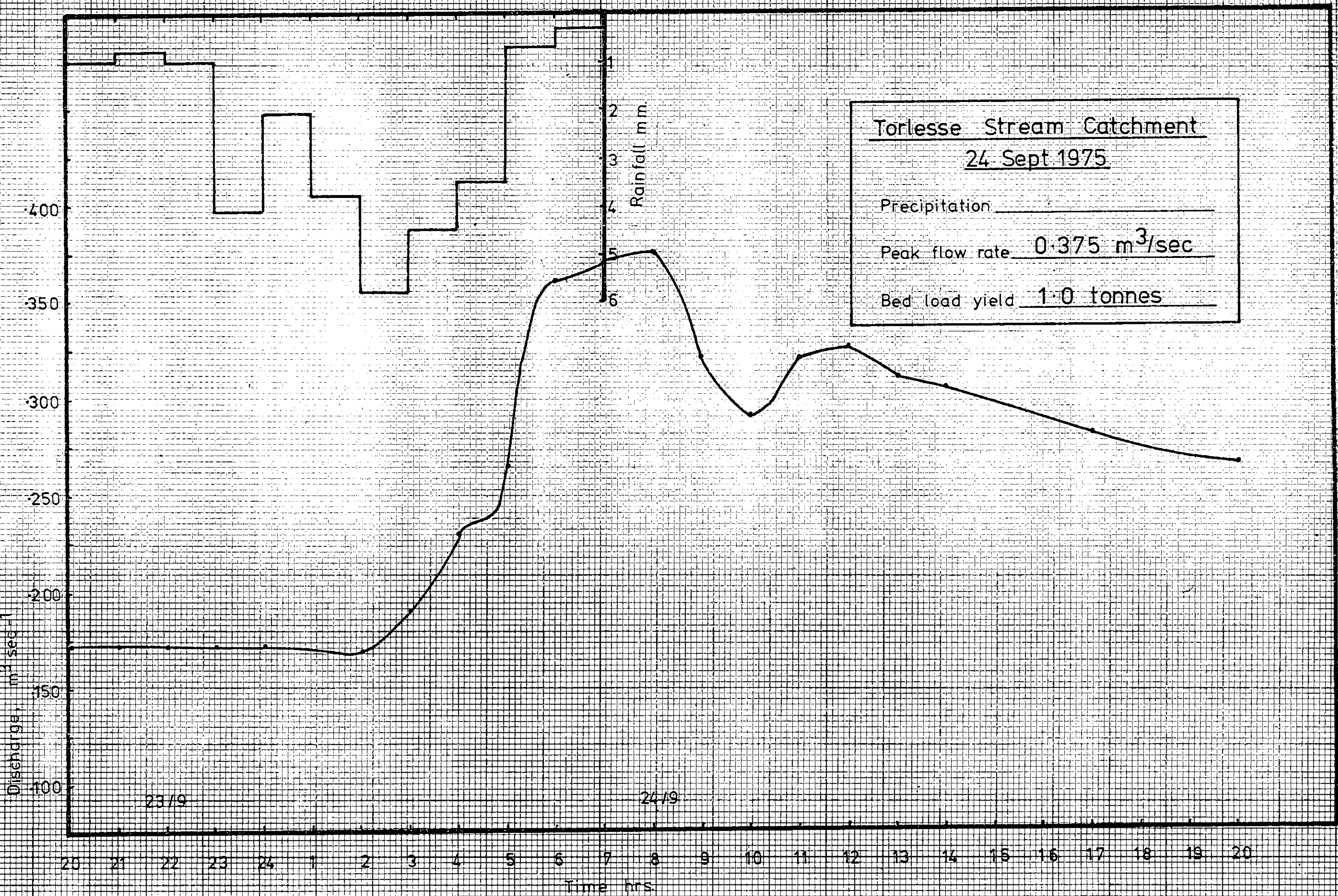
Bed load yield 3·0 tonnes (estimated)


Torlesse Stream Catchment
19 Aug. 1975
Precipitation 55mm
Peak flow rate 0·475 m³/sec
Bed load yield 15·0 tonnes
Flow m³ sec-1
Rainfall (mm)
Bed load yield kg.
Bed load transport rate kg min-1
19·8·75
20·8·75

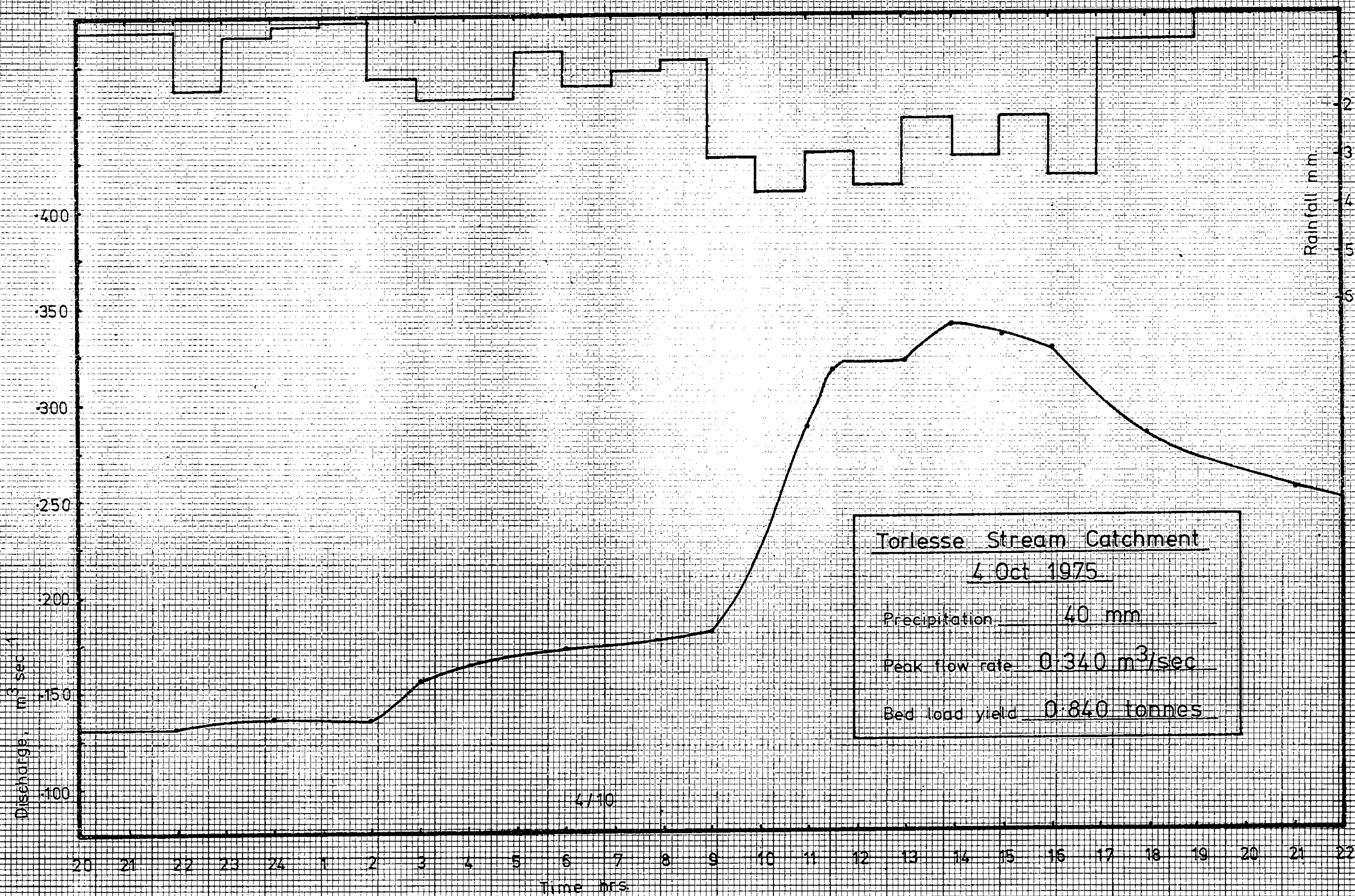

Torlesse Stream Catchment
30 Aug 1975
Precipitation 0 (snow melt)
Peak flow rate 0·185 m3/sec
Bed load yield 0·155 tonnes
·250
·200
·150
·100
·050
Discharge, m3 sec-1
12
13
14
15
16
17
18
19
20
21
22
23
24
Time hrs

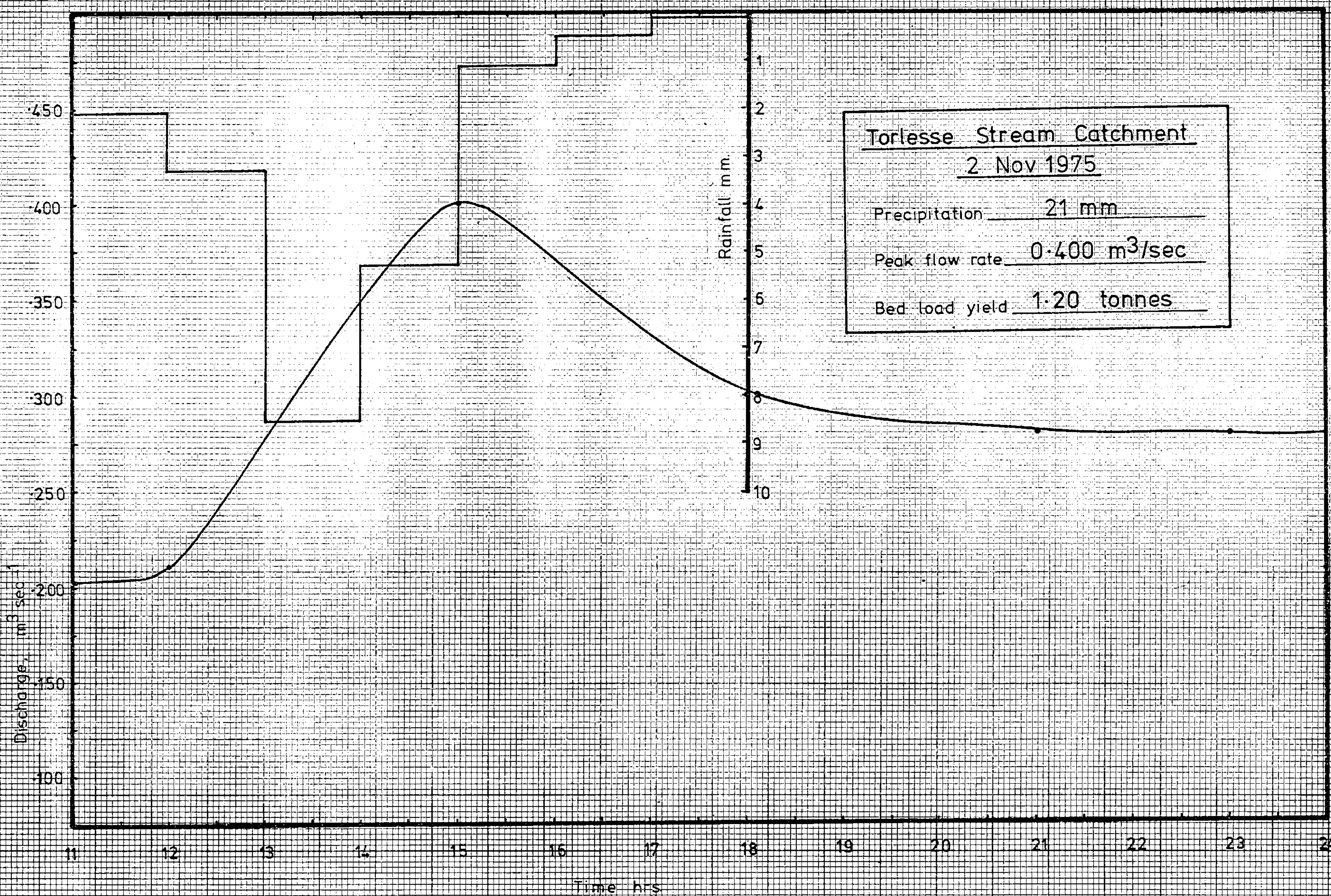

Torlesse Stream Catchment
4 Sept 1975
Precipitation 18 mm
Peak flow rate 0·230 m3/sec
Bed load yield 0·440 tonnes
Rainfall mm
1
2
3
4
5
Discharge, m3 sec-1
·050
·100
·150
·200
·250
·300
24
1
2
3
4
5
6
7
8
9
10
11
Time hrs


Torlesse Stream Catchment
20 Sept 1975
Precipitation 25 mm.
Peak flow rate 0·345 m3/sec
Bed load yield 1·00 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
Discharge, m3 sec-1
400
350
300
250
200
150
100
19/9
20/9
22 23 24 21 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time hrs.

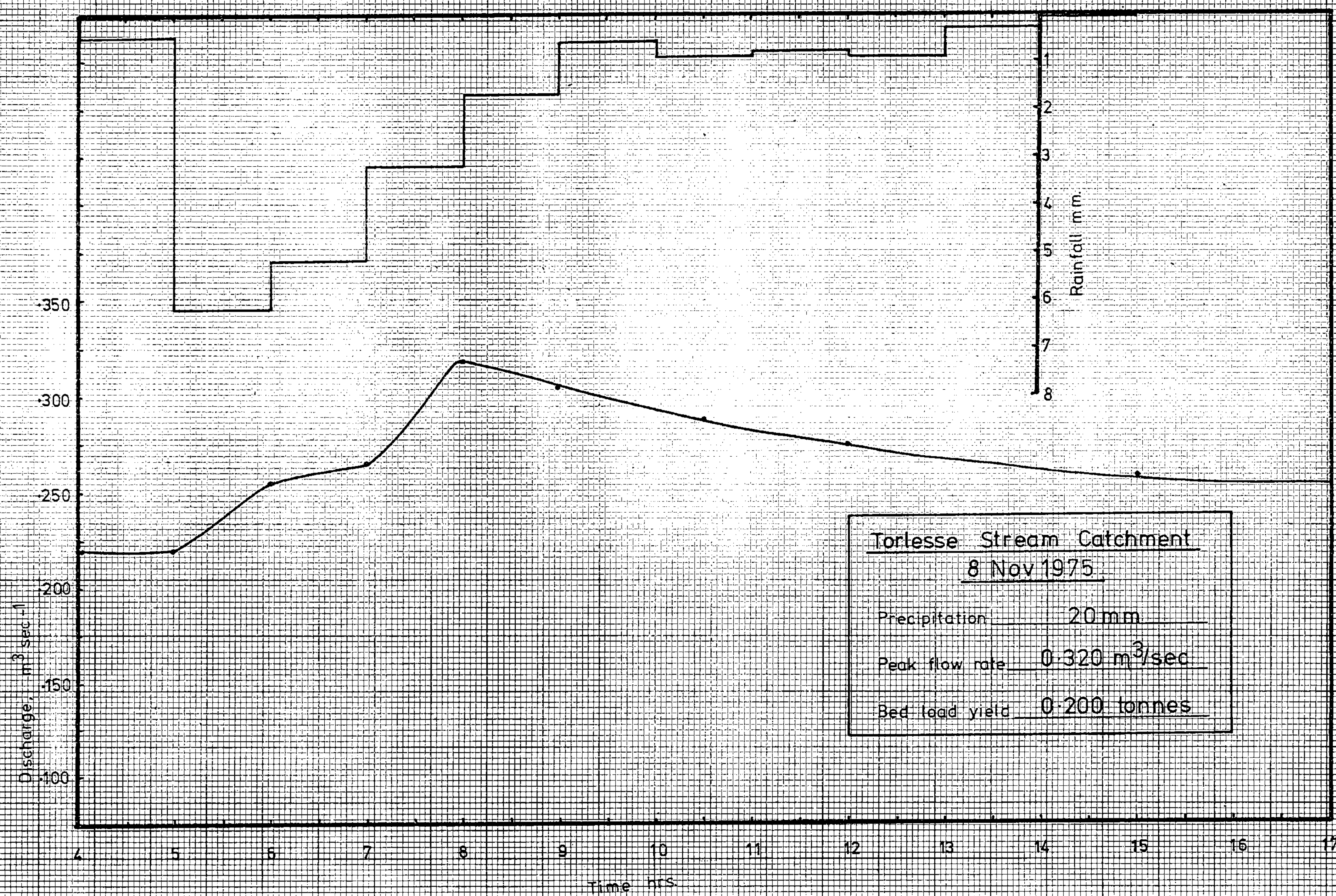


Torlesse Stream Catchment
24 Sept 1975
Precipitation
Peak flow rate 0·375 m3/sec
Bed load yield 1·0 tonnes
Rainfall mm
1
2
3
4
5
6
·400
·350
·300
·250
·200
·150
·100
Discharge, m3 sec-1
23/9
24/9
20
21
22
23
24
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time hrs.

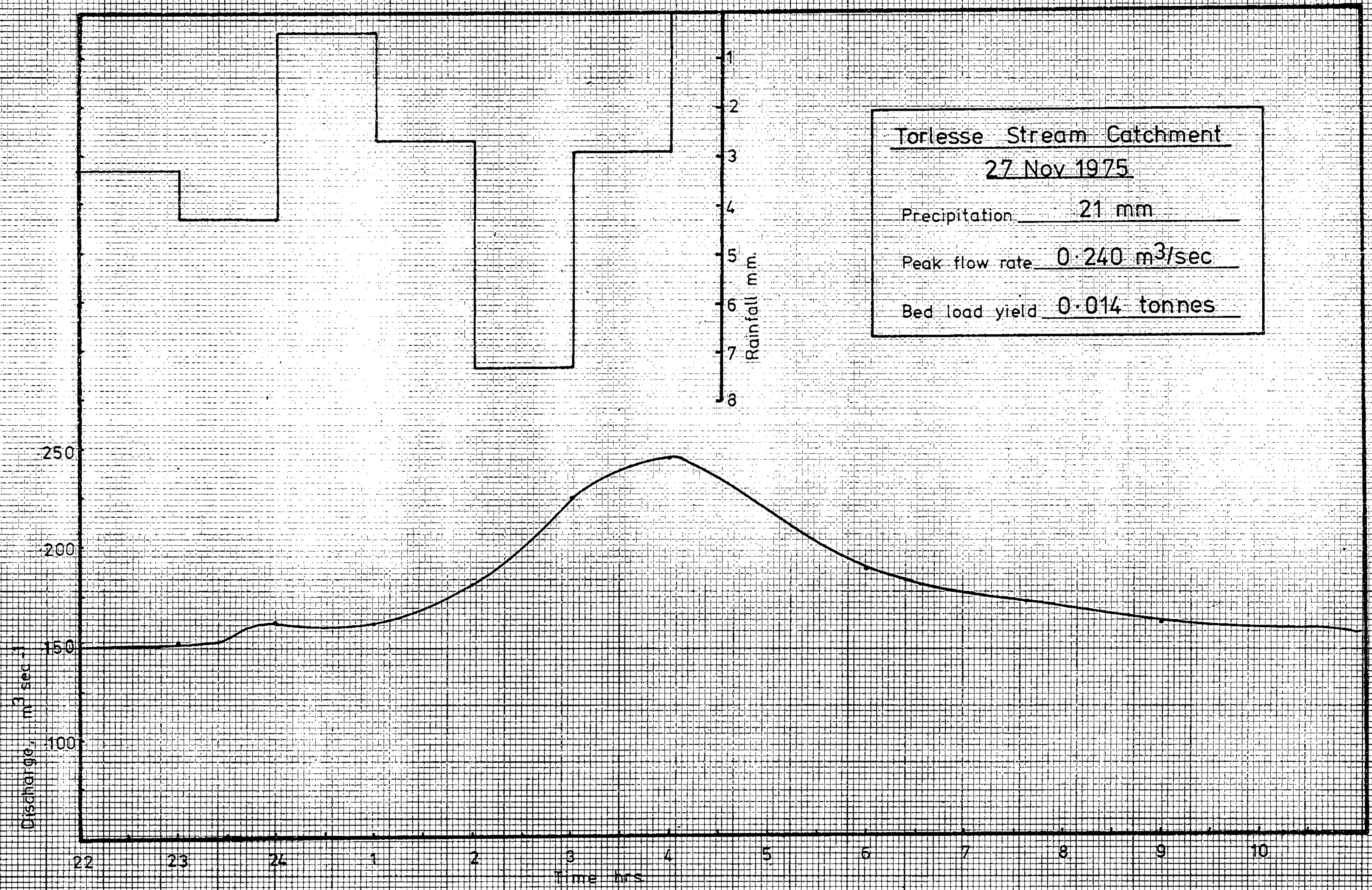

Torlesse Stream Catchment
4 Oct 1975
Precipitation 40 mm
Peak flow rate 0.340 m³/sec
Bed load yield 0.840 tonnes
Discharge, m³ sec⁻¹
·400
·350
·300
·250
·200
·150
·100
Rainfall mm
1
2
3
4
5
6
4/10
20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Time hrs



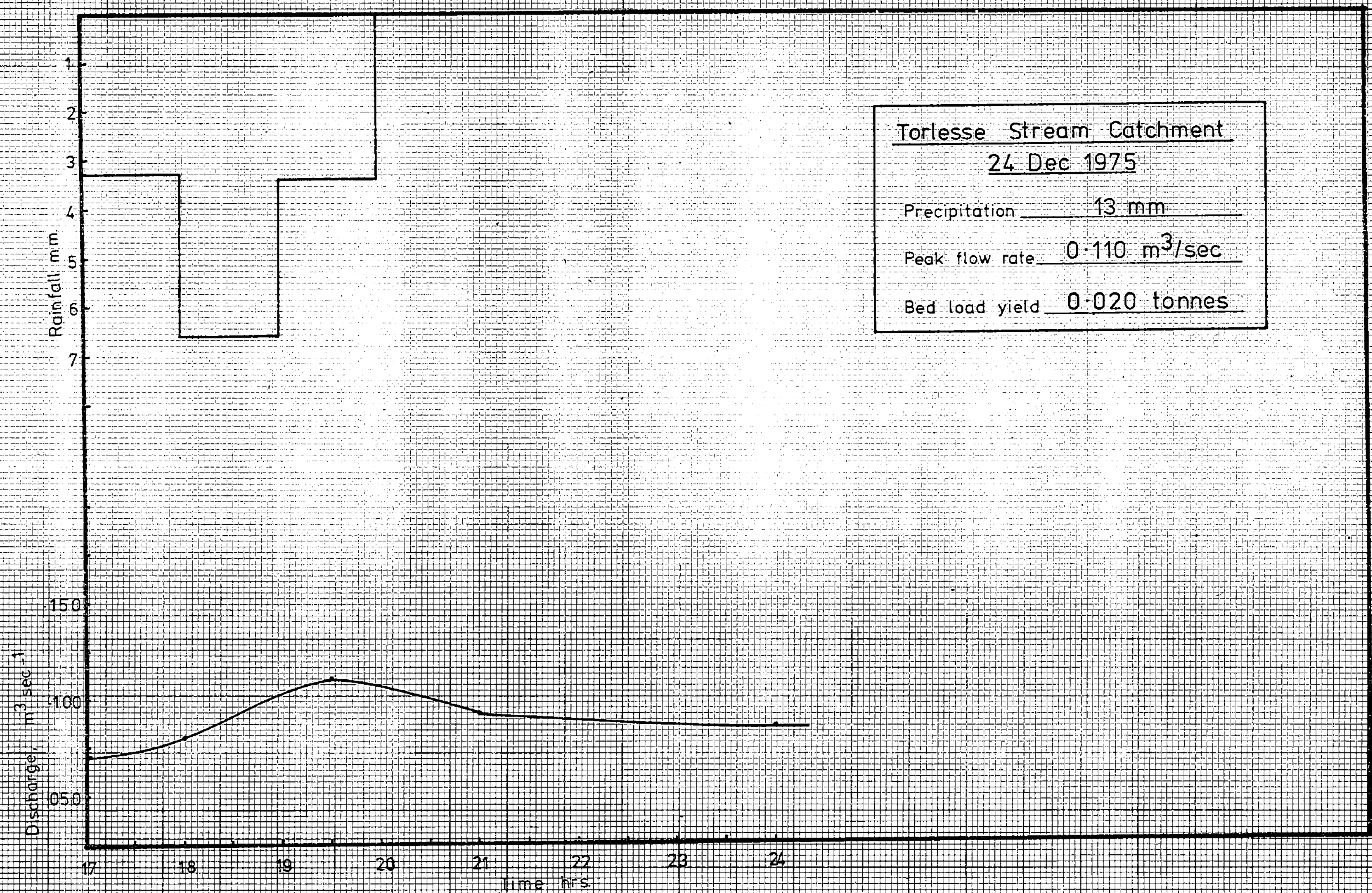
Torlesse Stream Catchment
2 Nov 1975
Precipitation 21 mm
Peak flow rate 0·400 m3/sec
Bed load yield 1·20 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
9
10
Discharge, m3 sec-1
·450
·400
·350
·300
·250
·200
·150
·100
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time hrs



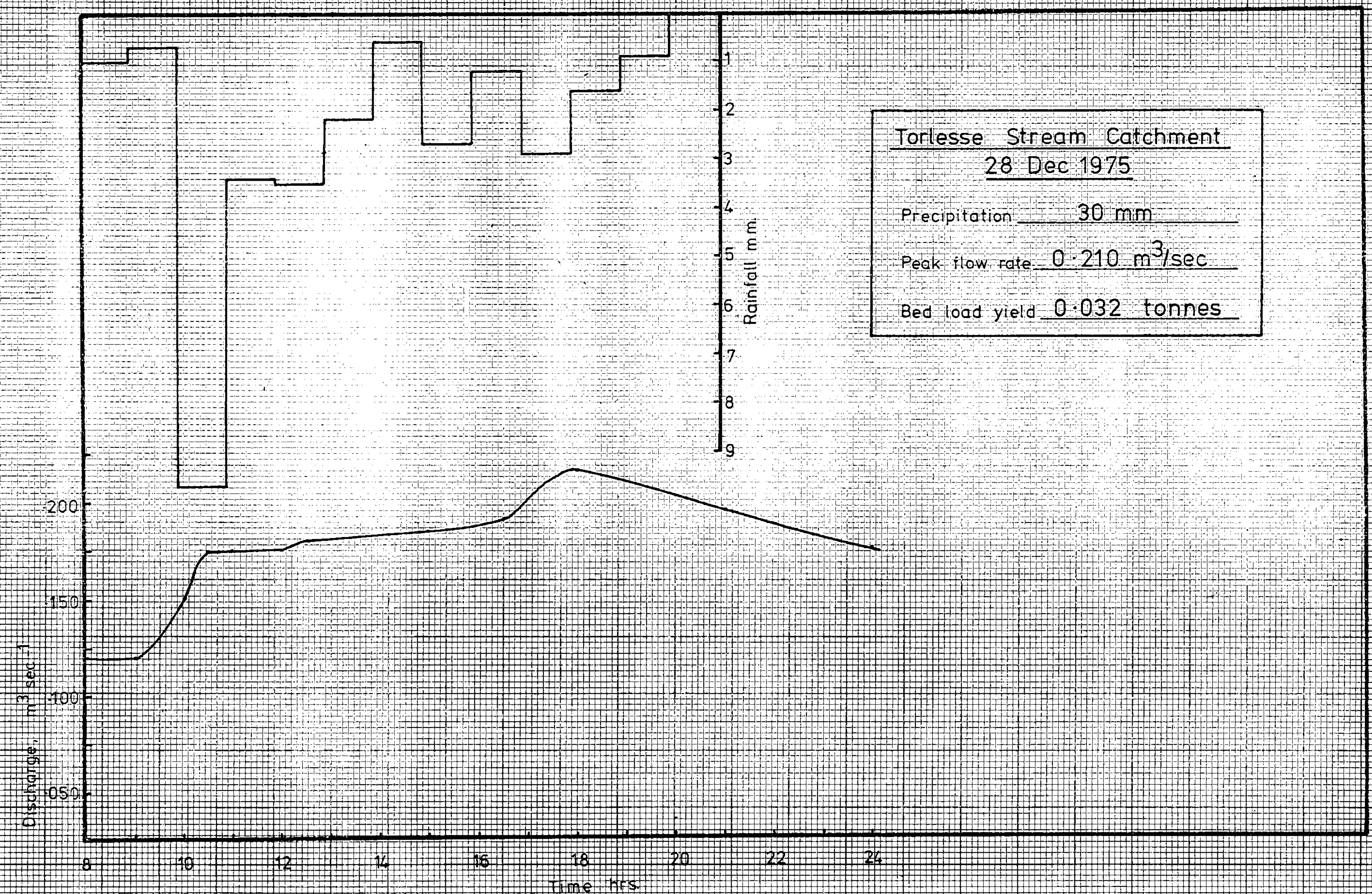
Torlesse Stream Catchment
8 Nov 1975
Precipitation 20 mm
Peak flow rate 0·320 m3/sec
Bed load yield 0·200 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
Discharge, m3 sec-1
100
150
200
250
300
350
Time hrs.
4
5
6
7
8
9
10
11
12
13
14
15
16
17



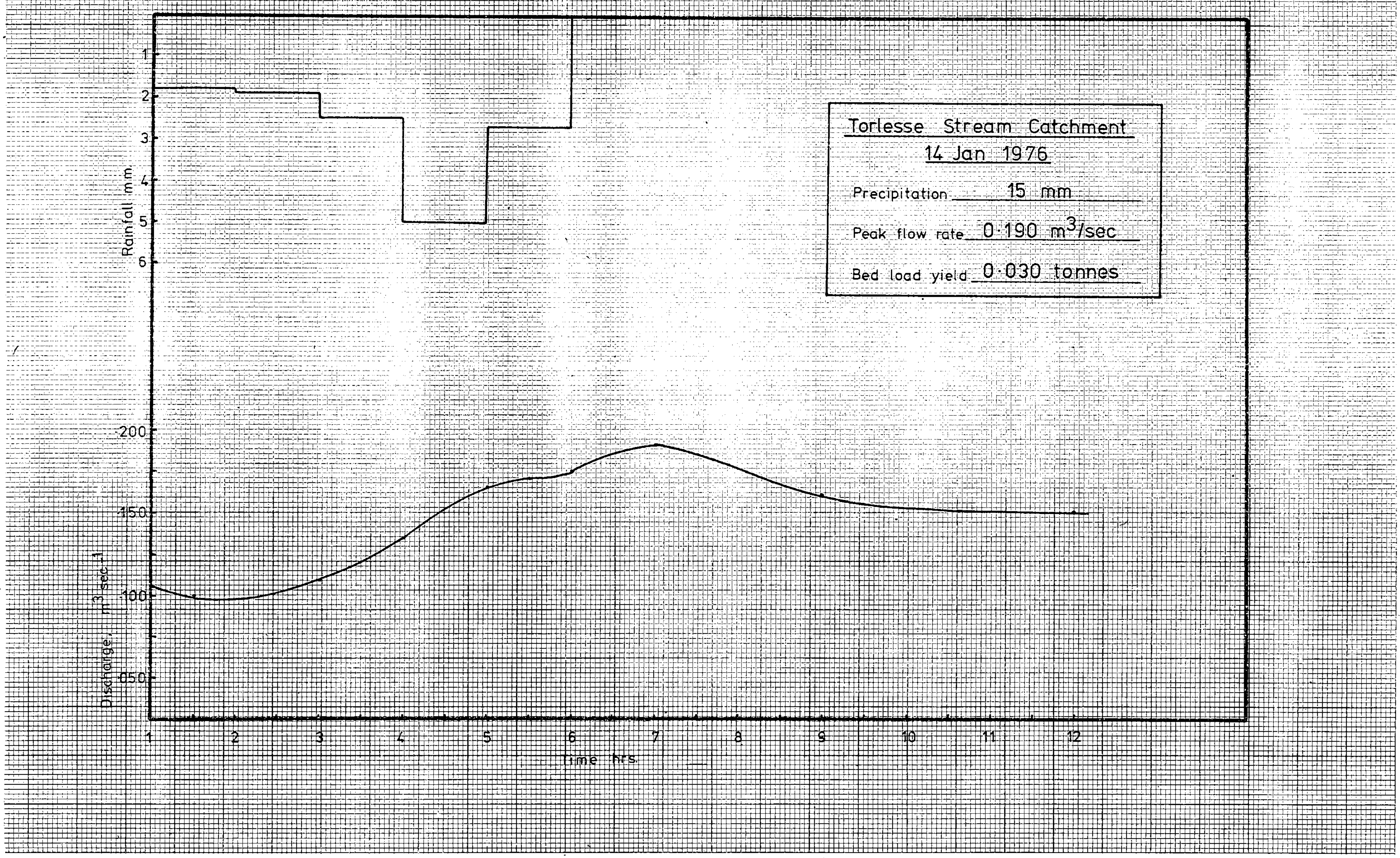
Torlesse Stream Catchment
27 Nov 1975
Precipitation 21 mm
Peak flow rate 0·240 m3/sec
Bed load yield 0·014 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
Discharge, m3 sec-1
250
200
150
100
22
23
24
1
2
3
4
5
6
7
8
9
10
Time hrs



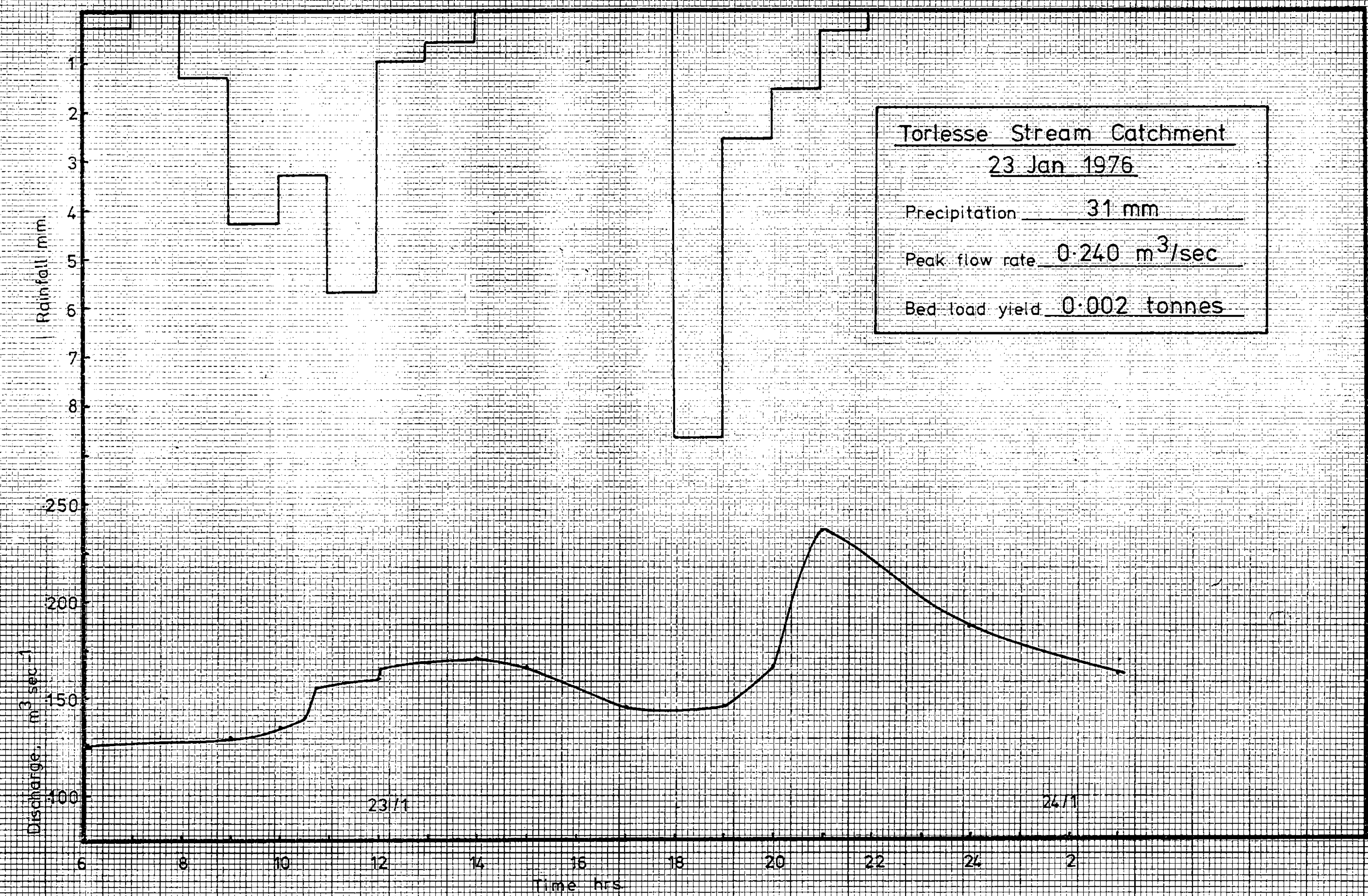
Torlesse Stream Catchment
24 Dec 1975
Precipitation 13 mm
Peak flow rate 0·110 m3/sec
Bed load yield 0·020 tonnes
Rainfall mm.
1
2
3
4
5
6
7
Discharge, m3 sec-1
·150
·100
·050
17
18
19
20
21
22
23
24
Time hrs.



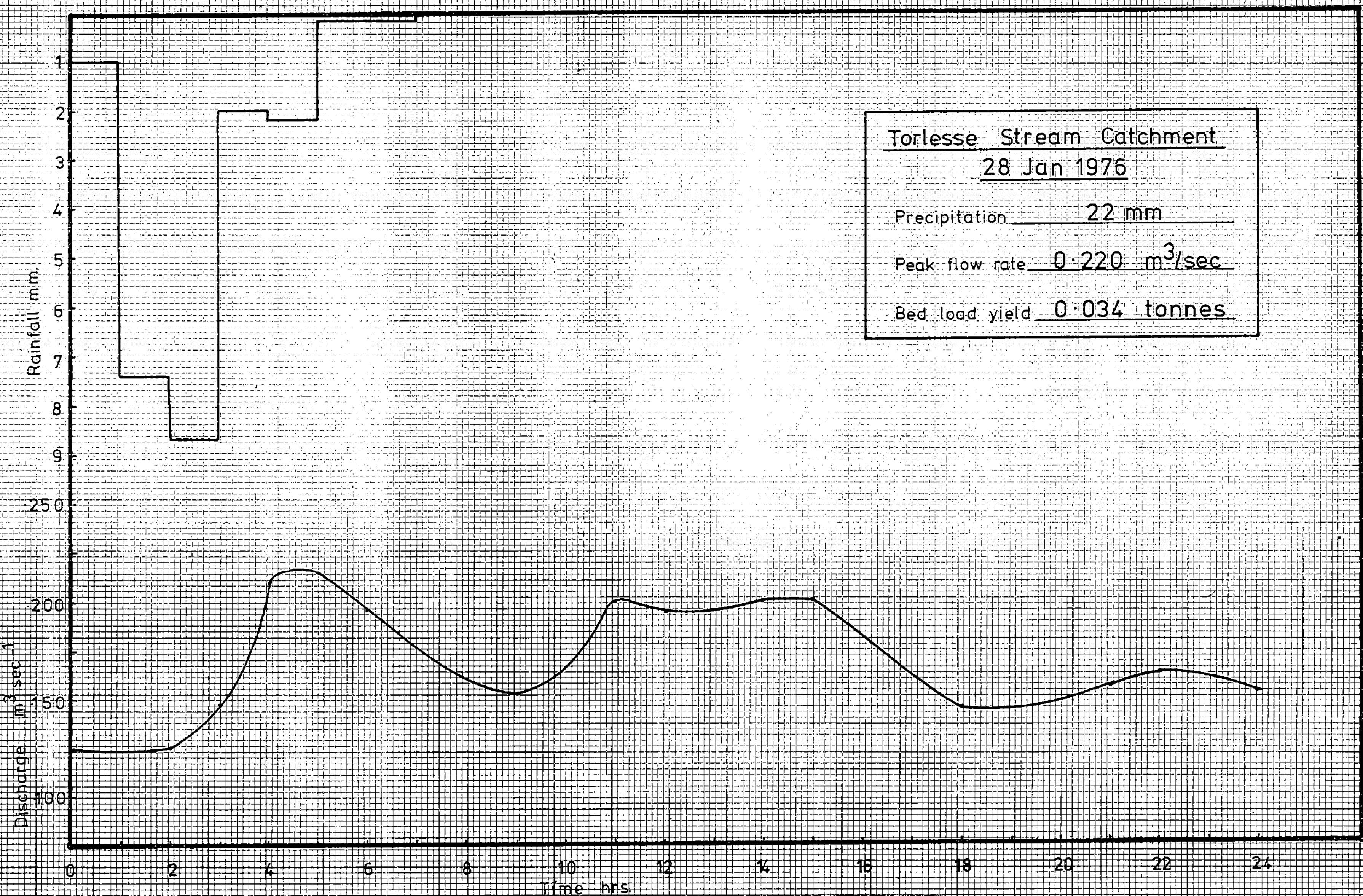
Torlesse Stream Catchment
28 Dec 1975
Precipitation 30 mm
Peak flow rate 0·210 m3/sec
Bed load yield 0·032 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
9
Discharge, m3 sec-1
200
150
100
050
8
10
12
14
16
18
20
22
24
Time hrs

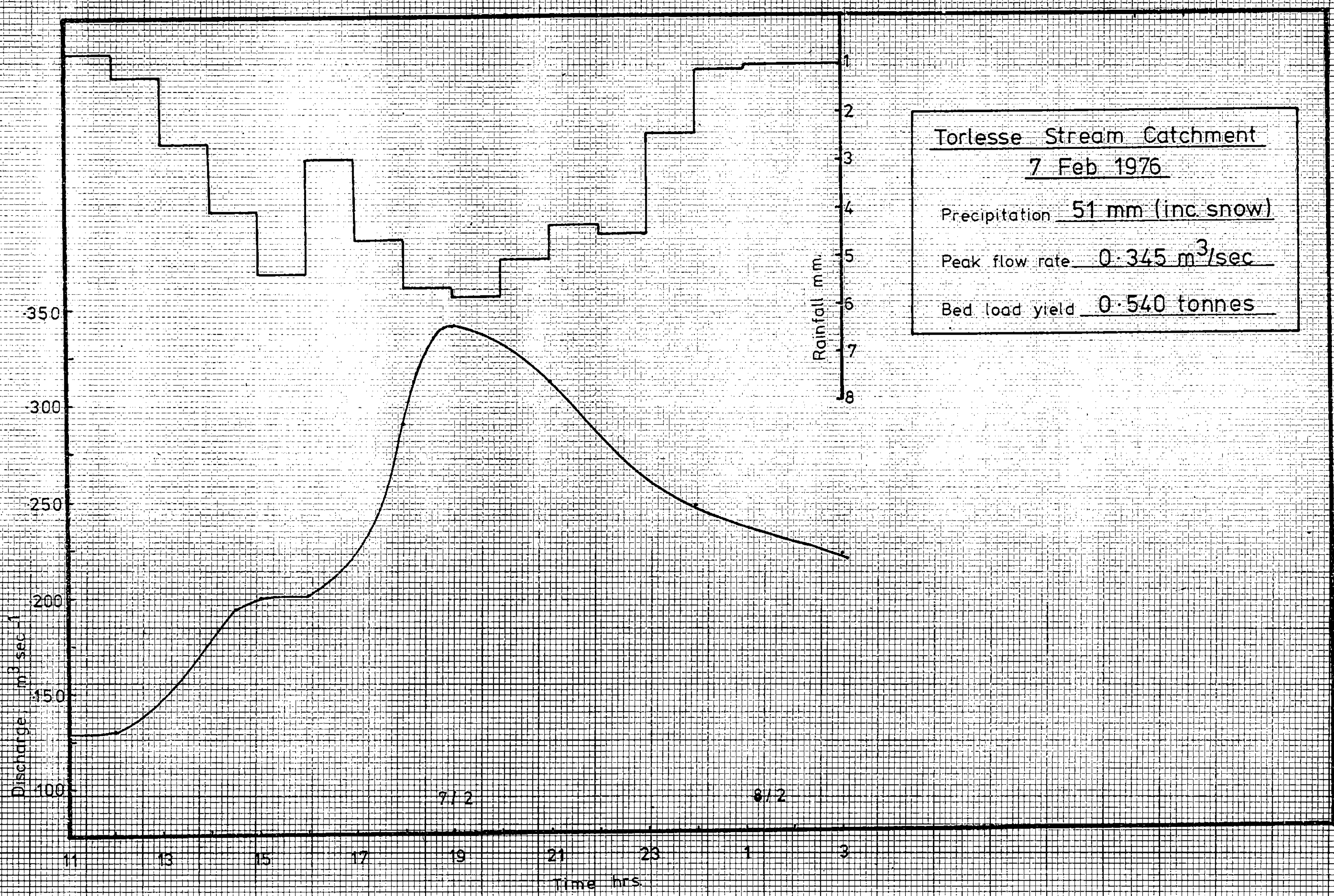


Torlesse Stream Catchment
14 Jan 1976
Precipitation 15 mm
Peak flow rate 0·190 m^3/sec
Bed load yield 0·030 tonnes
Rainfall mm
1
2
3
4
5
6
Discharge, m^3 sec^{-1}
·200
·150
·100
·050
1
2
3
4
5
6
7
8
9
10
11
12
Time hrs.

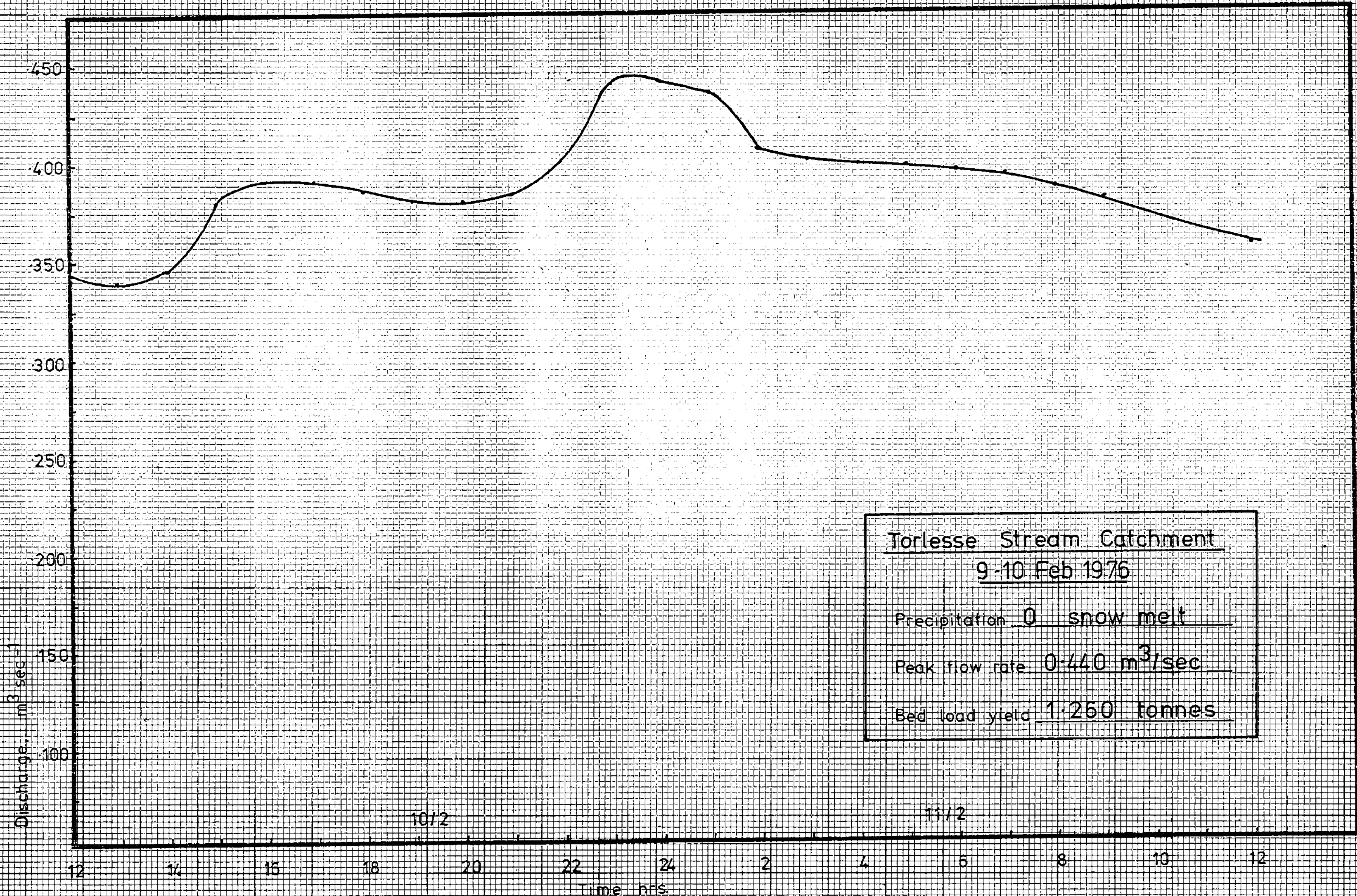


Tortesse Stream Catchment
23 Jan 1976
Precipitation 31 mm
Peak flow rate 0·240 m^3/sec
Bed load yield 0·002 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
250
200
150
100
Discharge, $m^3 sec^{-1}$
23/1
24/1
6
8
10
12
14
16
18
20
22
24
2
Time hrs

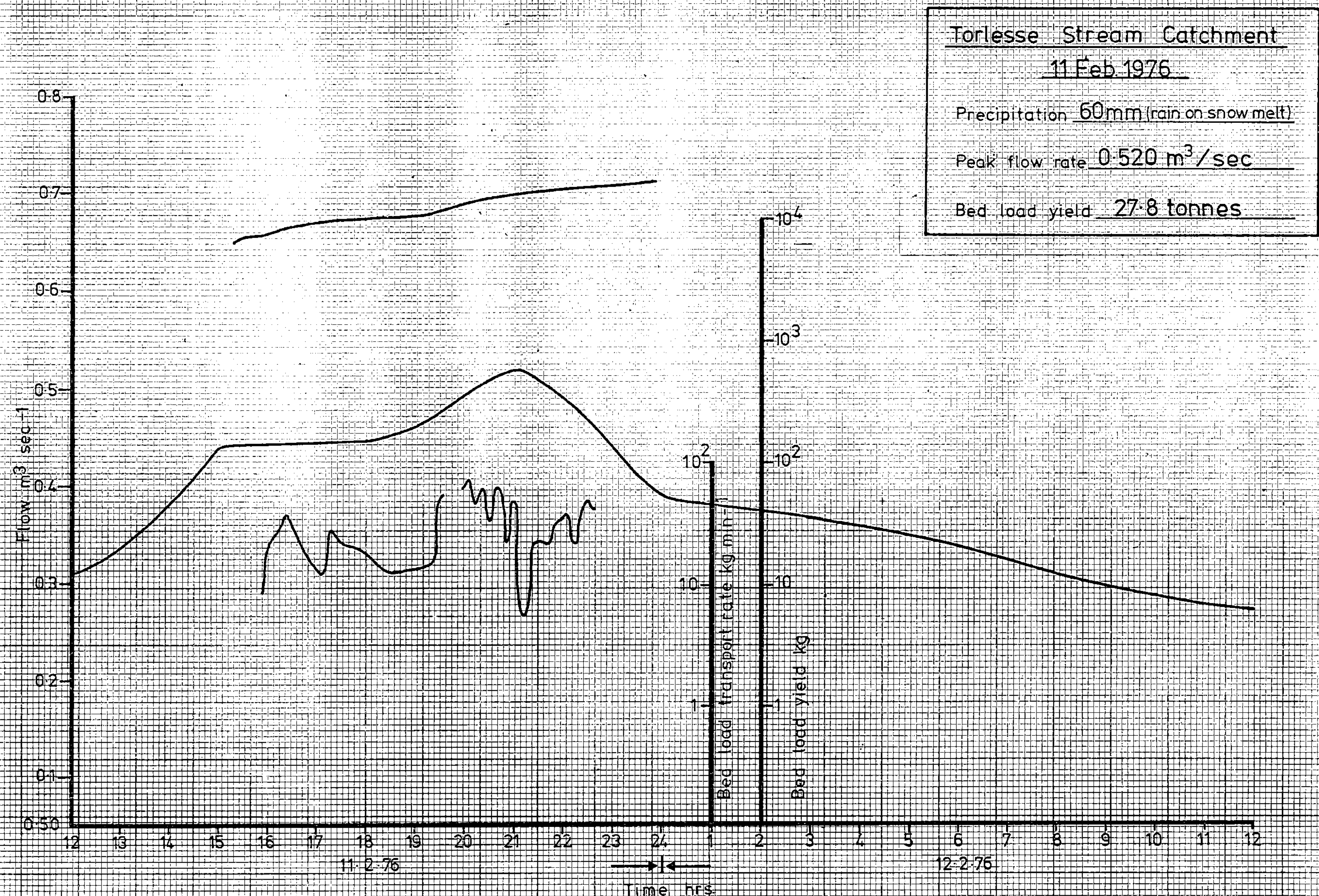

Torlesse Stream Catchment
28 Jan 1976
Precipitation 22 mm
Peak flow rate 0·220 m3/sec
Bed load yield 0·034 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
9
Discharge m3 sec-1
250
200
150
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Time hrs.



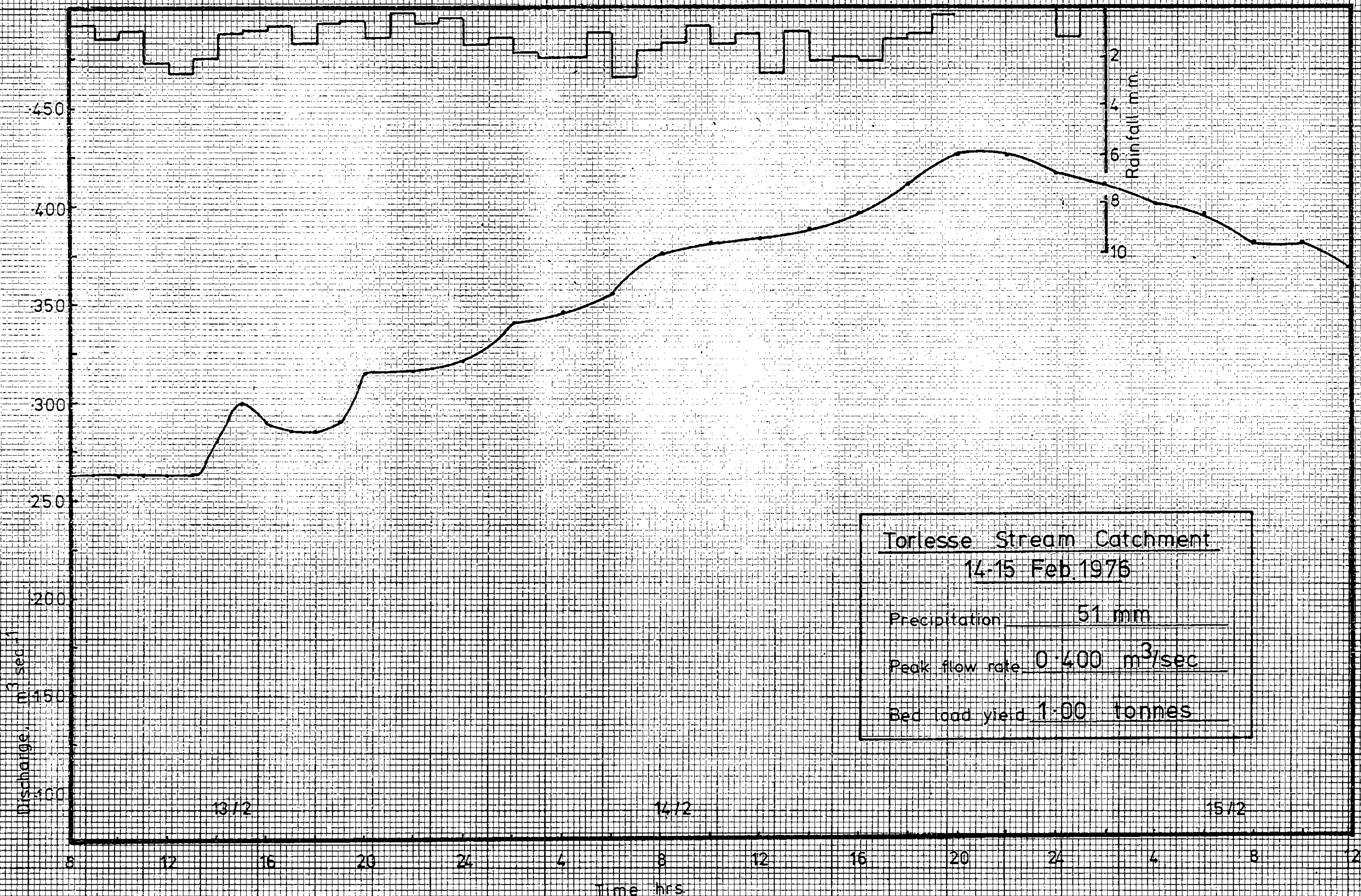
Torlesse Stream Catchment
7 Feb 1976
Precipitation 51 mm (inc snow)
Peak flow rate 0·345 m3/sec
Bed load yield 0·540 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
Discharge m3 sec-1
350
300
250
200
150
100
7/2
8/2
11
13
15
17
19
21
23
1
3
Time hrs



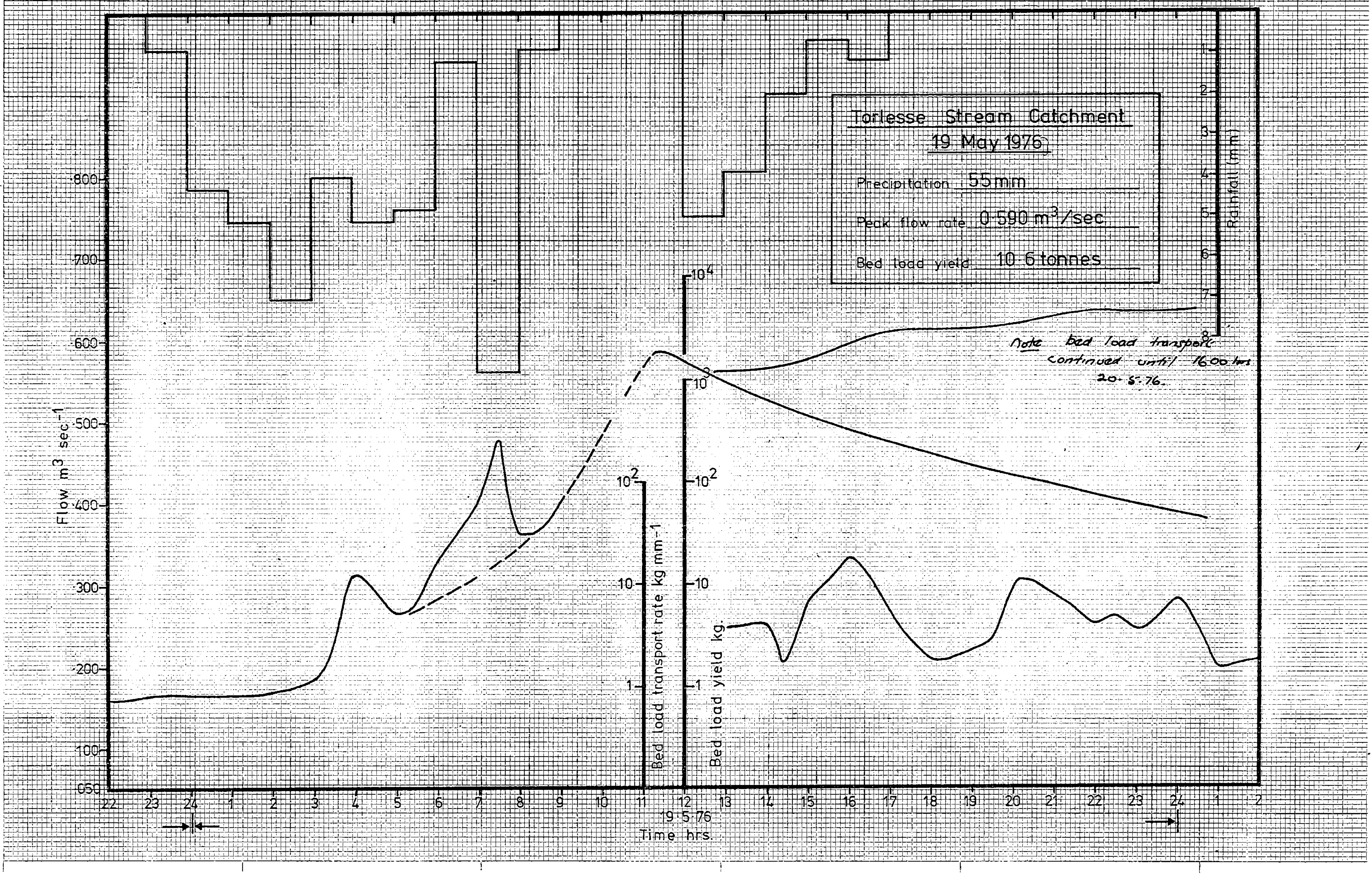
Torlesse Stream Catchment
9-10 Feb 1976
Precipitation 0 snow melt
Peak flow rate 0·440 m3/sec
Bed load yield 1·260 tonnes
Discharge, m3 sec-1
450
400
350
300
250
200
150
100
10/2
11/2
12
14
16
18
20
22
24
2
4
6
8
10
12
Time hrs



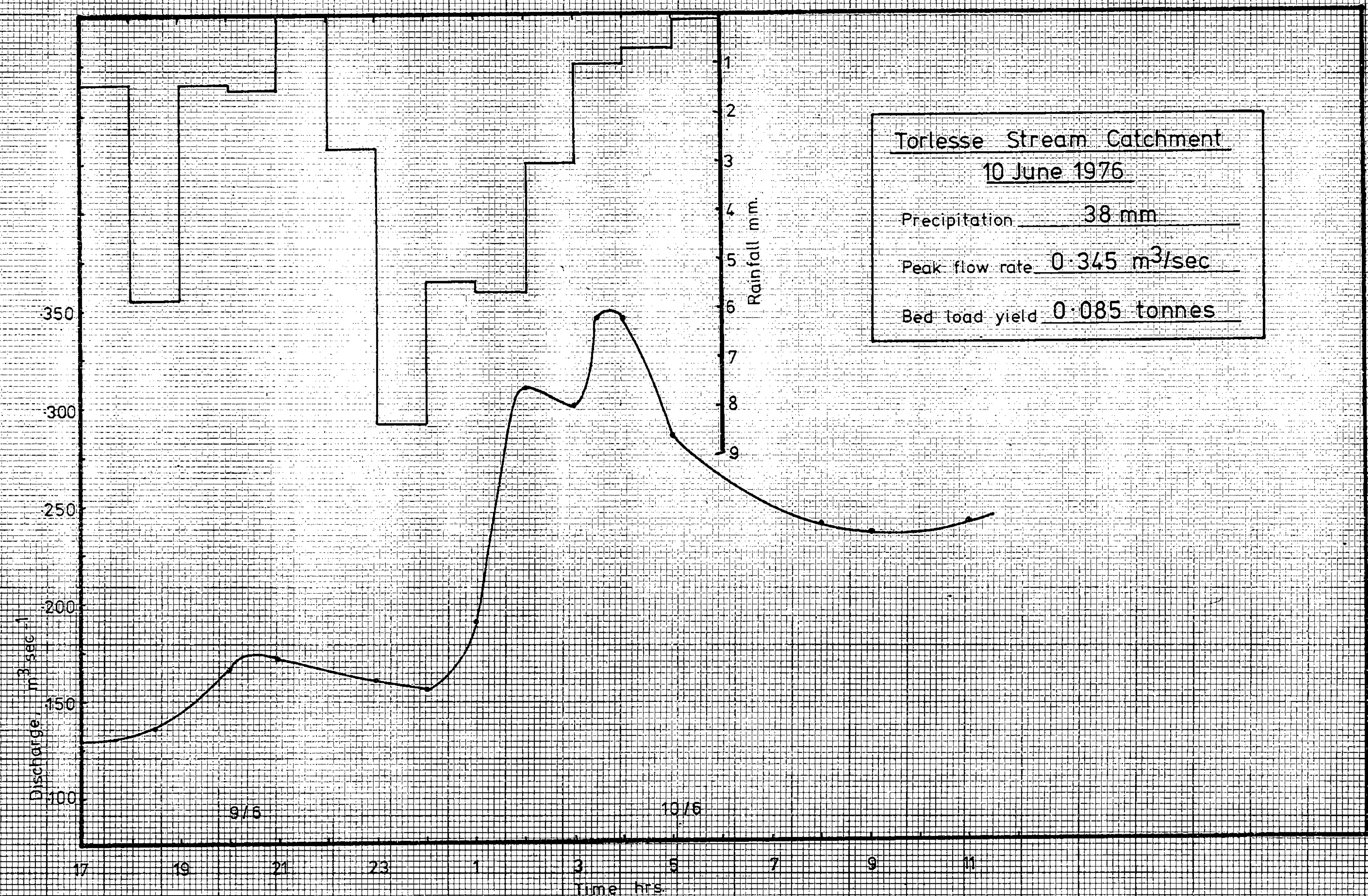
Torlesse Stream Catchment
11 Feb 1976
Precipitation 60mm (rain on snow melt)
Peak flow rate 0·520 m3/sec
Bed load yield 27·8 tonnes
Flow m3 sec-1
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·50
Bed load transport rate kg min-1
Bed load yield kg
10^4
10^3
10^2
10
1
12 13 14 15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12
11·2·76
12·2·76
Time hrs

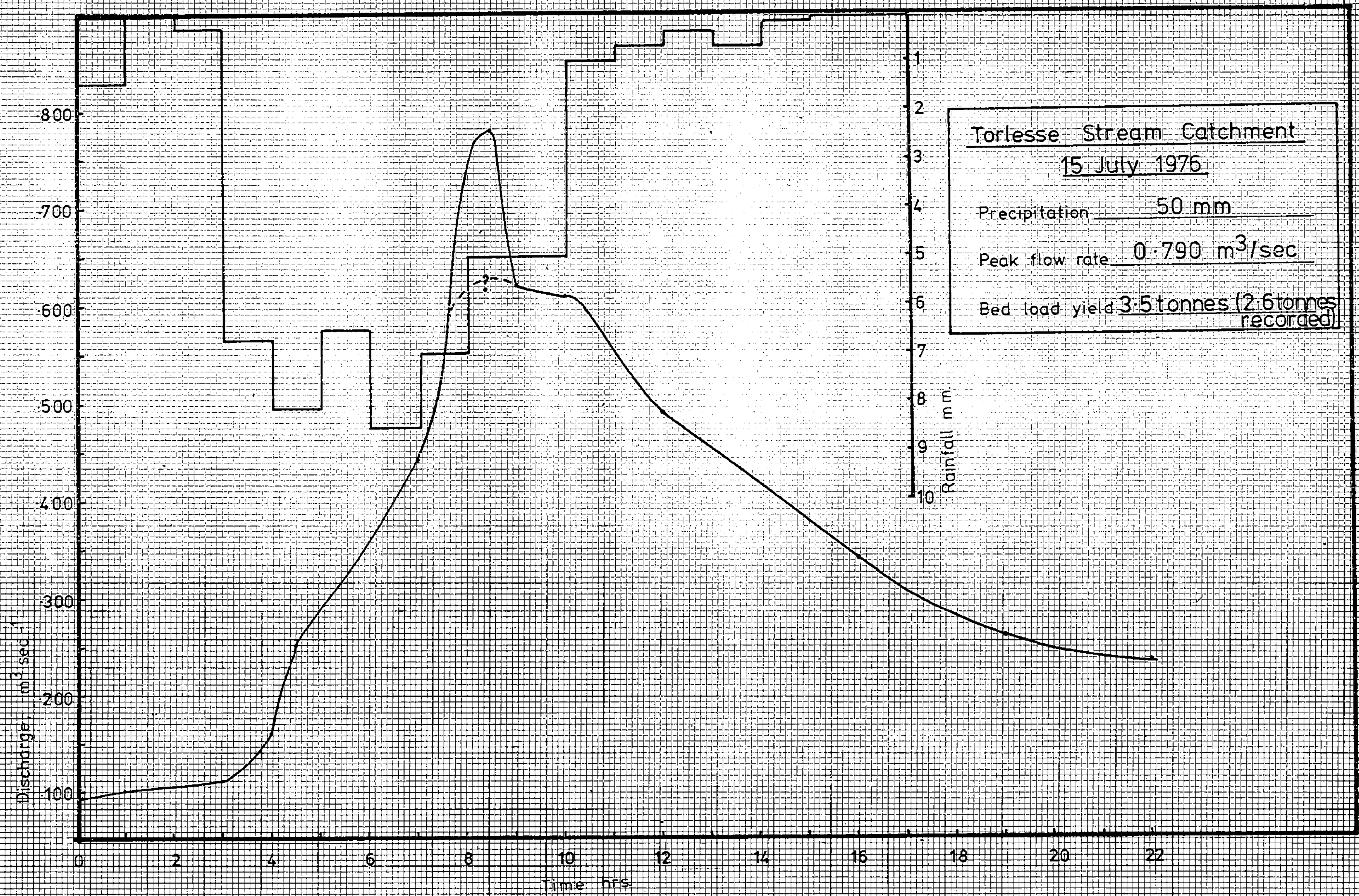


450
400
350
300
250
200
150
100
Discharge m3 sec-1
2
4
6
8
10
Rainfall mm
13/2
14/2
15/2
8
12
16
20
24
4
8
12
16
20
24
4
8
12
Time hrs
Torlesse Stream Catchment
14-15 Feb 1976
Precipitation 51 mm
Peak flow rate 0·400 m3/sec
Bed load yield 1·00 tonnes

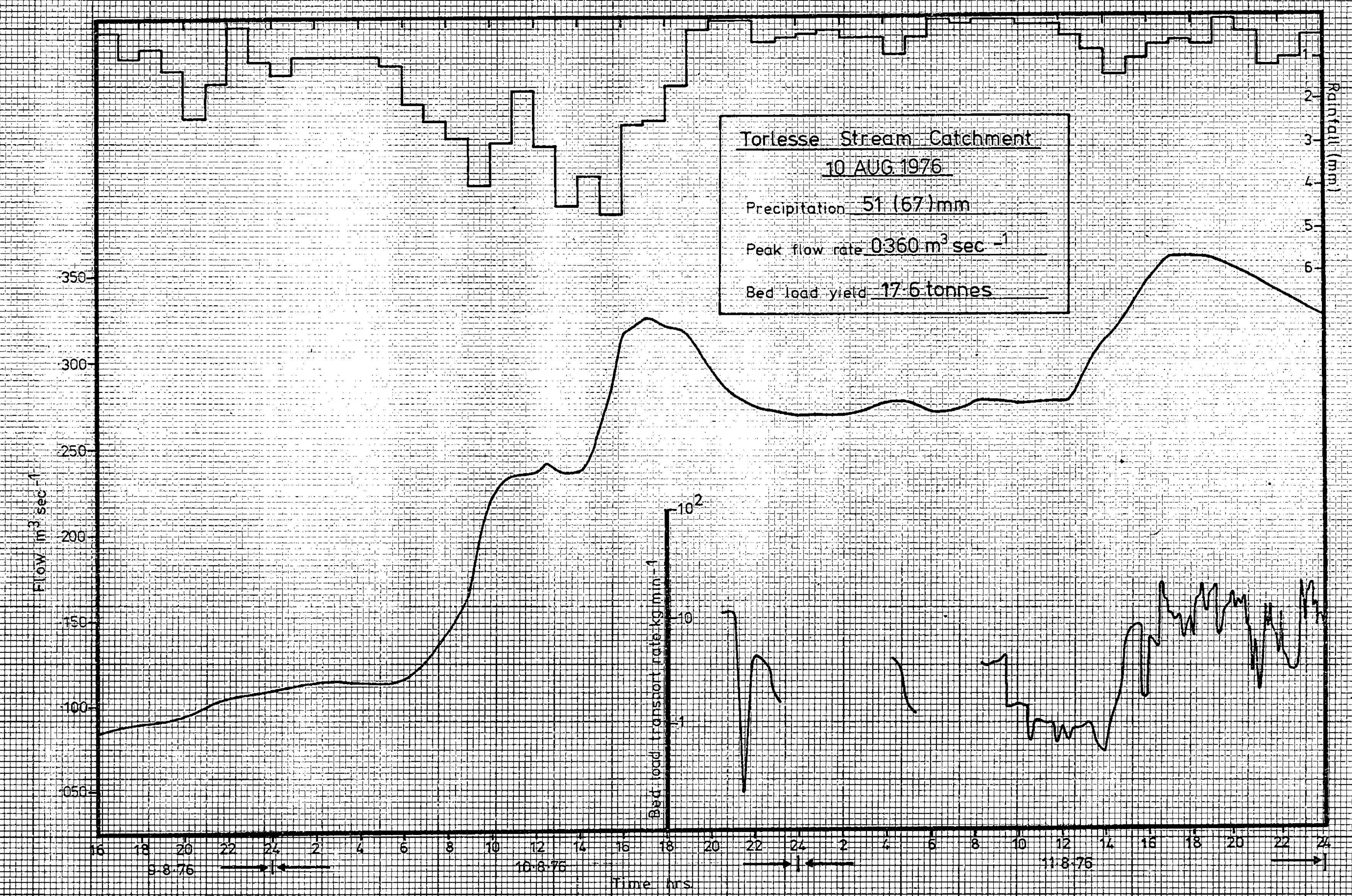


Torlesse Stream Catchment
19 May 1976
Precipitation 55 mm
Peak flow rate 0 590 m³/sec
Bed load yield 10 6 tonnes
Note bed load transport continued until 16.00 hrs 20-5-76.
Flow m3 sec-1
Bed load transport rate kg m.m-1
Bed load yield kg.
Rainfall (mm)
19 5 76
Time hrs.

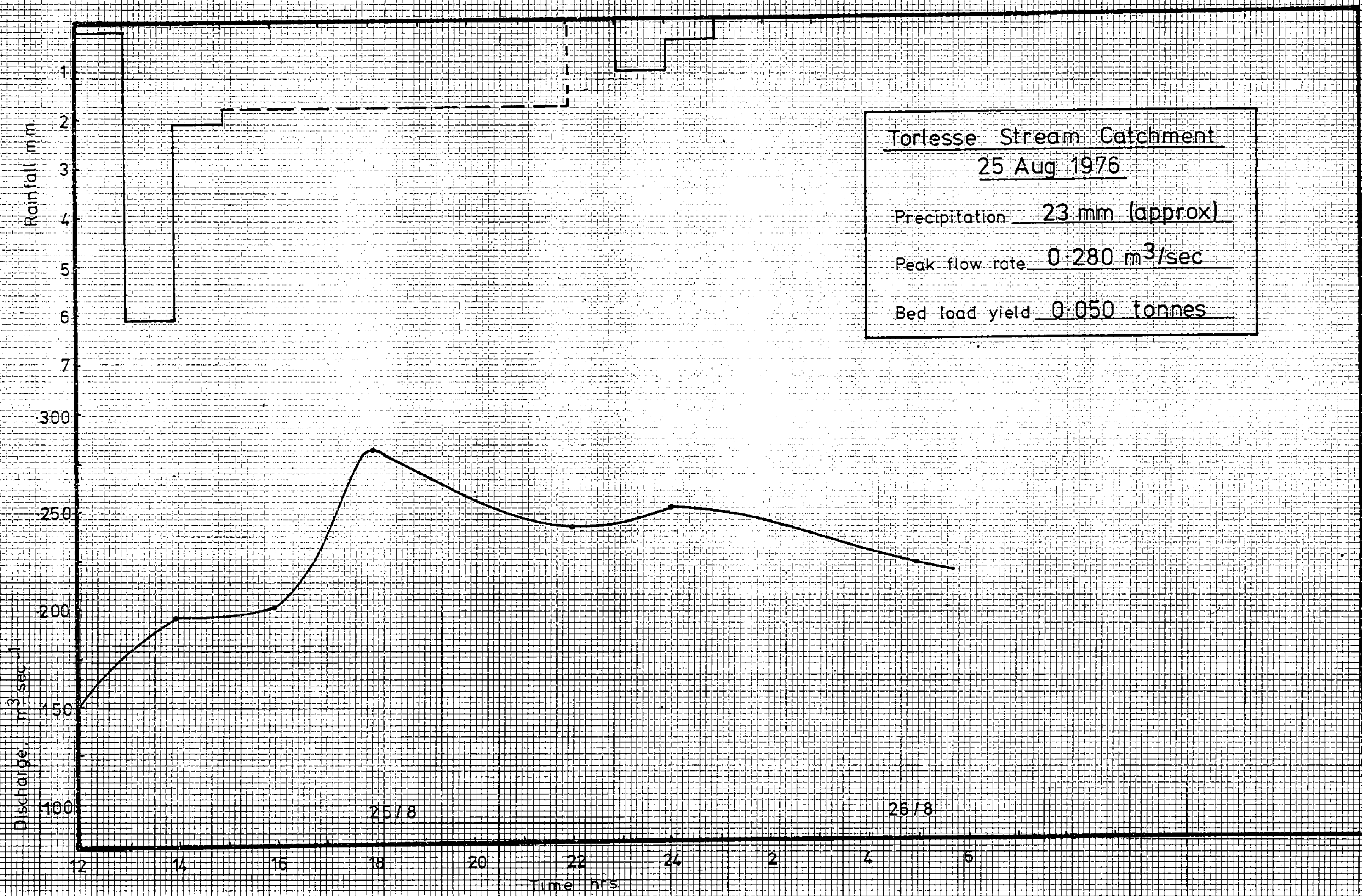

Torlesse Stream Catchment
10 June 1976
Precipitation 38 mm
Peak flow rate 0·345 m3/sec
Bed load yield 0·085 tonnes
Rainfall mm.
1
2
3
4
5
6
7
8
9
Discharge m3 sec-1
350
300
250
200
150
100
9/6
10/6
17
19
21
23
1
3
5
7
9
11
Time hrs.



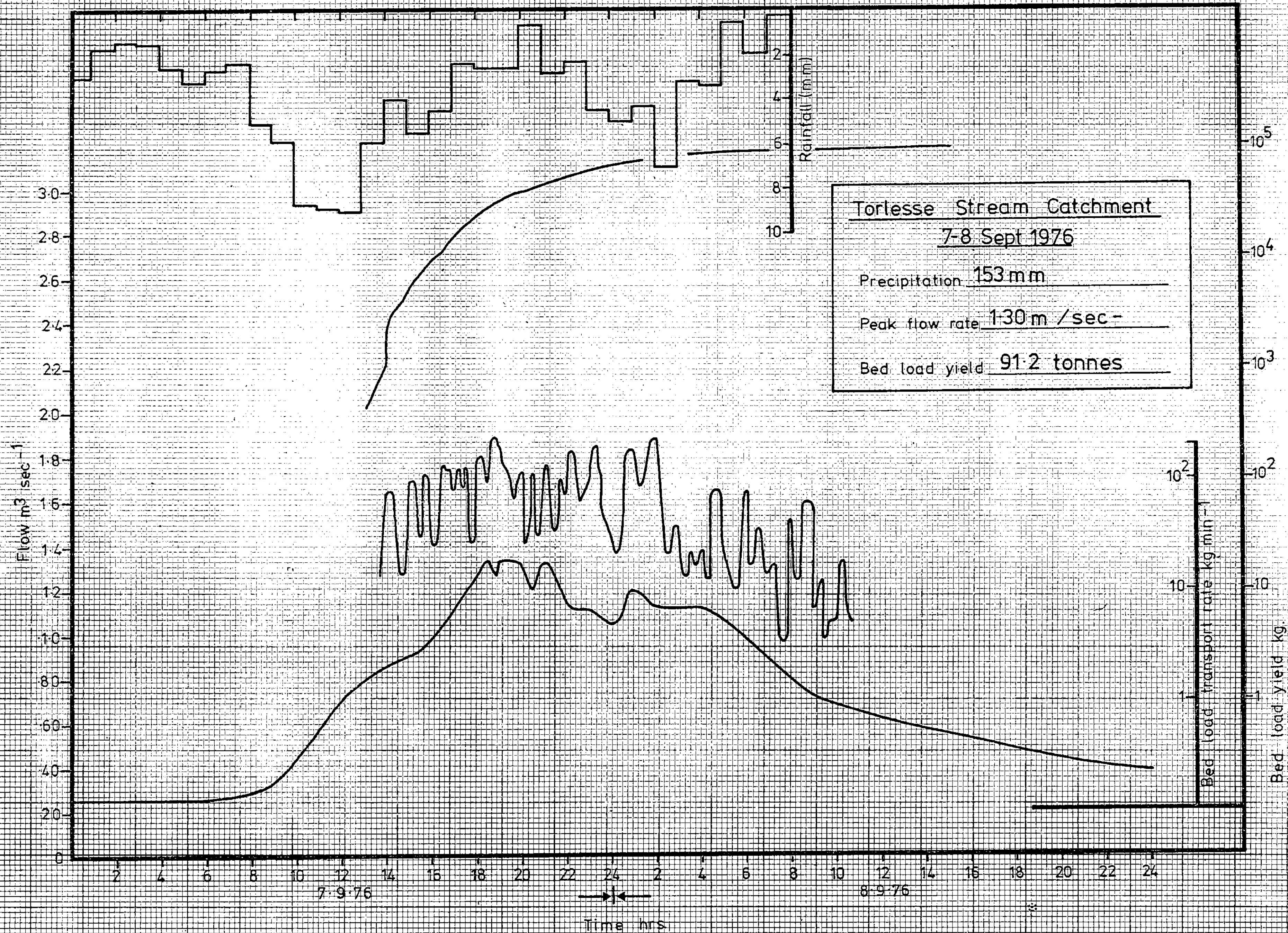
Torlesse Stream Catchment
15 July 1976
Precipitation 50 mm
Peak flow rate 0·790 m3/sec
Bed load yield 3·5 tonnes (2·6 tonnes recorded)
Discharge, m3 sec-1
Raintall mm
Time hrs
800
700
600
500
400
300
200
100
0
2
4
6
8
10
12
14
16
18
20
22
1
2
3
4
5
6
7
8
9
10



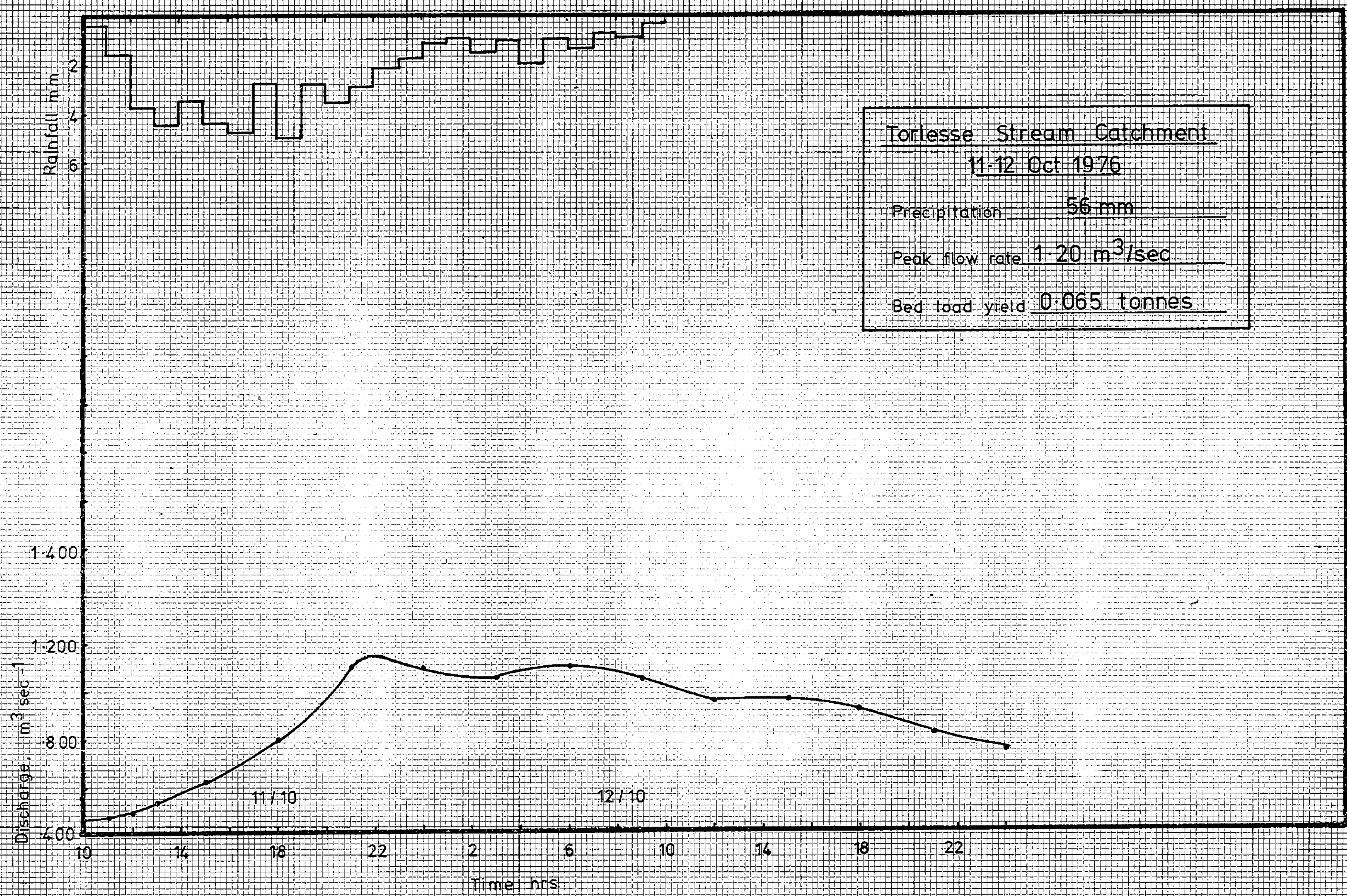
Torlesse Stream Catchment
10 AUG 1976
Precipitation 51 (67) mm
Peak flow rate 0·360 m³ sec⁻¹
Bed load yield 17·6 tonnes
Rainfall (mm)
Flow m³ sec⁻¹
Bed load transport rate kg min⁻¹
Time hrs
9·8·76
10·8·76
11·8·76



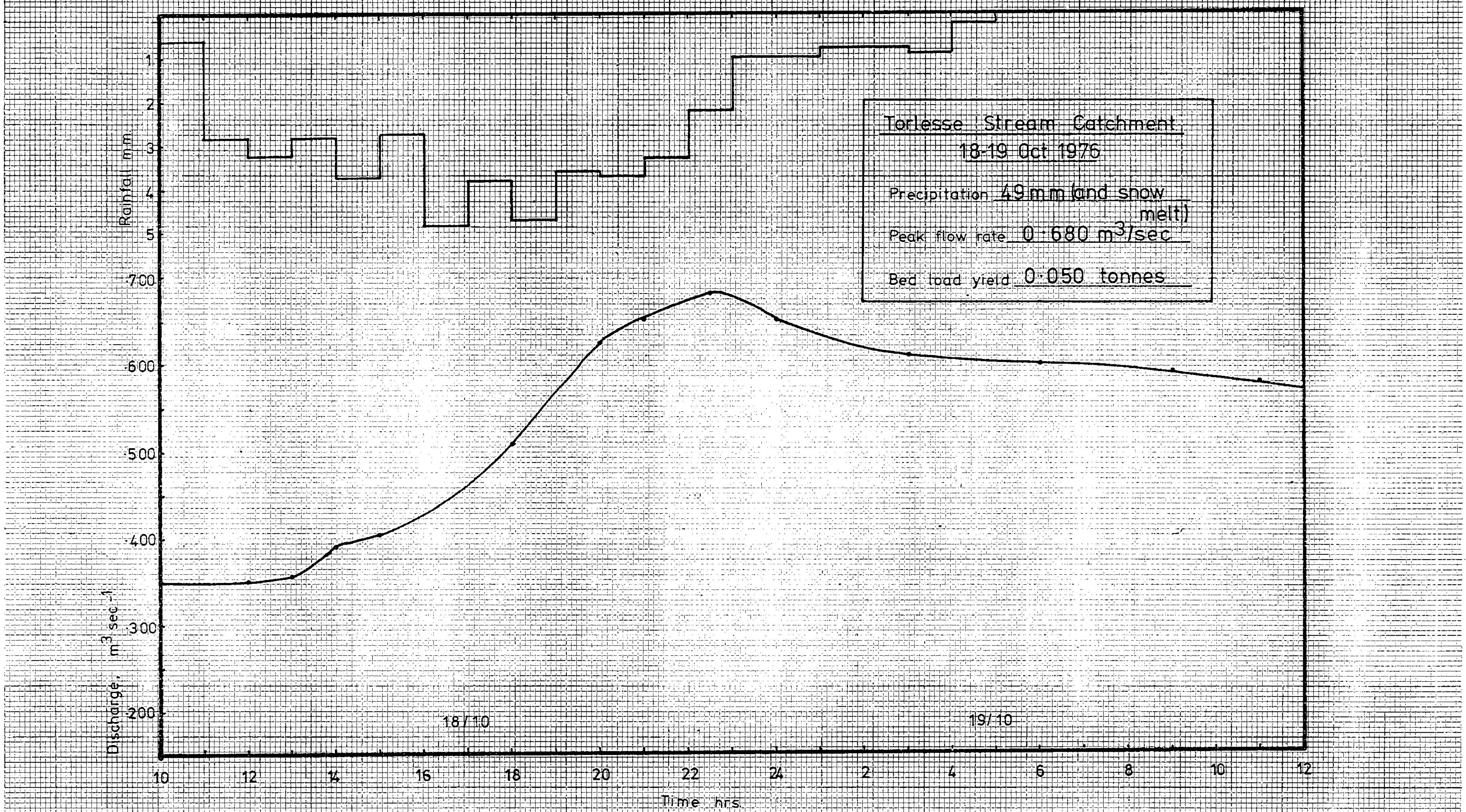
Torlesse Stream Catchment
25 Aug 1976
Precipitation 23 mm (approx)
Peak flow rate 0·280 m3/sec
Bed load yield 0·050 tonnes
Rainfall mm
1
2
3
4
5
6
7
Discharge, m3 sec-1
300
250
200
150
100
25/8
25/8
12
14
16
18
20
22
24
2
4
6
Time hrs



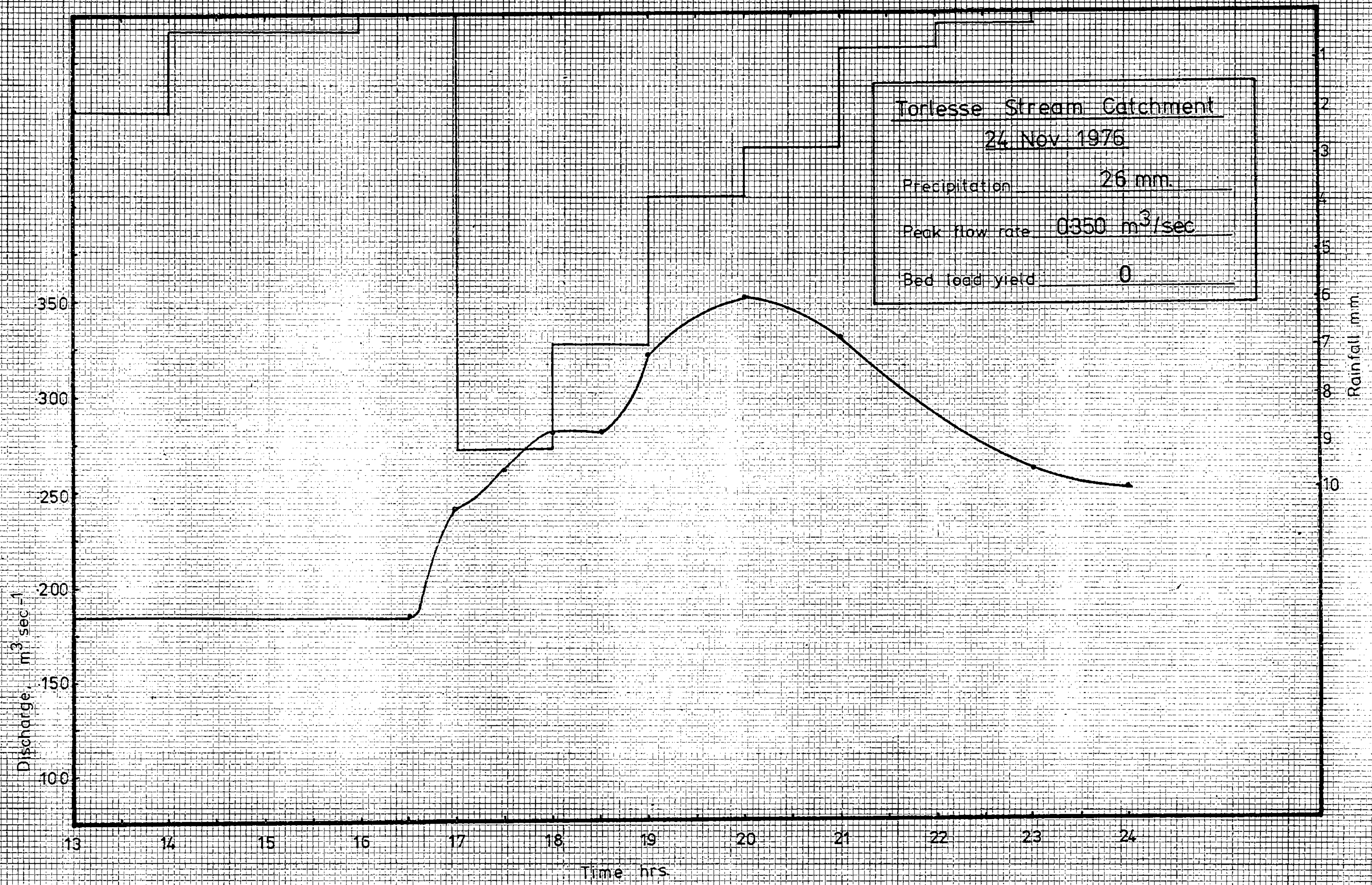
Torlesse Stream Catchment
7-8 Sept 1976
Precipitation 153 mm
Peak flow rate 1·30 m /sec
Bed load yield 91·2 tonnes
Rainfall (mm)
Flow m3 sec−1
Bed load transport rate kg min−1
Bed load yield kg
7·9·76
8·9·76
Time hrs



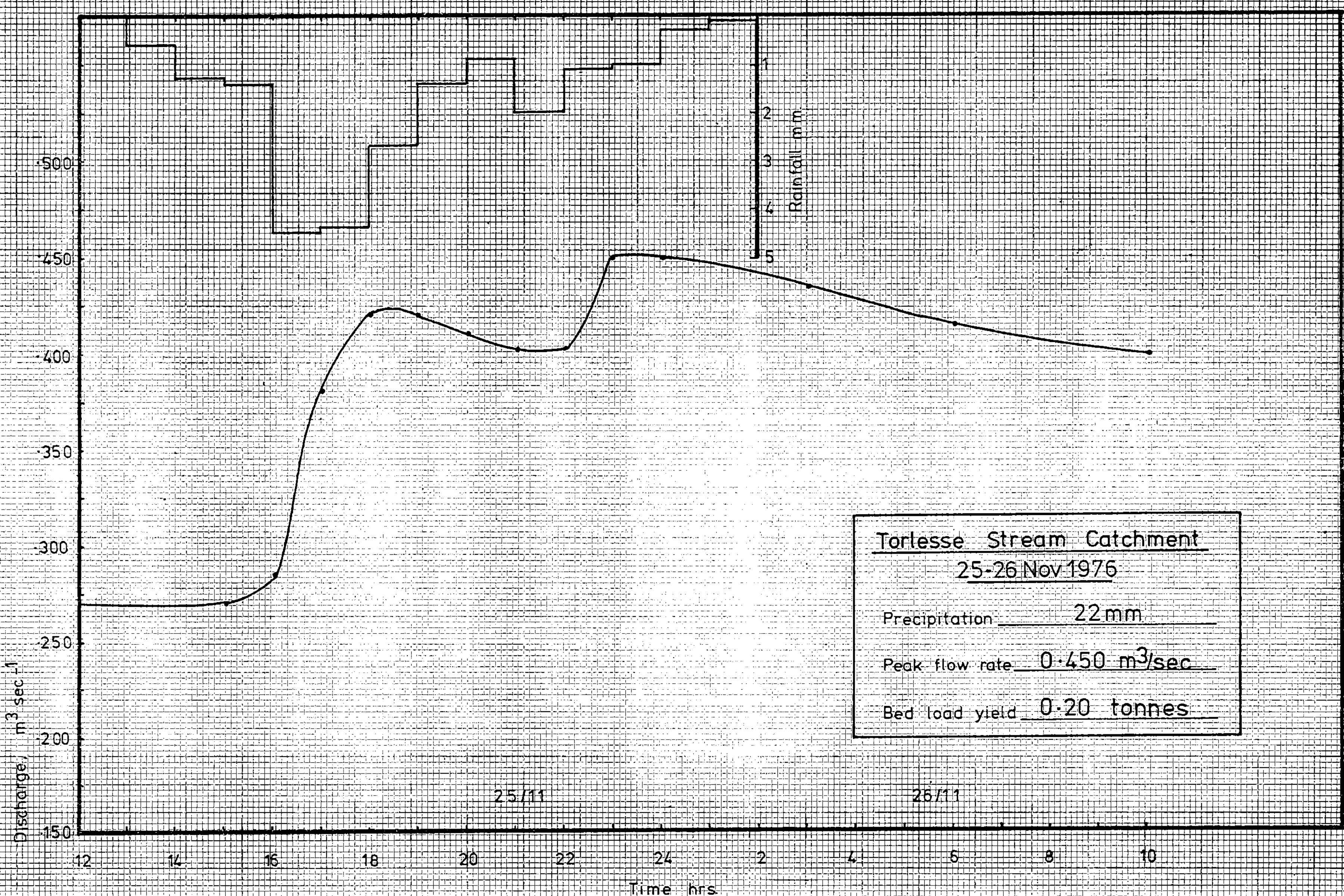
Torlesse Stream Catchment
11-12 Oct 1976
Precipitation 56 mm
Peak flow rate 1·20 m3/sec
Bed load yield 0·065 tonnes
Rainfall m.m.
2
4
6
1·400
1·200
·800
·400
Discharge, m3 sec-1
11/10
12/10
10
14
18
22
2
6
10
14
18
22
Time hrs



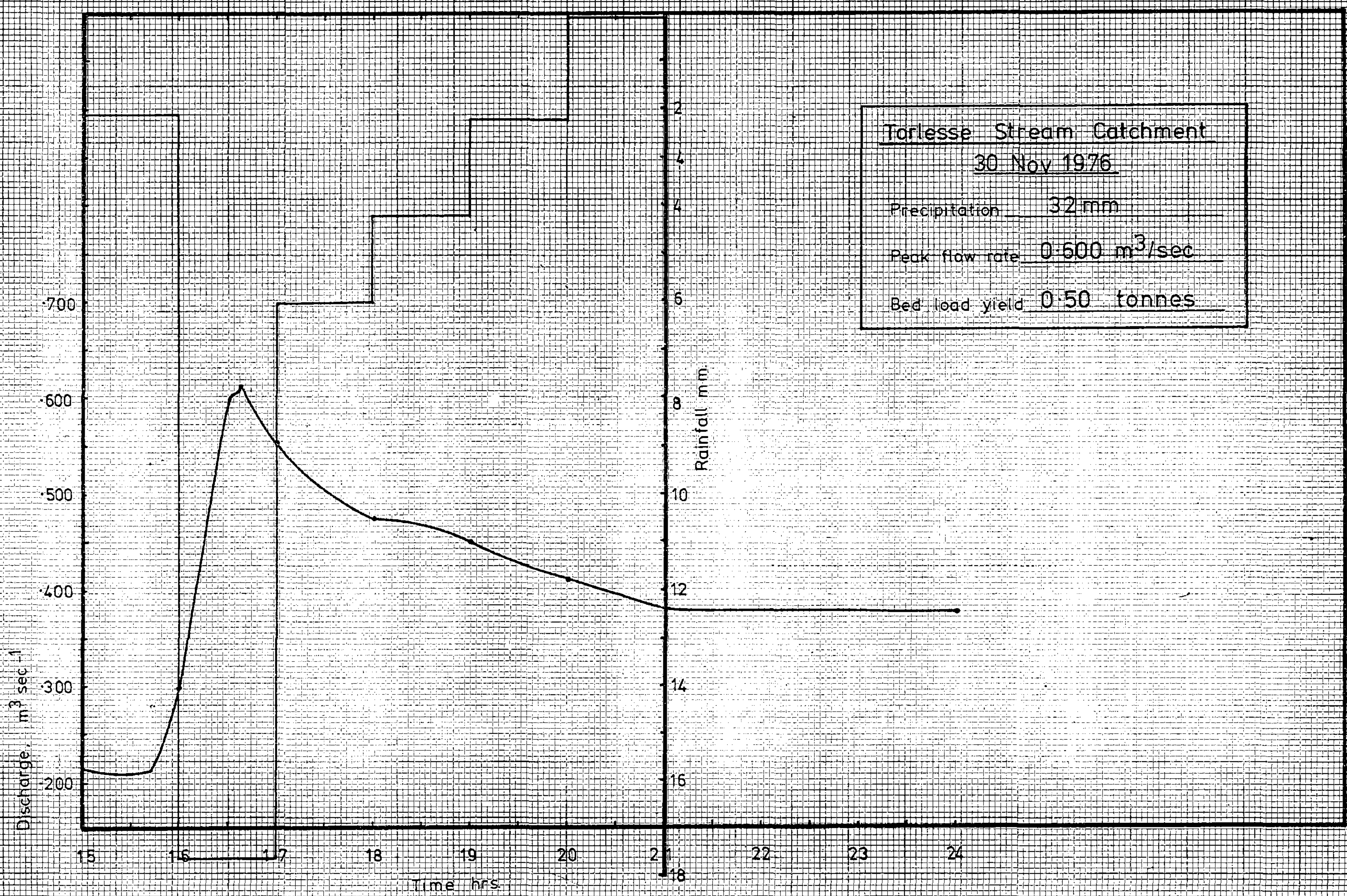
Torlesse Stream Catchment
18-19 Oct 1976
Precipitation 49 mm (and snow melt)
Peak flow rate 0·680 m³/sec
Bed load yield 0·050 tonnes
Rainfall mm
1
2
3
4
5
·700
·600
·500
·400
·300
·200
Discharge, m³ sec-1
18/10
19/10
10
12
14
16
18
20
22
24
2
4
6
8
10
12
Time hrs



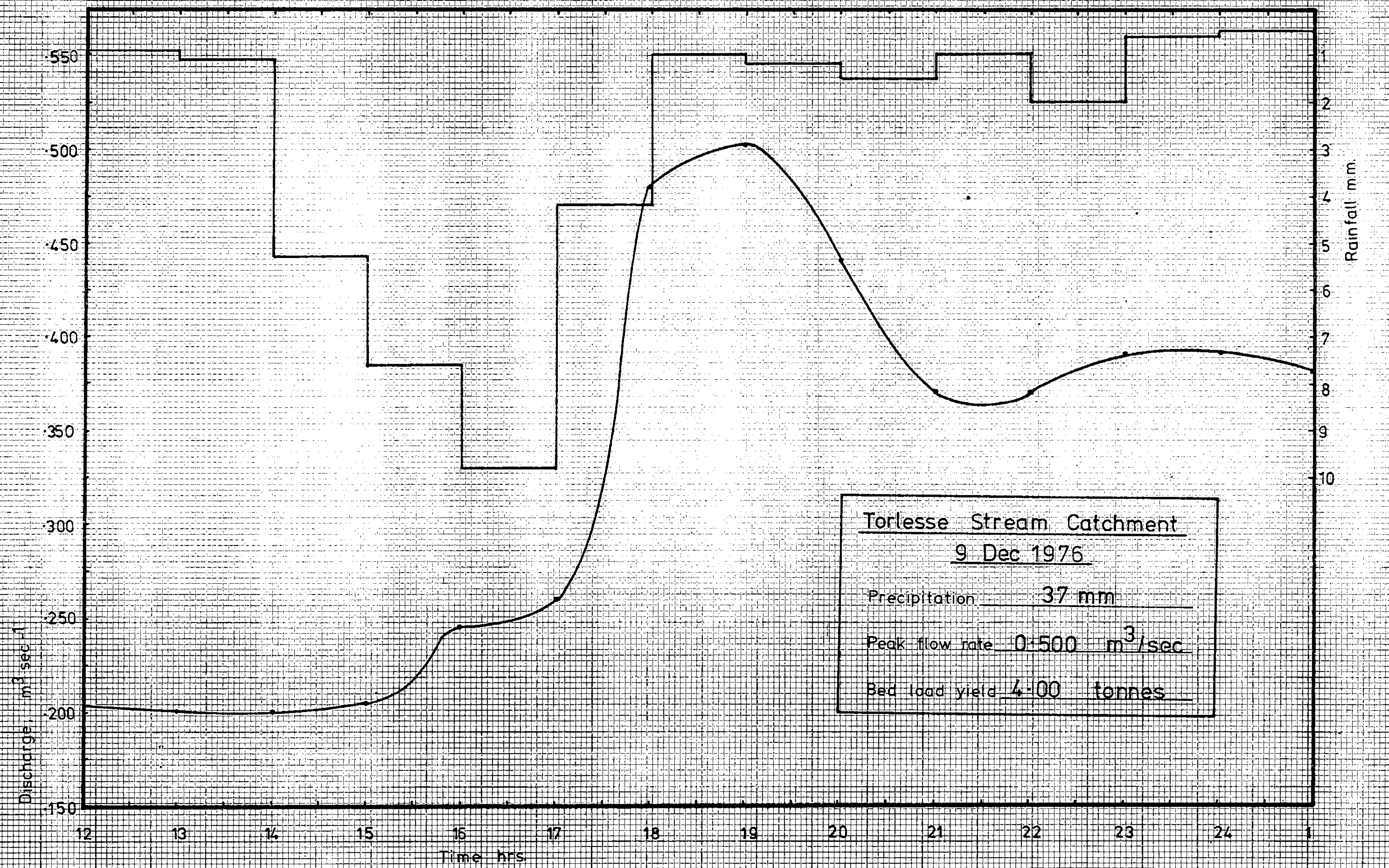
Torlesse Stream Catchment
24 Nov 1976
Precipitation 26 mm.
Peak flow rate 0350 m3/sec
Bed load yield 0
Discharge, m3 sec-1
350
300
250
200
150
100
Rainfall mm
1
2
3
4
5
6
7
8
9
10
13
14
15
16
17
18
19
20
21
22
23
24
Time hrs.

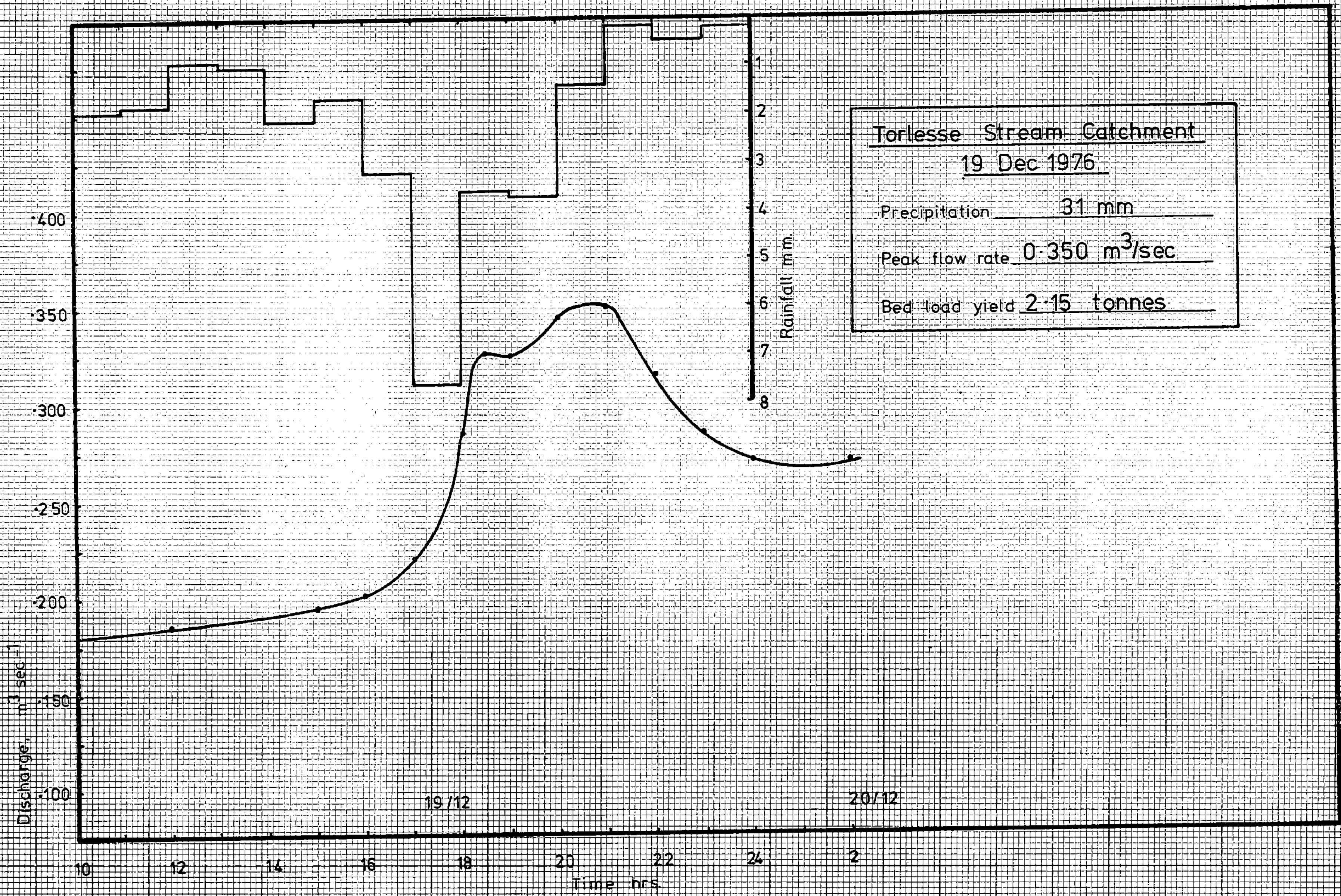


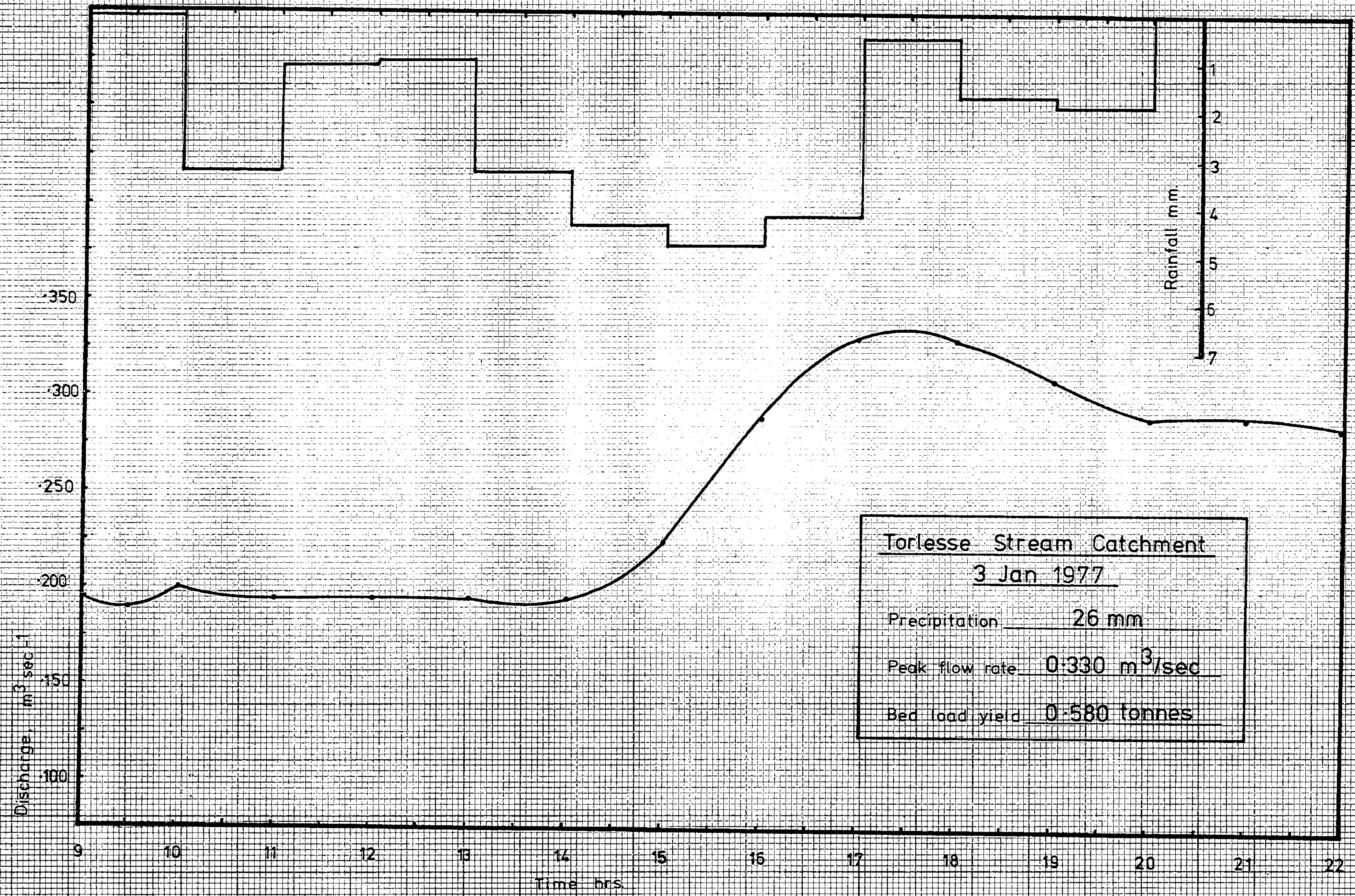
Torlesse Stream Catchment
25-26 Nov 1976
Precipitation 22 mm
Peak flow rate 0·450 m^3/sec
Bed load yield 0·20 tonnes
Rainfall mm
1
2
3
4
5
Discharge, $m^3\ sec^{-1}$
·500
·450
·400
·350
·300
·250
·200
·150
25/11
26/11
12
14
16
18
20
22
24
2
4
6
8
10
Time hrs



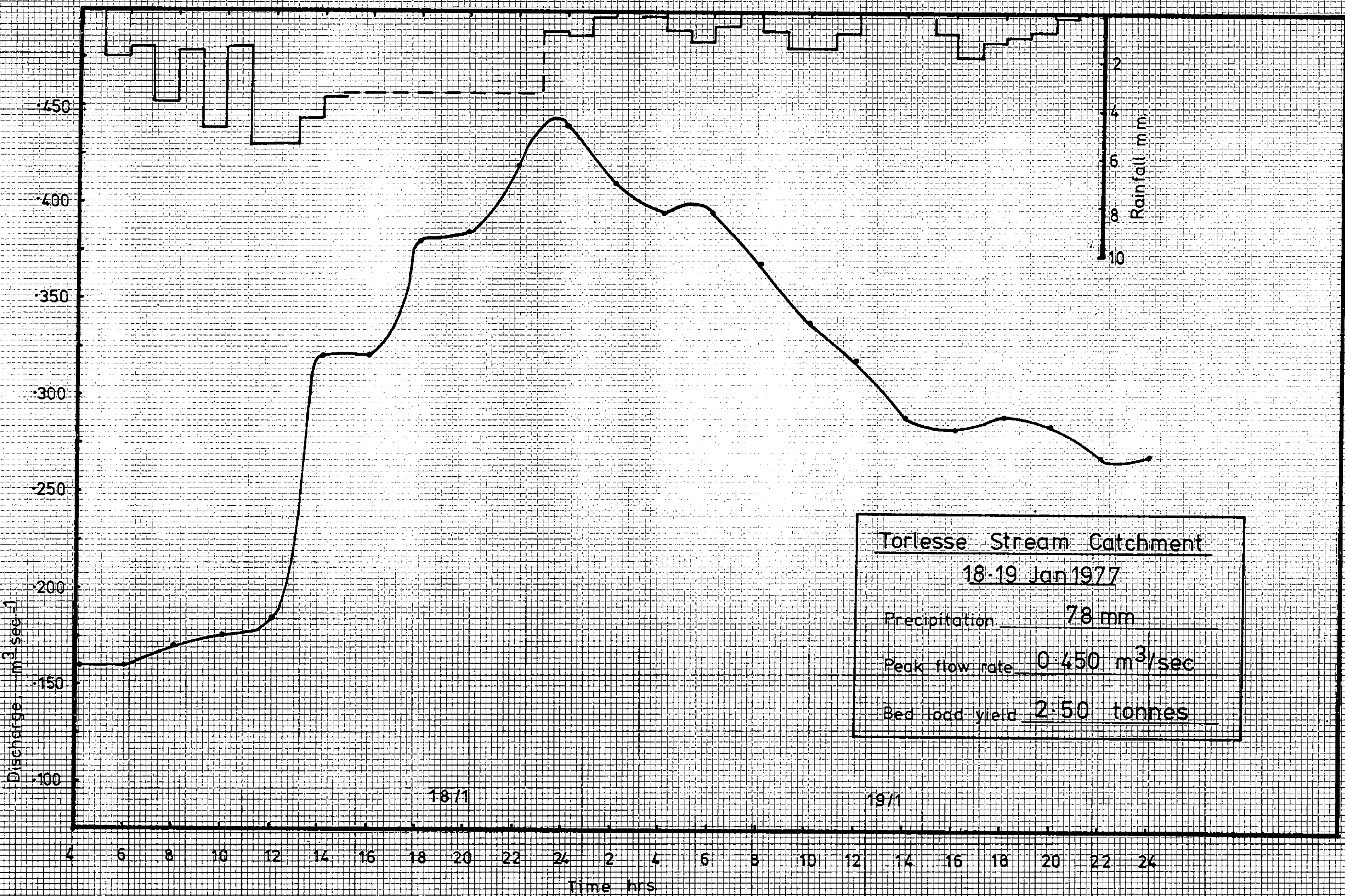
Torlesse Stream Catchment
30 Nov 1976
Precipitation 32 mm
Peak flow rate 0·600 m3/sec
Bed load yield 0·50 tonnes
Discharge. m3 sec-1
·700
·600
·500
·400
·300
·200
Rainfall mm.
2
4
6
8
10
12
14
16
18
15
16
17
18
19
20
21
22
23
24
Time hrs


Torlesse Stream Catchment
9 Dec 1976
Precipitation 37 mm
Peak flow rate 0·500 m3/sec
Bed load yield 4·00 tonnes
Discharge, m3 sec-1
·150
·200
·250
·300
·350
·400
·450
·500
·550
Rainfall mm.
1
2
3
4
5
6
7
8
9
10
12
13
14
15
16
17
18
19
20
21
22
23
24
1
Time hrs.

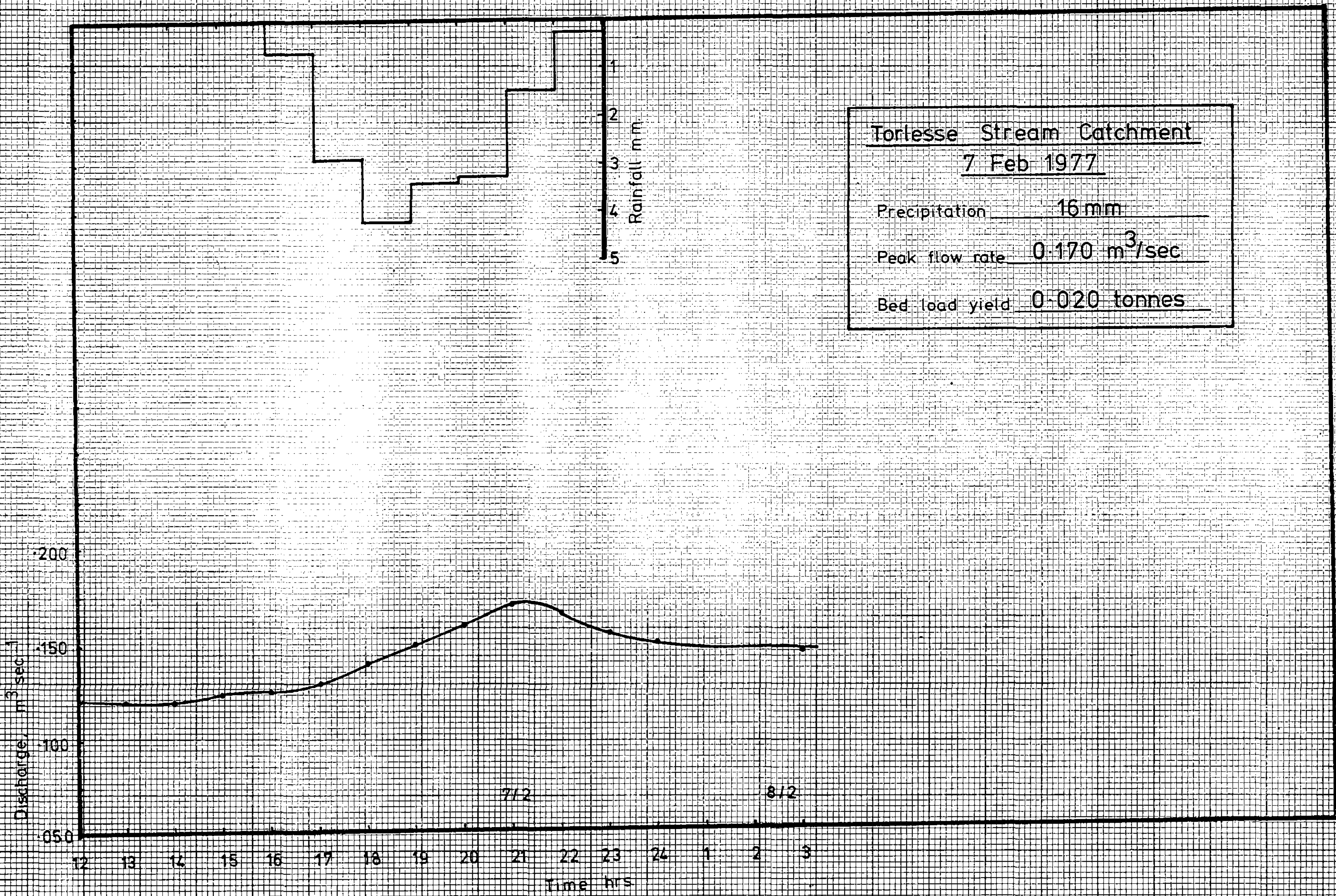

Torlesse Stream Catchment
19 Dec 1976
Precipitation 31 mm
Peak flow rate 0·350 m3/sec
Bed load yield 2·15 tonnes
Rainfall mm
1
2
3
4
5
6
7
8
·400
·350
·300
·250
·200
·150
·100
Discharge, m3 sec-1
19/12
20/12
10
12
14
16
18
20
22
24
2
Time hrs



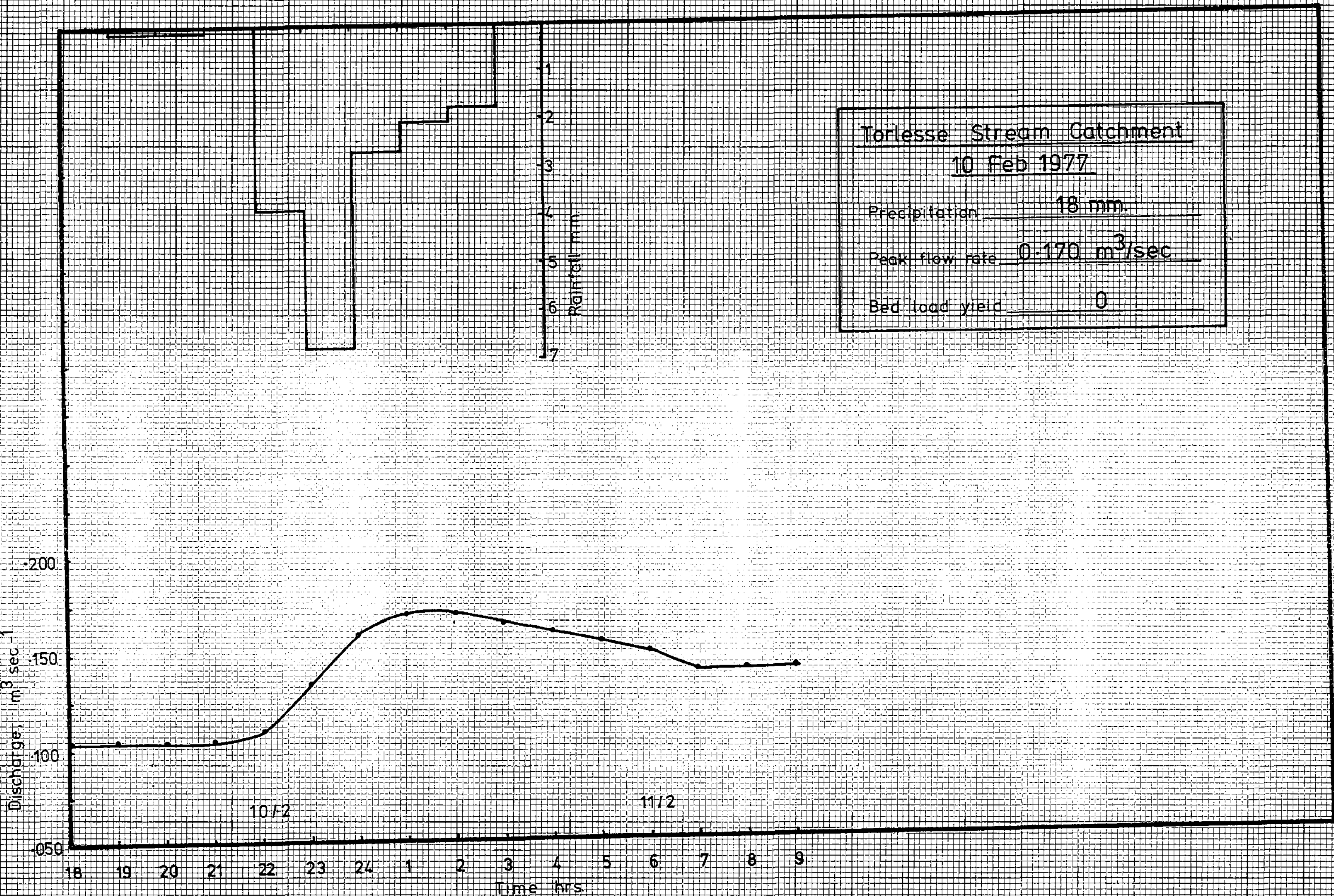
Torlesse Stream Catchment
3 Jan 1977
Precipitation 26 mm
Peak flow rate 0·330 m3/sec
Bed load yield 0·580 tonnes
Rainfall mm.
1
2
3
4
5
6
7
350
300
250
200
150
100
Discharge, m3 sec-1
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Time hrs.



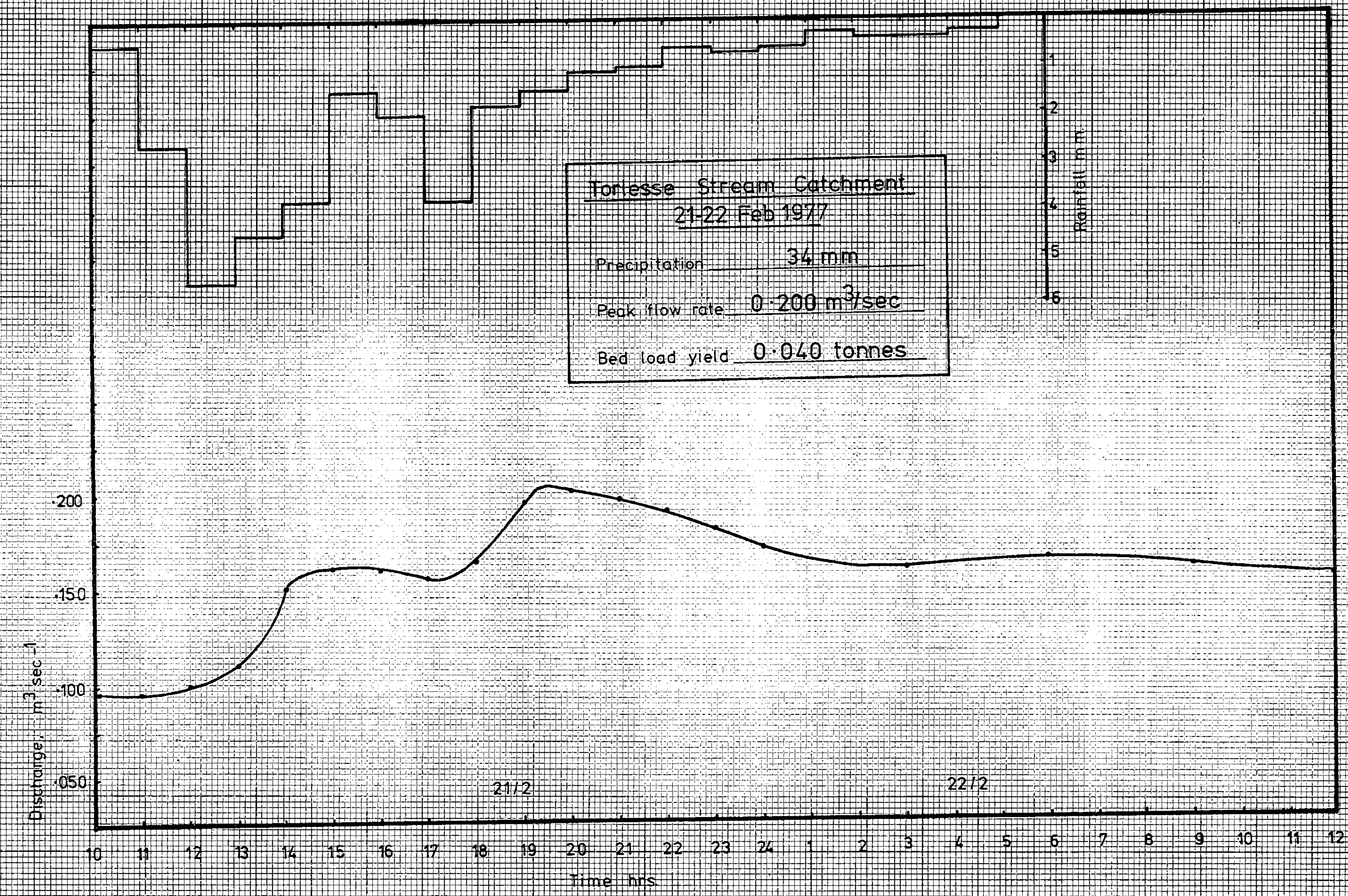
Torlesse Stream Catchment
18-19 Jan 1977
Precipitation 78 mm
Peak flow rate 0·450 m3/sec
Bed load yield 2·50 tonnes
Discharge m3 sec-1
·450
·400
·350
·300
·250
·200
·150
·100
Rainfall mm
2
4
6
8
10
18/1
19/1
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
22
24
Time hrs



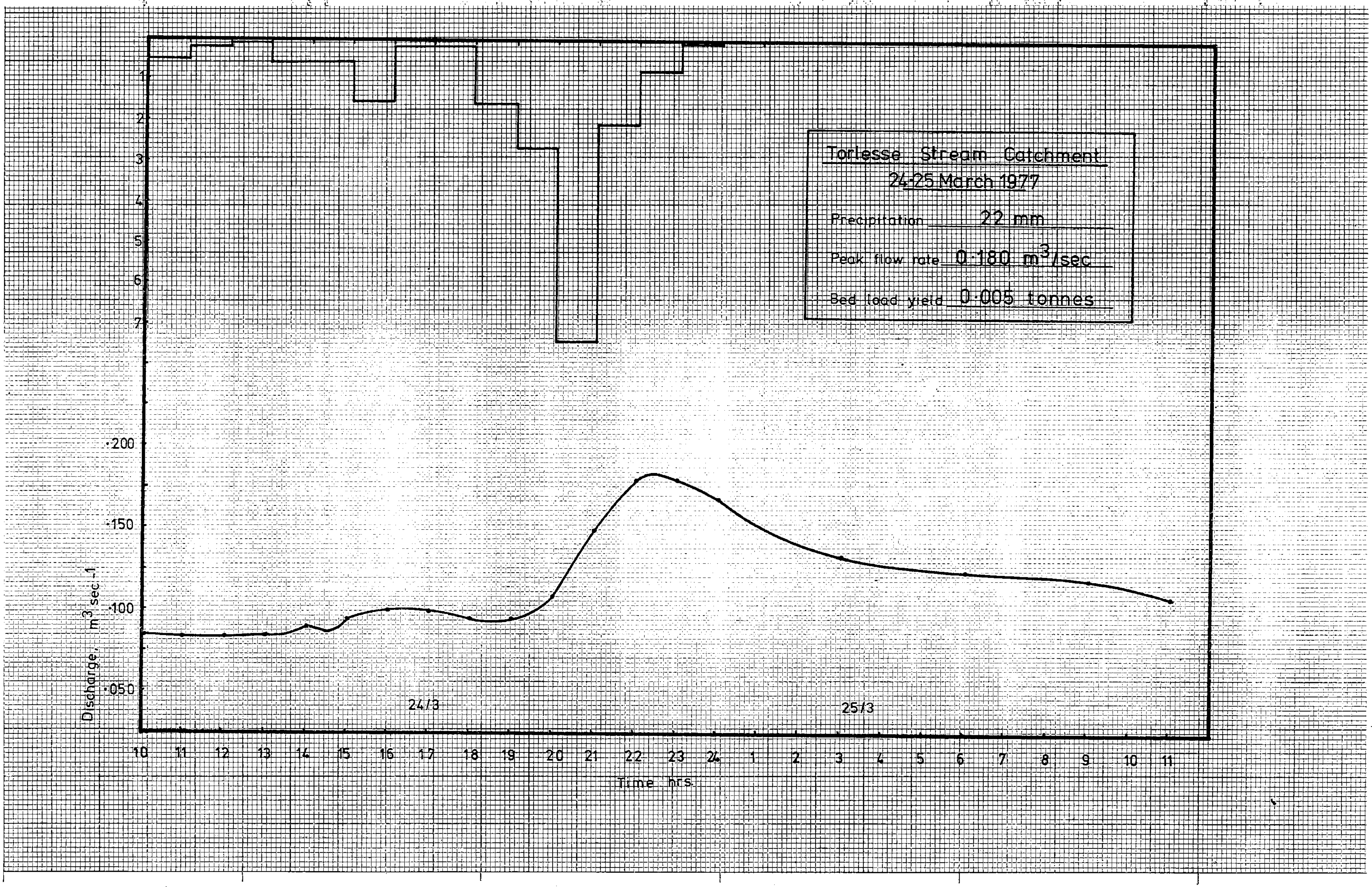
Torlesse Stream Catchment
7 Feb 1977
Precipitation 16 mm
Peak flow rate 0·170 m3/sec
Bed load yield 0·020 tonnes
Rainfall mm.
1
2
3
4
5
Discharge, m3 sec-1
·200
·150
·100
·050
7/2
8/2
12
13
14
15
16
17
18
19
20
21
22
23
24
1
2
3
Time hrs



Torlesse Stream Catchment
10 Feb 1977
Precipitation 18 mm.
Peak flow rate 0·170 m3/sec
Bed load yield 0
Rainfall mm.
1
2
3
4
5
6
7
Discharge, m3 sec-1
·200
·150
·100
·050
10/2
11/2
18
19
20
21
22
23
24
1
2
3
4
5
6
7
8
9
Time hrs



Torlesse Stream Catchment
21-22 Feb 1977
Precipitation 34 mm
Peak flow rate 0·200 m3/sec
Bed load yield 0·040 tonnes
Rainfall mm
1
2
3
4
5
6
Discharge, m3 sec-1
·200
·150
·100
·050
21/2
22/2
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12
Time hrs



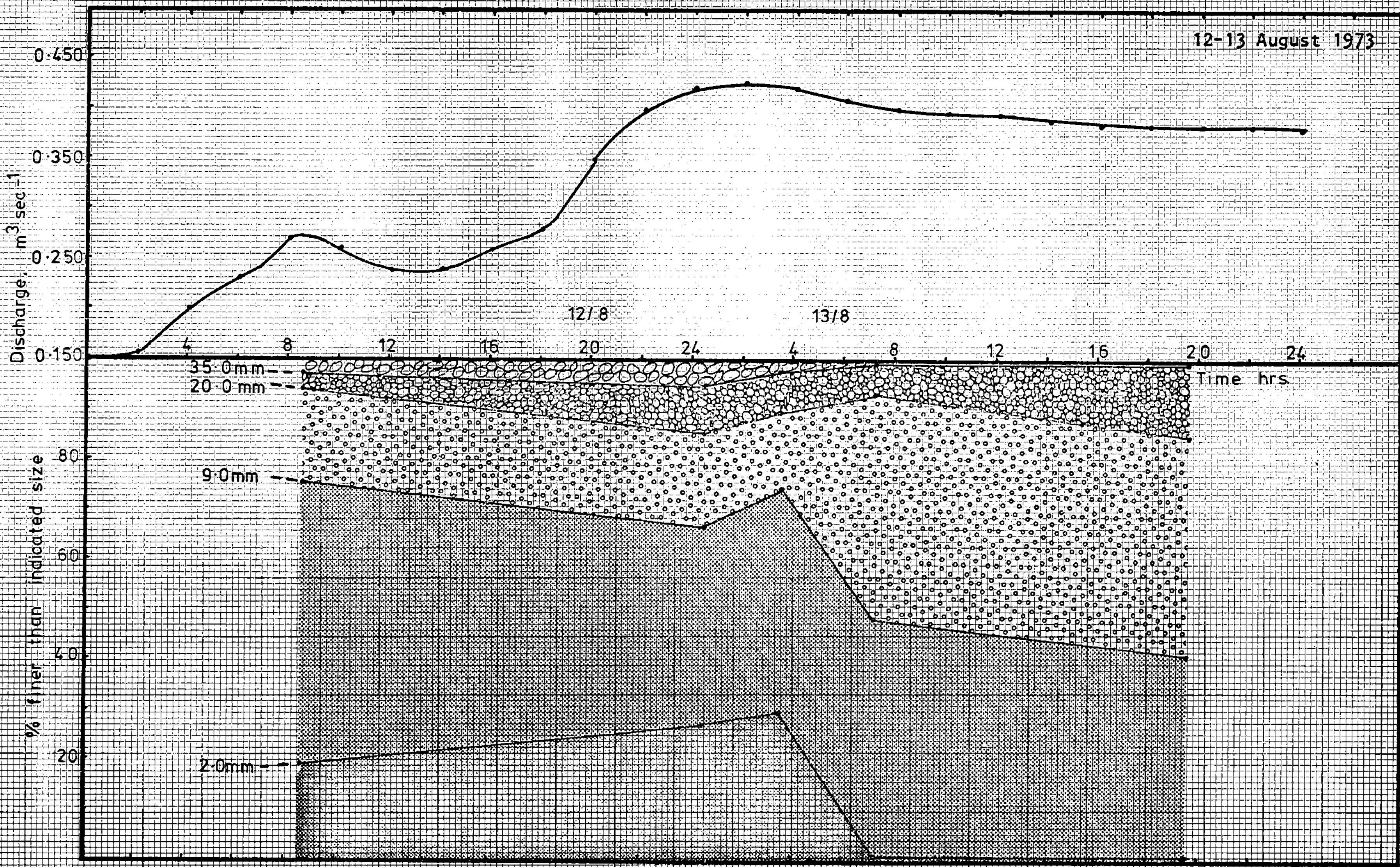
Torlesse Stream Catchment
24-25 March 1977
Precipitation 22 mm
Peak flow rate 0·180 m³/sec
Bed load yield 0·005 tonnes
1
2
3
4
5
6
7
·200
·150
·100
·050
Discharge, m³ sec⁻¹
24/3
25/3
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
1
2
3
4
5
6
7
8
9
10
11
Time hrs.

APPENDIX VII

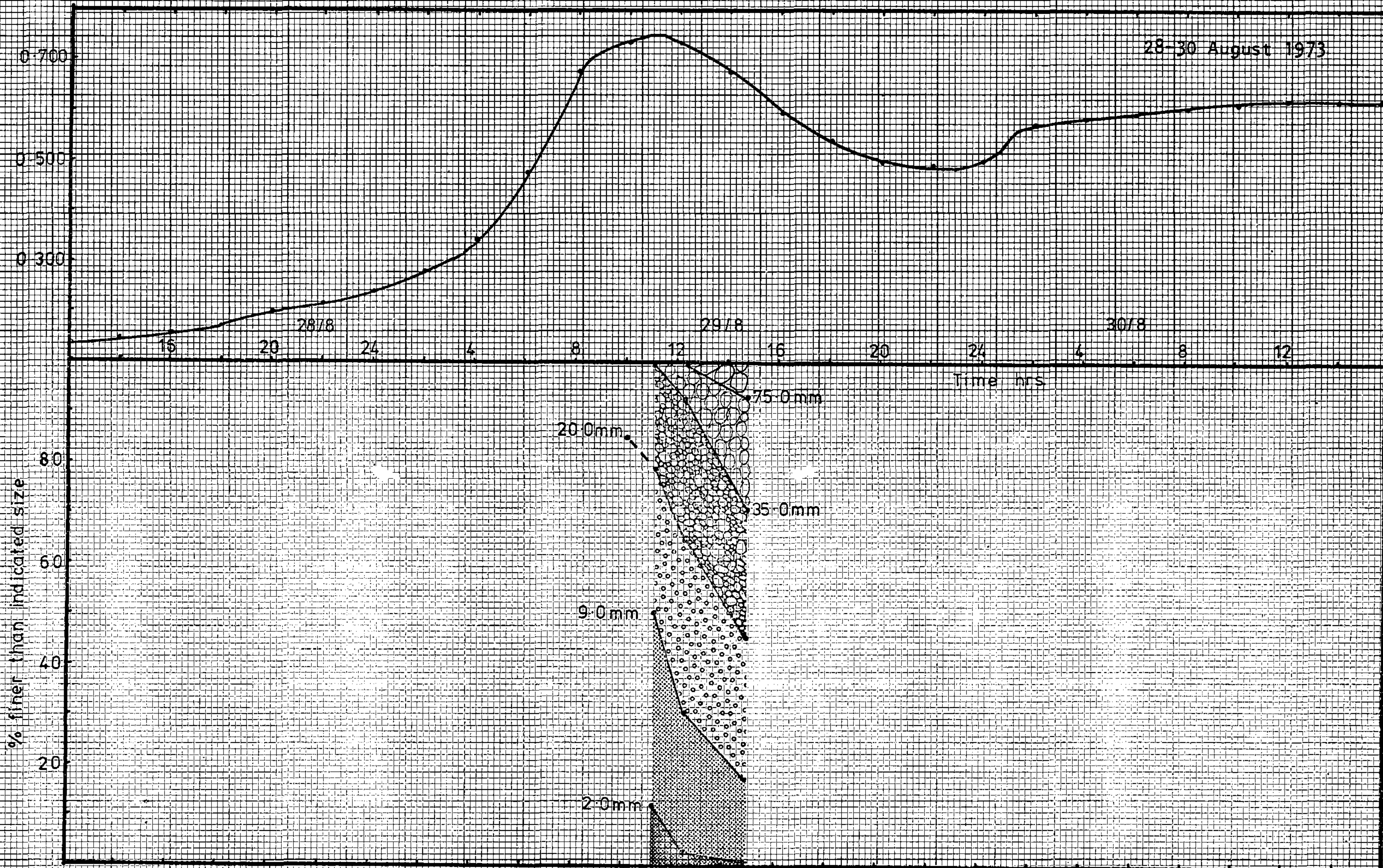
BED LOAD SEDIMENT SIZES FROM SOME STORMS, TORLESSE STREAM CATCHMENT.

EVENTS

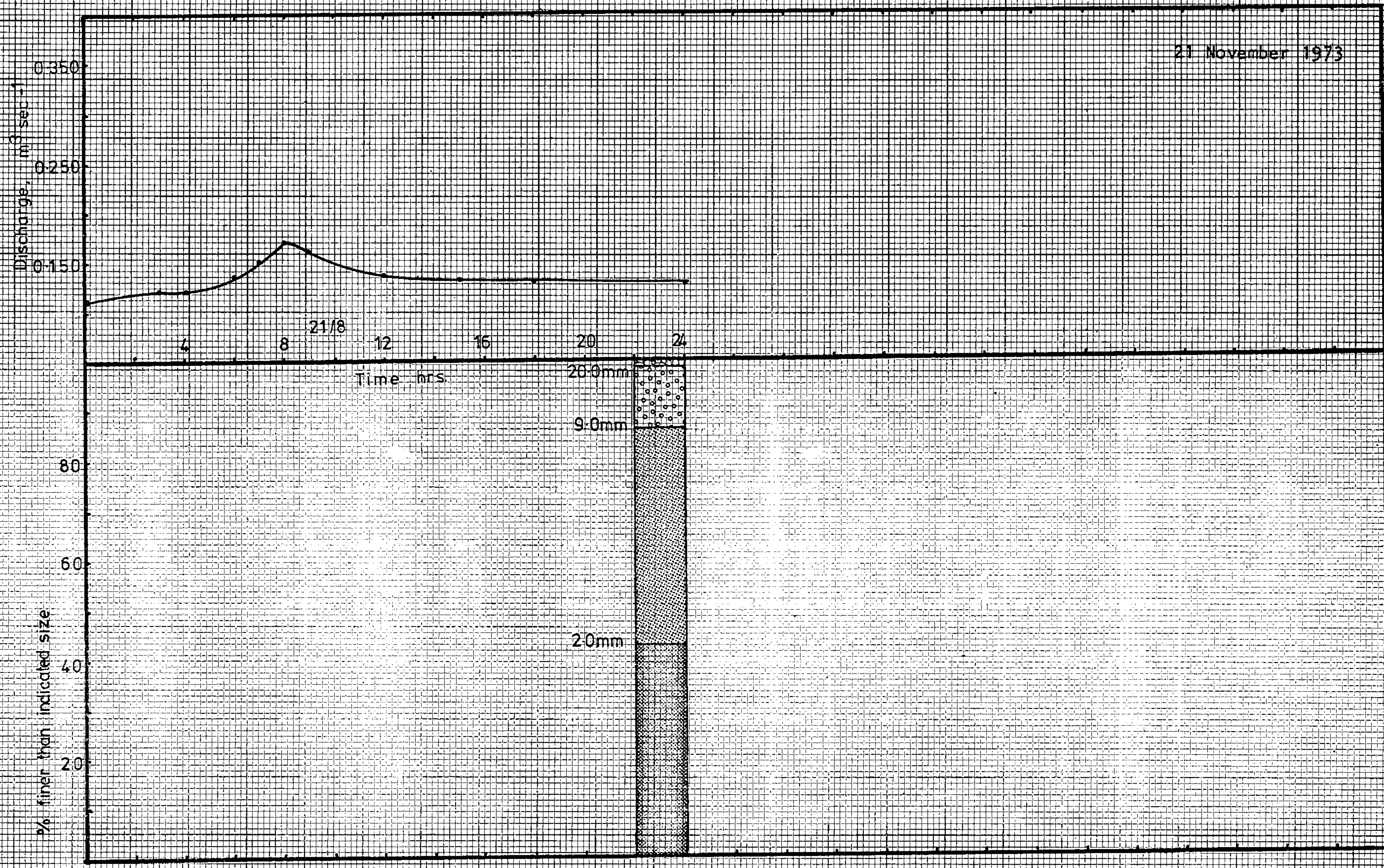
12 - 13	August	1973
29	August	1973
21	November	1973
16 - 17	January	1974
15 - 16	March	1974
21 - 23	June	1974
19 - 20	July	1974
8 - 9	October	1974
8 - 9	October	1974
20 - 23	January	1975
29 - 31	January	1975
11 - 13	March	1975
11 - 13	March	1975
1 - 2	April	1975
6 - 7	June	1975
14 - 15	July	1975
19 - 20	August	1975
8 - 9	February	1976
11 - 12	February	1976
16 - 17	February	1976
17	February	1976
30	April	1976
10 - 12	August	1976

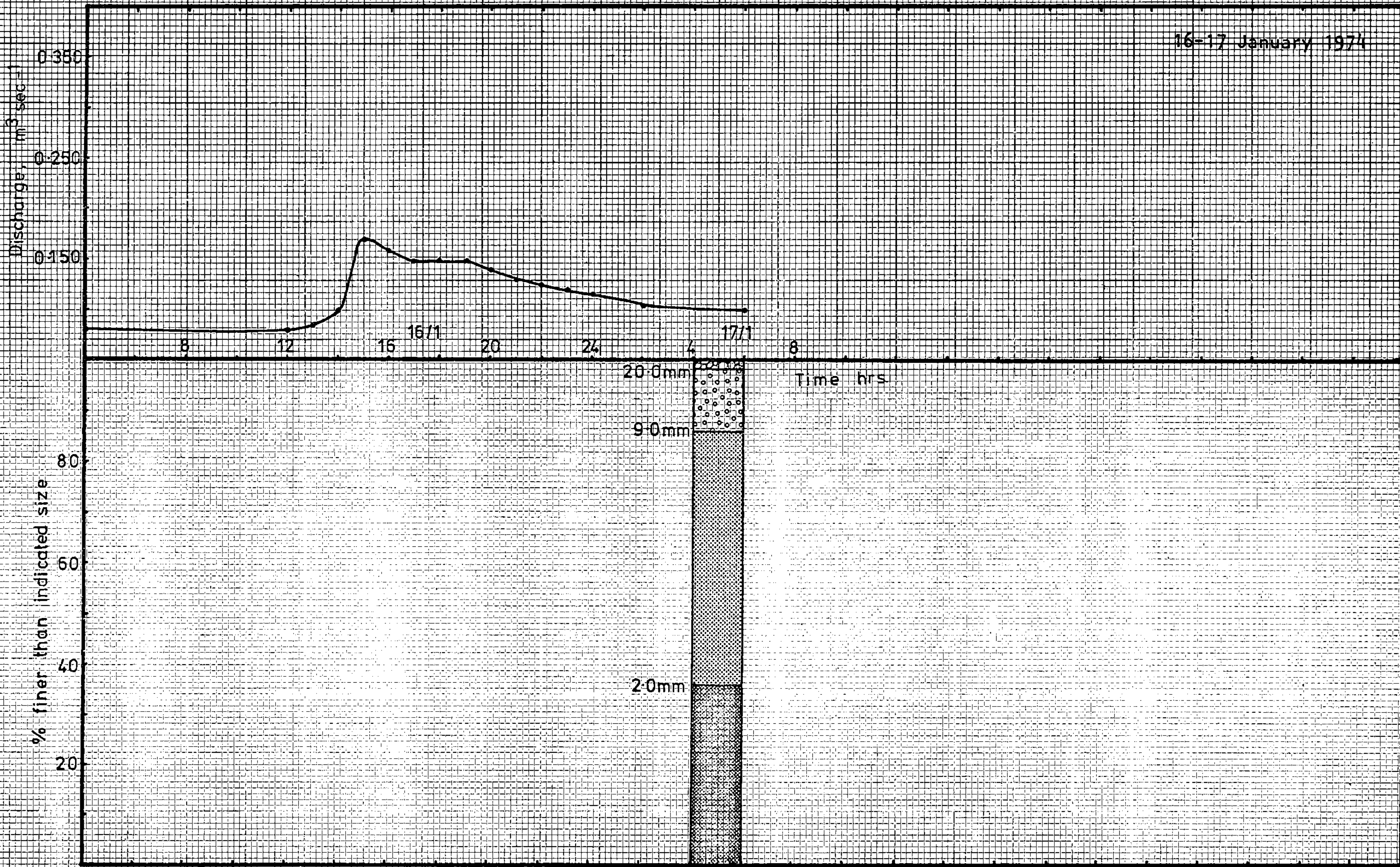


12-13 August 1973
Discharge, m3 sec-1
0·450
0·350
0·250
0·150
12/8
13/8
4
8
12
16
20
24
4
8
12
16
20
24
Time hrs
35·0mm
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

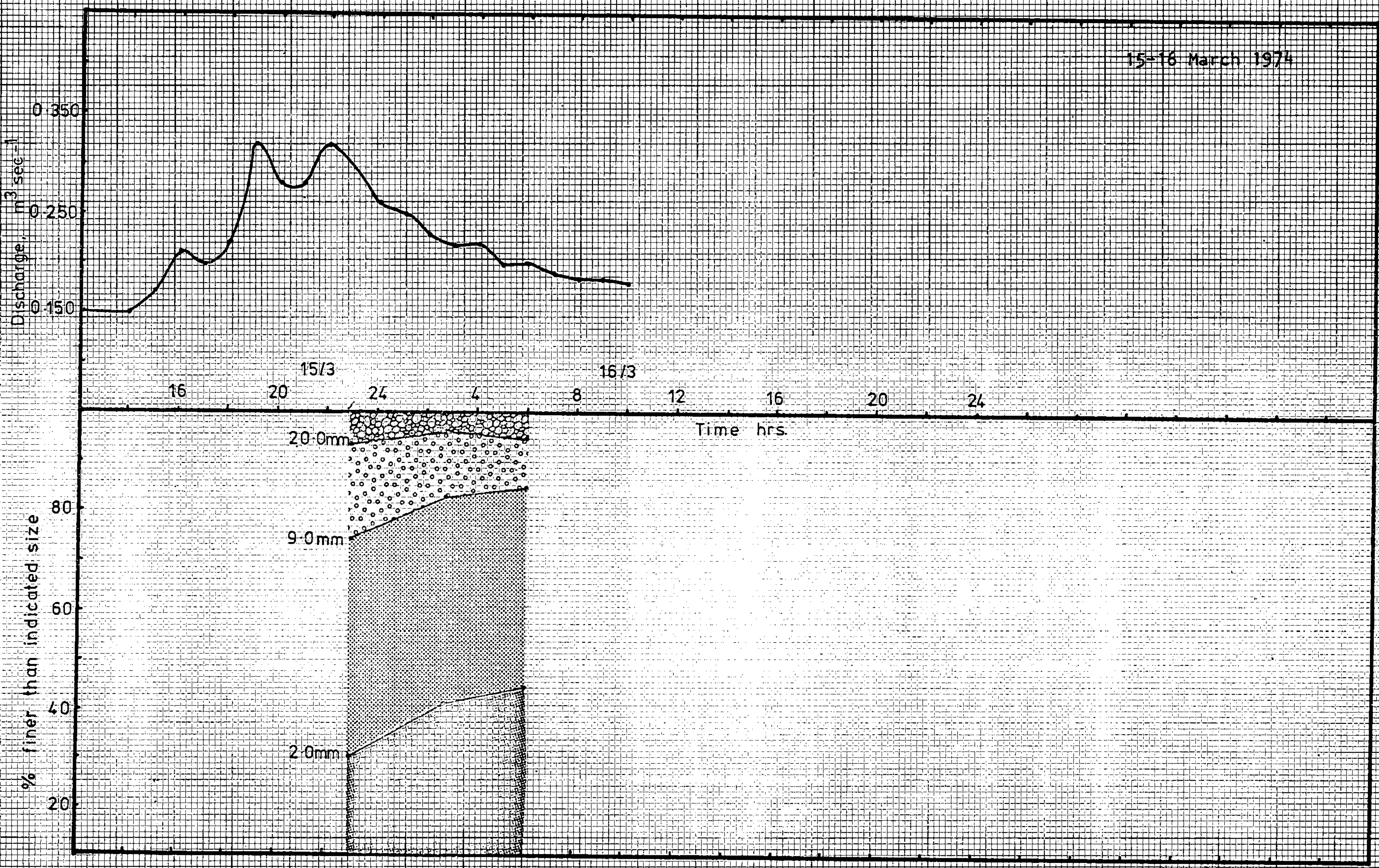


28-30 August 1973
0·700
0·500
0·300
28/8
29/8
30/8
15
20
24
4
8
12
16
20
24
4
8
12
Time hrs
75·0mm
20·0mm
35·0mm
9·0mm
2·0mm
80
60
40
20
% finer than indicated size

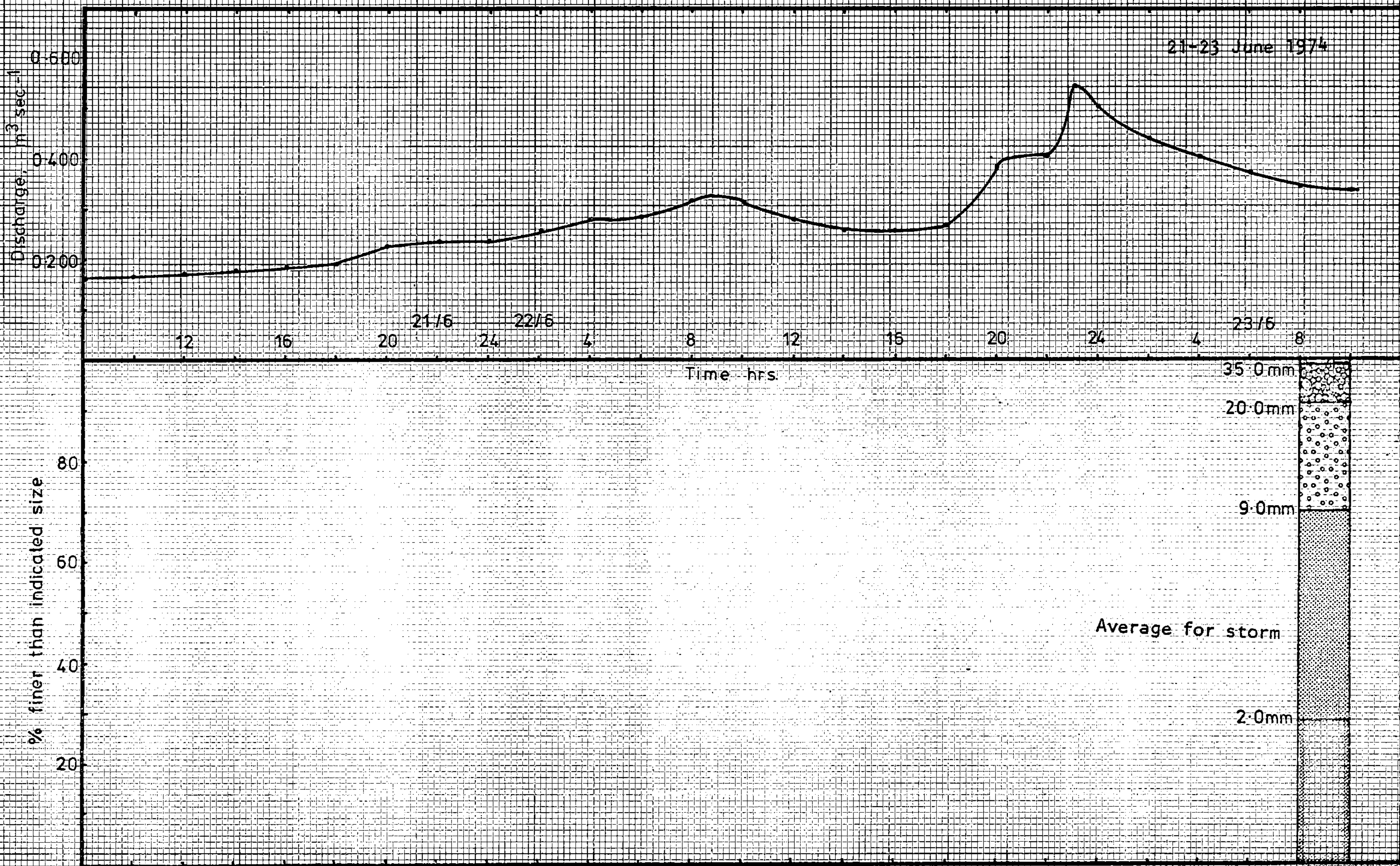

21 November 1973
Discharge, m³ sec⁻¹
0.350
0.250
0.150
21/8
4
8
12
16
20
24
Time hrs
20.0mm
9.0mm
2.0mm
% finer than indicated size
80
60
40
20

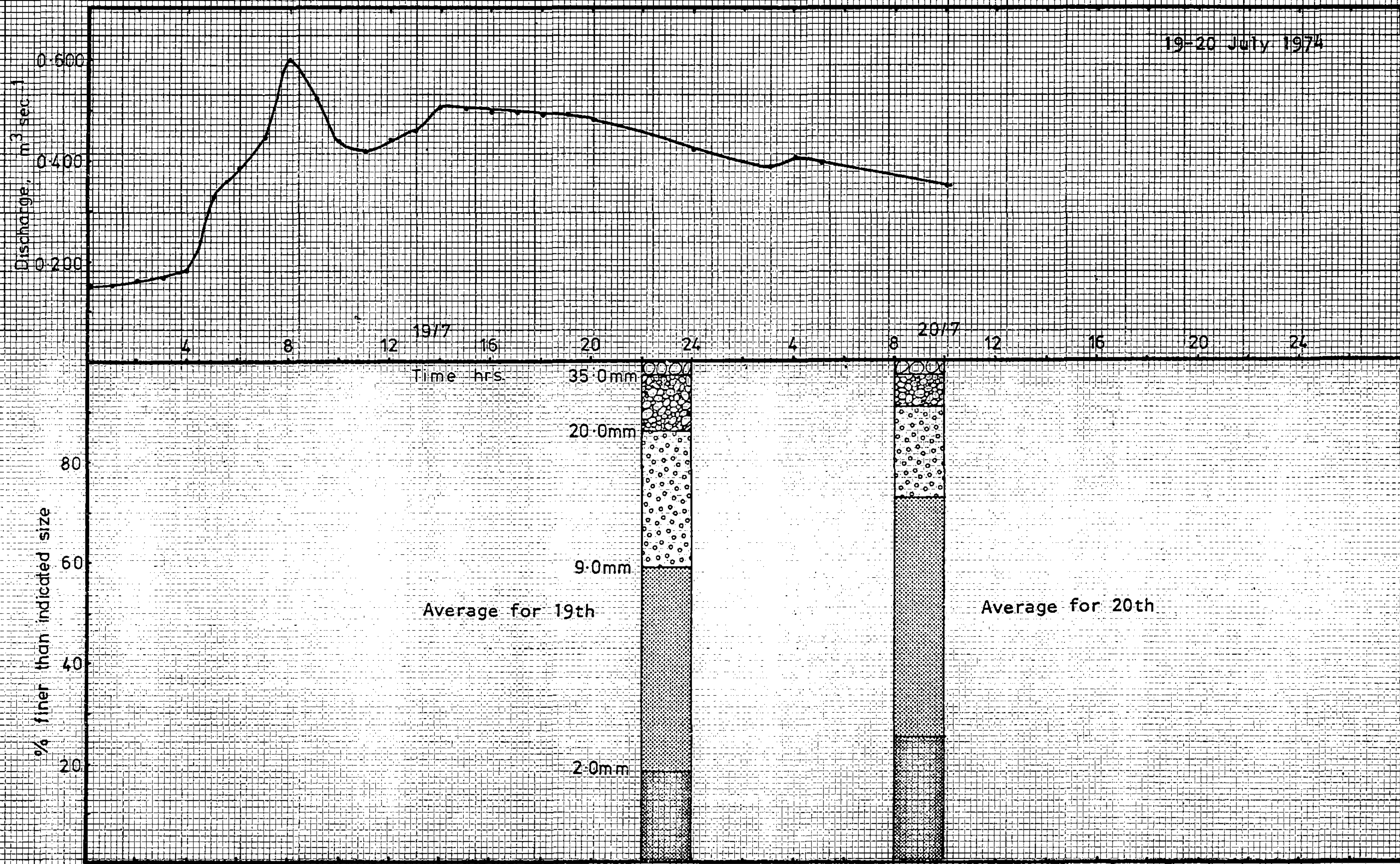


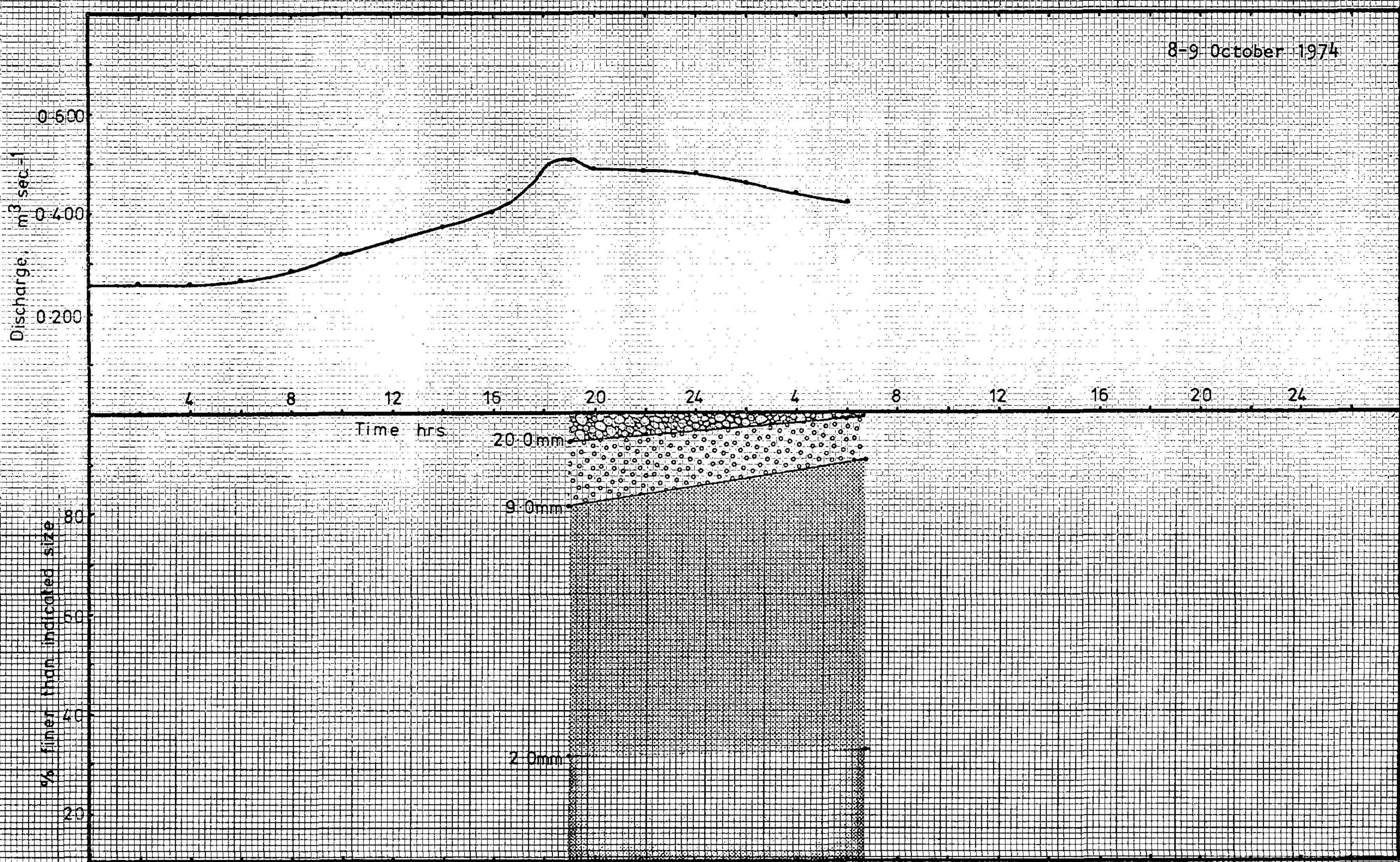
16-17 January 1974
Discharge, m³ sec⁻¹
0·350
0·250
0·150
16/1
17/1
8
12
16
20
24
4
8
Time hrs
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20



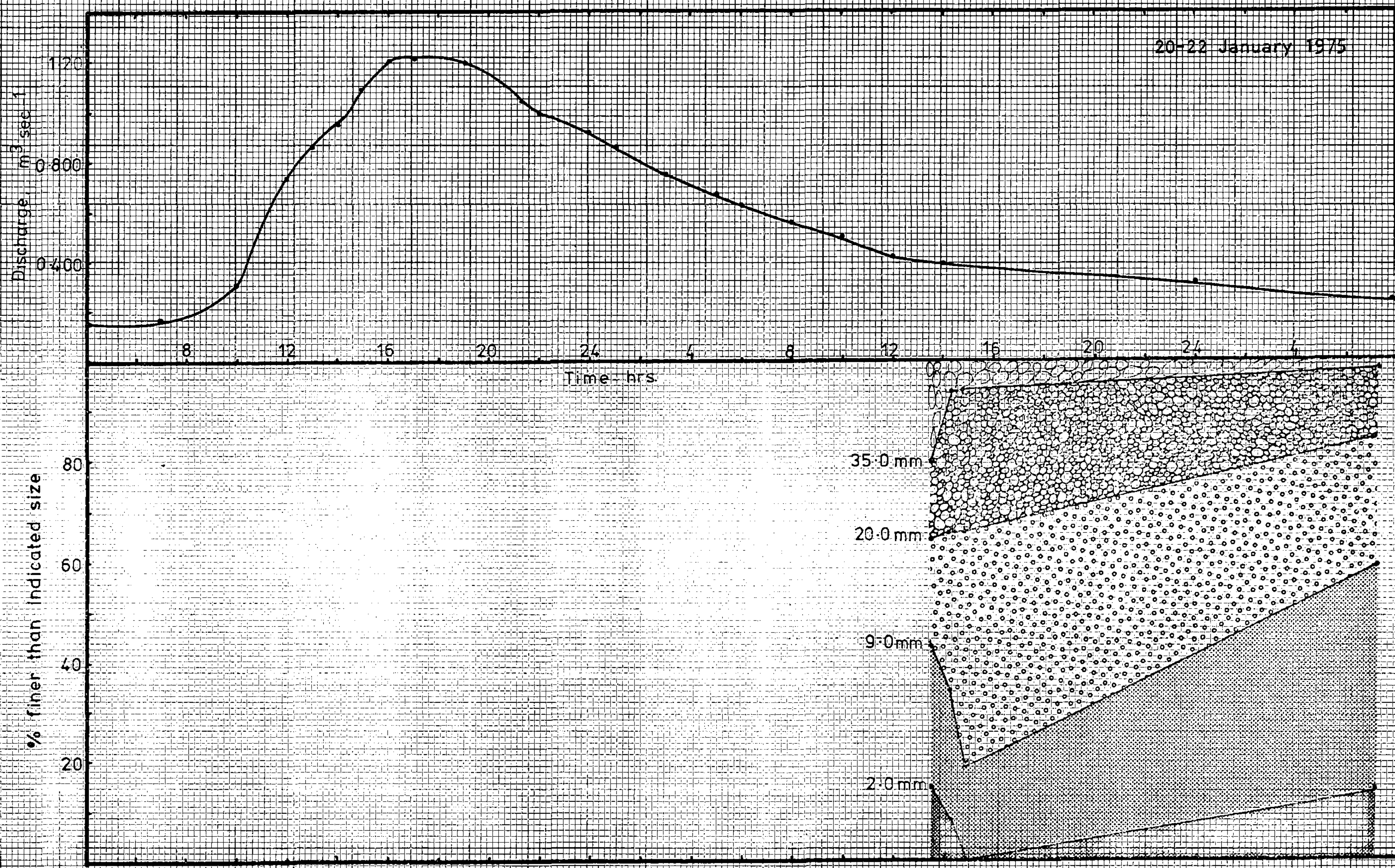
15-16 March 1974
Discharge, m3 sec-1
0·350
0·250
0·150
15/3
16/3
16
20
24
4
8
12
16
20
24
Time hrs.
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20


21-23 June 1974
Discharge, m^3 sec^-1
0.600
0.400
0.200
21/6
22/6
23/6
12
16
20
24
4
8
12
16
20
24
4
8
Time hrs
% finer than indicated size
80
60
40
20
35.0mm
20.0mm
9.0mm
2.0mm
Average for storm

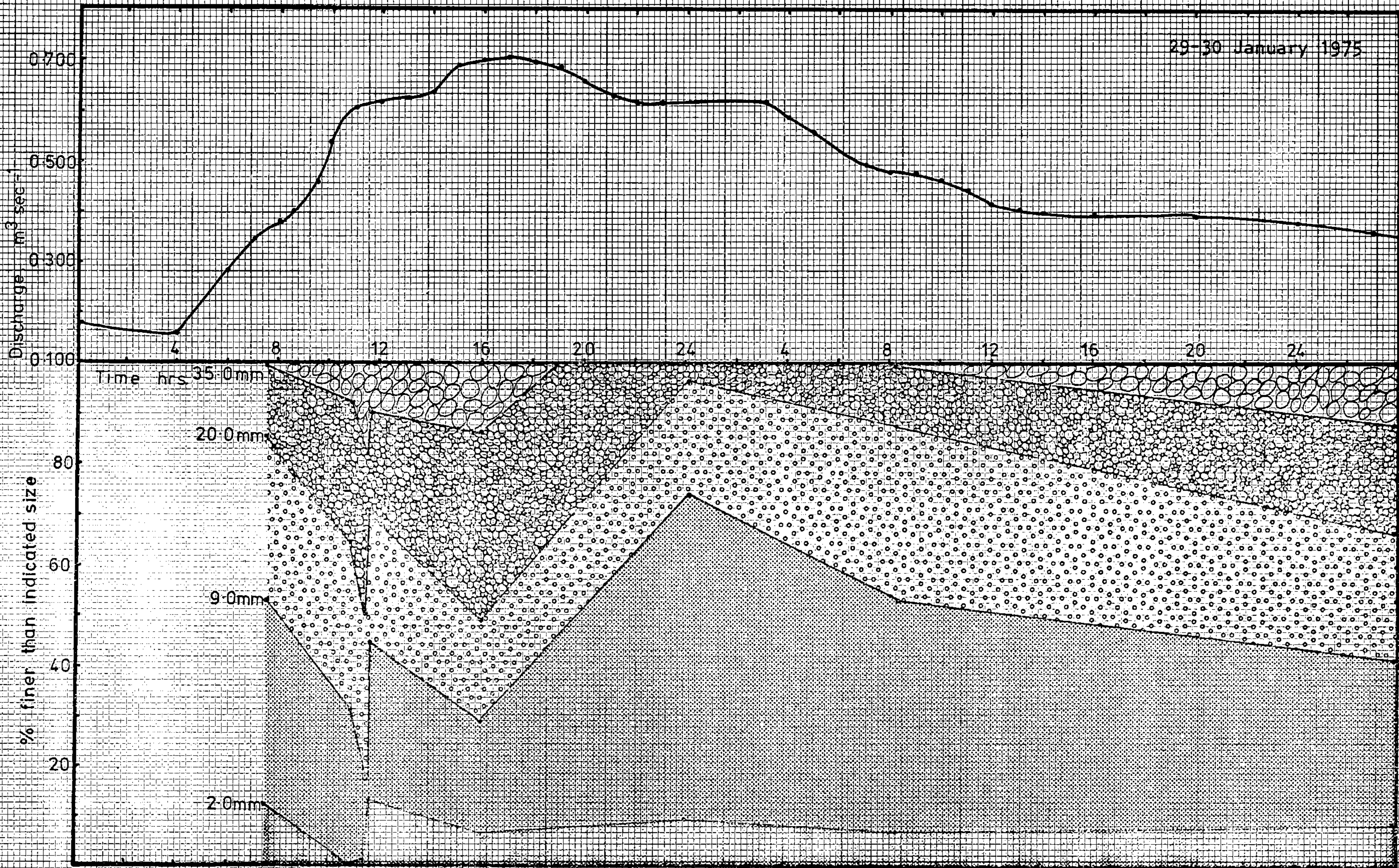

19-20 July 1974
Discharge, m3 sec-1
0·600
0·400
0·200
4
8
12
19/7
16
20
24
4
8
20/7
12
16
20
24
Time hrs.
% finer than indicated size
80
60
40
20
35·0mm
20·0mm
9·0mm
2·0mm
Average for 19th
Average for 20th

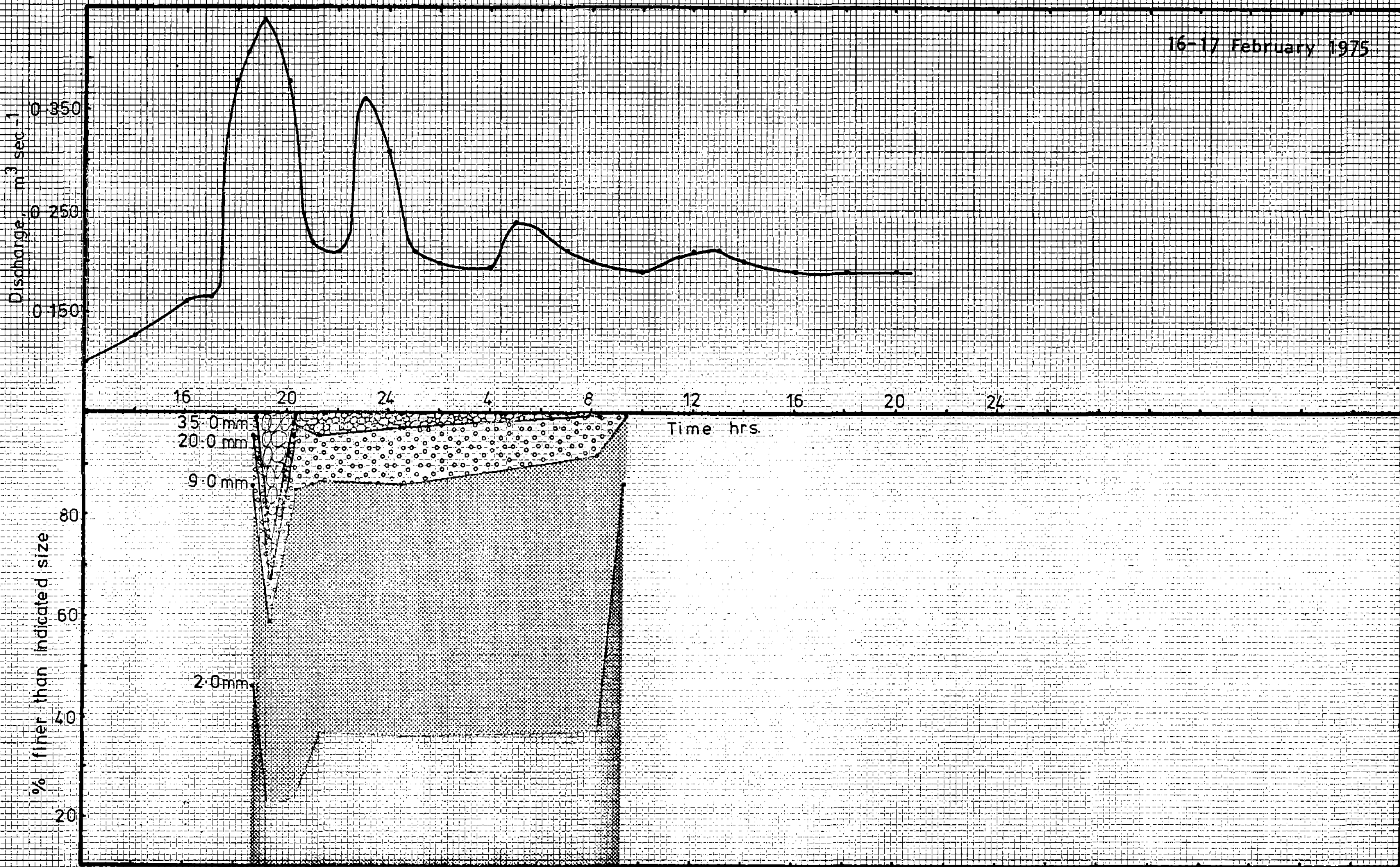


8-9 October 1974
Discharge, m^3 sec^{-1}
0·600
0·400
0·200
4
8
12
16
20
24
4
8
12
16
20
24
Time hrs
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

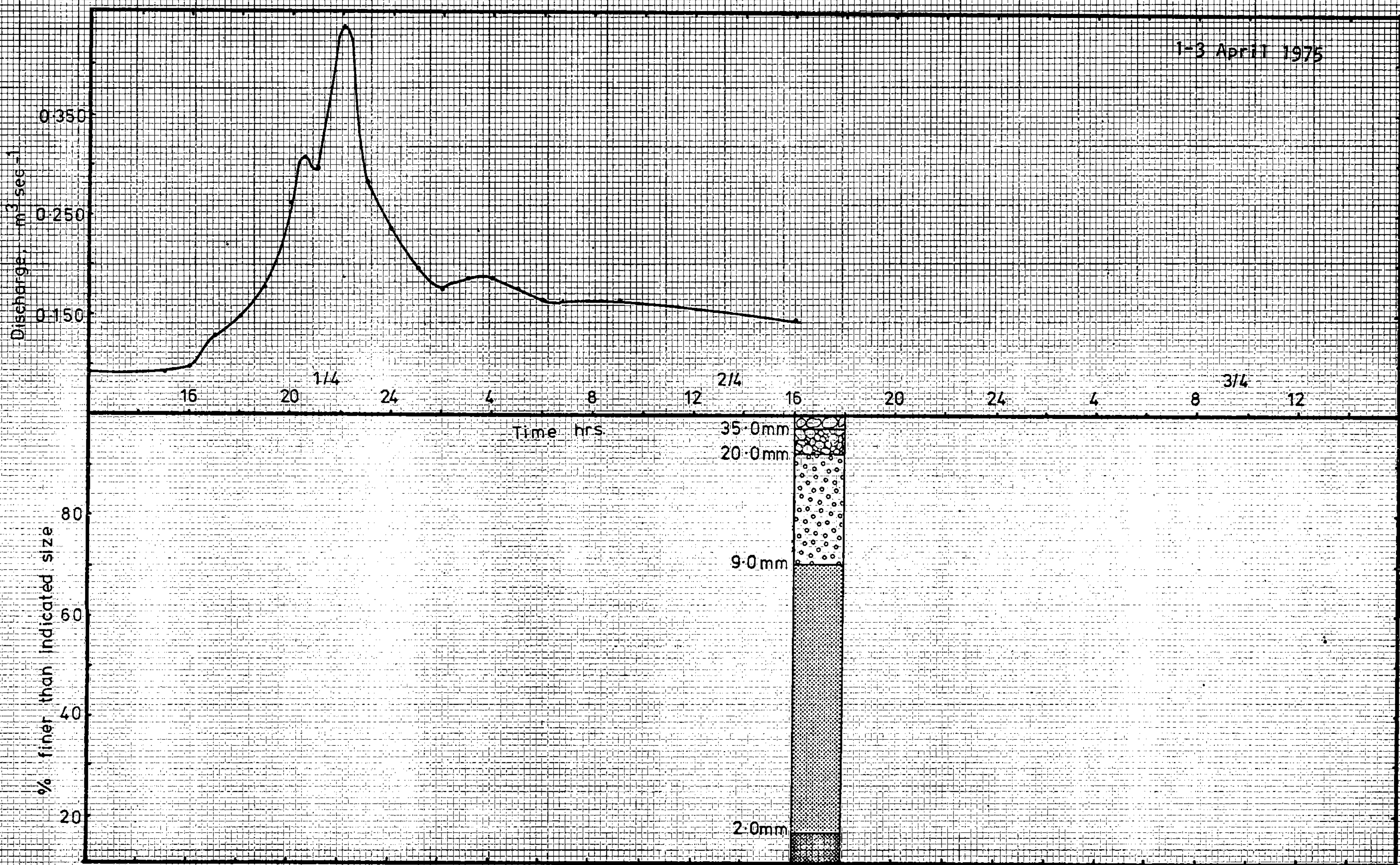


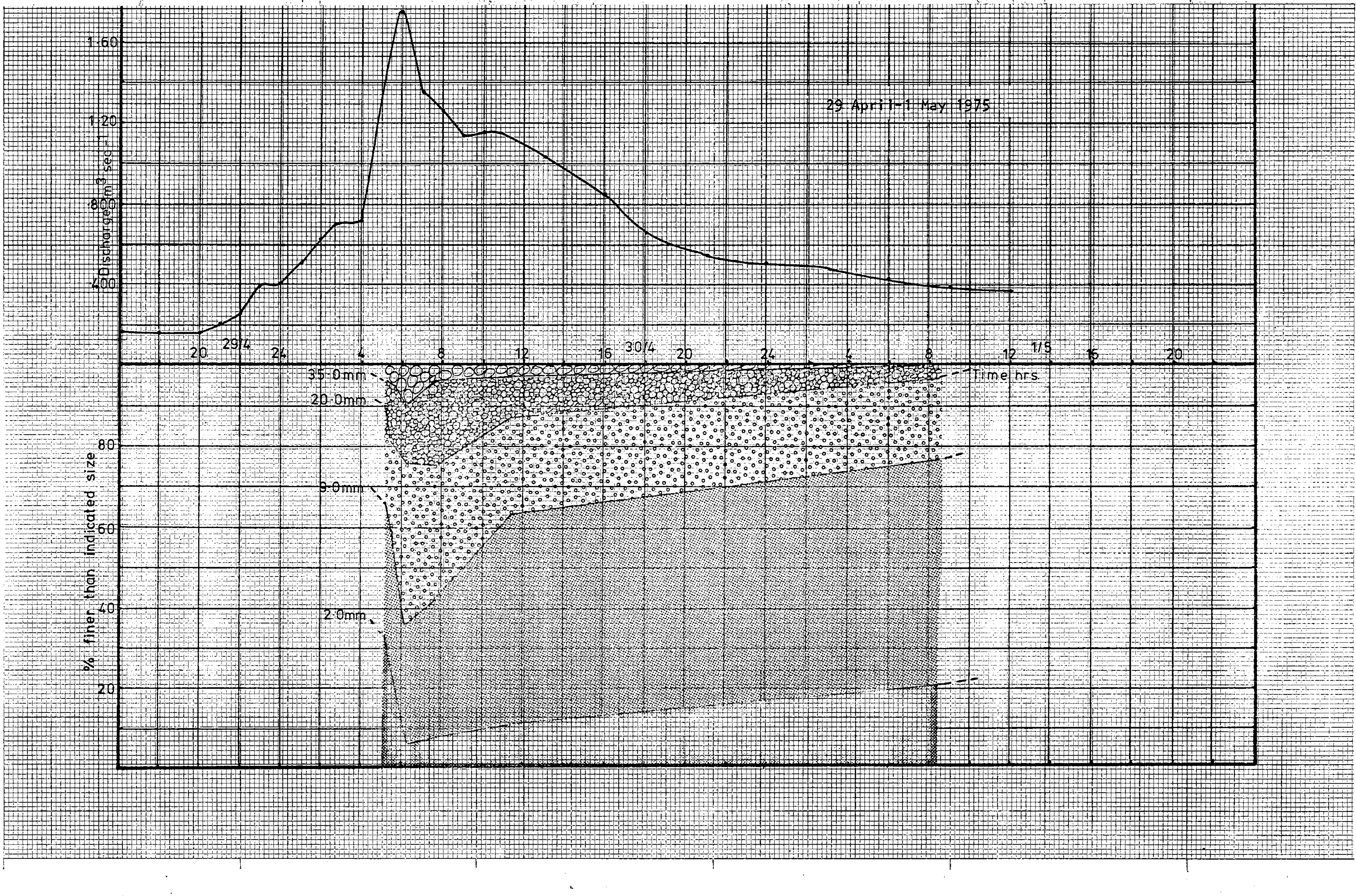
20-22 January 1975
Discharge, m3 sec-1
1.200
0.800
0.400
8
12
16
20
24
4
8
12
16
20
24
4
Time hrs
% finer than indicated size
80
60
40
20
35.0 mm
20.0 mm
9.0 mm
2.0 mm


29-30 January 1975
Discharge m³ sec⁻¹
0·700
0·500
0·300
0·100
4
8
12
16
20
24
4
8
12
16
20
24
Time hrs
35·0mm
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

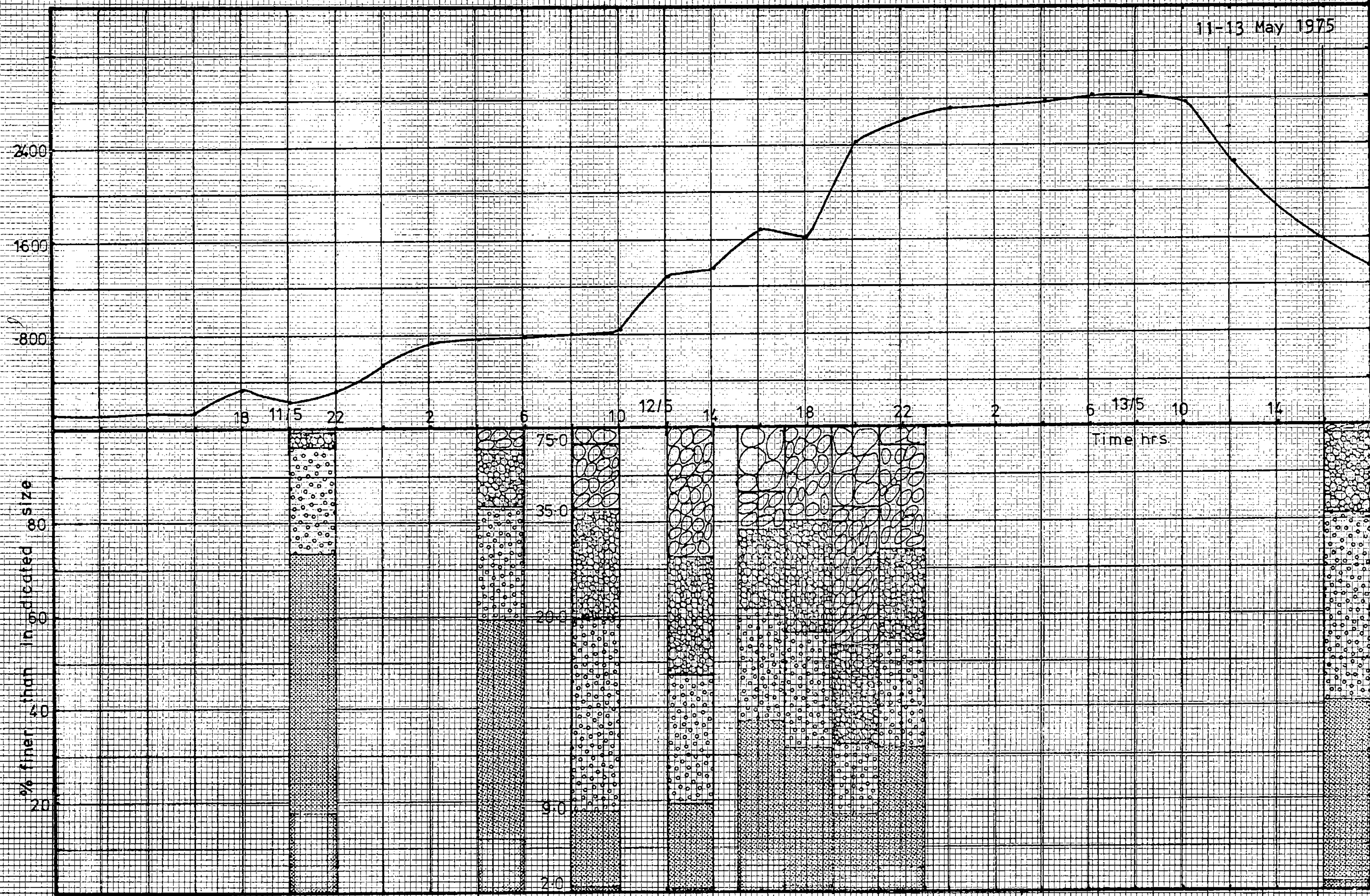


16–17 February 1975
Discharge, m3 sec-1
0·350
0·250
0·150
16
20
24
4
8
12
16
20
24
Time hrs.
35·0mm
20·0 mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

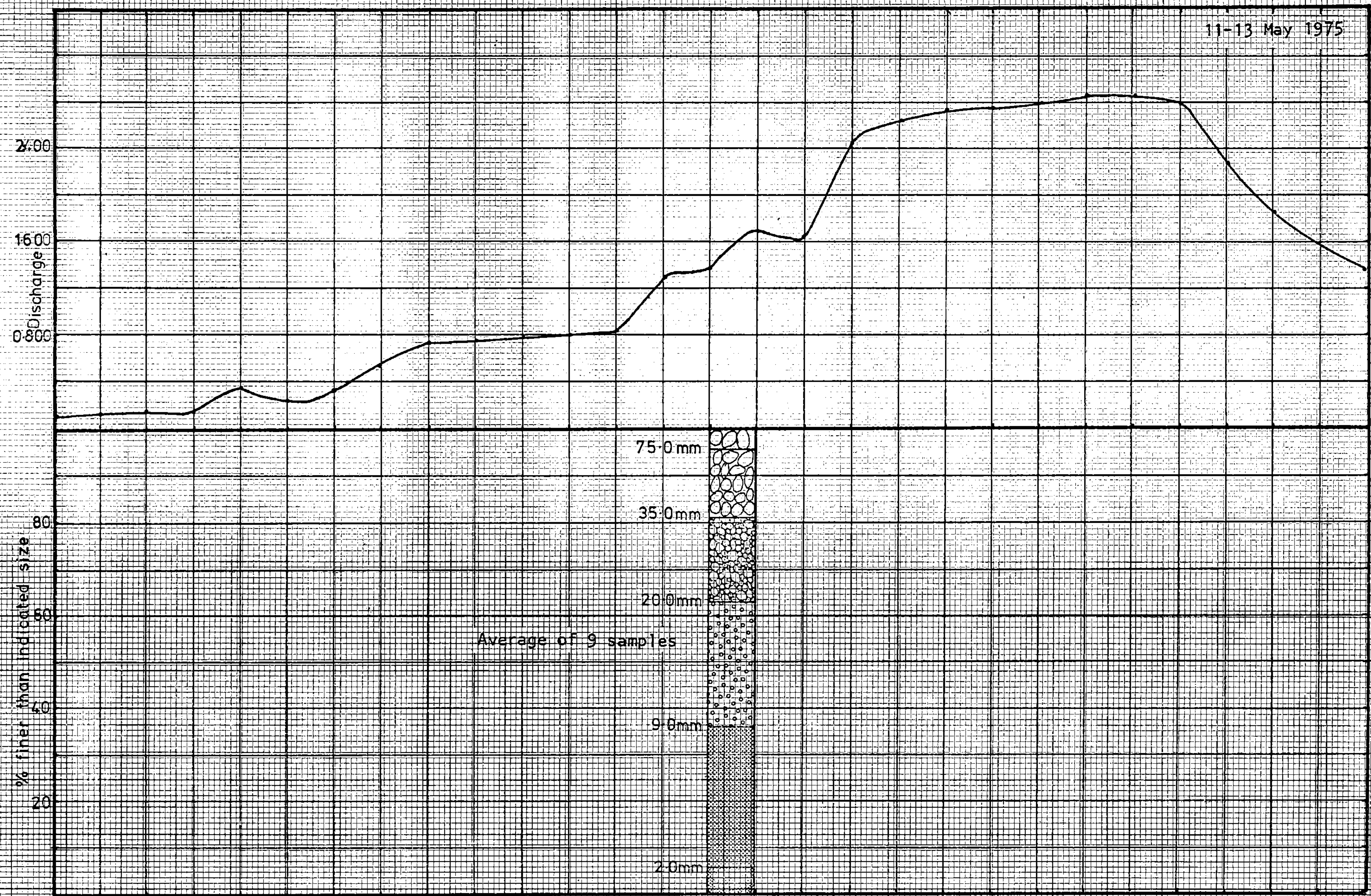

1-3 April 1975
Discharge, m³ sec⁻¹
0·350
0·250
0·150
1/4
2/4
3/4
16
20
24
4
8
12
Time hrs
35·0mm
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

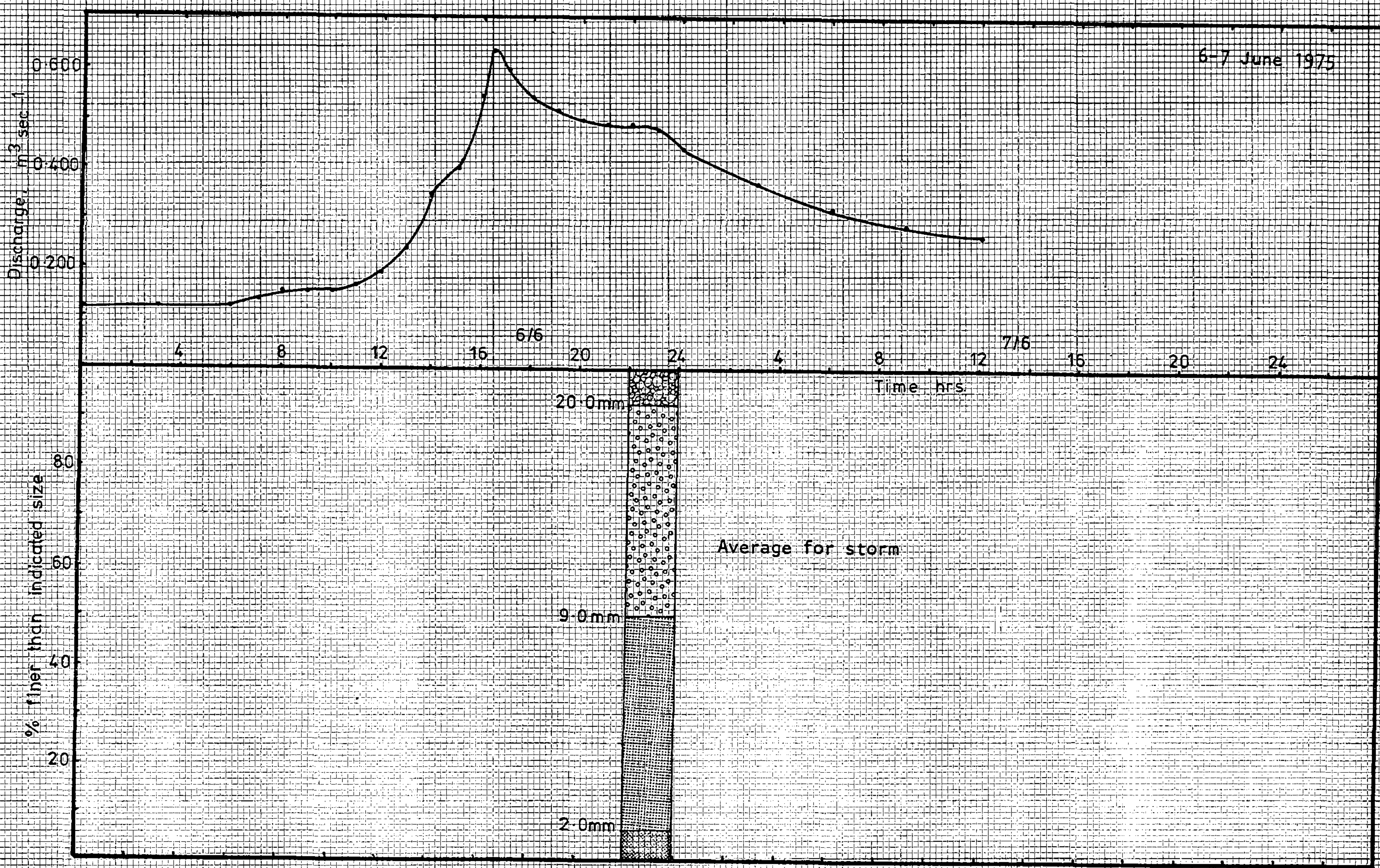


29 April–1 May 1975
Discharge $m^3 sec^{-1}$
1·60
1·20
·800
·400
20
29/4
24
4
8
12
16
30/4
20
24
4
8
12
1/5
16
20
Time hrs.
35·0mm
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20

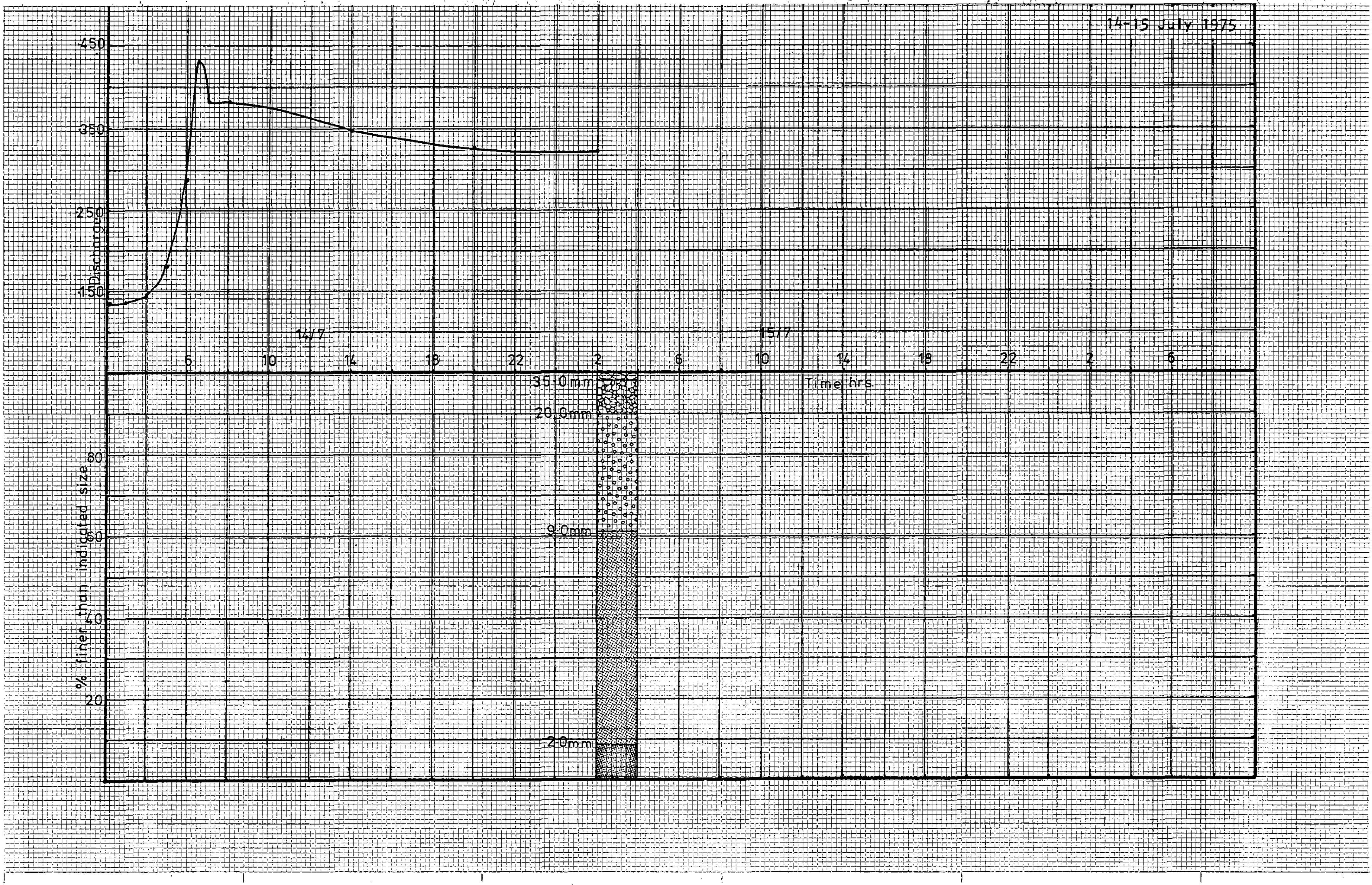


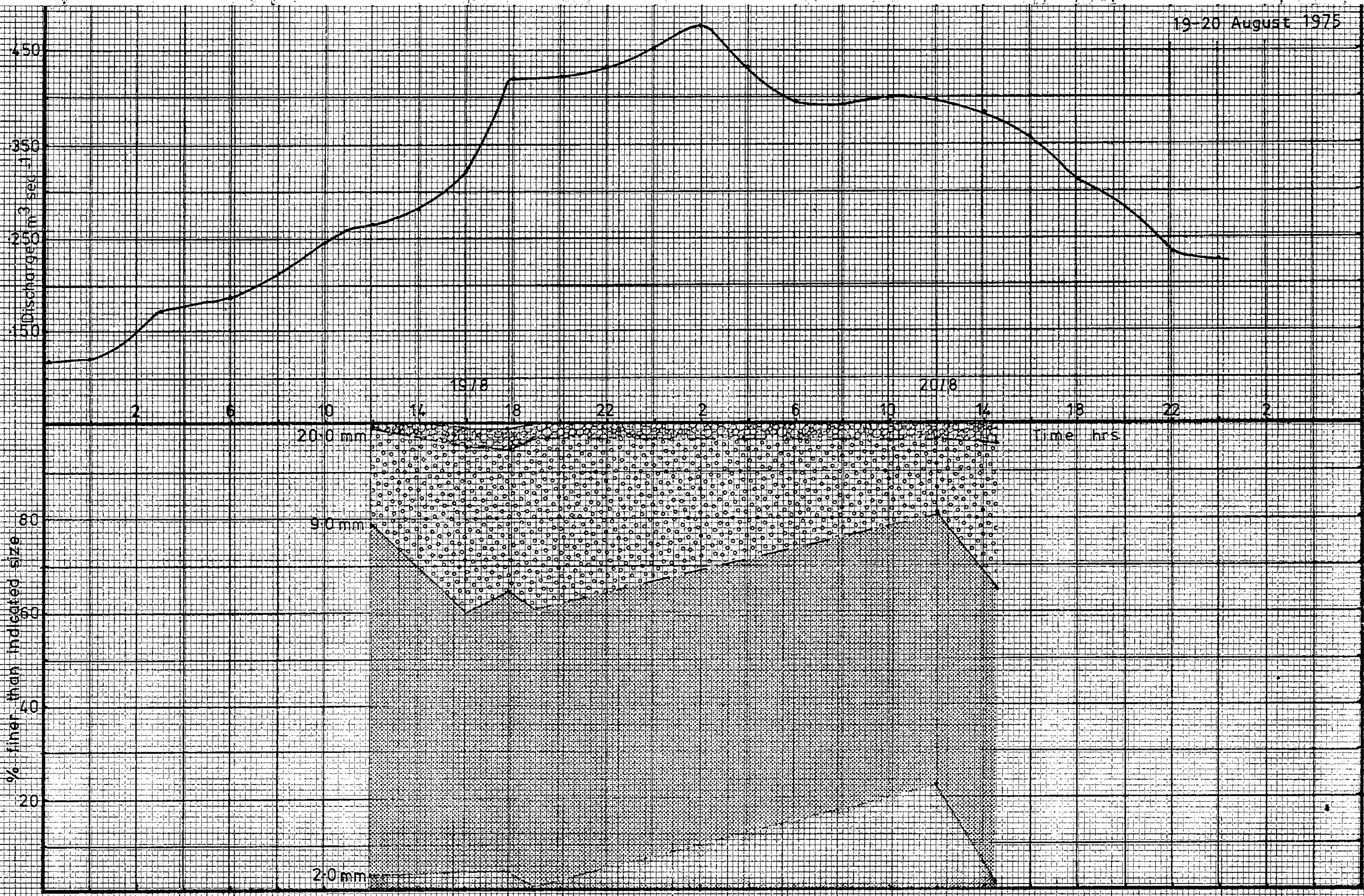
11-13 May 1975
2400
1600
800
18
11/5
22
2
6
10
12/5
14
18
22
2
6
13/5
10
14
Time hrs
75·0
35·0
20·0
9·0
2·0
% finer than indicated size
80
60
40
20


11-13 May 1975
Discharge
2·00
1·600
0·800
75·0 mm
35·0 mm
20·0 mm
9·0 mm
2·0 mm
Average of 9 samples
% finer than indicated size
80
60
40
20

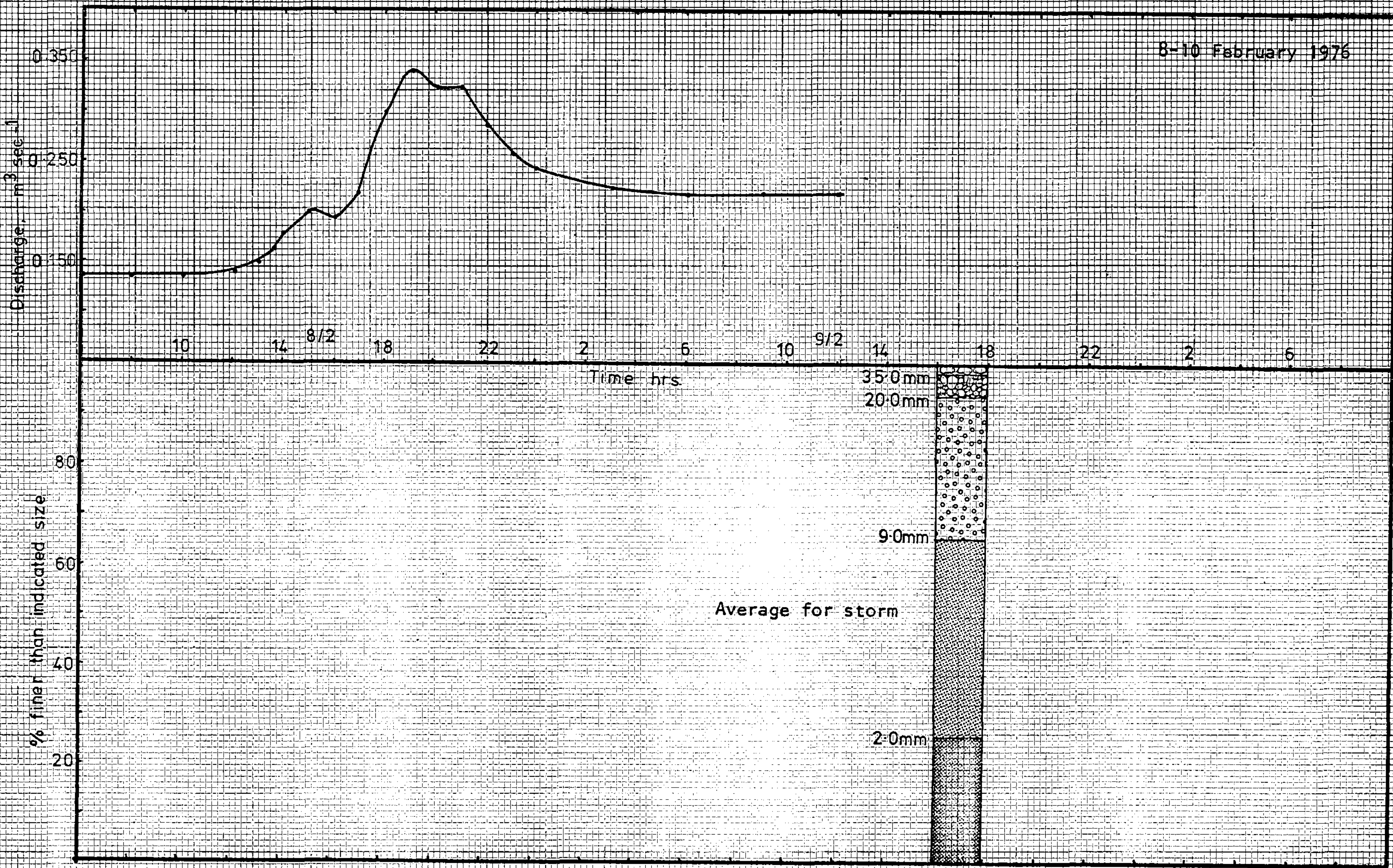


6-7 June 1975
Discharge, m3 sec-1
0·600
0·400
0·200
6/6
7/6
4
8
12
16
20
24
4
8
12
16
20
24
Time hrs
% finer than indicated size
80
60
40
20
20·0mm
9·0mm
2·0mm
Average for storm

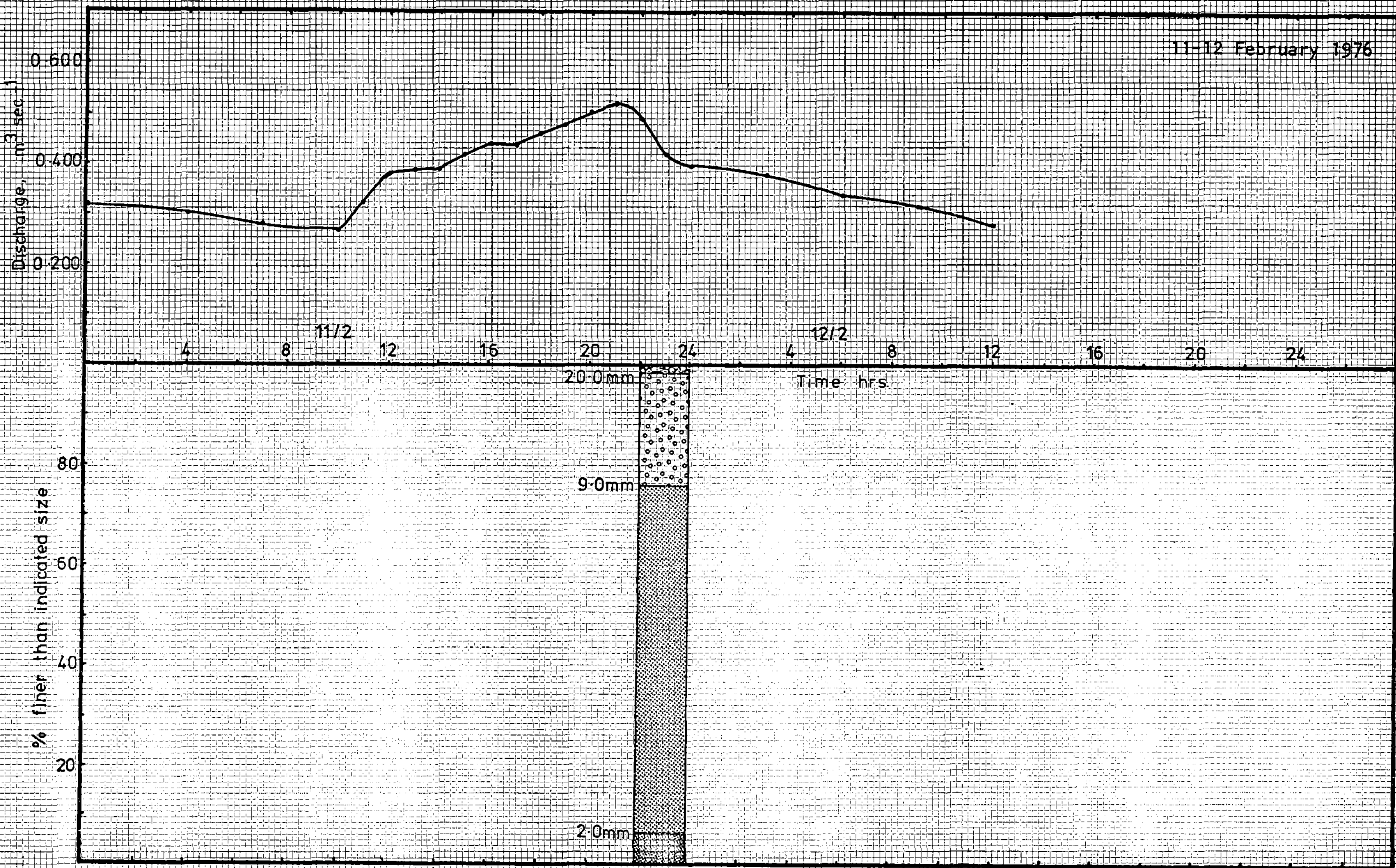

14-15 July 1975
450
350
250
150
Discharge
14/7
15/7
6
10
14
18
22
2
6
10
14
18
22
2
6
Time hrs
35.0mm
20.0mm
9.0mm
2.0mm
80
60
40
20
% finer than indicated size



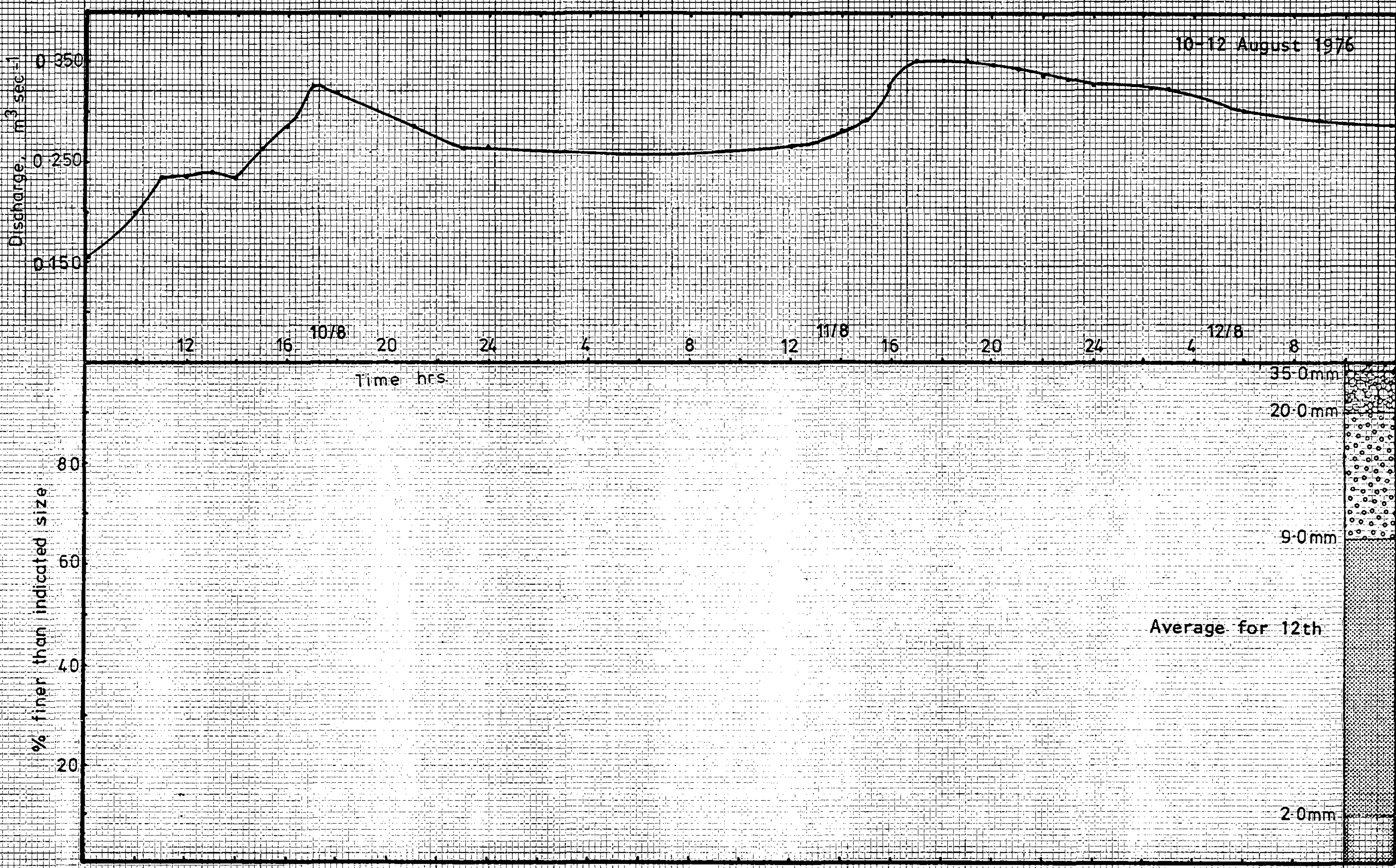
19-20 August 1975
450
350
250
150
Discharge m³ sec⁻¹
19/8
20/8
2
6
10
14
18
22
2
6
10
14
18
22
2
Time hrs
20·0 mm
9·0 mm
2·0 mm
80
60
40
20
% finer than indicated size



8-10 February 1976
0.350
0.250
0.150
Discharge m3 sec-1
10
14
8/2
18
22
2
6
10
9/2
14
18
22
2
6
Time hrs
35.0mm
20.0mm
9.0mm
2.0mm
80
60
40
20
% finer than indicated size
Average for storm



11-12 February 1976
Discharge, m3 sec-1
0·600
0·400
0·200
11/2
12/2
4
8
12
16
20
24
4
8
12
16
20
24
Time hrs
20·0mm
9·0mm
2·0mm
% finer than indicated size
80
60
40
20



10-12 August 1976
Discharge, m3 sec-1
0·350
0·250
0·150
12
16
10/8
20
24
4
8
12
11/8
16
20
24
4
12/8
8
Time hrs
% finer than indicated size
80
60
40
20
35·0mm
20·0mm
9·0mm
Average for 12th
2·0mm

APPENDIX VIII

MOVEMENT OF SHEEP WITHIN THE TORLESSE STREAM CATCHMENT, 1973.

R.P. Stratford, J.A. Hayward & E.J. Stevens.

INTRODUCTION

The Torlesse stream catchment is part of the upper Kowai catchment and is occupied under a pastoral lease by Brookside Station. This valley was used annually for grazing by a flock of half bred ewes from mid February to April.

The affect of domestic stock on the condition of South Island mountain lands has been the subject of much discussion and debate but curiously little study.

This study was carried out during the summer grazing periods of 1973 - 1975 in an attempt to better understand the distribution of animals within the Torlesse stream catchment.

Methods.

Following weaning (in February 1973) a ewe flock was released into the upper Kowai catchment. A number of these sheep were marked with "Ritchie" ear tags and canvas collars in order that they (or an associated mob) might be easily spotted. Although these sheep were released within the Torlesse stream catchment, they left within the first 24 hours in favour of the larger Kowai catchment and were not seen again during the period of observation. (That was a waste of effort!)

To plot sheep positions a grid was set over an aerial photograph which divided the area into 0.75 ha units. At three times each day (daybreak, mid-day and dusk) the number of sheep observed in each unit was recorded. It was found that all observations could be made from one point within the catchment (on Gingerbread spur). Observations were made every day and interrupted only by fog (or very wet weather) and the unavailability of staff during some weekends. Stock disturbance was kept to a minimum by careful movement to and from the observation point and by limiting other field work during the 1973 observation period.

Sheep were recorded for their presence or absence. No attempt was made to distinguish between activities such as grazing, sleeping or travelling. No observations were made between dusk and dawn.

The sheep were allowed a week after their release to settle down before observations began.

Because the observation times varied in length, the results for each unit of catchment area are expressed as the degree of utilization. This is defined as $\frac{N \times h}{H}$

Where N = number of animals present in a unit

h = time of presence in hours

H = total daylight hours for the period.

The summer grazing period was subdivided into seven periods and the degree of utilization data was converted to an approximate stocking rate for each period.

The most intensive observations were made during 1973. Early in 1974 it became evident that the distribution of animals was similar to the preceeding year. In consequence the observations for 1974 and 1975 were less intensive. The results presented here are for 1973.

Results

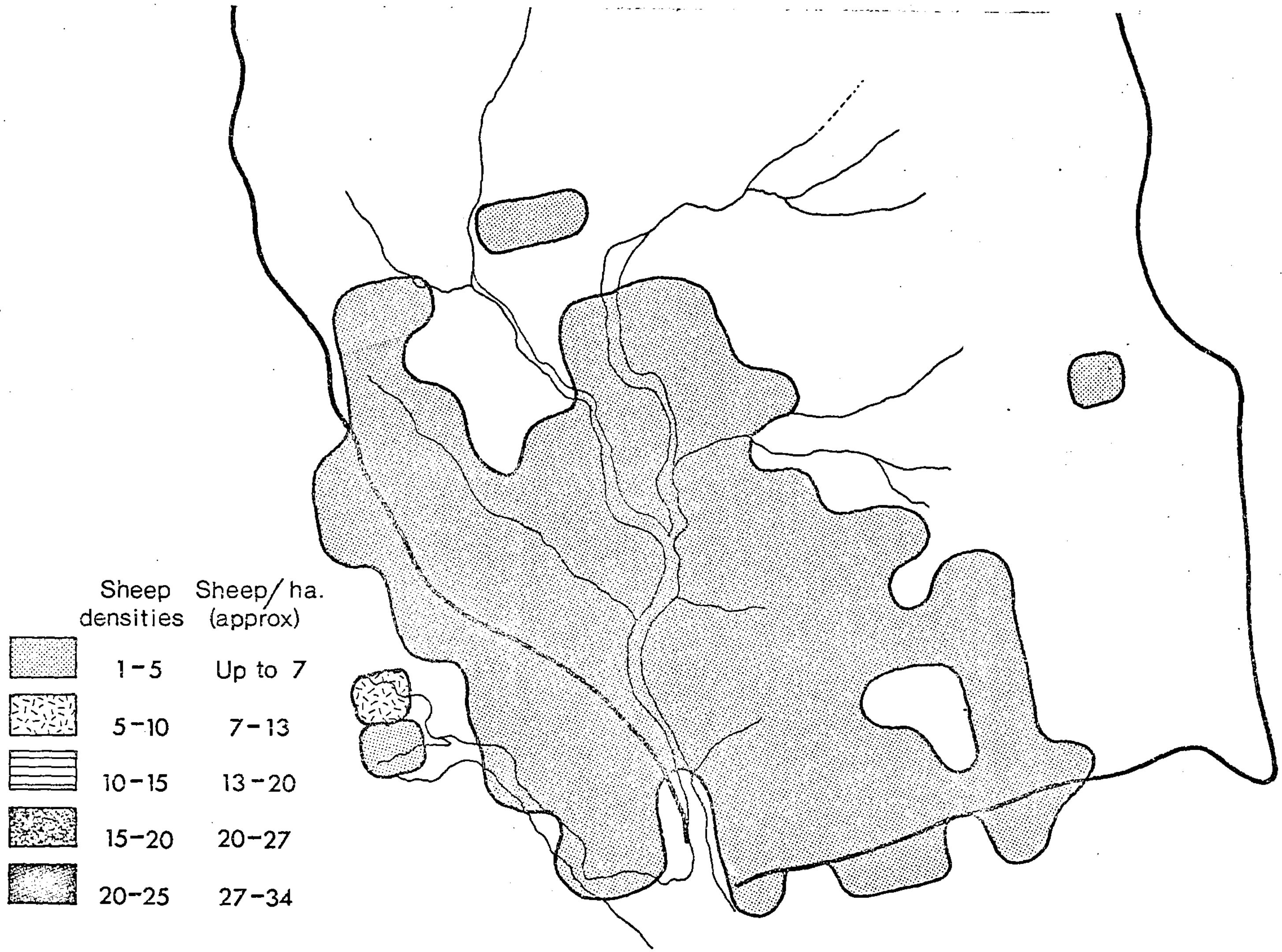
Period 1. 22. 2.73 - 4. 3.73 (10 days) (Fig. VIII.1).

Although the sheep had been in the catchment for one week there was much apparantly aimless movement as they adjusted to their weaned condition and their shift from farm land to hill country. Presence was even and lightly distributed over the more accessible parts of the catchment. Most of the sheep within the basin appeared to use the accessible sites above the stream as camp sites but left the catchment to graze. There was a lot of traffic in and adjacent to the stream channel.

Figure VIII.1 follows

FIGURE VIII.1.

Sheep presence, lower Torlesse stream catchment,
22 February - 4 March, 1973.


Sheep densities
Sheep/ha. (approx)
1-5
Up to 7
5-10
7-13
10-15
13-20
15-20
20-27
20-25
27-34

Period 2. 6. 3.73 - 9. 3.73 (4 days) (Fig. VIII.2)

By the 9th March there had been a general migration from the basin. Those sheep that remained had begun to show preference for particular areas within the basin.

Period 3. 17 - 18. 3.73 (2 days) (Fig. VIII.3)

Observations made between periods 2 and 3 indicate that sheep presence became increasingly localised with a few areas receiving quite high use. Movement in and out of the catchment was much reduced by the end of this period.

Period 4. 22 - 25. 3.73. (4 days) (Fig. VIII.4)

As heavier localised grazing reduced the feed supply, movement within and out of the catchment increased. This was a travelling and grazing activity unlike the mass migrations preceeding and during period 1. Stock presence over the whole catchment was less than periods 1 - 3.

Period 5. 26 - 29. 3.73 (4 days) (Fig. VIII. 5).

Movement in and out of the basin increased. This period was comparable to period 1. with a return to "mass" migrations but low total presence throughout the basin.

Period 6. 30. 3.73 to 1. 4.73 (3 days) (Fig. VIII. 6).

By the end of this period there was a return to localised presence by a "resident" flock. Although the pattern of presence was similar to that of periods 2 and 3 different areas were selected for higher levels of localised presence.

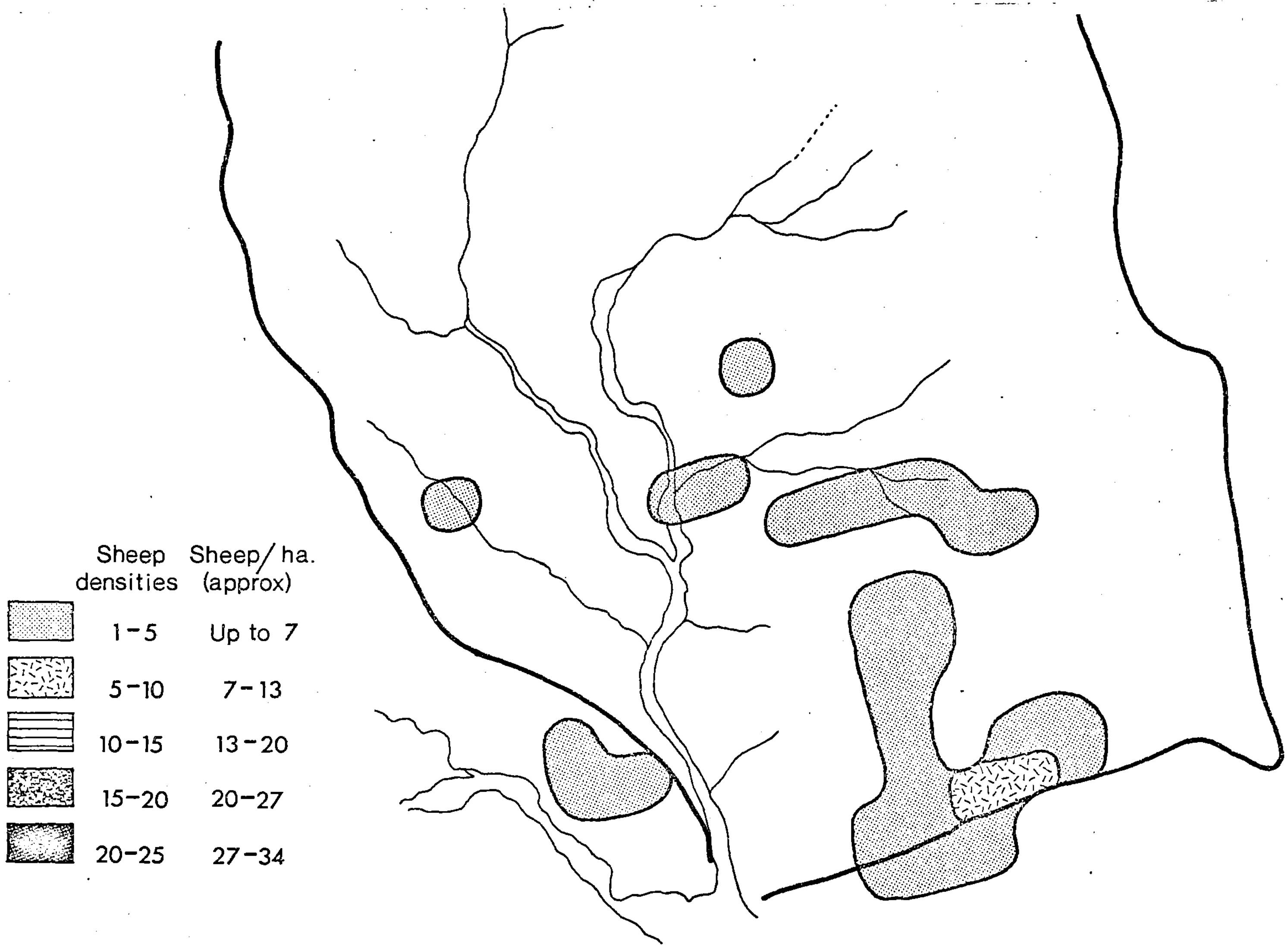
Period 7. 2 - 19. 3.73 (18 days) (Fig. VIII. 7).

Migration from the basin continued throughout this period. Animal numbers

Figures VIII.2, 3, 4, 5, 6, 7 follo

FIGURE VIII.2.

Sheep presence, lower Torlesse stream catchment 6 - 9 March 1973.



Sheep densities
Sheep/ ha. (approx)
1 – 5
Up to 7
5 – 10
7 – 13
10 – 15
13 – 20
15 – 20
20 – 27
20 – 25
27 – 34

FIGURE VIII.3.

Sheep presence, lower Torlesse stream catchment 17 - 18 March 1973.

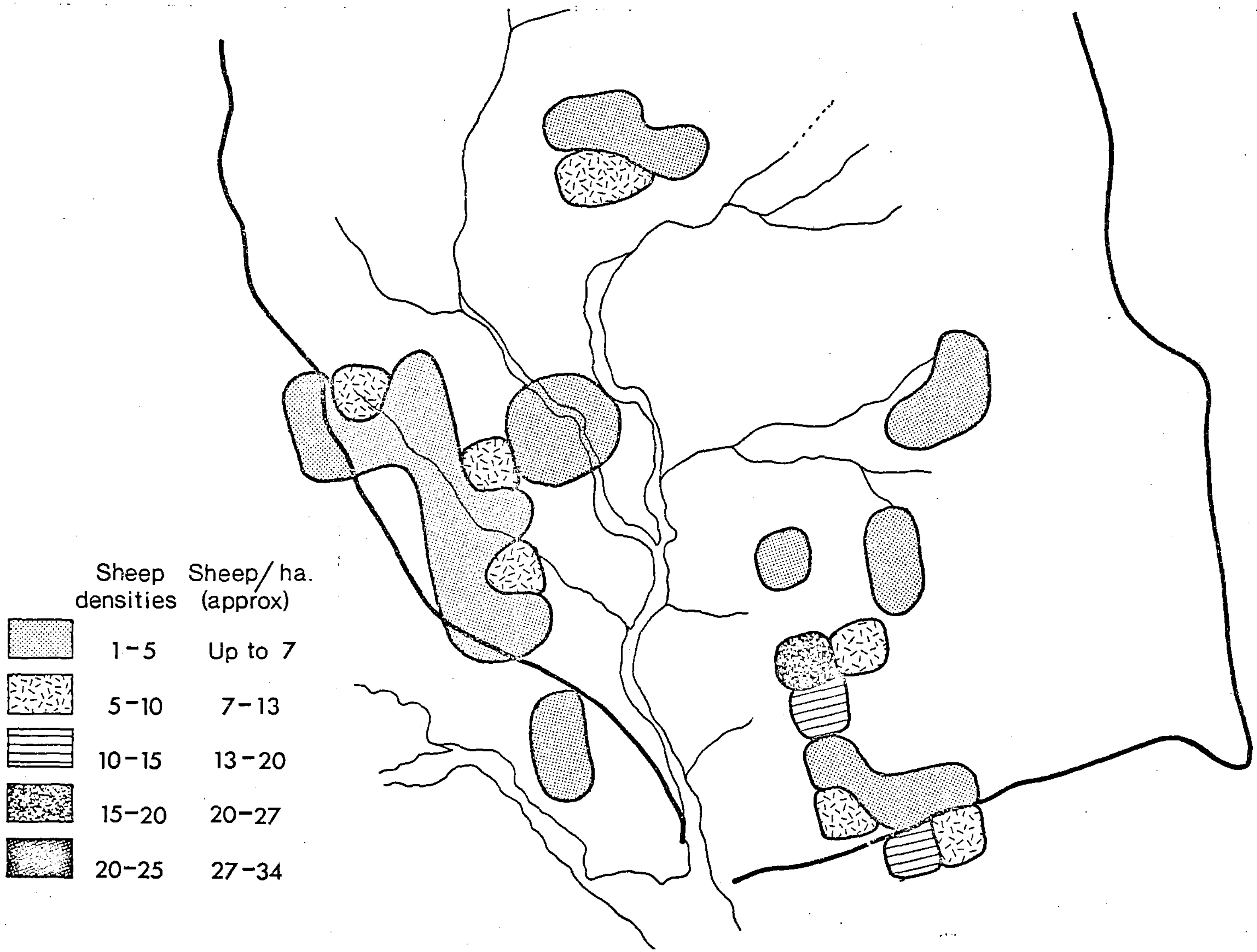

Sheep densities
Sheep/ha. (approx)
1-5
Up to 7
5-10
7-13
10-15
13-20
15-20
20-27
20-25
27-34

FIGURE VIII.4.

Sheep presence, lower Torlesse stream catchment 22 - 25 March 1973.

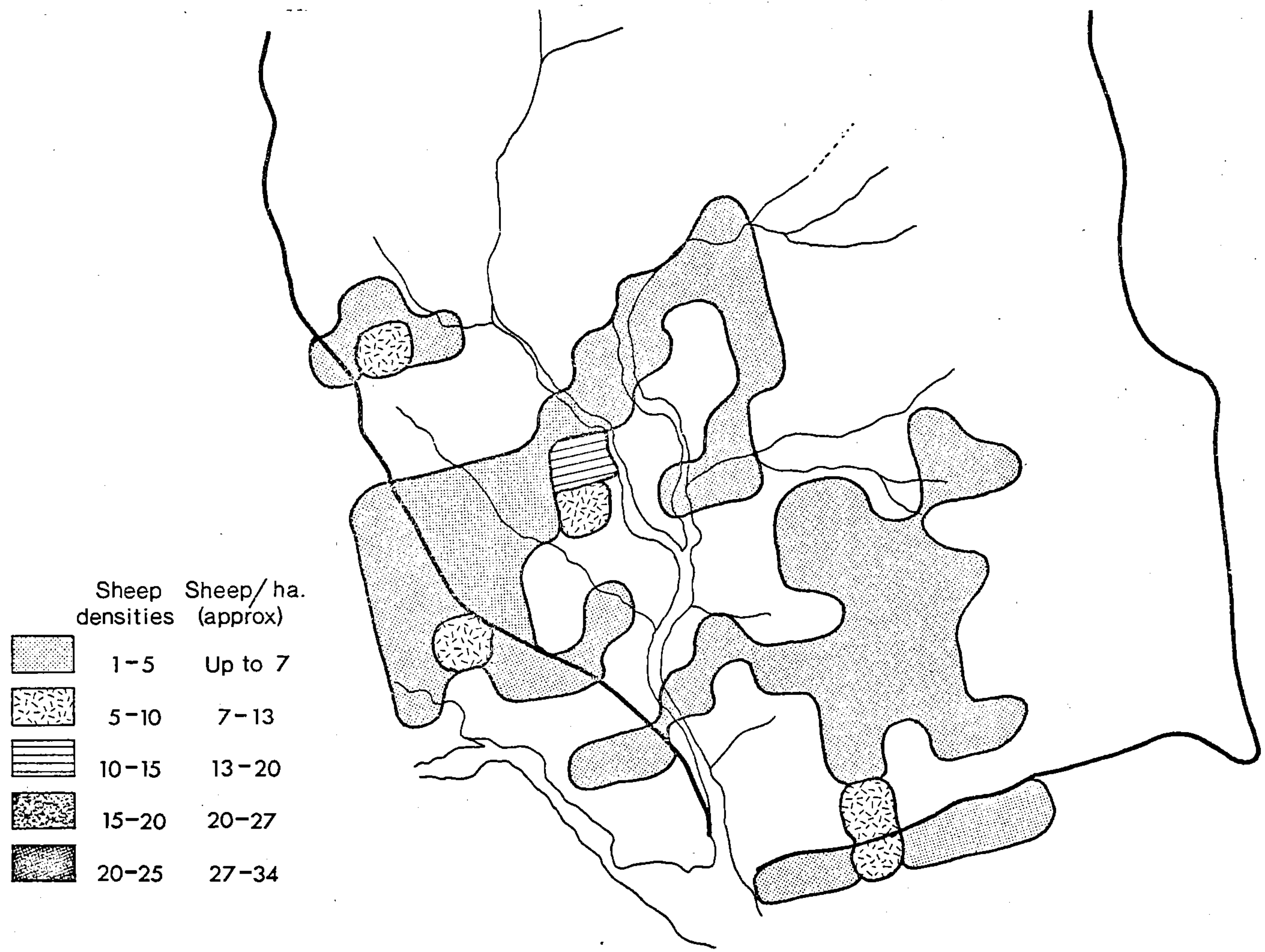
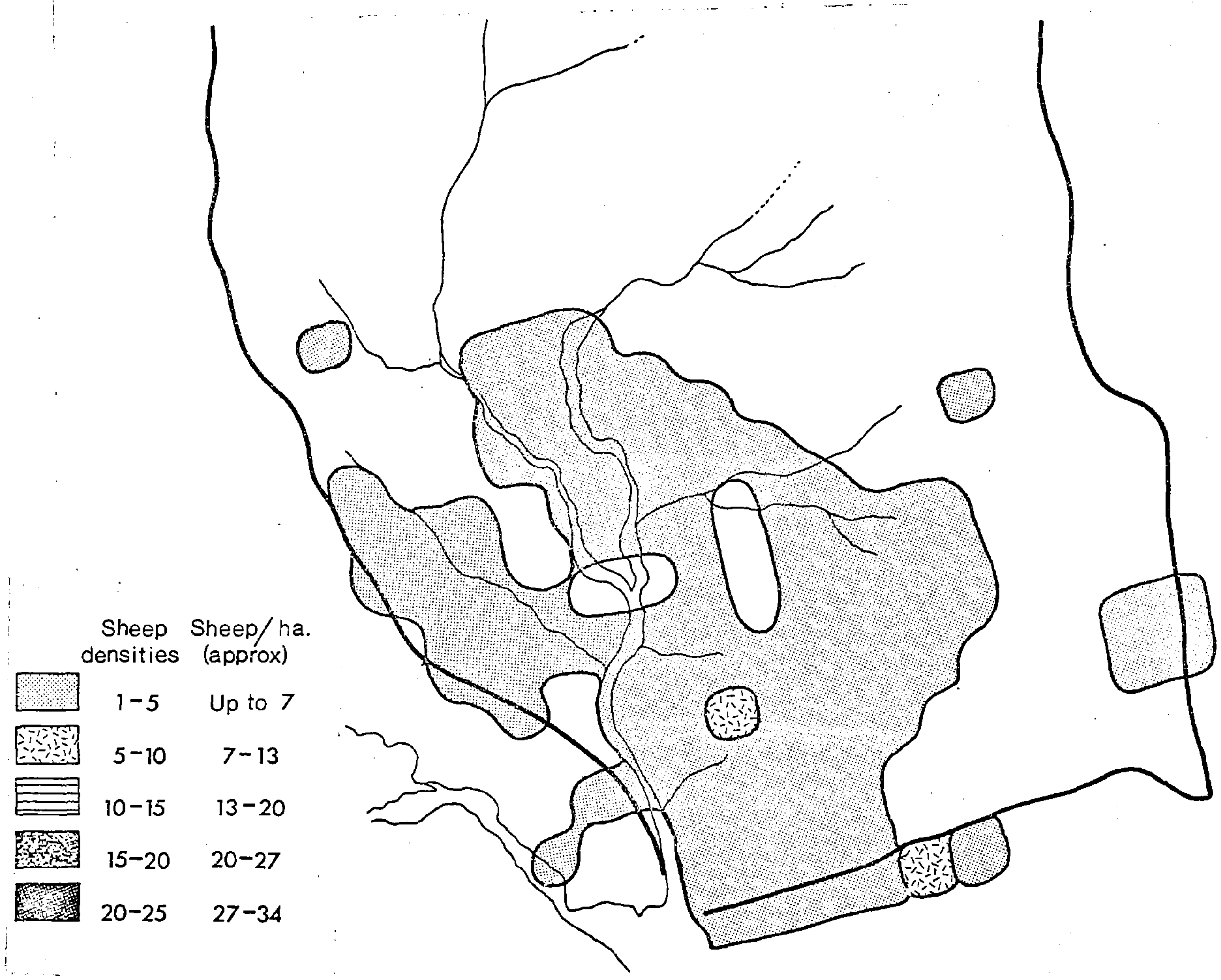

Sheep densities
Sheep/ha. (approx)
1–5
Up to 7
5–10
7–13
10–15
13–20
15–20
20–27
20–25
27–34

FIGURE VIII.5.

Sheep presence, lower Torlesse stream catchment 26 - 29 March 1973.



Sheep densities
Sheep/ ha. (approx)
1-5
Up to 7
5-10
7-13
10-15
13-20
15-20
20-27
20-25
27-34

FIGURE VIII.6.

Sheep presence, lower Torlesse stream catchment 30 March - 1 April 1973.

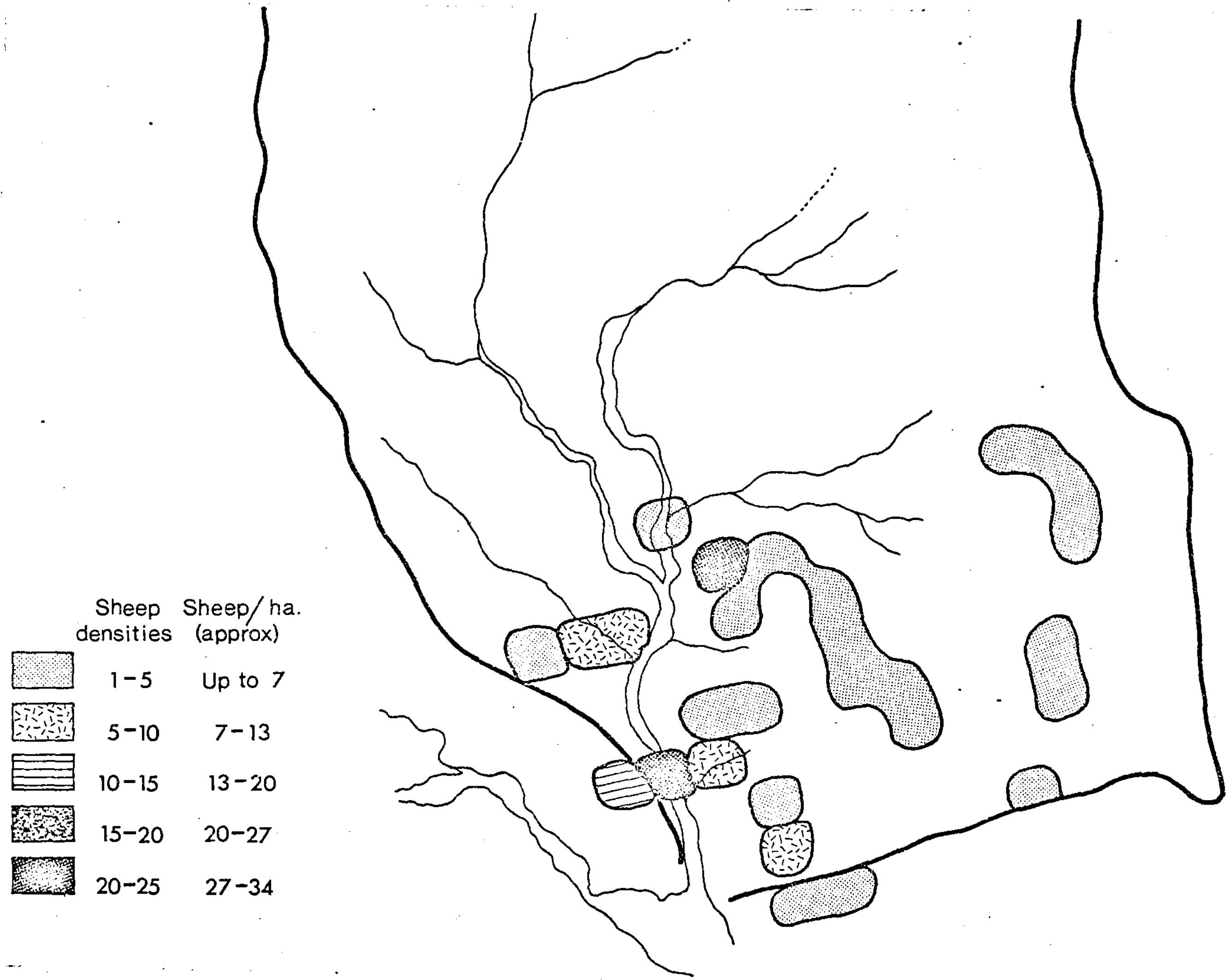
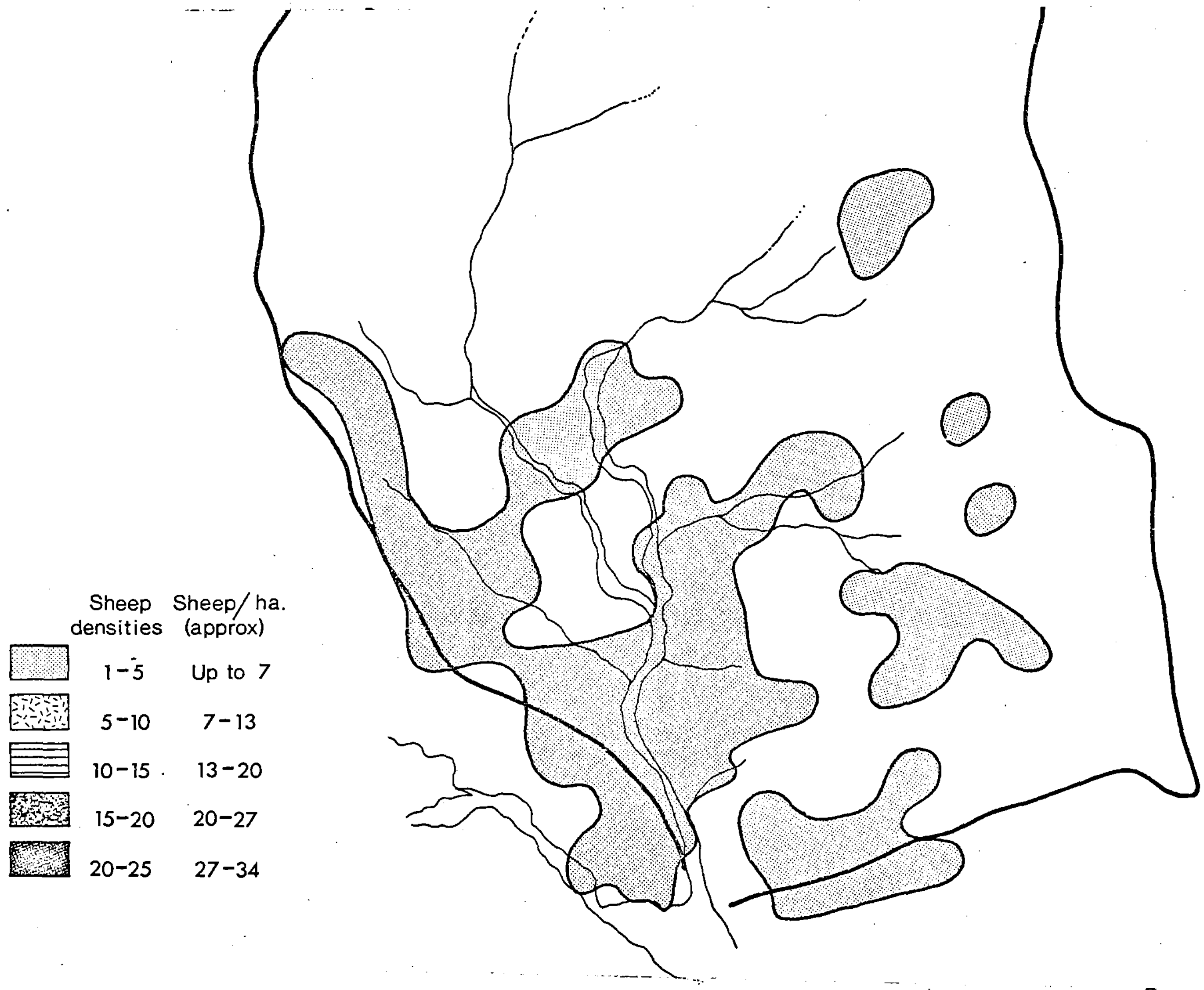

Sheep densities
Sheep/ ha. (approx)
1−5
Up to 7
5−10
7−13
10−15
13−20
15−20
20−27
20−25
27−34

FIGURE VIII.7.

Sheep presence, lower Torlesse stream catchment 2 - 19 March 1973.


Sheep densities
Sheep/ha. (approx)
1-5
Up to 7
5-10
7-13
10-15
13-20
15-20
20-27
20-25
27-34

declined in a manner similar to period 2. It was quite evident by the end of this period that the favoured feeding areas had been grazed out and that stock showed a greater tendancy to travel and feed at the same time. This was also observed in the adjacent upper Kowai catchment.

Figure VIII.8 summarises the presence of animals throughout the summer period. Figure VIII.8 cannot show the authors' clear impression that throughout the study period, stock adjusted their behaviour to the feed supply.

DISCUSSION

The results presented here are for a 57 day grazing period in 1973. In 1974 other field work increased stock disturbance and although the patterns of presence were comparable with 1973 the absolute numbers of animals within the catchment were less.

In 1975 there was an abundance of summer feed and fewer stock moved in to the catchment. Those that did favoured the lower slopes adjacent to the stream channel. The spring and summer of 1972/73 were drier than normal (Chapter 1 Vol II) and it is thought that in consequence the Kowai catchment (including the Torlesse stream catchment) provided less summer feed than normal. This was therefore likely to be the season for most extensive movement through the catchment.

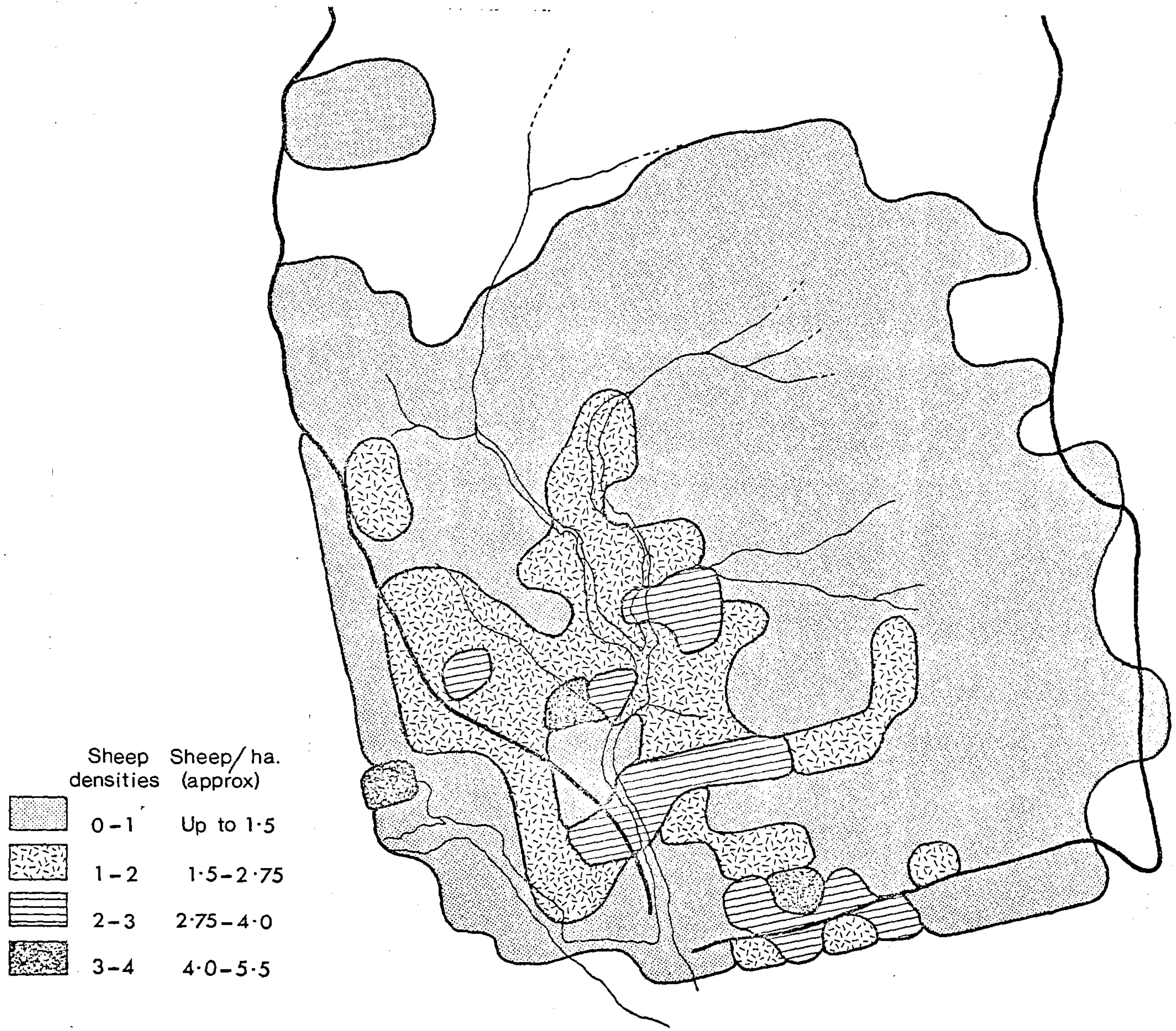
Despite this it was found that there was little stock presence above 1,100 m and at no time were stock observed above 1,300 m. That is, a majority of stock presence was on the 20% of the catchment that was the lowest altitude land. No animals were observed on the upper half of the catchment which is the most depleted of vegetation.

More than half of the area on which presence was recorded had a presence of less than 1.5 sheep per hectare for the 57 day grazing period. Almost all of the stock presence in excess of 1.5 sheep per hectare was on land with a ground cover of more than 80% (see Fig. VIII.8 and Fig. 9 Vol I).

Figure VIII.8 follows

FIGURE VIII.8.

Summary of sheep presence, Torlesse stream catchment
February - April 1973.


Sheep densities
Sheep/ ha. (approx)
0 – 1
Up to 1·5
1 – 2
1·5 – 2·75
2 – 3
2·75 – 4·0
3 – 4
4·0 – 5·5

Summary

The sheep utilising this catchment were half bred ewes. It is entirely possible that different breeds, ages and classes of livestock would behave in a different fashion than that described here.

Be that as it may, the findings of this study call into question the validity of attributing contemporary high altitude deterioration to the presence of sheep in at least this catchment. The opportunities for future stock management in at least this catchment are still open for study and discussion.

APPENDIX IX

AN ATTEMPT TO DETERMINE SOURCE AREAS OF STREAM SEDIMENTS BY X-RAY FLUORESCENCE.

INTRODUCTION

Channel surveys and field observations during floods showed that a majority of the sediments recovered at the sediment trap derived from Rainbow gully and a limited section of the Irishman stream. A method was sought which might confirm these observations and give quantitative estimates of their importance as source areas. The idea of labelling sediments at a variety of potential source areas and recovering a proportion of them at a downstream point is not new but was rejected because of the practical difficulties involved.

In an earlier study in the Torlesse stream catchment Martin (1972) had attempted to estimate sediment yields and source areas using natural characteristics of the bed material. Although his study was inconclusive it was a valuable contribution to an understanding of the opportunities and constraints of techniques involving natural tracers. Lithological composition was the most promising of the characteristics investigated.

This study was an attempt to develop Martin's work, by comparing the lithology of four rock types from the upper catchment with the lithologies of particles of sand sized material recovered from the sediment trap.

Martin's (1972) method of microscope sorting was time consuming, and the use of artificially labelled material was rejected because of anticipated problems of recovery and in the case of isotopes, safety. X-ray fluorescence had a number of potential advantages and was a technique judged worthy of further study.

METHODS

With the facilities and assistance of the Institute of Nuclear Sciences (see acknowledgements) the surfaces of rock samples were irradiated with X-rays in the hope that the elemental composition of each rock type might have a characteristic X-ray 'signature'. Four rock types were tested.

They were chert, dolorite, sandstone and argillite.

Under X-ray irradiation surface elements fluoresce in proportion to their presence. The energy levels of fluorescence can be monitored on an oscilliscope or stored in digital form. As changes in surface geometry alter the magnitude of fluorescence, the energy levels of fluorescence for each element are best expressed as a proportion of the largest and most common peak, iron.

RESULTS

Table IX.1 shows the fluorescent energy levels relative to iron, for elements within the four rock samples and the sand sample taken from the sediment trap. The large standard deviations of each estimate are due to wide variations in fluorescence levels when a different face of the same, apparantly homogeneous, rock was irradiated.

DISCUSSION

N.E. Whitehead *pers comm* wrote a computer programme to "juggle" the relative proportions of the rock types to obtain a minimum difference from the sand composition. This indicated that the best fit for the relative contributions of the four rock types to the sand sample was: chert 10%, argillite 60%, sandstone 20%, gabbro 10%.

An analysis of the overall precision of the original data suggested that the standard deviation of each percentage value was about 30% that is for example the argillite contribution might range from 40% - 80%. In view of the variability of fluorescence levels of each rock sample, Whitehead expressed surprise at this 'high' level of precision.

Further analyses suggested that the composition of the sand sample was chert 51% - 63%, argillite 20% - 25%, sandstone and gabbro 9% - 16%.

The levels of zinc and titanium in the sand sample are higher than those of

Table IX.1 follows

TABLE IX.1.

X-ray spectra of four rock samples and one sand sample, Torlesse stream catchment.

Source: N.E. Whitehead *pers comm.*

(Note: values are expressed as a ratio to iron peak value.)

	K	Ca	Ti	Cu	Zn	Pb	Rb	Sr
Chert	0.007	12.6	1.18	0.17	1.00	0.54	0.17	56
	±0.017	15	0.72	0.25	1.30	1.06	0.25	99
Argillite	0.68	0.09	1.10	0.19	0.63	0.51	5.2	5.2
	±0.58	0.15	0.06	0.04	0.09	0.18	0.9	6.1
Sandstone	0.43	0.84	1.12	0.59	0.79	1.05	7.9	60
	±0.09	0.80	0.15	0.26	0.16	1.05	4.2	10
Gabbro	0.66	2.02	2.40	0.42	0.31	0.21	1.08	61
	±0.97	0.31	0.40	0.23	0.13	0.34	0.38	52
Sand composition	0.37	0.95	0.80	0.187	0.43	0.38	3.19	17
(estimated)	±0.25	1.11	0.11	0.077	0.14	0.29	0.95	13
Sand composition	0.301	0.992	1.97	0.146	3.24	0.47	3.99	20
(actual)	±0.032	0.024	0.14	0.048	0.89	0.33	0.08	2

All figures given for errors represent one standard deviation.

the rock samples and the calculated sand composition. This would suggest that the sand sample was composed of material of higher than normal zinc and titanium status. This example illustrates the sampling problems associated with the method of X-ray fluorescence of these rock and sediment types.

Because of large within sample variability it is not possible for this method to add significantly to a quantitative understanding of sediment source areas. A visual estimate of sediment retained in the trap is able to provide information of comparable reliability.

Thus while the X-ray fluorescence method may have promise as a technique for tracing fine sediments in some catchments, it is not suited to the needs of a quantitative assessment of sediment sources in the Torlesse stream catchment.

Acknowledgement

I am particularly grateful to Dr. N.E. Whitehead (Department of Scientific and Industrial Research Institute of Nuclear Sciences) for his willing and painstaking assistance with this study.

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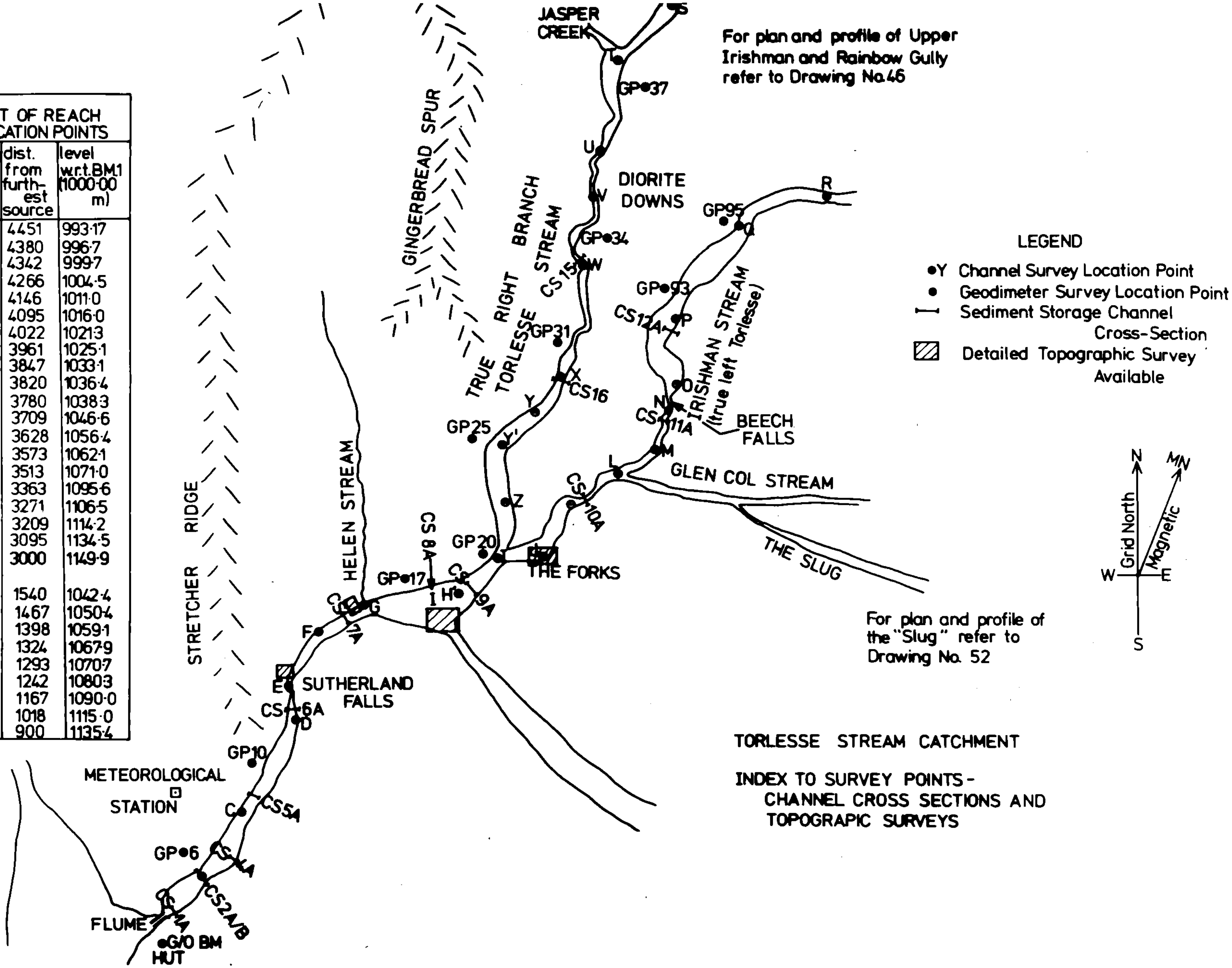
Whitehead N.E. *personal communication* X-ray spectra of sediment samples Torlesse stream catchment.

APPENDIX X

SURVEY INFORMATION OF TORLESSE AND KOWAI RIVERS.

LIST OF REACH LOCATION POINTS

stream location point	dist. from furthest source	level w.r.t.BM1 (1000·00 m)
A	4451	993·17
B'	4380	996·7
B	4342	999·7
C	4266	1004·5
D	4146	1011·0
E	4095	1016·0
F	4022	1021·3
G	3961	1025·1
H'	3847	1033·1
H	3820	1036·4
I	3780	1038·3
Z	3709	1046·6
Y'	3628	1056·4
Y	3573	1062·1
X	3513	1071·0
W	3363	1095·6
V	3271	1106·5
U	3209	1114·2
T	3095	1134·5
S	3000	1149·9
J'	1540	1042·4
K	1467	1050·4
L	1398	1059·1
M	1324	1067·9
N	1293	1070·7
O	1242	1080·3
P	1167	1090·0
Q	1018	1115·0
R	900	1135·4

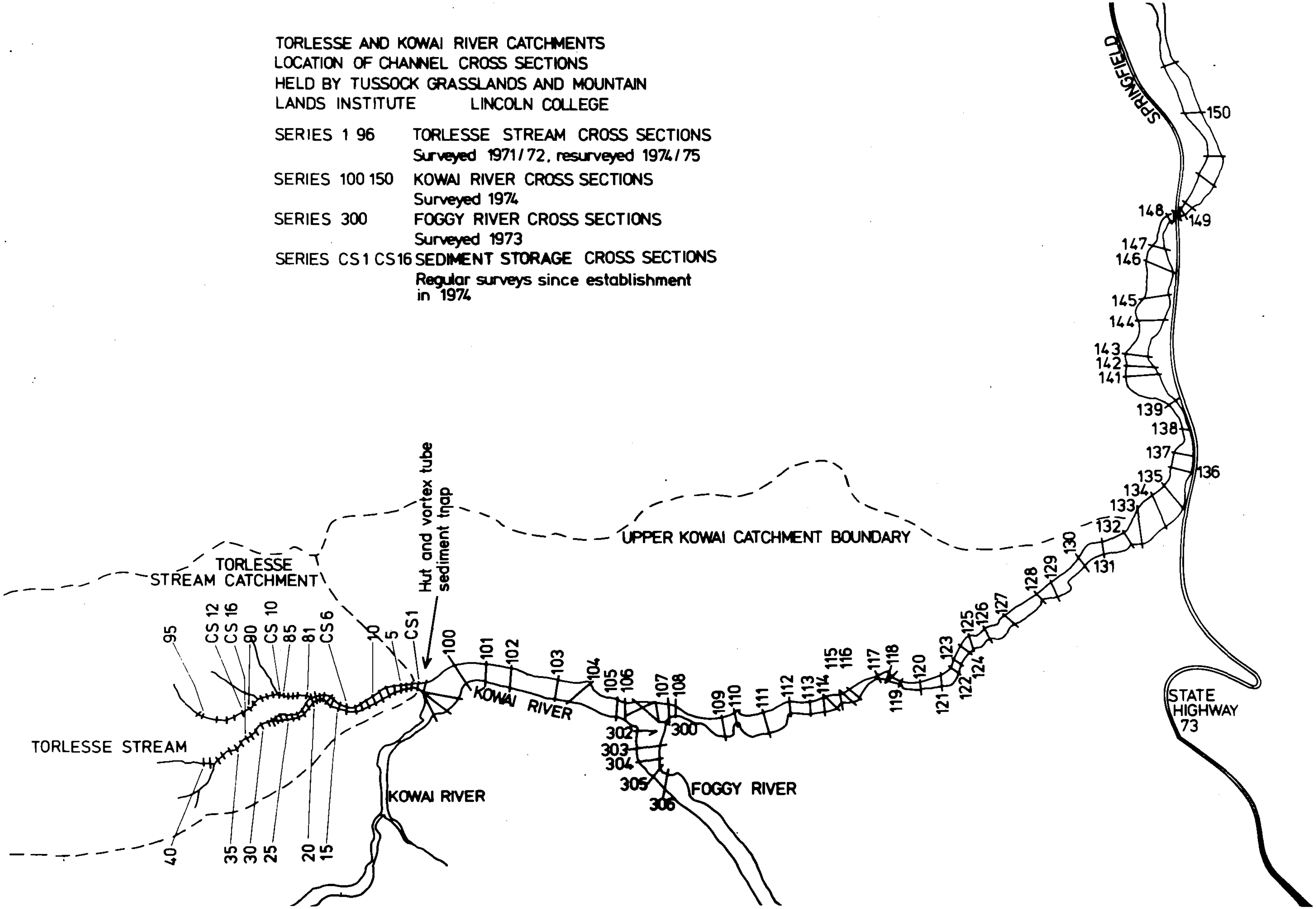


TORLESSE STREAM CATCHMENT

INDEX TO SURVEY POINTS - CHANNEL CROSS SECTIONS AND TOPOGRAPIC SURVEYS

TORLESSE AND KOWAI RIVER CATCHMENTS
LOCATION OF CHANNEL CROSS SECTIONS
HELD BY TUSSOCK GRASSLANDS AND MOUNTAIN
LANDS INSTITUTE LINCOLN COLLEGE

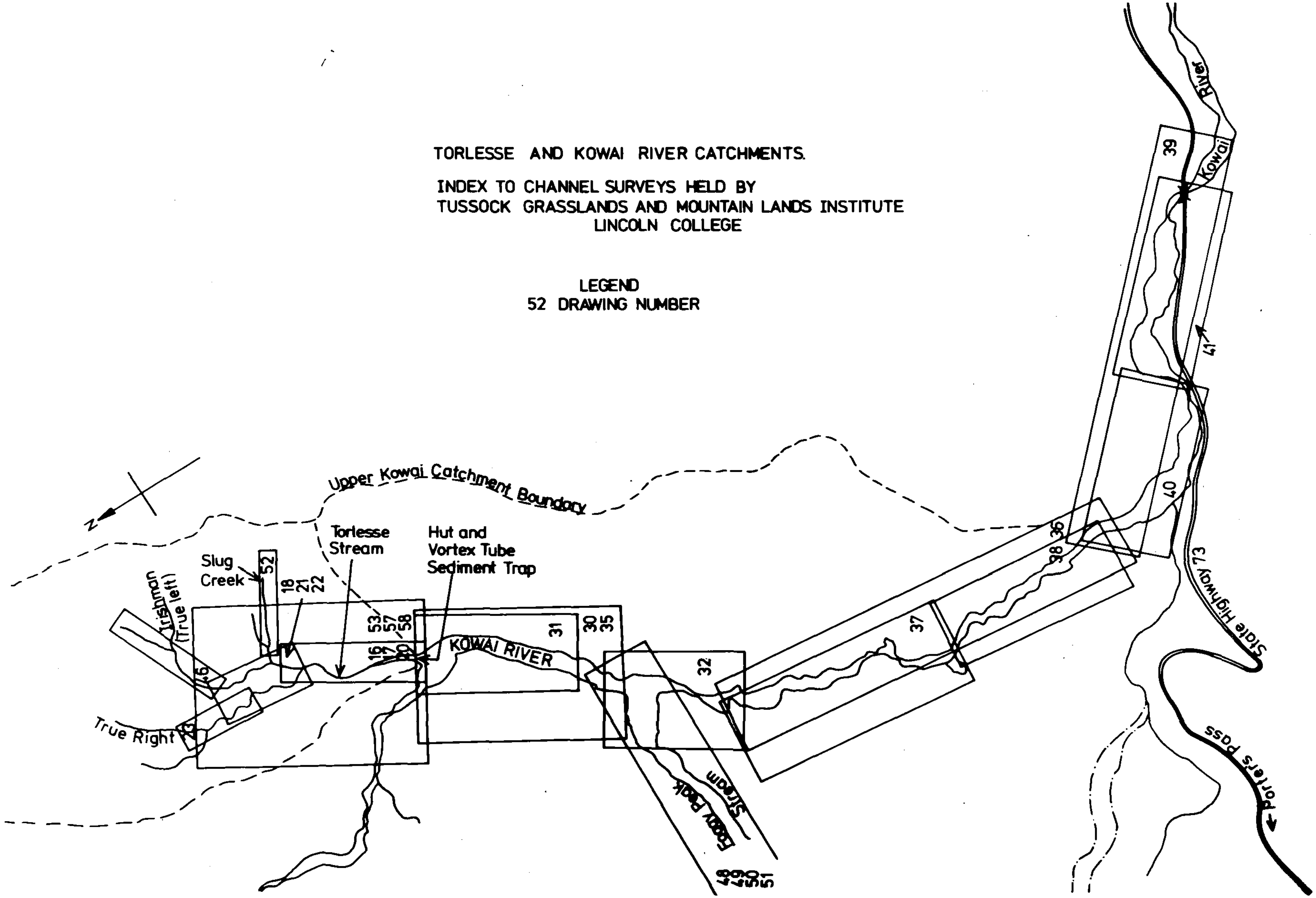
SERIES	1 96	TORLESSE STREAM CROSS SECTIONS Surveyed 1971/72, resurveyed 1974/75
SERIES	100 150	KOWAI RIVER CROSS SECTIONS Surveyed 1974
SERIES	300	FOGGY RIVER CROSS SECTIONS Surveyed 1973
SERIES	CS1 CS16	SEDIMENT STORAGE CROSS SECTIONS Regular surveys since establishment in 1974



TORLESSE AND KOWAI RIVER CATCHMENTS.

INDEX TO CHANNEL SURVEYS HELD BY
TUSSOCK GRASSLANDS AND MOUNTAIN LANDS INSTITUTE
LINCOLN COLLEGE

LEGEND
52 DRAWING NUMBER



APPENDIX XI

A LABORATORY STUDY OF STREAM ENERGY IN A SIMULATED POOL-RIFFLE CHANNEL.

INTRODUCTION

Field observations and experience indicated that the Torlesse stream channel was a series of steps and hydraulic jumps and that in a free state these played an important role in the dissipation of stream energy. However, when a pool was submerged by water and/or gravel,stream velocities increased, and its efficiency for energy dissipation was presumed to be markedly reduced (see Chapter 9 Vol II).

As it was difficult to obtain reliable field information a pilot study was carried out to consider the interaction of sediment and flow rate,on stream velocity through a pool riffle channel.

In 1962 Leopold & Langbein (1962) first introduced the concept of entropy to explain the evolution of stream patterns. Since that time there has been considerable interest in the application of thermodynamic principals of energy dissipation rate relationships to fluvial systems (see for example Yang 1971 a, b, & c, 1976).

In a recent review, Davy & Davies (in press) established that it was not valid to transfer certain thermodynamic laws governing the behaviour of entropy in a system to streams. While the observed behaviour of streams is not in qualitative conflict with entropy principles they caution against further *quantitative* application of these principles.

This study attempted to better understand the significance of pool riffle morphology to the dissipation of a stream's kinetic energy. Although it concerns some of the same principles as Yang (1971, 1976) and others have reported,its aim was to consider, in controlled conditions, some possible features of mountain stream behaviour. This study was not concerned with attempting to understand the evolution of mountain channel forms.

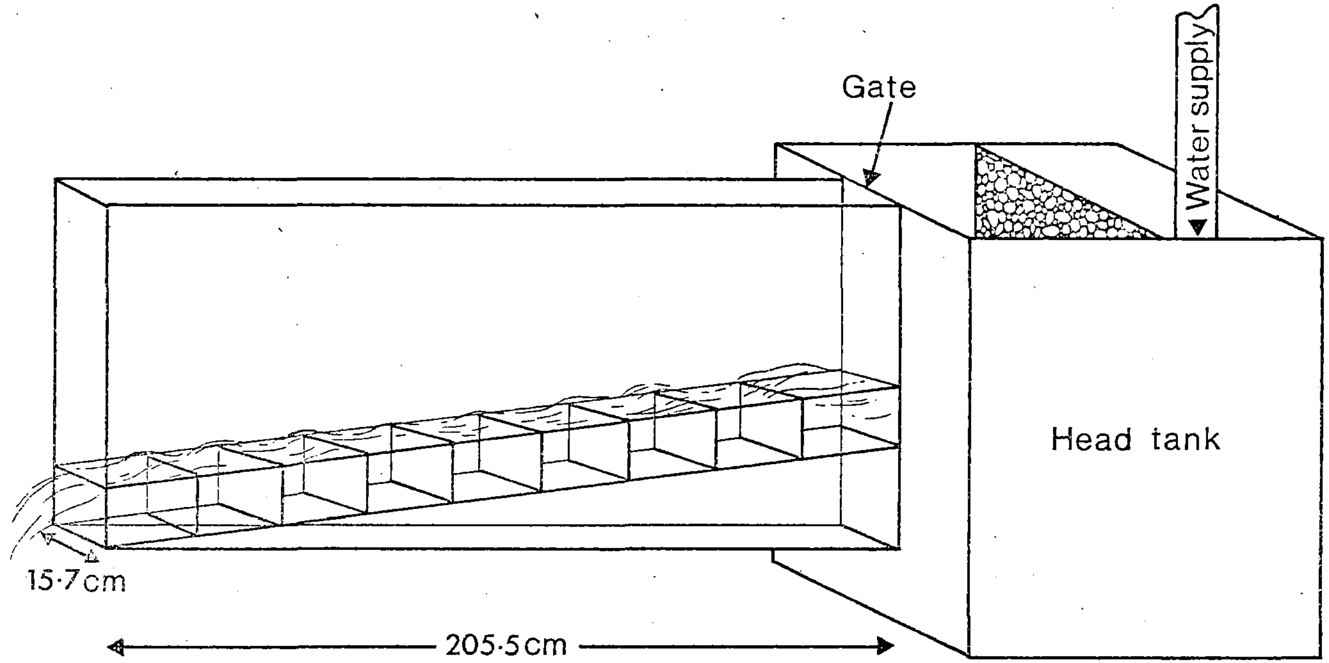
METHODS

Fig.XI.1 shows the model that was built to simulate the pool riffle channel

Figure XI.1. follows

FIGURE XI.1.

The laboratory model to simulate a mountain stream catchment.


Gate
Water supply
Head tank
15·7cm
205·5cm

of the Torlesse stream. The test reach was contained within a flume 2 m x 0.15 m. The channel slope was set at 0.03 and the step length to height ratio was arbitrarily set at 14:1. Water was supplied from a calibrated head tank.

Velocity measurements were made by injecting a salt solution (sodium carbonate) into the upstream pool and recording its passage through the test reach. Electrodes were set on upstream and down stream riffles and connected through conductivity meters to chart recorders.

The time between the peak values for upstream and down stream salt concentrations was used to estimate mean velocities. Test trials showed that the trace of downstream salt concentration was unreliable when gravel covered the down stream electrode. The last pool was therefore excluded from tests of the effects of gravel storage on stream velocity. Test trials also established that more reliable results were obtained when the upstream electrode was located on the third riffle (from the top). (Variability in entry conditions for water and salt into the upstream pool lead to variations in the storage and release of salt from that pool. This frequently produced a multiple peak of salt concentration of the upper riffle. By recording concentration at the third pool, the multipeak problem was eliminated.)

A series of trials was carried out in which mean velocities were determined for a range of flow conditions.

A second series of trials was then carried out for the same flow rates but with gravels occupying 1/4, 1/2, 3/4 and total pool storage capacity. At the beginning of each trial, gravel was placed parallel to the slope. Water flow repositioned the gravel, and at the highest flow rates scoured some of it to the lowest pool.

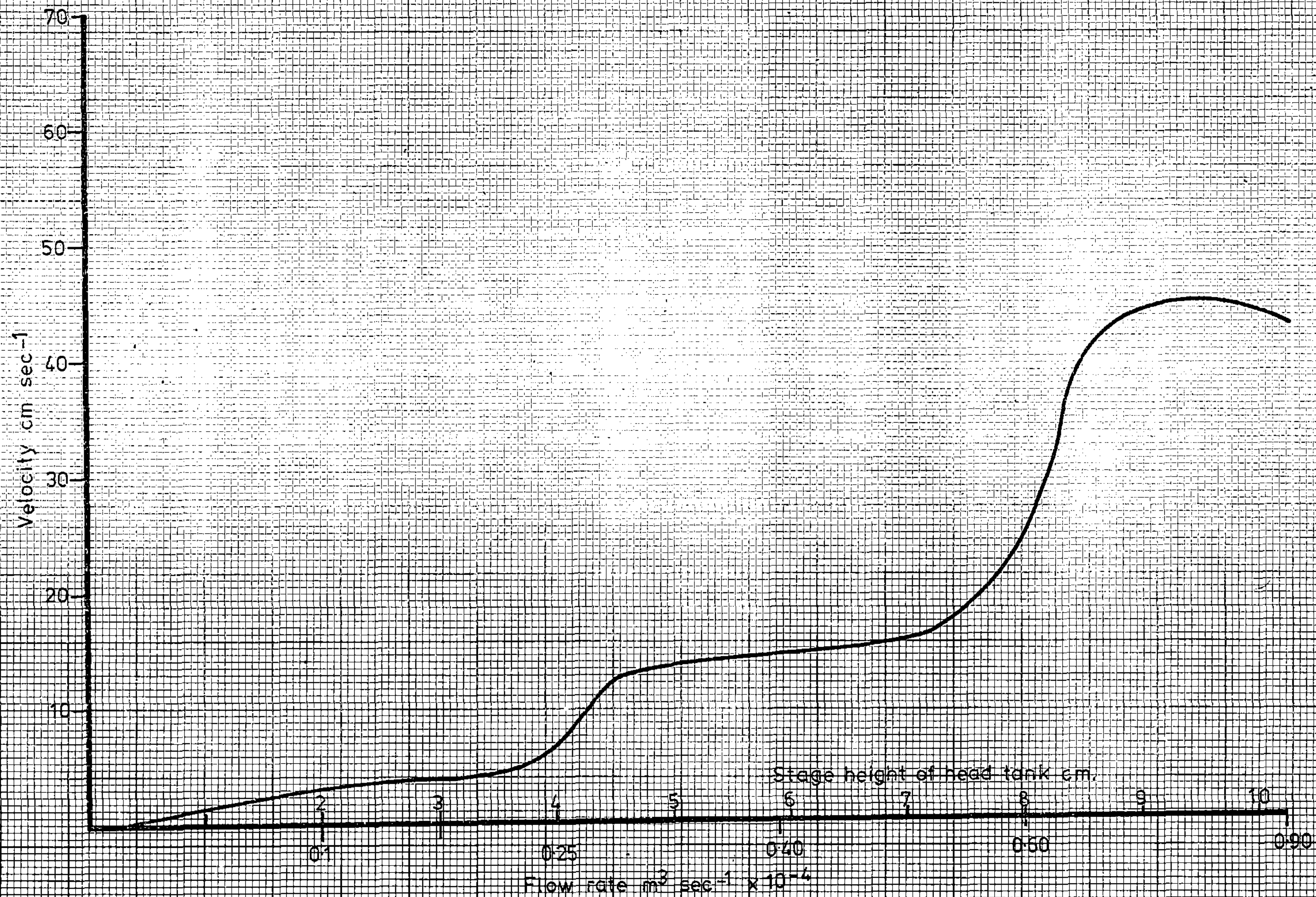
RESULTS

Figs. XI.2, XI.3 show velocity depth relations through the test channel,

Figures XI.2, XI.3 follow

FIGURE XI.2.

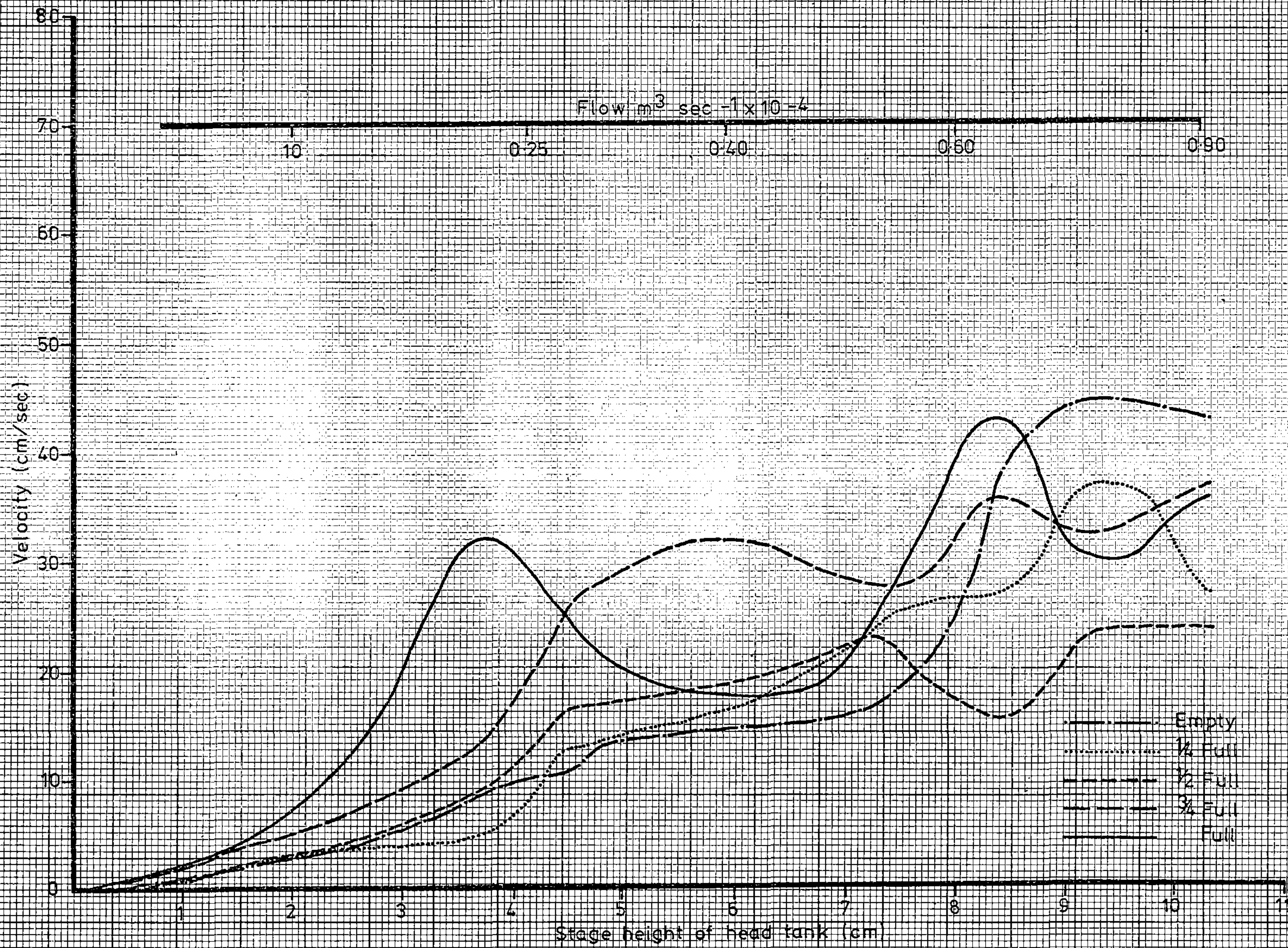
Mean velocities through laboratory model with increasing discharge.



70
60
50
40
30
20
10
Velocity cm sec-1
Stage height of head tank cm.
2
3
4
5
6
7
8
9
10
0·1
0·25
0·40
0·60
0·90
Flow rate m3 sec-1 x 10-4

FIGURE XI.3.

Mean velocities through laboratory model with increasing discharge and an increasing proportion of pool storage occupied by gravel.



Flow m3 sec -1 x 10 -4
10
0.25
0.40
0.60
0.90
Velocity (cm/sec)
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
Stage height of head tank (cm)
Empty
¼ Full
½ Full
¾ Full
Full

(i) without gravel in the pools (Fig. XI.2), (ii) with varying amounts of gravel occupying pool storage (Fig. XI.3). Fig. XI.4 shows flow and kinetic energy relations for flows with and without gravel.

DISCUSSION

The results open interesting and potentially significant fields for interpretation and further study. The fluctuating pattern of velocity,depth relations indicate significant interaction between flow rate, flow regimes and bed form. (Tranquil flow, tumbling flow and rapid flow (Morris 1968) may well be significant in the evolution of the 'major' and 'minor' pattern of channel morphology (Chapter 9 Vol II) but are outside the immediate aim of this study.) The hydraulic aspects of this study are therefore not included in this discussion.

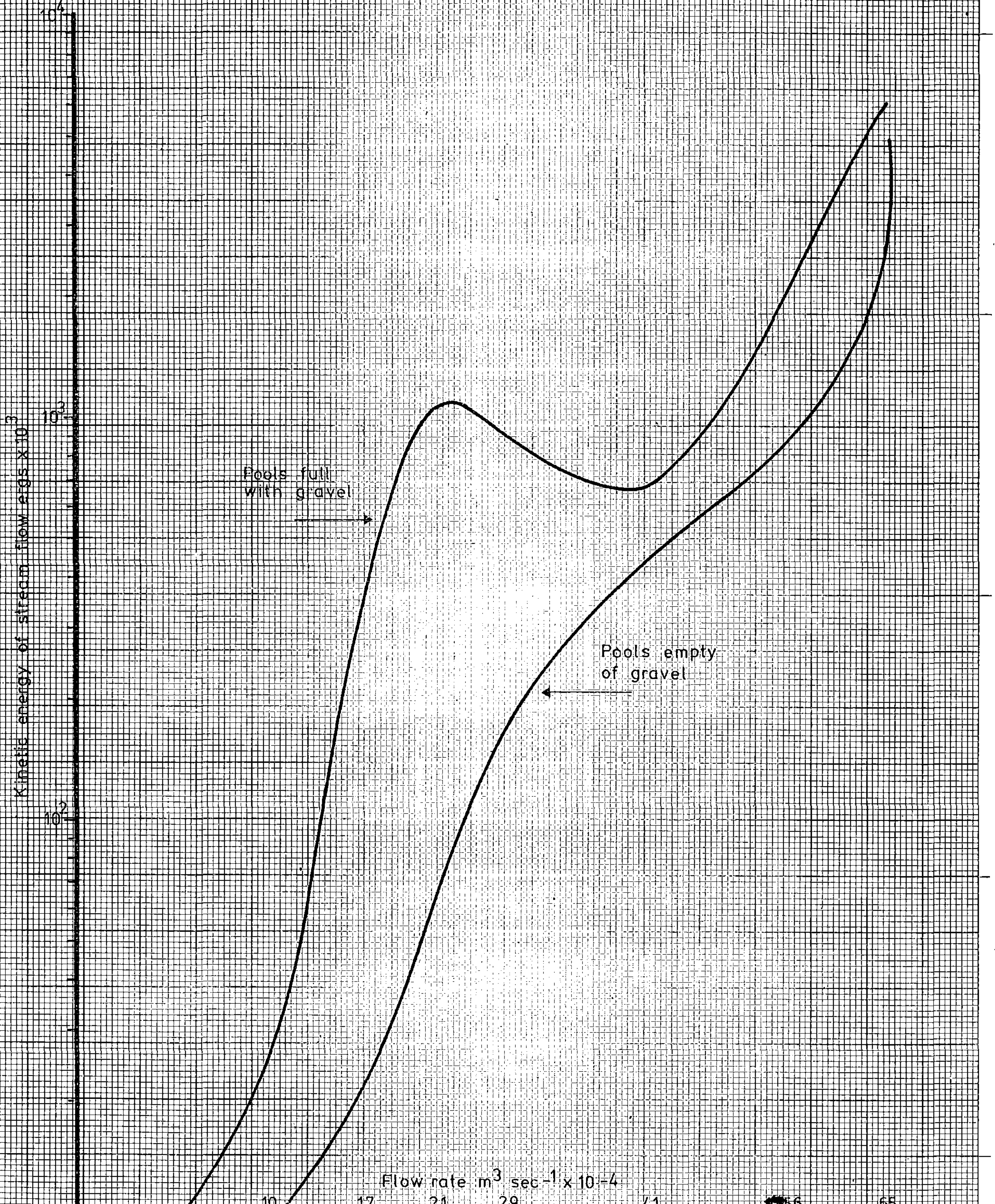
The results confirm field observations that gravels can affect stream velocities and kinetic energies when they occupy pool storage and thereby prevent energy dissipation by turbulent flow within the pool. However, if results from this laboratory model can be translated to the field, they would suggest gravel storage will have its most significant effect at lower flow rates. Figure XI.3 suggests that up to 50% of pool storage can be occupied without a significant effect on flow velocity. In fact, the presence of some gravel (1/4 full) may actually lower flow velocities. (This may have been caused by gravel reforming the pool into a more effective shape for turbulent flow within it.) However when 75% - 100% of pool storage capacity was occupied, the velocities of lower flows was increased up to 4 times. Figure XI.4 shows that this gives about a 20 x increase in kinetic energy. At higher rates of flow these differences were less pronounced.

Thus it appears that the major effect of gravel storage within the pools is to produce velocities which, in the absence of gravel, would only be found in larger (i.e. less frequent) events. At higher flow rates gravel effects on velocity are relatively minor.

Figure XI.4 follows

FIGURE XI.4.

Flow and kinetic energy relations in a simulated mountain stream channel with and without gravel storage in pools.



Kinetic energy of stream flow ergs x 10^3
10^4
10^3
10^2
10
Pools full with gravel
Pools empty of gravel
Flow rate m^3 sec^-1 x 10^-4
10
17
21
29
41
56
65
1
2
3
4
5
6
7
8
Depth head tank m x 10^-2

It must be emphasised that this was a laboratory study and it serves only to confirm field observations that gravel presence can significantly effect flow velocities and energy status. Because of the well known difficulties in translating results from hydraulic models to the real world, the results presented here should be regarded as tentative and qualitative. Further there is an obvious interaction of flow, flow regime and channel form at depths greater than 3.5 cm. Velocity results at the higher flow rates may well be unique to this model. Therefore the finding that gravels have their greatest influence on stream velocities and kinetic energy at lower flow rates should be considered as tentative. This topic clearly requires further investigation.

ACKNOWLEDGEMENTS

I am grateful to Messrs. Geoff. Thomson and Colin Tinker for their assistance with this study and to Dr. T.H.R. Davies for his advice and help. This study was carried out as part of a project on site selection for the rehabilitation of eroded land with financial support from the Department of Lands and Survey.

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