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Data storage and analysis for continuous rainfall-runoff modelling

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Interim Report to MAFF
Project FD0404

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Executive summary

The collection and storage of continuous records of hourly flow, potential evapotranspiration (PE) and rainfall data for the period from 1985 to 1992 for 14 catchments is presented. The records are stored on five tables on the ORACLE relational database.

Recording raingauge data contain more gaps and inaccuracies than initially was anticipated and much attention has been paid to optimizing the use of the available records. A quality coding system has been developed to assess the quality of the hourly rainfall data. Hourly rainfall data that meet certain quality requirements are used directly in calculating a catchment average hourly rainfall (CAHR).

In order to fill the gaps in the record the average variability method (AVM) is explored as a possible method of defining temporal profiles with which to disaggregate daily rainfall over days for which no hourly data are available. The temporal profiles derived here for two catchments in the NRA Severn-Trent region, and the subsequent calculation of the CAHR, are given as an example. The continuous hourly records will be used as an input to both the probability distributed model (PDM) and the time-area topographic extension (TATE) model in the near future as the first phase of data collection, storage and analysis is completed.

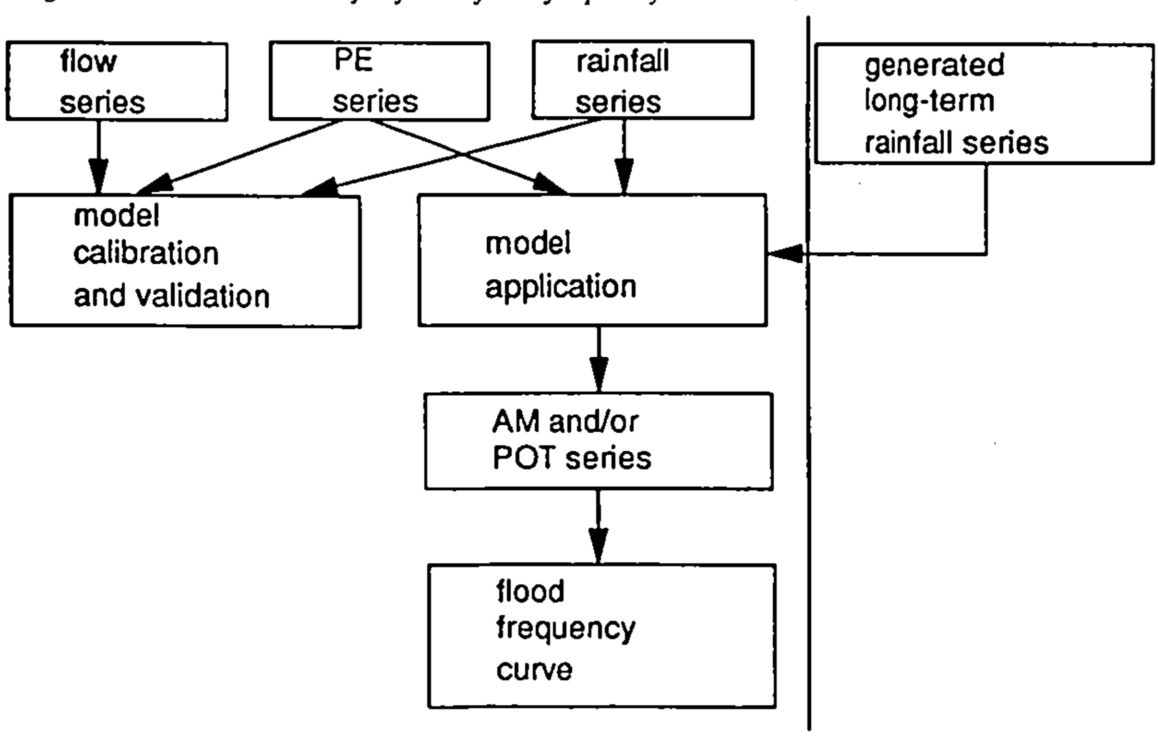
Contents

1 Introduction

The Flood Studies Report (FSR; NERC, 1975) presents an event-based rainfall-runoff model which currently forms part of the core of flood frequency estimation in the UK. The parameter in the FSR-model which is subject to the greatest potential error is the percentage runoff. This is because this parameter is dependent on the pre-event catchment wetness and needs to be estimated for each event. An alternative method to the event-based approach of the FSR-model, which would not have the same uncertainty in its estimation of pre-event catchment wetness, is the continuous simulation of runoff from rainfall. The advantage of continuous modelling would be that catchment wetness is taken into account over long periods and a consistent water balance for the catchment is preserved.

A framework for future flood frequency estimation, based on the initial thoughts on continuous modelling as described by Spijkers and Naden (1994), is presented in Figure 1.1. The ideas on which the framework is based are fairly straightforward. Initially, flow, PE and rainfall records are collected for a catchment and areal average values are estimated. Model parameters are determined in the calibration and validation phase, after which the chosen rainfall-runoff model can be applied to longer periods of available or generated PE and rainfall data series. Finally, annual maximum (AM) and peak-over-threshold (POT) values are extracted from the modelled flow estimates, which are then used to determine a flood frequency curve. It is anticipated that the estimation of the areal rainfall will determine the accuracy of the final flood frequency curve. Different methods of calculating the areal rainfall (e.g. kriging) and new sources of areal rainfall (e.g. weather radar) will be tested over the next few years. The advantage of this framework is that a whole range of different rainfall-runoff models can be employed. It is anticipated that different models may be more appropriate in different catchments. The TATE model (Calver, 1994) and PDM (Moore, 1985) are currently being investigated.

Figure 1.1 *Framework for future flood frequency estimation.*



In practice, derivation of catchment average PE and particularly rainfall series is not straightforward and this report will concentrate on the derivation of continuous rainfall series.

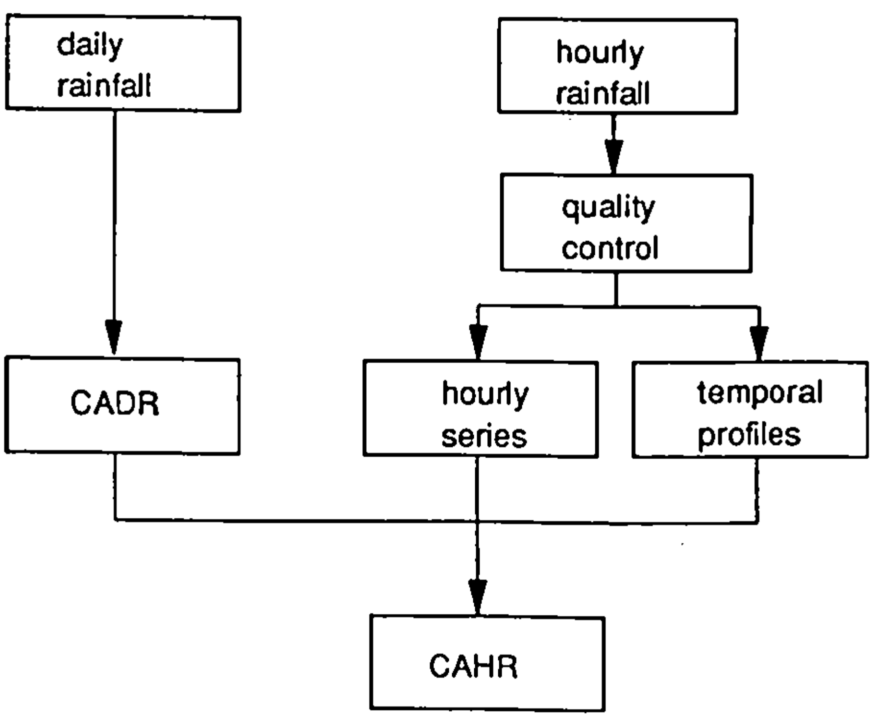
The collection and storage of hourly data for 18 catchments was initiated in June 1994 (see Spijkers and Naden, 1994). Flow, PE and rainfall data have been collected for the eight year period between 1985 and 1992. For continuous modelling, the requirement is for datasets without gaps and having a single consistent time step. If the time step changes, for example from hourly to daily in relatively dry periods between events, two different sets of model parameters would be required: one set for the hourly data and another for the daily data. This would mean that the model would have to be calibrated and validated twice and the modelling would become unnecessarily complicated. Alternatively, methods of disaggregating daily data into hourly time steps are required. Here, a method has been developed to calculate a continuous CAHR making maximum use of available hourly data but infilling using disaggregated daily data where necessary.

This Interim Report describes the progress which has been made in the period between June and November 1994. Section 2 explains how the data series are stored on a relational database, how the quality of the hourly data is checked, how gaps in the record are infilled and finally, how the CAHR is calculated using both hourly and daily rainfall data. Section 3 contains the conclusions from this work.

2 Catchment Average Hourly Rainfall

Section 2.1 describes how hourly rainfall and flow records are stored on the ORACLE relational database at the Institute of Hydrology (IH). Figure 2.1 summarises the procedure which will be used to calculate a CAHR from daily and recording raingauge data. Catchment average daily rainfall is denoted by CADR.

Figure 2.1 *Calculation of CAHR using daily and hourly rainfall values.*



The CADR is calculated from available daily raingauge data using the program AREARAIN. Recording raingauges are difficult to maintain operationally and the hourly rainfall records contain errors and/or gaps. Therefore, the quality of the recorded hourly rainfall should be checked before being used in CAHR calculations. The procedure to assess the quality of hourly rainfall records is described in Section 2.2. To obtain a continuous hourly rainfall record, the days on which no recording raingauge was in operation or when the observed values did not meet the quality requirements, need to be assigned hourly rainfalls. Section 2.3 describes how temporal profiles are derived from observed hourly rainfalls in order to disaggregate the CADR for the missing days in the hourly rainfall record. In Section 2.4 the calculation of the CAHR is described.

2.1 SUB-DAILY DATA COLLECTION AND STORAGE

Three tables on the ORACLE relational database were prepared for the storage of continuous hourly rainfall and flow data. These tables are:

CONT_HOURLY_RAIN	containing hourly rainfall data for all gauges,
HOURLY_RAIN_DETAIL	containing recording raingauge locations and details,
HOURLY_CATCH_DATA	containing hourly flow at the catchment outlet and the calculated CAHR.

Daily evapotranspiration data are stored in the tables MORECS_DAILY_POT_EVAP and MORECS_DAILY_ACT_EVAP.

The data in the tables cover the period from 1-1-1985 to 31-12-1992. A detailed description of the tables is given in Appendix A.

The hourly flow and rainfall records for six catchments were available from other projects at IH. In addition, data were requested, as described in Spijkers and Naden (1994), for another eight catchments operated by the NRA Severn-Trent and Thames regions. The data for the four catchments operated by the NRA Severn-Trent region were received in May 1994. Data for the four catchments operated by the NRA Thames region have recently been received and are currently being processed.

The 14 catchments, and the recording raingauges within or near the catchment boundary, are listed in Table 2.1. Data for four IH research sites are stored on other tables on the ORACLE database and these data will be copied onto the tables for this project in the near future. All catchments have between one and five recording raingauges within or near the catchment boundary.

Table 2.1 *Gauging stations and recording raingauges for which hourly data are held on ORACLE tables.*

NRA region	Number	Catchment	Recording raingauges	
			Name	Gauge No.
Severn-Trent	28008	Dove at Rocester Weir	Hollinsclough	101204
			Ashbourne	102367
			Carsington	102435
			Cauldon Low	103493
			Longcliffe	108786
	28039	Rea at Calthorpe Park	Ward End	9283282
			Frankley	95326
			Cannon Hill	95490
	28046	Dove at Izaak Wilton	Hollinsclough	101204
			Ashbourne	102367
			Cauldon Low	103493
			Tideswell	107931
	54027	Frome at Ebley Mill	Kingswood	419869
			Dowdeswell	458845
			Longford	459426
			Hempsted	460970
			Miserden	461467
	54034	Dowles Brook at Dowles	Trimpley	437138
Thames	38007	Canons Brook at Elizabeth Way	Thornwood	238605
			Rye Meads	9380120
	38020	Cobbins Brook at Sewardstone Road	Thornwood	238605
			Epping/High Beach	239258
	39007	Blackwater at Swallowfield	Basingstoke	270668
			Camberley	271490
			Farnham	280825
			Bordon	281185
	39017	Ray at Grendon Underwood	Bicester	259109
	39037	Kennet at Marlborough	Rodbourne/Swindon	249744
			Marlborough	266474
	39073	Churn at Cirencester	Shorncote	248331
			Rapsgate	248965
			Dowdeswell	458845
			Miserden	461467
Welsh	57006	Rhondda at Trehafod	Treherbert/Tyn-y-Waun	490292
Northumbria-Yorkshire	27047	Snaizeholme Beck at Low Houses	Tow Hill	47281
	27051	Crimple Beck at Burn Bridge	Eccup	9273517

2.2 DATA QUALITY CHECKS

Hourly rainfall records are not error free and the quality of the data needed further examination before being used for areal rainfall calculations. The hourly records are checked by comparing the daily totals from hourly raingauges with the daily raingauge observation at the same location. In the situation where a daily raingauge is not at the same location, or where the record of the daily raingauge is incomplete, the hourly data can be compared with another daily raingauge nearby. The maximum distance between the daily check-gauge and the recording gauge is arbitrary, but probably should not be more than 10 km because the spatial variability of the rainfall might then invalidate the quality checking of the hourly data.

Most recording raingauges now used in the UK are of the tipping-bucket type and, although this type of raingauge is generally reliable, some anomalies in the records have been encountered. These anomalies are as follows:

- The recording raingauge was often not working properly for a number of days before the gauge 'officially' stopped operating.
- The recording raingauge tipped twice at exactly the same time. This results in a recorded rainfall when there was none.
- The recording raingauge tips twice within 0-5 minutes. This is not always a measurement error but rainshowers with these high intensities are rare in Britain and the event should be checked carefully.
- Rainfall events are missing or the observed hourly rainfalls are much too low or high. These occasions probably indicate that the recording raingauge was not operating properly at the time of the rainfall event.
- The size of the tipping bucket is smaller than the accuracy with which daily raingauges can measure rainfall. If, for example, the volume of the tipping bucket represents 0.5 mm of rainfall, the recording raingauge will not measure less than this amount, while a daily raingauge with a 0.1 mm bucket may still measure between 0.1 and 0.4 mm.

The large number of hourly data values, covering 2922 days with more than 70,000 hourly values for each recording raingauge, make it very time consuming to check each day of hourly rainfalls manually. Apart from being time consuming, it is hard, or even impossible, to correct measurement errors or to estimate missing values in the hourly record.

It was therefore decided that hourly rainfall values will only be used if certain quality standards are met. Consequently, a coding system was developed and quality codes are assigned to each hourly value after comparing the daily total from the hourly recorded values with the daily raingauge observations at the same location or at a location nearby. Being based on the absolute and relative differences between the daily totals from hourly rainfalls and the daily check-gauge values, the quality codes 1-5 indicate different levels of accuracy. It will be noted that these codes may not be mutual exclusive depending on the rainfall total; in this case, lower number codes take precedence over higher numbers. In cases where differences become very large, a code 9 is given which indicates that the values are unreliable and should not be used. If any data are missing for the day, a code of 8 is awarded. The definitions for each quality code are presented in Table 2.2.

Table 2.2 *Definitions of quality codes for hourly raingauge records.*

Quality code	Code definition
0	Values that have not been checked yet.
1	The absolute difference between the daily total of the recording and daily raingauges was not more than 0.5 mm, and the relative difference was not more than 5 %.
2	The absolute difference between the daily total of the recording and daily raingauges was not more than 1.0 mm, and the relative difference was not more than 10 %.
3	The absolute difference between the daily total of the recording and daily raingauges was not more than 1.5 mm, and the relative difference was not more than 15 %.
4	The absolute difference between the daily total of the recording and daily raingauges was not more than 2.0 mm, and the relative difference was not more than 20 %.
5	The daily rainfall from the recording and/or daily raingauge was more than 15 mm, and the relative difference was not more than 40 %.
8	One or more hourly values were missing from the recording raingauge record. The measurements for this day are not complete and therefore should not be used.
9	The hourly values have been checked, there are no missing hours but the differences between the daily total of the recording and daily gauges did not fall within the limits set for codes 1 to 5 and code 8. The hourly data seem to be not accurate enough for use in the calculation of the catchment average rainfall.

As an example the quality coding is shown in Figure 2.2, where it is applied to one of the recording raingauges and its daily check-gauge. The figure shows that a considerable number of data values will not be used in further calculations because the total of the hourly values for the day differ too much from the daily raingauge value. Although the records are not perfect, the data analysis suggests that, for most recording raingauges, days with rainfalls over 20 mm have been recorded fairly accurately. This is important for flood frequency because floods are in general caused by rainfalls over 20 mm. Accuracy of lesser rainfalls is important with respect to the overall water balance and soil moisture storage within a catchment but the accuracy with which these lesser rainfalls are distributed over the day is probably not so important.

A computer program performs the quality coding automatically and stores the assigned codes in the table CONT_HOURLY_RAIN. The quality coding shows that generally the recording raingauge records become more reliable towards the end of the 1980s.

In order to obtain a continuous CAHR, at least one recording raingauge with good quality hourly data within or near the catchment boundary is needed for every day between 1985 and 1992. An overview of the number of days with reliable data, i.e. days on which one or more recording raingauges have data with a quality code between 1 and 5, is presented in Table 2.3 for all the catchments that have been analysed so far.

Figure 2.2 *Quality coding applied to daily and recording raingauge 95326.*

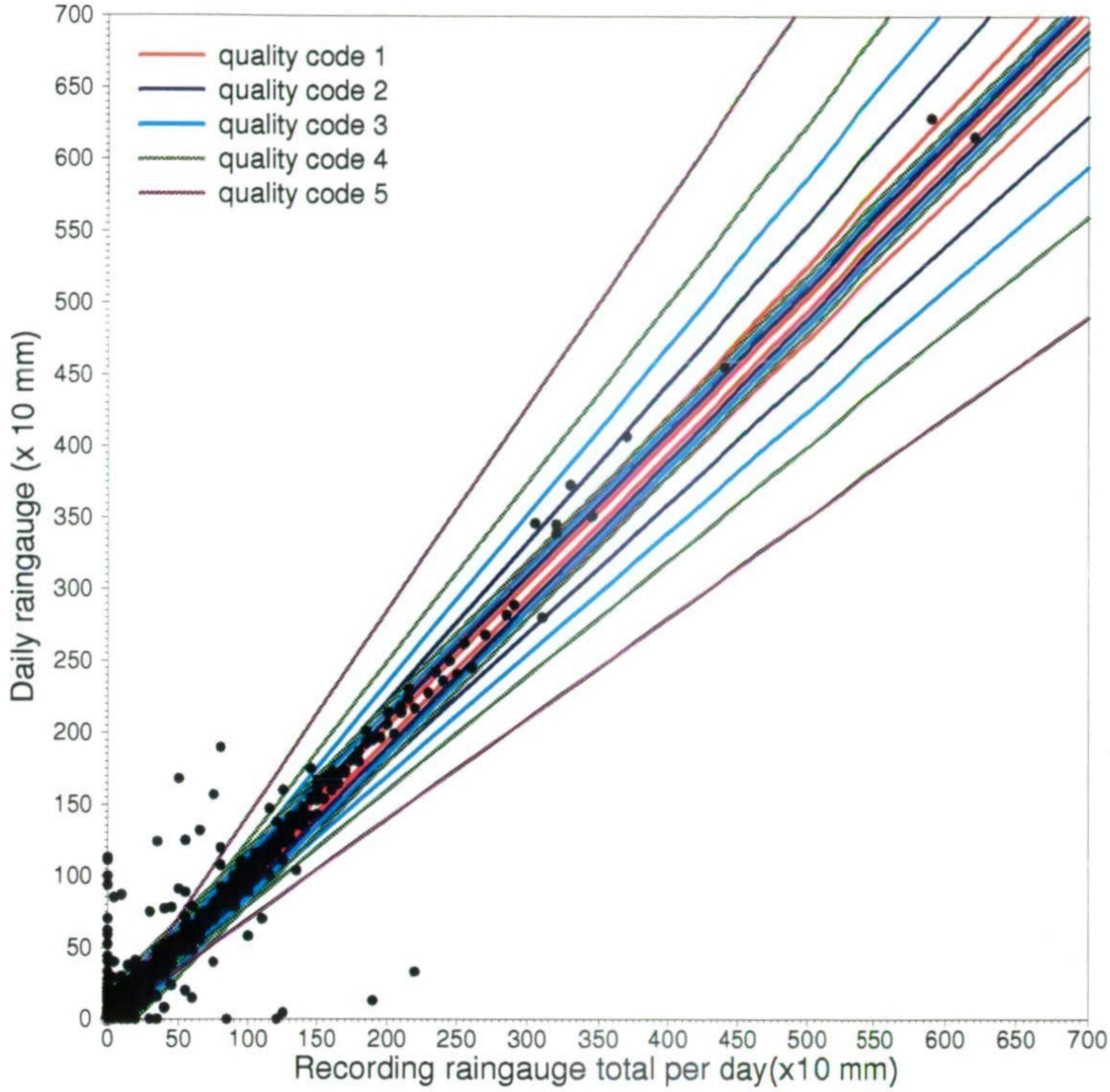


Table 2.3 *Quality of the recording raingauge data.*

Catchment		Total no. of days	Total no. of rec. gauges	No. of days without reliable data	No. of days with reliable data				
No.	Name				No. of rec. gauges				
					1	2	3	4	5
28008	Dove at Rocester Weir	2922	5	76	194	431	612	863	746
28039	Rea at Calthorpe Park	2922	3	419	463	803	1237		
28046	Dove at Izaak Wilton	2922	4	76	275	630	960	981	
54027	Frome at Ebley Mill	2557	5	140	619	203	343	639	613
54034	Dowles Brook at Dowles	2922	1	1406	1516				
38007	Canons Brook at Elizabeth Way	1888	2	305	940	643			
38020	Cobbins Brook at Sewardstone Road	1888	2	246	852	790			
57006	Rhondda at Trehafod	1553	1	726	827				
27047	Snaizeholme Beck at Low Houses	2922	1	2477	445				
27051	Crimple Beck at Burn Bridge	2922	1	2590	332				

The quality of data differs considerably between catchments. Some of the catchments for which data were already available at IH have poor data records. Originally these records were collected for event analysis and most of the data had, therefore, not previously been used or checked.

The table also shows that no hourly rainfall data are available for some days between 1985 and 1992 for four of these catchments. The periods in which hourly rainfall data are available are as follows:

Frome at Ebley Mill (54027) from 1/1/1986 to 31/12/1992,
Canons Brook at Elizabeth Way (38007) from 1/11/1987 to 31/12/1992,
Cobbins Brook at Sewardstone Road (38020) from 1/11/1987 to 31/12/1992,
Rhondda at Trehafod (57006) from 1/10/1988 to 31/12/1992.

Thus, for some of the catchments, more hourly rainfall data of better quality are required before a CAHR can be calculated. Other catchments have relatively few gaps in their record although there is no catchment without any gaps. These gaps need to be infilled in order to calculate a continuous CAHR. Section 2.3 describes how daily rainfall data will be disaggregated to fill the remaining gaps in the hourly record.

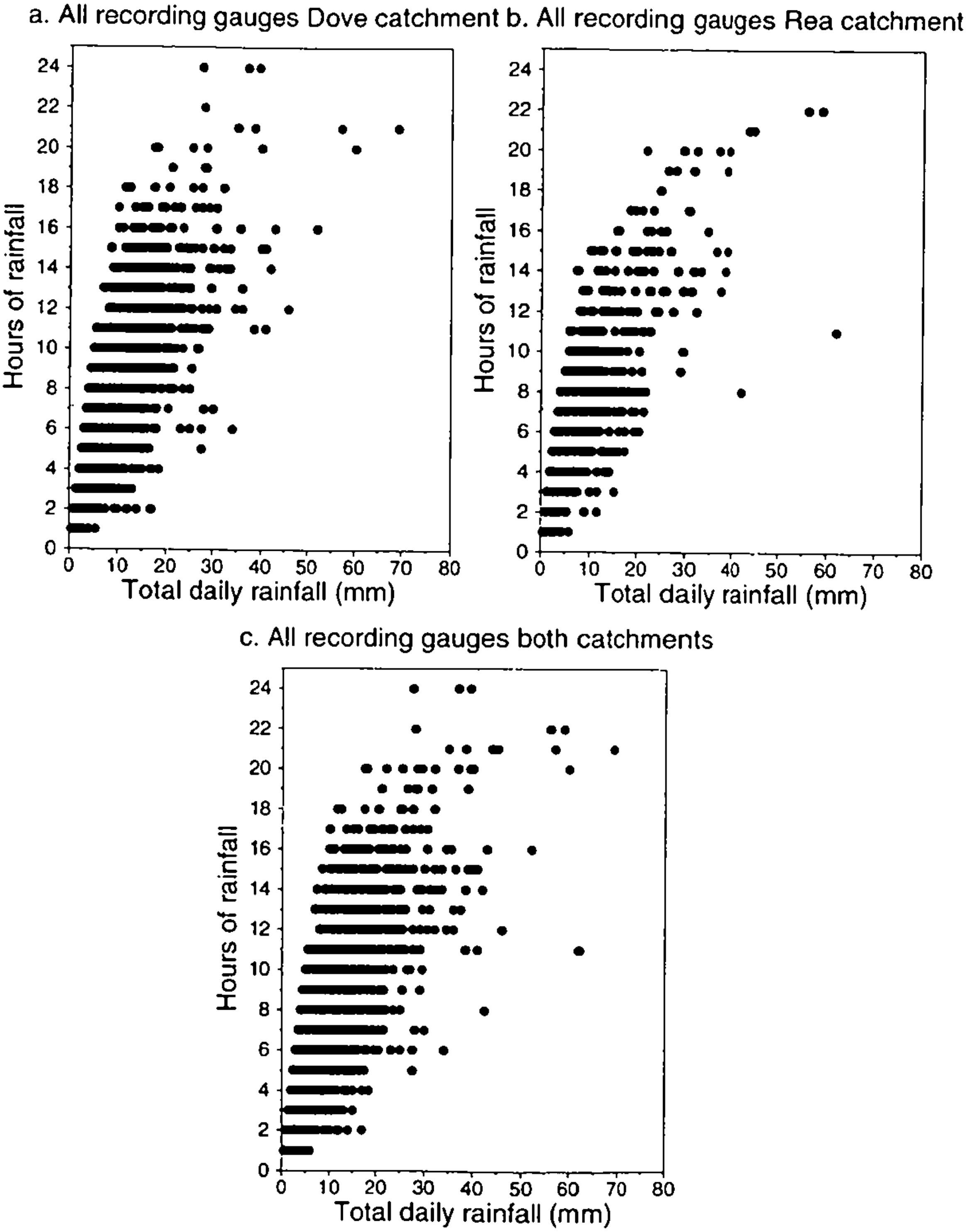
2.3 DISAGGREGATION OF DAILY RAINFALLS

Gaps in the hourly rainfall data need to be infilled to obtain a continuous hourly rainfall record. The method being investigated for this purpose uses the AVM, introduced by Pilgrim *et al.* (1969), to define rainfall profiles. The method was originally used to derive the temporal patterns of design rainfall for 16 durations from the 50 most intense rains recorded in Sydney during the period 1912 to 1962 for use in flood estimation. The method was later used by Stewart and Reynard (1991) to calculate a series of design rainfalls for durations from three to 12 days on large, reservoired catchments in north-west Scotland.

For this study, the method is used to determine a temporal profile for daily rainfalls based on observed hourly rainfall. This rainfall profile will then be used to disaggregate the CADR into 24 hourly values in cases where hourly rainfall data are lacking. The CADR is calculated from measured daily rainfalls using the program AREARAIN. The AVM was used by Naden (personal communication) for the disaggregation of daily rainfall for the Yorkshire Ouse and for this study the validity of the method is investigated for the Dove at Rocester Weir (28008) and the Rea at Calthorpe Park (28039), both in the NRA Severn-Trent region.

Figure 2.3 shows that there is a strong relationship between the amount of total daily rainfall and the number of hours in which rain falls. Figure 2.3a shows this relationship for the data of three recording raingauges in the Dove catchment, Figure 2.3b shows the same for five recording raingauges in the Rea catchment and in Figure 2.3c all recorded data for both catchments are shown in a single plot. No obvious differences were observed between the recorded data of the two catchments and the AVM was applied to the data from all eight recording raingauges in the two catchments lumped together.

Figure 2.3 *Total daily rainfall vs. number of rainfall hours for Dove (28008) and Rea (28039) catchments.*



Because of the clear interrelation between the total daily rainfall and the number of hours during which rain falls shown in Figure 2.3, the temporal rainfall profile was derived for different ranges of total daily rainfall. Three different ways of subdividing the total daily rainfall were tested; one divided the daily rainfall into five blocks and the other two divided the daily rainfall into three blocks but on different bases. The results of the disaggregated rainfalls from the three different subdivisions were compared to the observed data. The results of the comparisons between synthesised and observed data are presented in Table 2.4 for hourly maximum rainfall and in Table 2.5 for the number of hours in which the rain fell. The results of the three ways of subdividing the data only differ slightly and it was decided to use the subdivision of the daily rainfall into three blocks: 0-10 mm, 10-20 mm and ≥ 20 mm.

Table 2.4 *Statistics of maximum hourly rainfall using three different subdivisions.*

		Methods of subdividing the total daily rainfall		
	Observed	0-5mm, 5-10mm, 5-15mm, 15-20mm, >20mm	0-5mm, 5-15mm, >15mm	0-10mm, 10-20mm, >20mm
Mean	1.64	1.83	1.85	2.07
Coefficient of variance	0.92	0.74	0.77	0.82
Departure from normality	0.22	0.13	0.14	0.16
Median	1.0	1.6	1.6	1.4
Range	0.5-19.0	0.3-14.6	0.3-16.1	0.3-14.6

Table 2.5 *Statistics of number of wet hours per day using three different subdivisions.*

		Methods of subdividing the total daily rainfall		
	Observed	0-5mm, 5-10mm, 5-15mm, 15-20mm, >20mm	0-5mm, 5-15mm, >15mm	0-10mm, 10-20mm, >20mm
Mean	4.34	5.20	5.17	4.95
Coefficient of variance	0.81	0.74	0.72	0.71
Departure from normality	0.17	0.29	0.29	0.25
Median	3	4	4	4
Range	1-24	2-20	2-18	2-20

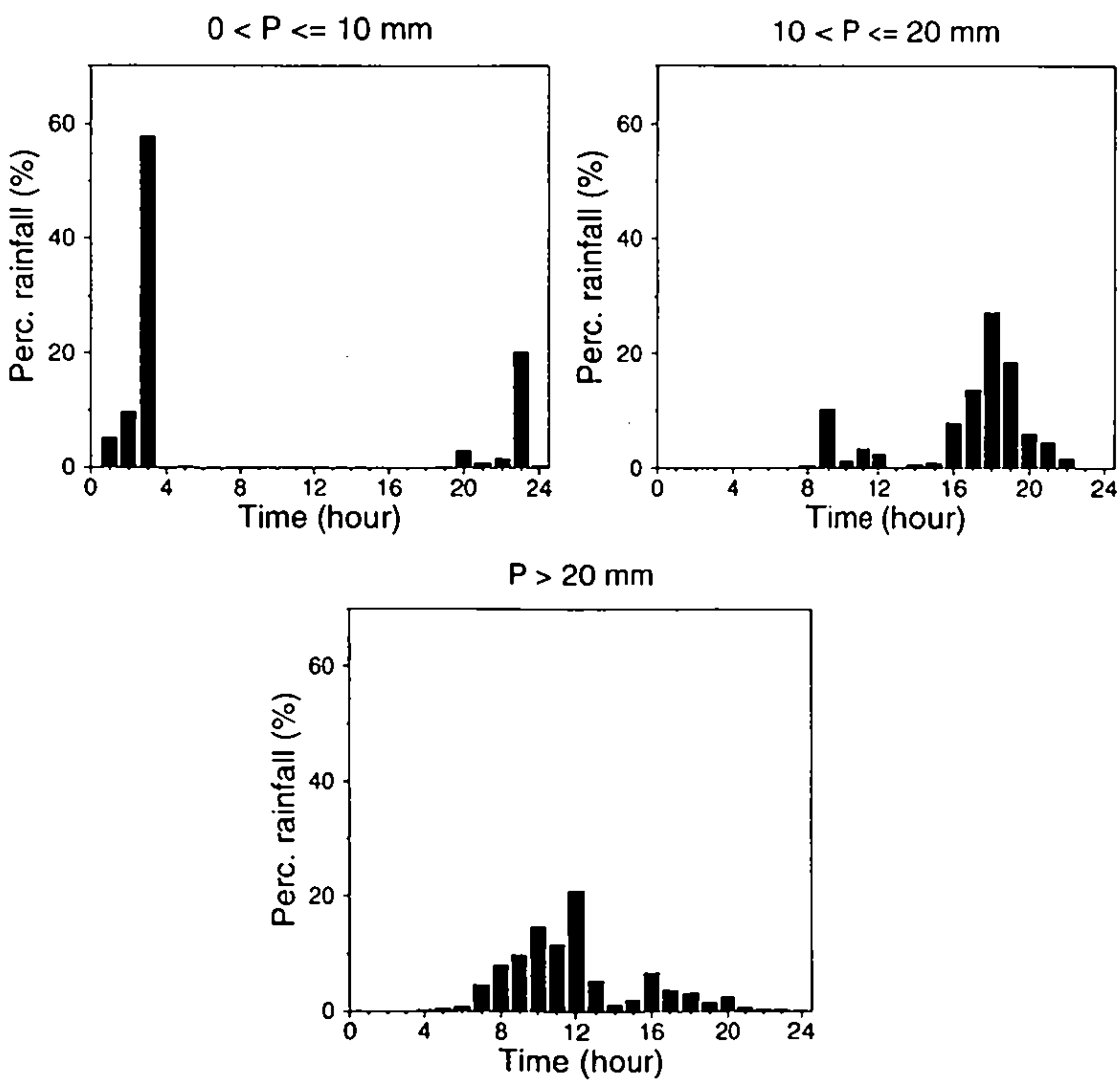
The temporal profiles that will be used for the disaggregation of the daily rainfalls in the Dove and Rea catchments are presented in Figure 2.4. The temporal profile for daily rainfalls between 0 and 10 mm looks peculiar and seems not to represent a typical rainfall profile. The same irregular features of the temporal profile for the smaller rainfalls is seen in temporal profiles derived from individual raingauge data and from the CAHR series and represents a shortcoming of the AVM.

It should be realised that most gaps in the hourly rainfall record are on days with less than 20 mm rainfall. These days are not likely to be essential for flood estimation, but to ensure that the catchment wetness is correctly estimated at the start of flood events these lower rainfalls should not be excluded from the rainfall record. The exact timing of these rainfalls is unlikely to have a major effect on the modelling results and therefore a crude method, like the AVM, to disaggregate the rainfall over the day will probably suffice.

The AVM was designed to derive typical profiles for events and its shortcomings with respect to its application to disaggregation have yet to be more rigorously assessed. For example, the temporal distribution of rainfall on a day of given rainfall depth is invariate and the timing of the rainfall within the day is independent of rainfall on adjacent days. Whether these prove significant in the generation of flow remains unknown. Another question which remains to be investigated is the stability of the profiles derived for different periods of data. Certainly, there was no seasonal variation identifiable in the records analysed for the Yorkshire region but whether this is a general observation and whether Lamb weather types (Lamb, 1972) could be used to refine this remains unknown.

The application of the profiles to calculate the CAHR is described in the next section.

Figure 2.4 *Temporal rainfall profiles for the disaggregation of daily rainfall in the Dove (28008) and Rea (28039) catchments.*



2.4 CATCHMENT AVERAGE HOURLY RAINFALL CALCULATIONS

A continuous average hourly rainfall series is calculated after the quality of the hourly rainfall values has been assessed and the temporal profiles for disaggregating daily rainfalls have been determined.

The UK network of daily raingauges is much denser than that of recording raingauges. The daily records are reliable and have been used for many studies. The quality analysis in Section 2.2 indicated that hourly rainfall records are not as reliable as daily rainfall records. Therefore the CAHR is calculated from both daily and hourly raingauge data to make the most efficient use of both records. In future, use of radar data may also be considered.

The daily raingauges are used for the calculation of a CADR using the program AREARAIN which uses the triangular method of Jones (1983). The distribution of the CADR over the day is then derived from the available hourly data if the quality is within certain limits, or directly from the CADR by disaggregation based on the temporal profiles determined using the AVM (Section 2.3).

The CAHR is calculated in two steps:

1. A CADR value is calculated from the daily rainfalls observed at raingauges within or near the catchment boundary.

2. The quality of the available hourly rainfall data on the table CONT_HOURLY_RAIN is checked for all the recording raingauges within or near the catchment boundary. If the quality standards are met for one recording raingauge the CADR calculated in the first step is distributed over the day according to the distribution of the hourly recording raingauge data.

   If the quality standards are met by two or more recording raingauges, the triangular method (Jones, 1983) is used to calculate the weight for each recording raingauge. The CAHR is calculated from the CADR for each hour of the day, based on these weights and the hourly rainfall at each recording raingauge.

   If the quality standards are not met by any of the recording raingauges, the CADR is disaggregated over the day, using the appropriate temporal profile for the amount of daily rainfall.

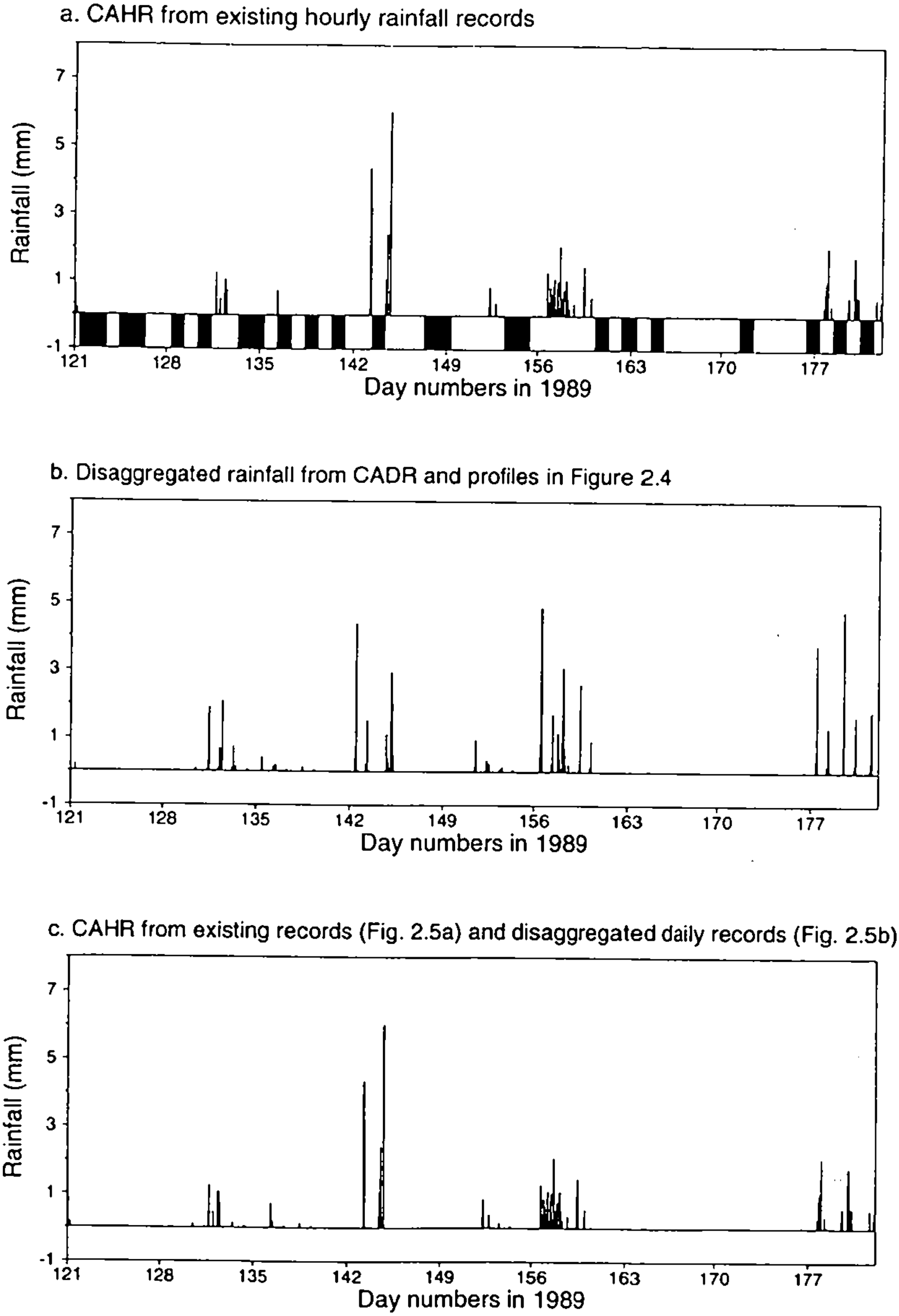
This procedure is demonstrated in Figure 2.5 for the Rea catchment (28039) for a two month period in 1989. In Figure 2.5a the CAHR, as calculated based on available hourly rainfall data with a quality code between 1 and 5, is shown. The gaps in the hourly record are indicated by negative values. Figure 2.5b shows the disaggregated rainfall for the same period based on the CADR and the rainfall profiles given in Figure 2.4. The final continuous CAHR is presented in Figure 2.5c, in which the gaps in the first figure are filled by disaggregated hourly rainfalls from Figure 2.5b.

Figure 2.5 *Example of the calculation of continuous Catchment Average Hourly Rainfall.*

a. CAHR from existing hourly rainfall records

b. Disaggregated rainfall from CADR and profiles in Figure 2.4

c. CAHR from existing records (Fig. 2.5a) and disaggregated daily records (Fig. 2.5b)



3 Conclusions

Hourly rainfall and flow data have been stored on the ORACLE database for ten catchments, while the data for four more catchments are currently being processed.

The quality of hourly raingauge records caused some concern because the records contain more gaps and inaccuracies than was anticipated. A system to assess the quality of the recorded hourly rainfall was developed. Hourly data that meet a certain accuracy criterion can now easily be selected and used for the calculation of catchment areal rainfall.

Two catchments, Snaizeholme Beck at Low Houses (27047) and Crimple Beck at Burn Bridge (27051), need additional hourly rainfall records before an areal hourly rainfall can be calculated. Two other catchments, Dowles Brook at Dowles (54034) and the Rhondda at Trehafod (57006), might also need additional data because just under 50 % of the available rainfall data are unreliable.

As a possible technique to fill the gaps in the hourly rainfall records, the AVM was used to derive temporal rainfall profiles for the Dove and Rea catchments in the NRA Severn-Trent region. The profiles are used to disaggregate the CADR on days without hourly rainfall data of a required quality.

The CAHR is calculated from both daily and hourly raingauge records and the program for the calculations was tested for two catchments in the NRA Severn-Trent region.

In the next phase of the study the CAHR records for these catchments will be used in the PDM (Moore, 1985), which is currently implemented in the NRA Northumbria & Yorkshire flood forecasting system, and in the TATE model (Calver, 1994).

Acknowledgements

We should like to thank MAFF for funding this work, the Meteorological Office for the MORECS evapotranspiration and soil moisture data, Lisa Stewart for the AVM and AREARAIN programs and the NRA Thames and Severn-Trent regions for making rainfall and flow records available.

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Abbreviations

AE	actual evapotranspiration
AM	annual maximum
AVM	average variability method
CADR	catchment average daily rainfall
CAHR	catchment average hourly rainfall
FSR	Flood Studies Report
IH	Institute of Hydrology
PDM	probability distributed model
PE	potential evapotranspiration
POT	peak-over-threshold
SMD	soil moisture deficit
TATE	time-area topographic extension

APPENDIX A: DESCRIPTIONS OF ORACLE TABLES CONTAINING CONTINUOUS HOURLY FLOW AND RAINFALL DATA BETWEEN 1985 AND 1992.

All tables are stored under the FLOOD user id.

1. TABLE: CONT_HOURLY_RAIN

```
Name                              Null?    Type
--------------------------------  -------- ----
GAUGE                             NOT NULL NUMBER(7)
TIME                              NOT NULL DATE
RAIN                                       NUMBER(4)
QUALITY                                    NUMBER(1)
```

GAUGE

The Met. Office numbers of the recording raingauges have been used where possible.

Some of the recorders operated by the local NRAs do not have a Met. Office number and these received a seven digit number. The first digit of this special number is a 9, followed by a 2 digit hydrometric area number and a 4 digit number related, as far as possible, to the number used by the NRAs. For example: gauge 9283282 is in hydrometric area number 28 and the NRA Severn-Trent region uses number 3282 for this gauge. Another example is gauge 9273517 which is in hydrometric area 27 and the NRA Yorkshire-Northumbria region uses number 63517 for this gauge.

TIME

The rainfall is stored for each hour and the time indicates the **end** of the hour in which the rain fell. ORACLE time format is used to ease retrieval in different formats. Dates are missing from the table when data were not available at the time of loading the table. For most gauges this probably means that the gauge was not in operation.

RAIN

The amount of rainfall is stored in tenths of mm. Example: 25 means 2.5 mm of rainfall. A negative value of -1 indicates that the rainfall was not measured.

QUALITY

A quality code is assigned to each rainfall value on the table. Details of the quality coding is given in Section 2.2.

2. TABLE: HOURLY_CATCH_DATA

Name	Null?	Type
CATCHMENT	NOT NULL	NUMBER(6)
TIME	NOT NULL	DATE
FLOW		NUMBER(8,3)
CARAIN		NUMBER(5,2)
QUALITY		NUMBER(1)

CATCHMENT	Gauging stations are numbered according to their IH National Surface Water Archive number.
TIME	Dates are stored in the same way as for the rainfall.
FLOW	The values are the flows at the date and time indicated in the time column. The values are not averaged hourly flows. Flow is given in m^3s^{-1}.
CARAIN	Catchment average hourly rainfall is in mm/h^{-1} and relates to rainfall falling in the preceeding hour.
QUALITY	Quality codes will be used for the flow and carain data. The coding indicates whether flow and/or rainfall were observed, disaggregated or filled in.

3. TABLE: HOURLY_GAUGE_DETAIL

Name	Null?	Type
GAUGE	NOT NULL	NUMBER(7)
EAST		NUMBER(5)
NORTH		NUMBER(5)
TEXT		CHAR(50)

GAUGE	The recording raingauge numbers as used in table cont_hourly_rain.
EAST	National grid reference easting.
NORTH	National grid reference northing.
TEXT	Comments on the recording raingauge.

4. TABLE: MORECS_DAILY_POT_EVAP

```
Name                            Null?    Type
------------------------------- -------- ----
SITE                            NOT NULL NUMBER(4)
TIME                            NOT NULL DATE
TEMPERATURE                              NUMBER(5,1)
PE_GRASS                                 NUMBER(4,1)
PE_DECWOOD                               NUMBER(4,1)
PE_CONWOOD                               NUMBER(4,1)
PE_UPLAND                                NUMBER(4,1)
PE_WCEREAL                               NUMBER(4,1)
PE_SCEREAL                               NUMBER(4,1)
```

SITE	Met. Office sites as listed in Table 4.1 in Spijkers and Naden (1994).
TIME	Date of the measurements.
TEMPERATURE	Daily temperature in degrees Celsius.
PE_GRASS	PE for grass.
PE_DECWOOD	PE for deciduous woodland.
PE_CONWOOD	PE for coniferous woodland.
PE_UPLAND	PE for upland heather.
PE_WCEREAL	PE for winter cereal.
PE_SCEREAL	PE for summer cereal.

5. TABLE: MORECS_DAILY_ACT_EVAP

```
Name                            Null?    Type
------------------------------- -------- ----
SITE                            NOT NULL NUMBER(4)
TIME                            NOT NULL DATE
AE_GRASS                                 NUMBER(4,1)
AE_DECWOOD                               NUMBER(4,1)
AE_CONWOOD                               NUMBER(4,1)
AE_UPLAND                                NUMBER(4,1)
AE_WCEREAL                               NUMBER(4,1)
AE_SCEREAL                               NUMBER(4,1)
SMD_GRASS                                NUMBER(5,1)
SMD_DECWOOD                              NUMBER(5,1)
SMD_CONWOOD                              NUMBER(5,1)
SMD_UPLAND                               NUMBER(5,1)
SMD_WCEREAL                              NUMBER(5,1)
SMD_SCEREAL                              NUMBER(5,1)
```

SITE	Met. Office sites as listed in Table 4.1 in Spijkers and Naden (1994).
TIME	Date of the measurements.
AE_GRASS	Actual Evapotranspiration (AE) for grass.
AE_DECWOOD	AE for deciduous woodland.
AE_CONWOOD	AE for coniferous woodland.
AE_UPLAND	AE for upland heather.
AE_WCEREAL	AE for winter cereal.
AE_SCEREAL	AE for summer cereal.
SMD_GRASS	Soil moisture deficit (SMD) for grass.
SMD_DECWOOD	SMD for deciduous woodland.
SMD_CONWOOD	SMD for coniferous woodland.
SMD_UPLAND	SMD for upland heather.
SMD_WCEREAL	SMD for winter cereal.
SMD_SCEREAL	SMD for summer cereal.