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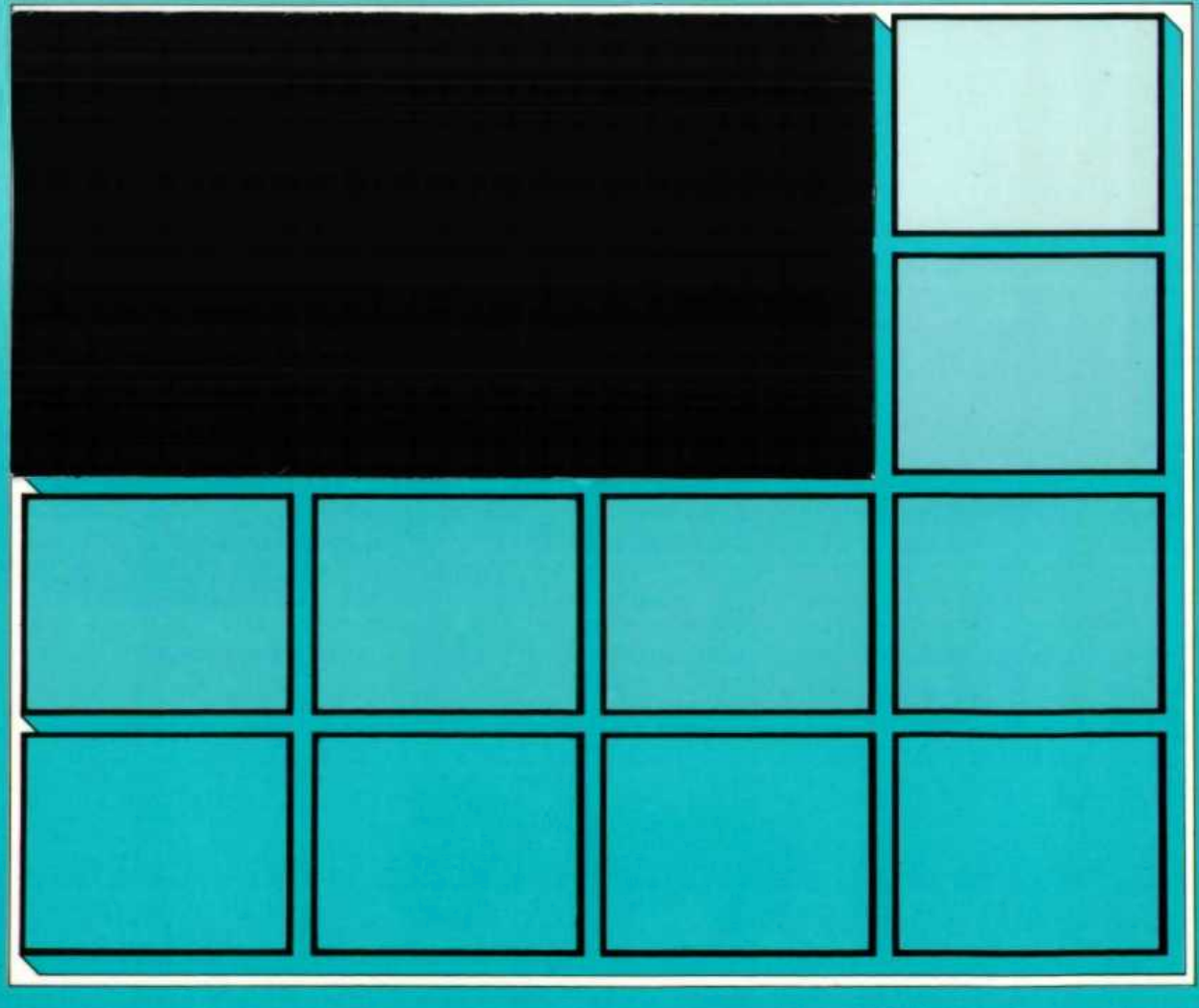

AN INVESTIGATION OF THE HEAVY RAINFALL OF 5-6th FEBRUARY, 1989 IN THE NESS, BEAULY AND CONON CATCHMENTS

A report to the North of Scotland Hydro-Electric Board

Rachel Law
Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxon, OX10 8BB

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1. Context

After a drier autumn than usual in North West Scotland the beginning of 1989 had above average precipitation. During January over three times the monthly average rainfall fell in some places. The first week of February also had high rainfall so that during the first six weeks of the year one third of the average annual rainfall had fallen compared with the usual one seventh (MacGregor, pers. comm.).

On the 5th February an intense depression formed near Iceland with an associated warm front which moved through North West Scotland during the afternoon of the 5th. This was followed by a trailing cold front in a strong south-westerly airstream which continued through the 6th February. During the two days heavy rain fell over much of North West Scotland. The largest 2-day total of 306.1 mm which occurred at Kinloch Hourn was a new British record. Other notable 2-day rainfalls were 285.4 and 261.1 mm around Loch Lochy. One day falls were also large but less exceptional (see Section 2). The rainfall was accompanied by a temperature rise which melted the snow on the hills that had formed part of the precipitation of early February. This increased the flow of water into the rivers. Widespread damage was caused by the resulting floods, particularly in the Ness and Conon areas. Modelling studies have indicated that the critical storm duration for the Conon catchment is 48 hours (Shaw, 1989).

This report aims to assess the rarity of the 2-day rainfall totals for the storm. In addition it looks at whether rainfall totals have been of greater depth in recent years and whether the FSR growth curves are applicable for the Ness region.

2. Rainfall data for the event

DAILY GAUGES

Seventy daily gauges were provided. Of these six were not used either because they lacked any data for the 5th and 6th February or they were considered to be too distant from the study area. Of the remaining 64 gauges, 35 had readings for both the 5th and 6th leaving 29 gauges that were not attended each day during the relevant time period. The 2-day totals for these gauges were estimated by allocating a proportion, to each day, which was similar to those proportions observed at nearby gauges. Where there was a nearby gauge with a similar rainfall total to the one with the missing data, this gauge was given greater influence in choosing the proportions than other nearby gauges. Hereafter both sources of 2-day totals are referred to as "observed".

The observed 2-day totals are mapped in Figure 1. The gauge locations are also shown to give some indication of which parts of the map are most reliable.

HISTOGRAMS

A number of the daily gauges provided have been used to draw histograms of the week's rainfall. A selection are presented in Figure 2. Missing data are indicated by a star next to the day number on the horizontal axis. The histograms show that there was widespread rain on the days preceding the storm, the largest falls being in the South West of the study area (e.g. gauge 693637 at Gairlochy). They also indicate how the storm rainfall was divided between the 5th and 6th February. This varied with region: the North and West of the study area tended to have higher rainfall on the 5th than the 6th (e.g. 789210 at Fannich Lodge, 778574 at Benmore) while the South and East had higher rainfall on the second day or similar totals on both days (e.g. 695547 at Fersit, 805591 at Culloden). This appears to be consistent with our knowledge of the synoptic feature responsible for the heavy rain.

The final histogram in Figure 2 (798224 at South Laggan) illustrates how the very large 2-day rainfalls were in most cases split evenly between the two days. This meant that the 2-day totals were much rarer than either of the 1-day values as seen in the following table using South Laggan as an example.

	1-day		2-day
South Laggan	5th Feb	6th Feb	5th + 6th
Rainfall	128.9	132.1	261.1
100 year event (FSR method)	111.7	111.7	151.2

SUBDAILY GAUGES

Data, from ten subdaily gauges provided, indicate that the period of heavy rainfall coincided unusually well with the rainfall measurement days, 9.00 am 5th February to 9.00 am 7th February. This needs to be accounted for in the assessment of storm rarity. Whereas the daily data provide a good description of the February 1989 storm depth, this will not generally be the case for other historical 2-day rainfall depths against which the rarity of the storm is assessed. The approach taken to allow for this was to estimate the 2-day depth that might have been recorded for the event, had the rainfall measurement day been otherwise defined. By reference to data from six subdaily gauges (in, or close to, the catchments) 48-hour depths were abstracted for eight further periods, commencing up to 12 hours earlier or 12 hours later than 9.00 am 5th Feb. The analysis indicated that such a storm might be expected to yield, on average, 2-day rainfall depths about 5% less than those actually recorded. For this reason a "downrating factor" of 95%

was applied to the 2-day depths before assessing the rarity of these totals.

3. Standard assessments of storm rarity

POINT RAINFALLS

Return periods have been calculated, using the FSR II method, for each of the "downrated" 2-day totals. The FSR II method has two stages in this case :-

1) Finding the 2-day M5 value at the gauge location. This was done by using a digitised form of the 2-day M5 map.

2) Converting the 2-day M5 values to different return periods using equations from Keers and Wescott(1977) based on the tables in FSR II 2.3.

The highest return periods found for the storm (after the rainfalls had been adjusted for the effect of synchronisation with rainfall measurement day) were 5500 years at Clunes Forest, 3800 years at Kinloch Hourn and 3400 years at South Laggan. The higher 2-day M5 value at Kinloch Hourn meant that despite having the largest 2-day rainfall it did not have the highest return period. The complete set of return periods can be found in the Appendix. A map of return period (T) is given in Figure 3. The interpolation from the gauge locations to a regular grid (required for contouring) is done on log T rather than T. The map of return period shows a similar structure to that of rainfall depth.

CATCHMENT RAINFALL

The IH triangle method (Jones 1983) has been used to calculate average 2-day rainfalls for the Ness, Beauly and Conon basins. The results are 139.8, 119.5 and 128.5 mm respectively. Again, to assess the rarity of these average rainfalls the coincidence with the rainfall measurement day must be accounted for by using average rainfalls of 95% of those calculated. The FSR II method for catchment rainfall frequency estimation is then used. (FSR II 8.1.2) The catchment is divided into two or three areas based on SAAR. The average 2-day M5 value for each of these areas is found and is then used as a representative point. For each return period, the catchment rainfalls are taken as the area weighted averages of the rainfalls at the representative points with the result being reduced by the appropriate areal reduction factor. This gives return periods of about 115 years for the Ness, 100 years for the Conon and 21 years for the Beauly.

4. Special investigations

TREND IN ANNUAL MAXIMUM 2-DAY RAINFALLS

The analysis is based on rainfall data from all the gauges within the Ness, Beauly and Conon hydrometric areas for which at least ten years of computerised data are held. This is a total of 63 gauges, two of which have over 60 years of records. The long-term gauge at Fort William was used to provide additional data before 1961.

Figure 4 shows annual maximum 2-day rainfall standardised by SAAR plotted against year for all the gauges. In addition the line obtained by simple regression of rainfall on year is plotted. The equation of the line is

2-day annual maximum/SAAR = 0.595 - 0.000110(Year-1900)

Both coefficients are significantly different from zero but the trend is relatively weak. The analysis does not support the view that heavy rainfalls in the area are increasing in frequency.

THE APPLICABILITY OF FSR II GROWTH FACTORS TO THE NESS REGION

The applicability of the FSR II growth factors to the Ness region was assessed by comparing the gauged and FSR 2-day frequencies for sites with long records. Three gauges were used: Garthbeg (803475), Achareidh (805939) and Fort William (691872). Figures 5 show the extreme value plots, fitted general extreme value distributions and the standard FSR synthesis. The figures show that the degree of correspondence between the FSR based frequency curves and the observed data is reasonably good and hence provide little evidence that the FSR II synthesis is inappropriate for this region. However there was insufficient time within the present study to verify, in the Ness area, the quality of the 2-day M5 map on which the rainfall frequency estimates are dependent.

5. Further research

Possible additional investigation can be divided into two areas, further research of the February 1989 storm and more general research related to rainfall in the region.

FEBRUARY 1989 STORM

The rarity and the widespread nature of the February 1989 storm and associated flooding suggest the possibility of further research particularly in the following areas:

(i) Collating and interpreting additional descriptive information available for the storm, for example from weather station and satellite data.

(ii) Assessing the contribution of the wet conditions prior to the storm to the severity of flooding. However, such assessment of the rarity of combined circumstances is non-trivial and would advisedly incorporate rainfall-runoff modelling of key catchments.

GENERAL RESEARCH POSSIBILITIES FOR THE REGION

Areas of possible additional investigation are as follows:

(i) Testing of the 2-day M5 map for the region

(ii) Further investigation of possible trends in rainfall frequency. To do this more thoroughly it would be helpful to analyse additional long-term daily rainfall records in the region and to consider catchment rainfalls as well as point rainfalls.

(iii) A comprehensive re-working of 1 and 2-day rainfall frequency in Northern Scotland using a focussed growth curve method (Reed and Stewart,1989).

To be convincing these analyses would require a more comprehensive dataset than at present held. It is understood that the Meteorological Office (Edinburgh) hold pre-1961 records of daily rainfall in manuscript form.

References

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Keers, J.F. and Wescott, P., 1977. A computer-based model for design rainfall in the United Kingdom. Met. Office Scientific Paper No. 36, HMSO, 14pp

National Environment Research Council, 1975. Flood Studies Report. 5 vols, NERC, London.

Reed, D.W. and Stewart, E.J., 1989. Weather radar and rural storm hazard. Proc. Weather radar and the water industry seminar, Wallingford, 6 April 1989, pp 79-91.

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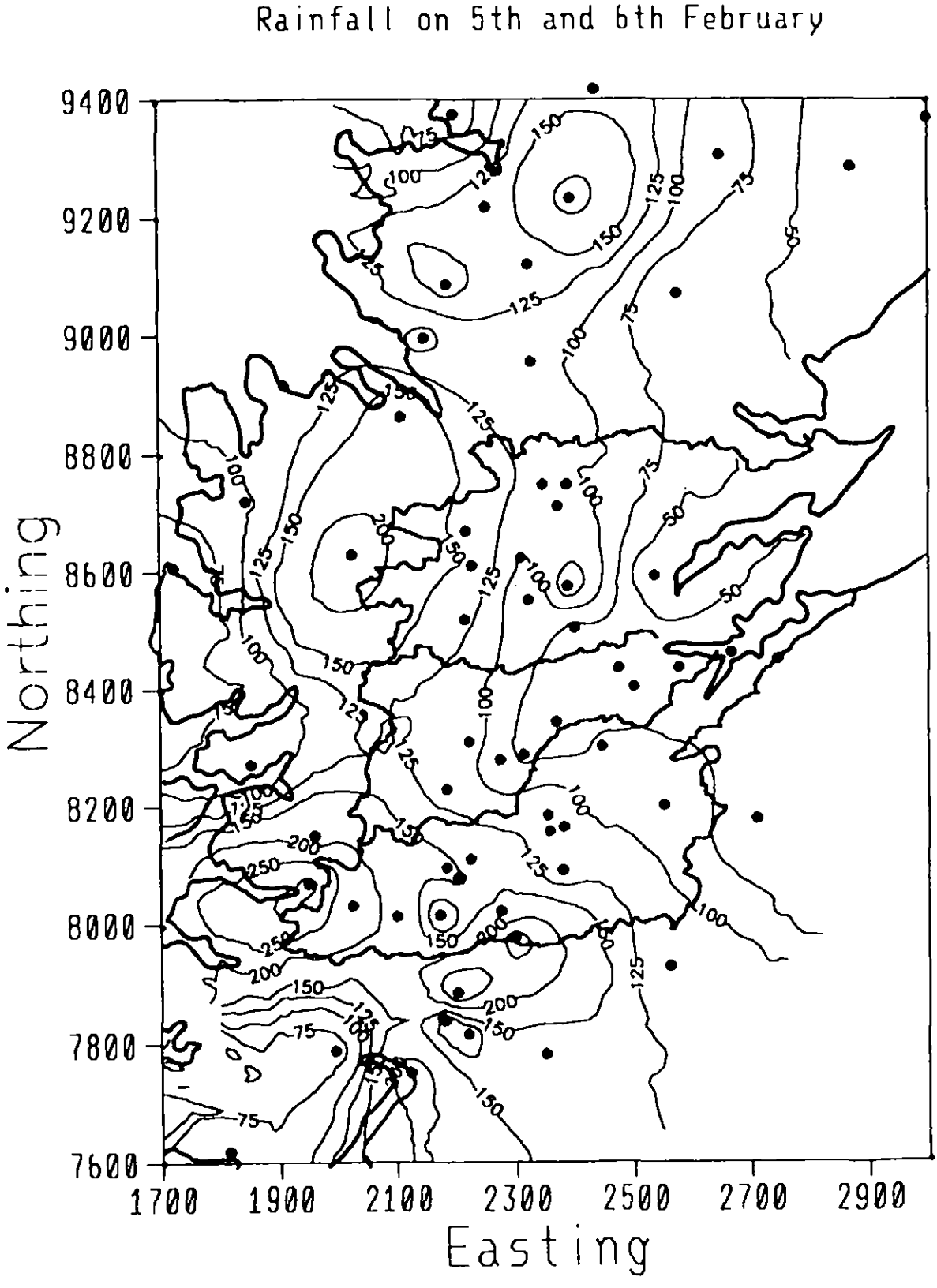


Figure 1: 2-day rainfall depths for 5-6th February 1989

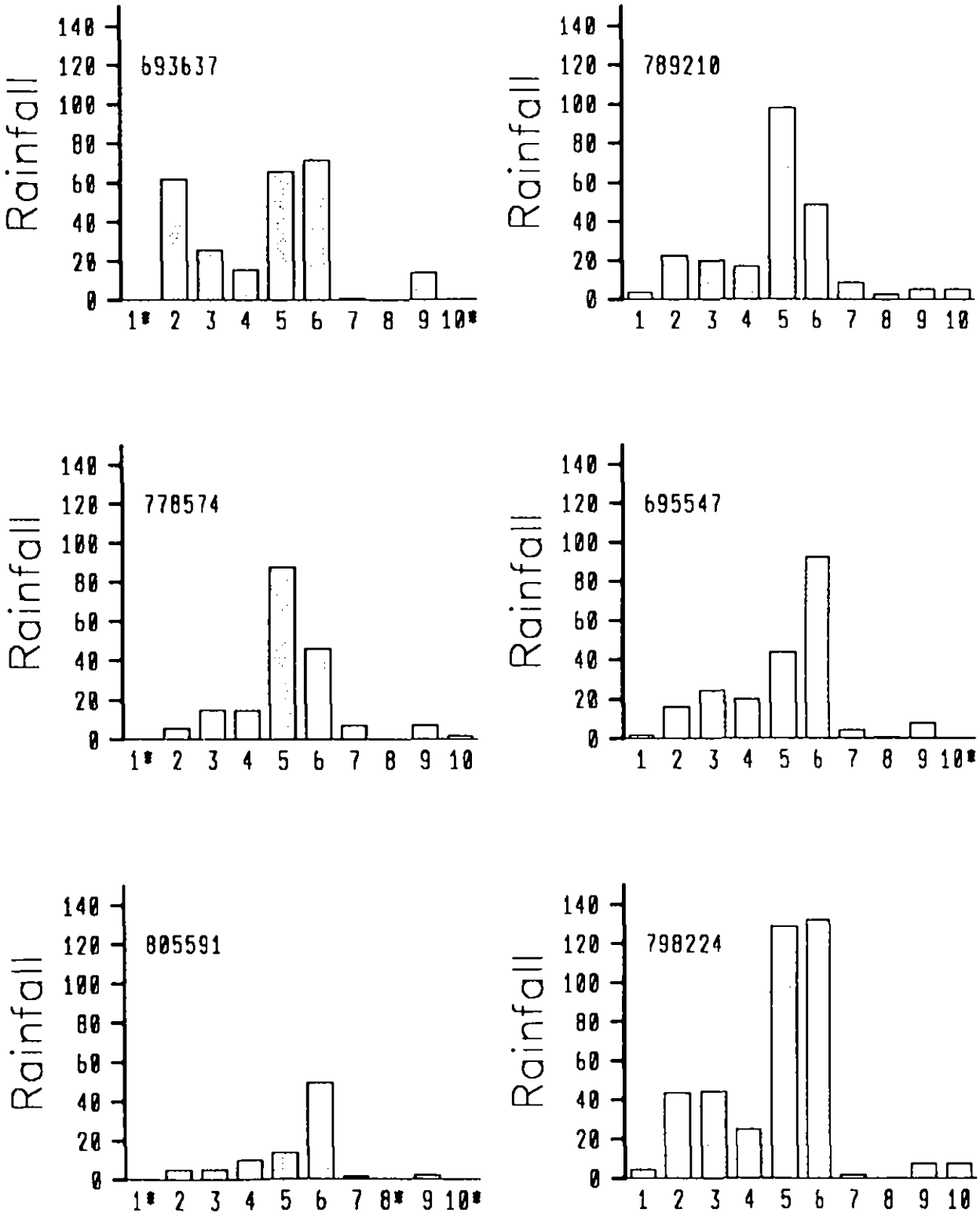


Figure 2: Rainfall for 1st-10th February at selected gauges

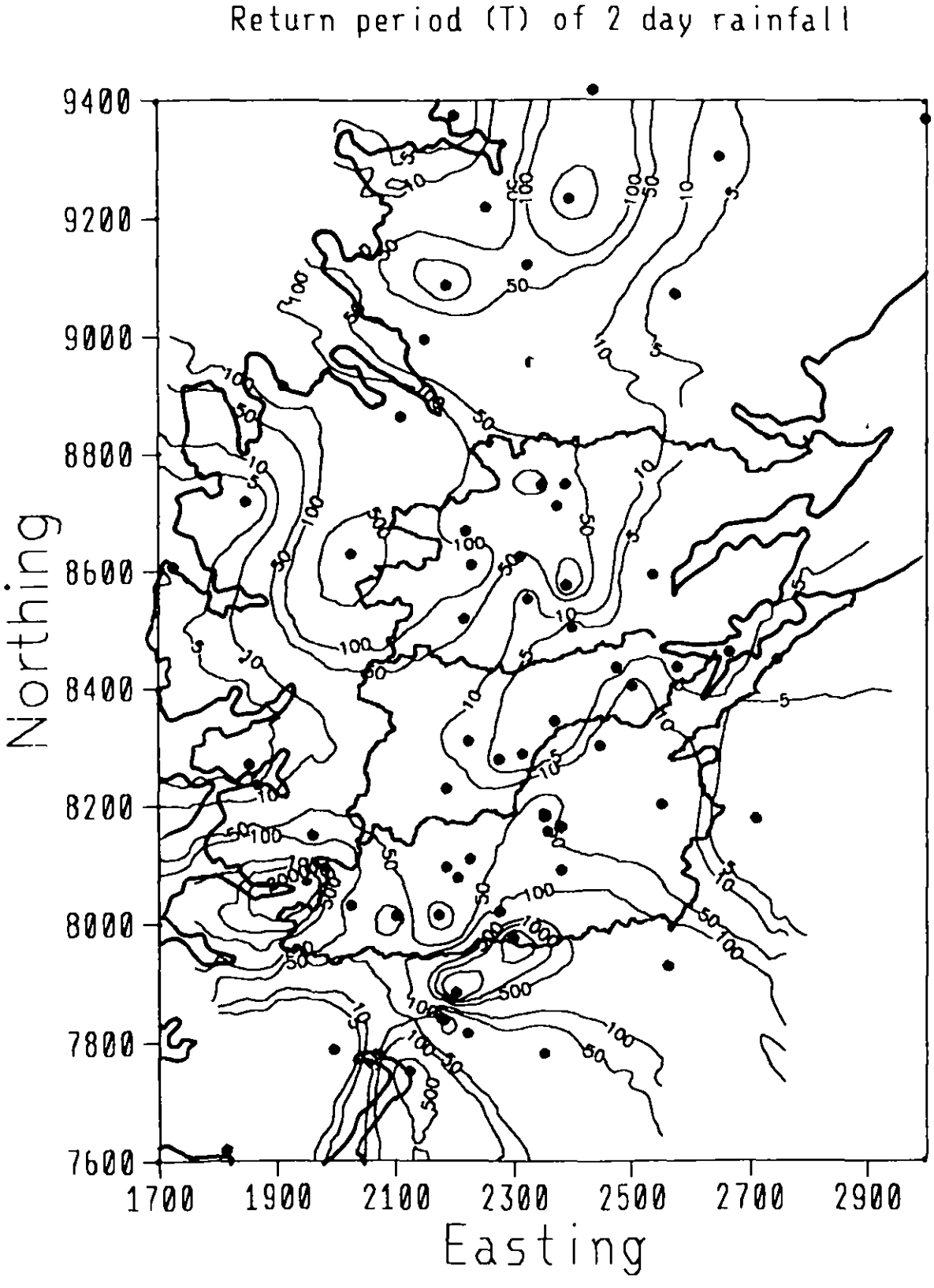


Figure 3: Estimated return period of the 2-day event

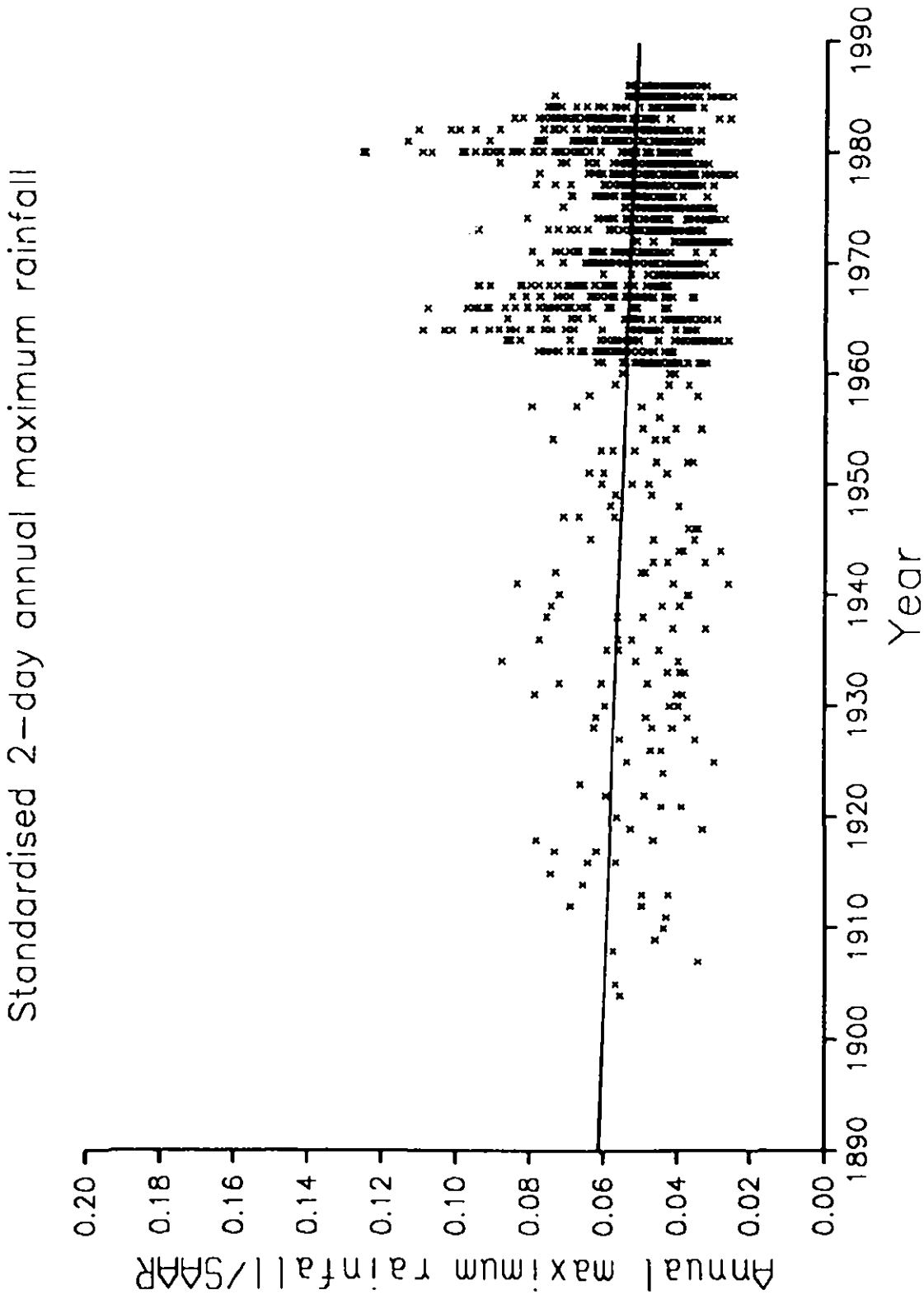


Figure 4: Time series of standardised 2-day annual maximum rainfall values

Figure 5b: 2-day rainfall frequency, Achareidh

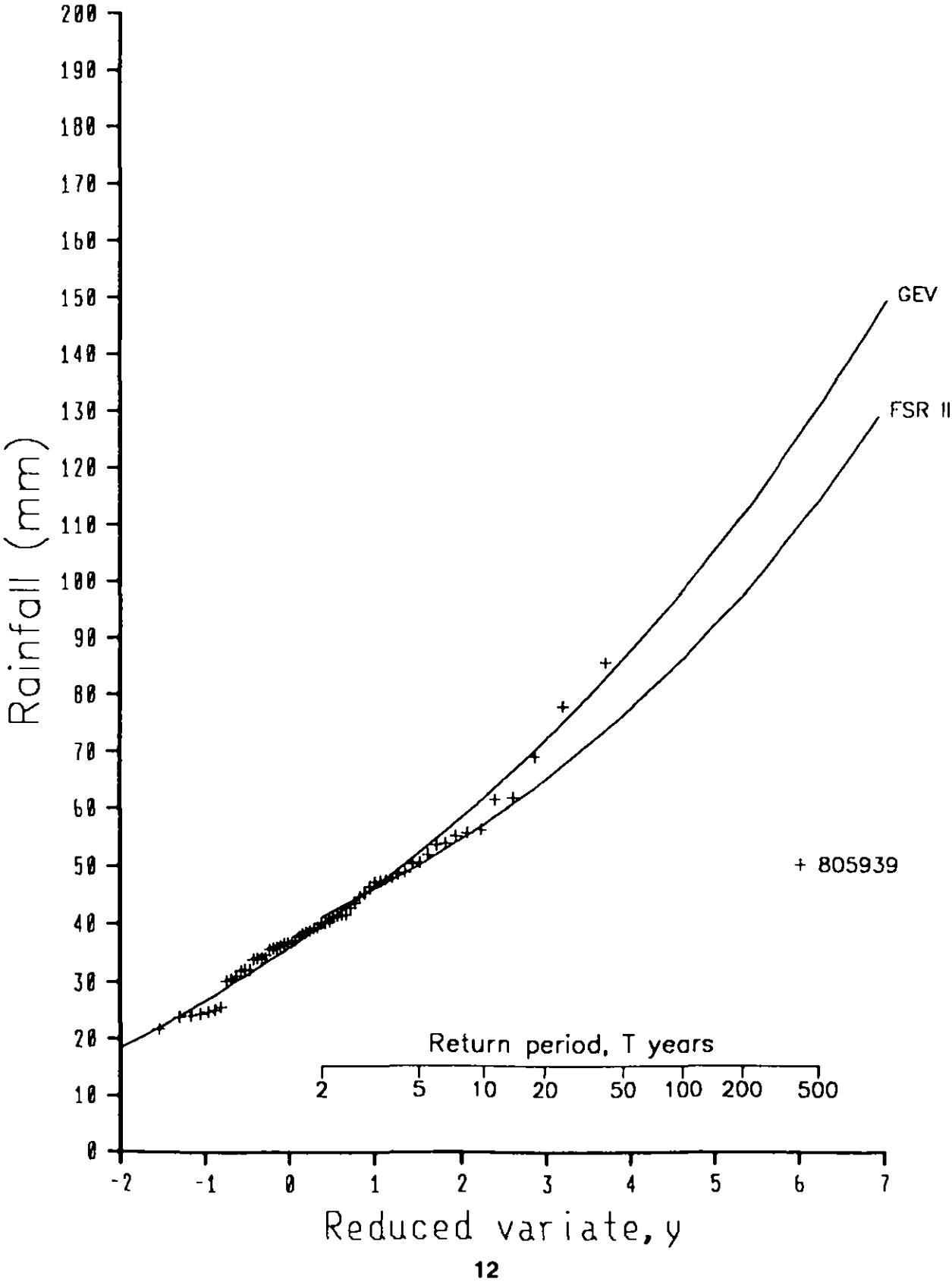


Figure 5a: 2-day rainfall frequency, Garthbeg

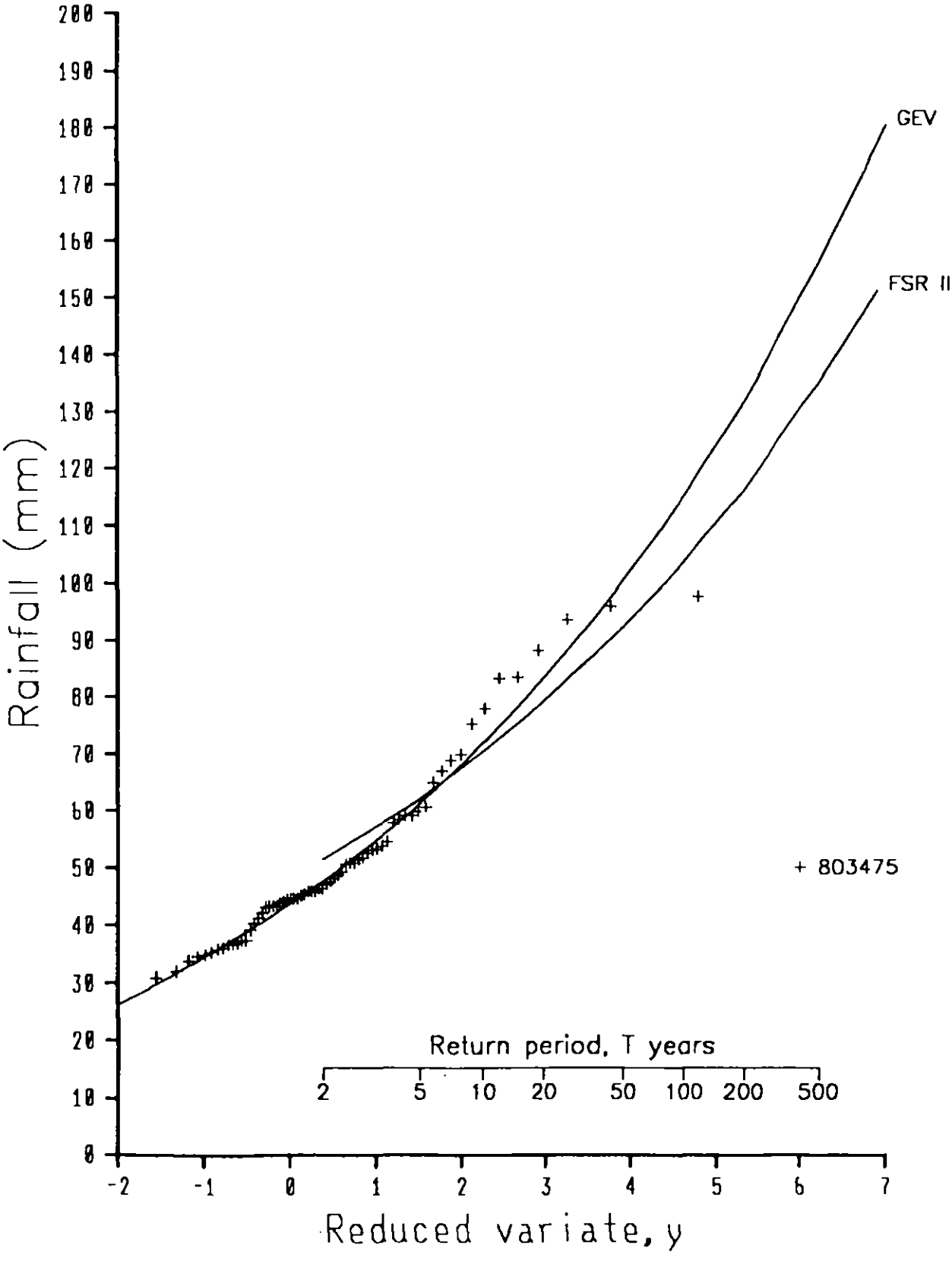
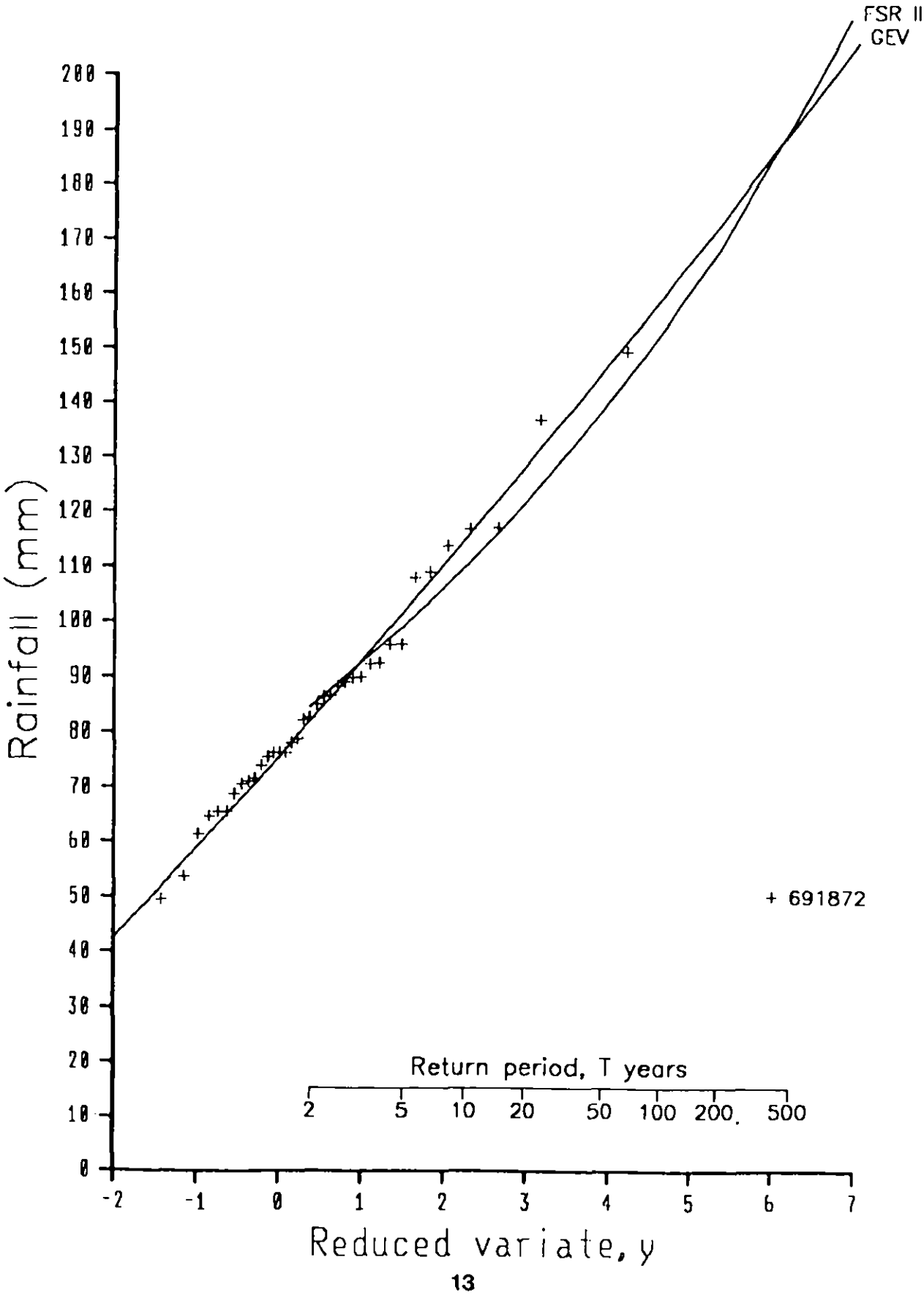


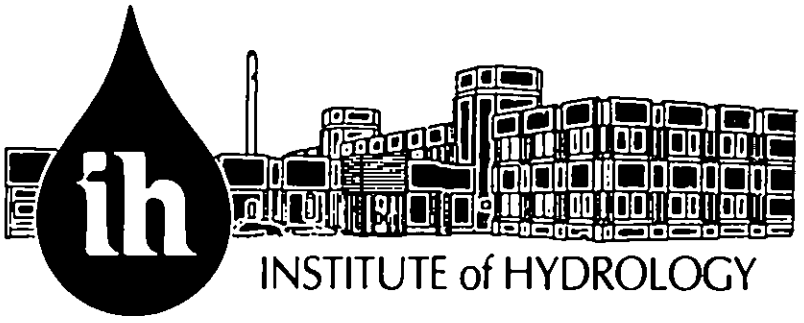
Figure 5c: 2-day rainfall frequency, Fort William



Appendix: Gauge details

Gauge Number	Grid ref. East	North	Rainfall 5th+6th (mm)	2-day MS (mm)	Return period (years)	Station name
692560	2202	7886	235.4	102	5500	Clunes Forest
693657	2177	7842	157.6	102	28	Gairlochy
693643	2182	7839	101e	101	3.5	Mucomir
695547	2351	7782	136.1	99	31	Fersit
696749	2221	7816	117.4	95	14	Spean Bridge
697239	2124	7751	215.4	97	900	Fort William
697582	1996	7788	69.0	99	<2.0	Corriebeg
701119	1814	7619	73.4	100	<2.0	Strontian
705926	1951	8070	306.1	125	3800	Kinloch Hourn
706484	1961	8151	184.8	124	70	Achnangart
708438	1853	9272	80e	30	4.0	Lochalsh (Nosti
710580	1724	8607	60e	57	5.0	Fearnmore
712255	1847	8720	99e	100	3.5	Bad Na Scalaig
713571	2025	8630	223.2	100	1000	Kinlochewe
738715	1912	8916	111.7	62	120	Sand
740241	2110	8863	164.7	84	300	Dundonnel
741928	2150	8995	94.8	76	14	Loch Dubh
741962	2187	9087	156.4	90	140	Knockanrock
743775	2254	9218	134e	104	20	Inchnadamph
745443	2200	9375	68.0	69	3.5	Duartmore
748843	2437	9417	144e	80	160	Gobernuisgach
752571	2651	9305	82.5	76	6.0	Loch Choire
756345	2999	9368	29.9	73	<2.0	Glutt
773652	2872	9285	53.3	58	<2.0	Kinbrace
778574	2324	9121	133.2	88	55	Benmore
781338	2396	9232	208e	95	800	Cassley PS
782882	2576	9071	56e	56	4.0	Lairg
788068	2538	8593	38e	50	<2.0	Dingwall
788696	2229	8611	150.4	78	230	Rosebank
789210	2219	8669	146.7	95	67	Fannich Lodge
789433	2310	8623	99e	64	48	Grudie
789696	2390	8575	136e	73	170	Luichart
789962	2216	8519	126.9	83	55	Scardroy Lodge
790309	2323	8551	78.9	72	6.5	Bridgend
791136	2347	8747	120e	69	110	Vaich
791188	2374	8710	112e	68	75	Blackbridge
791319	2388	8747	101.4	64	55	Strathrannoch
792337	2401	8504	73e	71	4.5	Orrin
794463	2185	8230	120.7	100	13	Affric Lodge
794727	2275	8280	77e	76	4.0	Benevean
795076	2314	8288	73.3	75	3.5	Fasnakyle
795625	2223	8310	112e	93	8.5	Mullardoch
795917	2370	8344	56e	75	<2.0	Glass Burn
797415	2475	8435	57e	57	4.0	Aigas
797616	2503	8403	69.4	56	12	Kiltarlity
798112	2573	8436	58.2	56	4.5	Lentran
798224	2299	7978	261.1	98	3400	South Laggan
798649	2025	8032	218e	149	72	Glenquoich Lodge
799028	2102	8014	139e	120	110	Kingie Camp
799278	2174	8016	105e	100	5.0	Inchlaggan
799626	2276	8022	153e	94	95	Invergarry Dam
800399	2381	8091	117.0	74	62	Fort Augustus

Gauge Number	Grid ref. East	North	Rainfall 5th+6th (mm)	2-day M5 (mm)	Return period (years)	Station name
801025	2185	8096	154e	109	40	Cluanie
801339	2204	8073	152e	106	45	Loyne
801386	2224	8110	139e	98	40	Caennacroc
802045	2358	8157	122e	75	75	Dundreggan
802141	2355	8134	123e	71	110	Bhlaraidh Headpond
802191	2382	8164	102e	72	30	Bhlaraidh
803521	2552	8201	94.0	64	35	Aberchalder
804431	2447	8302	77e	60	15	Balnain
805589	2668	8462	56.4	55	4.5	Inverness
805591	2746	8450	62.4	57	6.0	Culloden
813597	2562	7929	117.0	59	200	Glenshero
	2710	8178	58.2	75	<2.0	Coignafearn
	2329	8955	102.0	85	11	Corriemulzie



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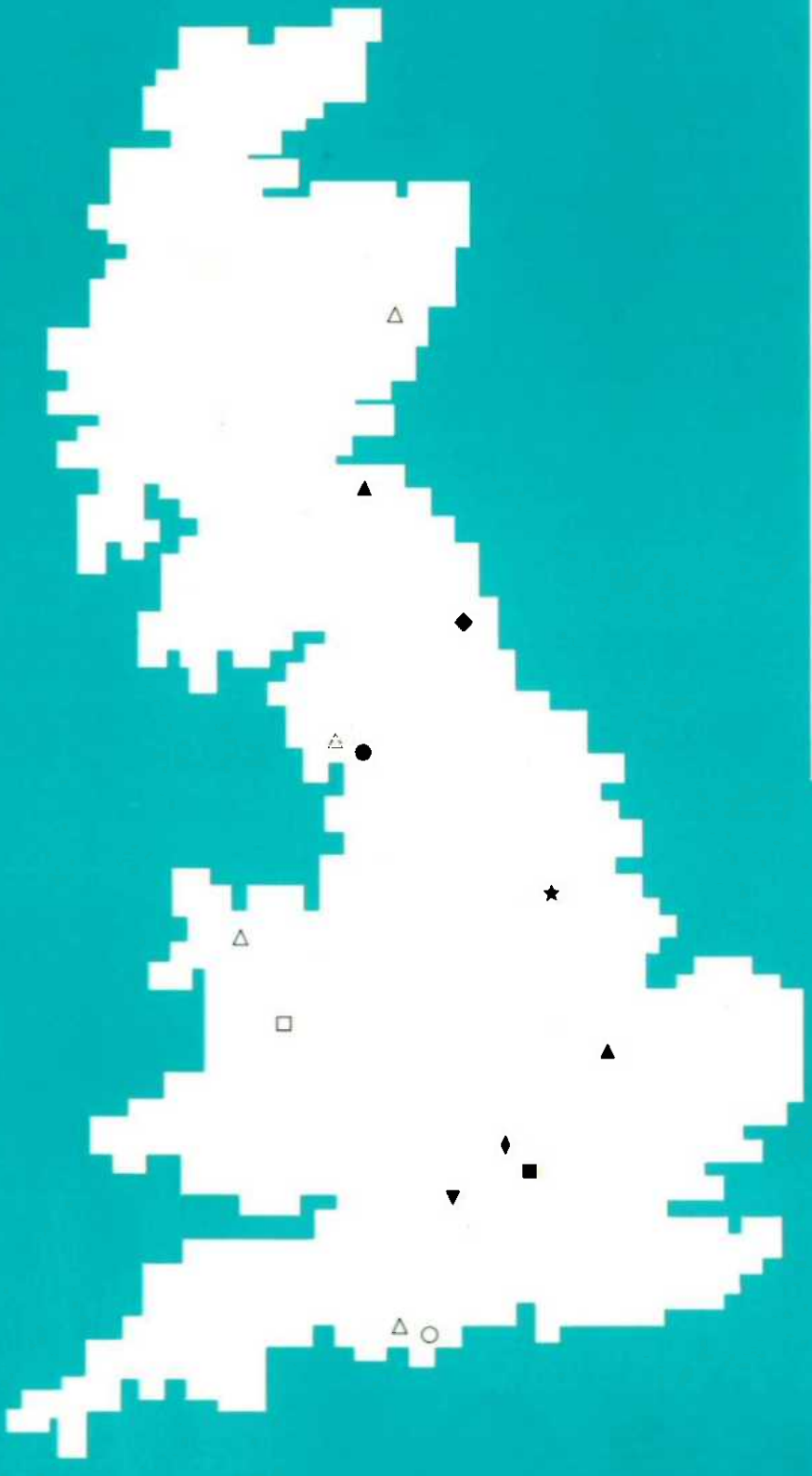

● **FRESHWATER BIOLOGICAL ASSOCIATION**
The Ferry House, Far Sawrey
Ambleside, Cumbria LA22 0LP
Tel: 09662 2468 Fax: 6914
Telex: 8950511 ONEONE G
REF 161730001

○ **The River Laboratory**
East Stoke, Wareham
Dorset BH20 6BB
Tel: 0929 462314 Fax: 462180
Telex: 8950511 ONEONE G
REF 161740001

■ **INSTITUTE OF HYDROLOGY**
Wallingford, Oxon OX10 8BB
Tel: 0491 38800 Fax: 32256 Telex: 849365

□ **Plynlimon Office**
Staylittle, Llanbrynmair
Powys SY19 7DB
Tel: 05516 652

INSTITUTE OF TERRESTRIAL ECOLOGY

▲ **Edinburgh Research Station**
Bush Estate, Penicuik, Midlothian EH26 0QB
Tel: 031 445 4343 Fax: 3943 Telex: 72579

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Tel: 04484 2264 Fax: 4705 Telex: 65102

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Mansfield Road, Oxford OX1 3SR
Tel: 0865 512361 Fax: 59962 Telex: 83147

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Dept of Plant Sciences, Sheffield University, Sheffield S10 2TN
Tel: 0742 768555 Fax: 760159 Telex: 547216

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