USE OF REGIONAL HYDROMETEOROLOGICAL RELATIONSHIPS IN OPERATIONAL HYDROLOGY

by

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SYNOPSIS

Synthetic streamflow models are increasingly being used in the planning, design and operation of water resources systems. Unfortunately, the historical data required for their calibration is often inadequate or non-existent.

The principal aim of this project is to show how, through the development of regional hydrometeorological relationships, the available data may be used to evaluate reliable model parameters for ungauged catchments. The study is based upon the region of England and Wales containing the Rivers Teifi, Tywi, Usk, Wye, Teme and Upper Severn.

A computer method of identifying possible errors in monthly data sets is developed and used for the verification of data supplied by the Water Data Unit.

A series of computer programs, designed for the statistical analysis of monthly data, is developed and a comprehensive analysis of the regional rainfall and streamflow data performed. Regional relationships are developed between rainfall and various streamflow parameters, including monthly means, standard deviations, skewness coefficients, lag-one correlation coefficients and lag-one regression coefficients. The spatial and temporal variation of monthly cross correlation coefficient is investigated and a method of predicting its seasonal variation for any two catchments is presented. Wherever possible the derived relationships are explained in terms of the physical processes involved.

Soil moisture is shown to be a key factor influencing both the spatial and temporal variation of several parameters. A soil moisture simulation model is developed and incorporated in a study of the variation of catchment storage and its influence on streamflow.

Finally, the derived relationships are used to predict the streamflow parameters for three totally independent catchments, and these are shown to compare very favourably with the corresponding parameters derived from historical records.

REGIONAL, STREAMFLOW, VERIFICATION, STOCHASTIC, CALIBRATION

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CHAPTER ONE

INTRODUCTION

1.1 GENERAL CONSIDERATIONS

The rapid increase in world population and the rise in living standards has generated an ever increasing demand for water. In order to meet this demand, water agencies throughout the world are increasingly developing large multipurpose water resources systems. These systems often involve more than one river catchment and many interconnected water facilities serving a vast variety of demands, including industrial and domestic consumption, irrigation, navigation, flood control, pollution control and even recreation.

The planning, design and operation of such systems is highly complicated and often requires the use of modern systems engineering techniques. The most powerful of these techniques is system simulation, which in the field of water resources was pioneered by researchers at Harvard University (Mass et al 1962). Systems simulation is essentially an experimental technique in which the real system, both natural and man-made, is represented by a computer model which includes economic functions for the assessment of benefits and costs. By simulating the performance of a proposed scheme over a long time, using a greatly reduced time scale, and then repeating this in a systematic manner for various modifications, the scheme which best satisfies the pre-defined economic objectives is determined. In this way both the water development and operating policies for the whole region may be optimised. The scope of recent research work in the field of mathematical modelling in hydrology can best be judged by references to the proceedings of the international symposia held at Fort Collins (1967), Illinois (1968), and Warsaw (1971). Prior to the development of simulation techniques, it was common practice in the developed world to use historical hydrometeorological data records as the sole basis for the design of new schemes. Basic to this method was the assumption that the past would repeat itself in the future, or at least that critical periods in the past could be treated as representative of those to be expected in the future. However, it can be shown that even where relatively long records exist they do not represent the full range of possible events. Also, long records are rarely available for more than a few of the points required for the study. Consequently, the traditional method of design has become increasingly inadequate as the systems have grown in complexity. Hence the development of synthetic hydrology which attempts to generate synthetic data sequences which are statistically indistinguishable from the historical data. A review of the models which are used to generate these sequences is presented in Chapter 2.

In addition to these deficiencies, the increasing effects of human activity on the elements of the hydrological cycle will tend more and more to render historical hydrological data of limited use for the direct prediction of corresponding behaviour in the future.

Kottegoda (1970) explained the complexity of the many variables involved in the rainfall/run-off process and classified them generally as topography, drainage area, elevation, tributary pattern, stream length, catchment retention, vegetation, geological structure, soil moisture capacity, infiltration, soil moisture content, capillary rise, deep percolation, base flow, interflow, evaporation, temperature, transpiration, radiation, windspeed, atmospheric pressure, humidity and cloudiness. This is an extensive list and some variables are clearly more dominant than others and many are interrelated. Topographical features, the channel system, catchment retention and soil moisture capacity, which are clearly highly dependent upon the geology, have a permanent influence on the run-off characteristics of a catchment. The processes of infiltration, capillary rise, deep percolation, interflow, ground water flow and base flow are dependent upon climate, geological structure and/or soil type. The processes of evaporation, transpiration and snow-melt are dependent upon many climatological and meteorological factors and upon the type of vegetation. These in turn are highly dependant upon topography. Meteorological variables are unsteady both spatially and temporally and are the prime cause of the stochastic nature of streamflow.

Dooge (1972) pointed out that research hydrologists have been prolific in the production of models of all types. There are linear and non-linear models, deterministic and stochastic models, lumped models and distributed models, component models and total catchment models, continuous models and discrete models, and so on. These concepts were used in all types of mathematical model types presented at the Fort Collins, Illinois and Warsaw symposia. The combination of the various factors gives rise to a wide variety of models at the disposal of the applied hydrologist. Dooge concluded that the hydrologists in the field are faced with the urgent need for solutions to practical problems and he urged that effort be directed towards the closing of the gap between theory and practice.

1.2 THE NEED FOR RELIABLE PARAMETERS

Available flow records are believed to contain many errors (Chow, 1964), and provide only a small sample from an infinite population. A continuous fifty year record for example is rare, and even with the rapid worldwide expansion of hydrological data collection networks in recent decades, it may well be generations before comprehensive stream gauging networks are established in every river basin. Even then it will be neither practical nor economical to establish flow gauges on every stream, and there will always be rivers for which no actual historical flow record exists. Also, the artificial and natural changes in the land use of the catchment will introduce trends or heterogeneity into existing records.

Hydrologists have always had to contend with inadequate, inaccurate and incomplete data records, and this situation therefore favours the introduction of synthetic flow data in hydrology provided these can be shown to be reliable.

Synthetic flow data are generated from existing historical records as mentioned earlier. The historical records are subjected to a statistical analysis which yields a set of statistical parameters, such as mean, standard deviation, skewness and autocorrelation coefficients, which are often then used as parameters in the models.

Since the synthetic data depend upon the historical records, they will tend to reflect all the errors inherent in the historical record. With random errors, this is merely an inconvenience resulting in an overall loss of accuracy, but all systematic errors pass undetected and undimensioned into the resulting similarly biased synthetic data.

The reliability of synthetic data sequences can be improved in two basic ways:

i) by the development of more advanced models which permit more precise reproduction of the essential flow characteristics,

and ii) by the development of methods of data analysis and interpretation which permit more reliable estimation of model parameters from the existing limited data sets.

The former has received, and continues to receive, a great deal of attention from research hydrologists throughout the world, while the latter has received comparatively little attention. Perhaps this is one of the areas which Dooge (1972) had in mind when he emphasised the gulf between research and practice.

The need for reliable flow parameters in the formulation of hydrological models is clear, but the data from which they have to be evaluated are often inadequate or non-existent. Any improvement in understanding of the hydrological processes, or development of analytical techniques, which facilitate better model calibration from existing data, would be of great value to operational hydrologists.

1.3 PROJECT OBJECTIVES

The objectives of this project are two-fold and may be stated as follows.

1) To improve the knowledge and understanding of the complex relationships between the many variables governing the spatial and temporal variation of river flow parameters.
2) To show how, through the development of regional hydrometeorological relationships, reliable estimates of river flow parameters for any set of points within that region can be evaluated.

This can be achieved with particular emphasis on the calibration of multivariate stochastic streamflow models.

The first of these objectives is purely scientific whereas the second is technological (i.e. it is concerned with the application of incomplete scientific knowledge to practical problems). It is hoped therefore that both the methods developed and the relationships derived in this project prove to be of practical as well as purely scientific value.

It should be made clear at this stage that this project is concerned only with naturalised monthly mean flows, and does not involve a study of dry weather flows or flood flows. Flood flows, and to a lesser extent dry weather flows, have been extensively researched by others (Beard, 1962, Cole, 1966, Ins. Civil Eng., 1975, Nat. Envir. Res. Council, 1975, IASH, 1974, Ward, 1978, Hudson and Hazen, 1964, Beron and Gustard, 1978).

The term 'naturalised' refers to flow records which have been adjusted to allow for unnatural abstraction from and/or discharges into the river (e.g. water supply abstractions and sewage discharges), and for the effect of the reservoir storage. These records are, therefore, as close to a truly natural flow record as one can possibly get. Since the aim of the project was to investigate the natural spatial and temporal variations of river flow, it was clearly essential to use naturalised flows.

1.4 METHODOLOGY

A brief description of the method used in this project is given below.

1) A review of modern methods of hydrological modelling was carried out so that a clear understanding of the model types and their data requirements could be gained (Chapter 2).

2) Consideration was given to the choice of region for this study. There were two basic requirements which needed to be satisfied. The first was the availability of an adequate number of long and reliable natural flow records. The second was the need for a large variation in ground level within the region so that the effect of altitude could be effectively examined. This lead to the choice of the region which includes the rivers Teifi, Tywi, Usk, Wye, Teme and Upper Severn. (Chapter 3).

3) Sets of naturalised monthly flows were obtained from the Water Data Unit and monthly mean areal rainfall records from the Meteorological Office.

4) A series of programs was developed in order to carry out an extensive statistical analysis of the data. (Chapter 4).

5) On commencing the statistical analysis it was found that the flow data was not as 'clean' as had been indicated by the Water Data Unit. A computer program was therefore developed to check the validity of the flow data, and apparently inconsistent flows were checked against daily flow records, rainfall records and data obtained from

the appropriate Water Authorities. Where flows were found to be clearly incorrect they were replaced by estimates based upon all the available evidence. (Chapter 5).

6) A comprehensive statistical analysis was carried out on the verified data. (Chapter 6).

7) The results of the statistical analysis were closely examined with a view to identifying relationship between the various parameters. (Chapter 7).

8) As a result of altitudinal effects identified in (7) above, it was decided to divide the region into sub-catchments and to analyse sub-catchment contributions to flow so that the altitudinal effect could be further magnified.

9) From the results of (7) and (8) a series of regional parameteric relationships was derived.

10) A simulation study was carried out into the variation of mean monthly soil moisture and groundwater store and their influence on monthly flows. (Chapter 7).

11) Consideration was given to the possible cause of the relationships derived in (9) and (10) above, and explanations have been given where possible.

12) The relationships derived in (9) and (10) above were used to estimate the monthly flow parameters at totally independent gauging stations, and comparisons made with the values obtained from the data records. (Chapter 8)

CHAPTER TWO

REVIEW OF STOCHASTIC STREAMFLOW MODELS

2.1 INTRODUCTION

This chapter outlines some of the stochastic methods used in analysing and modelling streamflow records.

The stochastic approach to streamflow modelling refers to the techniques used to generate synthetic hydrological data by assuming that they are realizations of a random process (DeCoursey, 1971). These data may be used either for input to some other model or to provide directly an estimate of the output of a hydrological process, (e.g. rainfall/run off models). In both cases the basic techniques of the generation processes are the same.

Models created for this purpose vary from a very realistic form using much information about the physical processes in converting input to output, to a "black box" form in which nothing is known of the physical process involved. Most of these models are of a parametric type in which elements of the hydrological system are combined and less detail about the internal structure of the model is known. Some streamflow models designed to provide synthetic sequences of hydrological data may be entirely stochastic. In such models there are no assumptions as to the internal structure of the real system. The synthetic sequences are developed entirely by a stochastic process. Such models are based on the stochastic properties of the historic data to which they are fitted. For example, monthly run-off at a streamflow station synthesized by a purely stochastic model could be based on the mean, standard deviation, and serial correlation of the historical data from the station.

The degree of complexity of the stochastic generator is a function of the statistical characteristics of the data to be generated and not of the type or size of the item being generated. The following sections describe several of the early models and methods of yield assessment and provide an introduction to the development and practical application of stochastic hydrology.

2.2 SOME TRADITIONAL METHODS OF ASSESSMENT AND SYNTHESIS

2.2.1 The Rippl Diagram

Mass curve analysis of the flow data was originated by Rippl (1883). If observed inflow data at a reservoir site is plotted cumulatively against time, evaluation of the yield is possible through a mere inspection of the graph. A typical Rippl diagram, or mass curve, is shown in figure (2.1). The difference between the ordinates of any two points on the curve is the summation of the flows during the intervening period of time. Thus, if the two points are connected by a straight line, the slope of the line will equal the average flow during that period, since it equals the total discharge divided by the corresponding total time interval. In the figure, the slope of the straight line AB joining the end points of the mass curve represents the average over the total period of the plotted record. Two straight lines A'B' and A"B" are drawn parallel to AB and tangentially to the mass curve at the lowest tangent point C and the highest tangent point D, respectively. The vertical intercept between these two straight lines represents the storage volume required to permit continuous release of water for the entire period. A reservoir having this capacity would be empty at C and full at D, assuming that it

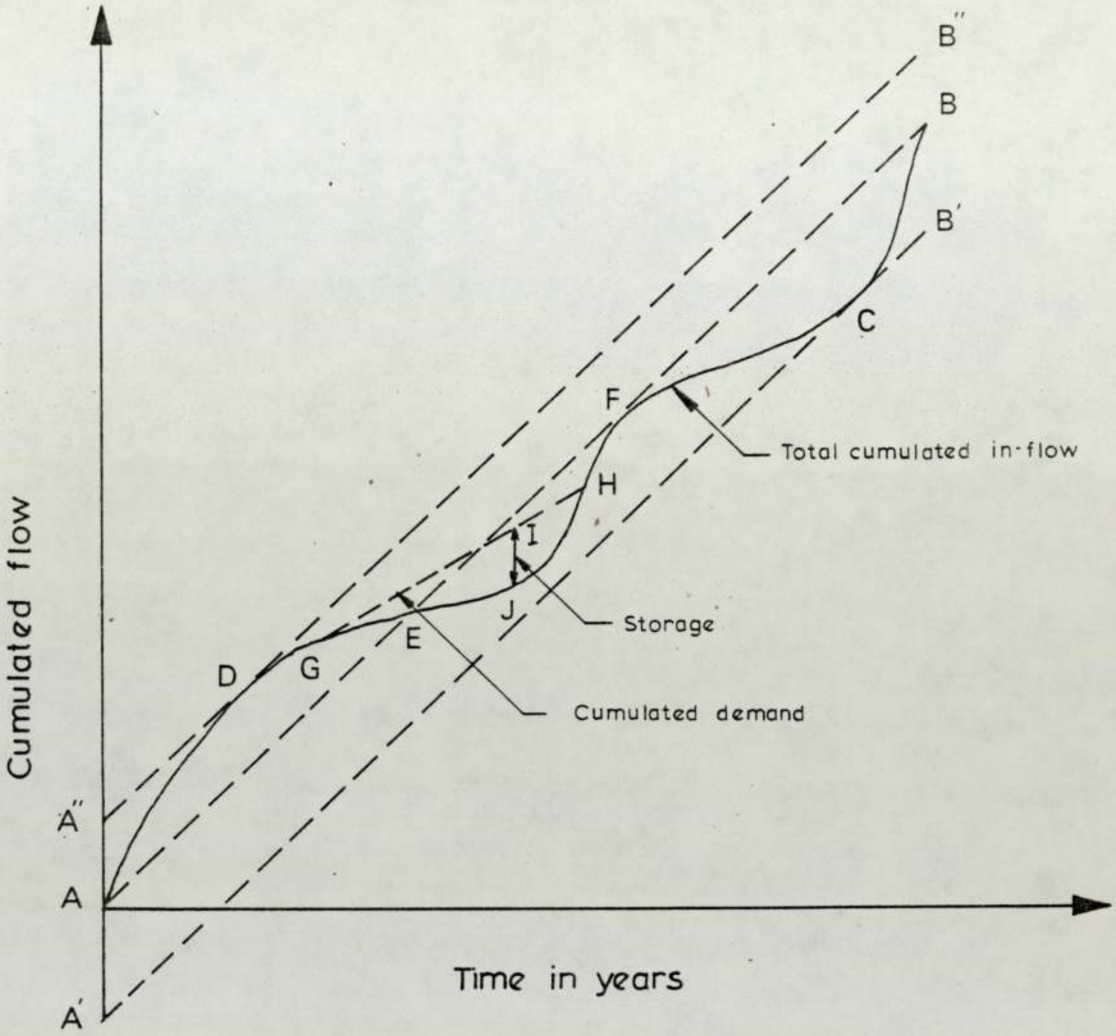


FIGURE 2.1 RIPPL DIAGRAM FOR STUDYING RESERVOIR STORAGE

contained a volume equal to AA' at the beginning of the period. If this reservoir were empty in the very beginning, it would be empty again at point E and during the period from F to B. If it were full in the very beginning, it would be full again at points F and B, but spill water between A and E. The rate of flow at any point on the mass curve is indicated by the slope of the curve. The rate of draft, or demand, is the rate at which water is required for use such as water supply or power can be represented by a straight line having a slope equal to the rate of demand is shown by the line GH which is drawn tangentially to any point on the mass curve. The required storage is given by the maximum intercept IJ, between such lines and the mass curve. If the storage is given, this curve can be used to determine the possible maximum uniform rate of flow by reverse procedure, that is by using the maximum slope of all trial draft lines which are drawn tangentially to the mass curve and have a maximum departure from it equal to the given storage.

2.2.2 Hazen's Method of Extrapolating Past Records

Hazen (1914) was perhaps the first to recognize the need for extrapolating past records in order to overcome the inadequacy of basing an analysis on limited historical data. His approach was to combine the records of the annual flows of fourteen streams after standardizing each record with its mean flow. The minimum and maximum number of years of observation in the records were twenty-five years and forty-five years respectively. A string of three hundred years was thus obtained, and Hazen used the cumulative mass diagram to determine the safe yield for a particular value of storage.

By using probability paper for plotting the annual yields, he determined the yield for a given degree of reliability with the coefficient of variation as an additional factor. The combination of several historical records from different catchments in order to obtain a single synthetic trace is crude when compared with modern methods, especially when one considers the interdependence of the various records. However, Hazen's original work on the practical application of probability methods to reservoir studies is highly commendable.

2.2.3 Duration Curves

The use of duration curves for studying the flow characteristics in streams evidently commenced in the late nineteenth century. However, the first comprehensive analysis on the subject was done by Foster (1934). By definition, a duration curve is a plot of flow values against the cumulative frequency of occurrence expressed as percentage of the time the flows are less than a given value.

A duration curve based on historical data can be treated as a probability curve to predict the probability of occurrence of future flows. It can also be used as a basis for studying and analysing the data in a manner comparable with studies on mass curves and hydrographs all of which have been used extensively since 1915. It is usual to compare the flow characteristics of streams in similar catchment basins through their duration curves prior to correlation or other analyses. A sharply rising duration curve shows a flashy river and a steadier river is represented by a flatter curve.

The use of duration curves in the present day design of regulating reservoirs and pumped storage schemes is valuable and its use in analysing historical data will continue to be of value. However, as a statistical tool to be used in methods of predicting and forecasting it is of limited scope and has been superseded by cumulative frequency diagrams.

2.2.4 Data Generation Using a Pack of Cards

The work of Hazen was extended by Sudler (1927) who introduced the chance element to the methods of synthesizing stream flows. From a chosen record he selected fifty representative annual stream flows and wrote the value of each on a card. The cards were shuffled and drawn one at a time until all the cards were used. The resulting set of observations gave a fifty year synthesized record of river flows. Similarly, the method was extended to obtain a one thousand year record. Sudler's results are misleading on account of the following basic limitations: (1) the historical data is faithfully reproduced, (2) the order of occurrence is changed, breaking the possible serial correlation in the flow values, (3) the maxima and minima cannot exceed the highest and lowest values marked on the cards, and (4) by drawing without replacement from the pack, a bias was introduced. Sudler also produced a series of charts for estimating storage capacities of rivers for various draft rates, but these have only limited application.

2.3 MONTE CARLO METHOD

This method is the simplest technique used in the generation of synthetic data and is the basis of all other sophisticated techniques developed later. The method is in effect merely a random selection of values from a population (generally assumed to be normally distributed) of known mean and variance, which have been set equal to the sample mean and variance of the present data sequence. It is assumed that the historical record possesses neither cyclic variation nor auto-correlation between successive values. This assumption severely limits the application of this technique in its basic form, for few hydrological data sequences conform to these constraints.

The Monte Carlo method may be expressed mathematically as

$$X_t = \overline{X} + e_t \, S_x \qquad (2.3)$$

where X_t is the generated value of the sequence at time t, and $\overline{X}$, S_x are the estimated mean and standard deviation of the historical record, e_t is a normal random deviate of zero mean and unit variance. The simulated sequence of synthetic data generated from the relationship will of course be stationary, normally distributed and without skewness or auto-correlation. Barnes (1954) employed the Monte Carlo technique in his investigation of reservoir yields in Australia by using estimates of the distributions of catchment annual mean run-off to simulate additional sequences of annual run-off. From these synthetic sequences and established routing techniques, Barnes was able to make estimates of the probabilities of failure of a reservoir system to meet specified demands. However, difficulty was encountered when it became clear that a monthly sequence would have to be generated in order to account for seasonal changes in storage.

In his study, Barnes employed mathematically acceptable techniques of generating the random normal deviates involving tables of random numbers and the central limit theorem. This was a major step forward from the crude techniques developed by Hazen (1914) and Sudler (1927), but the model still lacked many essential features. The inability of the simple Monte Carlo model to reproduce the cyclic patterns and auto correlation existing within the historical record has meant that this particular stochastic technique has not been widely used by engineering hydrologists, despite the fact that Monte Carlo methods in their crudest form have been available for hydrological use for half a century. In fact, the theory of time series analysis as a statistical technique has been established for a considerable length of time, but it is only recently that its application in the field of hydrology has been seriously considered.

2.4 AUTOREGRESSIVE PROCESS

An autoregressive process may be defined as a sequence of discrete data in which each value is influenced by the value of one or more of the preceding values.

In many natural phenomena, a level of persistence between discrete sequential values of a phenomenon can clearly be detected, as for example in the daily run-off record of a large river catchment. This persistence is expressed qualitatively by the correlation coefficient, r, between successive values, where

$$r = \frac{1/(N-1) \sum_{1}^{N-1} (x_i - \bar{x})\ (x_{i+1} - \bar{x})}{1/N \sum_{1}^{N} (x_i - \bar{x})^2} \tag{2.4}$$

The value of r may be between 0 and 1.0 and persistence is said to exist if r is significantly (i.e. in statistical sense) greater than 0.0. A data sequence, whether historical or simulated exhibiting auto-correlation between successive values is known as a first order Markov process. Yevdjevich (1963), found a simple lag-one correlation between annual values of run-off from a very large river catchment, as a result of the slow release of water from storage within the catchment, either from aquifers or lakes. It would seem reasonable therefore to expect a significant month-to-month correlation to appear in the flow records of smaller river catchments.

For a phenomenon with the same population mean and variance as that used to illustrate the basic Monte Carlo method in section 2.3, the Markov process, allowing for a lag-one persistence between sequential values, may be generated by the use of the following expression

$$X_t = \overline{X} + r(X_{t-1} - \overline{X}) + e_t S_x \sqrt{1-r^2} \quad (2.5)$$

where the notations are the same as already defined in section 2.3.

If from an analysis of a historical record of a phenomenon, having estimated mean $\overline{X}$, standard deviation S_x and auto-correlation coefficient r, two data generation procedures were to be carried out using (a) a simple Monte Carlo method, and (b) a first order Markov process, the resulting stochastic sequences would possess identical means and variances. However, the data generated by the Markov process would be more faithful to the historical record by virtue of the element of auto-correlation introduced into the synthesis.

It has so far been assumed that the distribution of the historical and synthetic data sets has been statistically normal without skewness effect.

This of course rarely exists in reality. To cope with skewed or non-normal distributed data, an expression involving coefficients of skewness may be introduced to equations 2.3 and 2.5 or by using alternative distributions to the random normal deviate e_t. In practice it is usually found that available hydrological records are of inadequate length to permit determination of the higher moment parameters of the distribution to any satisfactory level of significance. There is thus little, apart from mathematical elegance, to be gained from including any coefficient more complex than skewness in any generating process.

The first order Markov process overcame the problem of generating auto-correlated data sequences, but the problem of cyclic seasonal variations in streamflow which prevented Barnes and his contemporaries from making full use of the method of data generating, still remained.

2.5 THE THOMAS AND FIERING TECHNIQUE

Thomas and Fiering (1962) proposed a technique for the sequential generation of a stochastic data sequence preserving any seasonal or cyclic variations present in the historical record. This method which is essentially a mathematical elaboration of the auto-regressive model is represented in the following equation.

$$X_{i+1} = \overline{X}_{j+1} + b_j (X_i - \overline{X}_j) + e_{i+1} S_{j+1} (1 - r_j^2)^{\frac{1}{2}} \qquad (2.6)$$

where

$$b_j = r S_{j+1}/S_j \qquad (2.7)$$

The above recursion equation uses the same notation as before but with certain additions and modifications. $\overline{X}_j$ and $\overline{X}_{j+1}$ are the historical mean values of the variable X during the jth and (j+1)th intervals respectively within a repetitive cycle of wave length n intervals in which j assumes the integral values from 1 to n, (in case of monthly time intervals within the annual cycle, n = 12). Similarly S_{j+1} is the standard deviation of the (j+1)th set of the n sets of historical values of X. The differences between successive values of the n means, $\overline{X}_j$ necessitates the introduction of a regression coefficient b_j as a measure of the linear dependence of values of X in the (j+1)th period on values in the jth period, in conjunction with the corresponding lag-one correlation coefficient r. In the case where j=n, j+1 is set equal to 1 for the start of the next cycle; i is cumulative from one to infinity but the series generated, X_i will of course now possess a cyclic component of wave length n in addition to the stochastic and other deterministic components.

Since the introduction of the basic Thomas and Fiering technique outlined above, a number of modifications have been proposed. As the degree of skewness of each of the n seasonal distributions of X is unlikely to be the same, a uniform transformation will not be adequate and n separate transformations would be unwieldy and bearing in mind the small sample size the skewness will be unreliable. Consequently if the n separate distributions in the historical record exhibit significant amounts of skewness, a third moment expression is then introduced into equation 2.6. The form of this modification was proposed by Pearson (1967).

Harms and Campbell (1967) also modified the Thomas and Fiering technique to preserve the auto-correlation between annual values in a series of generated monthly run-offs. Kos (1967) introduced another modification to cope with the apparent inability of the basic technique to reproduce monthly sequences of low, dry weather flows with sufficient persistence.

2.6 MULTIVARIATE MODELS

All the models considered so far deal with flows for a single site, whereas many actual planning projects involve consideration of a number of sites, such as a system of reservoirs, pumping stations, sewage works and flood control zones.

Several new problems arise in the streamflow generation when several sites are used. It is not satisfactory simply to use single site generation procedures for each of the sites in turn, because flows at the various sites can be strongly interrelated. If a particular month is unusually wet at one site in an area, it is very likely that the same month will be wet at nearby sites. Moreover, if flow is high at one time on a particular stream, then it will tend to be high sometime later in a lower reach of the stream. Independent generation of the flow values for multiple sites cannot preserve spatial and temporal correlations between flows, consequently multivariate techniques were developed. Matalas (1967) and Fiering (1964) developed a multivariate generating process which preserved the cross correlation between the historic events at different stations as well as the estimates of mean, standard deviation, skewness coefficients and lag-one serial coefficients. The mathematics involved in this process is far more complicated than that for the single site models. The generation of a multivariate hydrological sequence for p-variates is governed by the following equation.

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \\ \vdots \\ y_{pt} \end{bmatrix} = \begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots & a_{1,p} \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots & a_{2,p} \\ a_{3,1} & a_{3,2} & a_{3,3} & \cdots & a_{3,p} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{p,1} & a_{p,2} & a_{p,3} & \cdots & a_{p,p} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{3,t-1} \\ \vdots \\ y_{p,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ \vdots & \vdots & \vdots & \\ b_{p1} & b_{p2} & b_{p3} & b_{pp} \end{bmatrix} \begin{bmatrix} E_{1t} \\ E_{25} \\ E_{3t} \\ \\ E_{pt} \end{bmatrix}$$

or in matrix notation

$$\underline{y_t} = \underline{A}\, \underline{y_{t-1}} + \underline{B}\, \underline{E_t} \qquad (2.7)$$

where $\underline{y_t}$ and $\underline{y_{t-1}}$ are the standardised flow vectors for times t and t-1 respectively and $\underline{A}$ and $\underline{B}$ are p x p matrices whose elements must be defined in such a way that the multivariates synthetic sequences generated by equation 2.7 will resemble the multivariate historic sequences in terms of estimated mean, standard deviation, skewness coefficient, lag-one serial coefficients and lag-zero cross correlation.

This basic principle for multivariate generating process is valid for generating mean annual flows while the case for monthly flows is somewhat different since the regression and correlation coefficients will in general vary from month to month (Mejia and Rouselle, 1967).

Many monthly multivariate models have been developed and a review of these models is given by Lawrance and Kottegoda (1977).

2.7 CONCLUSION

It is apparent from this review that hydrological modelling is a rapidly developing technology which clearly has a tremendous potential for practical application. At the present time much of the research work is concerned with improving the structure of the models so that they can more faithfully reproduce the characteristics of the historic record. The statistics which are commonly used as model parameters, or as measures of the flow characteristics against which the models can be tested, include mean, standard deviation, skewness coefficient, serial correlation coefficient and cross correlation coefficient. Since the historical data from which these parameters have to be estimated are often inadequate, there is clearly a need for the development of techniques which will enable practicing hydrologists to obtain the best possible estimates of these particular parameters.

CHAPTER THREE
THE REGION

3.1 INTRODUCTION

This chapter gives an outline description of the region selected for this study. The region includes several neighbouring river catchments in England and Wales. Map No 1 shows the region, its catchments and principal gauging stations. The main rivers in the region are the Wye, Severn, Teme, Usk, Tywi, Teifi and Taff. Tables (3.1) and (3.2) give details of the gauging stations and sub-catchments, and the length and reliability of the natural flow records. Gauges 15 to 19 in Table (3.1) were included in the initial considerations but had to be excluded from the analysis because their records were either too short or unreliable.

The Lugwardine gauge was found to be unreliable and private communications with staff at the Water Data Unit indicated that this was due to the station's inability to accurately gauge flood flows.

The records from the Kentchurch, Llandetty, Trallong and Tongwynlais gauging stations were too short and Tongwynlais was also unreliable because it contained an ungauged discharge from coal mines.

The region was divided into five River Authorities as a result of 1963 Water Resources Act; namely Wye, Severn, Usk, Glamorgan and South West Wales River Authorities. The region is intersected by a main watershed formed by the Cambrian Mountains, and Brecon Beacons (see Map No 2). These mountains form a natural barrier to the prevailing south westerly winds and produce a rain shadow effect in the leeward catchments.

The mean annual rainfall ranges from about 2400 mm in the mountains to 650 mm in the lowland area. (See Map No 3). The solid geology of the region consists mainly of sedimentary rocks of the Ordovician, Silurian and Devonian periods, and some Carboniferous and Triassic sediments in the north-east of the Region. There are also small outcrops of Pre-Cambrian and igneous rocks. The principal superficial deposits are boulder clay in the north-east, alluvium in the main river channels and glacial sand/gravel in the River Wye catchment near Hereford. The solid geology and superficial deposits are shown in Maps No 4 and 5. These were taken from the Geological Survey Maps of Great Britain published by the Ordnance Survey.

A general description of the river catchments is given in the following sections.

3.2 THE RIVER WYE CATCHMENT

This catchment is located at the centre of the Region and comprises all the river basins draining to the River Wye, which flows in a general south-easterly direction from Plynlimon in Mid-Wales to the Severn estuary. The catchment lying above the Cadora gauging station, has an area of 4040 Km^2 and, for the purpose of this study, has been divided into six sub-catchments; namely Rhayader, Caban Coch, Abernant, Upper Wye, Mid-Wye and Lower Wye. (See Map No 1).

As regards relief and drainage network, these sub-catchments can be classified into three broad types.

The first type, which may be termed 'mountainous', includes the Rhayader, Caban Coch and Abernant sub-catchments. These adjacent sub-catchments lie high in the Cambrian Mountains and slightly to the east of the main watershed formed by this range of mountains (See Map No 2). However, they are so close to the main ridge that they are not significantly affected by the rain shadow effect mentioned earlier. The geological formation of these sub-catchments is predominently Silurian sediments, which are both hard and relatively impermeable. (See Map No 4). The superficial deposits in this area have not been surveyed in detail, but they are known to comprise some upland peat, particularly in the Caban Coch sub-catchment, and some boulder clay in the Rhayader sub-catchment. The area has high rainfall, low evaporation and consequently a high percentage run-off. A system of reservoirs is contained with the Caban Coch sub-catchment which provide water to the City of Birmingham in the West Midlands County.

The second type, which may be termed 'upland', includes the Upper Wye and Mid-Wye sub-catchments, which are generally much lower than the mountainous sub-catchments but contain some mountainous terrain, for example the Radnor Forest and Black Mountains where the land rises to over 600 meters.

The Upper Wye sub-catchment is almost completely surrounded by mountains, the chain being broken only by the River Wye where it passes through a gorge near the Erwood gauging station. The rain shadow effect produced by these mountains is easily recognised by comparing the rainfall and topography of the region (Maps No 2 and 3). The geology consists of Silurian and Ordovician sediments with small areas of igneous rock and boulder clay.

The Mid-Wye sub-catchment is relatively long and narrow with hills on each side. The river flood plain widens considerably in the downstream direction and in parts consists of extensive deposits of alluvium and some glacial sands/gravels. The solid geology is predominantly Old Red Sandstone which is relatively impermeable.

The third type, which may be termed 'lowland', is represented by the Lower Wye sub-catchment which includes the Lugg and Monnow basins and is the largest sub-catchment on the River Wye. The general topography is fairly flat except at the sources of the rivers Lugg and Monnow. The river Wye below the Belmont gauging station flows eastward in a broad shallow valley and meanders in its lower reaches across a broad flood plain. The solid geology of this sub-catchment is predominantly Old Red Sandstone, apart from the Silurian rocks which form the hills at the source of the River Lugg. The superficial deposits are fairly extensive, particularly around the middle and lower reaches of the Lugg and the upper reaches of the Wye, and consists almost entirely of alluvium and glacial sand and gravel. The Monnow drainage basin and the area draining to the lower reaches of this sub-catchment contain few superficial deposits.

A detailed description of the River Wye Catchment is given in the Wye River Authority Report (1972).

3.3 THE RIVER SEVERN CATCHMENT

This catchment is located north of the River Wye catchment and comprises the Upper Severn river basin, (i.e. above Bewdley gauging station) and the River Teme (i.e. above Tenbury gauging station) which is a tributary of the River Severn. The River Severn, after rising at 610 meters above sea level, on the slopes of Plynlimon, flows in a generally north-easterly direction through the Vale of Powis to meet on its left bank the river Vyrnwy. It then flows in a south-easterly direction becoming southerly and meets the River Teme some twenty miles below the Bewdley gauging station. For the purpose of this study, the area has been divided into four sub-catchments, namely Vyrnwy, Upper Severn, Mid-Severn and Teme. Using the same general classification as for the River Wye, these sub-catchments may be classified as follows:

Vyrnwy	Mountainous
Upper Severn and Tenbury	Upland
Mid-Severn	Lowland

The Vyrnwy sub-catchment is similar to Rhayader, Caban Coch and Abernant in the River Wye catchment with average rainfall exceeding 2000 mm. The area is bounded by a series of mountains resulting in a high percentage run-off, and its principal feature is the Vyrnwy reservoir which supplies water to Liverpool. The geological formation of this area is entirely Silurian sediments, which are hard and relatively impermeable and there are no superficial deposits of any significant extent.

The Upper Severn sub-catchment is bounded by the Berwyn mountains in the north, Cambrian mountains in the west and by the hills of Rhyddhywel, Cilfaesty and Clun in the south. To the east lies the lowland area which forms the Mid-Severn sub-catchment. In the north east, the river meanders in the lowland area near the Montford gauging station. The rain shadow effect produced by the mountains is most pronounced in the south of the sub-catchment, where the rainfall on the hills is considerably less than on hills of similar height in the Cambrian Mountains to the west. The geology consists predominantly of Silurian and Ordovician sediments, but also includes a small area of Carboniferous deposits and a slightly larger area of Bunter Sandstone in the north east. The latter is far more permeable than the much older Silurian and Ordovician deposits. The sub-catchment also contains some igneous outcrops but these are small in extent. The superficial deposits are, however, extensive and consist mainly of boulder clay and some glacial sand and gravel. In the lower reaches, where the river meanders the alluvium forming the flood plain is quite extensive.

The Teme sub-catchment is also bounded by mountains; Caradoc Hills in the north, Clun Forest and Beacon Hill in the west and Brown Clee and Titterstone Clee in the east. The river rises in the hills in the west and flows in a general west-south-westerly direction to the gentler hill country near the Tenbury gauging station. This sub-catchment is similar in nature to the Mid-Wye sub-catchment, but it experiences a considerable rain shadow effect. The effect is due to the fact that this sub-catchment is well sheltered from the moist Atlantic air streams by extensive mountain ranges to the north west, west and south west. In terms of geology, this is a highly varied sub-catchment (see Map 4) since it contains a complicated mixture of rock types ranging in age from Pre-Cambrian to Carboniferous. In the west the Silurian sediments are predominant, whereas in the east Old Red Sandstone is the main rock type. However, the vast majority of the rocks contained within the sub-catchment are similar in one respect, that is they are relatively impermeable. The superficial deposits consist of some alluvium and river terrace deposits in the river valleys, a small amount of glacial sand and gravel, and boulder clay in the north.

The Mid-Severn sub-catchment is the largest of the four sub-catchments of the River Severn. Most of this area is flat and intensively cultivated. Due to the low average altitude and the effect of the rain shadow produced by the mountains to the south and west, average annual rainfall is low and reaches its regional minimum of about 650 mm within this sub-catchment. The area has a complicated geological formation and a substantial amount of superficial deposits which in total cover about 65% of the area. The solid geology of the area is varied and complex. It contains all the sedimentary rocks from Pre-Cambrian right through to the Lower Jurassic. The older rocks with their more complicated structure are confined to the south west, and are of low permeability. The younger rocks in the north and east consist of a large area of Bunter Sandstone which is permeable, and a smaller area of impermeable Keuper Marl. The Bunter Sandstone is an extensive aquifer and important source of potable water. The extensive superficial deposits consist of large areas of boulder clay, which in places provides an impermeable cover to the Bunter Sandstone, and smaller areas of glacial sand/gravel and river terrace deposits. There is very little alluvium in this sub-catchment because throughout most of its length the main river is eroding as opposed to depositing material.

A detailed description of the River Severn catchment can be found in the Severn River Authority Report (1974).

3.4 THE RIVER USK CATCHMENT

The River Usk catchment which is in the south of the Region has an area above Chain Bridge gauging station of 901 Km^2. The river rises at an altitude of 610 meters in the mountains to the west of the Brecon Beacons and flows east for about 24 Km before turning south-east to Chain Bridge, and eventually discharging into the Severn estuary. The river is bounded by the Brecon Beacons mountain chain on the south side, by the Mynydd Eppynt hills to the north and the Black Mountains to the north east. For the purpose of this study the catchment has been subdivided into two sub-catchments, Cray and Usk. Other sub-catchments were considered but as explained earlier, the flow records at the Llandetty and Trallong gauging stations were too short.

The Cray sub-catchment is a small (10.9 Km^2) mountainous catchment serving the Cray Reservoir, and is by far the wettest (about 2200 mm per year) sub-catchment in the Region. The reservoir which was built in 1907 forms about 5% of the total catchment area. The geological formation consists of relatively impermeable Old Red Sandstone which in part is covered by boulder clay.

The Usk sub-catchment may be termed 'upland' and represents the area above Chain Bridge gauging station minus the small Cray sub-catchment. It follows that the earlier general description of the River Usk catchment also applies to this sub-catchment. The climate is partly controlled by its upland character which results in a heavy rainfall over large areas and partly by its south-westerly position with consequent proximity to the Atlantic Ocean. The rainfall over the south is generally higher than on the land to the north, because of the rain shadow effect resulting from the prevailing west and south-westerly air streams being forced to rise by the Brecon Beacons mountain range. For example rainfall in the Black Mountains (altitude 810 m) is 900 m less than in the Brecon Beacons (altitude 885 m). The solid geology is predominantly Old Red Sandstone, but there is a small area in the south which consists of Coal Measures, Millstone Grit and Carboniferous Limestone. The latter are so small in extent that they have negligible effect on the relatively high impermeability of the catchment which results from the presence of the Old Red Sandstone. The superficial deposits are small in extent and consist of boulder clay, glacial sand and gravel and some alluvium in the river valley.

A detailed description of the areas is given in the Usk River Authority Report.

3.5 RIVERS TYWI (OR TOWY) AND TEIFI

These two rivers lie in the extreme south west of the Region and have many characteristics in common.

Firstly, they both rise in the Cambrian Mountains and then flow in a generally south-westerly direction. They are, therefore exposed to the prevailing south-westerly winds and consequently receive relatively high rainfall. This varies from 1300 mm to over 2400 mm in the Towy sub-catchment, and from 1100 mm to 1900 mm in the Teifi sub-catchment. There appears to be a very slight rain shadow effect in the Teifi sub-catchment due to the slight protection provided by the Mynydd Prescelly and Moelfre Hills.

Secondly, they both contain only one gauging station suitable for this study, and the sub-catchments corresponding to these, namely Ty-Castell and Glan Teifi, are similar in size, topography and geology.

Both sub-catchments are quite hilly and may be classified as 'upland'. The solid geology of both sub-catchments consist mainly of Ordovician and Silurian sediments. However, there is a small area in the south-east of the Towy sub-catchment which is more variable and contains Old Red Sandstone and some Carboniferous Limestone. Both sub-catchments may, however, be considered to be relatively impermeable. The superficial deposits are small in extent, consisting mainly of alluvium in the river valleys and some isolated deposits of boulder clay, peat and glacial sand and gravel.

A detailed description of these rivers is given in the South West Wales River Authority Report (1970).

3.6 SOURCES OF HYDROMETEOROLOGICAL DATA

The hydrometeorological data used in this study were supplied by the Water Data Unit, the Meteorological Office, the Severn Trent Water Authority and the Welsh National Water Development Authority.

The areal rainfall records for the Severn and Wye catchments were supplied by the two regional water authorities concerned, and the remainder of these data were supplied by the Meteorological Office. These records were then punched on cards and transferred to a computer file in a manner suitable for efficient use.

The stream flow data for the whole region were supplied by the Water Data Unit on magnetic tape. These data consisted of natural monthly flows (where available), monthly gauged flows and daily gauged flows. After verification (Chapter 5) the natural flow data were modified and extended using additional data obtained from the appropriate River Divisions of the Water

Authorities. This is described in detail in Chapter 5. The average annual potential evaporation was taken initially from the Meteorological Office map as given in Map 6, and then the monthly values were calculated using monthly percentage coefficients obtained from MAFF Bulletin No 16 (1967). The reason for adopting this procedure was the non-existence of the monthly records for the various sub-catchments in the region.

The average end-of-month soil moisture deficit (SMD) of the region was taken from Meteorological Office maps as given in figure 3.1. The values for the sub-catchments were then estimated by superimposing the sub-catchment boundaries onto these maps and evaluating the areal mean. These estimates were later improved by means of a soil moisture simulation model which is described in detail in Chapter 7.

3.7 SUMMARY

Table 3.3 below summarizes the principal features of each of the sub-catchments.

TABLE 3.1 DETAILS OF STREAMFLOW GAUGING STATIONS

GAUGE NO	STATION	RIVER	GRID REFERENCE	CATCHMENT AREA KM^2	LENGTH OF NATURAL RECORD	COMMENTS
1	Vyrnwy	Vyrnwy	SJ 019191	94.3	1936-1976	Flows measured by changes in reservoir level.
2	Montford	Severn	SJ 411145	2020	1957-1976	Flow measured by cableway with high quality rating.
3	Bewdley	Severn	SO 782762	4273.5	1936-1976	Flow measured by cableway. A large number of upstream abstraction and storage accounted in historic records.
4	Tenbury	Teme	SO 598685	1135	1957-1976	Flow measured by cableway with high quality rating.
5	Rhayader	Wye	SN 969676	167	1938-1976	
6	Caban Coch	Elan	SN 926645	184	1936-1976	Flows measured by changes in level of reservoir. Little persistence between monthly flows.
7	Abernant	Irfon	SN 892460	72.8	1938-1976	

TABLE 3.1 DETAILS OF STREAMFLOW GAUGING STATIONS (continued)

GAUGE NO	STATION	RIVER	GRID REFERENCE	CATCHMENT AREA KM^2	LENGTH OF NATURAL RECORD	COMMENTS
8	Erwood	Wye	SO 076445	1280	1938-1976	Run-off from this sub-catchment represents about one half of the total run-off in the Wye System.
9	Belmont	Wye	SO 485388	1900	1938-1976	Historical records of Jan and Feb 1963 were missing and were estimated using neighbouring stations.
10a	Cadora	Wye	SO 535090	4040	1937-1969	This gauging station was replaced by Redbrook from Oct 1969.
10b	Redbrook	Wye	SO 528110	4010	1969-1976	
11	Chain Bridge	Usk	SO 345056	912	1958-1976	Ground water abstracted by the National Coal Board to prevent interference with mining operations.
12	Cray	Cray	SN 890225	10.9	1936-1976	This sub-catchment has the highest areal annual rainfall in the whole region.
13	Ty-Castle	Tywi	SN 491204	1090	1959-1976	Flows measured by flat "V" weir
14	Glan Teifi	Teifi	SN 244416	894	1960-1976	Reliability of this gauge subject to seasonal weed cleaning.
15	Lugwardine	Lugg	SO 548405	886	1940-1976	These gauging stations have not been used in the study because their records are considered to be either unreliable or of too short duration.
16	Kentchurch	Monnow	SO 419251	138	1949-1974	
17	Llandetty	Usk	SO 127203	544	1966-1976	
18	Trallong	Usk	SN 947295	184	1964-1975	
19	Tongwynlais	Taff	ST 132818	486.9	1966-1972	

TABLE 3.2 DETAILS OF SUB-CATCHMENTS USED

Sub-catchment Name	Gauge Nos Involved	River	Sub-catchment Area Km^2	Length of Natural flow Record
Vyrnwy	1	Vyrnwy	94.3	1936-1976
Upper Severn	2 minus 1	Severn	1925.7	1957-1976
Mid Severn	3 minus 2	Severn	2253.5	1960-1976
Tenbury	4	Teme	1135	1957-1976
Rhayader	5	Wye	167	1938-1976
Caban Coch	6	Elan	184	1936-1976
Abernant	7	Irfon	72.8	1938-1976
Upper Wye	8 minus 5, 6 & 7	Wye	856.2	1938-1976
Mid Wye	9 minus 8	Wye	620	1938-1976
Lower Wye	10 minus 9	Wye	2140	1938-1976
Cray	12	Cray	10.9	1938-1976
Usk	11 minus 12	Usk	901.1	1958-1976
Ty-Castle	13	Tywi	1090	1959-1976
Glan Teifi	14	Teifi	894	1960-1976

TABLE 3.3 SUMMARY OF THE PRINCIPAL FEATURES OF THE REGION

Sub-catchment Name	Area Km2	Type	Approximate Median Altitude (m)	Mean Annual Areal Rainfall (mm) 1960-75)	Solid Geology	Superficial Deposits	Other Features
Vyrnwy	94.3	Mountainous	425	1879	Silurian sediments	No superficial deposits of any significant extent.	Contains Vyrnwy reservoir which supplies water to Liverpool.
Upper Severn	1925.7	Upland	250	1130	Silurian, Ordovican and Bunter Sandstone.	Mainly Boulder Clay and some glacial sand and gravel	
Mid-Severn	2253.5	Lowland	75	718	Contains all the sedimentary rocks from Pre-Cambrian to Lower Jurassic	Considerable amount of Boulder Clay and some glacial sand/ gravel.	This is the only sub-catchment in the region with a large proportion of permeable rock.
Tenbury	1135	Upland	200	849	Mixture of rock types. Silurian in the west and Old Sandstone in the east.	Alluvium and river terrace deposits in river valleys and small amount of glacial sand/ gravel and Boulder Clay in the north	The area is well sheltered from the moist Atlantic air, and exhibits a considerable rainshadow effect.
Rhayader	167	Mountainous	400	1631	These sub-catchments contains predominantly Silurian sediments.	Limited amounts of upland Peat in Caban Coch and some Boulder Clay in Rhayader	These all have high rainfall, low evaporation and consequently a high percentage run-off. Caban Coch contains several reservoirs which supply water to Birmingham.
Caban Coch	184	Mountainous	450	1821			
Abernant	72.8	Mountainous	425	1850			

TABLE 3.3 SUMMARY OF THE PRINCIPAL FEATURES OF THE REGION (Continued)

Sub-catchment Name	Area Km^2	Type	Approximate Median Altitude	Mean Annual Areal Rainfall (mm) 1960-75	Solid Geology	Superficial Deposits	Other Features
Upper Wye	856.2	Upland	275	1218	Consists of Silurian & Ordovican sediments with small areas of igneous rock.	A small amount of Boulder Clay.	The area is almost completely surrounded by mountains and exhibits a significant rain shadow effect.
Mid-Wye	620	Upland	175	911	Predominantly Old Red Sandstone.	Fairly extensive amounts of Alluvium & glacial sands/gravels.	The river flood plain widens considerably in the downstream direction.
Lower-Wye	2140	Lowland	75	833	Predominantly Old Red Sandstone.	Alluvium and glacial sand and gravel.	
Cray	10.9	Mountainous	425	2494	Old Red Sandstone.	Some Boulder Clay	Contains Cray Reservoir. Also, this area is by far the wettest in the region.
Usk	901.1	Upland	275	1353	Predominantly Old Red Sandstone & small area of Coal Measures Millstone Grit & Carboniferous.	Small areas of Boulder Clay, glacial sand & gravel & small Alluvium in the river valley.	Rain shadow effect on northern side of sub-catchment.
Tyca-stell	1090	Upland	200	1541	These sub-catchments consists mainly of Ordovician & Silurian sediments.	Consists mainly of Alluvium in the river valleys & some isolated deposits of Boulder Clay, Peat & glacial sand & gravel.	The only sub-catchments in the region which are on the exposed side of the main mountain barrier. They have many common characteristics.
Glan Teifi	894	Upland	200	1317			

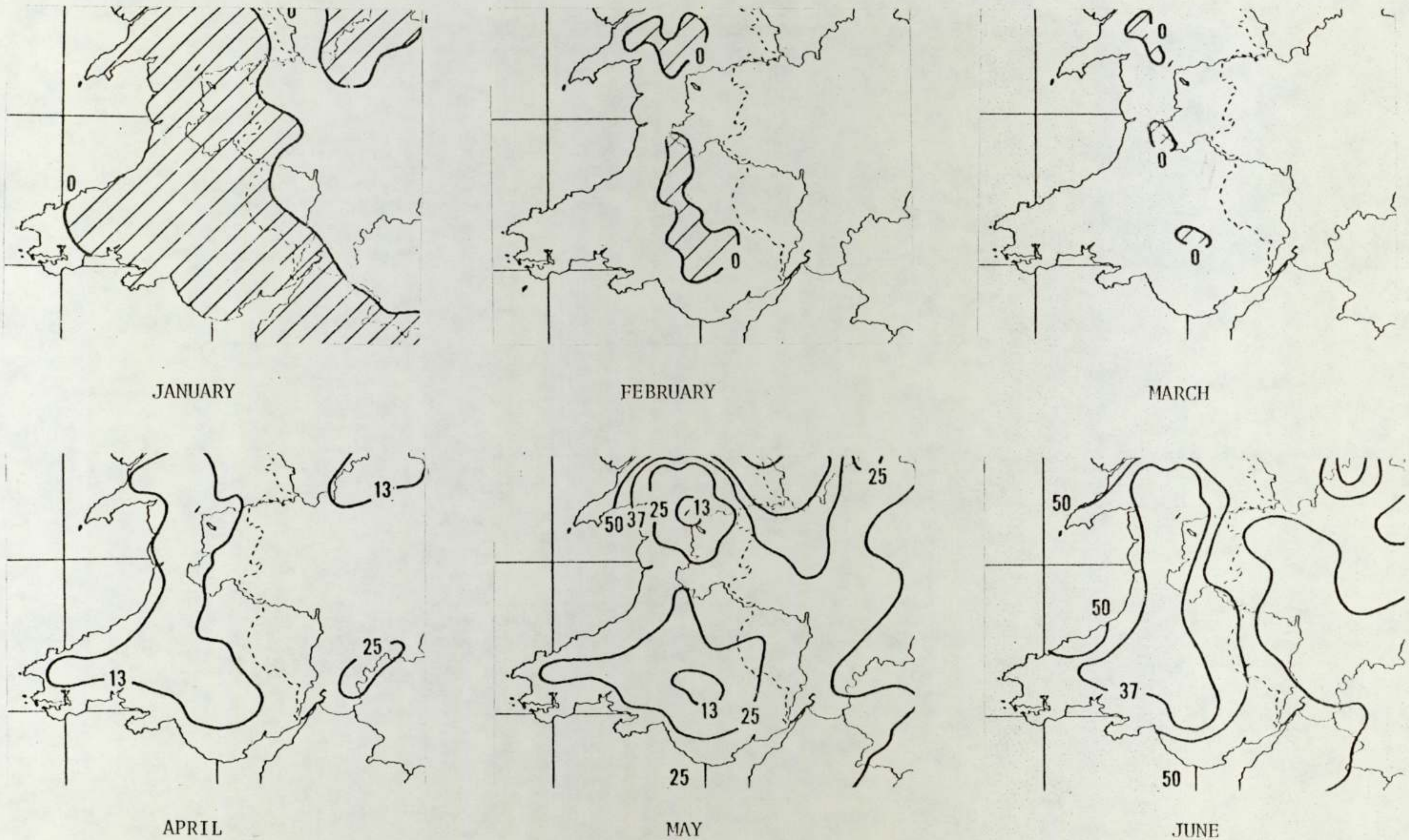


FIGURE 3.1 AVERAGE END OF MONTH ESTIMATED SOIL MOISTURE DEFICIT (1941-1970) (After Met. Office)

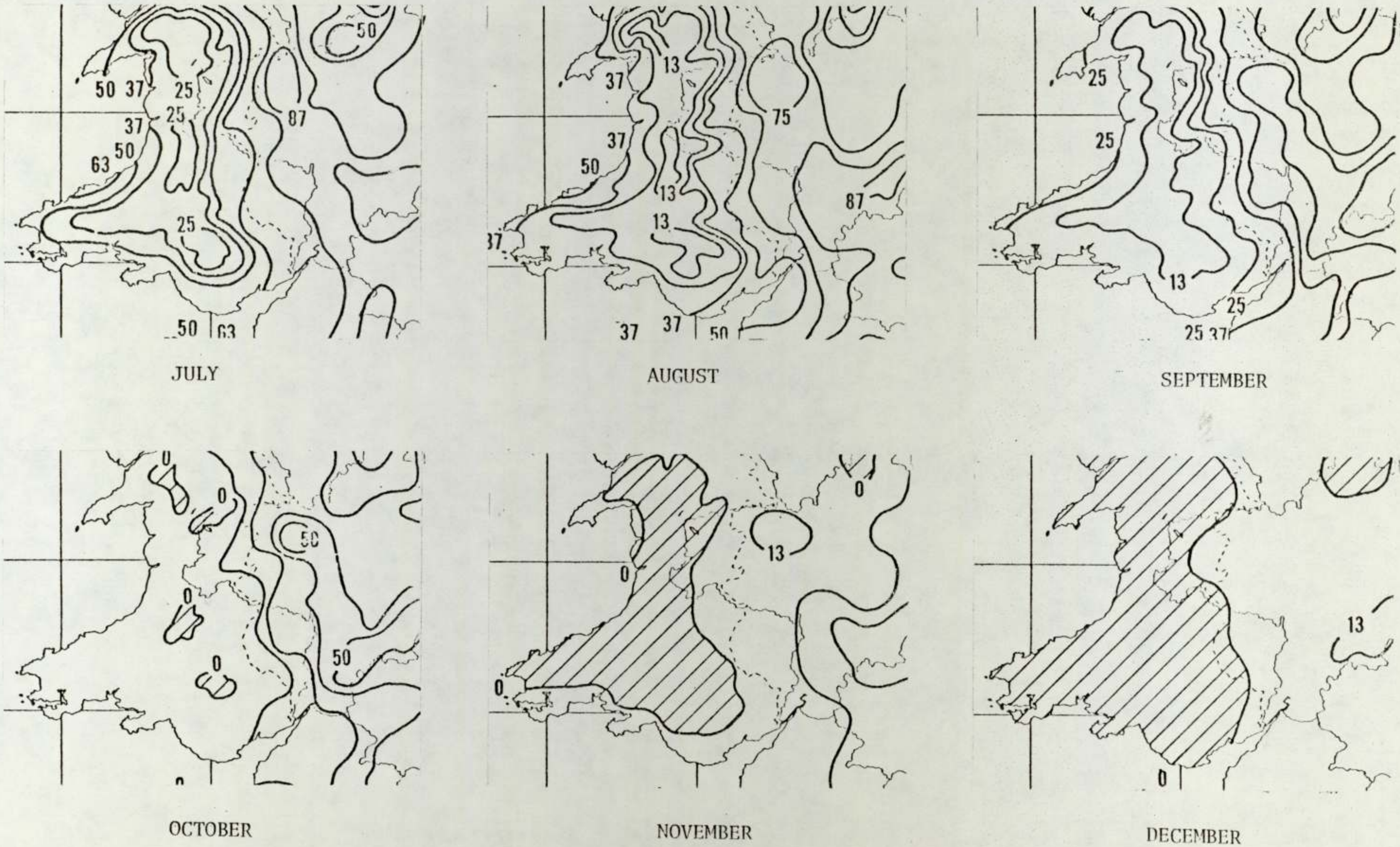


FIGURE 3.1 AVERAGE END OF MONTH ESTIMATED SOIL MOISTURE DEFICIT (1941-1970) (After Met. Office) (Continued)

CHAPTER FOUR

STATISTICAL CONSIDERATIONS

4.1 INTRODUCTION

One of the main characteristics of the river flow phenomenon is its variability with time. A series of observations recorded chronologically is termed a time series and its structure is the manner in which the observations vary with time. The structure of a river flow record depends on the type and size of river, and the size of the time interval between observations. The choice of a suitable time interval is an important step in the design of a gauging station. The unit of one day, or even longer may be adequate for large rivers, but shorter time intervals are necessary for smaller and/or flashy rivers in order to ensure that the information content of the series is maximised.

Having obtained a reliable 'continuous' record, statistical analysis may be based upon a series of mean flows corresponding to discrete time steps of any chosen length (i.e. daily, weekly, monthly or yearly means). The length of time step chosen for the analysis depends upon the purpose of the study and the time and money available for the analysis.

As stated earlier, this project is based upon the analysis of naturalised monthly mean flows. The reasons for this are:

i) the unit of one month is generally accepted as being suitable for most resource planning simulations. (James, 1969),

ii) naturalised monthly flow data were readily available,

iii) the unit of one month is sufficiently small for the investigation of temporal variations,

and iv) it was thought that a smaller time step may have limited the scope of the project by making it excessively time consuming and costly.

The following sections define the statistical parameters which form the basis of the analytical part of this project.

4.2 STATISTICS OF THE DISTRIBUTION

The characteristics of statistical distributions are described by the parameters of probability functions (Yevdjevich, 1964), which are expressed in terms of the moments of the distribution. The principal characteristics are, central tendency, variability and skewness.

In introducing the parameters of distributions, the usual procedure has been followed, that is the parameters of the distribution of the historical data were derived and used as estimates of the population parameters.

4.2.1 Central Tendency

The most reliable measure of central tendency is the mean. It is the first moment about the origin and is given by:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad (4.1)$$

where $\bar{x}$ is the best estimate of the population mean μ and x_i is the ith observation from a series of observations of length n.

4.2.2 Variability

Dispersion can be represented by the total range of values or by the average deviation about the mean. However, the parameter of statistical importance is the mean squared deviation as measured by the second moment about the mean. The parameter is termed the variance and is given by:

$$S^2 = \frac{1}{n} \sum_{i=1}^{n} (x_i - \mu)^2 \qquad (4.2)$$

or

$$S^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \qquad (4.3)$$

where S^2 is the best estimate of the population variance σ^2. The square root of the variance is a statistic known as the standard deviation (S), in which form variability is measured in the same unit as the variate and the mean, and hence it is easier to interpret and manipulate.

4.2.3 Skewness

The third moment of the distribution is used to define degree of assymetry or skewness

$$\alpha = \frac{1}{n} \sum_{i=1}^{n} (x_i - \mu)^3 \qquad (4.4)$$

or

$$\alpha = \frac{n}{(n-1)\ (n-2)} \sum_{i=1}^{n} (x_i - \bar{x})^3 \qquad (4.5)$$

The skewness coefficient C_s is given by

$$C_s = \alpha/S^3 \qquad (4.6)$$

For symmetrical distributions, the third moment is zero and $C_s = 0$. For right skewness (i.e. the long tail to the rightside) $C_s > 0$, and for left skewness $C_s < 0$.

4.3 LAG-ONE SERIAL CORRELATION AND REGRESSION COEFFICIENTS

In order to investigate the degree to which the recorded value of a hydrometerological phenomena (X) in a given month of the year is dependent upon the value in the preceding month, a parameter known as the lag-one serial correlation coefficient (r_1) is evaluated. This parameter describes the strength of the relationship between a value in a sequence and the value preceding it by one time interval; hence 'lag-one'. For strictly random sequences, the value of r_1 necessarily differs from zero only by sampling variation, and for sequences showing strong persistence its value is close to 1.0. The lag-one serial correlation coefficient for the jth month (r_j) is given by:

$$r_j = \frac{\text{Covar}\ (x_j,\ x_{j-1})}{\sqrt{\text{Var}\ (x_j)\ \text{Var}\ (x_{j-1})}}$$

$$= \frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)\ (x_{i,j-1} - \bar{x}_{j-1})}{\sqrt{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2 \sum_{i=1}^{n} (x_{i,\ j-1} - \bar{x}_{j-1})^2}} \qquad (4.7)$$

where,

j = month of year (1, 2, ... 12)

i = year of record (1, 2, ... n)

n = length of record (n years)

Another statistic relating to the nature of the interdependence between item x_j and proceding item x_{j-1} in a time series is the regression coefficient (b_j). This coefficient represents the slope of the linear regression line (Clark, 1973) relating x_{ij} to

$x_{i,\ j-1}$ and is given by:

$$b_j = r_j\ (S_j/S_{j-1}) \qquad (4.8)$$

Where r_j is the lag-one serial correlation coefficient and S_j and S_{j-1} are the standard deviations of x in the jth and (j-1)th month respectively.

4.4 CROSS CORRELATION COEFFICIENTS

The cross correlation coefficient is the most commonly used statistical parameter for measuring the degree of association between two variables. If x and y denote the two variables under consideration, the cross correlation is defined as:

$$r = \frac{\text{Covar}\ (xy)}{\sqrt{\text{Var}\ (x)\ \text{Var}(y)}} \qquad (4.9)$$

The best estimate of r from time series of length n is given by:

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})\ (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 .\ \sum_{i=1}^{n} (y_i - \bar{y})^2}} ,$$

which reduces to:

$$r = \frac{\sum_{i=1}^{n} x_i y_i - n\overline{xy}}{S_x\ S_y} \qquad (4.10)$$

where S_x and S_y are the standard deviations of x and y respectively.

Since S_x and S_y are positive, the sign of r depends on the sum of the cross products $(x_i - \bar{x})\ (y_i - \bar{y})$. Since this sum can vary between $+S_x Sy$ and $-S_x Sy$, the cross correlation coefficient varies from +1.0 to -1.0. If the sum of the cross products is zero, the variables x and y are independent and the correlation coefficient is zero. A high positive value of r indicates positive correlation, that is large values of x are associated with large values of y, and similarly for small values. A low value of the coefficient may indicate lack of association, that is x and y are independent. A negative value of r indicates inverse association, that is large values of x are associated with small values of y and vice versa.

4.5 LINEAR REGRESSION

A mathematical equation expressing one random variable as being correlatively related to another random variable, or to several random variables, is called a regression equation. The regression equation may be any function that can be fitted to a set of points of observed variables. The selection of the function to be fitted to the points determines the type and the degree of correlative association. If the function relating the two variables x and y is assumed to be linear, the regression equation represents the 'best' straight line that can be fitted to the plotted points, and gives the best estimate of y for any given value of x assuming that the relationship is in fact linear.

The linear regression line is generally fitted analytically by the method of least squares of the departures from the line.

If the estimated regression line is:

$$y = a + bx \tag{4.11}$$

then the regression coefficient (b) is given by

$$b = \frac{\sum_{1}^{n} (x_i - \overline{x})(y_i - \overline{y})}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \tag{4.12}$$

and

$$a = \bar{y} - b\bar{x} \tag{4.13}$$

The degree of linear correlation between the two variable is estimated by the sample correlation coefficient (r) which is given by:

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\left[\sum_{i=1}^{n} (x_i - \bar{x})^2 \cdot \sum_{i=1}^{n} (y_i - \bar{y})^2\right]^{\frac{1}{2}}} \tag{4.14}$$

A graphical method of estimating regression parameters is based on the principle that the graphically fitted straight line, by minimizing deviations from the line, leaves the same number of scattered points on both sides of the line, and these points are nearly homogeneously distributed along both sides.

4.6 DEVELOPMENT OF COMPUTER PROGRAMS

In order to effect the statistical analysis of the data, two main computer programs were developed. The first program (STATANAL) evaluates mean, standard deviation, skewness coefficient, correlation coefficient and regression coefficient for each month. This program also evaluates the annual mean for each year of the record, the overall mean annual and the lag-one to lag-fifteen serial correlation coefficients of annual mean data. The Fortran Listing and typical printout of STATANAL and its subroutines MFANAL and BSTAT are given in Appendix II.

The second program (CROSS) evaluates the monthly lag-zero cross correlation coefficients between any two records of a specified length. The Fortran listing of CROSS is given in Appendix II.

CHAPTER FIVE

ANALYSIS AND VERIFICATION OF HISTORICAL DATA

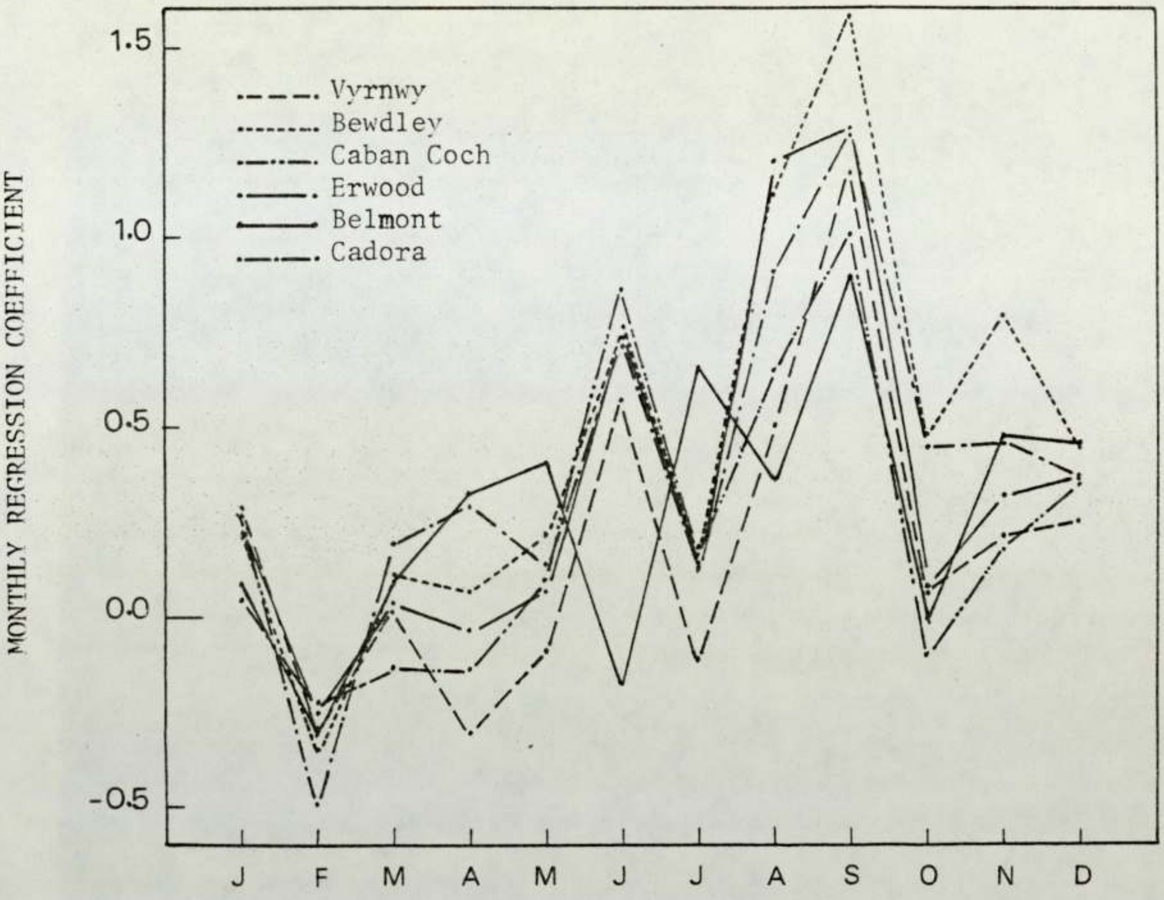
5.1 INTRODUCTION

This chapter briefly describes the results of the initial statistical analysis of the river flow data, and the problems regarding accidental data errors which were revealed by this analysis. The development and application of a method to check the homogeneity of the data is then described. Finally, a comparison is made between some of the statistical parameters calculated before and after verification of the data.

5.2 INITIAL STATISTICAL ANALYSIS OF HISTORICAL DATA

In the preliminary stage of this study, an extensive statistical analysis was carried out on the flow records from six gauging stations in the Wye and the Severn river basins. The period between 1950 and 1962 was chosen, because it was the only readily available naturalised flow record at that time.

The means, standard deviations, skewness and lag-one serial correlation and regression coefficients were calculated for each of the twelve months of the year using the 'STATANAL' program described in the previous chapter. The results were then represented in graphical form to facilitate visual interpretation. It was immediately apparent from inspection of these graphs that the results contained a number of anomalies. For example, a comparison between the correlation and regression coefficients for the flow at Belmont with those for the other stations. (Fig 5.1) reveals anomalies in the months of June and July. On investigating the cause of these anomalies, it was discovered that the flow data from the Water Data



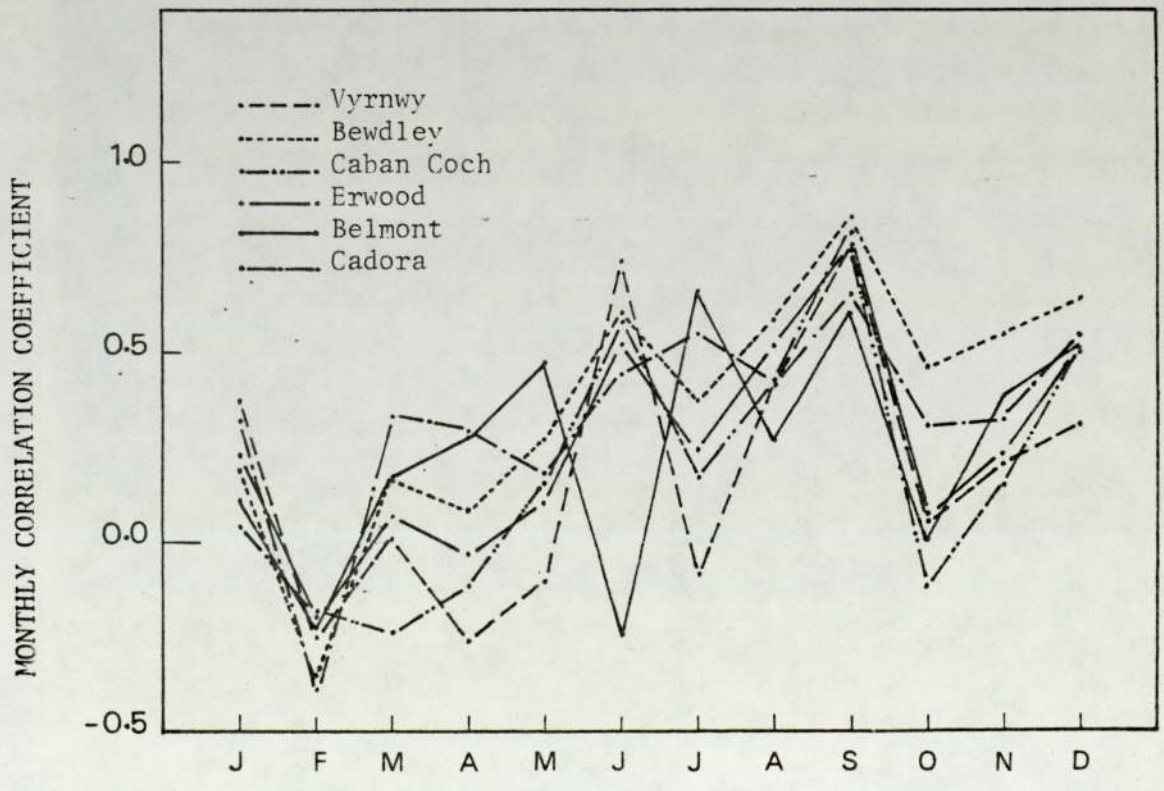


FIGURE 5.1 COMPARISON OF MONTHLY REGRESSION AND CORRELATION COEFFICIENTS OF RAW DATA (1950-1962)

Unit was not as 'clean' as had been indicated.

5.3 TYPES OF ERROR

Chow (1964), classified the errors inherent in meteorological data into two types: accidental and systematic. Accidental errors are usually due to the observer and sometimes due to the uncertain nature of the measuring instrument. Such errors may be considered as random errors; they are random in their incidence and variable in magnitude. Systematic errors may also arise from the observer or the instrument, but such errors are not random, they may be constant or vary in some regular way.

The sources of uncertainty which may affect hydrological data are: random measurement and computation errors; systematic data errors; non-homogeneity of the physical process; loss of information by approximating a continuous sequence in nature by observations in the form of a discrete series; sampling errors that result from a limited length of record; sampling errors that result from the use of a limited number of observational points; use of inefficient statistical methods in extracting the information from a pool of data; errors produced by various ambiguities in defining the population characteristics of importance to a problem; errors introduced in filling in missing data, and finally, errors introduced when typing and filing data in computing machines.

Inspection of the flow records for the Cadora and Belmont gauging stations (Table 5.1 and 5.2), as provided by the Water Data Unit, soon revealed the existence of accidental errors in the data. In these particular cases, the errors appear to be due to faulty transcribing of data.

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05300100 RIVER WYE AT CADORA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28.611	128.546	138.430
1937	195.017	207.727	179.811	82.787	34.821	19.869	17.914	12.047	12.491	17.321	37.493	89.588
1938	142.588	71.335	42.490	18.488	15.417	38.655	43.005	26.115	14.764	87.458	137.133	156.506
1939	244.958	116.998	99.414	69.731	26.147	14.375	77.090	46.156	16.716	19.630	181.843	132.104
1940	64.561	164.827	93.107	56.497	56.040	19.835	31.670	11.866	15.727	44.336	245.068	87.684
1941	87.684	213.624	132.762	59.874	37.377	46.782	17.452	38.403	23.938	56.497	63.793	1491.236
1942	93.759	86.690	70.100	80.041	59.132	31.896	22.518	22.065	28.603	60.726	32.806	112.990
1943	106.802	178.387	31.044	22.470	44.820	38.881	20.435	21.650	69.163	66.039	85.553	70.752
1944	108.334	52.715	22.696	19.746	12.624	13.102	[illegible].574	10.320	37.635	101.091	159.514	143.924
1945	67.343	191.500	48.730	48.171	33.064	65.586	40.559	35.789	59.106	109.071	68.253	154.517
1946	157.274	225.217	53.741	30.223	29.424	62.999	29.566	82.571	177.125	54.819	199.880	153.549
1947	139.263	43.768	332.610	135.429	9.988	28.830	23.275	12.371	9.925	9.577	46.781	53.764
1948	228.525	122.906	35.843	59.459	36.055	44.649	22.604	28.027	64.828	45.301	65.282	152.406
1949	127.075	50.511	59.031	76.910	31.845	25.069	10.242	9.546	9.156	64.761	131.252	135.629
1950	51.921	221.719	66.749	51.242	35.447	12.834	24.196	51.495	104.926	15.879	120.632	99.214
1951	150.683	144.576	147.816	117.908	48.455	27.231	13.002	20.524	27.988	18.147	210.247	124.041
1952	136.081	94.132	57.633	50.390	70.015	31.728	16.747	41.243	31.870	18.147	210.247	124.041
1953	136.081	94.132	57.633	50.390	70.015	31.728	16.747	41.243	31.870	38.851	93.361	52.556
1954	68.272	128.049	86.933	57.285	24.208	86.707	39.021	74.757	47.771	125.076	234.040	203.401
1955	104.575	91.889	93.333	56.691	91.351	135.837	28.204	13.116	14.150	16.458	48.455	89.299
1956	142.246	53.657	53.709	25.274	17.063	14.170	19.640	50.275	84.302	52.132	35.396	115.052
1957	107.944	184.655	100.639	29.959	21.402	12.505	27.261	54.878	110.946	58.333	106.529	87.245
1958	124.085	210.905	63.288	31.177	36.104	53.264	38.001	47.346	111.173	153.223	75.606	93.758
1959	202.297	44.797	64.308	83.450	52.103	23.056	21.226	11.038	5.748	35.679	85.461	220.844
1960	208.272	180.776	114.202	113.155	28.082	18.443	21.464	25.307	59.183	177.236	255.844	203.344
1961	150.816	134.704	41.286	97.552	67.734	18.652	15.659	21.133	22.328	83.620	49.073	116.581
1962	162.483	92.540	30.271	99.732	43.891	15.880	10.786	48.988	61.363	37.888	61.618	80.958
1963	24.464	29.874	204.392	100.044	57.568	29.620	34.065	20.705	30.129	31.064	155.828	51.084
1964	31.857	42.306	81.326	44.797	39.757	30.214	20.635	15.758	10.386	25.855	49.951	126.945
1965	162.426	35.453	83.563	58.163	45.534	38.001	30.271	27.465	78.693	46.393	73.029	251.333
1966	112.758	173.187	89.576	109.341	82.368	37.323	21.228	37.581	39.640	87.669	105.622	171.856
1967	98.407	144.398	108.454	36.529	86.423	37.803	21.620	30.446	61.165	178.833	110.332	108.058
1968	182.936	72.548	82.091	55.314	77.855	47.986	98.223	25.018	47.765	83.246	96.139	130.747
1969	168.891	124.978	116.647	61.267	108.682	57.424	18.406	28.297	16.858	17.511	85.105	103.632
1970	153.508	184.273	91.871	80.367	34.564	16.177	15.688	25.320	26.191	33.499	175.488	81.966
1971	155.522	104.886	86.326	42.007	27.008	56.808	21.982	32.100	15.117	0.000	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5.1 EXAMPLE OF ERRORS FOUND IN THE RAW STREAMFLOW RECORD FOR THE CADORA GAUGING STATION

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE A FORMAT)

05500200 RIVER WYE AT BELMONT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	96.979	55.829	38.664	43.427	18.624	25.530	72.501	10.504	24.073	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.281	25.258	66.581
1938	105.284	45.030	24.679	8.242	8.026	27.157	39.812	21.230	9.851	77.243	106.530	94.537
1939	138.516	145.286	06.865	41.627	12.508	6.464	60.937	31.870	7.684	8.558	137.249	84.543
1940	34.137	84.375	56.844	35.578	30.192	10.646	23.470	6.122	9.205	32.801	176.262	66.228
1941	39.465	122.394	74.876	31.865	22.218	21.902	7.195	33.059	14.475	53.820	45.083	67.911
1942	122.878	50.075	40.349	53.594	48.150	20.740	18.983	18.204	22.781	59.196	23.207	78.757
1943	110.444	103.326	11.572	14.202	38.019	34.363	17.589	19.398	6.269	54.972	71.841	47.150
1944	85.254	33.853	12.881	13.107	8.500	10.220	15.096	7.016	32.548	88.373	115.388	93.417
1945	42.442	120.916	24.963	31.723	17.515	43.947	21.350	17.747	34.047	64.876	30.223	87.379
1946	92.518	165.363	31.055	15.164	15.806	49.159	24.848	66.970	127.402	38.150	137.948	99.803
1947	86.747	21.124	199.201	75.260	29.734	10.546	9.946	4.586	4.413	3.829	47.718	49.165
1948	182.537	84.230	22.523	40.170	17.478	37.335	15.296	21.930	50.995	38.413	48.623	105.100
1949	81.566	30.024	37.992	53.273	22.723	14.559	3.676	5.228	4.123	53.241	97.442	109.665
1950	35.410	144.507	36.514	35.384	22.639	6.590	19.614	51.853	04.664	51.516	88.199	70.142
1951	101.470	85.254	89.420	73.403	26.726	11.077	6.401	16.106	37.056	12.823	132.146	82.019
1952	83.213	60.021	34.021	28.803	37.651	19.861	9.930	27.762	22.055	53.383	52.731	86.416
1953	31.412	52.421	34.247	47.518	23.559	11.251	22.807	23.196	42.016	28.073	69.093	32.451
1954	50.121	79.436	48.054	35.793	13.167	48.479	29.421	61.505	42.391	117.799	143.057	113.863
1955	56.719	49.583	32.111	59.806	75.946	14.776	4.236	8.226	50.914	15.866	36.642	6.201
1956	92.313	26.915	45.279	14.048	8.773	8.597	14.014	43.297	57.568	35.906	26.598	78.835
1957	69.093	108.143	64.619	14.062	13.997	9.786	26.468	50.914	90.728	45.505	67.394	54.737
1958	79.684	122.105	30.667	16.121	22.883	31.035	26.004	38.530	69.263	85.206	43.268	51.027
1959	106.075	20.567	36.444	53.689	25.497	10.659	13.847	5.978	2.591	30.044	65.667	133.147
1960	118.025	102.791	56.577	64.931	13.853	10.647	15.594	18.052	43.552	86.905	133.628	122.669
1961	89.901	80.058	18.970	55.926	37.605	6.745	8.492	13.220	14.847	74.417	39.389	86.367
1962	108.539	66.326	30.016	10.112	6.332	39.342	55.360	15.889	67.055	27.388	44.061	60.542
1963	0.000	0.000	120.687	58.871	40.465	22.404	32.083	21.192	27.309	29.450	118.167	28.430
1964	19.808	27.437	42.447	25.896	29.082	24.469	19.476	14.116	7.645	20.694	118.167	28.430
1965	19.808	27.437	42.447	25.896	29.082	24.469	19.476	13.785	8.399	30.967	56.527	182.477
1966	67.293	105.974	55.135	64.134	54.473	26.662	16.817	35.705	31.291	73.174	66.775	135.731
1967	59.986	89.775	54.534	22.067	55.503	25.187	17.640	27.714	46.936	128.342	62.162	68.176
1968	113.099	35.370	50.921	32.843	47.956	31.014	45.417	9.019	35.735	59.814	55.236	68.352
1969	98.082	65.200	52.333	37.365	69.802	30.944	8.527	21.935	7.723	12.496	67.663	75.851
1970	87.253	114.632	54.315	60.636	18.940	6.809	13.117	22.061	21.996	29.590	126.760	48.439
1971	98.312	62.179	47.816	21.119	12.613	30.913	7.987	16.340	7.769	29.883	38.758	37.755
1972	85.173	73.561	52:206	74.298	30.807	39.705	17.829	12.017	8.409	6.896	49.069	120.099
1973	34.939	65.233	32.852	25.016	30.138	12.015	13.529	30.909	16.341	27.536	30.813	58.338
1974	139.655	133.723	31.363	10.357	9.262	10.974	18.466	20.492	62.772	41.924	84.616	108.588
1975	114.485	45.285	37.786	29.628	18.295	7.438	0.000	6.192	12.738	14.334	29.636	0.000

TABLE 5.2 EXAMPLE OF ERRORS FOUND IN RAW STREAMFLOW RECORD FOR THE BELMONT GAUGING STATION

Having found serious errors in one data set, it was clear that all of the data would have to be checked for possible accidental errors.

5.4 VERIFICATION OF HISTORIC DATA

As a result of the discovery of accidental errors in the historical flow data records, a computer system for the automatic verification of multi-site hydrological data was developed and tested using the monthly records of rainfall and streamflow.

The main program 'CONSISTENT', reads the historic data from a magnetic tape and stores it in a form suitable for easy access by the various subroutines that effect the analysis.

The main program and its principal subroutine 'CHECK', which performs the verification process, are given in Appendix II together with their Fortran listing.

5.5 METHOD OF DATA CONSISTENCY ANALYSIS

Consider two sets of monthly hydrometeorological data measured at two separate sites within a region. Let the variables at sites 1 and 2 by $X_{i,j}$ and $Y_{i,j}$ respectively, where i, is the year from the start of the record and j is the month of year.

These data can be expressed in matrix form as follows:

Site 1 Site 2

$$\begin{bmatrix} X_{1,1} & X_{1,2} & \cdots & X_{1,12} \\ X_{2,1} & X_{2,2} & \cdots & X_{2,12} \\ \vdots & \vdots & & \vdots \\ X_{n,1} & X_{n,2} & \cdots & X_{n,12} \end{bmatrix} \qquad \begin{bmatrix} Y_{1,1} & Y_{1,2} & \cdots & Y_{1,12} \\ Y_{2,1} & Y_{2,2} & \cdots & Y_{2,12} \\ \vdots & \vdots & & \vdots \\ Y_{n,1} & Y_{n,2} & \cdots & Y_{n,12} \end{bmatrix}$$

where n is the number of years chosen for the analysis. A commonly used graphical method of testing the consistency of X and Y is the double mass curve technique which involves plotting accumulated values of X against corresponding accumulated values of Y for each time step in the sequences. If both X and Y are homogeneous the resulting graph will consist of a single straight line, as represented by line AB in figure 5.2. If however, one or both contain accidental errors the line will include steps, but the slope will remain constant, as shown by line AB'. The position of a step indicates the position in the record of the error, but it does not indicate in which record the error is to be found unless one of the records has already been shown to be homogeneous. If a systematic error has been introduced to one of the records at some stage the line will have a different slope before and after the introduction of the error, as represented by lines AC and CB". In order to determine which is the offending record, either X or Y must first be shown to be homogeneous by comparison with another record Z.

This technique has been computerized by Chang and Lee, (1974). However, the double mass technique is not ideal for locating accidental errors since the resulting steps in the line are often quite small. Also, this graphical technique is not well suited to computerisation, and so it was decided to develop a computer method specifically designed for the identification of accidental errors.

5.5.1 Choice of Error Indicator

In order to identify probable accidental errors it is necessary to devise a statistic which can be used as an indicator of apparent

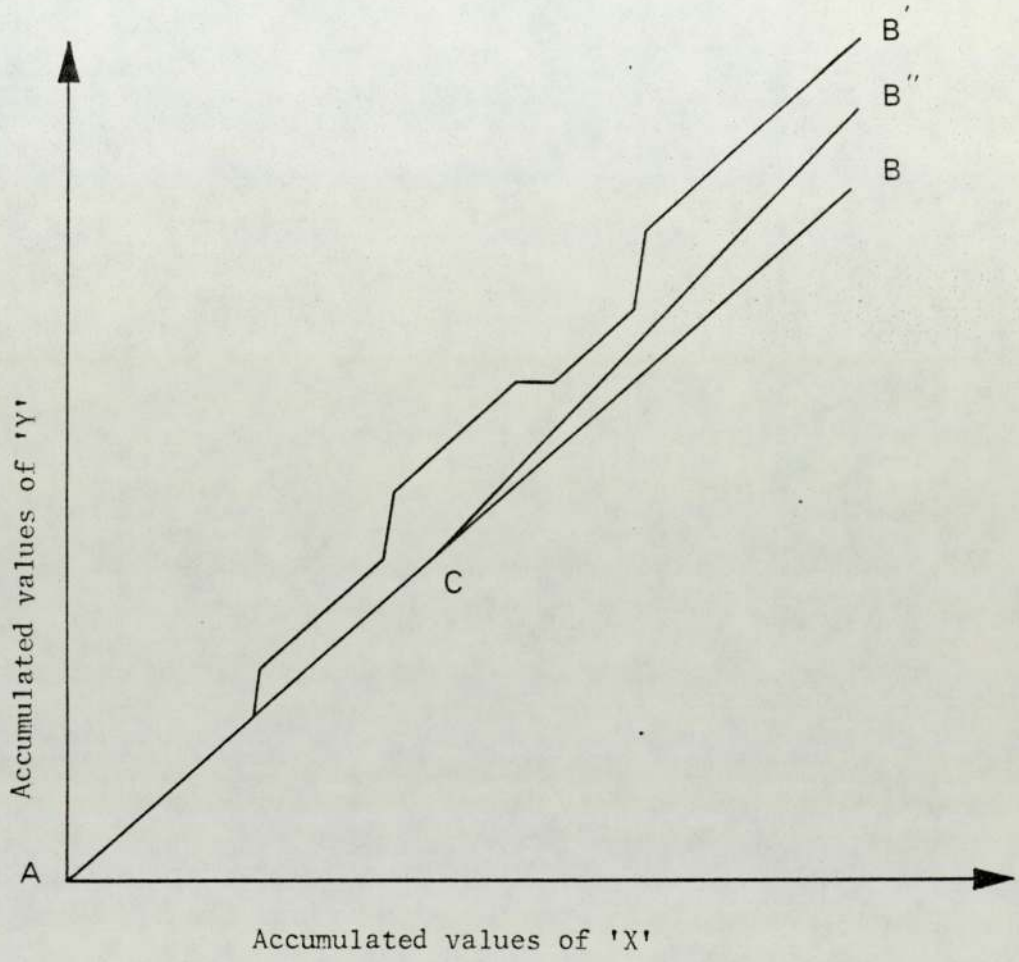


FIGURE 5.2 DOUBLE MASS CURVE METHOD OF DATE CONSISTENCY ANALYSIS

inconsistency. The words 'probable' and 'apparent' are used here in recognition of the fact that it is not generally possible to say with absolute certainty that an item of data is incorrect; it is normally a matter of probability. This indicator clearly has to make use of the interdependence that exists between data sets from different sites within a region. It must, therefore, be a statistic which in some way compares corresponding items of data from different sets, and thus identifies the probable inconsistencies. The reliability of the indicator will clearly depend upon the nature of the spatial and temporal variability of the variable concerned.

An added factor is that hydrometeorological variables exhibit seasonal variation of mean, variance and skewness. For relatively short records this can present a problem, because there are too few data available for the verification to be satisfactorily carried out on a month by month basis. If, on the other hand, the months are not analysed separately, the problem arises that the indicator itself may possess seasonal variation, thus adding a bias into the process of identifying probable errors. The degree of seasonal variation in the indicator will depend upon the degree of seasonal similarity between the variables, and the mathematical form of the indicator.

It is possible to devise several different indicators which can be used to test the consistency of the data sets X_{ij} and Y_{ij}, and some of these are given below.

(a) Ratio of observations (R_{ij})

$$R_{ij} = \frac{X_{ij}}{Y_{ij}} \qquad 5.1$$

This indicator is simple to evaluate and is closely related to the indicator used in the double mass curve method, where ΣX_{ij} is plotted against ΣY_{ij}. However, if the seasonal variation of the monthly means of X and Y are not in phase and proportional in magnitude, the monthly means of R_{ij} will exhibit seasonal variation. Alternatively, if R_{ij} is stationary with respect to mean, its variance and skewness may still show seasonal variation.

(b) Standardised ratio of observations (r_{ij})

$$r_{ij} = \frac{R_{ij}}{\overline{R}_j} \qquad 5.2$$

where $\overline{R}_j = \frac{\overline{X}_j}{\overline{Y}_j} = \frac{\text{mean of } X_{ij} \text{ for month j}}{\text{mean of } Y_{ij} \text{ for month j}}$

The advantages of standardising the ratio of the observations are two-fold.

i) it makes the ratio stationary with respect to mean (i.e. $\overline{r}_j = 1.0$ for each month j),

and ii) it makes the ratio matrices (r_{ij}) of different stations combination directly comparable because they have a common mean of 1.0.

The main disadvantage is that errors affect the magnitude of the $\overline{R}_j$'s, and this in turn tends to off-set their effect on R_{ij}, thus reducing the efficiency of r_{ij} as an error indicator.

(c) Deviation between standardised observations (Δ_{ij})

$$\Delta_{ij} = \left[\frac{X_{ij}-\overline{X}_j}{S_{xj}}\right] - \left[\frac{Y_{ij}-\overline{Y}_j}{S_{yj}}\right] \qquad 5.3$$

where $\overline{X}_j$ and $\overline{Y}_j$ are the mean values of X_{ij} and Y_{ij} respectively in month j.

S_{xj} and S_{yj} are the standard deviations of X_{ij} and Y_{ij} respectively in month j.

Provided the proportion and magnitude of errors in each month is small, this method has the advantage that the indicator is stationary with respect to both mean and variance. However, since S_{xj} and S_{yj} are even more sensitive than $\overline{X}_j$ and $\overline{Y}_j$, it follows that the masking effect mentioned in (b) above is even greater in this case. In fact, this effect not only reduces the ability of Δ_{ij} to identify real errors, but also makes it more prone to making incorrect identifications.

The choice of the mathematical form of the indicator therefore involves consideration of two conflicting aims, namely:

a) to avoid using sample statistics, such as mean and standard deviation, because their values are affected by the errors and thus reduce the reliability of the indicator;

and b) to eliminate seasonal bias of the indicator by means of standardisation.

Clearly a compromise has to be made, and for the purpose of this study it was decided to use r_{ij} as the indicator, since this goes some way to satisfying both aims.

5.5.2 Identification of Probable Errors

Having obtained the standardised ratio of observations matrix (r_{ij}) for given data sets X_{ij} and Y_{ij} it remains to locate the probable errors. An accidental error in either record does in general, but not always, produce a value of r_{ij} which tends towards one of the two extremes of the distribution. That is the r_{ij}

value tends to be extremely large or extremely small as illustrated in Table 5.3 which shows a typical r_{ij} matrix.

In order to computerise the identification of probable errors, it is necessary to devise an algorithm which locates the extreme values of r_{ij} and memorises their positions in the r_{ij} matrix. However, before this could be done, it is necessary to adopt a definition of an 'extreme value'. Two types of definition are possible:

(i) in terms of upper and lower percentiles (e.g. the 2.5% and 97.5% percentiles of the cumulative frequency curve).

and (ii) in terms of a specified number of standard deviations above and below the mean.

The choice of a definition can, in fact, be made quite arbitrarily because it is used not to define errors, but to define probable errors requiring further investigation. The problem with definition (i) is that it identifies a set number of probable errors irrespective of how many actual errors exist. This can lead to the unnecessary investigation of a large number of perfectly valid items of data, or can result in the failure to identify some errors. The problem with definition (ii) is that because r_{ij} cannot be negative the distribution of r_{ij} tends to be skewed to the right, thus requiring different definitions of the upper and lower limits. To make things worse, different station combinations produce r_{ij} matrices having different skewness coefficients, thus necessitating definitions of upper and lower limits in terms of functions of mean, standard deviation and skewness coefficient.

After investigating both definitions of extreme values an algorithm based upon upper and lower percentiles was developed. Details of this procedure are as follows:

(i) Calculate r_{ij} matrix and produce fourteen element histograms (Subroutine Histo)

(ii) evaluate cumulative frequency curve based upon fourteen plotting positions.

(iii) evaluate the upper (97.5%) and lower (2.5%) limits by linear interpolation between plotting positions.

Figure 5.3 shows a typical percentage cumulative frequency curve of r_{ij} and illustrates the use of upper and lower acceptance limits.

In order to record the location of probable errors, each data set was allocated in nx12 'score matrix', '$\overset{K}{g}_{ij}$' (i = 1 to n years, j = 1 to 12 months and K number of combination between stations included in the matrix) in which each element was initially set equal to zero. The locations of the probable errors were then recorded on this matrix by changing the value in the appropriate elements from zero to unity. Table 5.4 shows the score matrix '$\overset{1}{g}_{ij}$' for the indicator matrix (r_{ij} given in Table 5.3.

Although this matrix records the location of probable errors, it does not indicate in which record, X_{ij} or Y_{ij}, the error is to be found. However, if record X_{ij} is tested against several other records and the scores in the score matrix for station X are allowed to accumulate, then a clear indication of the probable errors in record X_{ij} is built up. To understand why this is so, consider the score matrix for station X resulting from K

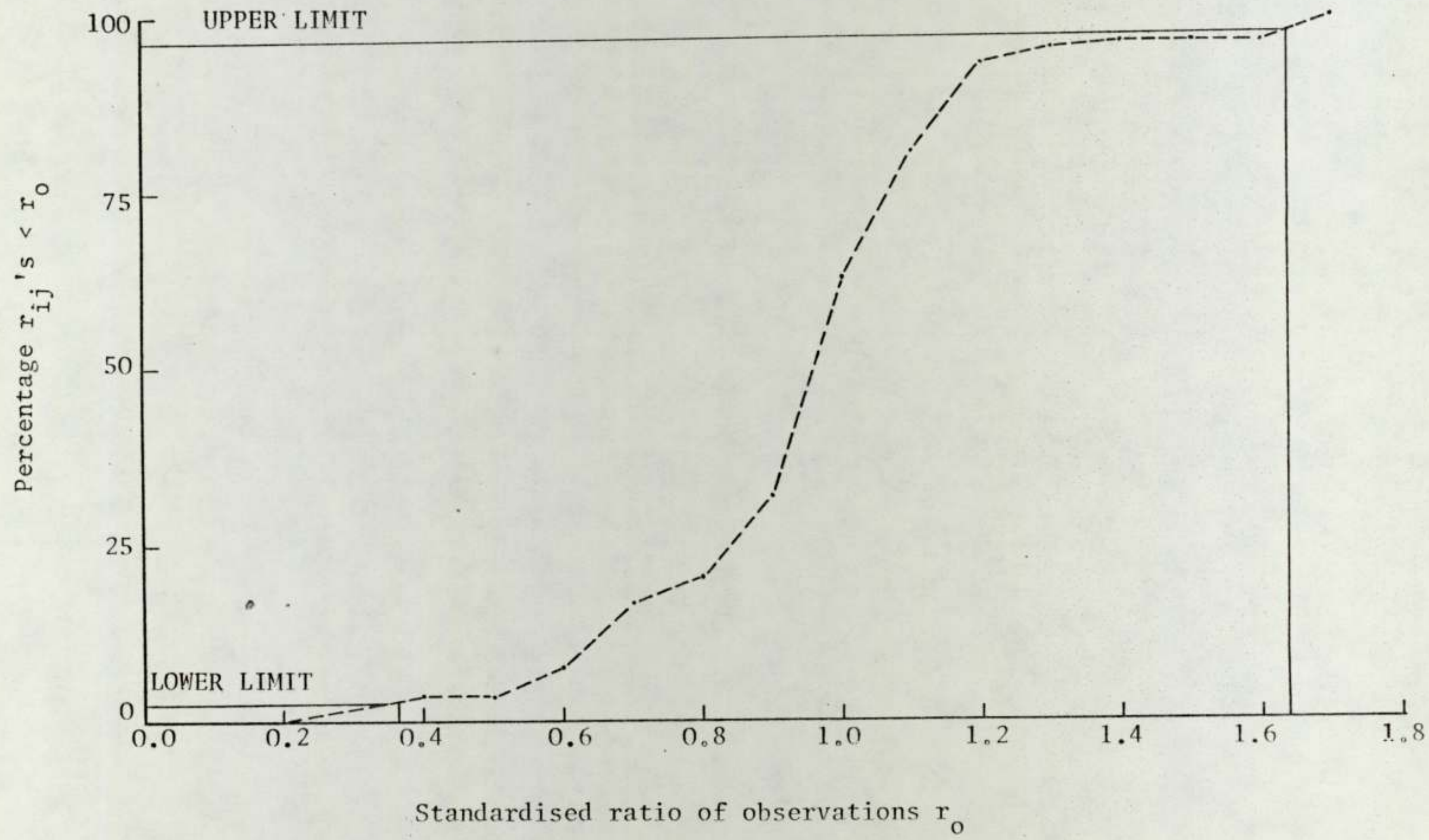


FIGURE 5.3 TYPICAL CUMULATIVE FREQUENCY CURVE OF r_{ij} (BELMONT/ERWOOD)

TABLE 5.3 (r_{ij}) MATRIX (BELMONT/ERWOOD)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	0.965	0.974	0.915	0.902	1.010	0.869	0.643	0.915	0.678	1.104	1.077	1.184
1951	1.096	0.968	0.975	0.992	1.310	0.956	0.914	0.917	0.659	1.159	0.956	0.920
1952	0.918	0.873	0.934	1.053	1.055	0.816	0.622	0.943	0.597	0.907	1.032	1.114
1953	1.073	0.879	0.809	0.924	0.991	0.844	0.635	0.904	0.641	0.981	0.982	1.114
1954	0.950	0.920	0.982	0.900	0.948	0.706	0.624	0.961	0.709	1.122	1.064	1.093
1955	1.073	1.087	0.657	1.820	1.168	0.178	0.264	2.420	4.724	0.924	0.989	0.098
1956	0.975	1.195	1.036	1.091	1.011	0.854	0.600	0.867	0.616	0.970	0.960	1.011
1957	0.958	1.042	0.929	1.286	1.195	1.154	0.680	0.960	0.619	0.961	1.083	1.107
1958	0.988	0.915	1.125	1.121	0.816	0.747	0.589	0.982	0.671	1.101	1.095	1.121
1959	1.015	1.297	0.950	0.898	1.156	0.854	0.616	1.250	1.199	0.835	0.900	1.034
1960	0.965	0.939	1.025	0.989	1.148	0.859	0.539	0.759	0.585	1.069	1.020	1.129
1961	1.019	1.003	1.015	0.903	1.011	0.836	0.564	0.792	0.560	0.873	0.865	1.112
1962	1.004	0.906	1.645	0.121	0.183	3.328	5.709	0.330	0.744	0.994	0.976	0.966

TABLE 5.4 SCORE MATRIX (g_{ij}) FOR THE INDICATOR MATRIX (r'_{ij})

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	1	0	1	1	1	1	0	0	1
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	1	1	1	1	1	1	0	0	0	0

TABLE 5.5 FINAL SCORE MATRIX (g_{ij}^{k}) FOR BELMONT RECORD

AFTER COMPARISON WITH SIX OTHER RECORDS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	0	0	0	0	0	0	0	0	0	1	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	2	1	0
1953	1	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	1	3	0	5	4	3	5	0	0	5
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	1	0	0	1	0	0	0	0	0
1958	0	0	0	0	1	0	0	0	0	0	0	0
1959	0	0	0	0	1	0	0	1	3	0	0	0
1960	0	0	0	0	0	0	1	0	0	1	0	0
1961	0	0	0	0	0	0	1	0	1	0	0	0
1962	0	0	2	5	5	5	5	4	0	0	0	0

combinations with other stations. If X_{ij} contains an accidental error at location (p,q) then, since each combination should cause unity to be added to location (p,q) of X's score matrix, the final score in location (p,q) of X's score matrix should be K. If, on the other hand, an error exists in one of the other records at location (p',q') this will appear as a score of unity in the final score matrix of X, but as a score of K in the score matrix of the offending record.

Thus, by combining each catchment or sub-catchment record with several other catchment records it was possible to identify the most serious accidental errors in the data. Table 5.5 gives the final score matrix, after seven combinations, for the Belmont (1950-62) record (i.e. station X in the above examples) and clearly indicates the location of the most serious probable errors.

The less serious accidental error will of course go totally undetected. However, since these will only have a slight effect on the sample statistics, with the possible exception of the higher moment statistics, and their effect will be further smoothed when plotting region curves, their continued existence in the data is tolerable.

The final score matrices for the streamflow and rainfall records are given in Appendix III, and a complete list of the station combinations used is given in Table 5.6.

5.6 CORRECTION OF INCONSISTENT DATA

Examination of the final score matrix for each gauging station and rainfall record revealed the location of the most probable accidental errors. Each of these apparently inconsistent items of data was then carefully checked against all other relevant information

TABLE 5.6 STATION COMBINATIONS USED IN THE VERIFICATION ANALYSES

Verification Test No	Stations Involved	Period Analysed	Site Combination	Maximum Possible Score (K)
1	Bewdley Vyrnwy Montford Cadora Belmont Caban Coch Erwood	1950-62	Each station tested against all other stations	6
2	Bewdley Vyrnwy Cadora Belmont Abernant Caban Coch Erwood Cray	1938-73	Each station tested against all other stations	7
3	Rhayader Abernant Caban Coch Cadora Belmont Erwood Kentchurch	1938-73	Rhayader tested against all other stations	6
4	Vyrnwy Montford Tenbury Kentchurch Chain Bridge Cray Tycastell Glan Teifi	1960-75	Each station tested against all other stations	7

in order to confirm the validity or otherwise of the original data.

In the case of the flow data the other relevant data included:

(i) daily gauged flows;

(ii) monthly naturalised flows obtained from the appropriate River Division (NB. these proved to be more reliable than Water Data Unit data);

and (iii) percentage streamflow from the catchment and its neighbouring catchments.

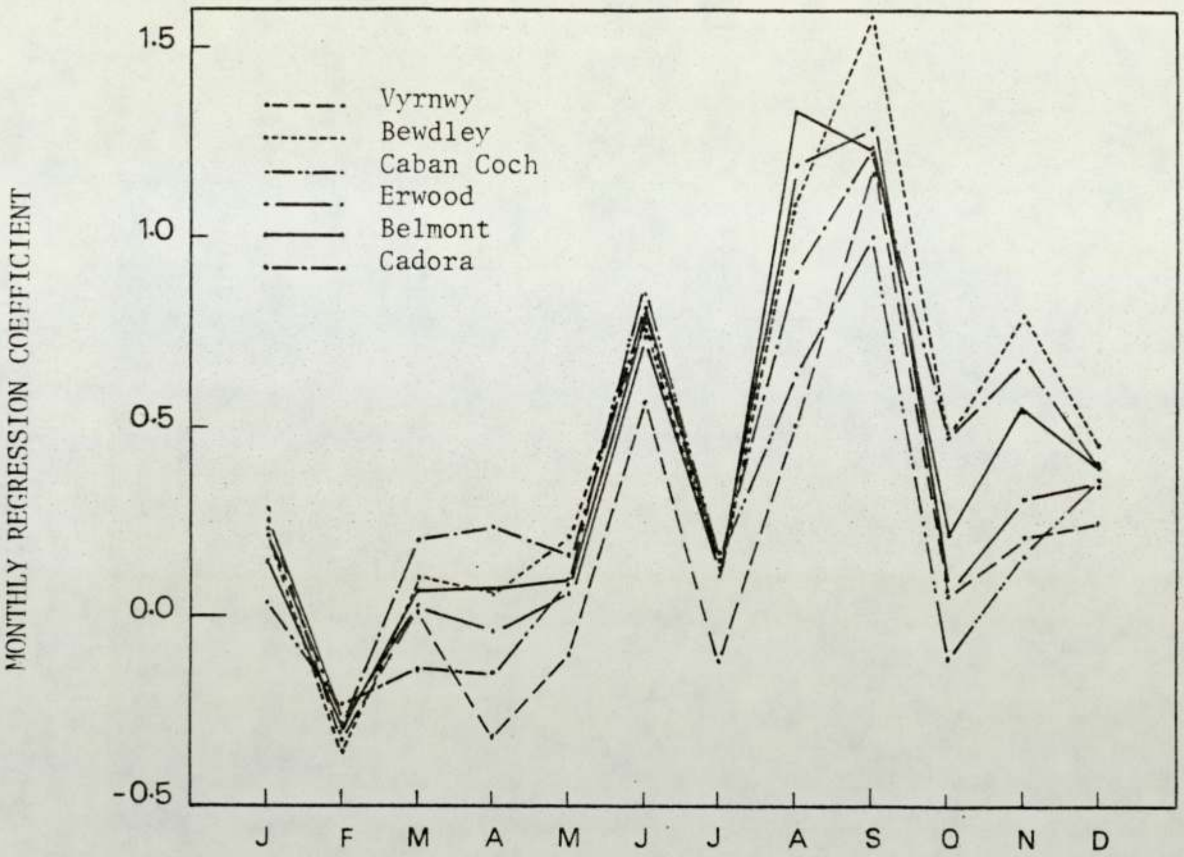
Items of data found to be invalid were 'corrected' using judgement and/or the best available information from items (i) to (iii) above. Apparent inconsistencies which were not corrected, because they were judged to be consistent, were in general of two types:

(i) those which were due to localised heavy rainfall causing high streamflow in one catchment only;

and (ii) those which occurred due to extremely low flows distorting the r_{ij} ratio (NB. even a high percentage error in these flows is of insignificant magnitude).

A complete list of all the 'probable errors' in the streamflow data, together with full details of any corrections made, is given in Table 5.7. The full results of the statistical analysis carried out on the verified data are given in the next chapter, but part of the results of the serial correlation and regression analysis are shown in figure 5.4. Comparison of this result with the original results (figure 5.1) clearly demonstrates the improvement which verification has made on the Belmont record.

In the case of the rainfall records the apparent inconsistencies were investigated but it was decided not to make any correction because:



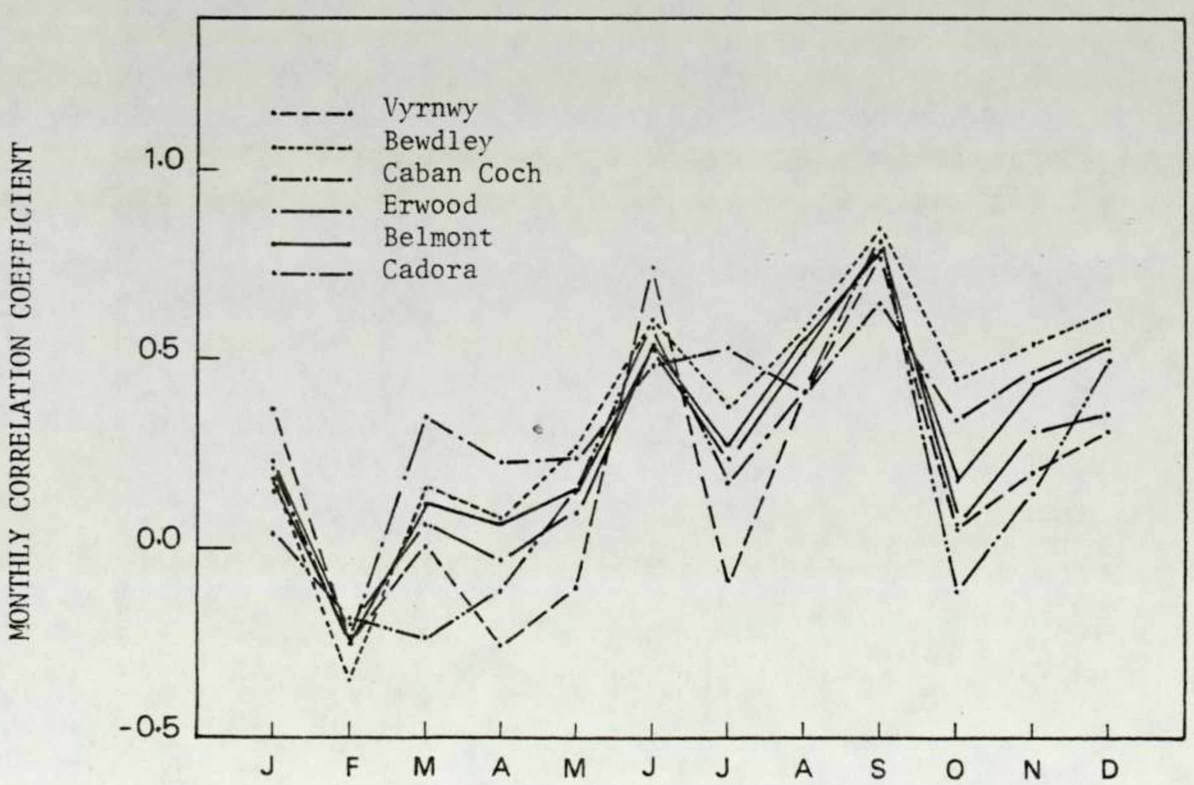


FIGURE 5.4 COMPARISON OF MONTHLY REGRESSION AND CORRELATION COEFFICIENTS OF ADJUSTED DATA (1950-1962)

TABLE 5.7 ITEMS OF INCONSISTENT DATA AND CORRECTED VALUES

GAUGING STATION	PERIOD OF RECORD	RAW VALUES	ADJUSTED VALUES	REMARKS
Vyrnwy	June 1940	Missing	0.250	Value estimated by regressing Vyrnwy flows against Caban Coch flows
Montford	Sept 1974	Missing	43.000	Value estimated using percentage streamflow from the catchment and its neighbouring catchments
Cadora	May 1938	15.417	21.100	Values were estimated from the daily records
	Dec 1941	1491.236	90.502	
	May 1947	9.988	60.300	
	Oct 1952	18.147	73.900	Raw data for 1952/53 was found to be identical to the data 1951/52. These data were replaced by data obtained from the Wye River Division of WNWDA
	Nov 1952	210.247	87.700	
	Dec 1952	124.041	153.900	
	Jan 1953	136.081	57.300	
	Feb 1953	94.132	81.100	
	Mar 1953	57.633	51.000	
	Apr 1953	50.390	83.300	
	May 1953	70.OL5	43.100	
	Jun 1953	31.728	23.400	
	Jul 1953	16.747	27.100	
	Aug	41.243	29.100	
	Sep 1953	31.870	53.300	
Belmont	Sept 1943	6.269	62.000	Error appears to be due to misplaced decimal point. Adjusted value taken from daily record available
	Jan 1955	56.719	55.300	Raw data for 1955 appeared to be placed in confused order, and were replaced by data obtained from the Wye River Division of WNWDA
	Feb 1955	49.583	48.700	
	Mar 1955	32.111	49.700	
	Apr 1955	59.806	31.500	
	May 1955	75.946	58.900	
	Jun 1955	14.776	74.000	
	Jul 1955	4.236	14.200	
	Aug 1955	8.226	4.300	
	Sep 1955	50.914	8.100	
	Oct 1955	15.866	15.600	
	Nov 1955	36.642	35.900	
	Dec 1955	6.201	61.000	
	Jan 1962	108.539	108.500	
	Feb 1962	66.828	66.800	
	Mar 1962	30.016	15.900	
	Apr 1966	10.112	67.100	

TABLE 5.7 ITEMS OF INCONSISTENT DATA AND CORRECTED VALUES (CONT.)

GAUGING STATION	PERIOD OF RECORD	RAW VALUES	ADJUSTED VALUES	REMARKS
Belmont	May 1962	6.332	30.000	Raw data for 1962 appeared to be placed in confused order, and were replaced by data obtained from the Wye River Division of WNWDA
	Jun 1962	39.842	10.100	
	Jul 1962	55.360	6.300	
	Aug 1962	15.889	39.800	
	Sep 1962	67.055	55.400	
	Oct 1962	27.388	27.400	
	Nov 1962	44.061	44.100	
	Dec 1962	60.542	60.500	
	Jan 1963	Missing	21.991	Record missing becuase of severe winter condition. Value estimated by regressing Belmont flow against Cadora flows
	Feb 1963	Missing	14.922	
	Jan 1965	19.898	108.900	Raw data for 1965 was found to be identical to the data of the previous year. These data were replaced by data obtained from the Wye River Division of WNWDA
	Feb 1965	27.487	21.100	
	Mar 1965	42.447	47.400	
	Apr 1965	25.896	35.800	
	May 1965	29.082	30.800	
	Jun 1965	24.469	24.800	
	Jul 1965	19.476	19.900	
	Aug 1965	13.785	19.200	
	Sep 1965	8.399	52.600	
	Oct 1965	30.967	30.900	
	Nov 1965	56.527	56.500	
	Dec	182.477	182.500	
	Feb 1939	145.286	77.000	The raw records gave negative values when evaluating the sub-catchment record. These data were replaced by data obtained from the River Wye Division of WNWDA
	Jan 1942	122.878	65.000	
	Sep 1967	46.936	55.000	
	Sep 1969	7.723	12.000	
Erwood	Jan 1963	Missing	15.293	Record missing because of severe winter condition. Value estimated by regressing Erwood flow against Montford
	Feb 1963	Missing	12.698	
Cray	Sep 1958	-0.008	0.008	Error apparently due to misplaced sign

NOTE: All flow records between 1970 and 1976 as obtained from the Water Data Unit were gauged flows and had not been naturalised. Naturalised flows were later obtained from the appropriated Region Divisions.

(i) non of the apparent errors were gross errors (i.e. several orders of magnitude)

(ii) most of the apparent errors investigated in detail proved to be due to localised storms

(iii) the maximum percentage of probable errors in any month was five percent

(iv) the rainfall statistics which were to be evaluated from the data were not particularly error sensitive.

5.7 PREPARATION OF SUB-CATCHMENT RAINFALL AND STREAMFLOW DATA

The decision to analyse rainfall and streamflow based upon sub-catchment areas as well as main catchment areas (see Section 6.1), meant that sub-catchment records had to be evaluated from the catchment records. The manner in which this was done is best described by considering a typical catchment containing several sub-catchments as shown in figure 5.5. Let Q_1, Q_2 ..... Q_5 be the flows (m^3/s) past gauging stations 1, 2, ...5 respectively.
Let A_1, A_2, ... A_5 be the total area of the catchments above gauging stations 1, 2, ... 5 respectively.
Let R_1, R_2, ... R_5 be the mean areal rainfalls over the catchments above gauging stations 1, 2, ... 5 respectively.
The object is to obtain the flows (Q_A and Q_B) and mean areal rainfall corresponding to sub-catchments I and II.

The flow records (m^3/s) for the sub-catchments can be obtained simply by deducting the appropriate upstream flow records from the downstream flow record. Thus,

$$Q_I(m^3/s) = Q_1 - Q_2$$

and

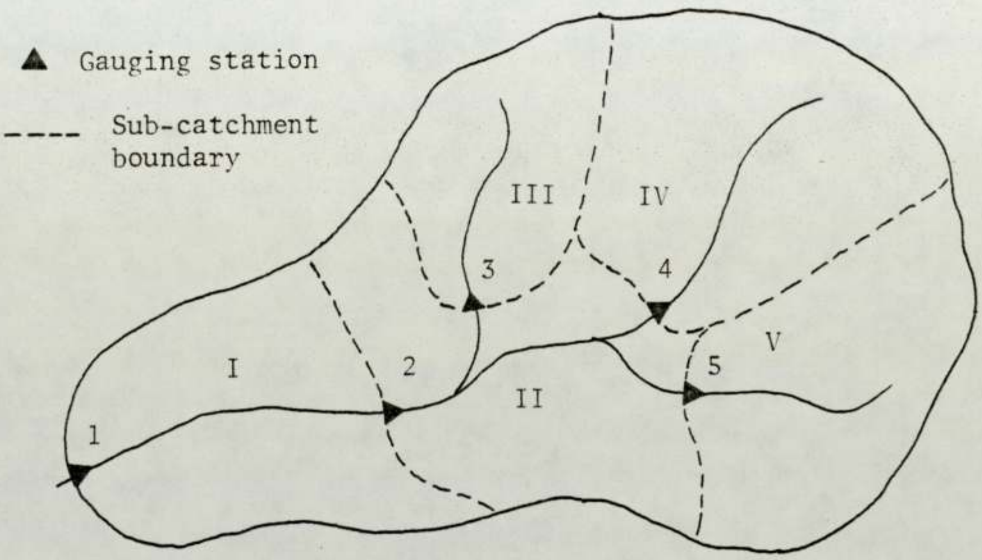


FIGURE 5.5 TYPICAL CATCHMENT CONTAINING SEVERAL SUB-CATCHMENTS

$$Q_{II}(m^3/s) = Q_2 - (Q_3+Q_4+Q_5)$$

These flows may be converted to flows expressed in terms of equivalent rainfall (mm) as follows:

$$Q_{(mm)} = KN\ Q_j/A_j$$

where K is a conversion factor = $\frac{24x60x60}{1000}$ = 86.4

N is the number of days in the month

Q_j is the sub-catchment flows in m^3/s

A_j is the sub-catchment area in Km^2

The equations relating the catchment and sub-catchment mean areal rainfalls are:

$$R_1A_1 = R_2A_2 + R_IA_I$$

and $$R_2A_2 = R_3A_3 + R_4A_4 + R_5A_5 + R_{II}A_{II}$$

where R_IA_I and $R_{II}A_{II}$ are the products of mean areal rainfall and sub-catchment area for subcatchments I and II respectively and R_1A_1, R_2A_2 .... R_5A_5 are the products of mean areal rainfall and catchment area for the catchments above gauging stations 1, 2 ... 5 respectively.

Thus $$R_I\ (mm) = \frac{(R_1A_1 - R_2A_2)}{(A_1 - A_2)}$$

and

$$R_{II}\ (mm) = \frac{(R_2A_2 - R_3A_3 - R_4A_4 - R_5A_5)}{A_2 - A_3 - A_4 - A_5}$$

A computer program 'RAIN' was developed for the general application of this type of procedure. The Fortran listing is given in Appendix II.

The sub-catchment streamflow and rainfall records evaluated using 'RAIN' are given in Appendix I.

CHAPTER SIX
RESULTS OF THE STATISTICAL ANALYSIS

6.1 INTRODUCTION

This chapter presents the results of the various statistical analyses carried out on the verified rainfall and streamflow data. These analyses may be categorised as follows:

(i) length of record, long or short;

(ii) type of record, gauging station or sub-catchment;

(iii) type of analysis, basic statistics of the record or cross correlation between records.

Figure 6.1 shows the length of verified streamflow and rainfall record available for analysis for each of the sub-catchments and gauging stations. The desirability of dividing the analysis into a long record analysis (1938-1975) and a short record analysis (1960-1975) is clearly apparent from this figure. The long record analysis provides more reliable statistics than the short record analysis but fewer plotting points from which to derive relationships. Thus, by carrying out both analyses the amount of information available for interpretation is maximised.

The type of record may be either 'gauging station' or 'sub-catchment' or both. A record is a sub-catchment record if it applies to one of the sub-catchments detailed in Table 3.2 and shown on Map 1. A record is a gauging station record if it applies to one of the gauging stations detailed in Table 3.1 and shown on Map 1. A gauging station record is associated with the whole of the catchment above the gauging station and may therefore include several sub-catchments. If it only includes one sub-catchment, it is both

FIGURE 6.1 BAR CHART OF USABLE RAINFALL AND STREAMFLOW RECORD

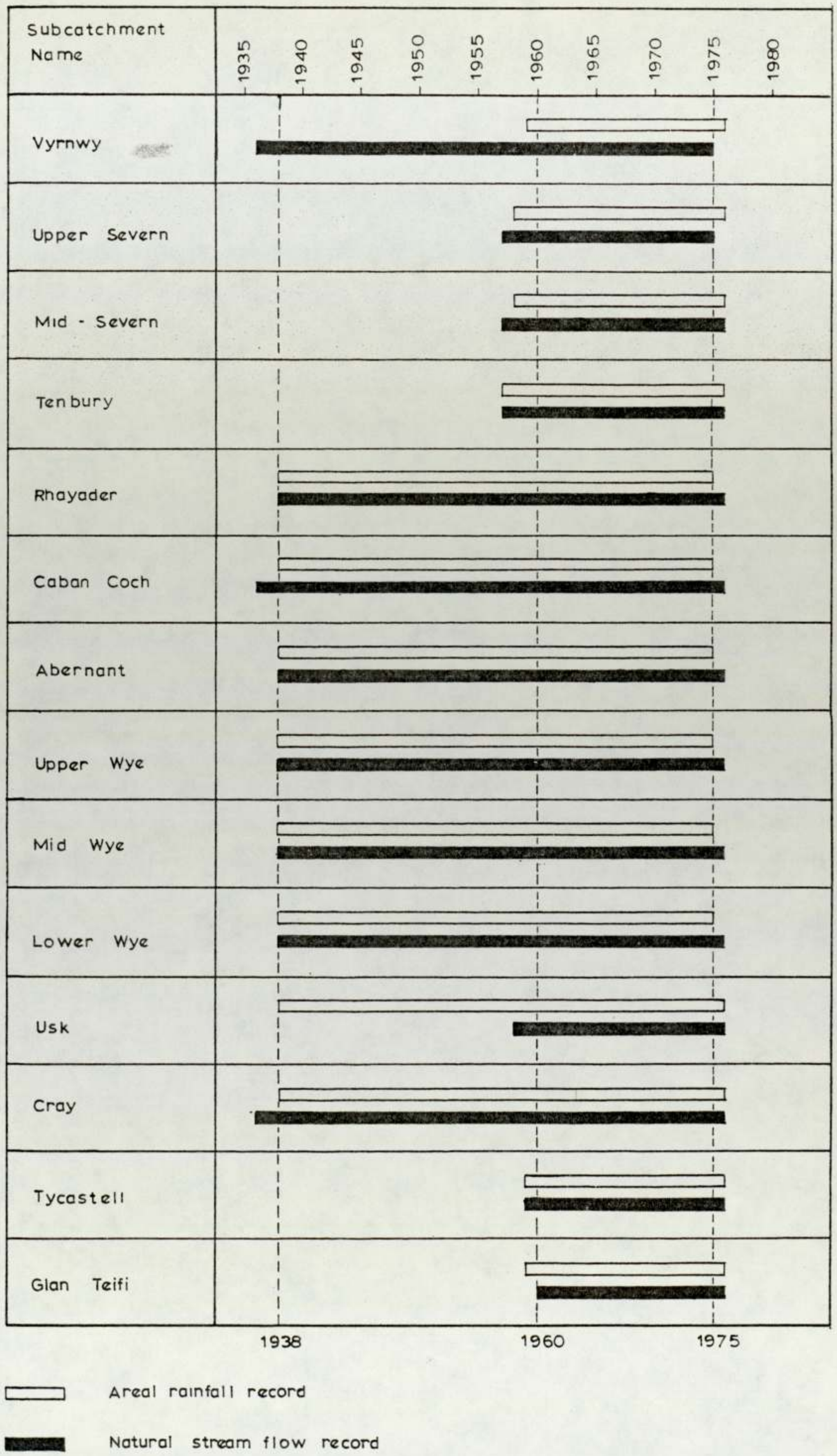
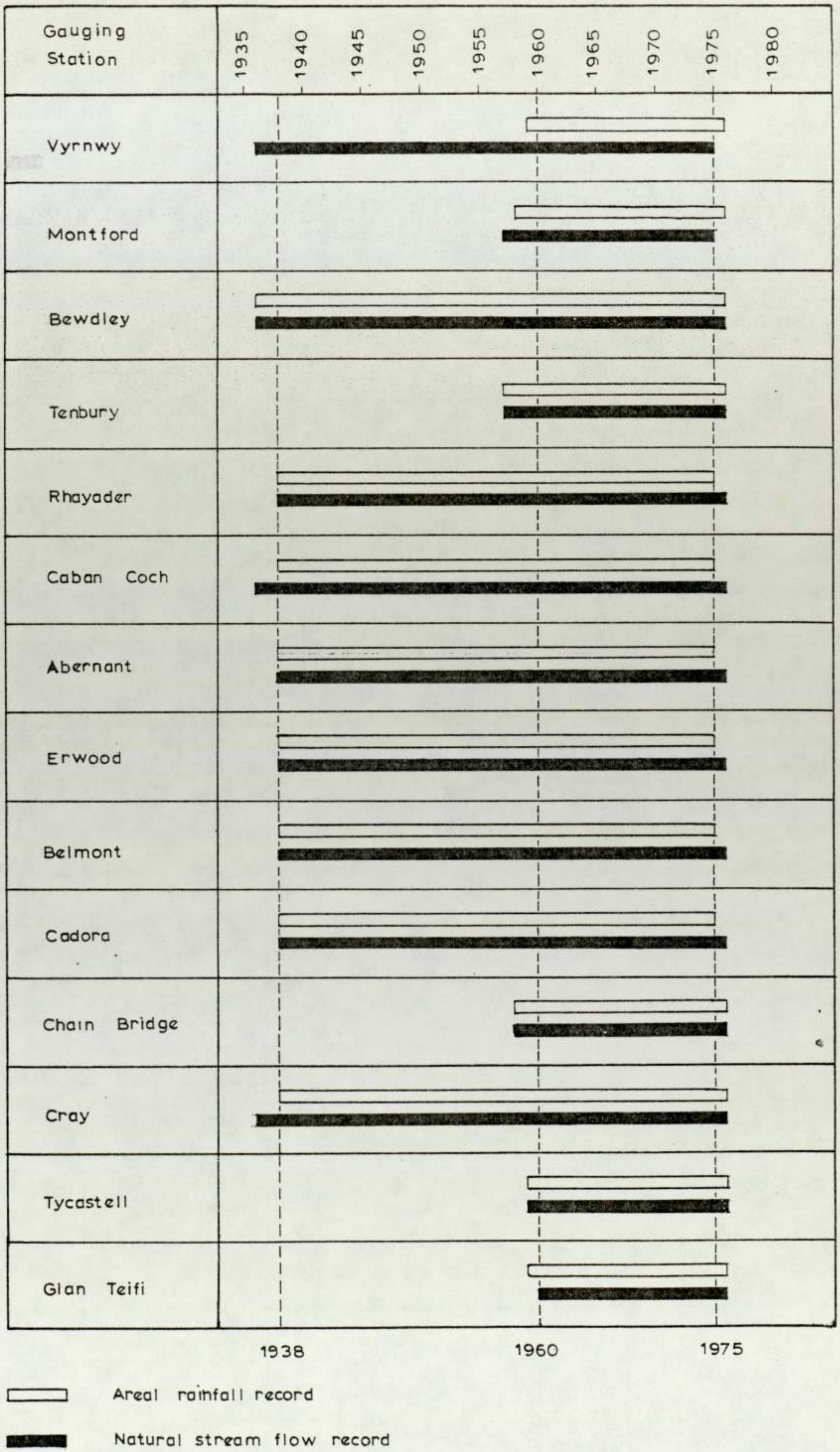


FIGURE 6.1 BAR CHART OF USABLE RAINFALL AND STREAMFLOW RECORD (CONT.)



a gauging station record and a sub-catchment record (e.g. Caban Coch), but for the purpose of this study such records are referred to as sub-catchment records.

The type of analysis includes the evaluation of monthly statistics for individual sites and the evaluation of the monthly cross correlation that exists between sites. The monthly statistics evaluated for individual sites are presented as follows.

(i) rainfall - mean and standard deviation;

(ii) streamflow - mean, standard deviation, skewness coefficient, lag-one correlation and regression coefficients;) Evaluated using computer program STATANAL

(iii) evaporation - mean potential (see section 3.6);

(iv) soil moisture - mean deficit (see section 3.6);

(v) percentage run-off - 100 x mean flow/mean rainfall.

The only departure from this format is that in the case of the Vyrnwy sub-catchment, the rainfall means of the long record have been estimated by comparison with Caban Coch rainfall because the Vyrnwy record was incomplete. In view of this fact, no estimate was made of the standard deviation of rainfall at Vyrnwy. The combinations of sites used for the lag-zero cross correlation analysis are detailed in Tables 6.33 and 6.34.

Since skewness coefficient, being related to the third moment of the distribution, was likely to be the statistic most sensitive to length of record and errors introduced by the formation of sub-catchment data sets, it was decided to test its sensitivity by analysing the long gauging station records in two halves. Thus, the monthly skewness coefficients were evaluated for nine records for the periods 1944 to 1975 (32 years), 1944 to 1959 (16 years) and 1960 to 1975 (16 years).

All of these data are presented in this chapter as shown in Table 6.1 below.

Table 6.1 Presentation of Results

		Period	Section	Tables
Individual Site Basic statistic	Sub-catchments	1938 - 75 (long record)	6.2	6.2 to 6.9
Individual Site Basic statistic	Sub-catchments	1960 - 75 (short record)	6.3	6.10 to 6.23
	Gauging Stations	1938 - 75	6.4	6.24 to 6.27
	Gauging Stations	1960 - 75	6.5	6.28 to 6.32
Cross Correlation Analysis	Gauging Stations	1960 - 75	6.6	6.33
	Sub-catchments	1960 - 75	6.7	6.34
Skewness Coefficient Sensitivity Analysis	Gauging Stations	1944 - 75 1944 - 59 1960 - 75	6.8	6.35 6.36

6.2 BASIC STATISTICS OF INDIVIDUAL SUB-CATCHMENTS (1938-75)

TABLE 6.2 STATISTICAL PARAMETERS (1938-1975) FOR VYRNWY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
** Mean (mm)	217.00	160.00	118.50	114.50	108.00	100.50	124.50	143.00	148.50	186.50	202.50	209.50	1833.00
Stan. Dev. (mm)	-	-	-	-	-	-	-	-	-	-	-	-	-
STREAMFLOW (Q)													
Mean (m^3/s)	6.54	5.35	3.94	3.28	2.65	1.91	2.32	3.02	4.04	4.97	6.57	6.80	51.38
Mean (mm)	185.76	138.48	111.91	90.16	75.27	52.50	65.89	85.78	111.05	141.16	180.59	193.14	1413.69
Stan. Dev. (mm)	89.19	77.91	65.32	49.20	44.87	37.66	42.88	48.85	76.97	89.74	91.82	82.36	
Skew. Coef.	0.30	0.48	2.24	0.42	0.80	0.94	1.65	0.28	0.48	1.05	0.49	0.91	
Lag-one Coef's													
Regression	0.03	-0.04	-0.25	0.19	0.15	0.31	-0.01	0.20	0.88	0.15	0.02	-0.00	
Correlation	0.02	-0.05	-0.33	0.24	0.17	0.35	-0.01	0.18	0.54	0.13	0.02	-0.00	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	2	4	13	25	50	45	38	20	5	1	0	
NET RAINFALL													
R-E (mm)	211.00	150.00	97.50	74.50	49.00	31.50	54.50	85.00	116.50	168.50	192.50	203.50	1434.00
PERCENTAGE RUN-OFF													
100 Q/R	86	87	94	79	70	52	53	60	75	76	89	92	78

*Estimated as described in section 3.6 ** Estimated from Caban Coch rainfall data and Vyrnwy rainfall means given in the Severn River Authority Report (1971)

TABLE 6.3 STATISTICAL PARAMETERS (1938-1975) FOR RHAYADER SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	183.39	133.24	107.26	102.63	103.71	92.89	118.71	131.89	144.03	150.29	188.97	189.68	1646.71
Stan. Dev. (mm)	78.26	73.55	53.49	48.65	45.50	45.91	51.86	56.20	76.63	69.19	90.70	82.34	
STREAMFLOW (Q)													
Mean (m3/s)	9.97	8.40	5.58	4.89	3.19	2.66	3.00	4.00	5.45	6.62	9.88	10.48	74.13
Mean (mm)	159.90	122.77	89.49	75.90	51.16	41.29	48.11	64.15	84.59	106.17	153.35	168.08	1164.96
Stan. Dev. (mm)	73.13	65.04	50.68	42.68	29.19	28.56	28.23	41.06	64.57	58.22	74.81	71.37	
Skew. Coef.	0.23	0.34	1.88	0.74	0.87	0.92	1.07	0.85	1.22	0.85	0.69	0.95	
Lag-one Coef's													
Regression	-0.06	-0.07	-0.25	0.24	0.15	0.24	-0.00	0.31	1.17	0.13	-0.04	0.03	
Correlation	-0.06	-0.07	-0.36	0.28	0.22	0.24	-0.00	0.21	0.72	0.14	-0.03	0.04	
EVAPORATION (E)													
* Mean Potential (mm)	6	11	23	42	63	74	74	61	34	20	11	7	426
SOIL MOISTURE													
* Mean Deficit (mm)	0	1	2	15	27	40	45	20	15	8	2	0	
NET RAINFALL													
R-E (mm)	177.39	122.24	84.26	60.63	40.71	18.89	44.71	70.89	110.03	130.29	177.97	182.68	1220.71
PERCENTAGE RUN-OFF													
100 Q/R	87	92	83	74	49	44	41	49	59	71	81	89	71

* Estimated as described in section 3.6

TABLE 6.4 STATISTICAL PARAMETERS (1938-1975) FOR CABAN COCH SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	206.47	151.89	122.71	115.63	109.39	96.97	124.68	139.92	153.55	165.26	207.37	213.32	1807.18
Stan. Dev. (mm)	84.06	77.34	60.51	52.36	47.62	50.36	54.05	62.70	78.17	72.95	94.89	86.50	
STREAMFLOW (Q)													
Mean (m^3/s)	11.71	9.63	6.86	5.69	4.25	3.48	3.87	5.14	6.97	8.45	12.13	12.59	90.78
Mean (mm)	170.46	127.74	99.86	80.15	61.87	49.02	56.33	74.82	98.19	123.00	170.87	183.27	1295.58
Stan. Dev. (mm)	74.24	67.79	62.45	43.11	33.92	37.75	35.66	49.49	69.45	64.05	77.20	76.86	
Skew. Coef.	0.03	0.14	2.59	0.40	0.65	0.74	1.02	0.78	0.66	0.51	0.50	1.06	
Lag-one Coef's													
Regression	0.02	-0.01	-0.33	0.18	0.15	0.20	-0.02	0.19	0.90	0.08	-0.04	-0.06	
Correlation	0.02	-0.01	-0.40	0.26	0.20	0.18	-0.02	0.14	0.62	0.09	-0.05	-0.06	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	1	13	25	37	25	13	13	0	0	0	
NET RAINFALL R-E (mm)	200.47	141.89	101.71	75.63	50.39	27.97	54.68	81.92	121.55	147.26	197.37	207.32	1408.18
PERCENTAGE RUN-OFF 100 Q/R	83	84	81	69	57	51	45	53	64	74	82	86	72

* Estimated as described in section 3.6

TABLE 6.5 STATISTICAL PARAMETERS (1938-1975) FOR ABERNANT SUB_CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	204.32	143.63	121.03	113.82	112.53	101.37	127.29	140.03	154.34	168.39	204.50	205.16	1796.40
Stan. Dev. (mm)	87.99	80.72	53.74	54.64	53.62	55.32	49.86	58.76	79.02	82.77	101.30	75.19	
STREAMFLOW (Q)													
Mean (m^3/s)	4.94	4.08	2.81	2.37	1.83	1.62	1.62	2.17	2.84	3.51	4.94	5.17	37.89
Mean (mm)	181.75	136.79	103.38	84.38	67.33	57.68	59.60	79.84	101.12	129.14	175.89	190.21	1367.11
Stan. Dev. (mm)	80.57	72.42	59.60	47.00	39.00	40.59	41.57	47.46	73.70	78.00	84.03	87.20	
Skew. Coef.	0.01	0.42	1.82	0.45	0.70	0.79	2.08	0.30	0.78	1.57	0.70	1.25	
Lag-one Coef's													
Regression	0.07	0.02	-0.17	0.25	0.26	0.24	0.16	0.21	1.02	0.17	0.11	-0.07	
Correlation	0.08	0.02	-0.23	0.30	0.33	0.22	0.16	0.19	0.63	0.16	0.10	-0.07	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	1	13	25	37	25	13	13	2	0	0	
NET RAINFALL													
R-E (mm)	198.32	133.63	100.03	73.82	53.53	32.37	57.29	82.03	122.34	150.39	194.50	199.16	1397.40
PERCENTAGE RUN-OFF													
100 Q/R	89	95	85	74	60	57	47	57	66	77	86	93	76

* Estimated as described in section 3.6

TABLE 6.6 STATISTICAL PARAMETERS (1938-1975) FOR UPPER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	129.49	92.11	75.82	74.69	84.51	71.04	83.61	96.39	100.67	108.67	140.11	131.08	1188.10
Stan. Dev. (mm)	57.87	55.17	41.82	36.31	37.27	36.36	34.83	40.62	52.64	55.91	70.31	56.48	
STREAMFLOW (Q)													
Mean (m^3/s)	39.96	35.45	21.24	16.81	11.74	8.56	5.97	8.38	14.97	19.99	35.62	39.10	257.79
Mean (mm)	125.00	101.06	66.44	50.89	36.73	25.91	18.68	26.21	45.32	62.53	107.83	122.31	788.94
Stan. Dev. (mm)	58.47	59.38	45.08	29.46	23.74	21.07	15.67	19.77	42.62	47.05	62.45	50.11	
Skew. Coef.	0.25	0.63	2.89	0.43	1.28	1.68	2.80	1.14	1.12	1.12	1.03	0.53	
Lag-one Coef's													
Regression	-0.02	0.12	-0.14	0.21	0.15	0.29	0.06	0.32	1.30	0.31	0.07	0.08	
Correlation	-0.02	0.10	-0.20	0.31	0.19	0.32	0.09	0.26	0.58	0.29	0.05	0.10	
EVAPORATION (E)													
* Mean Potential (mm)	6	11	24	45	67	78	79	65	37	21	11	7	451
SOIL MOISTURE													
* Mean Deficit (mm)	0	1	2	17	26	42	50	25	15	10	5	0	
NET RAINFALL													
R-E (mm)	123.49	81.11	51.82	29.69	17.51	-7.96	4.61	31.39	63.58	87.68	129.11	124.08	737.10
PERCENTAGE RUN-OFF													
100 Q/R	97	110	88	68	43	36	22	27	45	58	77	93	66

* Estimated as described in section 3.6

TABLE 6.7 STATISTICAL PARAMETERS (1938-1975) FOR MID-WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	93.54	60.21	57.95	54.83	72.67	60.31	66.50	79.84	74.82	79.26	96.43	83.96	880.32
Stan. Dev. (mm)	49.00	42.43	36.67	32.60	35.47	29.53	34.04	43.12	42.63	50.46	58.61	46.87	
STREAMFLOW (Q)													
Mean (m^3/s)	16.47	16.34	12.35	8.82	7.05	5.86	4.45	4.44	4.80	8.07	12.41	14.81	115.87
Mean (mm)	71.15	64.33	53.35	36.87	30.46	24.50	19.22	19.18	20.07	34.86	51.88	63.98	489.85
Stan. Dev. (mm)	35.08	31.97	44.97	23.37	19.48	19.02	14.73	19.74	25.38	31.75	38.55	35.04	
Skew. Coef.	0.58	0.75	3.65	2.30	1.54	1.87	1.19	2.68	3.23	1.30	0.99	0.76	
Lag-one Coef's													
Regression	0.11	0.15	-0.06	0.45	0.34	0.32	0.35	0.57	1.09	0.55	0.61	0.41	
Correlation	0.11	0.15	-0.05	0.83	0.43	0.32	0.47	0.43	0.82	0.45	0.49	0.47	
EVAPORATION (E)													
* Mean Potential (mm)	7	12	25	47	70	82	83	68	39	22	12	8	475
SOIL MOISTURE													
* Mean Deficit (mm)	0	2	3	19	28	45	70	50	30	13	8	1	
NET RAINFALL													
R-E (mm)	86.54	48.21	32.95	7.83	2.67	-21.69	-16.50	11.84	35.82	57.26	84.43	75.96	405.32
PERCENTAGE RUN-OFF													
100 Q/R	76	107	92	67	42	41	29	24	27	44	54	76	56

*Estimated as described in section 3.6

TABLE 6.8 STATISTICAL PARAMETERS (1938-1975) FOR LOWER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	90.89	60.09	56.67	54.22	67.88	51.62	61.83	73.87	71.69	74.33	96.11	83.02	842.21
Stan. Dev. (mm)	43.85	38.78	33.67	28.83	31.99	27.24	35.57	35.49	38.15	45.15	52.23	38.32	
STREAMFLOW (Q)													
Mean (m^3/s)	48.90	48.92	36.74	24.67	18.66	14.40	8.71	7.65	11.28	15.60	32.89	40.28	308.68
Mean (mm)	61.20	55.80	45.98	29.88	23.35	17.44	10.90	9.57	13.66	19.52	39.84	50.41	377.55
Stan. Dev. (mm)	29.17	29.18	28.62	14.47	10.99	13.26	10.70	5.72	12.52	22.97	30.32	27.60	
Skew. Coef.	0.43	0.21	2.38	1.09	0.60	2.68	4.05	0.40	2.45	2.91	1.79	0.78	
Lag-one Coef's													
Regression	0.30	0.21	0.06	0.33	0.30	0.53	0.26	0.31	0.84	0.81	0.69	0.41	
Correlation	0.29	0.21	0.06	0.63	0.41	0.42	0.34	0.59	0.37	0.46	0.51	0.46	
EVAPORATION (E)													
* Mean Potential (mm)	7	13	27	50	74	87	88	72	41	23	13	8	503
SOIL MOISTURE													
* Mean Deficit (mm)	1	2	4	20	30	50	75	65	37	15	13	5	
NET RAINFALL													
R-E (mm)	83.89	47.09	29.67	4.22	-6.12	-35.38	-26.17	1.87	30.69	51.33	83.11	75.02	339.21
PERCENTAGE RUN-OFF													
100 Q/R	67	93	81	55	34	34	18	13	19	26	41	61	45

*Estimated as described in section 3.6

TABLE 6.9 STATISTICAL PARAMETERS (1938-1975) FOR CRAY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	283.54	181.92	162.19	146.60	159.47	142.01	155.89	185.31	208.31	222.67	264.91	271.59	2384.41
Stan. Dev. (mm)	140.86	118.88	97.34	76.47	74.51	74.02	69.64	82.63	114.73	134.84	144.06	138.59	
STREAMFLOW (Q)													
Mean (m^3/s)	0.98	0.75	0.53	0.47	0.38	0.34	0.33	0.44	0.58	0.67	0.90	0.98	7.36
Mean (mm)	240.81	167.94	130.23	111.77	93.38	80.85	81.09	108.12	137.92	164.64	214.02	240.81	1771.58
Stan. Dev. (mm)	117.95	98.53	81.09	59.45	51.60	59.45	51.60	63.89	97.50	115.49	116.52	117.95	
Skew. Coef.	0.17	0.23	2.14	0.12	0.55	0.91	1.91	0.36	0.48	1.79	0.59	0.91	
Lag-one Coef's													
Regression	0.07	0.04	-0.15	0.15	0.11	0.24	0.03	0.12	0.96	0.18	0.02	-0.06	
Correlation	0.07	0.05	-0.20	0.20	0.14	0.20	0.04	0.10	0.60	0.15	0.02	-0.06	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	339
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	2	13	18	37	25	15	13	3	0	0	
NET RAINFALL													
R-E (mm)	277.54	171.92	141.19	106.60	100.47	73.01	85.89	100.31	176.31	204.67	254.91	265.59	1985.41
PERCENTAGE RUN-OFF													
100 Q/R	85	92	80	76	59	57	52	58	66	74	81	89	74

*Estimated as described in section 3.6

6.3 BASIC STATISTICS OF INDIVIDUAL SUB-CATCHMENTS (1960-75)

TABLE 6.10 STATISTICAL PARAMETERS (1960-1975) FOR VYRNWY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	203.96	150.87	124.52	134.51	125.31	95.55	119.81	138.69	166.92	169.97	220.60	228.00	1878.71
Stan. Dev. (mm)	93.56	82.34	62.73	53.10	61.19	40.77	42.38	49.74	83.64	102.84	87.68	121.08	
STREAMFLOW (Q)													
Mean (m^3/s)	6.20	4.86	4.01	3.91	3.08	1.67	1.96	2.86	4.10	4.73	6.54	7.23	51.17
Mean (mm)	176.10	125.79	113.90	107.47	87.48	45.90	55.67	81.23	112.70	134.35	179.76	205.35	1425.70
Stan Dev. (mm)	78.96	65.48	62.20	51.40	46.58	30.24	27.83	41.18	69.27	90.04	79.44	100.83	
Skew. Coef.	-0.66	-0.01	2.11	0.28	0.07	1.28	0.67	0.59	0.72	1.64	1.27	0.60	
Lag-one coef's													
Regression	0.07	0.16	-0.46	0.04	0.13	0.22	0.09	-0.30	0.22	0.49	-0.12	-0.26	
Correlation	0.09	0.18	-0.53	0.05	0.15	0.33	0.10	-0.20	0.13	0.39	-0.13	-0.21	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	2	4	13	25	50	45	38	20	5	1	0	
NET RAINFALL													
R-E (mm)	197.96	140.87	103.52	94.51	66.31	26.55	49.81	80.69	134.92	151.97	210.60	222.00	1479.71
PERCENTAGE RUN-OFF													
100 Q/R	86	83	91	80	70	48	46	59	68	79	81	90	76

* Estimated as described in section 3.6

TABLE 6.11 STATISTICAL PARAMETERS (1960-1975) FOR UPPER SEVERN SUB_CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	114.66	82.59	72.47	81.11	85.46	66.97	84.10	94.60	103.11	95.77	125.20	121.84	1129.89
Stan. Dev. (mm)	48.97	44.89	27.89	28.58	47.11	31.07	28.04	31.62	47.79	52.61	54.18	63.13	
STREAMFLOW (Q)													
Mean (m^3/s)	67.79	55.53	41.15	35.37	27.09	13.25	12.09	15.97	22.44	34.75	56.83	73.80	456.07
Mean (mm)	94.29	70.38	57.23	47.61	37.68	17.83	16.82	22.21	30.20	48.33	76.49	102.65	621.72
Stan. Dev. (mm)	45.41	34.79	24.56	24.15	22.85	10.11	13.89	11.78	19.93	37.15	41.44	59.57	
Skew. Coef.	-0.17	0.18	1.39	0.62	1.53	1.00	3.19	1.82	0.35	1.96	1.03	1.49	
Lag-one coef's													
Regression	0.06	0.09	-0.19	0.13	-0.02	0.23	0.46	-0.06	0.48	0.83	0.21	0.02	
Correlation	0.07	0.11	-0.30	0.13	-0.03	0.50	0.35	-0.07	0.28	0.46	0.18	0.02	
EVAPORATION (E)													
* Mean potential (mm)	7	11	25	48	71	83	84	69	39	22	11	8	478
SOIL MOISTURE													
* Mean Deficit (mm)	2	3	4	15	32	52	63	62	52	28	8	4	
NET RAINFALL													
R-E (mm)	107.66	71.59	49.47	33.11	14.46	-16.03	0.10	25.60	64.11	73.77	114.20	113.84	651.89
PERCENTAGE RUN-OFF													
100 Q/R	82	85	77	59	44	27	20	23	29	50	61	84	55

* Estimated as described in section 3.6

TABLE 6.12 STATISTICAL PARAMETERS (1960-1975) FOR MID-SEVERN SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	65.55	45.73	48.11	54.37	64.64	49.32	64.99	67.97	65.92	57.66	71.94	62.35	718.35
Stan. Dev. (mm)	30.59	23.79	19.37	23.31	41.80	22.20	24.22	29.99	39.55	36.41	31.48	32.92	
STREAMFLOW (Q)													
Mean (m^3/s)	39.30	34.11	28.61	21.55	19.05	11.10	10.21	9.38	11.84	15.09	24.20	33.97	258.41
Mean (mm)	46.71	36.95	34.00	24.79	22.64	12.77	12.14	11.15	13.62	17.94	27.84	40.38	300.93
Stan. Dev. (mm)	21.73	16.57	10.26	8.66	14.52	6.37	11.40	6.55	10.85	16.38	18.52	27.37	
Skew. Coef.	0.21	0.18	0.19	1.08	2.65	1.22	3.77	-0.43	1.65	2.70	2.71	1.74	
Lag-one Coef's													
Regression	0.07	0.56	0.14	0.03	0.10	0.37	0.70	0.25	0.31	0.77	0.97	0.66	
Correlation	0.09	0.67	0.24	0.04	0.06	0.81	0.41	0.44	0.18	0.53	0.83	0.46	
EVAPORATION (E)													
* Mean Potential (mm)	8	13	28	53	53	92	93	76	43	24	13	9	522
SOIL MOISTURE													
* Mean Deficit (mm)	4	5	6	18	35	63	85	77	65	45	13	7	
NET RAINFALL													
R-E (mm)	57.55	32.73	20.11	1.37	11.46	-42.68	-28.01	-8.03	22.92	33.66	58.94	53.35	196.35
PERCENTAGE RUN-OFF													
100 Q/R	71	81	71	46	35	26	19	16	21	31	39	65	42

*Estimated as described in section 3.6

TABLE 6.13 STATISTICAL PARAMETERS (1960-1975) FOR TENBURY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	89.51	62.35	61.37	64.54	69.86	51.33	62.57	74.25	75.42	70.48	88.48	79.15	849.33
Stan. Dev. (mm)	42.65	34.07	24.39	25.95	39.81	21.58	21.66	30.55	37.38	48.35	40.96	36.92	
STREAMFLOW (Q)													
Mean (m3/s)	28.49	23.37	19.95	13.41	12.51	6.00	4.88	4.00	5.46	10.22	17.41	22.39	167.74
Mean (mm)	67.23	50.26	47.08	30.62	28.67	13.70	11.52	9.44	12.47	24.12	39.76	52.84	387.71
Stan. Dev. (mm)	28.46	25.23	21.57	13.22	19.28	6.94	11.26	4.74	8.38	26.50	27.86	32.52	
Skew. Coef.	-0.27	0.29	1.49	0.97	1.92	1.17	3.75	0.32	0.56	2.23	1.42	1.48	
Lag-one coef's													
Regression	-0.15	0.50	-0.01	0.08	-0.05	0.30	0.61	0.12	0.35	1.83	0.80	0.46	
Correlation	-0.17	0.51	-0.01	0.13	-0.04	0.80	0.39	0.28	0.19	0.60	0.73	0.41	
EVAPORATION (E)													
* Mean Potential (mm)	7	12	26	49	49	85	86	71	40	23	12	8	484
SOIL MOISTURE													
* Mean Deficit (mm)	3	4	5	19	36	65	70	65	55	37	10	5	
NET RAINFALL													
R-E (mm)	82.51	50.35	35.37	15.54	20.86	-33.67	-23.43	3.25	35.42	47.48	76.48	71.15	365.33
PERCENTAGE RUN-OFF													
100 Q/R	75	81	77	47	41	27	18	13	17	34	45	67	46

*Estimated as described in section 3.6

TABLE 6.14 STATISTICAL PARAMETERS (1960-1975) FOR RHAYADER SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	181.94	130.38	107.00	122.00	111.75	86.69	103.87	125.75	137.94	139.25	184.44	199.87	1630.88
Stan. Dev. (mm)	81.98	69.67	41.19	50.94	53.65	39.78	38.38	31.92	65.10	71.17	73.13	107.71	
STREAMFLOW (Q)													
Mean (m^3/s)	10.07	8.02	5.46	6.04	4.01	2.40	2.59	3.69	4.91	6.52	9.52	11.45	74.69
Mean (mm)	161.51	117.22	87.57	93.75	64.31	37.25	41.54	59.18	76.21	104.57	147.76	183.64	1174.51
Stan Dev. (mm)	75.22	60.65	42.02	48.89	33.68	23.59	22.29	26.30	46.87	60.79	63.48	91.74	
Skew. Coef.	-0.11	0.15	2.03	0.42	0.01	0.62	0.34	-0.12	0.75	1.51	1.23	0.66	
Lag-one Coef's													
Regression	0.03	0.08	-0.20	0.28	0.01	0.22	0.04	-0.27	0.55	0.34	0.09	-0.36	
Correlation	0.03	0.08	-0.32	0.23	0.02	0.31	0.05	-0.23	0.30	0.27	0.08	-0.26	
EVAPORATION (E)													
* Mean potential (mm)	6	11	23	42	63	74	74	61	34	20	11	7	426
SOIL MOISTURE													
* Mean Deficit (mm)	0	1	2	15	27	40	45	20	15	8	2	0	
NET RAINFALL													
R-E (mm)	175.94	119.38	84.00	80.00	48.75	12.69	29.87	64.75	103.94	119.25	173.44	192.87	1204.88
PERCENTAGE RUN OFF													
100 Q/R	89	90	82	77	58	43	40	47	55	75	80	92	72

*Estimated as described in section 3.6

TABLE 6.15 STATISTICAL PARAMETERS (1960-1975) FOR CABAN COCH SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	218.44	153.12	125.31	137.19	115.44	91.25	109.50	133.31	152.63	155.06	206.06	224.13	1821.44
Stan. Dev. (mm)	92.47	77.05	48.28	54.16	50.29	41.72	39.19	36.04	67.23	72.81	69.56	113.16	
STREAMFLOW (Q)													
Mean (m^3/s)	12.59	9.29	6.96	7.03	4.98	3.16	3.15	4.73	6.76	8.21	11.73	13.95	92.52
Mean (mm)	183.27	123.23	101.31	99.03	72.49	44.51	45.85	68.85	95.23	119.51	165.24	203.06	1321.58
Stan. Dev. (mm)	81.08	62.74	54.59	46.35	34.50	31.13	23.44	32.02	61.14	63.61	59.45	103.93	
Skew. Coef.	-0.65	-0.32	2.58	-0.17	0.08	0.51	0.31	0.36	0.51	0.89	0.98	0.64	
Lag-one Coef's													
Regression	0.00	0.28	-0.37	0.10	0.01	0.17	-0.09	-0.30	0.49	0.27	-0.05	-0.37	
Correlation	0.00	0.33	-0.46	0.11	0.02	0.18	-0.13	-0.22	0.25	0.27	-0.06	-0.22	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	1	13	25	37	25	13	13	0	0	0	
NET RAINFALL													
R-E (mm)	212.44	143.12	104.31	97.19	56.44	22.25	39.50	75.31	120.63	137.06	196.06	218.13	1422.44
PERCENTAGE RUN OFF													
100 Q/R	84	80	81	72	63	49	42	52	62	77	80	91	73

*Estimated as described in section 3.6

TABLE 6.16 STATISTICAL PARAMETERS (1960-1975) FOR ABERNANT SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	220.87	148.56	118.94	137.06	121.75	100.25	119.37	139.31	163.12	168.50	209.19	203.13	1850.06
Stan. Dev. (mm)	95.11	79.93	43.46	55.77	53.15	44.99	33.26	37.06	73.35	94.02	76.59	93.72	
STREAMFLOW (Q)													
Mean (m^3/s	5.39	4.15	2.96	2.93	2.32	1.61	1.52	2.25	2.79	3.65	4.82	5.89	40.28
Mean (mm)	198.30	139.14	108.90	104.32	85.36	57.32	55.92	82.78	99.34	134.29	171.61	216.70	1453.98
Stan. Dev. (mm)	87.56	71.41	59.97	49.49	40.10	37.74	28.70	41.94	62.31	90.14	62.31	114.79	
Skew. Coef.	-0.60	0.49	2.28	0.06	-0.09	0.69	0.64	0.36	0.80	2.12	0.95	0.81	
Lag-one Coef's													
Regression	0.05	0.21	-0.20	0.09	0.23	0.24	0.30	-0.23	0.67	0.44	-0.06	-0.53	
Correlation	0.07	0.24	-0.26	0.11	0.29	0.25	0.41	-0.16	0.43	0.31	-0.08	-0.29	
EVAPORATION (E)													
* Mean potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	1	13	25	37	25	13	13	2	0	0	
NET RAINFALL													
R-E (mm)	214.87	138.56	97.94	97.06	62.75	31.25	49.37	81.31	131.12	150.50	199.19	197.13	1451.06
PERCENTAGE RUN-OFF													
100 Q/R	90	94	92	76	70	57	47	59	61	80	82	107	79

*Estimated as described in section 3.6

TABLE 6.17 STATISTICAL PARAMETERS (1960-1975) FOR UPPER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	135.46	94.13	77.66	88.58	88.34	67.92	83.13	91.86	110.12	107.76	135.83	137.67	1218.47
Stan. Dev. (mm)	62.12	55.03	30.87	35.75	42.34	32.55	25.29	28.06	51.55	64.86	59.67	67.70	
STREAMFLOW (Q)													
Mean (m^3/s)	40.83	32.61	21.82	19.41	14.72	7.40	5.46	7.38	13.01	20.12	32.15	40.25	255.55
Mean (mm)	127.73	92.96	68.26	58.76	46.05	22.40	17.08	23.09	39.39	62.94	98.42	125.91	782.99
Stan. Dev. (mm)	57.75	50.34	33.25	32.48	26.81	14.96	13.08	13.70	34.30	54.96	52.04	60.72	
Skew. Coef.	-0.76	0.13	2.23	0.29	0.95	1.47	2.81	0.85	0.99	1.63	1.36	0.64	
Lag-one coef's													
Regression	-0.04	0.28	-0.14	0.11	0.01	0.27	0.41	-0.26	1.02	0.74	0.07	-0.05	
Correlation	-0.04	0.29	-0.23	0.11	0.02	0.47	0.46	-0.26	0.39	0.48	0.07	-0.04	
EVAPORATION (E)													
* Mean Potential (mm)	6	11	24	45	67	78	79	65	37	21	11	7	451
SOIL MOISTURE													
* Mean Deficit (mm)	0	1	2	17	26	42	50	25	15	10	5	0	
NET RAINFALL													
R-E (mm)	129.46	83.13	53.66	43.58	21.34	-9.08	4.13	26.86	73.12	86.76	124.83	130.67	767.47
PERCENTAGE RUN-OFF													
100 Q/R	94	99	88	66	52	33	21	25	36	58	72	91	64

*Estimated as described in section 3.6

TABLE 6.18 STATISTICAL PARAMETERS (1960-1975) FOR MID-WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	101.62	69.45	65.41	65.53	77.65	64.26	65.06	71.04	77.67	79.99	90.74	82.07	910.49
Stan. Dev. (mm)	49.89	44.05	31.65	36.32	42.05	29.28	34.03	30.75	42.52	66.18	55.48	46.33	
STREAMFLOW (Q)													
Mean (m^3/s)	17.86	15.91	11.78	8.47	7.83	5.73	4.65	3.18	2.86	6.67	9.41	14.34	108.71
Mean (mm)	77.16	62.63	50.89	35.41	33.83	23.96	20.09	13.74	11.96	28.81	39.34	61.95	459.77
Stan. Dev. (mm)	27.73	31.34	24.58	16.85	22.98	15.05	17.88	14.56	13.84	30.41	32.11	41.43	
Skew. Coef.	10.34	1.10	0.60	1.27	2.21	1.05	1.45	1.50	2.46	1.72	0.65	1.05	
Lag-one Ceof's													
Regression	-0.05	0.93	-0.21	0.45	0.63	0.30	0.54	0.35	0.72	1.34	0.73	0.47	
Correlation	-0.07	0.75	-0.29	0.63	0.48	0.44	0.47	0.43	0.73	0.63	0.67	0.38	
EVAPORATION (E)													
* Mean Potential (mm)	7	12	25	47	70	82	83	68	39	22	12	8	475
SOIL MOISTURE													
* Mean Deficit (mm)	0	2	3	19	28	45	70	50	30	13	8	1	
NET RAINFALL													
R-E (mm)	94.62	57.45	40.41	18.53	7.65	-17.74	-17.94	3.04	38.67	57.99	78.74	74.07	435.49
PERCENTAGE RUN-OFF													
100 Q/R	76	90	78	54	44	37	31	19	15	36	43	75	50

*Estimated as described in section 3.6

TABLE 6.19 STATISTICAL PARAMETERS (1960-1975) FOR LOWER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	93.44	61.08	59.43	61.89	66.98	50.40	63.18	66.15	76.27	71.44	86.03	76.88	833.17
Stan. Dev. (mm)	44.09	35.26	25.40	30.70	37.07	26.08	42,82	26.22	36.99	53.72	42.05	35.08	
STREAMFLOW (Q)													
Mean (m^3/s)	51.10	47.98	40.98	27.11	21.37	13.12	10.13	7.85	8.81	17.44	30.25	36.64	312.77
Mean (mm)	63.96	54.72	51.29	32.84	26.75	15.89	12.68	9.82	10.67	21.83	36.64	45.86	382.95
Stan. Dev. (mm)	28.94	27.85	22.54	13.67	11.06	8.36	14.99	5.51	6.67	28.29	34.37	28.64	
Skew. Coef.	-0.68	-0.03	0.80	0.78	0.66	1.19	3.70	-0.19	2.25	2.97	2.72	1.04	
Lag-one Coef's													
Regression	0.09	0.72	0.08	0.15	0.06	0.48	0.67	0.24	0.31	1.45	1.08	0.43	
Correlation	0.09	0.68	0.11	0.23	0.07	0.62	0.38	0.66	0.24	0.37	0.86	0.54	
EVAPORATION (E)													
* Mean potential (mm)	7	13	27	50	74	87	88	72	41	23	13	8	503
SOIL MOISTURE													
* Mean Deficit (mm)	1	2	4	20	30	50	75	65	37	15	13	5	
NET RAINFALL													
R-E (mm)	86.44	48.08	32.43	11.89	-9.02	-36.60	-24.82	-5.75	35.27	48.44	73.03	68.88	330.17
PERCENTAGE RUN-OFF													
100 Q/R	68	90	86	53	40	32	20	15	14	31	43	60	46

*Estimated as described in section 3.6

TABLE 6.20 STATISTICAL PARAMETERS (1960-1975) FOR USK SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	165.37	111.44	91.44	96.82	95.83	77.07	81.74	96.56	121.84	120.50	148.75	145.33	1352.70
Stan. Dev. (mm)	81.42	65.34	43.94	47.99	47.99	34.65	28.09	31.97	59.68	83.56	77.41	73.54	
STREAMFLOW (Q)													
Mean (m^3/s)	53.11	42.92	29.80	24.40	19.34	11.90	9.25	10.94	16.55	26.64	38.29	47.01	330.15
Mean (mm)	157.86	116.26	88.58	70.19	57.49	34.23	27.49	32.52	47.61	79.18	110.14	139.73	961.28
Stan. Dev. (mm)	67.29	63.74	45.80	33.31	24.17	18.06	15.99	13.17	32.42	67.86	70.53	74.99	
Skew. Coef.	-0.47	0.46	2.33	0.50	0.40	1.33	3.00	0.14	1.91	1.78	1.64	0.95	
Lag-one Coef's													
Regression	-0.08	0.56	-0.10	0.18	0.13	0.33	0.27	-0.23	0.51	0.71	0.34	0.07	
Correlation	-0.08	0.54	-0.16	0.24	0.19	0.43	0.31	-0.28	0.20	0.35	0.32	0.06	
EVAPORATION (E)													
* Mean Potential (mm)	7	12	24	46	68	80	81	66	37	21	12	7	461
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	1	13	20	37	40	30	16	5	0	0	
NET RAINFALL													
R-E (mm)	158.37	99.44	67.44	50.82	27.83	-2.93	0.74	30.56	84.84	99.50	136.75	138.33	891.70
PERCENTAGE RUN-OFF													
100 Q/R	95	104	97	72	60	44	34	34	39	66	74	96	71

*Estimated as described in section 3.6

TABLE 6.21 STATISTICAL PARAMETERS (1960-1975) FOR CRAY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	319.35	201.57	161.01	181.31	164.22	138.95	147.17	183.86	220.71	221.08	269.60	285.18	2494.00
Stan. Dev. (mm)	156.33	130.68	96.20	81.97	83.95	67.07	54.29	55.67	109.40	158.02	128.77	166.70	
STREAMFLOW (Q)													
Mean (m^3/s)	1.03	0.74	0.52	0.54	0.44	0.30	0.28	0.41	0.55	0.65	0.84	1.08	7.40
Mean (mm)	253.10	165.71	127.78	128.41	108.12	71.34	68.80	100.75	130.79	159.72	199.75	265.38	1779.65
Stan. Dev. (mm)	132.69	98.53	78.63	64.21	54.06	52.32	34.40	49.14	73.72	135.15	102.25	154.81	
Skew. Coef.	0.11	0.09	2.79	0.12	-0.00	0.98	0.05	0.67	0.40	2.31	1.72	0.57	
Lag-one Coef's													
Regression	0.06	0.27	-0.32	0.00	0.10	0.32	0.03	-0.49	0.38	0.50	-0.06	-0.13	
Correlation	0.07	0.33	-0.44	0.00	0.12	0.32	0.05	-0.35	0.24	0.27	-0.08	-0.09	
EVAPORATION (E)													
* Mean Potential (mm)	6	10	21	40	59	69	70	58	32	18	10	6	399
SOIL MOISTURE													
* Mean Deficit (mm)	0	0	2	13	18	37	25	15	13	3	0	0	
NET RAINFALL													
R-E (mm)	313.35	191.57	140.01	141.31	105.22	69.96	77.17	125.86	188.71	203.08	259.60	279.18	2095.00
PERCENTAGE RUN-OFF													
100 Q/R	79	82	79	71	66	51	47	55	59	72	74	93	71

* Estimated as described in section 3.6

TABLE 6.22 STATISTICAL PARAMETERS (1960-1975) FOR TY-CASTLE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	178.29	113.02	92.38	108.83	103.63	93.32	103.26	122.42	139.84	148.05	168.83	168.75	1540.64
Stan. Dev. (mm)	87.42	66.99	39.41	43.68	48.86	44.81	30.83	32.49	64.70	91.21	65.65	86.20	
STREAMFLOW (Q)													
Mean (m^3/s)	67.21	51.03	34.41	34.72	26.91	17.40	15.29	22.51	30.61	42.23	56.67	67.44	466.52
Mean (mm)	165.15	114.27	84.55	82.56	66.12	41.38	37.57	55.51	72.79	103.77	134.76	165.72	1124.15
Stan. Dev. (mm)	75.36	57.39	37.03	36.95	32.73	29.30	23.32	25.68	51.01	77.35	58.59	75.14	
Skew. Coef.	-0.59	0.51	1.63	-0.01	-0.03	0.82	1.78	0.00	0.83	1.80	1.60	0.50	
Lag-one Coef's													
Regression	0.10	0.43	-0.09	0.14	0.14	0.29	0.41	-0.24	0.86	0.59	-0.00	-0.17	
Correlation	0.10	0.52	-0.16	0.13	0.16	0.31	0.53	-0.22	0.42	0.40	-0.01	-0.14	
EVAPORATION (E)													
* Mean Potential (mm)	7	12	25	47	70	82	83	68	39	22	12	8	475
SOIL MOISTURE													
* Mean Deficit (mm)	0	3	4	13	25	27	45	25	15	10	0	0	
NET RAINFALL													
R-E (mm)	171.29	101.02	67.38	61.83	33.63	11.32	20.26	54.52	100.84	126.05	156.83	160.75	1065.64
PERCENTAGE RUN-OFF													
100 Q/R	93	101	92	76	64	44	36	45	52	70	80	98	73

*Estimated as described in section 3.6

TABLE 6.23 STATISTICAL PARAMETERS (1960-1975) FOR GLAN TEIFI SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	153.51	94.42	78.54	95.43	84.42	79.09	88.24	103.81	118.44	126.67	148.70	146.12	1317.41
Stan. Dev. (mm)	73.93	52.81	35.76	37.92	35.32	37.27	24.18	31.39	57.87	67.83	57.60	71.19	
STREAMFLOW (Q)													
Mean (m^3/s)	48.43	37.37	25.04	25.01	21.03	13.41	10.30	15.10	19.83	31.07	41.30	49.46	337.35
Mean (mm)	145.09	102.03	75.02	72.51	63.01	38.88	30.86	45.24	57.49	93.08	119.74	148.18	991.13
Stan. Dev. (mm)	65.79	44.67	34.96	27.60	25.68	30.67	21.24	25.74	48.68	66.39	47.78	59.53	
Skew. Coef.	10.44	-0.05	1.61	-0.07	0.05	1.84	1.51	0.69	0.97	1.18	1.52	0.91	
Lag-one-Coef's													
Regression	0.03	0.39	-0.04	0.14	0.21	0.65	0.47	-0.02	0.07	0.73	0.10	-0.32	
Correlation	0.03	0.53	-0.05	0.17	0.24	0.53	0.71	-0.02	0.04	0.56	0.14	-0.27	
EVAPORATION (E)													
* Mean Potential (mm)	8	13	27	50	74	87	88	72	41	23	13	8	504
SOIL MOISTURE													
* Mean Deficit (mm)	0	2	3	13	35	45	50	30	20	12	0	0	
NET RAINFALL													
R-E (mm)	145.51	81.42	51.54	45.43	10.42	-7.12	0.24	31.81	77.44	103.67	135.70	138.12	813.41
PERCENTAGE RUN-OFF													
100 Q/R	95	108	96	76	75	49	35	44	49	73	81	101	75

* Estimated as described in section 3.6

6.4 BASIC STATISTICS OF INDIVIDUAL GAUGING STATIONS (1938-75)

TABLE 6.24 STATISTICAL PARAMETERS (1938-1975) FOR ERWOOD GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	151.84	109.00	89.24	86.45	92.18	79.34	96.58	109.76	116.92	125.63	159.82	154.76	1371.53
Stan. Dev. (mm)	65.12	61.47	46.02	40.53	40.01	39.79	39.03	45.93	59.82	60.27	77.37	63.57	638.93
STREAMFLOW (Q)													
Mean (m^3/s)	66.58	57.55	36.50	29.77	21.01	16.33	14.47	19.68	30.23	38.56	62.58	67.33	460.59
Mean (mm)	139.32	109.74	76.38	60.28	43.96	33.07	30.28	41.18	61.22	80.69	126.72	140.89	943.73
Stan. Dev. (mm)	62.65	61.06	48.09	33.19	25.82	24.32	19.27	26.80	50.04	50.05	65.12	56.79	523.20
Skew. Coef.	0.17	0.45	2.73	0.42	1.00	1.28	2.18	0.75	0.97	1.06	0.84	0.79	
Lag-one Coef's													
Regression	-0.03	0.04	-0.20	0.21	0.17	0.28	0.03	0.28	1.28	0.22	0.02	0.03	
Correlation	-0.03	0.04	-0.28	0.30	0.22	0.29	0.03	0.20	0.66	0.22	0.02	0.03	
PERCENTAGE RUN-OFF													
100 Q/R	95	126	89	77	50	46	33	39	58	67	88	95	75

TABLE 6.25 STATISTICAL PARAMETERS (1938-1975) FOR BELMONT GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	132.82	93.08	79.03	76.13	85.82	73.13	86.76	100.00	103.18	110.50	139.13	131.66	1211.24
Stan. Dev. (mm)	56.15	52.20	41.76	35.63	37.26	34.92	34.57	42.07	52.19	54.58	69.08	54.30	564.71
STREAMFLOW (Q)													
Mean (m^3/s)	83.05	73.89	48.86	38.58	28.07	22.19	18.91	24.12	35.03	46.63	74.98	82.15	576.46
Mean (mm)	117.07	94.92	68.88	52.63	39.57	30.27	26.66	34.00	47.79	65.73	102.29	115.81	795.62
Stan. Dev. (mm)	50.73	49.78	46.11	26.93	21.72	20.93	16.14	22.26	39.68	41.33	54.00	46.15	435.76
Skew. Coef	0.27	0.39	3.08	0.39	0.90	1.37	1.79	1.02	1.29	0.95	0.87	0.83	
Lag-one Coef's													
Regression	-0.08	0.02	-0.20	0.27	0.21	0.30	0.08	0.29	1.30	0.26	0.13	0.09	
Correlation	-0.08	0.02	-0.24	0.46	0.26	0.30	0.10	0.21	0.71	0.25	0.10	0.10	
PERCENTAGE RUN-OFF													
100 Q/R	92	128	91	77	48	46	32	35	52	62	82	92	71

TABLE 6.26 STATISTICAL PARAMETERS (1938-1975) FOR CADORA GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	110.61	75.61	67.18	64.53	76.32	61.74	72.32	86.16	86.50	91.34	116.34	105.89	1014.53
Stan Dev. (mm)	48.68	44.35	37.02	31.32	33.97	29.97	29.99	37.87	44.30	48.44	59.57	44.37	489.85
STREAMFLOW (Q)													
Mean m3/s)	131.95	122.81	85.59	63.25	46.72	36.59	27.62	31.77	46.31	62.23	107.87	122.42	885.147
Mean (mm)	87.48	74.20	56.74	40.58	30.97	23.48	18.31	21.06	29.71	41.26	69.21	81.16	574.16
Stan. Dev. (mm)	36.26	36.50	36.12	19.61	14.86	15.82	11.04	11.34	23.69	27.96	39.16	33.09	305.45
Skew. Coef.	-0.05	0.21	2.95	0.53	0.90	2.15	2.94	1.06	1.59	1.38	1.07	0.72	
Lag-one Coef's													
Regression	0.01	0.09	-0.13	0.31	0.25	0.39	0.12	0.16	1.47	0.37	0.38	0.20	
Correlation	0.01	0.08	-0.14	0.56	0.35	0.35	0.18	0.15	0.68	0.32	0.26	0.24	
PERCENTAGE RUN-OFF 100 Q/R	82	123	88	70	42	42	26	25	38	47	66	80	62

TABLE 6.27 STATISTICAL PARAMETERS (1938-1975) FOR BEWDLEY GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	95.89	70.41	62.60	61.80	72.53	61.84	79.89	87.80	83.74	85.22	105.67	94.89	962.28
Stan Dev. (mm)	36.88	38.01	29.83	27.37	34.73	27.86	32.61	37.21	44.10	42.59	53.73	38.00	442.92
STREAMFLOW (Q)													
Mean (m^3/s)	113.62	105.51	72.37	53.89	40.79	29.06	24.43	30.06	42.52	54.81	91.58	106.74	762.40
Mean (mm)	71.21	60.26	45.36	32.69	25.56	17.63	15.31	18.84	25.79	34.35	55.55	66.90	469.45
Stan. Dev. (mm)	33.15	31.05	26.69	15.81	15.06	10.09	9.40	11.04	20.58	22.12	32.24	31.63	258.86
Skew. Coef.	0.55	0.56	2.70	0.68	1.96	1.77	3.22	1.36	1.25	1.19	1.24	1.69	
Lag-one Coef's													
Regression	-0.04	-0.21	-0.14	0.30	0.22	0.31	0.15	0.37	1.25	0.41	0.45	0.24	
Correlation	-0.04	-0.20	-0.18	0.49	0.24	0.44	0.17	0.31	0.65	0.40	0.30	0.25	
PERCENTAGE RUN-OFF													
100 Q/R	74	86	72	53	35	29	19	21	31	40	53	71	49

6.5 BASIC STATISTICS OF INDIVIDUAL GAUGING STATIONS (1960-75)

TABLE 6.28 STATISTICAL PARAMETERS (1960-1975) FOR MONTFORD GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	118.83	85.77	76.81	83.61	87.32	68.30	85.76	96.66	106.09	99.24	129.66	126.80	1164.84
Stan. Dev. (mm)	50.87	46.51	29.08	29.49	47.49	31.44	28.06	31.99	49.19	54.58	55.58	65.59	519.87
STREAMFLOW (Q)													
Mean (m^3/s)	73.99	60.39	45.15	39.29	30.17	14.91	14.06	18.84	26.55	39.38	63.38	81.03	507.23
Mean (mm)	98.11	72.97	59.87	50.42	40.00	19.13	18.64	24.98	34.07	52.35	81.33	107.44	659.31
Stan. Dev. (mm)	46.82	36.10	25.87	25.33	23.59	10.87	14.02	12.87	21.63	39.15	42.84	61.14	360.23
Skew. Coef.	-0.23	0.15	1.47	0.60	1.36	1.05	3.04	1.61	0.24	1.97	1.10	1.40	
Lag-one Coef's													
Regression	0.06	0.10	-0.22	0.12	-0.01	0.23	0.42	-0.09	0.46	0.82	0.18	-0.01	
Correlation	0.08	0.11	-0.33	0.12	-0.01	0.48	0.34	-0.10	0.26	0.47	0.16	-0.01	
PERCENTAGE RUN-OFF 100 Q/R	86	107	81	67	48	31	23	27	36	55	70	88	45

TABLE 6.29 STATISTICAL PARAMETERS (1960-1975) FOR ERWOOD GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	158.31	110.44	90.69	102.69	97.19	75.56	91.69	104.94	122.87	122.12	156.44	161.49	1394.88
Stan. Dev. (mm)	70.37	60.81	34.64	40.47	45.17	35.06	28.08	29.20	56.14	67.67	63.17	79.70	610.98
STREAMFLOW (Q)													
Mean (m^3/s)	68.88	54.08	37.21	35.41	26.03	14.56	12.71	18.05	27.47	38.50	58.58	71.55	463.04
Mean (mm)	144.13	103.12	77.86	71.71	54.47	29.48	26.60	37.77	55.63	80.56	118.62	149.72	949.67
Stan. Dev. (mm)	64.09	53.70	38.46	36.71	28.50	18.77	14.23	18.54	40.60	57.19	53.62	72.57	496.98
Skew. Coef.	-0.66	0.03	2.37	0.14	0.41	0.95	1.35	0.60	0.85	1.68	1.42	0.66	
Lag-one Coef's													
Regression	-0.00	0.25	-0.20	0.12	0.04	0.25	0.20	-0.45	0.84	0.57	0.02	-0.18	
Correlation	-0.01	0.27	-0.31	0.12	0.05	0.37	0.27	-0.35	0.37	0.41	0.02	-0.14	
PERCENTAGE RUN-OFF													
100 Q/R	95	117	89	78	58	43	30	37	50	68	84	96	74

TABLE 6.30 STATISTICAL PARAMETERS (1960-1975) FOR BELMONT GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	139.81	97.06	82.44	90.56	90.81	71.87	83.00	93.87	108.13	108.37	135.00	135.88	1236.81
Stan. Dev. (mm)	61.25	51.53	32.33	35.32	43.21	30.46	24.63	27.45	49.25	65.29	57.90	64.02	542.64
STREAMFLOW (Q)													
Mean (m^3/s)	86.74	69.99	48.89	43.88	33.86	20.30	17.37	21.24	30.33	45.17	67.99	85.89	571.74
Mean (mm)	122.28	89.91	69.05	59.86	47.73	27.69	24.49	29.94	41.38	63.68	92.75	121.08	789.84
Stan. Dev. (mm)	50.37	45.06	32.35	27.20	24.01	15.42	14.24	13.56	28.47	45.12	43.56	59.05	398.41
Skew. Coef.	-0.76	0.15	2.08	0.17	0.51	0.38	1.72	0.51	0.85	1.43	1.30	0.86	
Lag-one Coef's													
Regression	-0.05	0.38	-0.21	0.16	0.07	0.30	0.30	-0.26	0.82	0.67	0.14	-0.03	
Correlation	-0.05	0.39	-0.31	0.19	0.09	0.46	0.34	-0.27	0.38	0.44	0.14	-0.02	
PERCENTAGE RUN-OFF 100 Q/R	91	116	87	73	55	43	31	33	43	61	76	93	69

TABLE 6.31 STATISTICAL PARAMETERS (1960-1975) FOR CADORA GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	115.25	78.00	70.25	75.37	78.19	60.50	59.56	79.19	91.25	88.81	109.06	104.63	1020.06
Stan. Dev. (mm)	51.10	42.07	27.73	31.87	39.68	26.65	23.31	25.83	42.33	57.77	49.09	47.53	464.96
STREAMFLOW (Q)													
Mean (m^3/s)	137.84	117.97	89.96	70.99	55.23	33.42	27.49	29.09	39.14	62.61	98.24	122.53	884.51
Mean (mm)	91.38	71.27	59.64	45.55	36.62	21.44	18.23	19.29	25.11	41.51	63.03	81.23	574.30
Stan. Dev. (mm)	37.12	34.93	26.21	18.95	16.34	10.80	13.28	6.70	15.53	33.53	36.37	39.15	288.91
Skew. Coef.	-1.07	0.13	1.55	0.12	0.70	0.84	3.60	0.23	0.84	1.76	1.83	0.91	
Lag-one Coef's													
Regression	-0.07	0.56	-0.12	0.17	0.10	0.35	0.39	-0.09	0.80	0.94	0.58	0.22	
Correlation	-0.07	0.55	-0.17	0.22	0.12	0.51	0.33	-0.17	0.33	0.45	0.52	0.21	
PERCENTAGE RUN-OFF 100 Q/R	83	144	88	67	49	39	27	25	31	49	64	81	61

TABLE 6.32 STATISTICAL PARAMETERS (1960-1975) FOR CHAIN BRIDGE GAUGING STATION

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
RAINFALL (R)													
Mean (mm)	167.21	112.52	92.27	97.82	96.65	77.81	82.52	97.61	123.02	121.71	150.19	147.00	1366.34
Stan. Dev. (mm)	82.29	66.07	44.50	43.39	48.38	34.98	28.18	32.13	60.21	84.33	77.98	74.58	677.02
STREAMFLOW (Q)													
Mean (m3/s)	54.14	43.66	30.33	24.94	19.78	12.21	9.53	11.35	17.10	27.29	39.13	48.09	337.56
Mean (mm)	159.00	116.85	89.07	70.88	58.09	34.70	27.99	33.33	48.60	80.15	111.21	141.23	971.10
Stan. Dev. (mm)	67.96	64.10	46.14	33.57	24.46	18.45	16.01	13.48	32.83	68.52	70.80	75.74	532.06
Skew. Coef.	-0.46	0.46	2.35	0.48	0.39	1.31	2.93	0.14	1.88	1.79	1.65	0.93	
Lag-one Coef's													
Regression	-0.07	0.55	-0.11	0.18	0.13	0.33	0.26	-0.25	0.52	0.71	0.33	0.06	
Correlation	-0.08	0.54	-0.16	0.24	0.19	0.42	0.31	-0.30	0.21	0.35	0.31	0.06	
PERCENTAGE RUN-OFF 100 Q/R	99	130	100	81	63	50	35	36	44	69	82	100	77

6.6 CROSS CORRELATION ANALYSIS BETWEEN GAUGING STATIONS (1960-75)

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975)

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Vyrnwy Bewdley	0.888	0.882	0.708	0.886	0.707	0.695	0.497	0.739	0.796	0.764	0.827	0.793	949.31
Vyrnwy Montford	0.899	0.901	0.807	0.908	0.794	0.832	0.584	0.818	0.784	0.850	0.851	0.869	713.87
Vyrnwy Tenbury	0.793	0.808	0.662	0.712	0.613	0.389	0.361	0.449	0.568	0.465	0.687	0.638	1029.38
Vyrnwy Cadora	0.876	0.839	0.715	0.800	0.776	0.685	0.557	0.691	0.795	0.717	0.797	0.754	858.65
Vyrnwy Belmont	0.901	0.872	0.784	0.860	0.808	0.741	0.671	0.672	0.819	0.806	0.879	0.856	641.90
Vyrnwy Abernant	0.909	0.886	0.826	0.889	0.808	0.893	0.735	0.705	0.841	0.869	0.844	0.863	28.65
Vyrnwy Rhayader	0.898	0.830	0.842	0.853	0.855	0.789	0.887	0.737	0.842	0.899	0.864	0.872	247.83
Vyrnwy Caban	0.905	0.865	0.854	0.888	0.880	0.749	0.801	0.629	0.820	0.873	0.860	0.866	57.27
Vyrnwy Erwood	0.917	0.893	0.826	0.893	0.847	0.814	0.783	0.717	0.837	0.859	0.900	0.887	483.83
Vyrnwy Chain Bridge	0.803	0.845	0.802	0.727	0.844	0.813	0.602	0.544	0.826	0.787	0.833	0.813	512.37
Vyrnwy Cray	0.816	0.902	0.873	0.868	0.856	0.879	0.727	0.776	0.858	0.885	0.874	0.883	615.29

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Vyrnwy Tycastell	0.851	0.840	0.783	0.819	0.776	0.865	0.547	0.604	0.773	0.833	0.852	0.875	338.07
Vyrnwy Teifi	0.840	0.819	0.647	0.770	0.672	0.723	0.399	0.396	0.690	0.750	0.809	0.808	561.30
Montford Tenbury	0.756	0.871	0.860	0.732	0.833	0.708	0.867	0.488	0.834	0.685	0.809	0.792	315.51
Montford Cadora	0.831	0.896	0.864	0.782	0.851	0.807	0.912	0.605	0.835	0.864	0.874	0.839	144.78
Montford Delmont	0.863	0.914	0.864	0.838	0.867	0.849	0.843	0.569	0.806	0.892	0.922	0.904	71.97
Montford Abernant	0.873	0.893	0.816	0.862	0.710	0.794	0.489	0.584	0.793	0.852	0.767	0.872	685.22
Montford Chayader	0.872	0.859	0.863	0.802	0.842	0.809	0.518	0.578	0.811	0.869	0.809	0.873	466.04
Montford Caban	0.867	0.891	0.838	0.818	0.796	0.719	0.368	0.391	0.846	0.838	0.769	0.862	656.60
Montford Erwood	0.887	0.921	0.863	0.850	0.884	0.840	0.814	0.576	0.831	0.904	0.891	0.898	230.04
Montford Chain Bridge	0.757	0.858	0.840	0.726	0.757	0.846	0.877	0.568	0.712	0.882	0.900	0.855	201.50

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Montford Cray	0.744	0.869	0.781	0.814	0.696	0.799	0.317	0.613	0.729	0.825	0.806	0.846	1329.16
Montford Tycastell	0.798	0.848	0.794	0.788	0.799	0.863	0.824	0.473	0.799	0.841	0.843	0.857	375.80
Montford Teifi	0.791	0.826	0.716	0.746	0.639	0.812	0.692	0.260	0.765	0.793	0.843	0.839	152.57
Bewdley Montford	0.908	0.917	0.913	0.921	0.915	0.870	0.911	0.858	0.894	0.902	0.909	0.915	235.44
Bewdley Tenbury	0.850	0.886	0.885	0.783	0.892	0.835	0.911	0.679	0.867	0.820	0.876	0.867	715.27
Bewdley Cadora	0.876	0.905	0.879	0.810	0.866	0.886	0.922	0.687	0.847	0.917	0.922	0.876	90.66
Bewdley Belmont	0.856	0.896	0.846	0.840	0.861	0.862	0.790	0.580	0.809	0.881	0.905	0.899	307.41
Bewdley Abernant	0.858	0.863	0.762	0.872	0.653	0.718	0.347	0.594	0.796	0.753	0.787	0.842	920.66
Bewdley Rhayader	0.857	0.808	0.836	0.762	0.796	0.805	0.434	0.522	0.834	0.777	0.753	0.840	701.48
Bewdley Caban	0.868	0.869	0.787	0.796	0.738	0.746	0.310	0.377	0.811	0.770	0.754	0.831	892.04

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Bewdley Erwood	0.878	0.901	0.833	0.835	0.864	0.837	0.767	0.593	0.824	0.861	0.867	0.873	436.94
Bewdley Chain Bridge	0.751	0.854	0.799	0.755	0.715	0.826	0.861	0.669	0.793	0.882	0.909	0.861	436.94
Bewdley Cray	0.705	0.851	0.698	0.832	0.612	0.737	0.212	0.584	0.744	0.732	0.813	0.795	1564.60
Bewdley Tycastell	0.793	0.870	0.762	0.806	0.747	0.827	0.780	0.596	0.825	0.768	0.850	0.839	375.80
Bewdley Teifi	0.796	0.866	0.712	0.786	0.629	0.813	0.682	0.452	0.780	0.739	0.847	0.842	388.01
Tenbury Cadora	0.882	0.900	0.906	0.770	0.878	0.730	0.888	0.639	0.781	0.867	0.882	0.901	170.73
Tenbury Belmont	0.822	0.863	0.861	0.702	0.860	0.704	0.756	0.523	0.741	0.741	0.797	0.826	387.48
Tenbury Abernant	0.789	0.8]9	0.760	0.722	0.659	0.393	0.231	0.421	0.690	0.475	0.650	0.698	1000.73
Tenbury Rhayader	0.781	0.711	0.821	0.489	0.717	0.595	0.369	0.323	0.650	0.469	0.570	0.675	781.55
Tenbury Caban	0.818	0.797	0.790	0.619	0.665	0.489	0.169	0.396	0.718	0.508	0.591	0.671	972.11

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Tenbury Erwood	0.821	0.852	0.838	0.657	0.801	0.603	0.686	0.502	0.737	0.661	0.726	0.757	545.55
Tenbury Chain Bridge	0.764	0.884	0.810	0.769	0.708	0.583	0.824	0.486	0.621	0.770	0.820	0.851	517.01
Tenbury Cray	0.688	0.833	0.711	0.716	0.550	0.425	0.137	0.347	0.605	0.476	0.694	0.672	1644.67
Tenbury Tycastell	0.779	0.872	0.749	0.677	0.724	0.566	0.764	0.439	0.753	0.544	0.723	0.763	691.31
Tenbury Teifi	0.813	0.876	0.707	0.703	0.670	0.638	0.668	0.534	0.738	0.566	0.762	0.770	468.08
Cadora Belmont	0.908	0.919	0.912	0.909	0.915	0.896	0.833	0.845	0.918	0.889	0.888	0.894	216.75
Cadora Abernant	0.879	0.859	0.815	0.849	0.792	0.765	0.450	0.836	0.894	0.739	0.793	0.776	830.00
Cadora Rhayader	0.852	0.799	0.870	0.742	0.831	0.838	0.497	0.709	0.866	0.726	0.726	0.763	610.82
Cadora Caban	0.897	0.871	0.835	0.803	0.800	0.837	0.365	0.739	0.903	0.752	0.740	0.752	801.38
Cadora Erwood	0.904	0.902	0.892	0.867	0.890	0.887	0.814	0.861	0.912	0.859	0.844	0.843	374.82

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Cadora Chain Bridge	0.858	0.897	0.887	0.915	0.857	0.868	0.909	0.828	0.864	0.906	0.915	0.912	346.28
Cadora Cray	0.823	0.857	0.784	0.854	0.723	0.782	0.332	0.808	0.818	0.729	0.833	0.800	1473.94
Cadora Tycastell	0.887	0.887	0.827	0.836	0.820	0.820	0.834	0.699	0.882	0.776	0.847	0.851	520.58
Cadora Teifi	0.892	0.882	0.790	0.810	0.788	0.826	0.701	0.502	0.870	0.761	0.847	0.810	297.35
Belmont Abernant	0.918	0.898	0.894	0.892	0.844	0.802	0.637	0.886	0.915	0.861	0.833	0.885	613.26
Belmont Rhayader	0.896	0.863	0.909	0.847	0.876	0.874	0.658	0.785	0.877	0.821	0.847	0.879	394.07
Belmont Caban	0.915	0.913	0.890	0.858	0.848	0.837	0.519	0.803	0.902	0.847	0.833	0.868	584.63
Belmont Erwood	0.931	0.930	0.925	0.921	0.904	0.898	0.895	0.878	0.926	0.923	0.921	0.925	158.07
Belmont Chain Bridge	0.873	0.885	0.909	0.868	0.828	0.861	0.867	0.778	0.883	0.919	0.910	0.900	129.53
Belmont Cray	0.882	0.877	0.861	0.884	0.743	0.789	0.549	0.824	0.843	0.841	0.866	0.886	1258.87

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Belmont Tycastell	0.905	0.874	0.894	0.872	0.867	0.827	0.883	0.666	0.893	0.888	0.889	0.900	303.83
Belmont Teifi	0.904	0.851	0.853	0.829	0.755	0.828	0.705	0.467	0.853	0.860	0.871	0.862	80.60
Abernant Rhayader	0.911	0.822	0.889	0.826	0.800	0.847	0.737	0.771	0.881	0.887	0.852	0.906	219.18
Abernant Caban	0.916	0.878	0.913	0.875	0.846	0.853	0.680	0.744	0.905	0.900	0.880	0.916	28.62
Abernant Chain Bridge	0.820	0.871	0.858	0.794	0.830	0.847	0.555	0.764	0.893	0.836	0.794	0.799	483.72
Abernant Cray	0.872	0.879	0.889	0.906	0.851	0.920	0.748	0.856	0.895	0.911	0.838	0.859	643.94
Abernant Tycastell	0.881	0.871	0.906	0.912	0.884	0.887	0.642	0.718	0.904	0.918	0.890	0.890	309.42
Abernant Teifi	0.873	0.828	0.869	0.851	0.759	0.754	0.453	0.453	0.850	0.856	0.792	0.878	532.65
Rhayader Caban	0.916	0.893	0.906	0.884	0.896	0.903	0.886	0.873	0.891	0.904	0.903	0.927	190.56
Rhayader Erwood	0.910	0.885	0.920	0.892	0.903	0.891	0.775	0.871	0.893	0.869	0.893	0.915	236.00

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Rhayader Chain Bridge	0.758	0.720	0.873	0.651	0.762	0.803	0.544	0.611	0.860	0.778	0.767	0.780	264.54
Rhayader Cray	0.827	0.780	0.875	0.807	0.743	0.808	0.743	0.725	0.811	0.852	0.810	0.865	863.12
Rhayader Tycastell	0.846	0.701	0.879	0.796	0.833	0.819	0.546	0.609	0.862	0.845	0.841	0.868	90.24
Rhayader Teifi	0.844	0.690	0.817	0.751	0.688	0.874	0.410	0.379	0.825	0.781	0.788	0.833	313.47
Caban Erwood	0.922	0.919	0.920	0.907	0.883	0.877	0.681	0.873	0.915	0.890	0.886	0.908	426.56
Caban Chain Bridge	0.807	0.816	0.854	0.712	0.796	0.791	0.395	0.597	0.826	0.807	0.757	0.777	455.10
Caban Cray	0.848	0.840	0.902	0.852	0.827	0.817	0.644	0.709	0.834	0.862	0.842	0.836	672.56
Caban Tycastell	0.875	0.815	0.863	0.842	0.823	0.804	0.397	0.579	0.865	0.880	0.860	0.879	280.80
Caban Teifi	0.884	0.808	0.825	0.789	0.650	0.811	0.296	0.434	0.838	0.850	0.792	0.862	504.03
Erwood Chain Bridge	0.853	0.868	0.897	0.806	0.819	0.893	0.842	0.768	0.881	0.910	0.873	0.862	28.54

TABLE 6.33 LAG ZERO CROSS CORRELATION OF GAUGING STATIONS (1960-1975) Cont.

STATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL IN MM
Erwood Cray	0.865	0.880	0.890	0.885	0.786	0.877	0.618	0.807	0.850	0.886	0.871	0.899	1099.12
Erwood Tycastell	0.894	0.862	0.882	0.867	0.839	0.876	0.830	0.700	0.902	0.911	0.912	0.909	145.76
Erwood Teifi	0.891	0.843	0.847	0.820	0.716	0.846	0.662	0.438	0.873	0.878	0.869	0.868	77.47
Chain Bridge Cray	0.874	0.900	0.869	0.822	0.847	0.872	0.468	0.762	0.857	0.841	0.865	0.842	1127.66
Chain Bridge Tycastell	0.899	0.919	0.876	0.786	0.806	0.873	0.882	0.704	0.877	0.867	0.862	0.883	174.30
Chain Bridge Teifi	0.895	0.892	0.805	0.762	0.800	0.811	0.692	0.441	0.820	0.834	0.863	0.839	48.93
Cray Tycastell	0.907	0.881	0.864	0.873	0.781	0.903	0.520	0.751	0.830	0.900	0.856	0.876	953.36
Cray Teifi	0.894	0.859	0.801	0.846	0.685	0.732	0.251	0.453	0.737	0.822	0.820	0.793	1176.59
Tycastell Teifi	0.926	0.903	0.880	0.864	0.750	0.762	0.734	0.612	0.903	0.895	0.884	0.900	223.23
Abernant Erwood	0.925	0.901	0.901	0.897	0.810	0.875	0.719	0.863	0.922	0.904	0.872	0.915	455.18

6.7 CROSS CORRELATION ANALYSIS BETWEEN SUB-CATCHMENTS (1960-75)

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975)

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Vyrnwy Up-Severn	0.892	0.894	0.775	0.902	0.767	0.800	0.526	0.777	0.733	0.829	0.834	0.858	749	H/M_D	H/M
Vyrnwy Mid-Severn	0.701	0.735	0.346	0.678	0.519	0.288	0.367	0.267	0.625	0.371	0.611	0.524	1160	H/L	H/L
Vyrnwy Tenbury	0.793	0.808	0.662	0.712	0.613	0.389	0.361	0.449	0.568	0.465	0.687	0.638	1029	H/M_D	H/L
Vyrnwy Caban Coch	0.905	0.865	0.854	0.888	0.880	0.749	0.801	0.629	0.820	0.873	0.860	0.866	57	H/H	H/H
Vyrnwy Rhayader	0.898	0.830	0.842	0.853	0.855	0.789	0.887	0.737	0.842	0.899	0.864	0.872	248	H/H	H/H
Vyrnwy Abernant	0.909	0.886	0.826	0.889	0.808	0.893	0.735	0.705	0.841	0.869	0.844	0.863	29	H/H	H/H
Vyrnwy Up-Wye	0.908	0.890	0.793	0.871	0.791	0.757	0.506	0.675	0.814	0.805	0.885	0.870	660	H/M_W	H/M
Vyrnwy Mid-Wye	0.642	0.683	0.497	0.240	0.418	0.228	0.351	0.031	0.094	0.330	0.549	0.535	968	H/L	H/L
Vyrnwy Lower Wye	0.728	0.734	0.571	0.573	0.609	0.457	0.366	0.118	0.376	0.463	0.604	0.378	1046	H/L	H/L

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Vyrnwy Cray	0.816	0.902	0.873	0.868	0.856	0.879	0.727	0.776	0.858	0.885	0.874	0.883	615	H/H	H/H
Vyrnwy Usk	0.801	0.843	0.799	0.721	0.842	0.808	0.590	0.529	0.823	0.783	0.832	0.811	526	H/H_M	H/M
Up-Severn Mid-Severn	0.676	0.761	0.705	0.724	0.820	0.543	0.834	0.335	0.579	0.595	0.664	0.751	412	M_D/L	M/L
Up-Severn Tenbury	0.750	0.873	0.868	0.731	0.841	0.742	0.882	0.483	0.852	0.703	0.813	0.799	281	M_D/M_D	M/L
Up-Severn Caban Coch	0.860	0.890	0.820	0.808	0.775	0.701	0.311	0.341	0.823	0.824	0.753	0.856	692	M_D/H	M/H
Up-Severn Rhayader	0.867	0.858	0.849	0.794	0.826	0.797	0.461	0.536	0.779	0.855	0.796	0.868	501	M_D/H	M/H
Up-Severn Abernant	0.867	0.891	0.799	0.856	0.688	0.764	0.446	0.549	0.759	0.839	0.752	0.867	720	M_D/H	M/H
Up-Severn Up-Wye	0.875	0.919	0.851	0.833	0.884	0.829	0.872	0.573	0.782	0.891	0.907	0.885	89	M_D/M_W	M/M
Up-Severn Mid-Wye	0.566	0.776	0.709	0.328	0.512	0.532	0.729	0.119	0.040	0.565	0.775	0.710	219	M_D/L	M/L

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBIANTION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Up-Severn Lower Wye	0.672	0.813	0.808	0.563	0.701	0.584	0.825	0.147	0.614	0.688	0.711	0.520	297	M_D/L	M/L
Up-Severn Cray	0.735	0.862	0.754	0.806	0.669	0.773	0.264	0.570	0.683	0.808	0.792	0.837	1364	M_D/H	M/H
Up-Severn Usk	0.749	0.855	0.829	0.713	0.736	0.835	0.873	0.552	0.668	0.882	0.899	0.851	223	M_D/M_W	M/M
Mid-Severn Tenbury	0.873	0.804	0.767	0.783	0.903	0.789	0.901	0.712	0.565	0.885	0.838	0.893	131	L/M_D	L/L
Mid-Severn Caban Coch	0.710	0.716	0.517	0.603	0.589	0.574	0.225	0.183	0.556	0.414	0.572	0.648	1103	L/H	L/H
Mid-Severn Rhayader	0.668	0.606	0.609	0.525	0.662	0.567	0.314	0.189	0.675	0.366	0.485	0.652	913	L/H	L/H
Mid-Severn Abernant	0.668	0.693	0.489	0.749	0.515	0.397	0.168	0.345	0.610	0.335	0.670	0.659	1132	L/H	L/H
Mid-Severn Upper Wye	0.691	0.775	0.628	0.668	0.819	0.596	0.815	0.468	0.598	0.604	0.664	0.707	500	L/M_W	L/M
Mid-Severn Mid-Wye	0.474	0.646	0.629	0.549	0.549	0.456	0.568	0.031	0.201	0.719	0.639	0.806	192	L/M_W	L/M

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Mid-Severn Lower Wye	0.881	0.833	0.810	0.705	0.765	0.798	0.885	0.462	0.550	0.875	0.895	0.731	115	L/L	L/L
Mid-Severn Cray	0.498	0.707	0.372	0.737	0.438	0.431	0.081	0.272	0.592	0.331	0.664	0.578	1776	L/H	L/H
Mid-Severn Usk	0.600	0.736	0.550	0.717	0.595	0.562	0.796	0.554	0.748	0.648	0.743	0.748	634	L/M_W	L/M
Tenbury Caban Coch	0.818	0.797	0.790	0.619	0.665	0.489	0.169	0.396	0.718	0.508	0.591	0.671	972	M_D/H	L/H
Tenbury Rhayader	0.781	0.711	0.821	0.489	0.717	0.595	0.369	0.323	0.650	0.469	0.570	0.675	782	M_D/H	L/H
Tenbury Abernant	0.789	0.829	0.760	0.722	0.659	0.393	0.231	0.421	0.690	0.475	0.650	0.698	1001	M_D/H	L/H
Tenbury Up-Wye	0.821	0.878	0.852	0.684	0.831	0.646	0.858	0.586	0.750	0.735	0.771	0.794	369	M_D/M_W	L/M
Tenbury Mid-Wye	0.657	0.789	0.768	0.520	0.701	0.654	0.717	0.174	0.207	0.798	0.812	0.872	61	M_D/L	L/L
Tenbury Lower Wye	0.866	0.890	0.891	0.775	0.791	0.628	0.847	0.323	0.606	0.891	0.865	0.812	16	M_D/L	L/L

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Tenbury Cray	0.688	0.833	0.711	0.716	0.550	0.425	0.137	0.347	0.605	0.476	0.694	0.672	1645	M_D/H	L/H
Tenbury Usk	0.765	0.884	0.811	0.768	0.711	0.587	0.831	0.488	0.620	0.775	0.821	0.853	503	M_D/M_W	L/M
Caban Coch Rhayader	0.916	0.893	0.906	0.884	0.896	0.903	0.886	0.873	0.891	0.904	0.903	0.927	191	H/H	H/H
Caban Coch Abernant	0.916	0.878	0.913	0.875	0.846	0.853	0.680	0.744	0.905	0.900	0.880	0.916	29	H/H	H/H
Caban Coch Up-Wye	0.902	0.899	0.897	0.872	0.818	0.764	0.310	0.774	0.883	0.832	0.830	0.857	603	H/M_W	H/M
Caban Coch Mid-Wye	0.694	0.772	0.619	0.169	0.452	0.369	0.146	- 0.004	0.144	0.394	0.410	0.507	911	H/L	H/L
Caban Coch Lower Wye	0.757	0.751	0.698	0.586	0.596	0.671	0.173	-0.058	0.532	0.484	0.541	0.351	988	H/L	H/L
Caban Coch Cray	0.848	0.840	0.902	0.852	0.827	0.817	0.644	0.709	0.834	0.862	0.842	0.836	673	H/H	H/H
Caban Coch Usk	0.805	0.814	0.852	0.707	0.793	0.788	0.383	0.587	0.823	0.803	0.754	0.773	469	H/M_W	H/M

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	COMBINATION TYPE GROUP II
Rhayader Abernant	0.911	0.822	0.889	0.826	0.800	0.847	0.737	0.771	0.881	0.887	0.852	0.906	219	H/H	H/H
Rhayader Up-Wye	0.902	0.899	0.897	0.872	0.818	0.764	0.310	0.774	0.883	0.832	0.830	0.857	412	H/M_W	H/M
Rhayader Mid-Wye	0.647	0.671	0.694	0.177	0.493	0.448	0.334	-0.050	0.118	0.356	0.444	0.529	720	H/L	H/L
Rhayader Lower-Wye	0.677	0.652	0.751	0.444	0.630	0.614	0.275	-0.087	0.468	0.463	0.497	0.361	798	H/L	H/L
Rhayader Cray	0.827	0.780	0.875	0.807	0.743	0.808	0.743	0.725	0.811	0.852	0.810	0.865	863	H/H	H/H
Rhayader Usk	0.756	0.718	0.871	0.645	0.760	0.801	0.531	0.601	0.859	0.774	0.765	0.776	278	H/M_W	H/M
Abernant Up-Wye	0.911	0.895	0.874	0.884	0.739	0.797	0.463	0.839	0.905	0.860	0.830	0.879	632	H/M_W	H/M
Abernant Mid-Wye	0.695	0.770	0.694	0.380	0.629	0.262	0.373	0.259	0.187	0.403	0.457	0.560	940	H/L	H/L
Abernant Lower Wye	0.709	0.744	0.650	0.646	0.582	0.553	0.215	-0.018	0.446	0.434	0.647	0.383	1017	H/L	H/L

TABLE 6.34 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Abernant Cray	0.872	0.879	0.889	0.906	0.851	0.920	0.748	0.856	0.895	0.911	0.838	0.859	644	H/H	H/H
Abernant Usk	0.817	0.870	0.856	0.789	0.827	0.842	0.543	0.753	0.891	0.832	0.792	0.796	497	H/M_W	H/M
Up-Wye Mid-Wye	0.717	0.789	0.717	0.419	0.458	0.395	0.768	0.036	0.166	0.632	0.669	0.727	308	M_W/L	M/L
Up-Wye Lower Wye	0.755	0.832	0.818	0.691	0.784	0.691	0.748	0.183	0.459	0.675	0.684	0.567	385	M_W/L	M/L
Up-Wye Cray	0.862	0.889	0.870	0.881	0.731	0.833	0.352	0.781	0.831	0.853	0.858	0.905	1276	M_W/H	M/H
Up-Wye Usk	0.877	0.891	0.903	0.847	0.790	0.892	0.887	0.820	0.875	0.930	0.895	0.893	134	M_W/M_W	M/M
Mid-Wye Lower Wye	0.605	0.821	0.734	0.690	0.490	0.255	0.475	-0.462	-0.002	0.627	0.747	0.833	77	L/L	L/L
Lower Wye Cray	0.783	0.750	0.595	0.392	0.366	0.219	0.324	0.229	0.167	0.381	0.596	0.622	1584	L/H	L/H
Mid-Wye Usk	0.785	0.828	0.771	0.675	0.557	0.406	0.733	0.199	0.235	0.650	0.777	0.820	442	L/M_W	L/M

TABLE 6.3 LAG-ZERO CROSS CORRELATION BETWEEN SUB-CATCHMENTS (1960-1975) Continued

COMBINATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DIFF. IN ANNUAL RAINFALL MM	COMBINATION TYPE GROUP I	GROUP II
Lower Wye Cray	0.629	0.770	0.624	0.674	0.583	0.615	0.093	0.055	0.385	0.441	0.691	0.442	1661	L/H	L/H
Lower Wye Usk	0.729	0.852	0.790	0.861	0.798	0.711	0.797	0.204	0.435	0.730	0.806	0.712	520	L/M_W	L/M
Cray Usk	0.871	0.898	0.867	0.817	0.843	0.868	0.449	0.747	0.853	0.837	0.863	0.838	1141	H/M_W	H/M

Group Classifications based upon Annual Rainfall (r)

Group I

H - High $r > 1600$ mm

M_W - Medium/wet $1600 > r > 1218$ mm

M_D - Medium/dry $1218 > r > 849$ mm

L - Low $r < 849$ mm

Group II

H - High $r > 1600$ mm

M - Medium $1600 > r > 1130$ mm

L - Low $r < 1130$ mm

6.8 SKEWNESS COEFFICIENT SENSITIVITY ANALYSIS

TABLE 6.35 VARIATION OF SKEWNESS COEFFICIENT
FOR FIVE SMALL MOUNTAINOUS CATCHMENTS

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1944-1975												
Vyrnwy	0.61	0.55	2.26	0.33	0.80	0.92	0.94	0.31	0.32	1.24	0.49	0.69
Rhayader	0.37	0.37	2.00	0.59	0.82	1.00	0.69	0.74	1.13	1.02	0.57	0.79
Caban Coch	0.18	0.19	2.57	0.17	0.76	0.75	0.93	0.74	0.55	0.70	0.50	0.92
Abernant	0.09	0.33	1.86	0.26	0.71	0.77	0.52	0.24	0.65	1.67	0.29	1.09
Cray	0.21	0.25	2.09	-0.01	0.56	0.95	0.09	0.41	0.35	1.88	0.67	0.76
Average	0.29	0.34	2.16	0.27	0.73	0.88	0.63	0.49	0.60	1.30	0.50	0.85
1944-1959												
Vyrnwy	1.54	0.59	2.65	0.40	1.93	0.72	0.86	0.08	0.07	1.14	0.11	0.89
Rhayader	1.12	0.43	2.02	0.30	2.33	1.05	0.95	0.46	0.88	0.78	0.07	0.43
Caban Coch	1.56	0.42	2.73	0.36	1.94	0.70	0.91	0.44	0.47	0.68	0.34	0.24
Abernant	1.13	0.30	1.90	0.36	2.15	0.89	0.54	0.23	0.47	1.23	0.03	0.28
Cray	0.31	0.37	1.94	0.36	1.37	0.92	0.04	0.09	0.01	1.65	0.o7	0.48
Average	1.13	0.42	2.25	0.21	1.94	0.86	0.64	0.26	0.38	1.10	0.12	0.37
1960-1975												
Vyrnwy	0.66	0.01	2.11	0.28	0.07	1.28	0.67	0.59	0.72	1.64	1.27	0.60
Rhayader	0.11	0.15	2.03	0.42	0.01	0.62	0.34	0.12	0.75	1.51	1.23	0.66
Caban Coch	0.65	0.32	2.58	0.17	0.08	0.51	0.31	0.36	0.51	0.89	0.98	0.64
Abernant	0.60	0.49	2.28	0.06	0.09	0.69	0.64	0.36	0.80	2.12	0.95	0.81
Cray	0.11	0.09	2.79	0.12	0.00	0.98	0.05	0.67	0.40	2.31	1.72	0.57
Average	0.38	0.08	2.36	0.14	0.01	0.82	0.40	0.37	0.64	1.69	1.23	0.66

TABLE 6.36 VARIATION OF SKEWNESS COEFFICIENT FOR FOUR LARGE CATCHMENTS

						1944-1975						
MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bewdley	0.18	0.65	2.81	0.65	1.98	1.85	3.48	1.31	1.10	1.15	1.13	1.58
Cadora	0.31	0.28	3.01	0.53	0.85	2.05	3.65	1.03	1.47	1.31	1.23	0.26
Belmont	0.33	0.46	3.23	0.38	1.01	1.37	1.12	0.99	1.20	1.07	0.87	0.72
Erwood	0.22	0.53	2.82	0.33	1.05	1.29	0.71	0.70	0.86	1.16	0.87	0.61
Average	0.11	0.48	2.97	0.47	1.22	1.64	2.24	1.01	1.16	1.17	1.03	0.79
						1944-1959						
Bewdley	0.76	0.67	2.82	0.98	1.86	1.82	1.40	1.11	0.82	0.91	1.08	0.22
Cadora	0.52	0.40	3.35	1.09	1.18	1.88	0.26	0.63	1.10	0.82	0.97	0.32
Belmont	1.49	0.57	3.32	0.73	1.91	1.31	0.04	0.57	0.93	0.91	0.66	0.01
Erwood	1.30	0.65	3.05	0.32	2.41	1.14	0.13	0.37	0.64	0.63	0.63	0.01
Average	1.02	0.57	3.14	0.78	1.84	1.54	0.44	0.67	0.87	0.82	0.84	0.13
						1960-1975						
Bewdley	0.37	0.03	0.94	0.59	1.97	0.92	3.77	1.05	0.60	1.56	1.44	1.72
Cadura	1.07	0.13	1.55	0.12	0.70	0.84	3.60	0.23	0.84	1.76	1.83	0.91
Belmont	0.76	0.15	2.08	0.17	0.51	0.38	1.72	0.51	0.85	1.43	1.30	0.86
Erwood	0.66	0.03	2.37	0.14	0.41	0.95	1.35	0.60	0.85	1.68	1.42	0.66
Average	0.72	0.07	1.74	0.26	0.90	0.77	2.61	0.60	0.79	1.61	1.50	1.04

CHAPTER SEVEN

ANALYSIS AND INTERPRETATION OF RESULTS

7.1 INTRODUCTION

This chapter deals primarily with the analyses and interpretation of the results tabulated in the previous chapter. It includes the analysis and interpretation of the spatial and temporal variation of the rainfall and streamflow parameters and the derivation of rainfall/streamflow relationships. The variation of potential and actual evapotranspiration is also considered, and a soil moisture simulation model which was used for the estimation of the temporal variation of soil moisture storage is described. The final section deals with the spatial and temporal variation of catchment storage.

7.2 MEAN MONTHLY RAINFALL

A regression analysis between mean monthly rainfall and the mean annual rainfall was performed on the sub-catchment data sets using the following linear equation

$$R_i = b_i + m_i R_a \tag{7.1}$$

where

R_a = mean annual rainfall,

R_i = mean rainfall for the ith month,

m_i = slope of regression line for the ith month,

b_i = regression line intercept for the ith month.

Three sub-catchments were not included in this analysis but were later plotted on the R_i/R_a graphs (see Figures 7.1/1 to 7.1/4). Tycastell and Glan Teifi were excluded because they are located on the exposed side of the main mountain barrier and could therefore belong to a different rainfall regime, than the other sub-catchments.

Cray was excluded on the basis that its rainfall data was relatively unreliable, being based upon a single near-by gauge.

The regression coefficients indicated that the monthly mean rainfall and annual rainfall are highly correlated for each month of the year throughout the Region, and a plot of the monthly slope and intercept parameters shows a generalised annual cycle as shown in Figure 7.2. Mean monthly rainfall for any point or area within the region may be estimated from the mean annual rainfall (obtained from Map No 3) using:

1) the linear regression curve with the smoothed slope and intercept parameters from Figure 7.2;

or 2) the set of derived regression lines given in Figure 7.1/1 to 7.1/4.

The temporal variation of mean monthly rainfall has also been expressed in terms of a percentage of mean annual rainfall (Table 7.1) and plotted separately for the high, medium and low rainfall sub-catchments in Figure 7.3.

Inspection of these three graphs reveals the following characteristics.

1) The high rainfall sub-catchments exhibited a high degree of consistency in their seasonal variation of mean areal rainfall. The months of November, December and January were far wetter than the other months. There was a general decline in rainfall from January through to June, except for a minor peak in April, followed by a gradual increase up to November.

2) The seasonal variation of mean areal rainfall in the medium rainfall sub-catchments was similar to that in the high rainfall sub-catchments, but was less consistent and the

TABLE 7.1 MEAN MONTHLY RAINFALL OF SUB-CATCHMENT EXPRESSED AS A PERCENTAGE OF MEAN ANNUAL RAINFALL (1960-75)

SUB-CATCHMENT NAME	RAINFALL (MM)	MONTHLY RAINFALL % OF ANNUAL											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Cray	2494	12.80	8.08	6.46	7.27	6.58	5.57	5.90	7.37	8.85	8.86	10.81	11.43
Tycastell	1541	11.57	7.33	5.99	7.06	6.72	6.06	6.70	7.94	9.07	9.61	10.96	10.95
Glan Teifi	1317	11.66	7.17	5.96	7.25	6.41	6.01	6.70	7.88	8.99	9.62	11.29	11.09
Tenbury	849	10.54	7.34	7.23	7.60	8.23	6.05	7.37	8.75	8.88	8.30	10.42	9.32
Usk	1353	12.22	8.24	7.76	7.16	7.08	5.70	6.04	7.14	9.01	8.91	10.99	10.74
Mid-Wye	911	11.15	7.62	7.18	7.19	8.52	7.05	7.14	7.80	8.53	8.78	9.96	9.01
Up-Wye	1218	11.12	7.73	6.38	7.27	7.25	5.58	6.83	7.54	9.04	8.85	11.15	11.30
Up-Severn	1130	10.15	7.31	6.59	7.18	7.56	5.93	7.44	8.37	9.12	8.48	11.08	10.78
Mid-Severn	718	9.31	6.37	6.70	7.57	8.98	6.87	9.05	9.47	9.18	8.03	10.02	8.68
Vyrnwy	1879	10.85	8.03	6.63	7.16	6.67	5.09	6.38	7.38	8.88	9.05	11.74	12.13
Lower Wye	833	11.22	7.33	7.13	7.43	8.04	6.05	7.58	7.94	9.16	8.58	10.33	9.23
Abernant	1850	11.94	8.03	6.43	7.41	6.58	5.42	6.45	7.53	8.82	9.11	11.31	10.98
Rhyader	1631	11.16	7.99	6.56	7.48	6.85	5.32	6.37	7.71	8.46	8.54	11.31	12.25
Caban Coch	1821	12.00	8.41	6.88	7.53	6.34	5.01	6.01	7.32	8.38	8.52	11.32	12.31

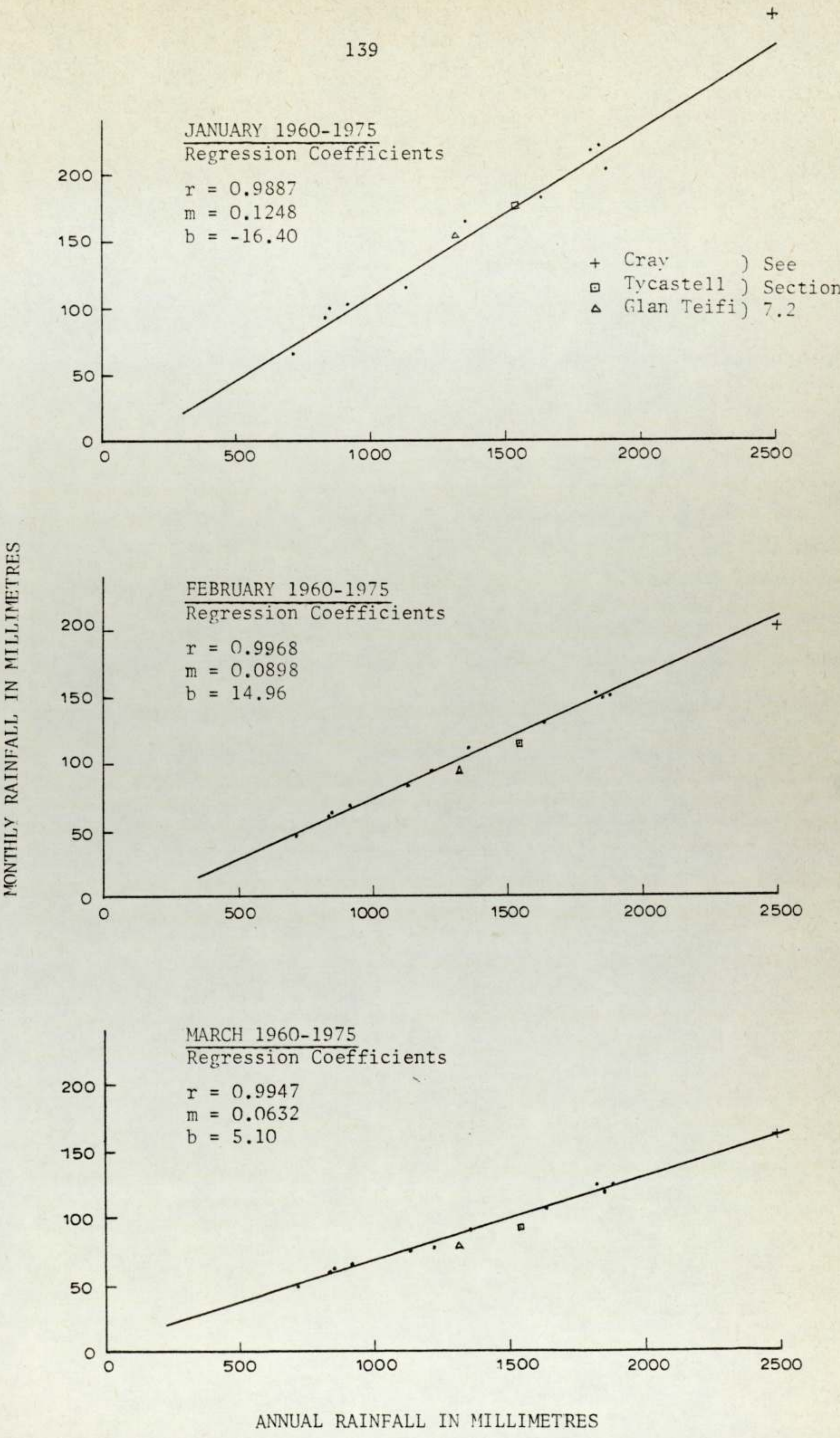


FIGURE 7.1/1 LINEAR REGRESSION ANALYSIS OF MEAN MONTHLY/ANNUAL RAINFALL

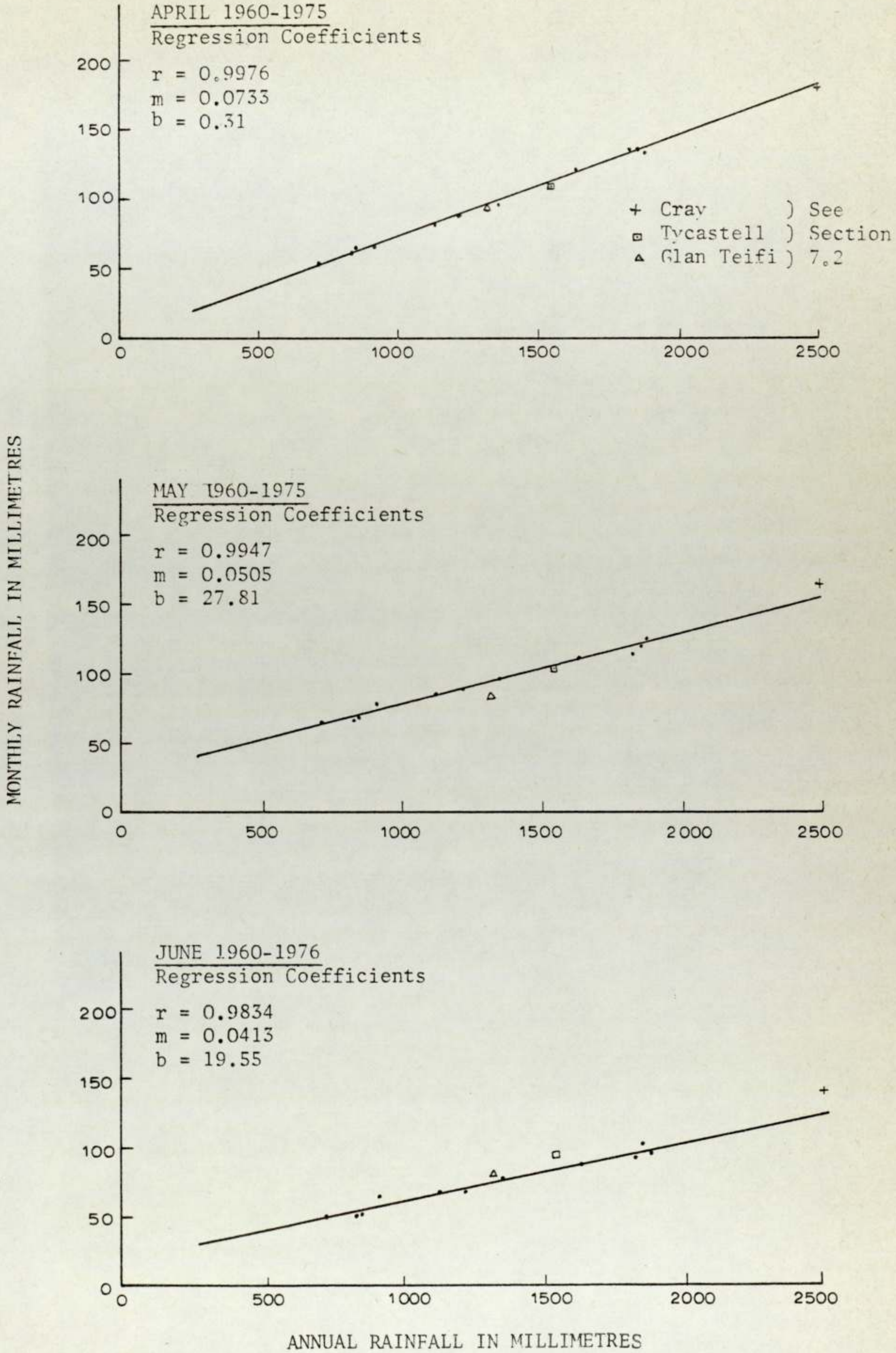


FIGURE 7.1/2 LINEAR REGRESSION ANALYSIS OF MEAN MONTHLY/ANNUAL RAINFALL

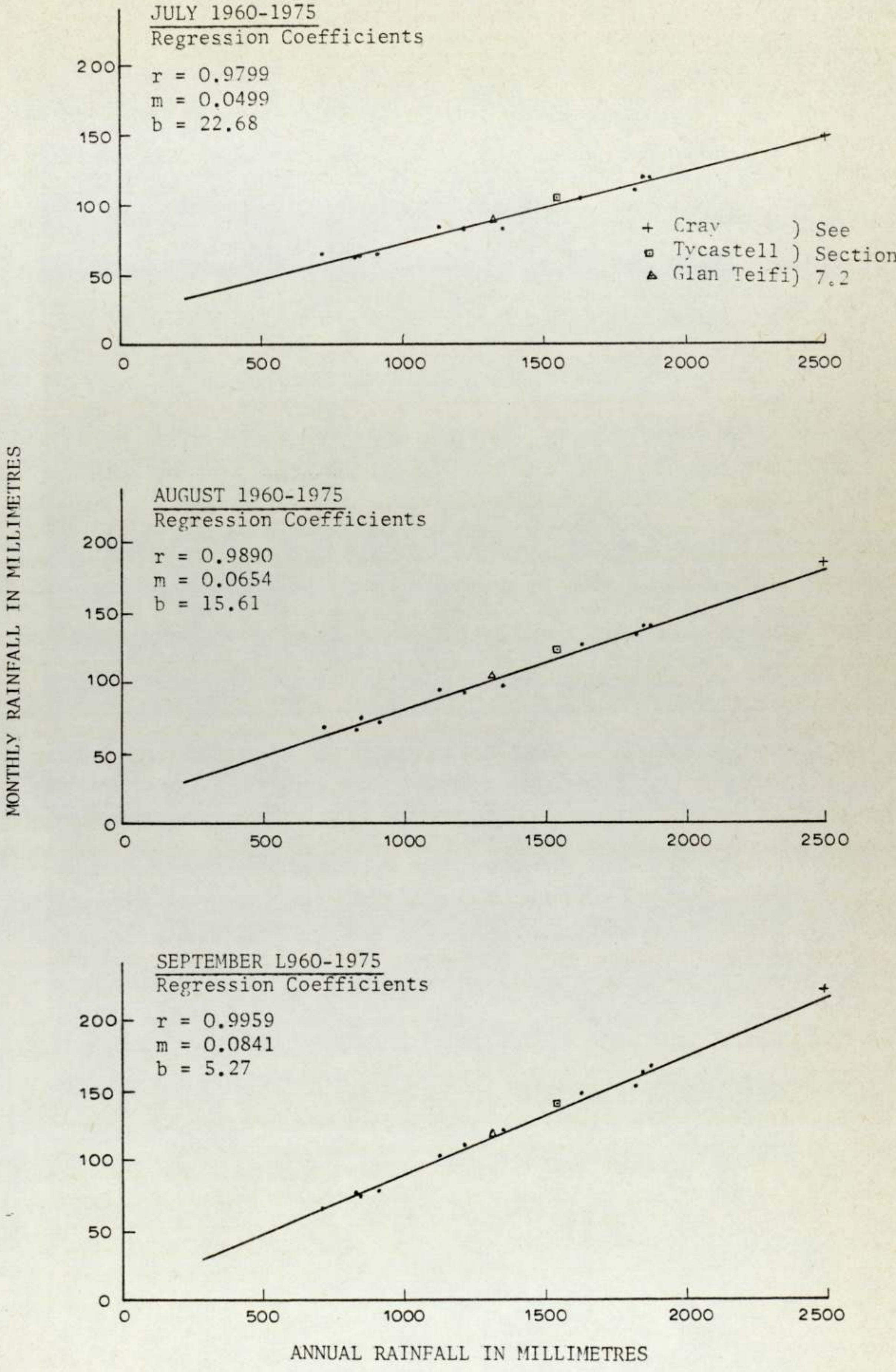


FIGURE 7.1/3 LINEAR REGRESSION ANALYSIS OF MEAN MONTHLY/ANNUAL RAINFALL

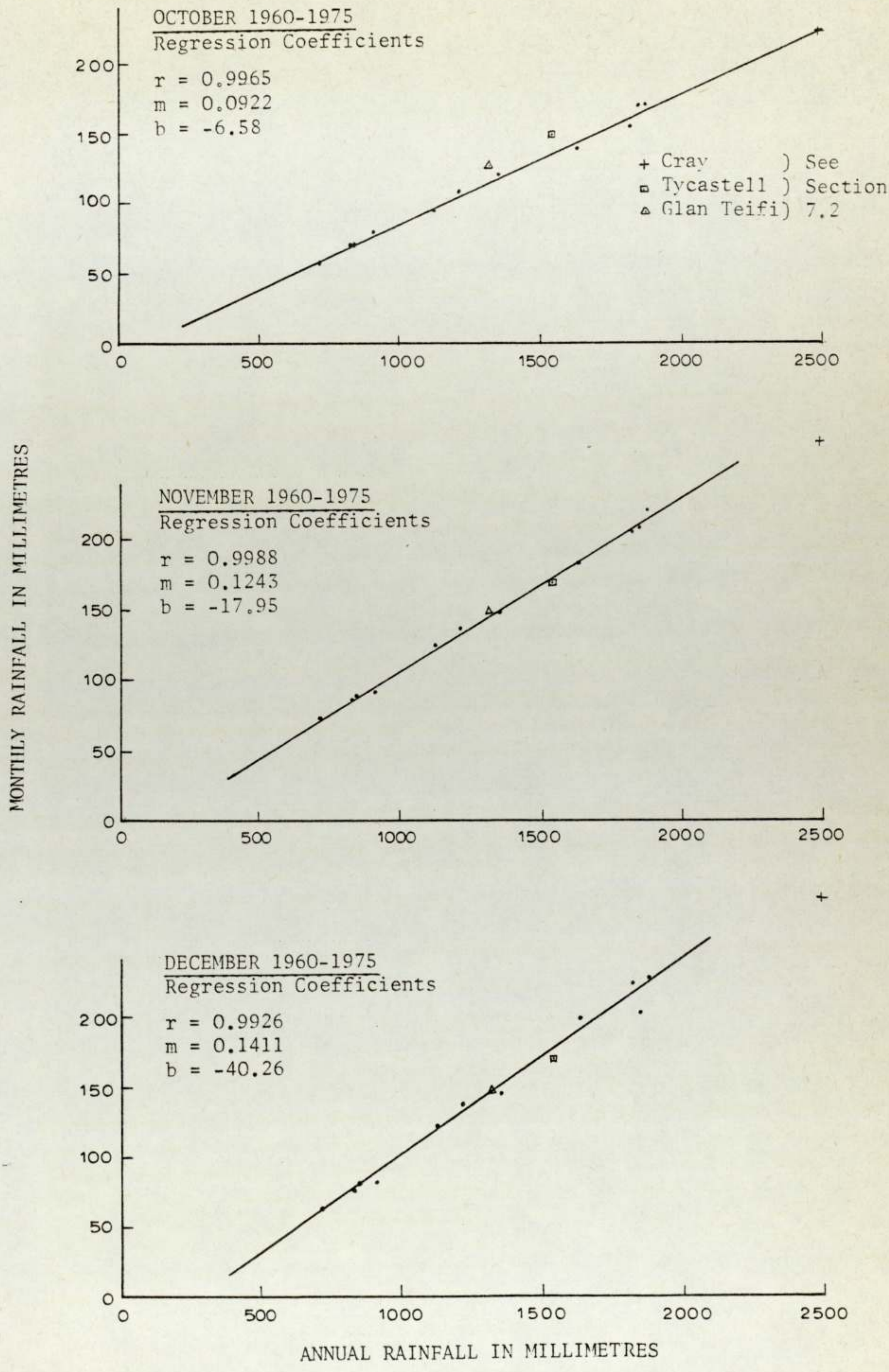


FIGURE 7.1/4 LINEAR REGRESSION ANALYSIS OF MEAN MONTHLY/ANNUAL RAINFALL

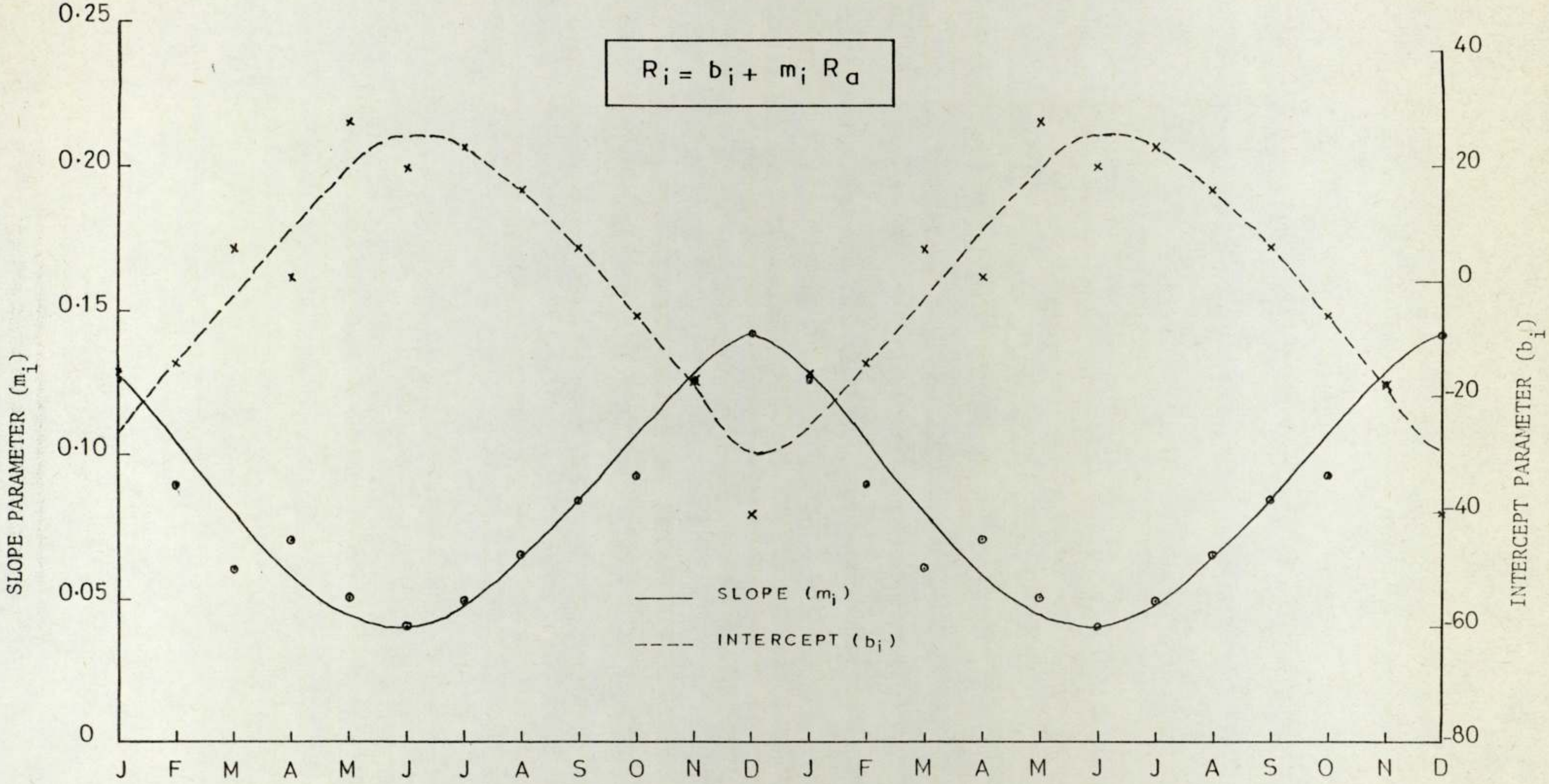


FIGURE 7.2 TEMPORAL VARIATION OF THE REGIONAL MEAN MONTHLY RAINFALL PARAMETERS (1960-75)

[Graph plotted over two year cycle to ensure continuity]

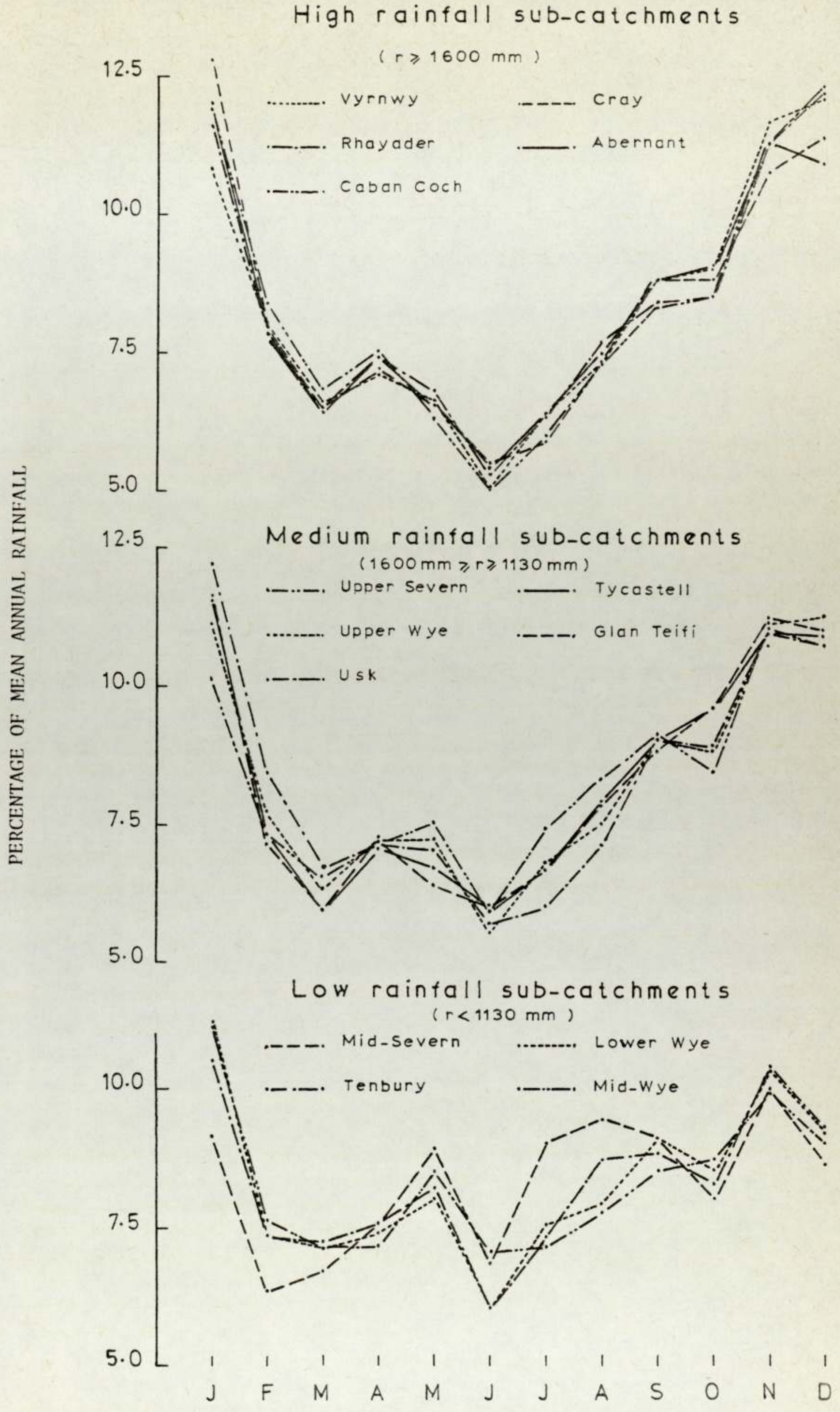


FIGURE 7.3 VARIATION OF MEAN MONTHLY RAINFALL EXPRESSED AS PERCENTAGE OF MEAN ANNUAL RAINFALL (1960-75)

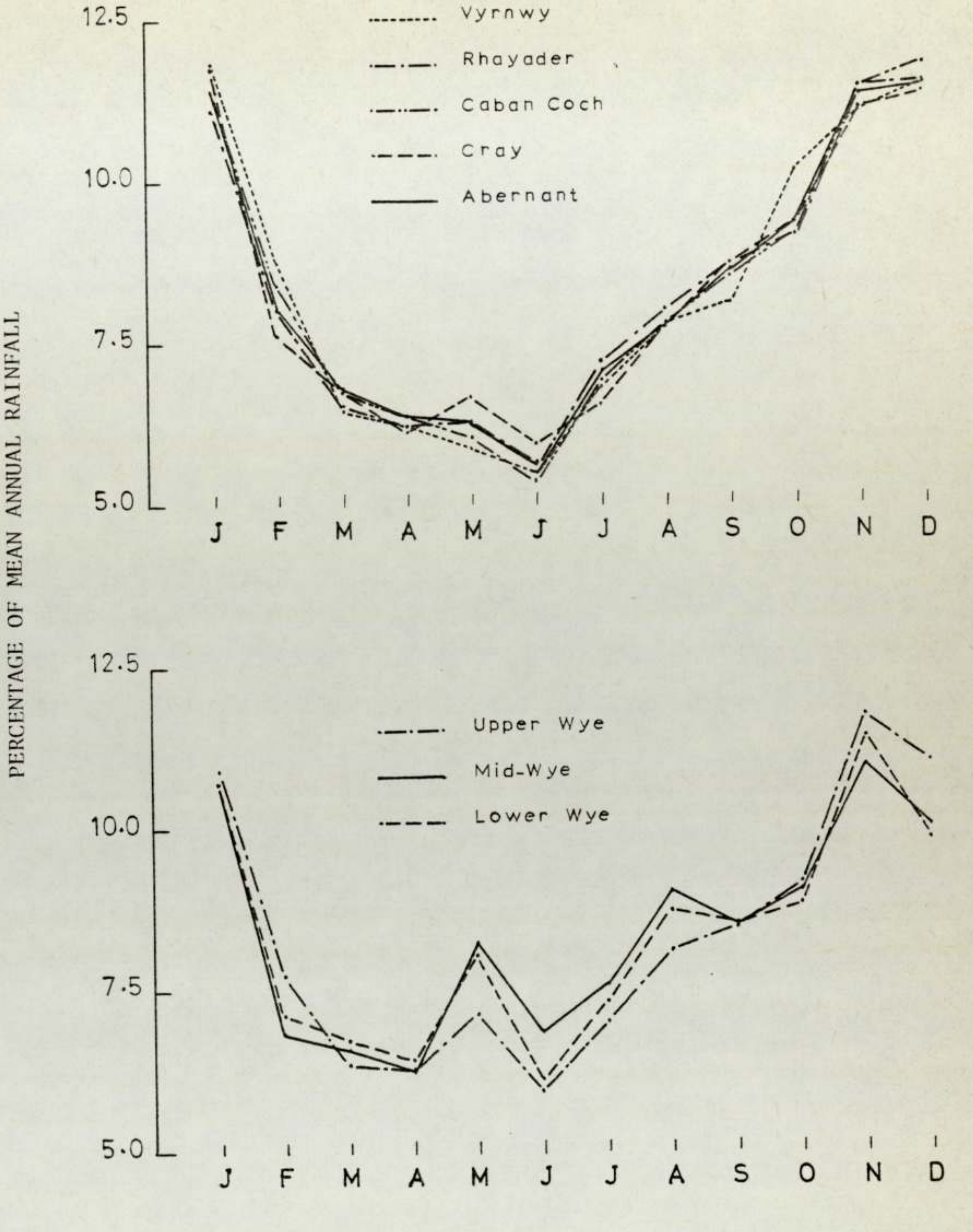


FIGURE 7.4 VARIATION OF MEAN MONTHLY RAINFALL EXPRESSED AS PERCENTAGE OF MEAN ANNUAL RAINFALL (1938-75)

June minimum was less pronounced. There was also a smaller difference between the winter maximum and the summer minimum.

3) The low rainfall sub-catchments were far less consistent in their seasonal variation of rainfall than were the other sub-catchments. The difference between winter and summer was far less pronounced. The driest month was June followed by February, March and April, and the wettest months were November and January.

In order to check the sensitivity of these characteristics, a similar analysis was carried out on the long record (1938-75) data. The results of this analysis (Figure 7.4) corresponded closely with the short record results in all respects except the presence of a April peak in the high rainfall regions. It was therefore concluded that this was not a long term characteristic of rainfall in the wetter parts of the Region.

7.3 MEAN MONTHLY STREAMFLOW

Figures 7.5 to 7.7 show the temporal variation of the mean and standardised mean monthly streamflows for each of the sub-catchments for the period 1960-1975.

For convenience they were grouped into two major drainage basins; River Severn (Fig 7.5) and River Wye (Fig 7.6), and a miscellaneous group (Fig 7.7) containing the Usk, Cray, Tycastell and Glan Teifi sub-catchments. In order to study the differences in temporal variation that existed between the catchments, it was clearly necessary to standardise the flow in some way. This was achieved by expressing the mean monthly flows for each sub-catchment as a ratio of one twelfth of the mean annual flow. Thus, the standardised mean monthly flow ($\overline{q}_i$) for the ith month was evaluated as follows:

$$\overline{q}_i = 12\ \overline{Q}_i/\overline{Q}_a \qquad (7.2)$$

where $\overline{Q}_i$ = mean monthly flow for the ith month (m^3/s), and

$\overline{Q}_a$ = mean annual flow (m^3/s).

Inspection of the standardised mean flow curves (1960-75) showed several features worth noting.

1) A general annual cycle with winter maximum and summer minimum which was clearly related to the variation of rainfall minus evaporation, as would be expected, but not completely defined by it.
2) Maximum flow in high rainfall sub-catchments was reached in December, whereas in low rainfall sub-catchments it was not reached until January. However, this was only to be expected since it corresponded with the occurrence of maximum rainfall in these catchments (see Fig 7.3).
3) The general decline in mean flow between January and June showed a marked levelling off between March and April, particularly in the high rainfall sub-catchments. Once again inspection of the rainfall distributions (Fig 7.3) showed that this was due to the spring time peak in rainfall which was particularly distinct in the high rainfall sub-catchments.
4) Minimum flow in high rainfall sub-catchments occurred in June/July, whereas that in the low rainfall sub-catchments occurred in August/September, in spite of the fact that rainfall increased significantly in July, August and September.

This is a feature which is of considerable importance and is discussed later in this section and again in much greater detail later in the chapter.

In order to assess the sensitivity of these features to the length of record used in the analysis, the monthly flow distributions corresponding to the long records (1938-75) for the Wye sub-catchments (Fig 7.8) were compared with the corresponding short record distributions (Fig 7.6). It was clear from this comparison that the levelling off of flow between March and April, which was so apparent in the 1960-75 data, was far less pronounced in the 1938-75 data, and could not therefore be considered as a general feature. The other features were, however, confirmed by this comparison.

To investigate the influence of mean annual rainfall upon the temporal variation of mean monthly flows, the data were grouped into three categories based upon annual rainfall as defined in Table 7.2. These data were plotted, as shown in Fig 7.9, and used to evaluate mean distributions for the three categories (Fig 7.10).

The most important features of these are:

i) the close fit between the distribution for the high rainfall sub-catchments inspite of the fact that some of them are almost 100 Km apart;

ii) the very late increase in flow which is characteristic of low rainfall sub-catchments.

The latter point was mentioned earlier and was described as being of great importance. The reason for this is that it is due to the replenishment of sub-catchment storage, in particular the replenishment of soil moisture. During the summer months the low rainfall sub-catchments accumulate a large soil moisture deficit which must be replenished before any significant increase in streamflow can

TABLE 7.2 SUB-CATCHMENTS CLASSIFICATION BASED UPON ANNUAL RAINFALL (1960-75)

Sub-catchment Name	Annual Rainfall (mm)	Classification I	Classification II
Cray	2494	High	Excluded
Vyrnwy	1879	High	High
Abernant	1850	High	High
Caban Coch	1821	High	High
Rhayader	1631	High	High
*Tycastell	1541	Medium/wet	Medium
Usk	1353	Medium/wet	Medium
*Glan Teifi	1317	Medium/wet	Medium
Upper Wye	1218	Medium/wet	Medium
Upper Severn	1130	Medium/dry	Medium
Tenbury	849	Medium/dry	Low
*Mid-Wye	911	Low	Low
Lower Wye	833	Low	Low
Mid-Severn	718	Low	Low

Note:

GROUP I

High (H) $r > 1600$ mm
Medium/wet (M_w) $1600 > r > 1218$ mm
Medium/dry (M_d) $1218 > r > 849$ mm
Low (L) $r < 849$ mm

GROUP II

High (H) $r > 1600$ mm
Medium (M) $1600 > r > 1130$ mm
Low (L) $r < 1130$ mm

* These sub-catchments were not included in the cross correlation analysis.

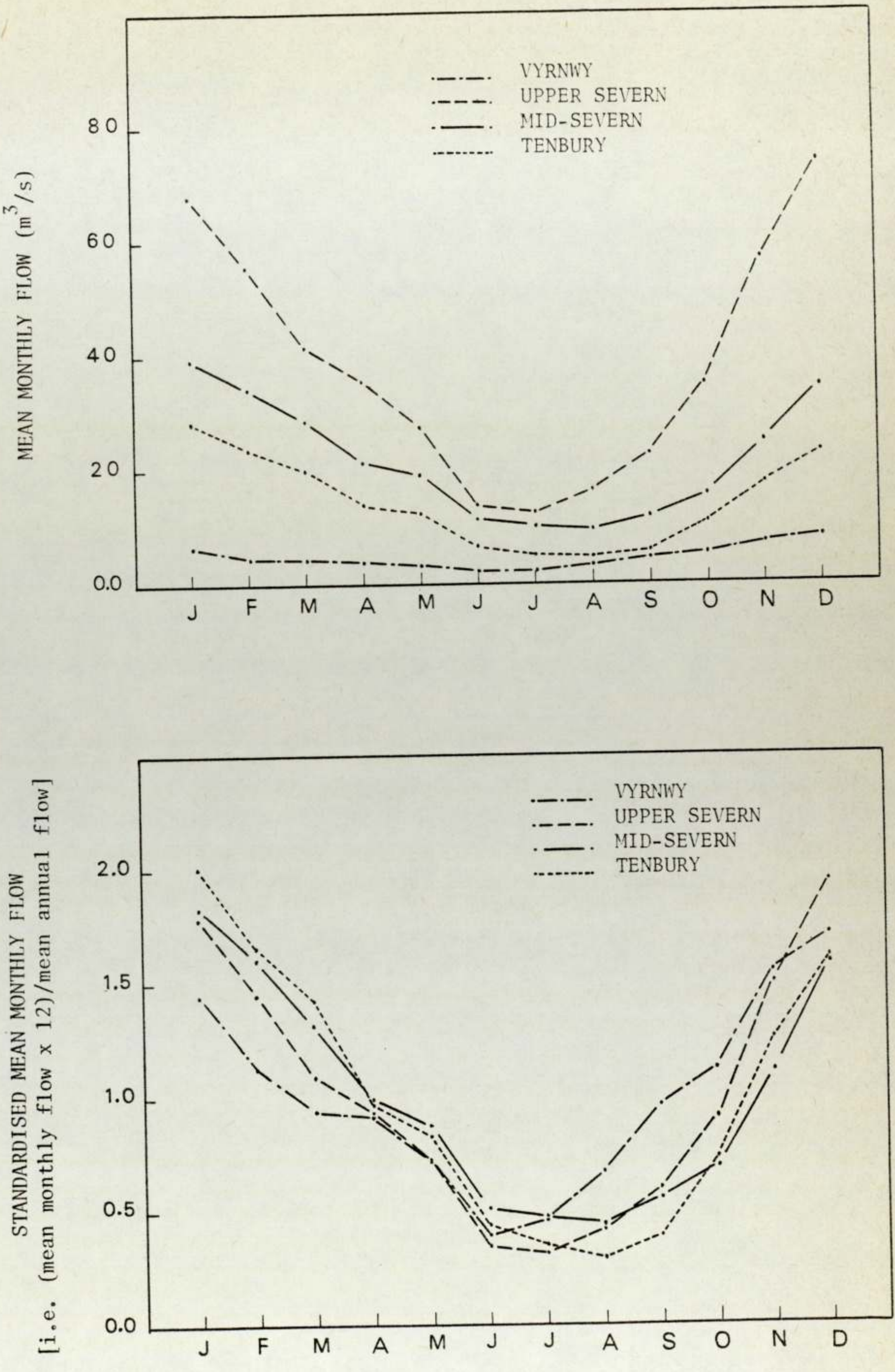


FIGURE 7.5 MEAN AND STANDARDISED MEAN FLOWS FOR RIVER SEVERN SUB-CATCHMENTS (1960-1975)

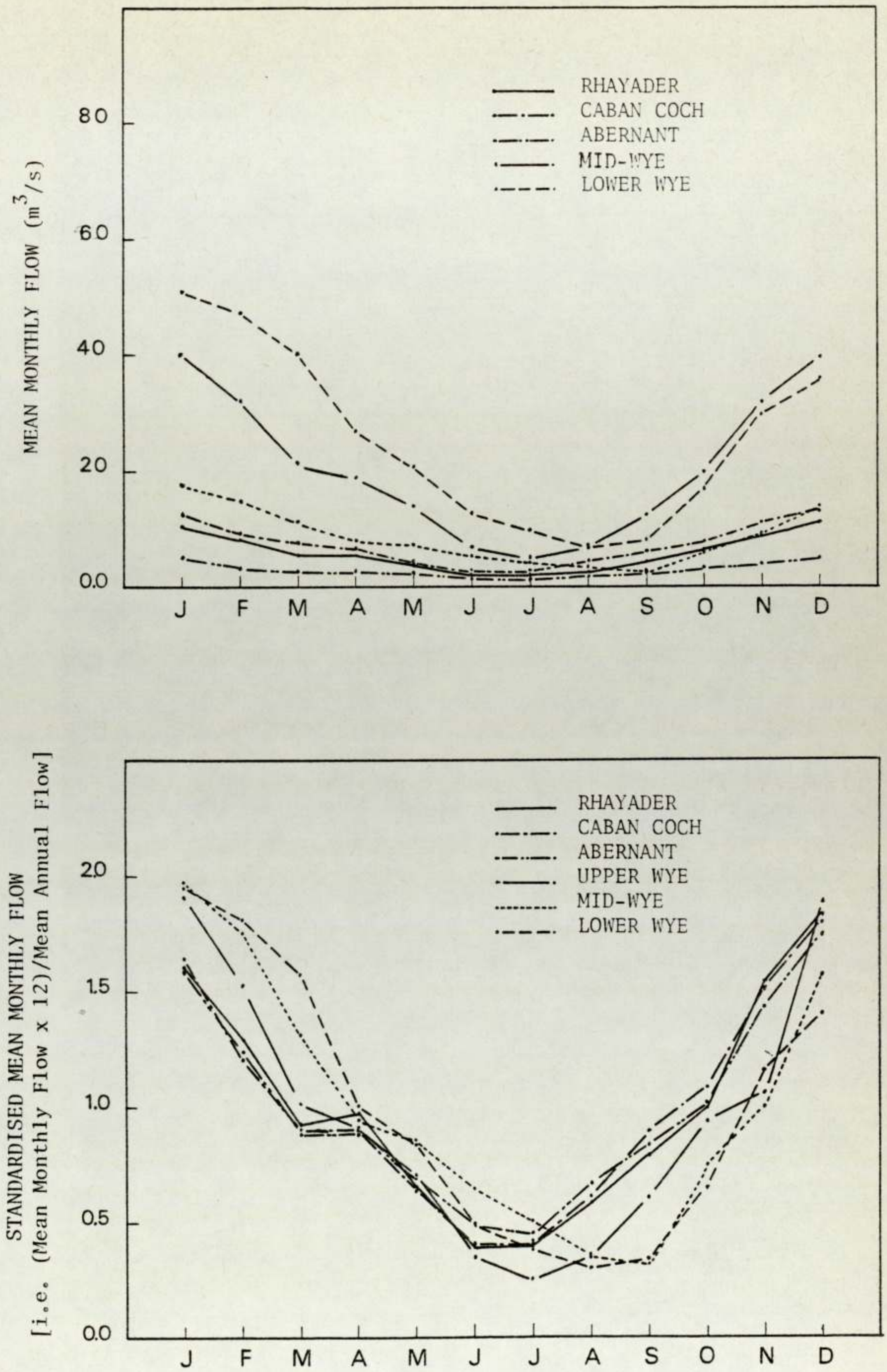


FIGURE 7.6 MEAN AND STANDARDISED MEAN FLOWS FOR RIVER WYE SUB-CATCHMENTS (1960-1975)

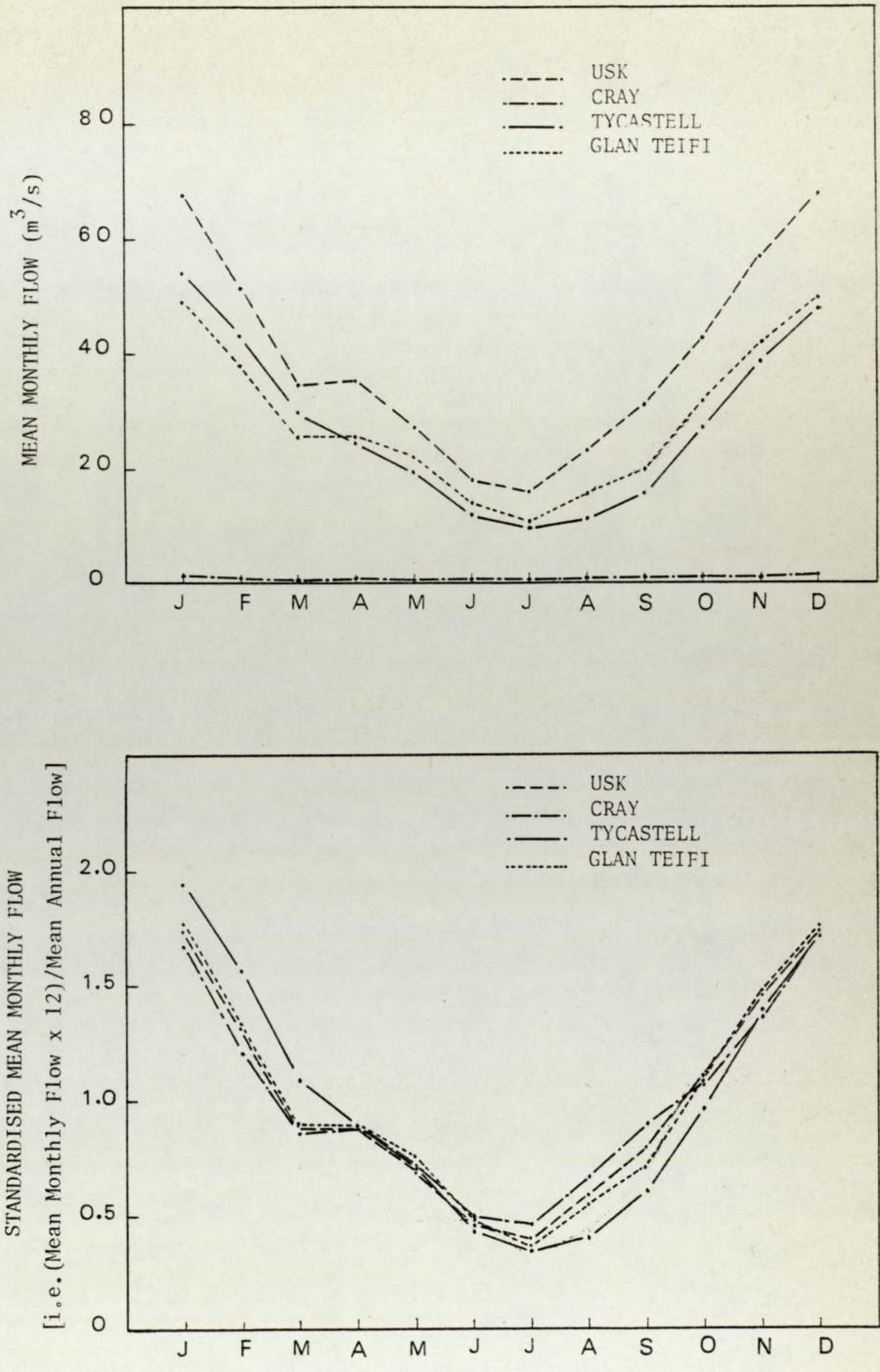
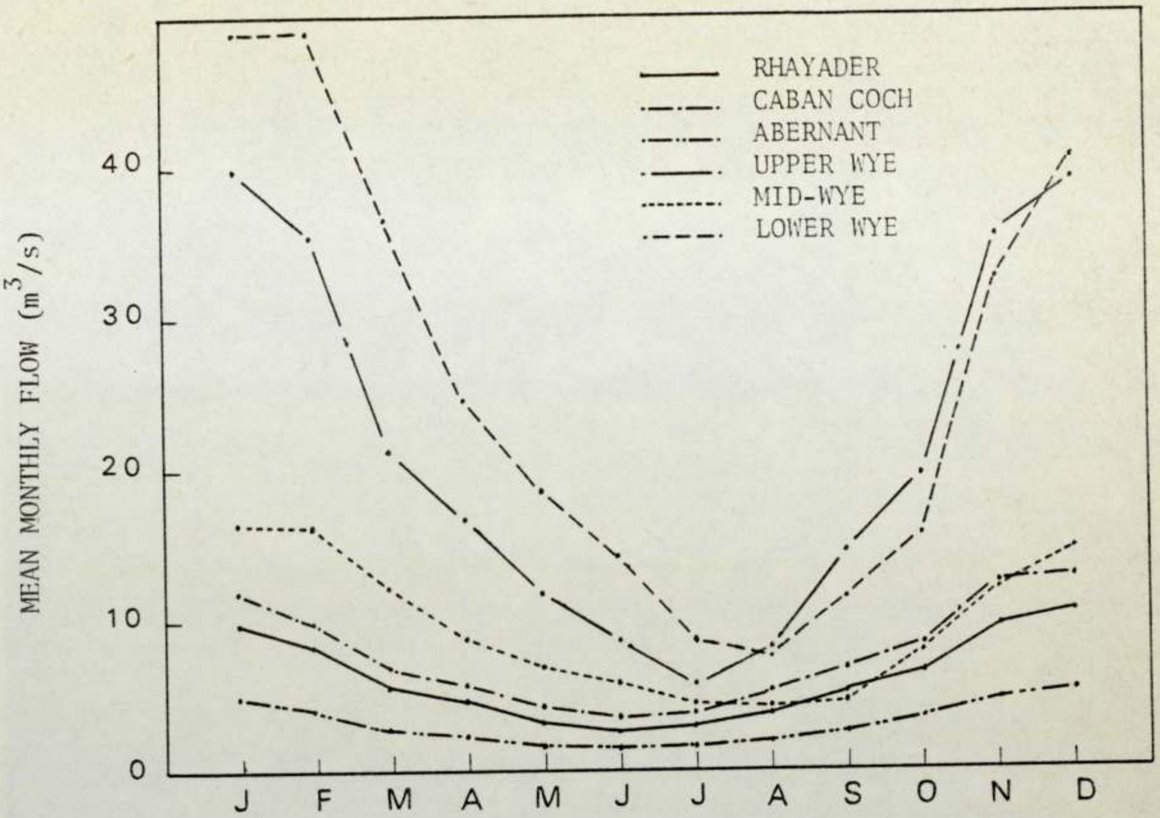


FIGURE 7.7 MEAN AND STANDARDISED MEAN FLOWS FOR RIVER USK, TOWY AND TEIFI SUB-CATCHMENTS (1960-1975)



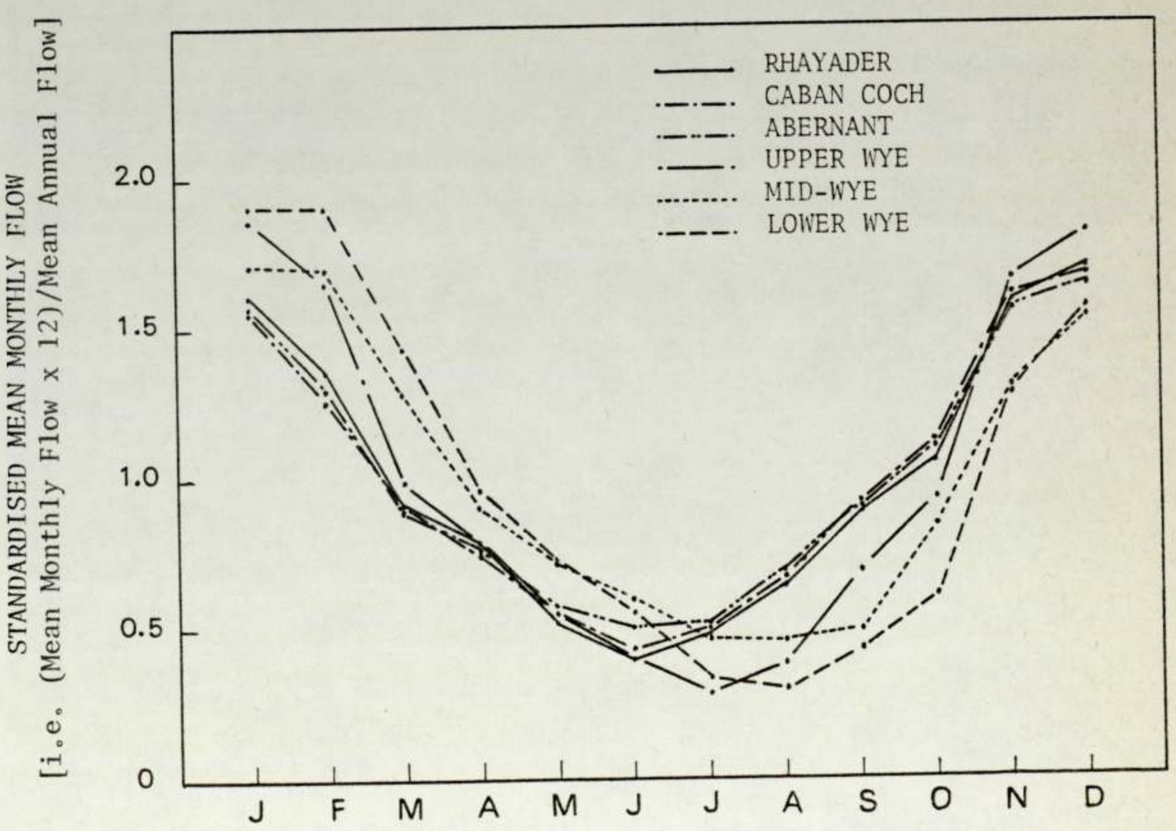


FIGURE 7.8 MEAN AND STANDARDISED MEAN FLOWS FOR RIVER WYE SUB-CATCHMENTS (1938-1975)

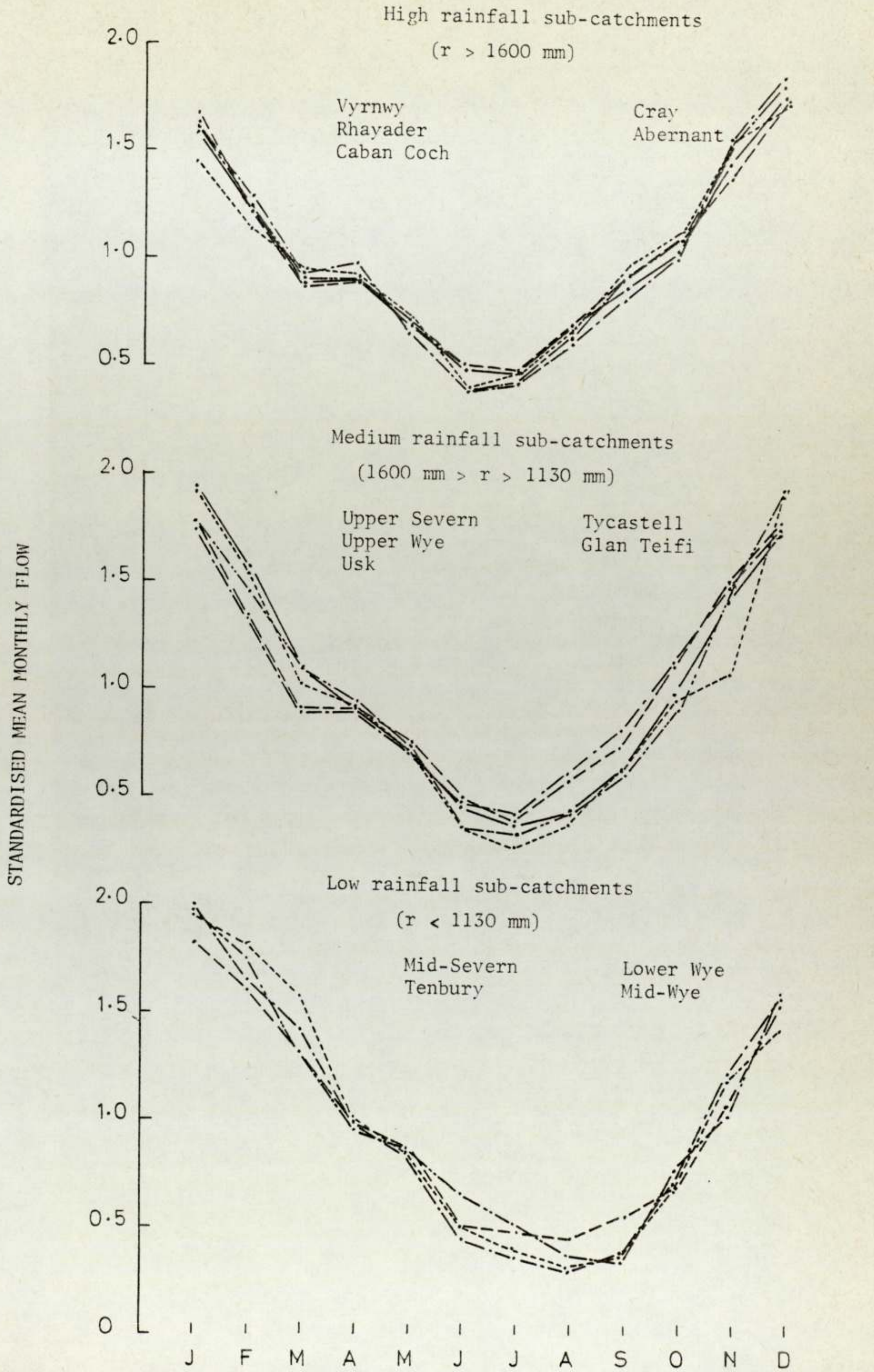


FIGURE 7.9 TEMPORAL VARIATION OF STANDARDISED MEAN MONTHLY FLOW (1960-75)

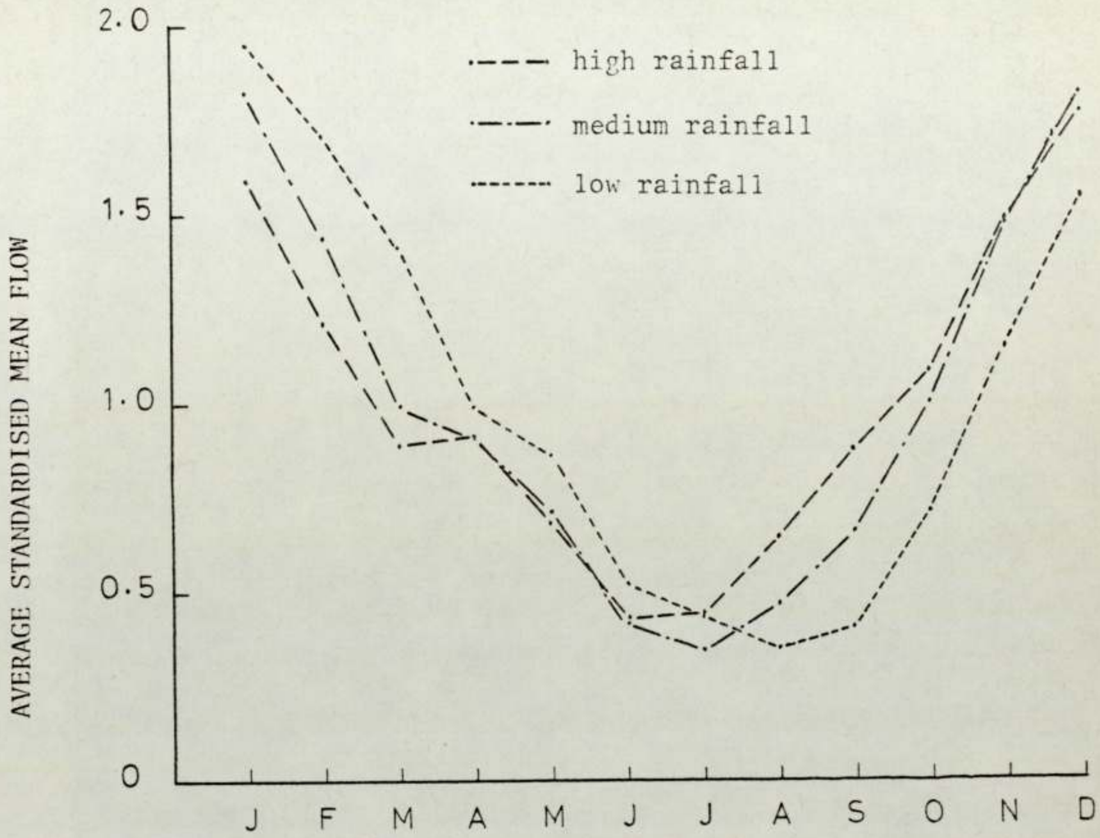


FIGURE 7.10 VARIATION OF AVERAGE STANDARDISED MEAN FLOW BETWEEN THE GROUPED SUB-CATCHMENTS (1960-75)

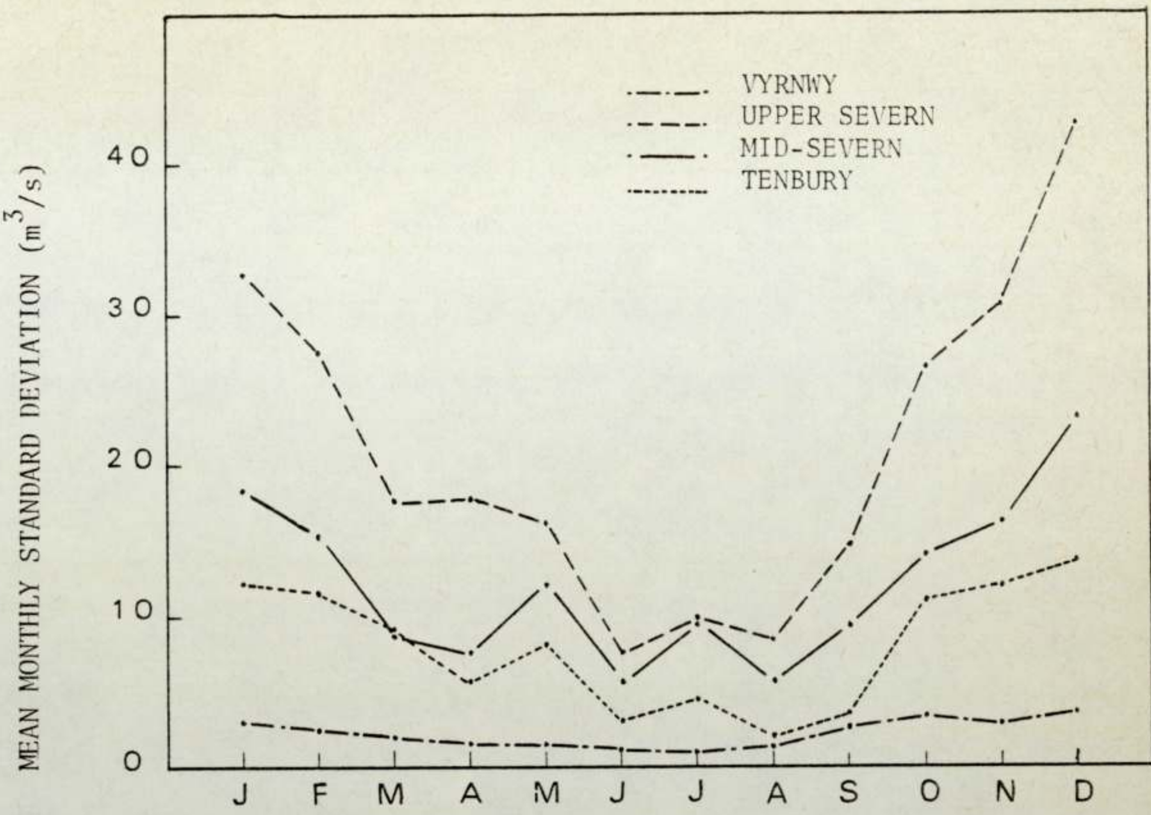
occur. Thus the shift in the minimum flow from June in high rainfall regions to August in regions of low rainfall is due primarily to the accumulation of soil moisture deficit in the low rainfall/high evaporation regions. This phenomenon is considered in detail in Section 7.10 and 7.11.

7.4 STANDARD DEVIATION OF MONTHLY STREAMFLOW

Figure 7.11 to 7.13 show the plot of mean monthly standard deviation and the standardised mean standard deviation for the river basin groupings defined in the previous section. These figures reveal that annual cycles, similar to those for mean flow also exist for the standard deviations of monthly flows. The standardisation of standard deviations was achieved by expressing monthly values as ratios of the standard deviation of the mean annual flow.

In order to assess the sensitivity of the standard deviation to the length of record used in the analysis, the short record standard deviations for the Wye sub-catchments (Fig 7.12) were compared with the corresponding values obtained for the long record (Fig 7.14). It was clear from this comparison that the variation due to the difference in record length was small compared with variations that existed between the sub-catchments. Both records displayed a distinct temporal variation in standardised standard deviation which was similar in form to the temporal variation of the standardised streamflow.

To investigate the influence of mean annual rainfall upon the temporal variation of the standardised standard deviation of monthly streamflow, the sub-catchments were grouped into the three categories used earlier. The monthly variation of the standardised standard deviation of each group was plotted as shown in (Fig 7.15).



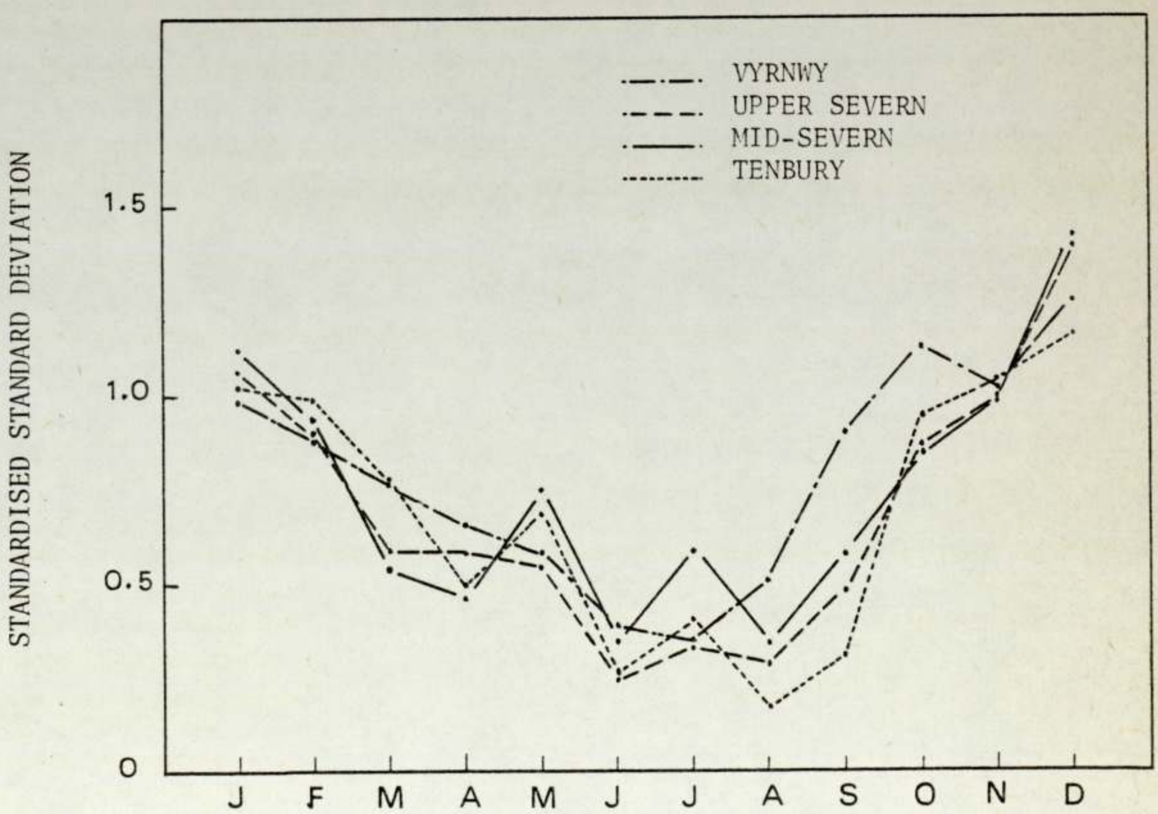


FIGURE 7.11 MEAN AND STANDARDISED STANDARD DEVIATION FOR RIVER SEVERN SUB-CATCHMENTS (1960-1975)

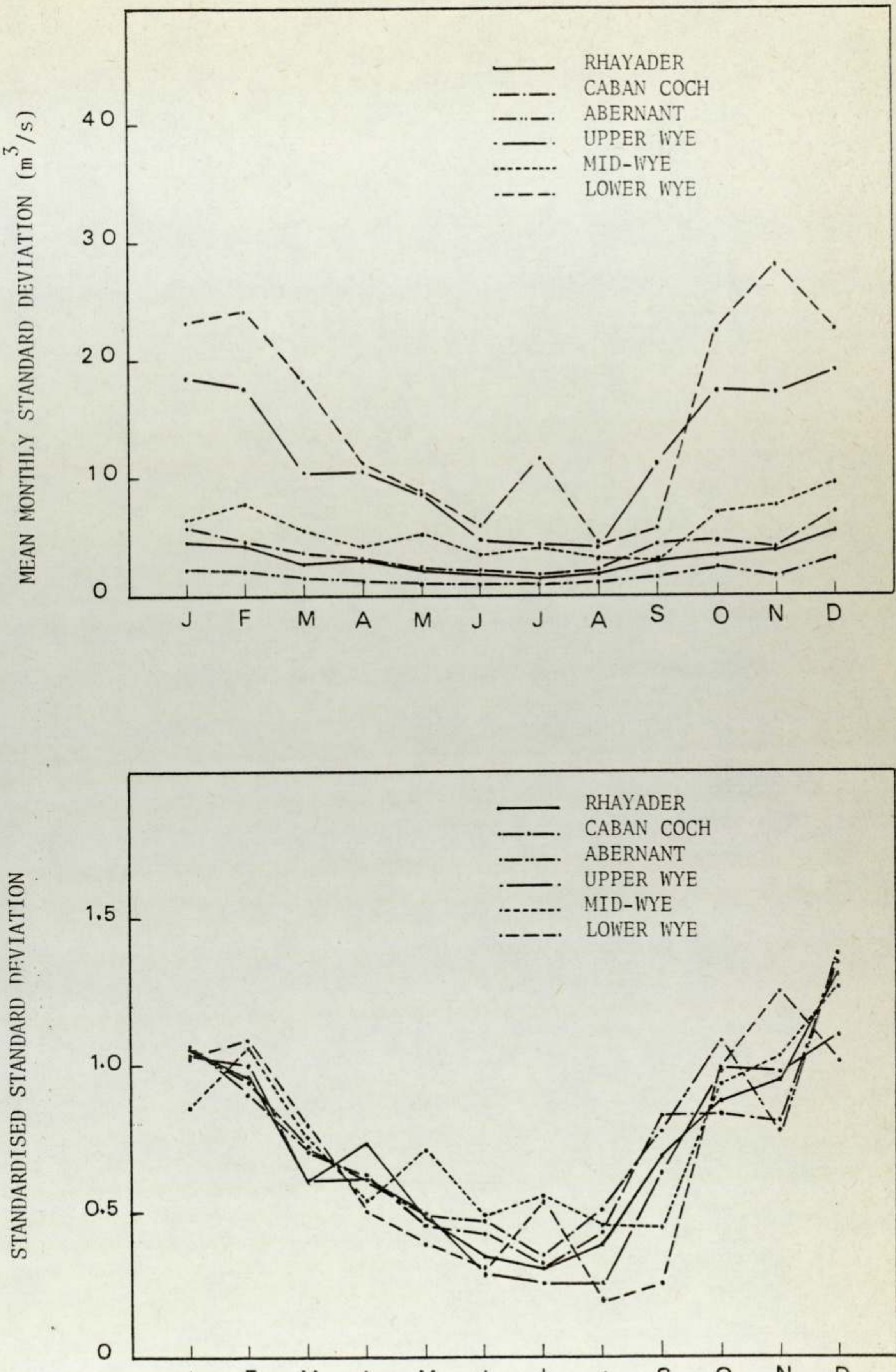
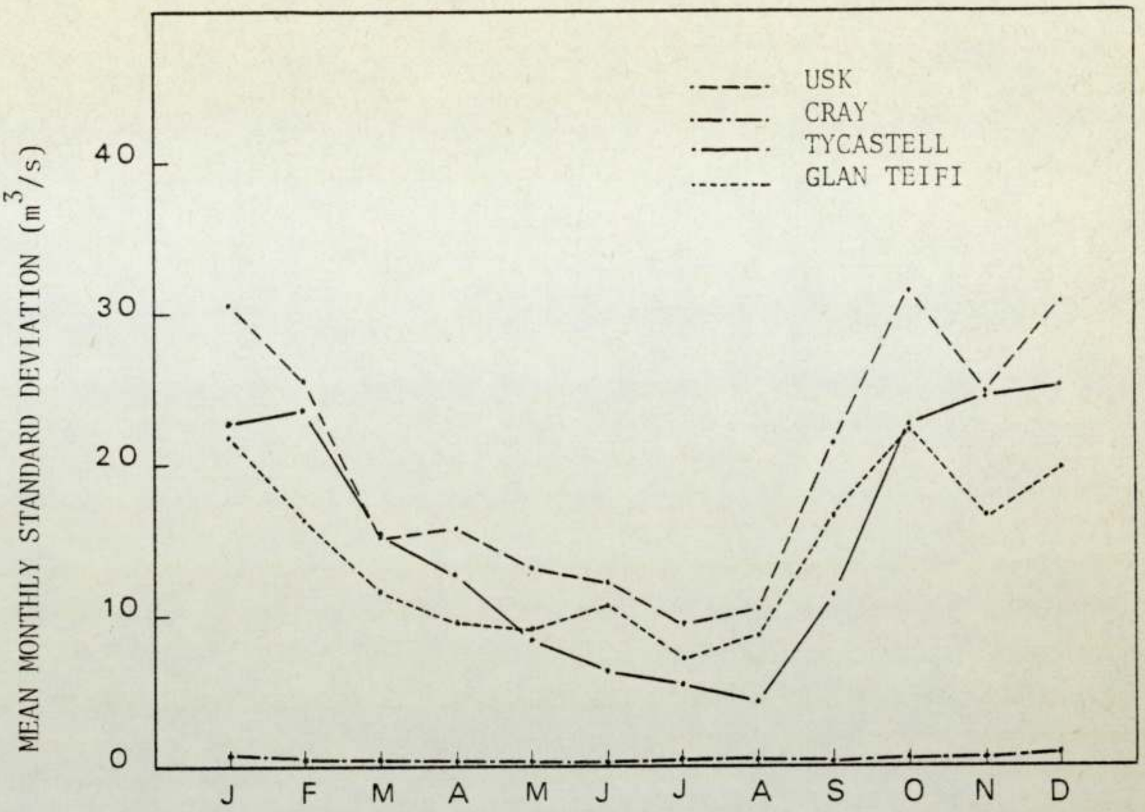


FIGURE 7.12 MEAN AND STANDARDISED STANDARD DEVIATION FOR RIVER WYE SUB-CATCHMENTS (1960-1975)



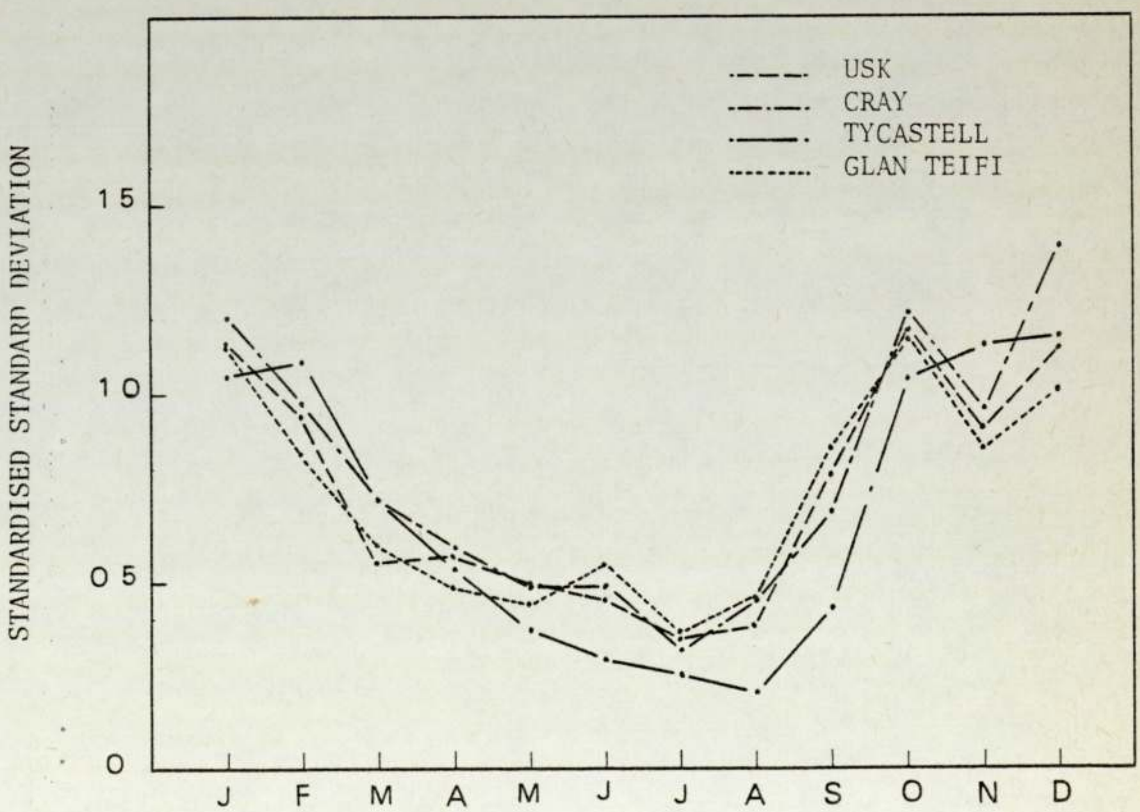
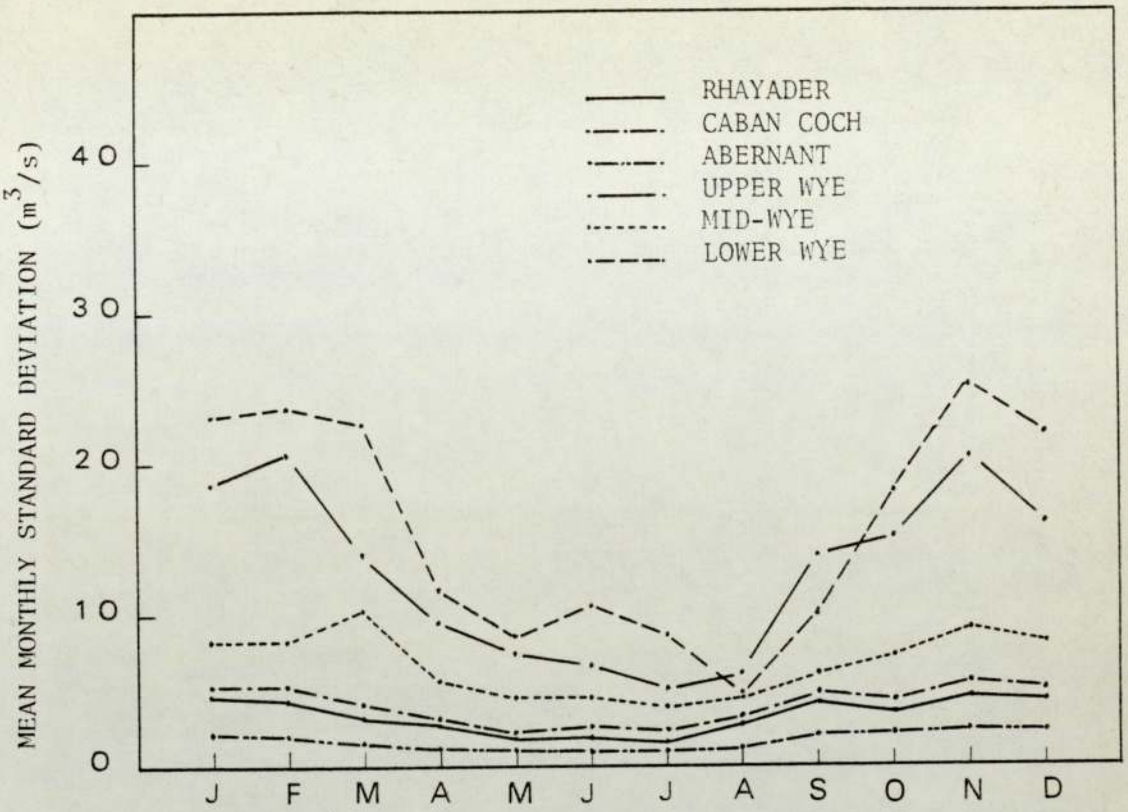


FIGURE 7.13 MEAN AND STANDARDISED STANDARD DEVIATION FOR RIVER USK, TOWY AND TEIFI SUB-CATCHMENTS (1960-1975)



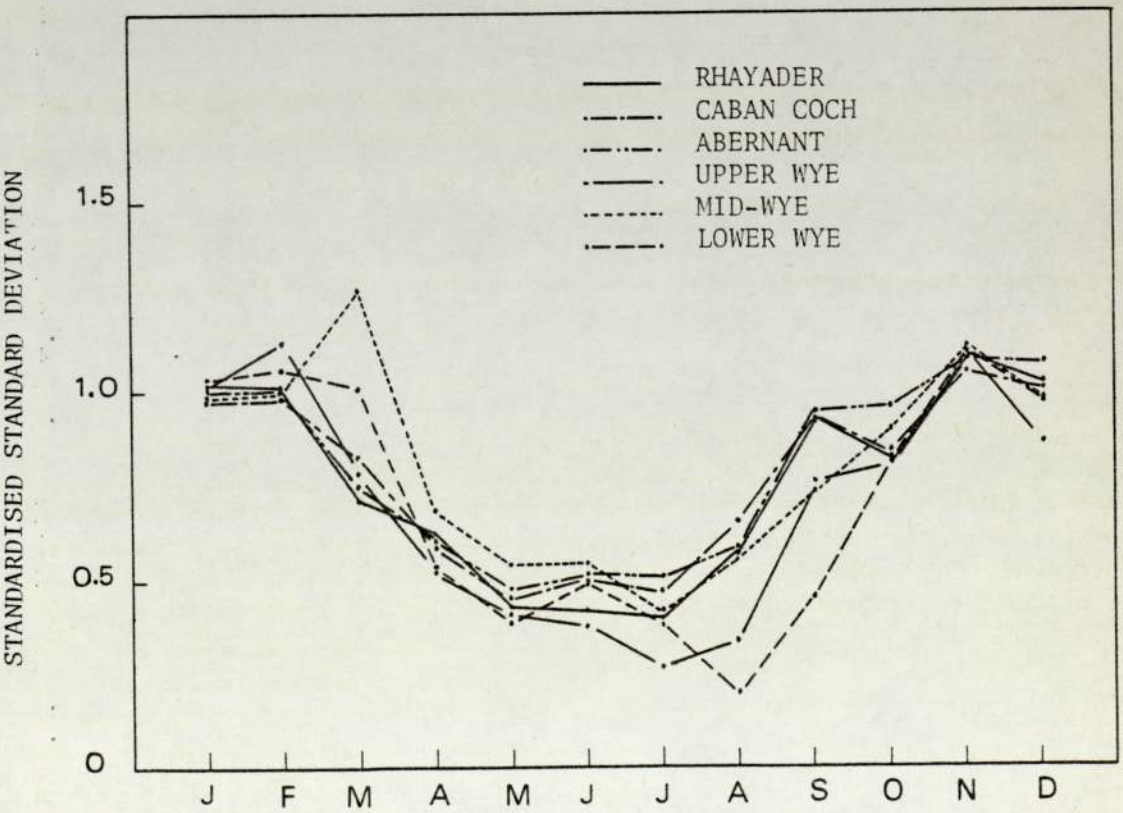


FIGURE 7.14 MEAN AND STANDARDISED STANDARD DEVIATION FOR RIVER WYE SUB-CATCHMENTS (1938-1975)

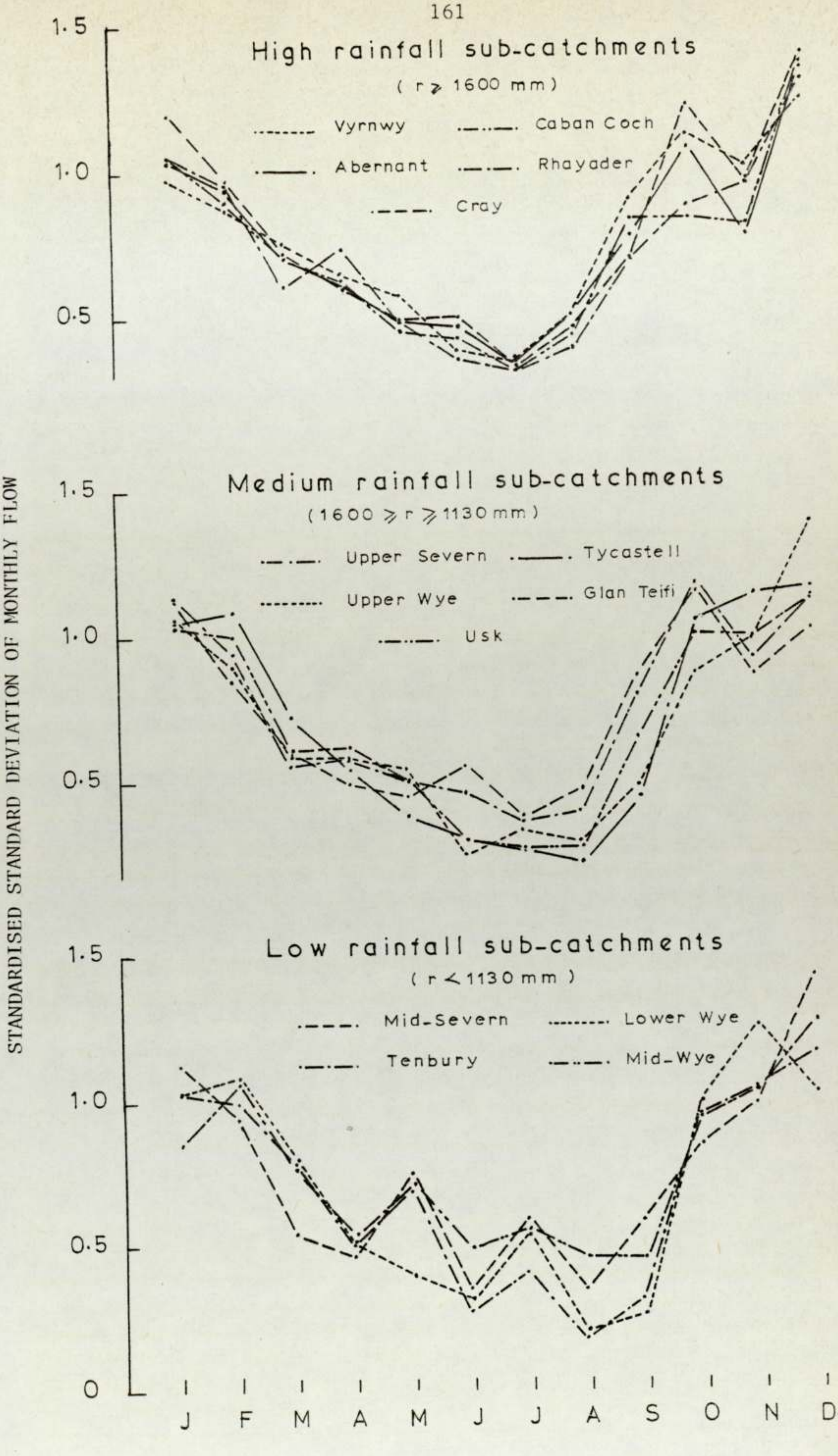


FIGURE 7.15 TEMPORAL VARIATION OF STANDARDISED STANDARD DEVIATION OF MONTHLY FLOW (1960-75)

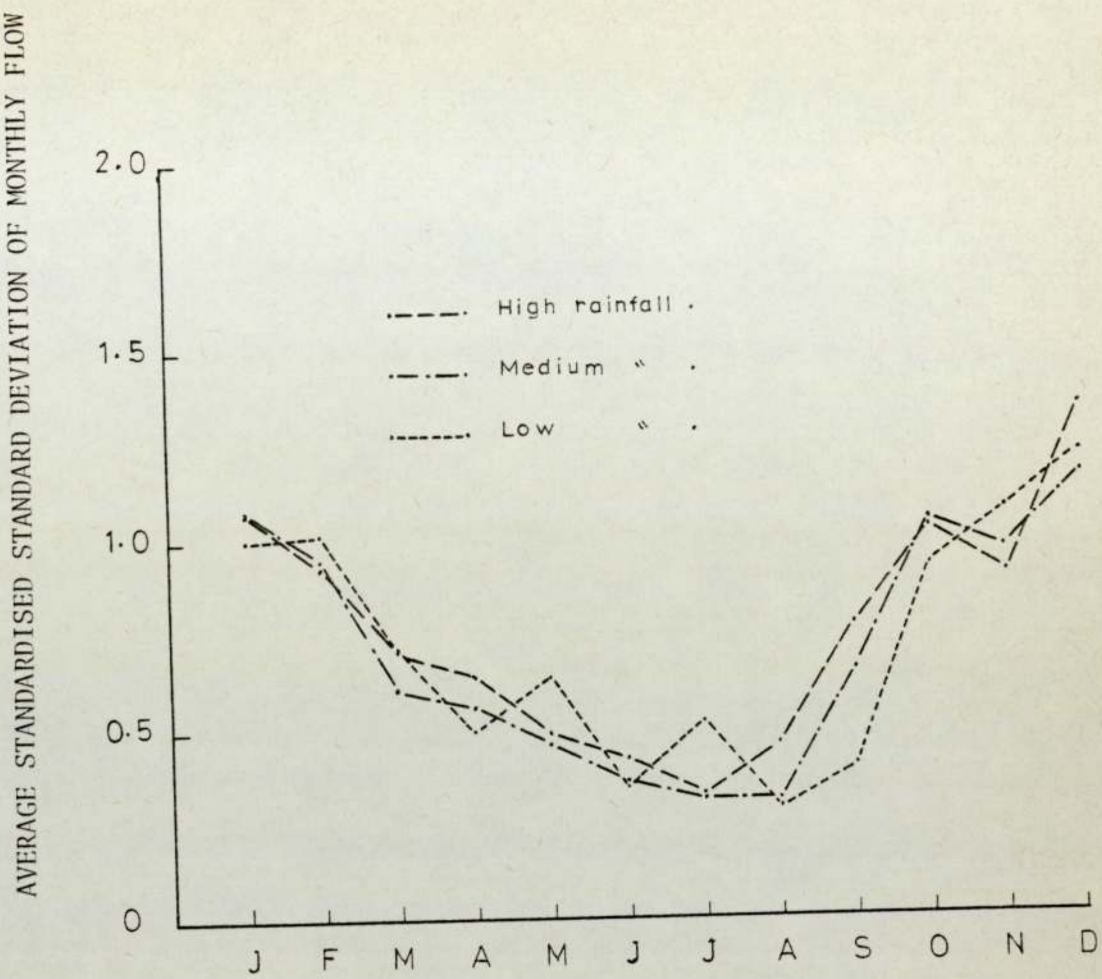


FIGURE 7.16 VARIATION OF STANDARDISED STANDARD DEVIATION OF MEAN FLOW BETWEEN THE GROUPED SUB-CATCHMENTS

The average variation for each of the three groups is shown in (Fig 7.16).

The most important features of these are:

1) the high rainfall sub-catchments were more consistent in their temporal variations than were the low rainfall catchments;
2) all three categories showed a steady decline in standard deviation starting in January and continuing through into the summer months;
3) all three categories showed a rapid increase in the standard deviation in the late summer and autumn;
4) the increase in standard deviation commenced earlier for high rainfall sub-catchments than for the low rainfall sub-catchments.

The rapid increase in standard deviation mentioned in item (3) above was not apparent in the long record data (Fig 7.14) and is therefore not considered to be a proven characteristic. The temporal variation of standard deviation is clearly related to the temporal variation of mean flow. However, it is not a simple linear relationship, but it does in part explain the characteristic mentioned in item (4) above.

7.5 SKEWNESS COEFFICIENT OF MONTHLY STREAMFLOW

Figure 7.17 illustrates the variation of the monthly skewness coefficients for the sub-catchments grouped into high, medium and low rainfall classifications. The results reveal that most of the sub-catchments in each group behave in a very similar manner. Figures 7.18 and 7.19 illustrate the sensitivity of these results to the length of record used in the analysis.

The results of the short record analysis (Fig 7.17) show that the skewness coefficient for high rainfall regions remains constant at about 0.5 throughout the year except for a peak in October of 1.4 and a very distinct peak of 2.2 in March. The results of the sensitivity test (Fig 7.18) tend to indicate that both of these peaks are significant. The March peak is thought to be due to snow melt run-off, which on occasions produces exceptionally high flows, and consequently high skewness coefficients. No adequate explanation has been found for the occurence of the October peak.

The medium rainfall group exhibits peaks of 1.8 and 2.3 in March and July respectively. Again the March peak, now less pronounced, is thought to relate to snow melt run-off. No adequate explanation has been found for the existance of the July peak.

The low rainfall group exhibits no peaks at all in March which implies that the snow melt effect on skewness is negligible in lowland regions. This is an acceptable explanation since snow rarely lies for more than a few days in lowland areas. July and August exhibit extreme high and low values of skewness, but it is difficult to say whether these are occurrences of statistical significance.

The sensitivity test, which was carried out on main catchment data, to avoid problems relating to possible errors in the Lower Wye data set, tended to indicate that these were in fact chance occurrences. However, it can be concluded from the results that the skewness coefficients throughout the year tend to be higher for flows from low rainfall sub-catchments than for flows from high rainfall sub-catchments.

A parameter, which was considered to be an important factor governing the magnitude of the skewness coefficient, was the ratio of mean monthly flow to monthly standard deviation (Ratio).

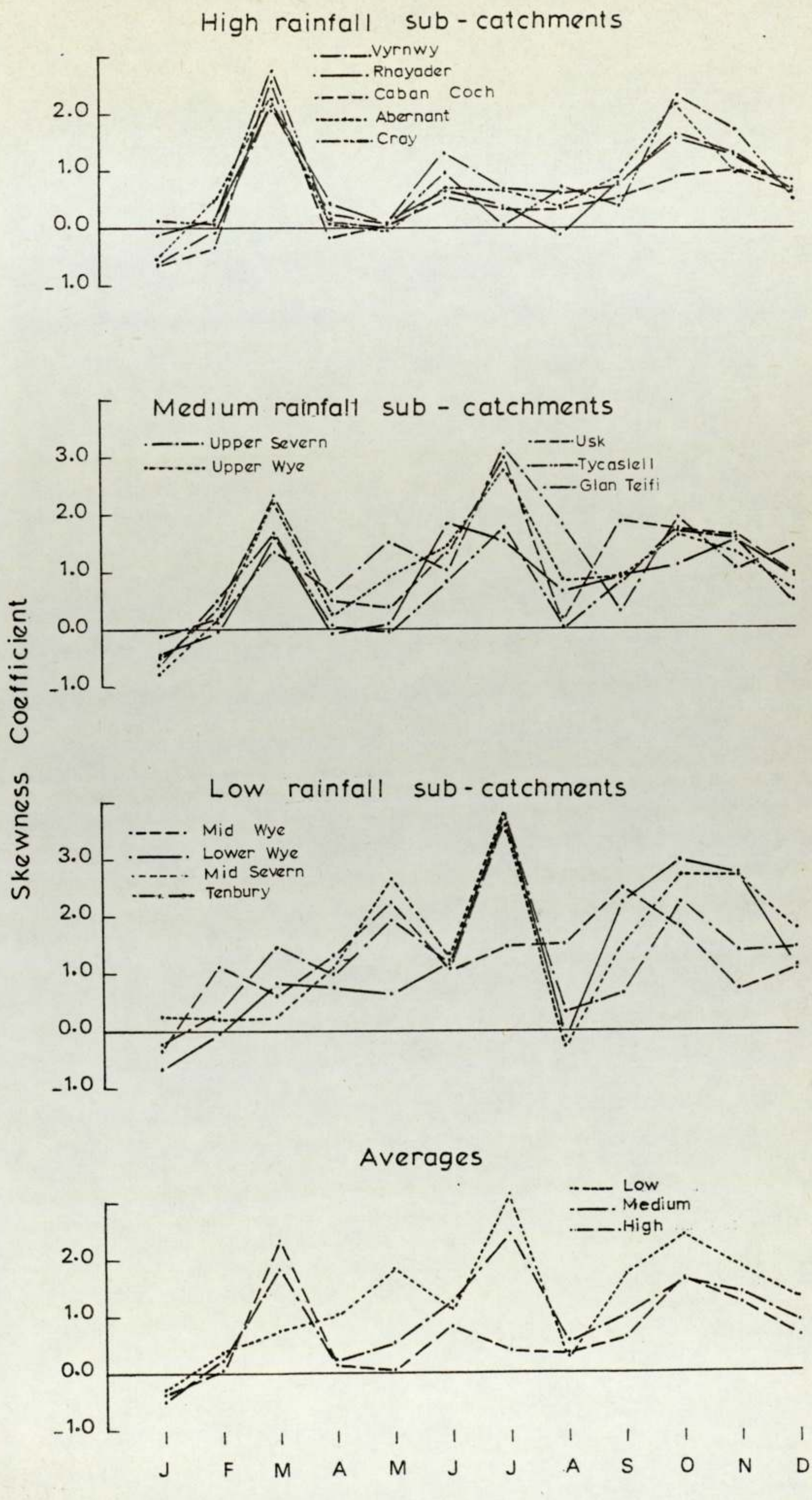


FIGURE 7.17 VARIATION OF MONTHLY SKEWNESS COEFFICIENTS (1960-75)

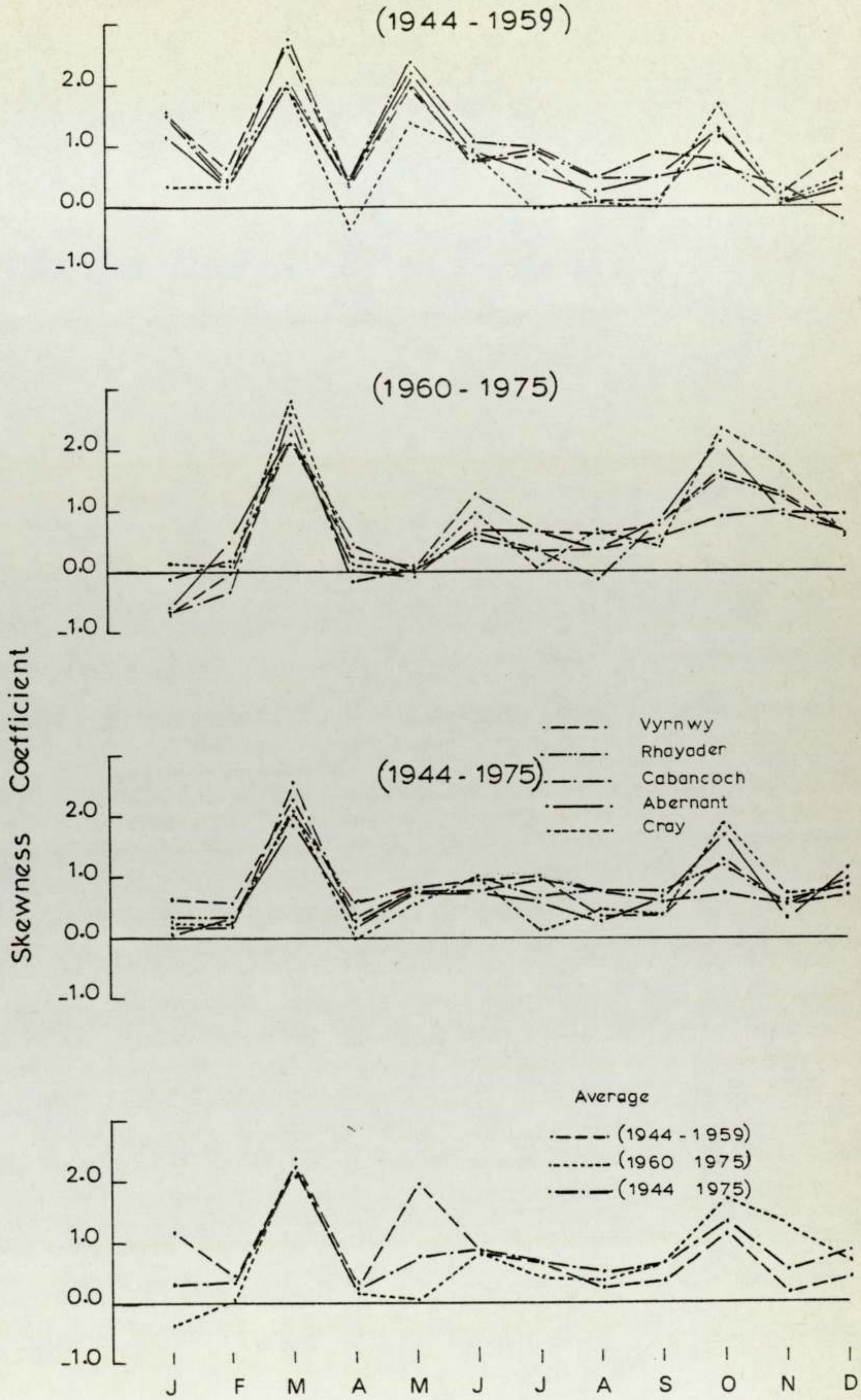


FIGURE 7.18 VARIATION OF MONTHLY SKEWNESS COEFFICIENTS FOR FIVE MOUNTAINOUS (HIGH RAINFALL) SUB-CATCHMENTS

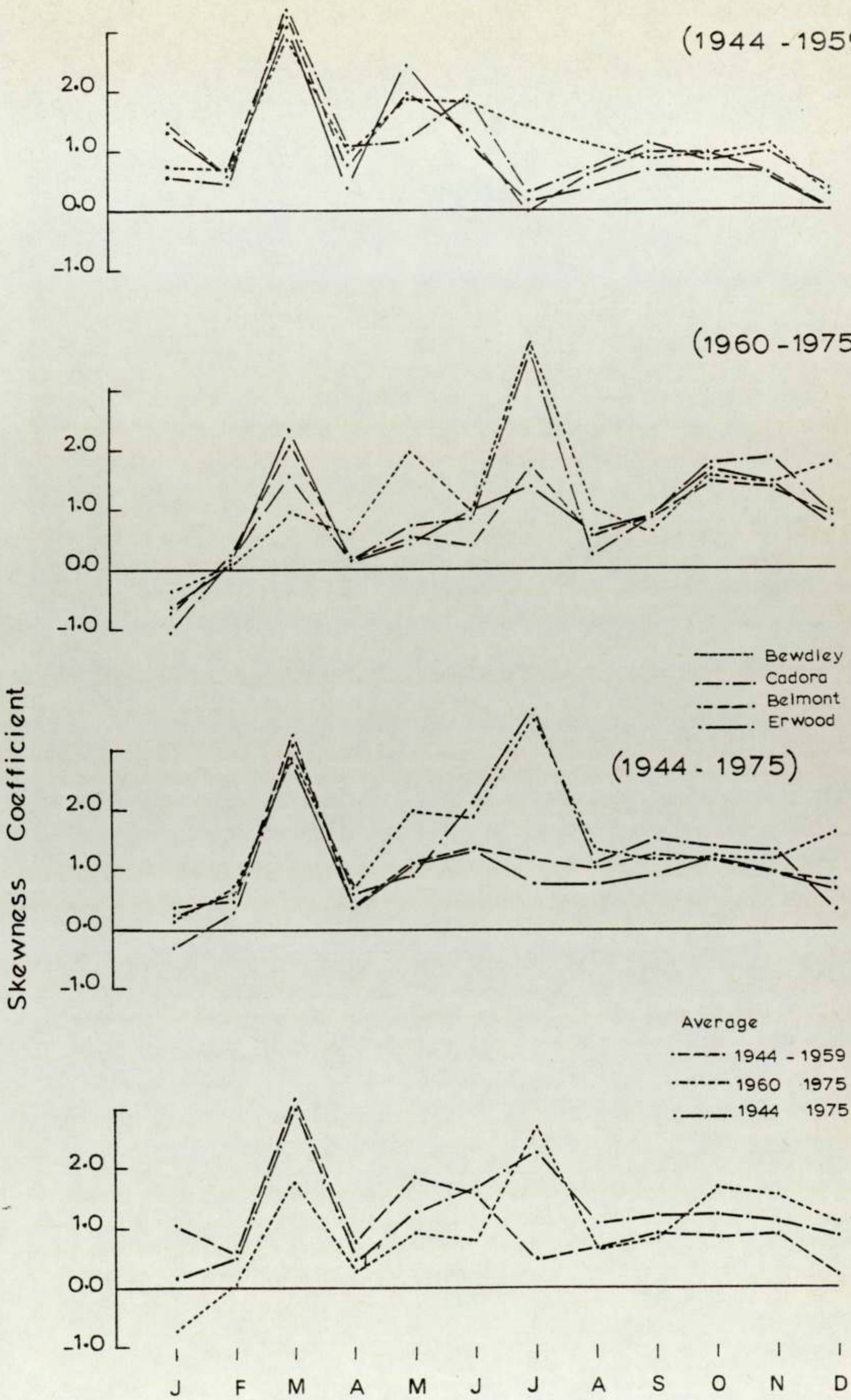


FIGURE 7.19 VARIATION OF MONTHLY SKEWNESS COEFFICIENTS FOR FOUR MAIN CATCHMENTS

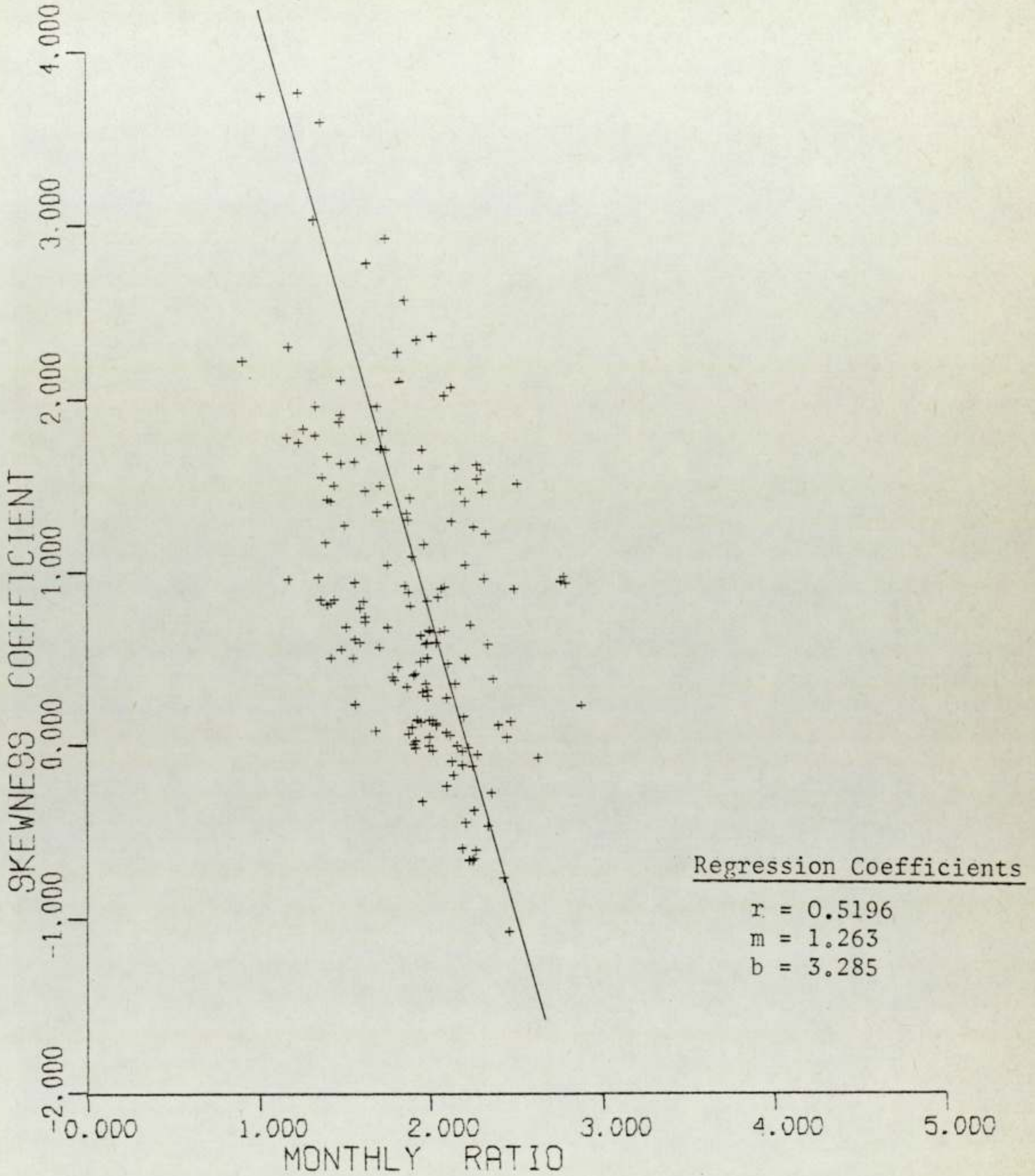


FIGURE 7.20 MONTHLY RATIO (i.e. mean/st.dev.) AND SKEWNESS COEFFICIENT RELATIONSHIP

Clearly, the skewness of a distribution, which has a lower bound of zero, will tend to increase as the Ratio (mean/stand.dev.) decreases. Since streamflow has a lower bound of zero, it is reasonable to assume that its skewness coefficient will be related to Ratio. On plotting skewness coefficient against Ratio (Fig 7.20) it was apparent that a relatively weak relationship existed of the form:

$$(\text{Skew}) = 3.29 - 1.26\ (\text{Ratio}) \qquad (7.4)$$

However, a strong relationship could not be expected in this case, because skewness coefficient is a third order moment which tends to exaggerate sampling errors and the sample was relatively small.

7.6 SERIAL CORRELATION AND REGRESSION COEFFICIENTS OF MONTHLY STREAMFLOW

Figures 7.21 and 7.22 show the temporal variation of the monthly serial correlation coefficient and monthly regression coefficient respectively. Both show the variation for the sub-catchments grouped into the three rainfall categories. Within each group the variations were fairly consistent, except for Mid-Wye in the low rainfall group. However, inconsistency in the behaviour of this sub-catchment was not confined to serial correlation, it was most pronounced in its cross correlation coefficients (Section 7.7). No conclusive explanation has been found for these inconsistancies but they may be related to excessive bank storage within the Mid-Wye sub-catchment or simply to adverse combinations of gauging errors. Figures 7.21 and 7.22 also show the average variations for each of the three groups, excluding Mid-Wye.

It is difficult to draw any definite conclusions from these graphs, but two features are worth noting.

1) Taken overall the serial correlation coefficients are highest for the low rainfall (i.e. lowland) sub-catchments and lowest for the high rainfall (i.e. mountainous) sub-catchments. The range of the average values for each group is:

low rainfall	0.0 to 0.8
medium rainfall	-0.2 to 0.5
high rainfall	-0.4 to 0.3

The most likely explanation for this is that the lowland sub-catchments are slower draining and have a larger base-flow contribution than the mountainous sub-catchments, hence their flows are more persistent.

2) The effect of snow melt, which was apparent in the distribution of monthly skewness coefficients, is also apparent in the distribution of monthly serial correlation coefficients. In the mountainous and upland regions the months of January and February are often months during which snow accumulates. During March, however, much of this melts and adds to normal discharge, hence the flow in March increases at the expense of the flow in February. This results in negative correlation between February and March, hence the lag-one serial correlation coefficient for March tends to be negative, especially in the mountainous sub-catchments where the occurrence and accumulation of snow is greatest.

The most notable of the other variations is the distinct negative correlation coefficients that occur in August in both the high rainfall and medium rainfall groups. No conclusive explanation has been found for these, but they may be associated with the return

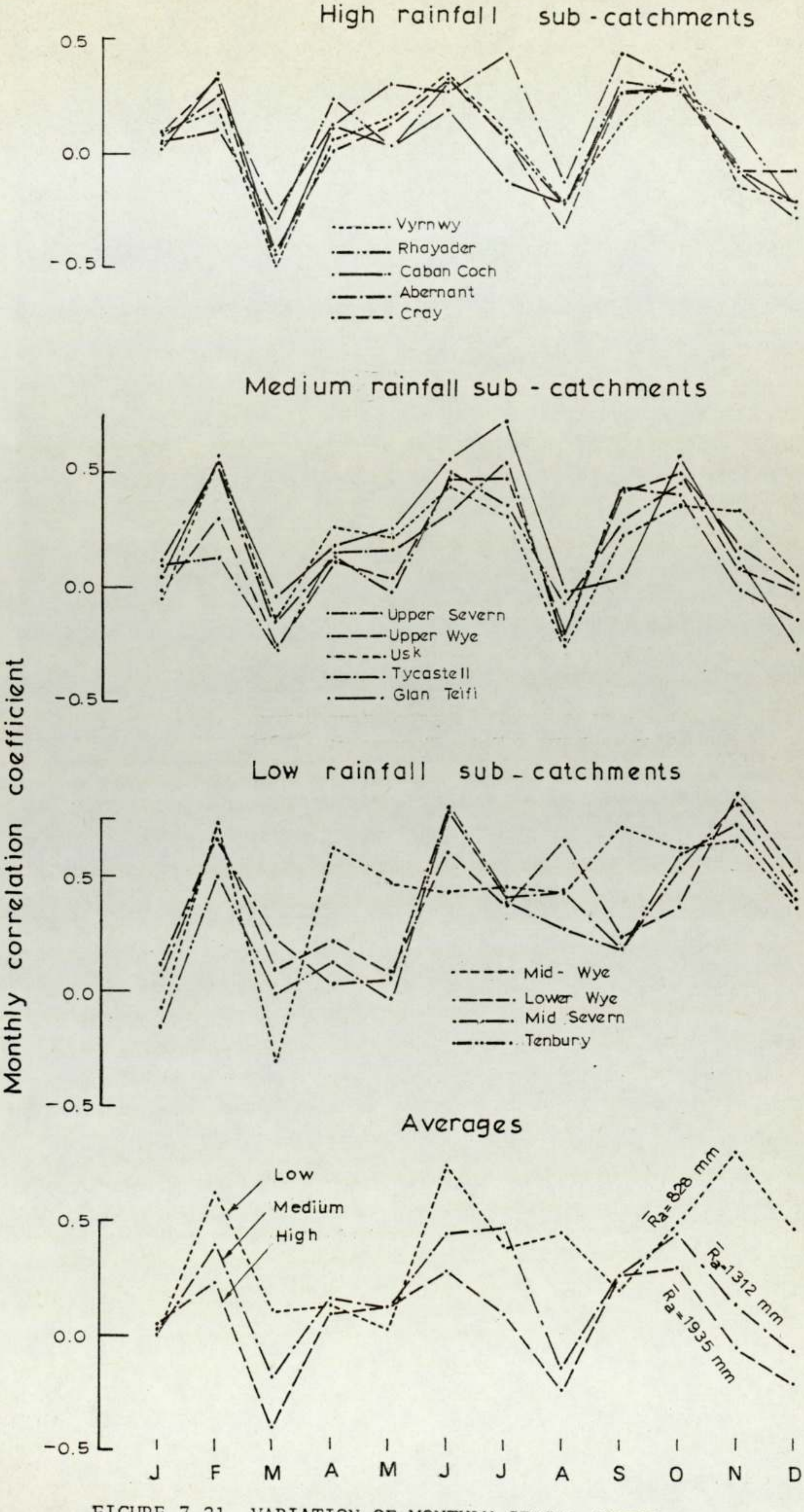


FIGURE 7.21 VARIATION OF MONTHLY SERIAL CORRELATION COEFFICIENTS (1960-75)

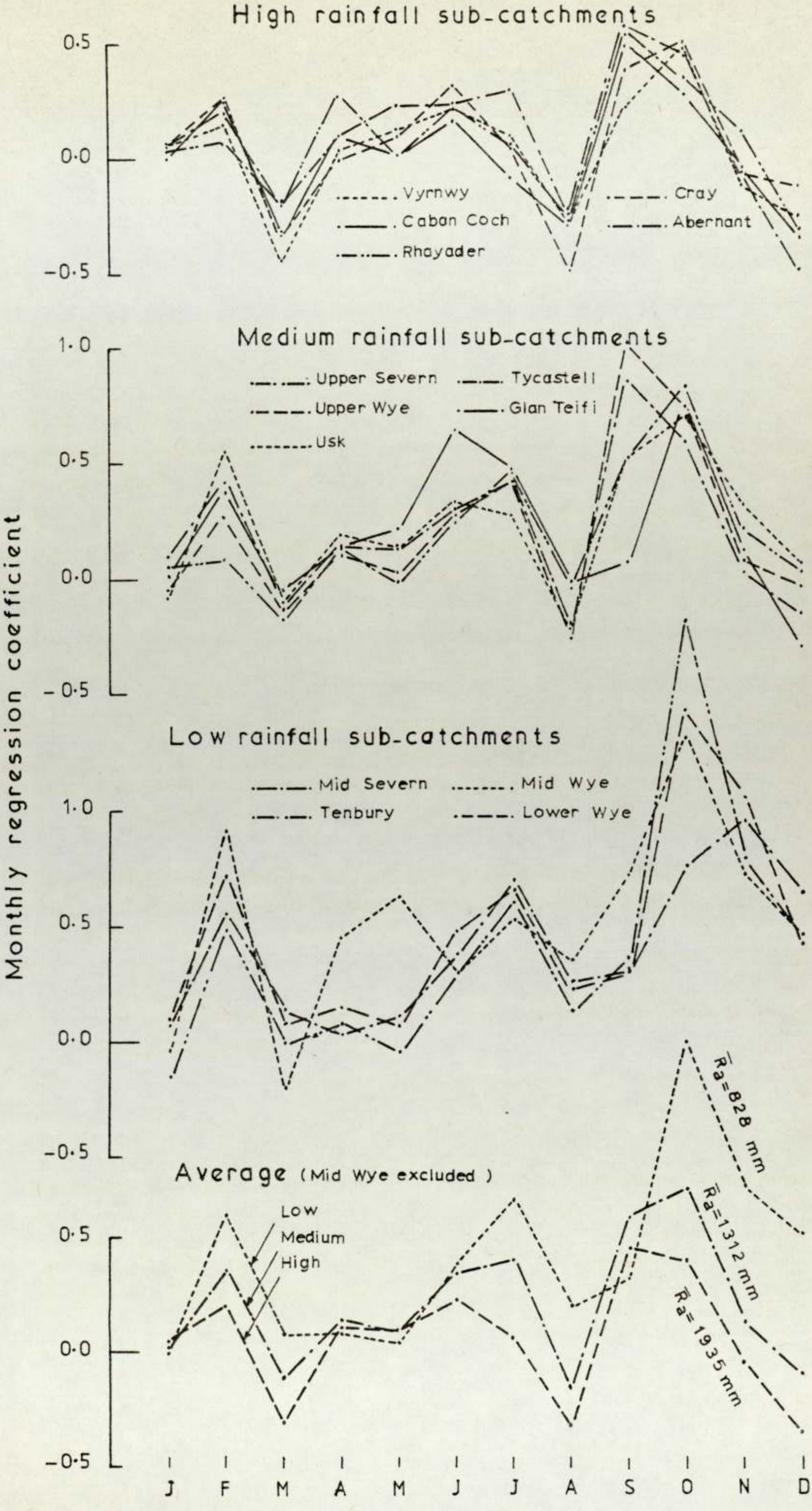


FIGURE 7.22 VARIATION OF MONTHLY REGRESSION COEFFICIENTS

to field capacity. On the other hand, it may be possible to explain these and other variations in terms of the temporal variation of rainfall. An investigation into the temporal variation of the serial correlation coefficients of monthly rainfall could prove valuable in this respect.

The temporal variation of the monthly regression coefficients are closely related to that of the serial correlation coefficients since:

$$b_j = r_j \; (S_j/S_{j-1}) \tag{7.5}$$

where,

b_j = regression coefficient for month j

S_j and S_{j-1} = the standard deviation of the monthly flow in months j and j-1.

r_j = lag-one serial correlation coefficient for month j.

Hence the two parameters are related by the factor (S_j/S_{j-1}) which tends to be less than one during the first half of the year and greater than one during the second half of the year. If this factor is taken into account, the comments made earlier about the variation of serial correlation coefficient also apply to the variation of regression coefficient.

7.7 CROSS CORRELATION ANALYSIS OF MONTHLY STREAMFLOW

7.7.1 Introduction

Gauging station flow data and the derived sub-catchment flow data were used in this analysis and both exhibited strong cross correlation between the individual data sets. This was especially true for high rainfall regions throughout the year, and also for other regions during the winter months. The medium and low rainfall catchments/sub-catchments exhibited relatively low cross correlation during the months of July and August. The lowest cross correlation coefficients were obtained when low rainfall sub-catchments were compared with high rainfall sub-catchments.

Inspection of the results indicated that the principal factor governing the cross correlation coefficient between any two gauging stations was the difference in mean areal rainfall between their respective catchments. Consequently, graphs were plotted of cross correlation coefficient against difference in mean areal rainfall for each month of the year. This analysis was initially carried out using the gauging station data, but was later extended to include the sub-catchment data in order to magnify the differences in mean areal rainfall and reduce the effect of rainfall variation within each catchment.

A complete set of the cross correlation coefficient/rainfall difference graphs is given in Appendix IV. Typical winter (February) and summer (August) graphs relating to the gauging station data and the sub-catchment data are given in Figures 7.23 and 7.24. Inspection of these illustrates the point made earlier that the cross correlation coefficients were consistently high in the winter months and far less consistent and lower in the months of July to August.

In view of the high degree of scatter in the summer months, especially in the case of the sub-catchments, it was clear that other important factors were involved. Further analysis of the results indicated that the distance between the catchments had little effect upon the cross correlation coefficient, but that the average of the mean areal rainfall of the two sub-catchments did. The sub-catchments were, therefore, classified into groups according to their

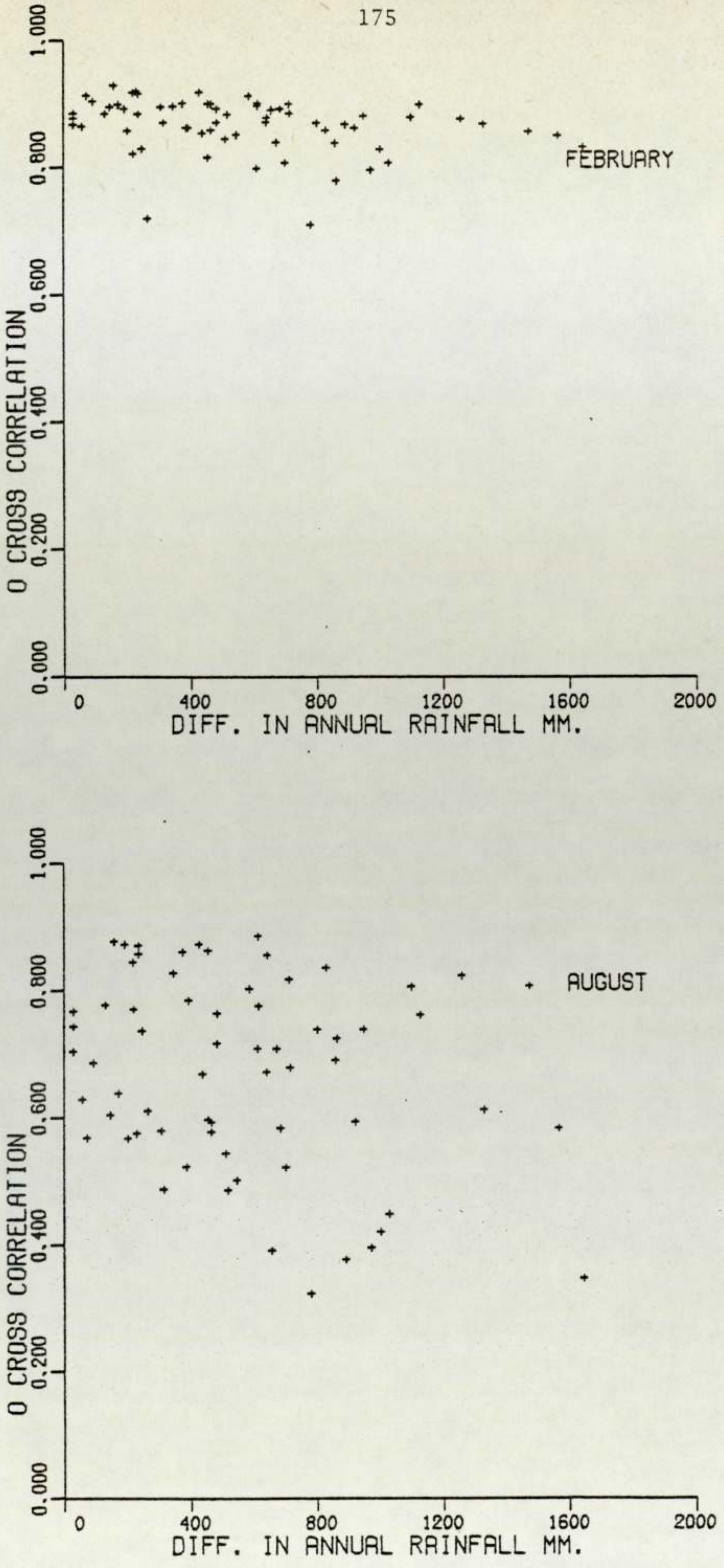
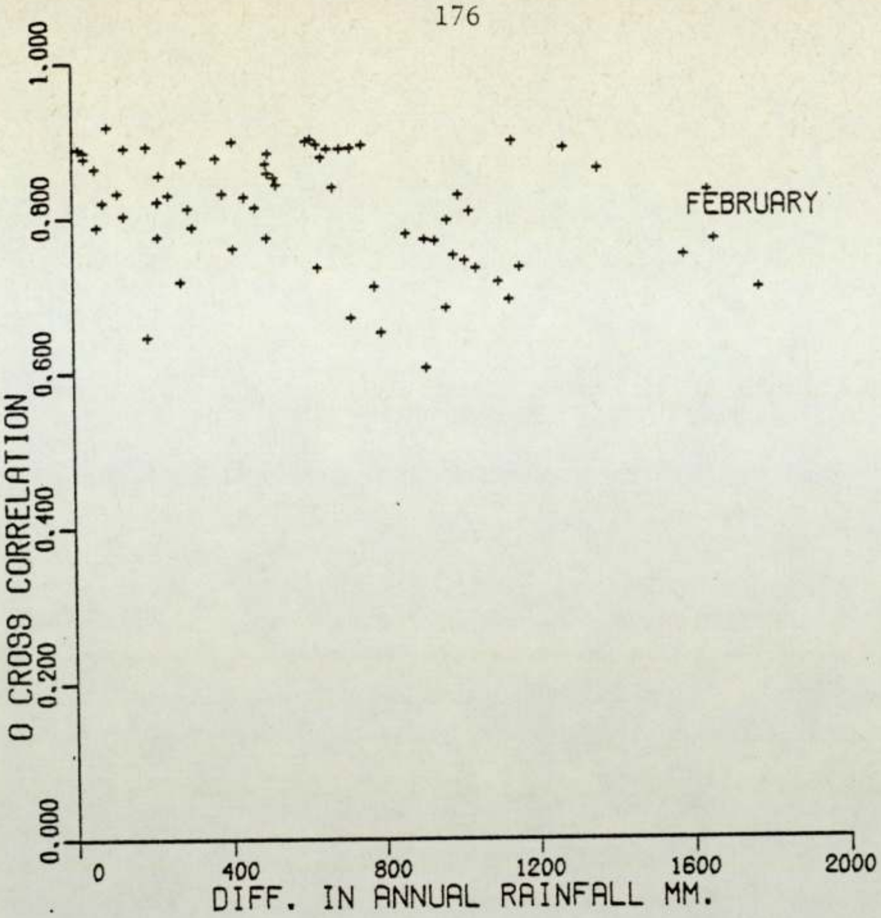


FIGURE 7.23 COMPARISON BETWEEN FEBRUARY AND AUGUST CROSS CORRELATION/ DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING RECORDS (1960-75)



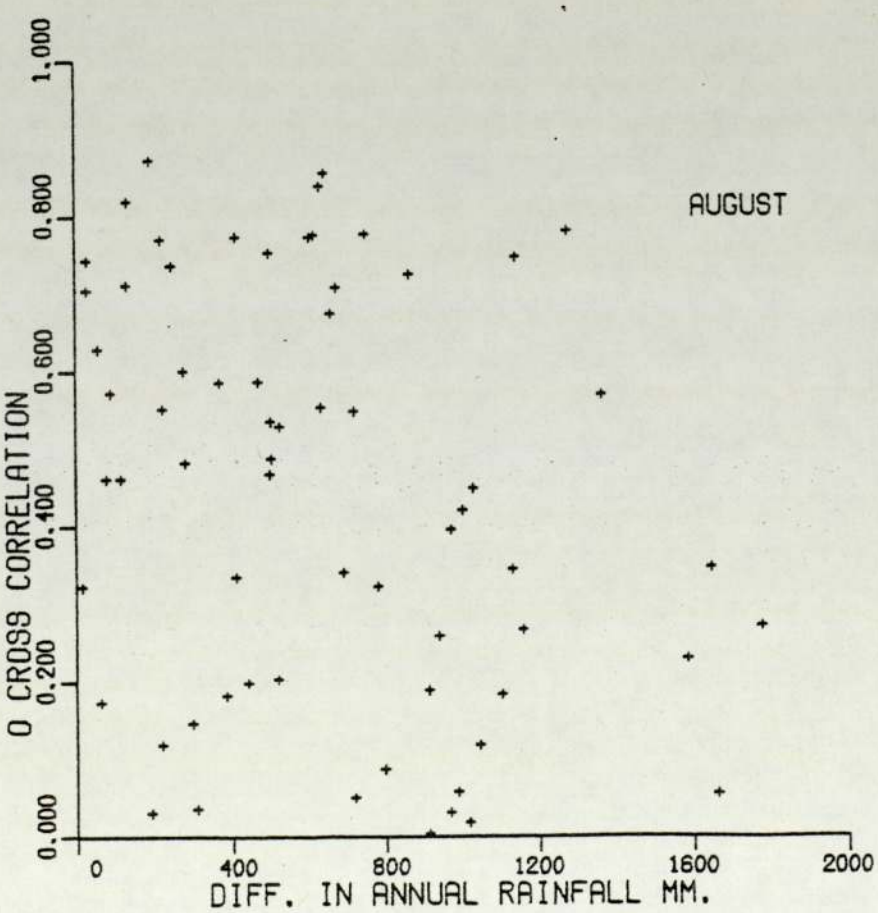


FIGURE 7.24 COMPARISON BETWEEN FEBRUARY AND AUGUST CROSS CORRELATION/ DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENT RECORDS (1960-75)

mean areal rainfall. Two classifications were used and these are given in detail in Table 7.2. Classification II, which grouped the sub-catchments into high, medium and low rainfall, was the same as that used earlier in relation to the other flow parameters, except that in this case Cray was excluded because of its exceptionally high rainfall. Classification I differed from II in that it used four rainfall groupings instead of three, thus the number of possible combinations of any two groups was ten for Classification I and six for Classification II. The mean cross correlation coefficients and their standard deviation for each of these groups are given in Table 7.3 and 7.4.

7.7.2 Spatial and Temporal Variation

The mean monthly lag-zero cross correlation coefficients were plotted for each group combination. However, before attempting to draw a curve through the plotted points, crude upper and lower limits (placed 2 x stand. dev. /$\sqrt{N}$ above and below the means, where N is the number of combinations) were drawn. These were then used as guides when drawing the 'best fit' curve through the plotted means. Figures 7.25 and 7.26 show the curves for each of the combinations within Classification I and Figures 7.27 and 7.28 show those for Classification II. Figure 7.29 shows these curves combined onto one graph for each classification.

These graphs clearly reveal several characteristics of the temporal variation of cross correlation between flows which, to the author's knowledge, have not previously been described.

1) There is a distinct mid-summer decline in cross correlation irrespective of the nature of the sub-catchments involved.
2) This decline is largest when the two sub-catchments differ greatly in nature (i.e. mountainous and lowland).

TABLE 7.3 MEAN AND STANDARD DEVIATION OF MONTHLY LAG-ZERO CROSS CORRELATION OF GROUP 1

Group Combination	No of Combinations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
H/H	10	0.882 (0.038)	0.858 (0.038	0.877 (0.029)	0.865 (0.031)	0.836 (0.044)	0.845 (0.055)	0.758 (0.079)	0.752 (0.072)	0.857 (0.033)	0.884 (0.019)	0.856 (0.026)	0.879 (0.029)
H/M_W	10	0.854 (0.055)	0.862 (0.058)	0.858 (0.037)	0.806 (0.087)	0.796 (0.041)	0.802 (0.037)	0.444 (0.101)	0.706 (0.102)	0.857 (0.033)	0.821 0.029)	0.824 (0.042)	0.836 (0.045)
H/M_D	10	0.809 (0.065)	0.837 (0.056)	0.774 (0.056)	0.742 (0.121)	0.693 (0.082)	0.613 (0.175)	0.328 (0.129)	0.471 (0.140)	0.701 (0.079)	0.655 (0.186)	0.712 (0.089)	0.764 (0.100)
H/L	10	0.675 (0.071)	0.711 (0.050)	0.563 (0.133)	0.622 (0.095)	0.572 (0.065)	0.517 (0.119)	0.225 (0.104)	0.127 (0.150)	0.526 (0.104)	0.410 (0.056)	0.598 (0.073)	0.498 (0.129)
M_W/M_D	4	0.810 (0.062)	0.884 (0.027)	0.836 (0.020)	0.750 (0.066)	0.791 (0.081)	0.724 (0.127)	0.859 (0.020)	0.550 (0.043)	0.705 (0.074)	0.821 (0.078)	0.850 (0.065)	0.846 (0.038)
M_W/L	4	0.694 (0.068)	0.799 (0.053)	0.697 (0.129)	0.734 (0.087)	0.749 (0.104)	0.640 (0.072)	0.789 (0.029)	0.352 (0.187)	0.560 (0.144)	0.664 (0.053)	0.724 (0.064)	0.684 (0.080)
M_D/L	4	0.772 (0.113	0.817 (0.054)	0.793 (0.078)	0.711 (0.102)	0.804 (0.083)	0.636 (0.108)	0.852 (0.034)	0.379 (0.238)	0.591 (0.023)	0.765 (0.147)	0.770 (0.097)	0.744 (0.160)

N.B. M_W/M_W, M_D/M_D, L/L } These groups combinations were excluded because they each produced only one sub-catchment combination

Also, all Mid-Wye sub-catchment combinations (L) were excluded for the reasons given in Section 7.6.

TABLE 7.4 MEAN AND STANDARD DEVIATION OF MONTHLY LAG ZERO CROSS CORRELATION OF GROUP II

Group Combination	No of Combinations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
H/H	6	0.909 (0.007)	0.862 (0.030)	0.872 (0.036)	0.869 (0.025)	0.848 (0.038)	0.839 (0.060)	0.788 (0.086)	0.743 (0.080)	0.863 (0.034)	0.889 (0.015)	0.867 (0.021)	0.892 (0.028)
H/M	12	0.857 (0.051)	0.857 (0.064)	0.840 (0.140)	0.810 (0.095)	0.787 (0.059)	0.782 (0.115)	0.448 (0.099	0.645 (0.146)	0.831 (0.055)	0.822 (0.026)	0.804 (0.042)	0.839 (0.039)
H/L	12	0.733 (0.053)	0.731 (0.064)	0.639 (0.140)	0.612 (0.095)	0.613 (0.059)	0.499 (0.115)	0.269 (0.083)	0.211 (0.189)	0.547 (0.168)	0.437 (0.054)	0.594 (0.065)	0.553 (0.143)
M/M	3	0.808 (0.188)	0.888 (0.032)	0.861 (0.038)	0.798 (0.074)	0.803 (0.075)	0.852 (0.035)	0.877 (0.008)	0.648 (0.149)	0.775 (0.149)	0.901 (0.104)	0.900 (0.006)	0.876 (0.022)
M/L	9	0.718 (0.065)	0.823 (0.055)	0.759 (0.108)	0.712 (0.080)	0.767 (0.082)	0.629 (0.071)	0.821 (0.039)	0.383 (0.169)	0.628 (0.136)	0.684 (0.060)	0.742 (0.064)	0.717 (0.109)
L/L	3	0.873 (0.008)	0.842 (0.044)	0.823 (0.063)	0.754 (0.043)	0.820 (0.073)	0.738 (0.096)	0.878 (0.028)	0.499 (0.197)	0.574 (0.029)	0.884 (0.008)	0.866 (0.029)	0.812 (0.081)

N.B.

Mid-Wye subcatchment combinations were excluded for the reasons given in Section 7.6.

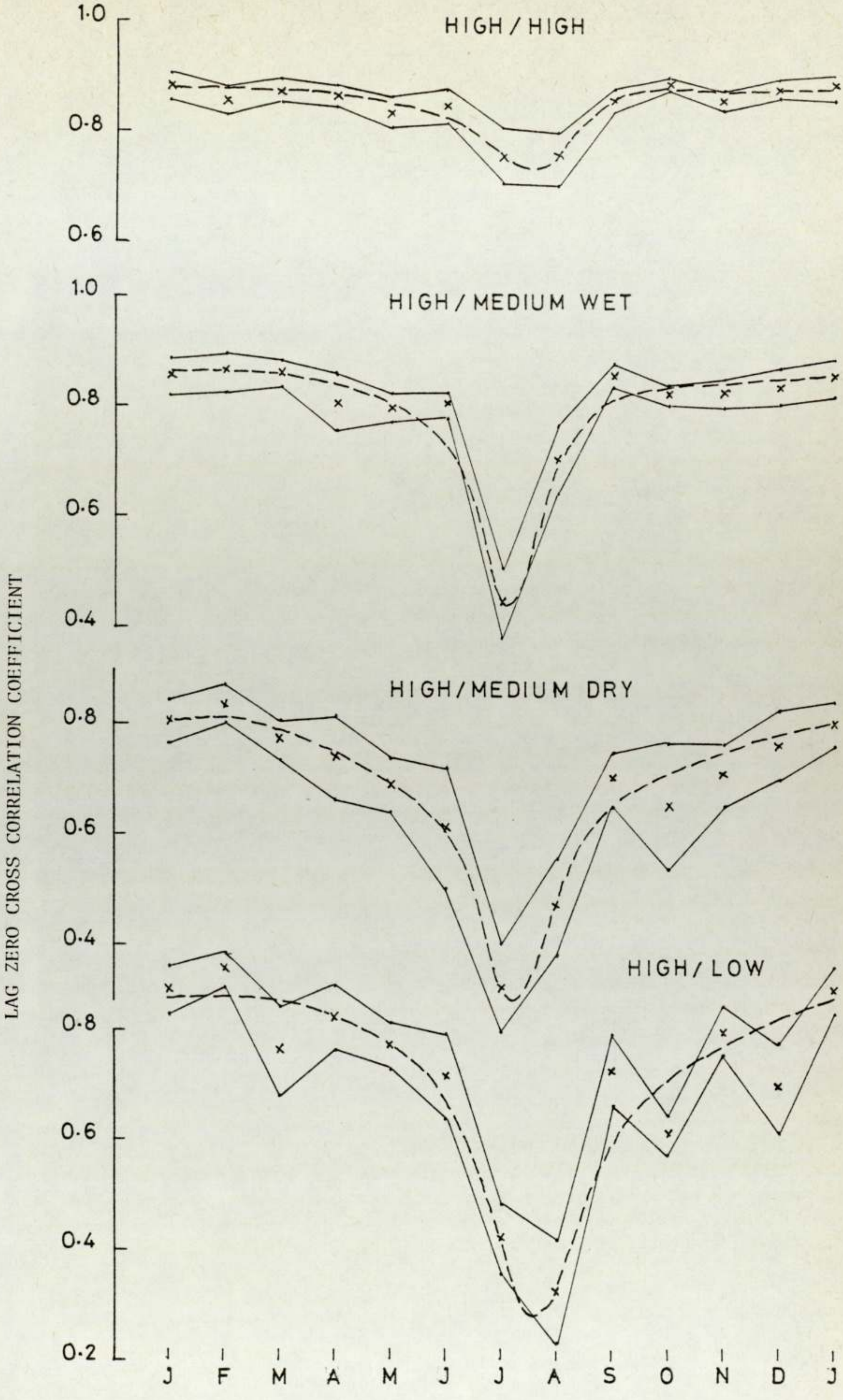


FIGURE 7.25 VARIATION OF MONTHLY LAG ZERO CROSS CORRELATION OF CLASSIFICATION I (1960-75)

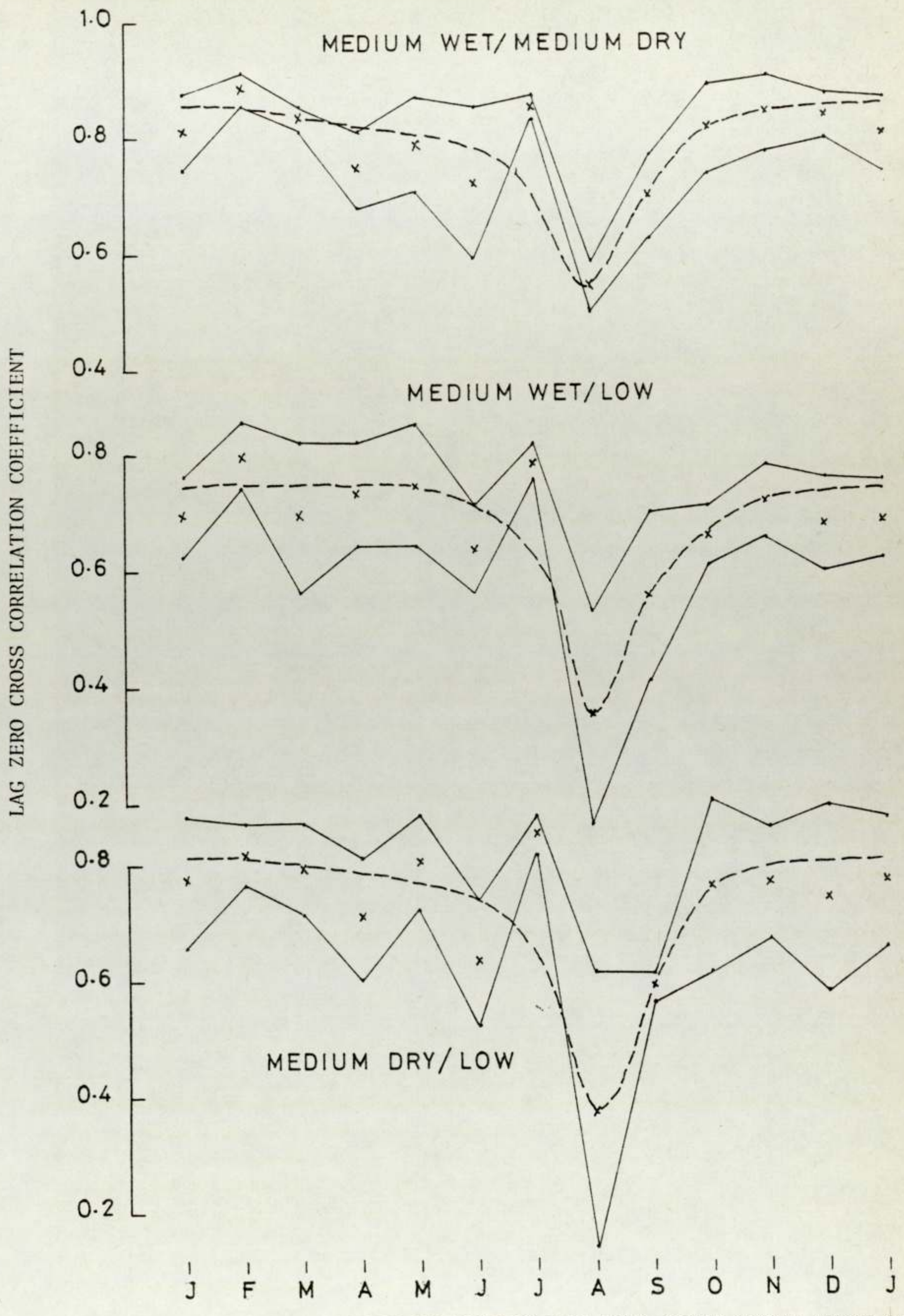


FIGURE 7.26 VARIATION OF MONTHLY LAG ZERO CROSS CORRELATION OF CLASSIFICATION I (1960-75)

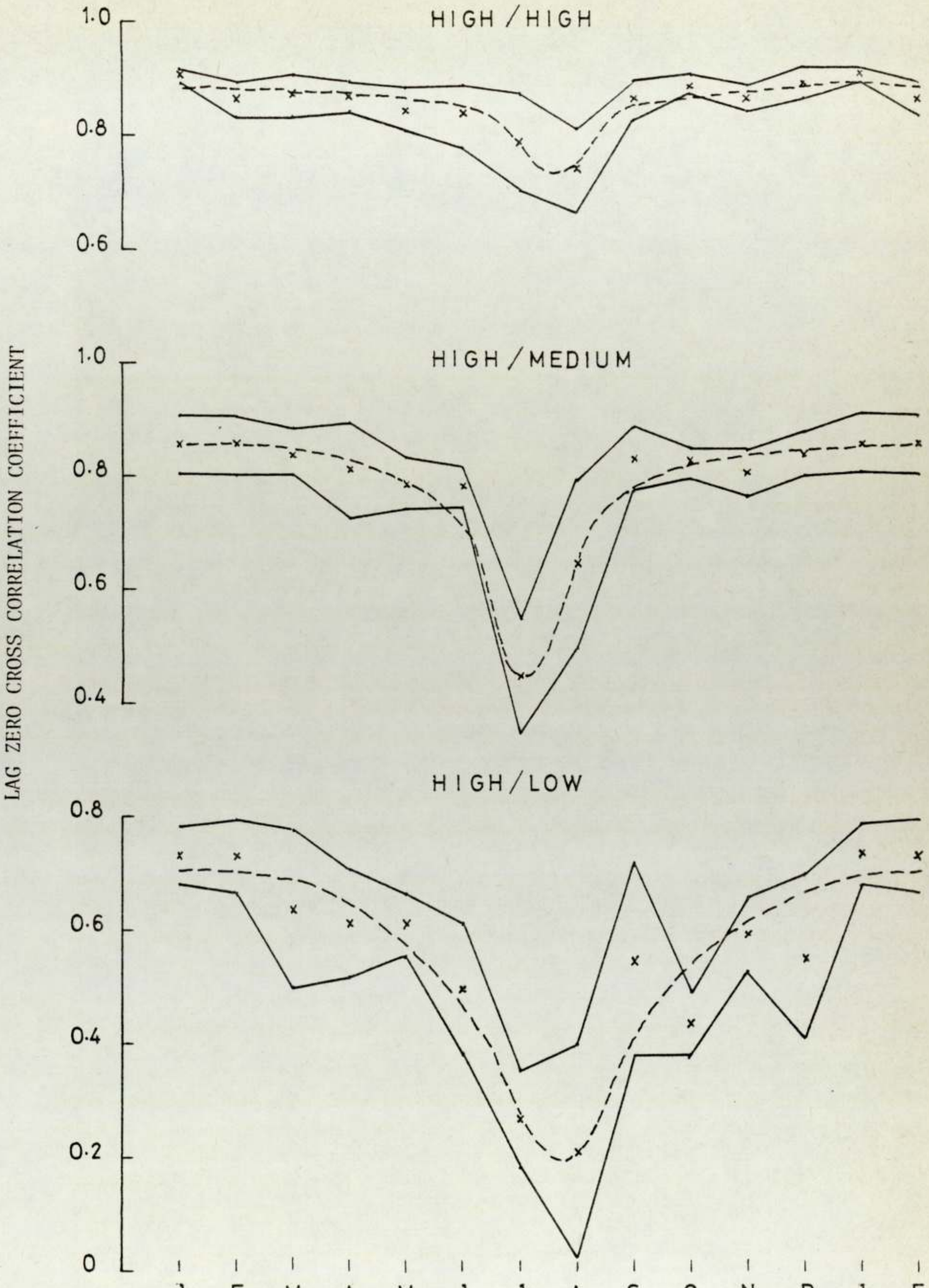


FIGURE 7.27 VARIATION OF MONTHLY LAG ZERO CROSS CORRELATION OF CLASSIFICATION II (1960-75)

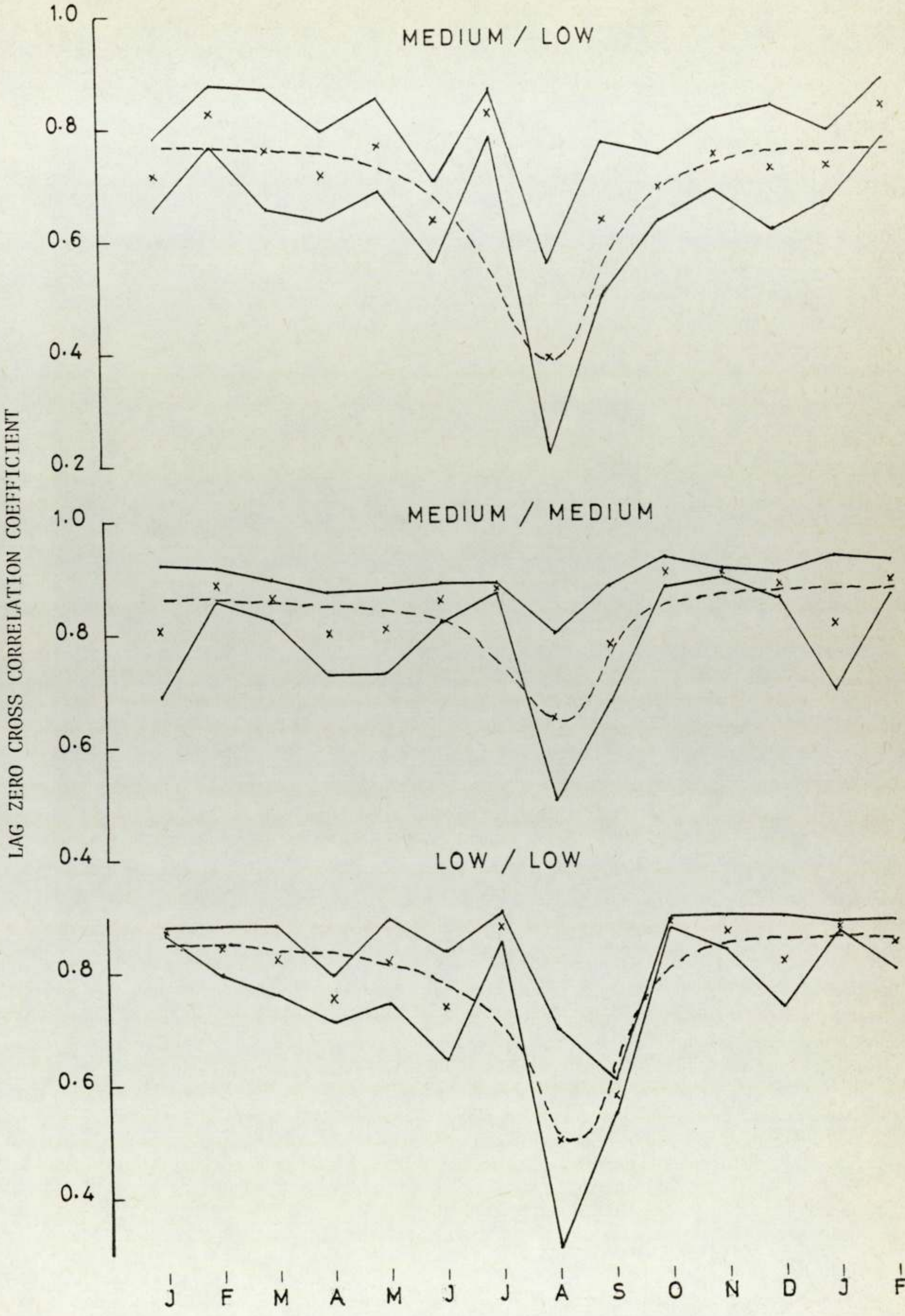
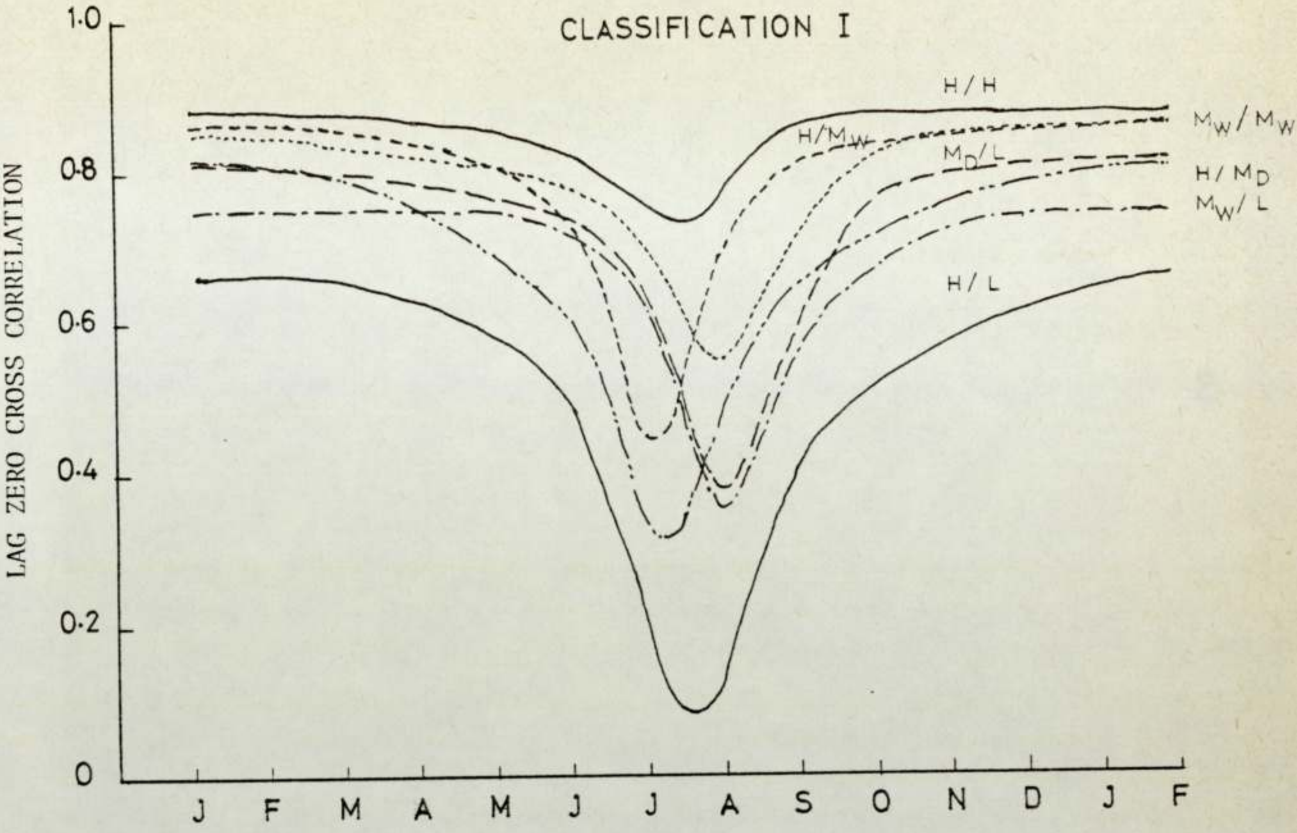


FIGURE 7.28 VARIATION OF MONTHLY LAG ZERO CROSS CORRELATION OF CLASSIFICATION II (1960-75)



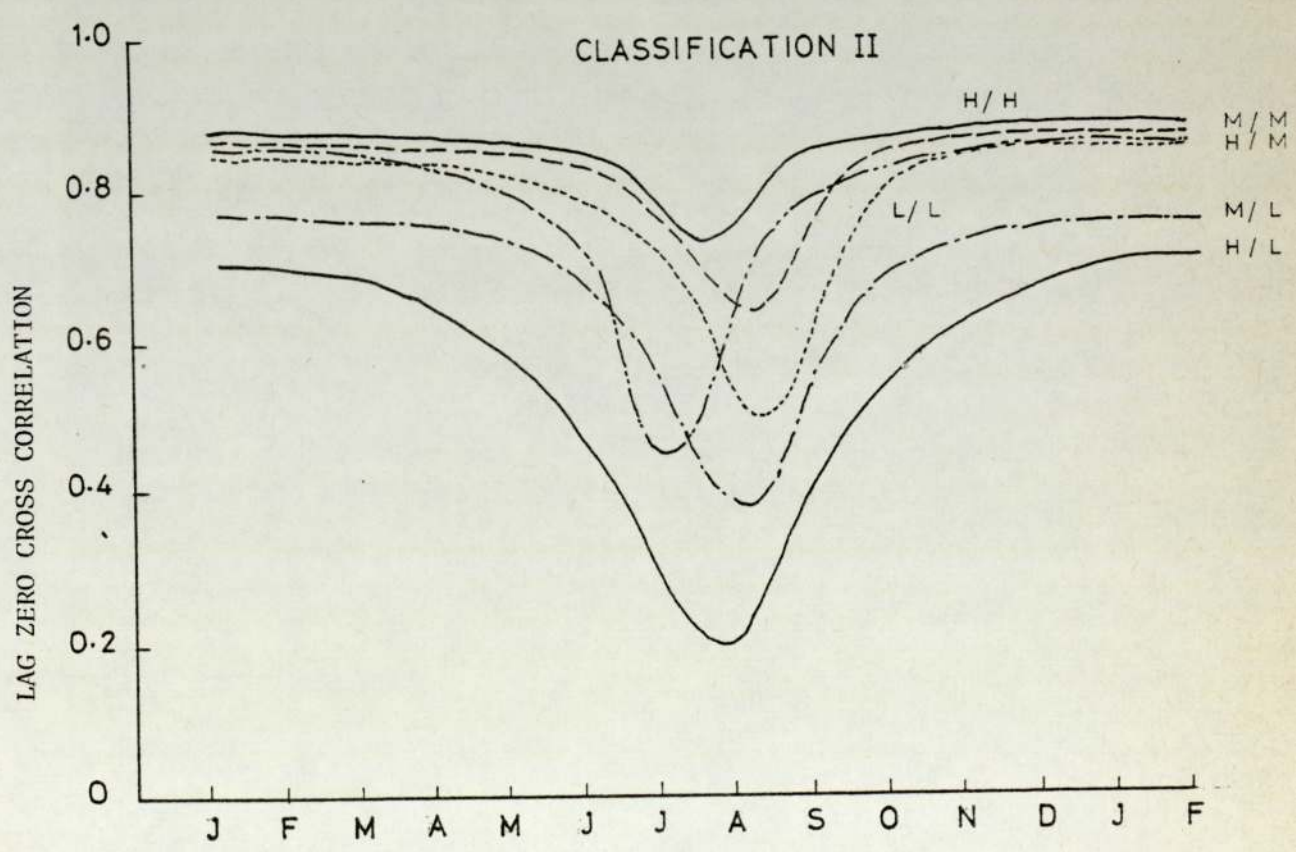


FIGURE 7.29 VARIATION OF SMOOTHED LAG-ZERO CROSS CORRELATION OF CLASSIFICATION I AND II (1960-75)

3) Where the sub-catchments do not differ in nature, the decline is greatest if they are both lowland (i.e. low rainfall) sub-catchments.

4) Cross correlation is consistently high (between 0.7 and 0.9) during the winter months, but is greater between sub-catchments which are similar in nature (i.e. both high or both low rainfall) than between those which are different in nature.

It is thought that these characteristics are in some way related to the spatial and temporal distribution of soil moisture deficit, and the precise relationship is not clear. The parameters which have been used here, namely rainfall difference and rainfall average, are closely related to soil moisture deficit. The average maximum soil moisture deficit at a point is related to the mean annual rainfall, and the average difference in soil moisture deficit between two points is related to the rainfall difference between the points. There are, however, other factors which may be of importance, and it is clear that further investigation into this topic is both necessary and desirable.

The effect of distance between sub-catchments upon the cross correlation coefficient was investigated by plotting the mean winter (i.e. December, January and February) cross correlation coefficients for the mountainous sub-catchments against the distance between the centres of the sub-catchments involved. Table 7.5 lists these data and Figure 7.30 shows the plotted points and linear regression line relating cross correlation coefficient to distance apart. The equation of the line is:

$$\gamma_{wm} = 0.90 - 0.0004D \qquad (7.6)$$

TABLE 7.5 MEAN WINTER CROSS CORRELATION BETWEEN MOUNTAINOUS SUB-CATCHMENTS

Sub-catchment Combinations	Distance Apart in K_m	Dec	Jan	Feb	Average
Vyrnwy Up-Severn	20.00	0.858	0.892	0.894	0.881
Vyrnwy Rhayader	47.50	0.872	0.898	0.830	0.867
Vyrnwy Caban Coch	55.00	0.866	0.905	0.865	0.879
Vyrnwy Abernant	71.25	0.863	0.909	0.886	0.886
Rhayader Caban Coch	10.00	0.927	0.916	0.893	0.912
Rhayader Abernant	23.75	0.909	0.911	0.822	0.880
Caban Coch Abernant	15.00	0.916	0.916	0.878	0.903

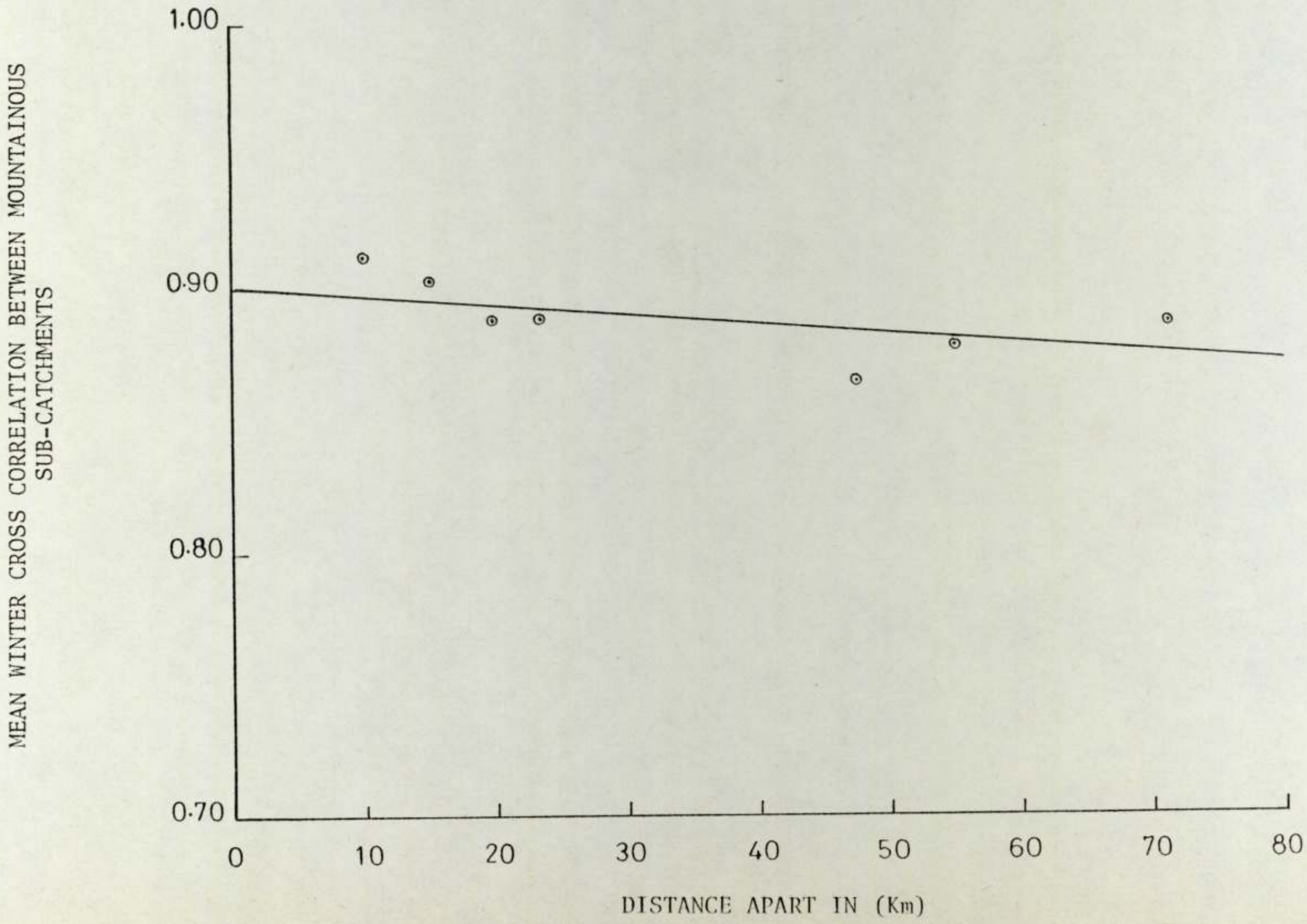


FIGURE 7.30 LINEAR RELATIONSHIP BETWEEN MEAN WINTER CROSS CORRELATION AND DISTANCE BETWEEN SUB-CATCHMENTS

where

γ_{wm} = winter cross correlation coefficient for mountainous sub-catchments

D = distance between centres of gravity of the sub-catchments (Km)

In view of the relatively low correlation coefficient for this relationship (r = 0.5582) it was not worthwhile attempting to obtain a corresponding relationship for other less consistent periods and catchment types. The advantage of using the winter values of the mountainous catchments was that these were highly consistent and therefore well suited for the excercise.

7.7.3 Development of General Equations

In view of the importance of cross correlation coefficients in multi-variate stochastic streamflow models (Fiering and Jackson, 1971), it was decided to develop a method for the prediction of cross correlation coefficients for ungauged catchments, using only annual rainfall data and the distance between the catchments.

The method adopted involved estimating the winter maximum (γ_m), the summer depression (γ_d) and a width parameter (w), which was defined as shown in (Fig 7.31). The proposed method of estimating the cross correlation curve for the whole year is also shown in Fig 7.31 . Before the method could be applied it was necessary to develop an empirical equations for the estimation of γ_m, γ_d, and w.

Values of γ_m, γ_d, and w were obtained from (Fig 7.29) for each of the sub-catchment combinations in Classifications I and II and tabulated as shown in Tables 7.6 and 7.7 In view of the relatively small variation in w, and the fact that its evaluation was somewhat prone to error, it was decided to treat it as a constant having a

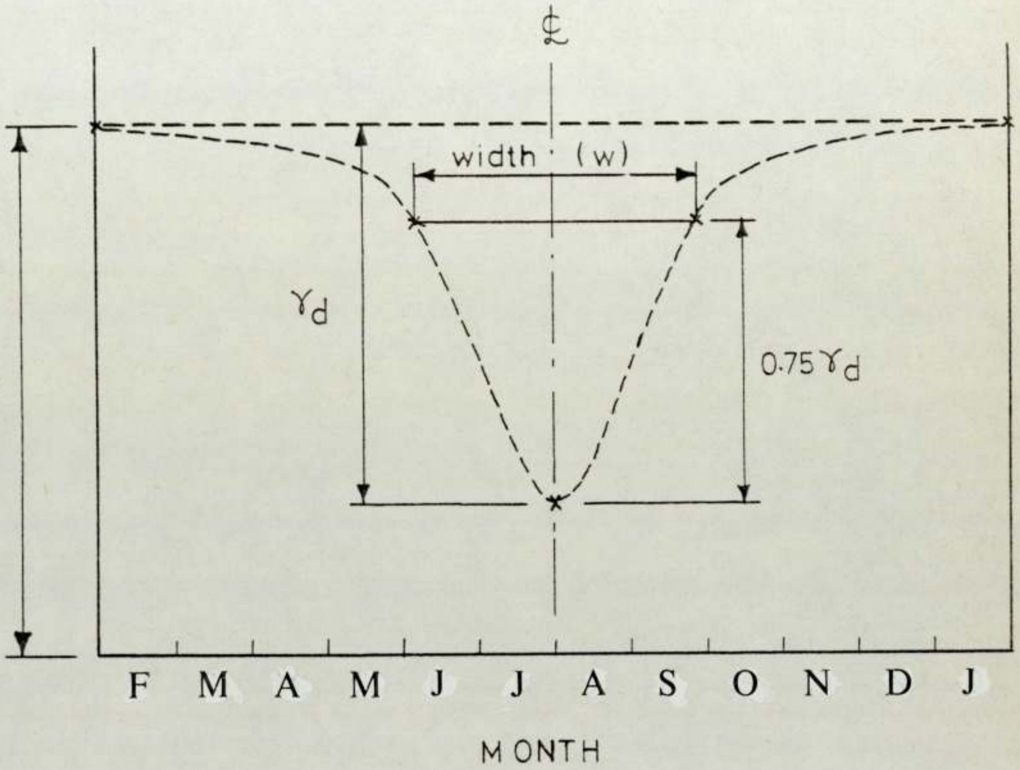


FIGURE 7.31 IDEALISED TEMPORAL VARIATION OF LAG ZERO CROSS CORRELATION COEFFICIENT

γ_m = Winter Maximum
γ_d = Summer Depression
W = Width Parameter

TABLE 7.6 MEAN VALUES OF THE PRINCIPAL PARAMETERS FOR THE CLASSIFICATION I GROUPINGS

Sub-catchment Combinations	Average Annual Rainfall R_a (mm)	Difference in Mean Annual Rainfall R_d	Mean Distance Apart (Km)	Winter Maximum γ_m	Summer Depression γ_d	Width w Months
H/H	1935	357	46	0.88	0.15	3.5
H/M_W	1610	650	46	0.86	0.42	4.5
H/M_D	1462	946	57	0.80	0.49	2.7
H/L	1355	1160	79	0.67	0.58	4.4
M_W/M_D	1138	296	64	0.85	0.26	2.6
M_W/L	1031	510	65	0.75	0.40	3.0
M_D/L	883	214	52	0.81	0.43	3.1

TABLE 7.7 MEAN VALUES OF THE PRINCIPAL PARAMETERS FOR THE CLASSIFICATION II GROUPINGS

Sub-catchment Combinations	Average Annual Rainfall R_a (mm)	Difference in Mean Annual Rainfall R_d	Mean Distance Apart (Km)	Winter Maximum γ_m	Summer Depression γ_d	Width w Months
H/H	1795	129	37	0.89	0.13	2.7
H/M	1514	562	46	0.85	0.40	3.0
H/L	1298	995	71	0.70	0.51	5.5
M/M	1234	149	60	0.88	0.33	3.1
M/L	1017	433	61	0.77	0.39	4.0
L/L	800	87	51	0.84	0.34	3.2

Note:

R_a is the average of the mean annual rainfalls of the sub-catchments in the group.

R_d is the average of the difference in mean annual rainfall between the sub-catchment combinations in each group.

value equal to the overall mean of the values listed in Tables 7.6 and 7.7. Hence the recommended value is 3.4 months.

A detailed investigation into the relationship between γ_m and rainfall difference ($\overline{R}_d$), rainfall average ($\overline{R}_a$) and distance apart (D) showed that the simplest and best form of an equation relating these variables was:

$$\gamma_m = \gamma_o - a_1 D - a_2 \overline{R}_d \ (R_o - \overline{R}_a)^n \qquad (7.7)$$

Various graphical analyses such as that shown in Figure 7.32 indicated that the values of the constants γ_o, a_1, a_2, R_o and n were approximately 0.9, 0.0004, 4 x 10^{-10}, 2000 and 2.2 respectively. Further numerical analysis based upon the method of least squares indicated that the following equation, which has convenient coefficients, was close to the optimum.

$$\gamma_m = 0.90 - 0.0004D - 3.5^{-10} \ \overline{R}_d (2000 - \overline{R}_a)^{2.0} \qquad (7.8)$$

where

D = distance between centres of gravity of the two catchments (Km)

$\overline{R}_d$ = difference in annual mean areal rainfalls of the two catchments (mm);

$\overline{R}_a$ = average of the annual mean areal rainfalls of the two catchments (mm).

A comparison made between the γ_m values calculated from the data (summarised in Tables 7.6 and 7.7) and the estimated values obtained using equation (7.8) is given in Table 7.8.

To develop a method to estimate the summer depression (γ_d) values a similar approach to that outlined above was adopted. This investi-

TABLE 7.8 COMPARISON BETWEEN THE CALCULATED VALUES OF γ_m (TABLES 7.6 AND 7.7) AND THE ESTIMATED VALUES OBTAINED USING EQUATION (7.8)

	Sub-catchment Combination	γ_m		
		Sample Size	Calculated Values	Estimated Values (Eqn 7.8)
Classification I	H/H	10	0.88	0.89
	H/M_W	10	0.86	0.85
	H/M_D	10	0.80	0.79
	H/L	10	0.67	0.71
	M_W/M_D	4	0.85	0.81
	M_W/L	4	0.75	0.72
	M_D/L	4	0.81	0.80
Classification II	H/H	6	0.89	0.89
	H/M	12	0.85	0.85
	H/L	12	0.70	0.71
	M/M	3	0.88	0.86
	M/L	9	0.77	0.73
	L/L	3	0.84	0.84

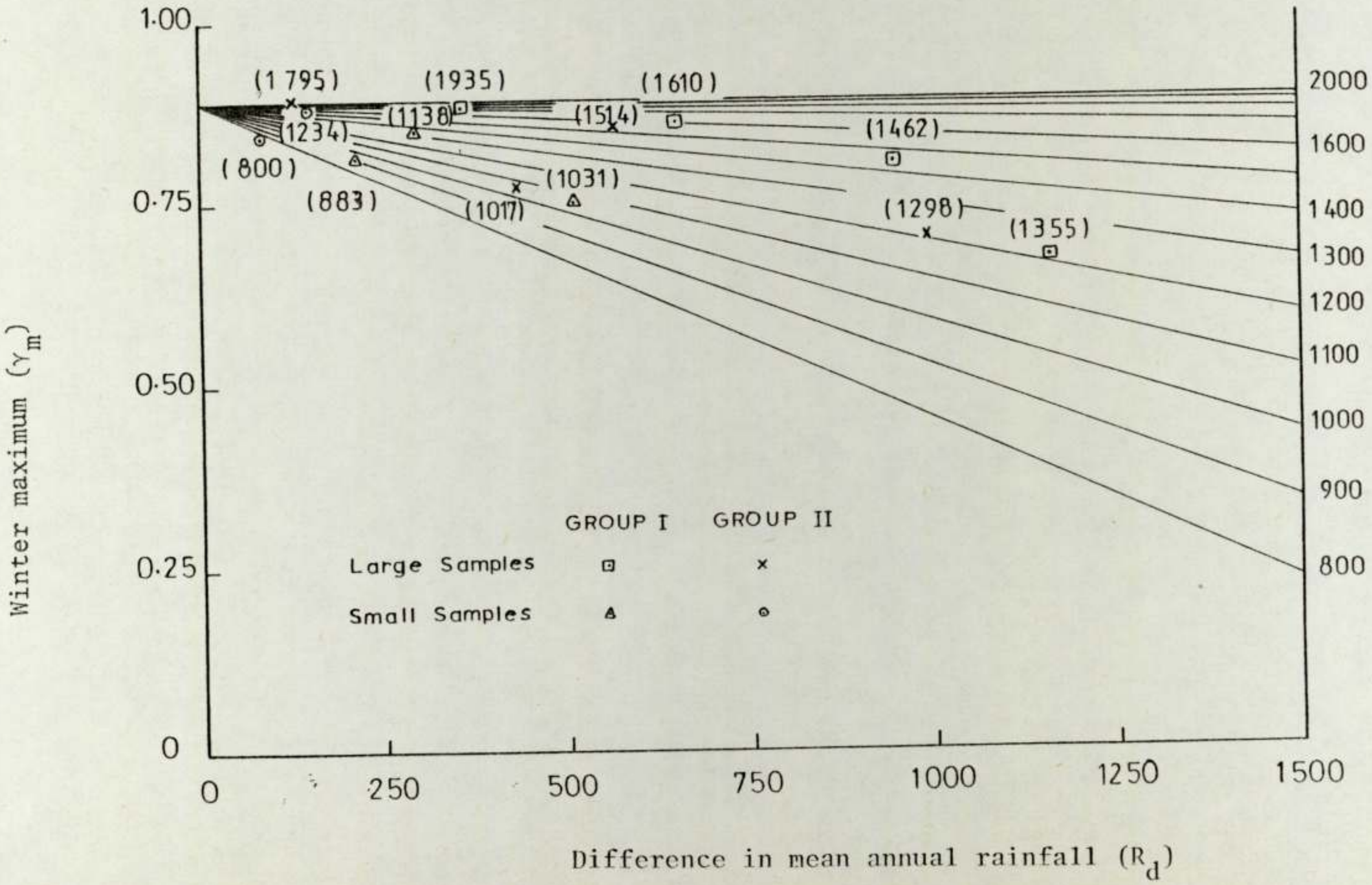


FIGURE 7.32 RELATIONSHIP BETWEEN DIFFERENCE IN MEAN ANNUAL RAINFALL AND WINTER MAXIMUM CROSS CORRELATION COEFFICIENT

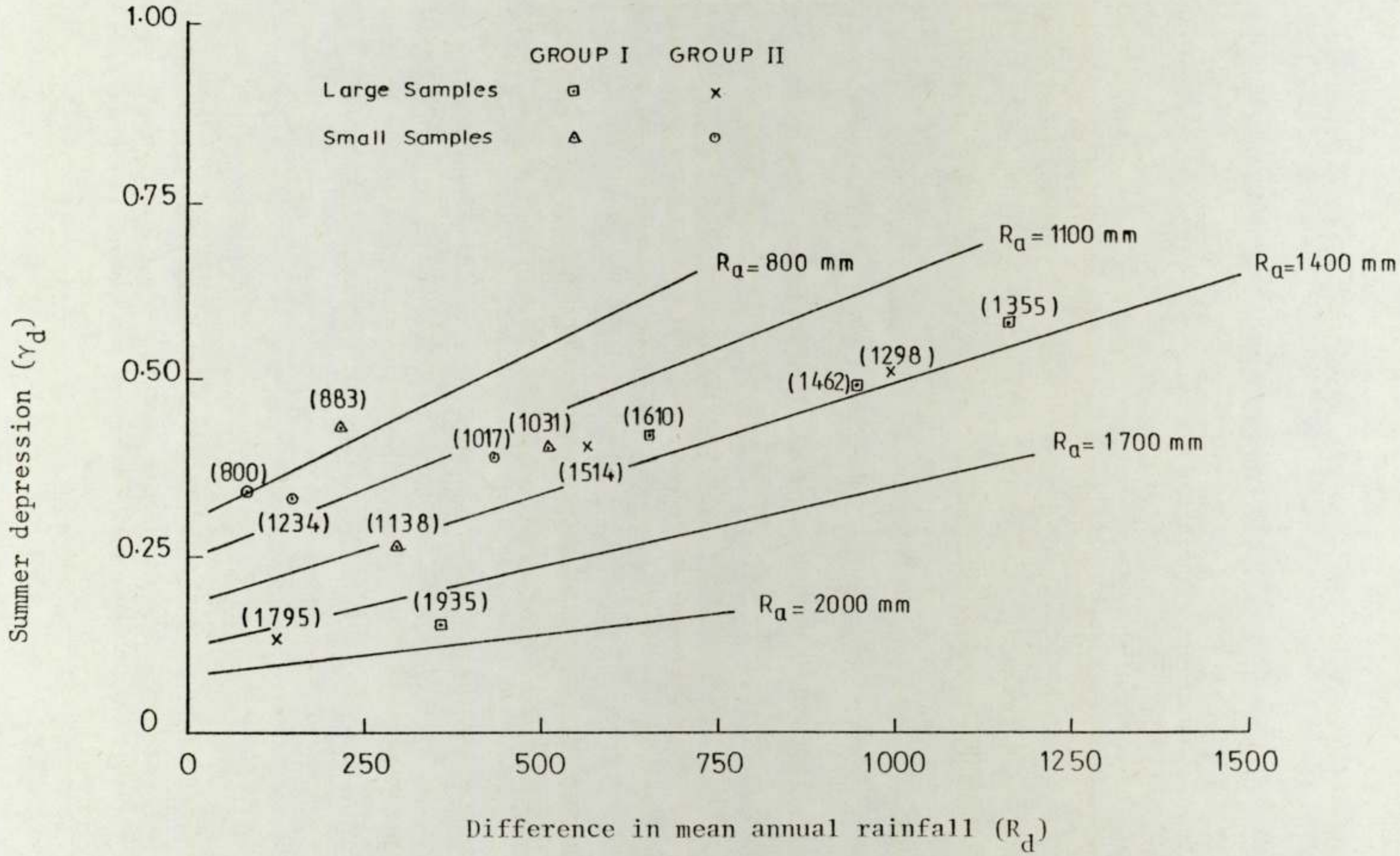


FIGURE 7.33 RELATIONSHIP BETWEEN DIFFERENCE IN MEAN ANNUAL RAINFALL AND THE SUMMER DEPRESSION OF THE CROSS CORRELATION COEFFICIENTS

gation resulted in the following equation which relates γ_d to rainfall difference ($\overline{R}_d$) and rainfall average ($\overline{R}_a$)

$$\gamma_d = \left[\frac{2400 - \overline{R}_a}{1800}\right] \times \left[\frac{600 + \overline{R}_d}{1800}\right] \qquad (7.9)$$

Figure 7.33 shows both the measured values of γ_d from Table 7.6 and a set of five theoretical curves based upon equation (7.9). The $\overline{R}_a$ values corresponding to the plotted points are shown enclosed in brackets and the $\overline{R}_a$ value for each of the theoretical curves is also given. The discrepancies between the plotted points and the lines based on the equation are in some cases quite large (approximately 20% error), but considering the errors involved in the evaluation of the measured values of γ_d (see graphs 7.25 to 7.29), errors of this magnitude can be expected.

Equations 7.8 and 7.9, together with the constant w, thus provide a means of estimating the cross correlation coefficient between any two ungauged catchments for any month of the year using mean areal rainfall data only.

7.8 RAINFALL/STREAMFLOW RELATIONSHIPS

The development of rainfall/streamflow relationships was an important part of the investigation, since a stated aim of the project was to devise methods of estimating streamflow parameters for ungauged catchments. In stating this aim it was assumed that the available meteorological data would be limited to one of the following.

1) Mean annual areal rainfall estimated from the Annual Rainfall Map (Map 3);

2) Mean annual areal rainfall estimated from local raingauge records;

3) Mean monthly areal rainfalls estimated from local raingauge records;

4) Any one of (1), (2) and (3) above plus mean annual areal evapotranspiration.

In view of these assumptions the rainfall/streamflow relationships listed below were investigated.

1) Mean annual areal rainfall (mm) against monthly streamflow (mean and standard deviation in mm) for both short (1960-75) and long (1938-75) records. These are shown in Figures 7.34/1 to 7.34/4 (short record) and Figures 7.35/1 and 7.35/4 (long record).

2) Mean monthly areal rainfall (mm) against monthly streamflow (mean and standard deviation in mm) for both the short and long records. These are shown in Figures 7.36/1 to 7.36/4 (short record) and Figures 7.37/1 to 7/37/4 (long record).

For the same reasons as stated in Section 7.2 the Cray, Tycastell and Glan Teifi data were not included in the regression analysis.

The rainfall/streamflow relationships was assumed to be of the general form:

$$Q_i = b_i + m_i R \qquad (7.10)$$

where

Q_i = mean monthly streamflow in the ith month (mm)

b_i = intercept coefficient for the ith month (mm)

m_i = slope coefficient for the ith month (mm)

R = rainfall (mm) (either mean monthly R_i or mean annual R_a)

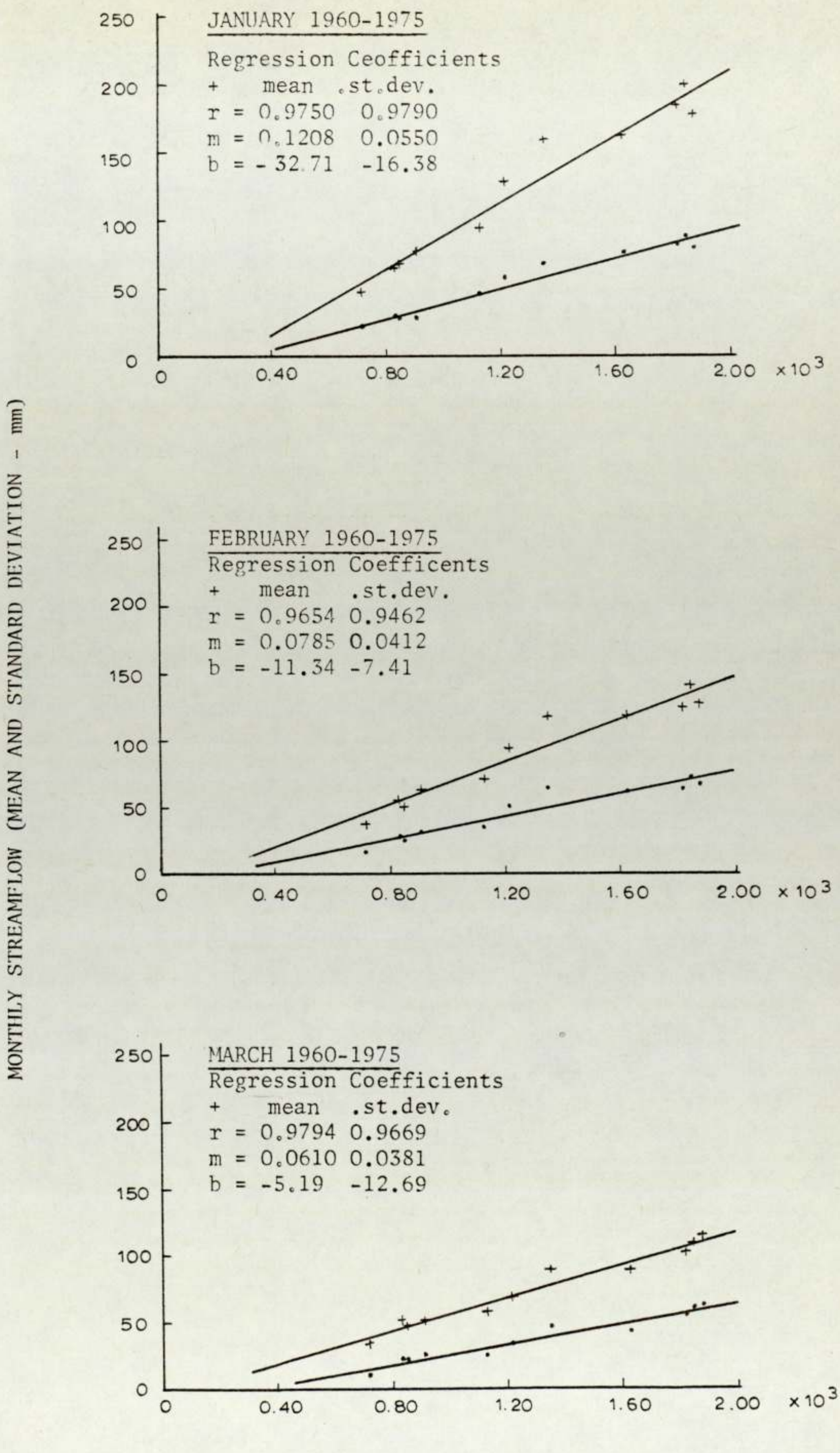


FIGURE 7.34/1 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW (1960-75)

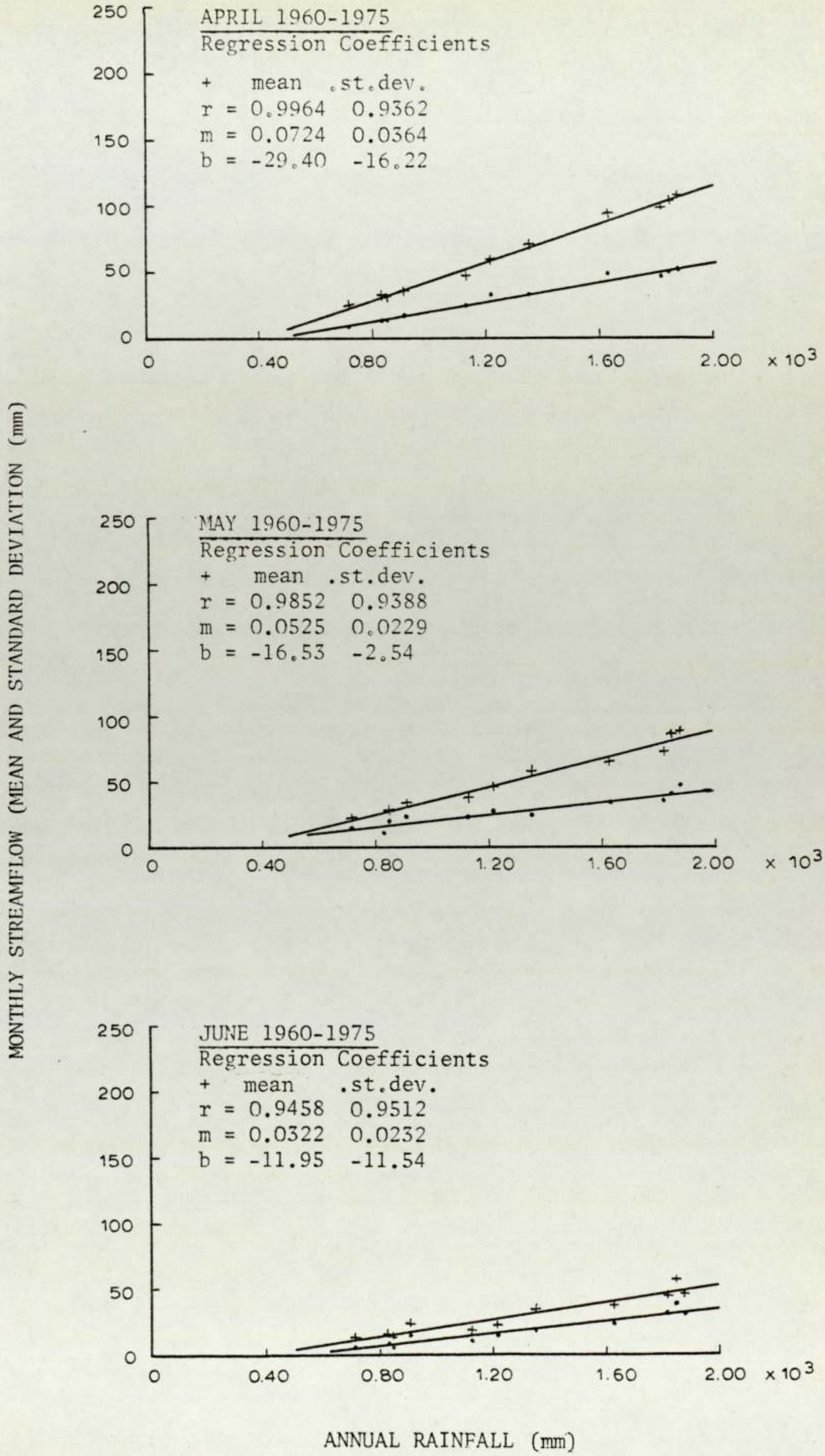


FIGURE 7.34/2 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF SHORT RECORDS

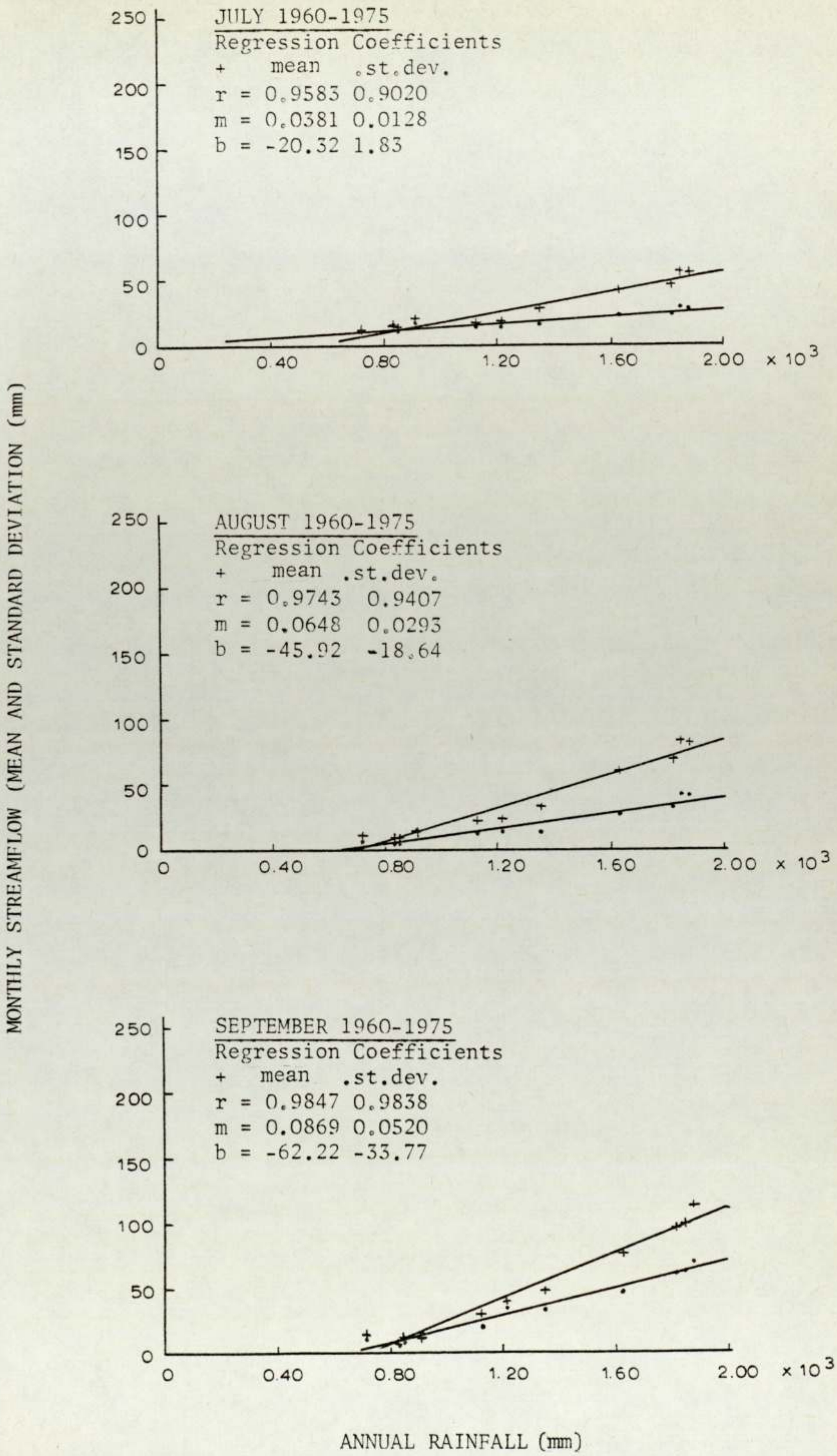


FIGURE 7.34/3 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF SHORT RECORDS

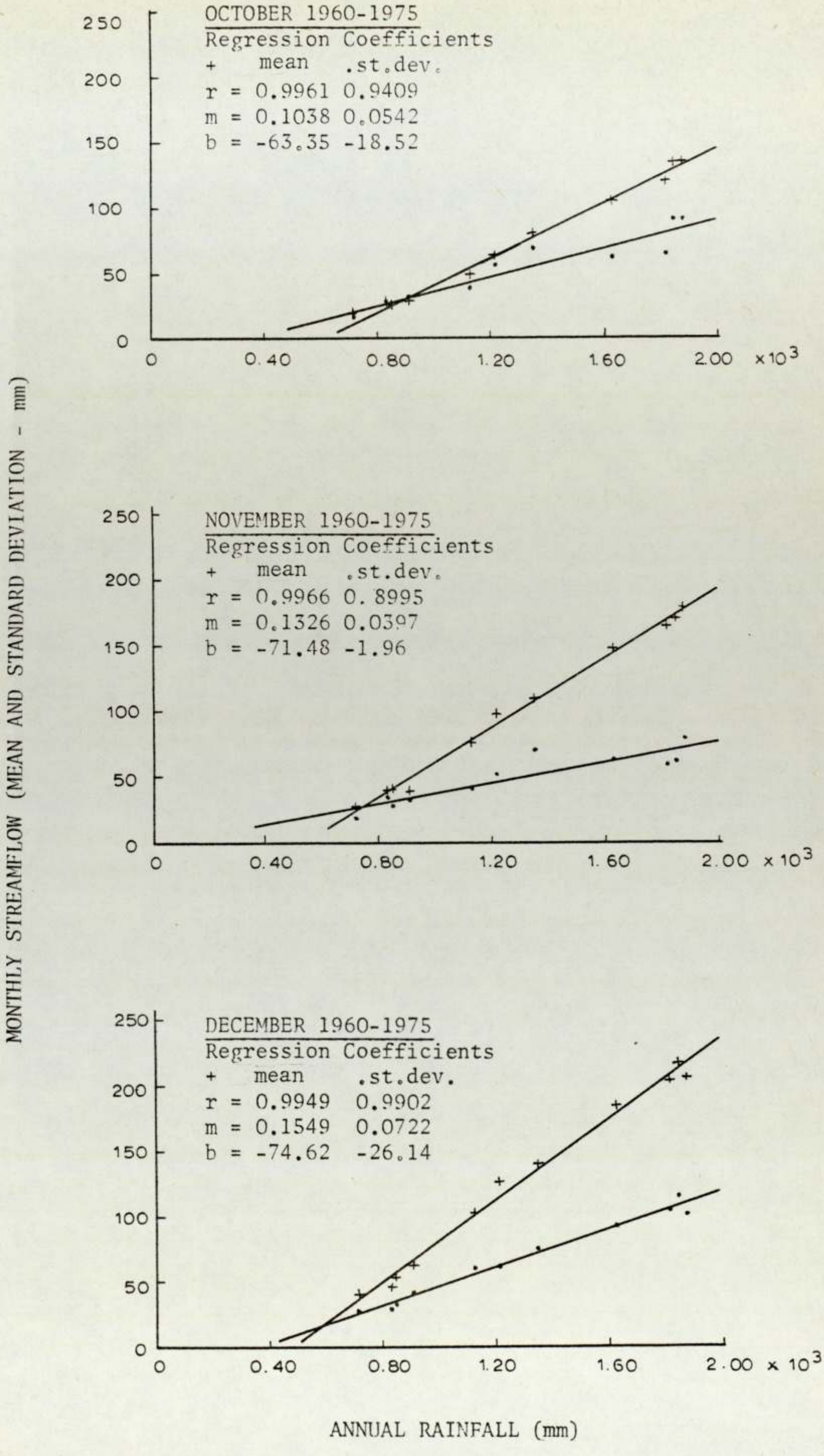


FIGURE 7.34/4 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF SHORT RECORDS

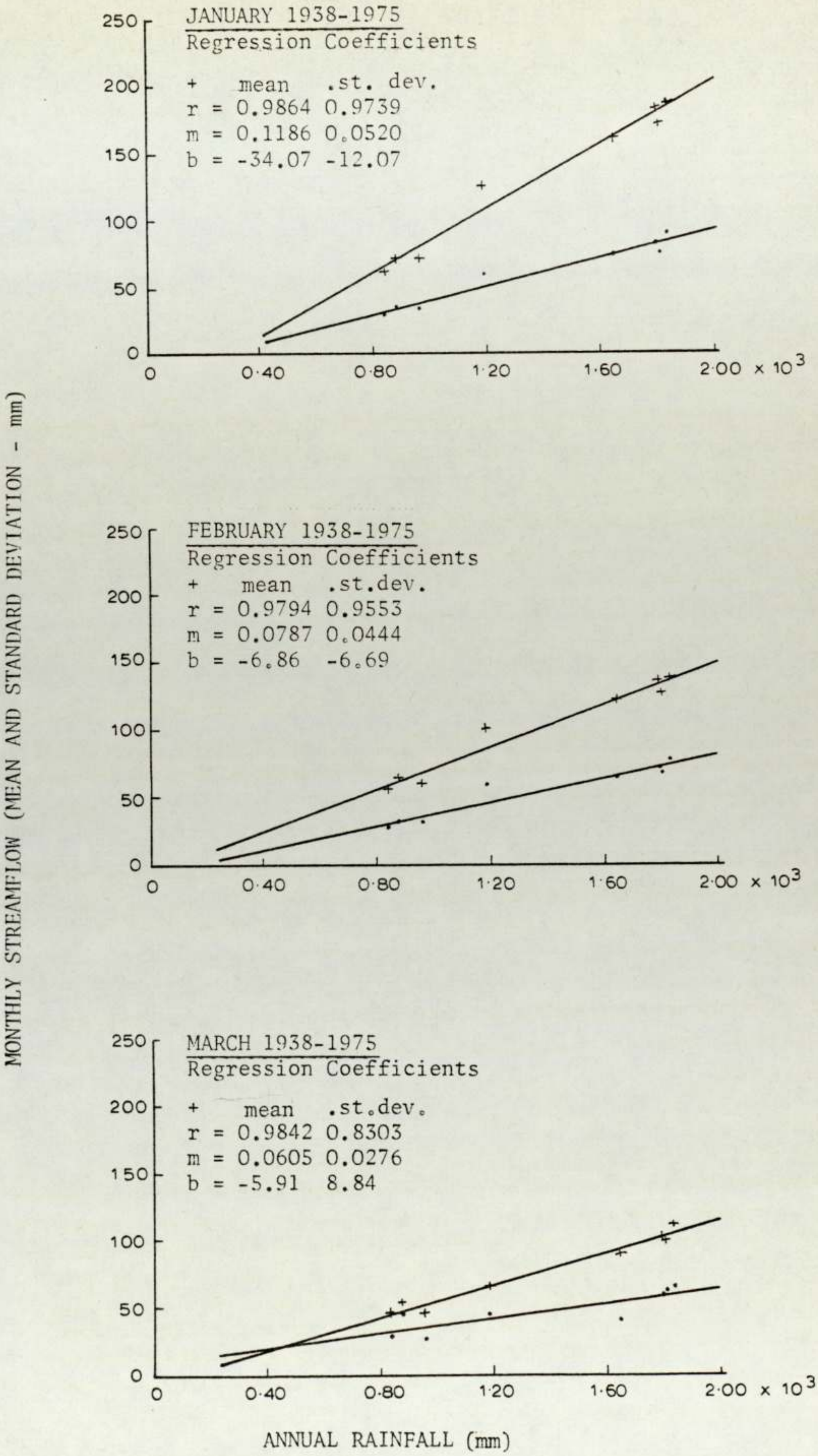


FIGURE 7.35/1 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW (1938-75)

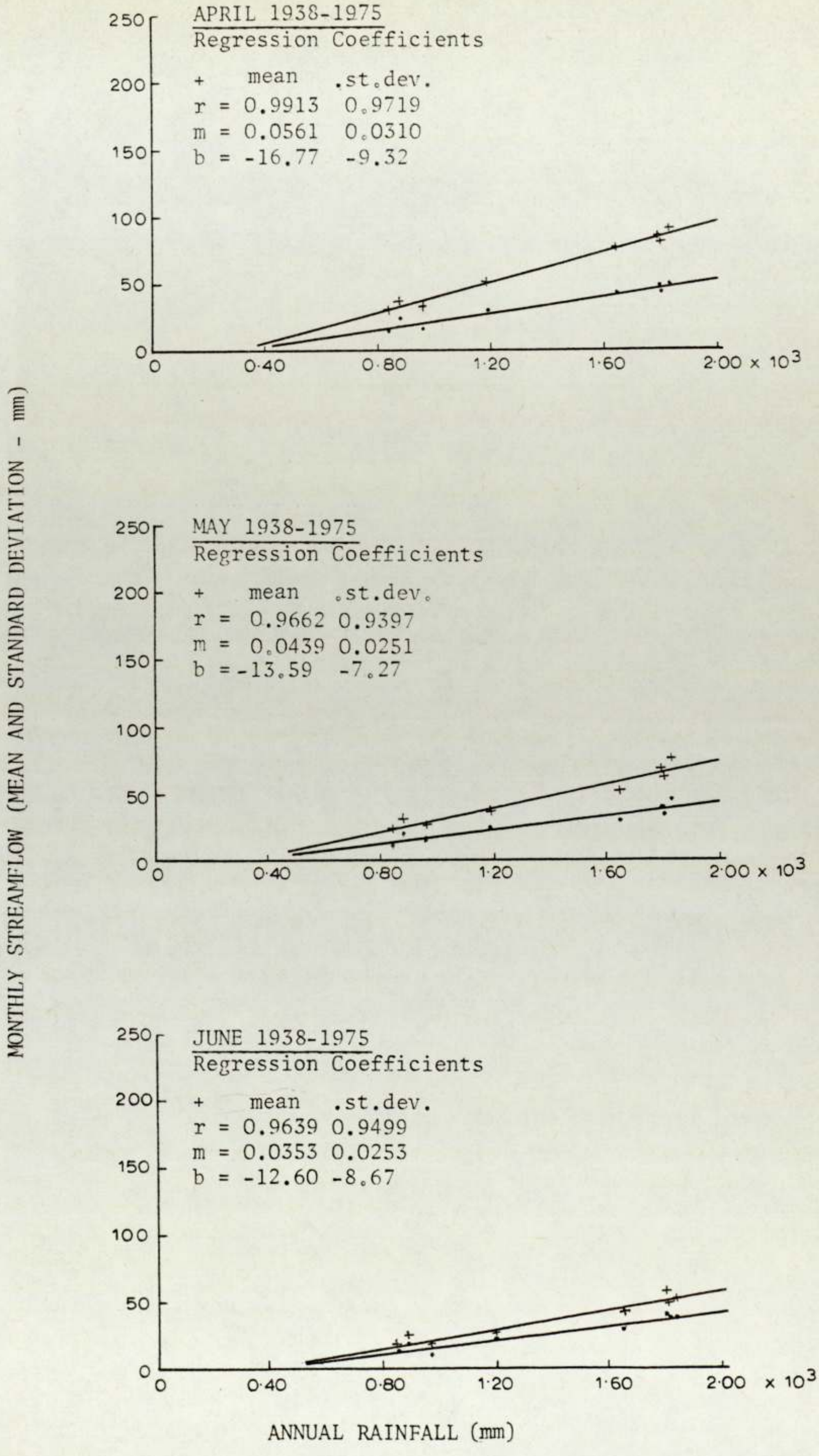


FIGURE 7.35/2 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF LONG RECORDS

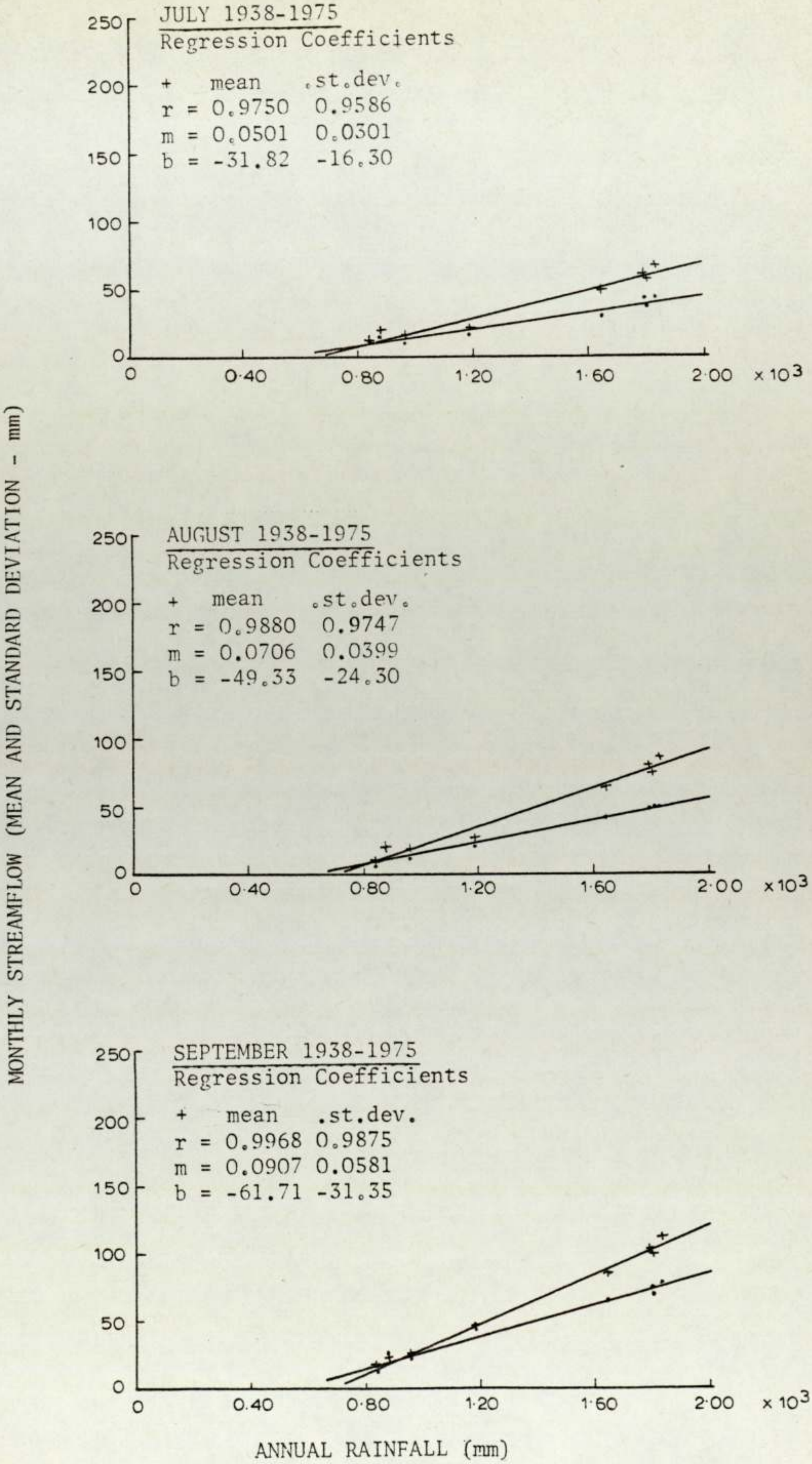


FIGURE 7.35/3 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF LONG RECORDS

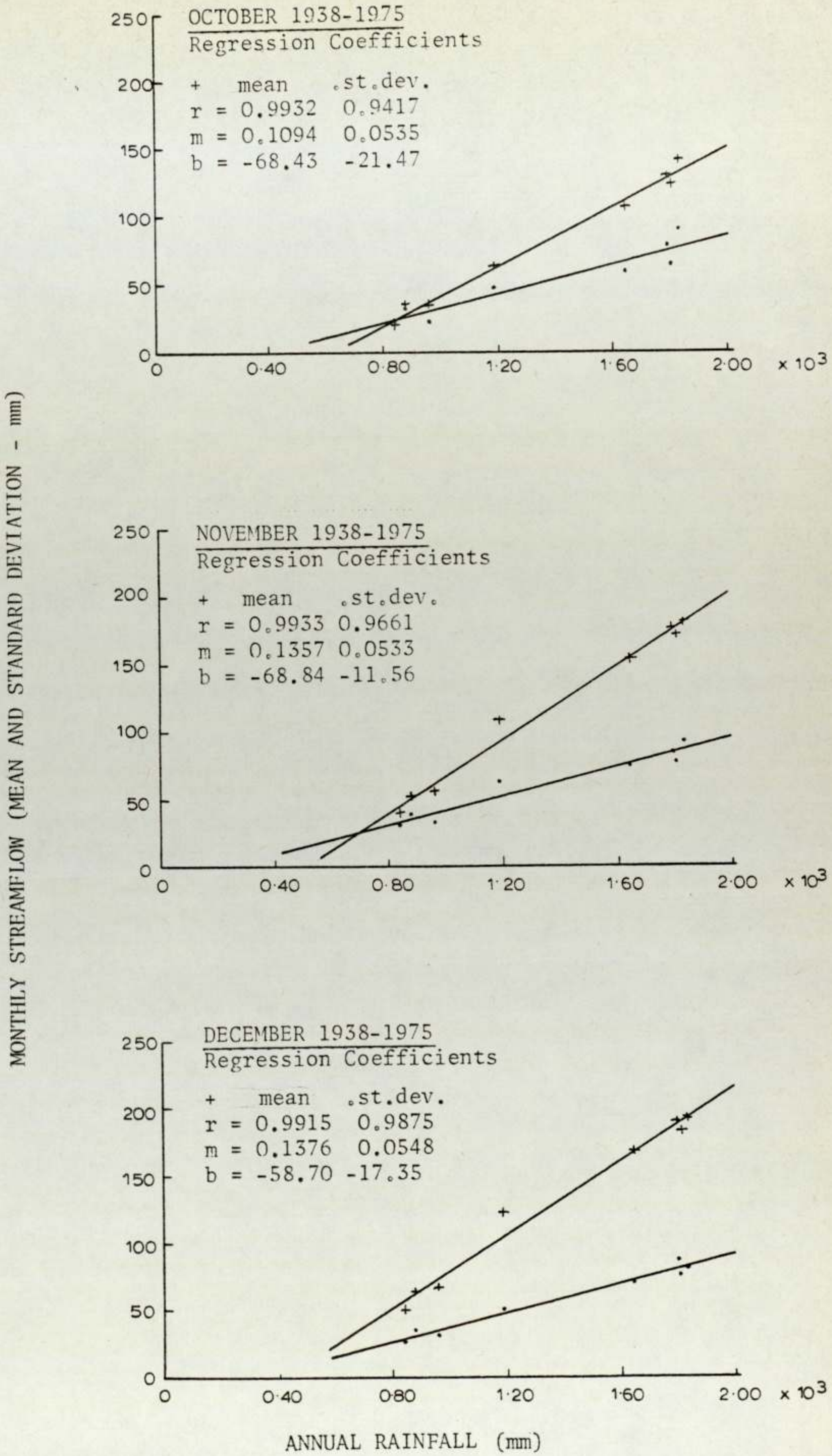


FIGURE 7.35/4 LINEAR REGRESSION OF ANNUAL RAINFALL AND MONTHLY STREAMFLOW OF LONG RECORDS

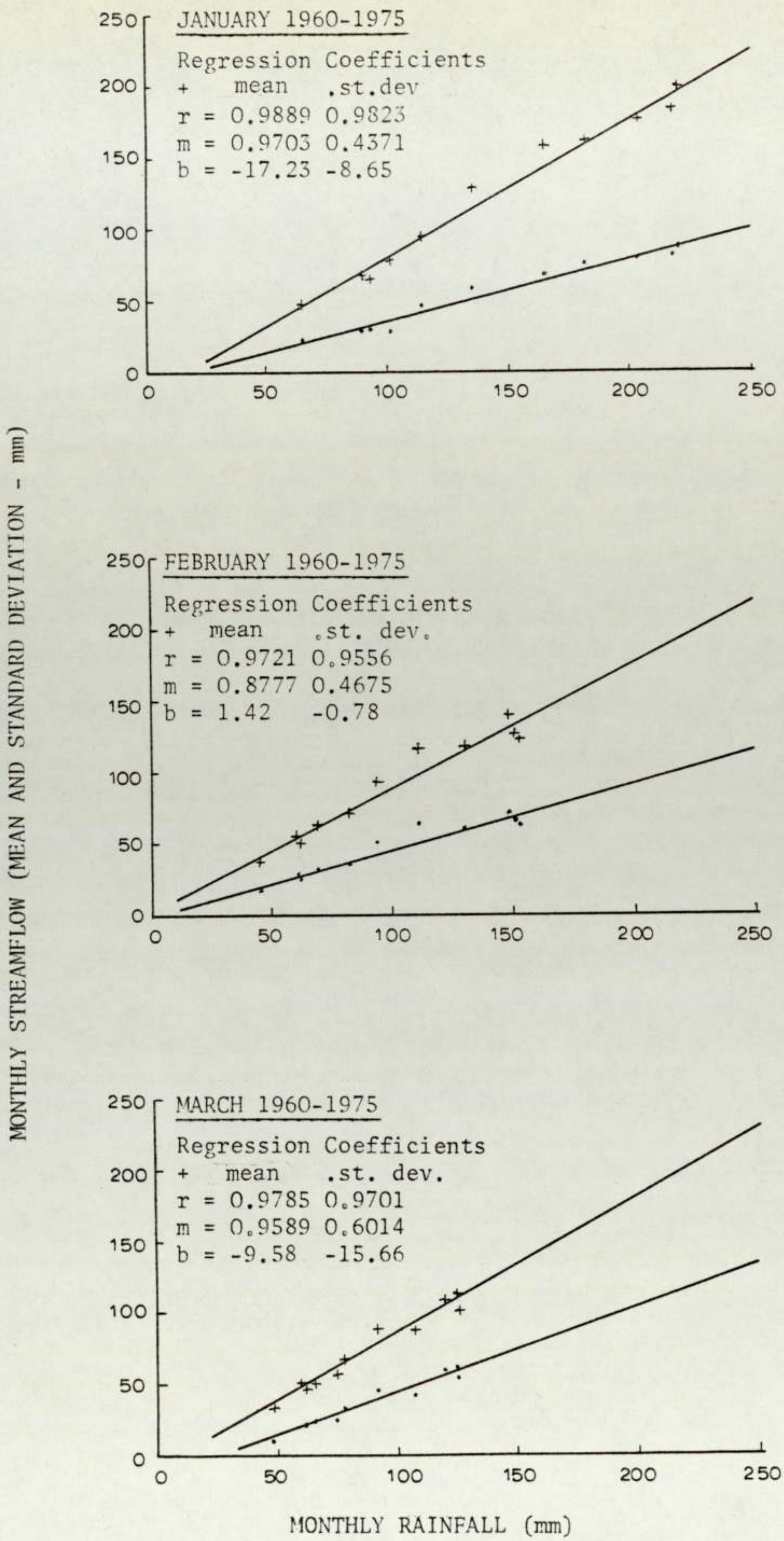


FIGURE 7.36/1 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW (1960-75)

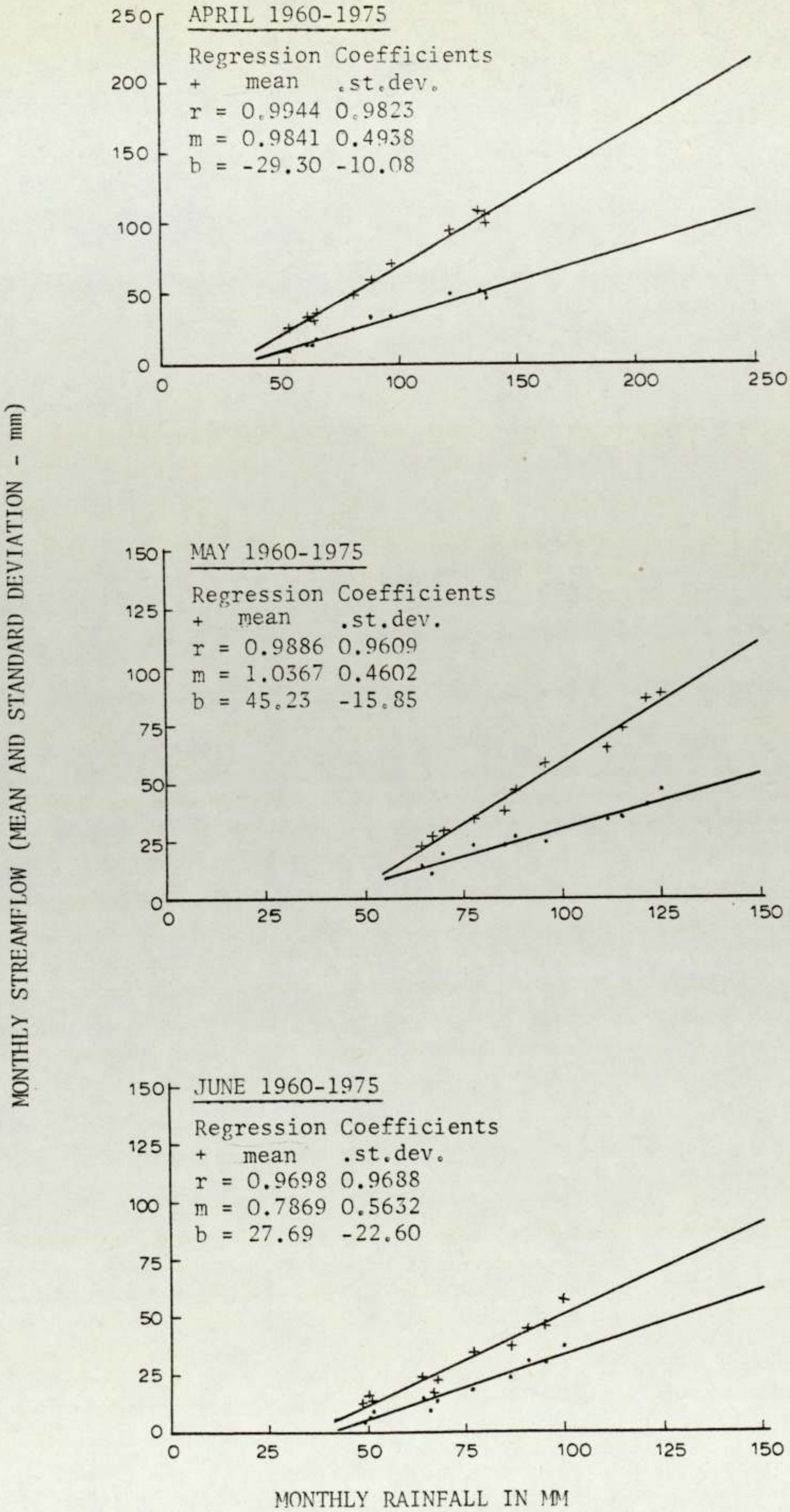


FIGURE 7.36/2 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF SHORT RECORDS

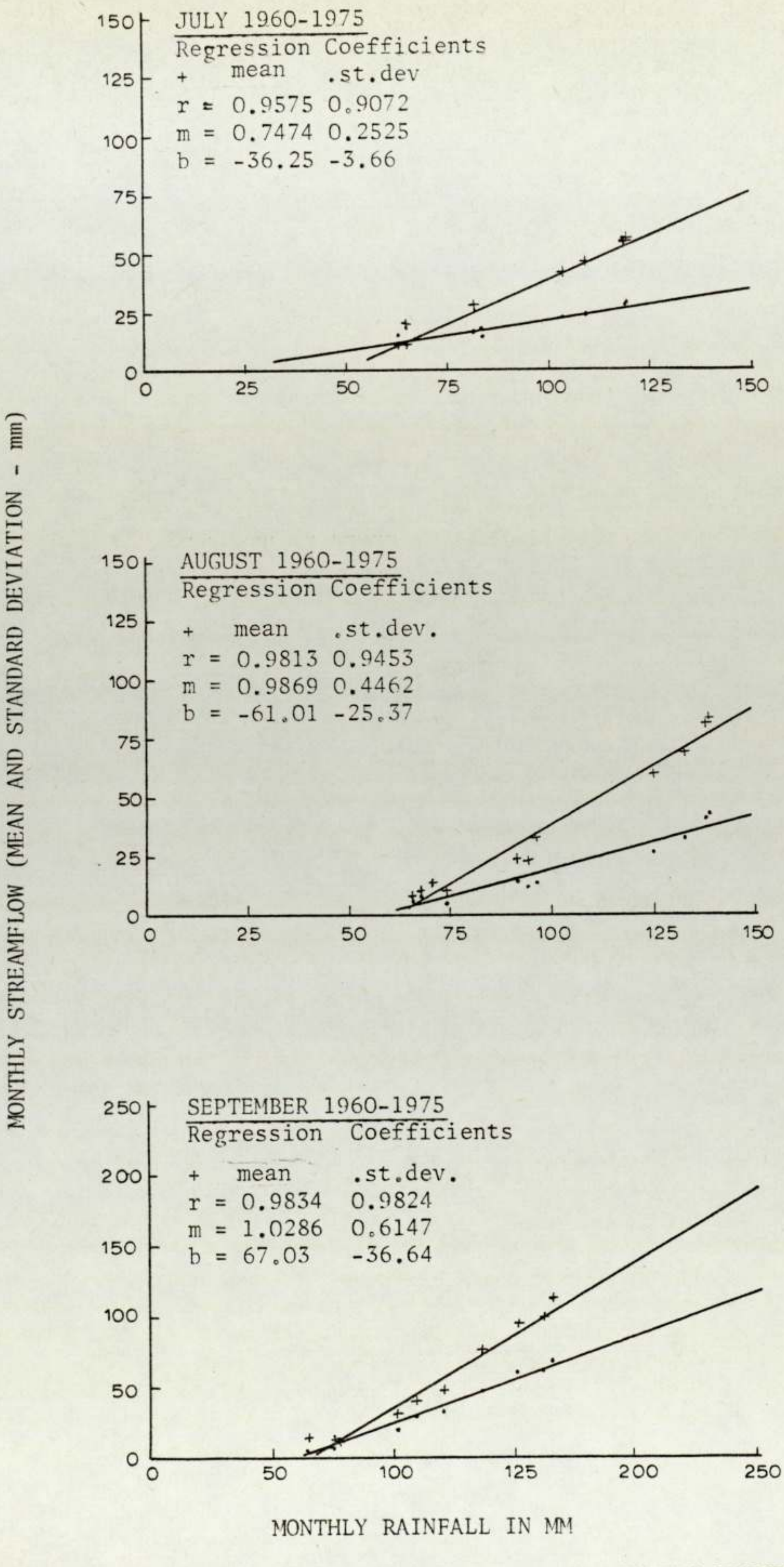


FIGURE 7.36/3 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF SHORT RECORDS

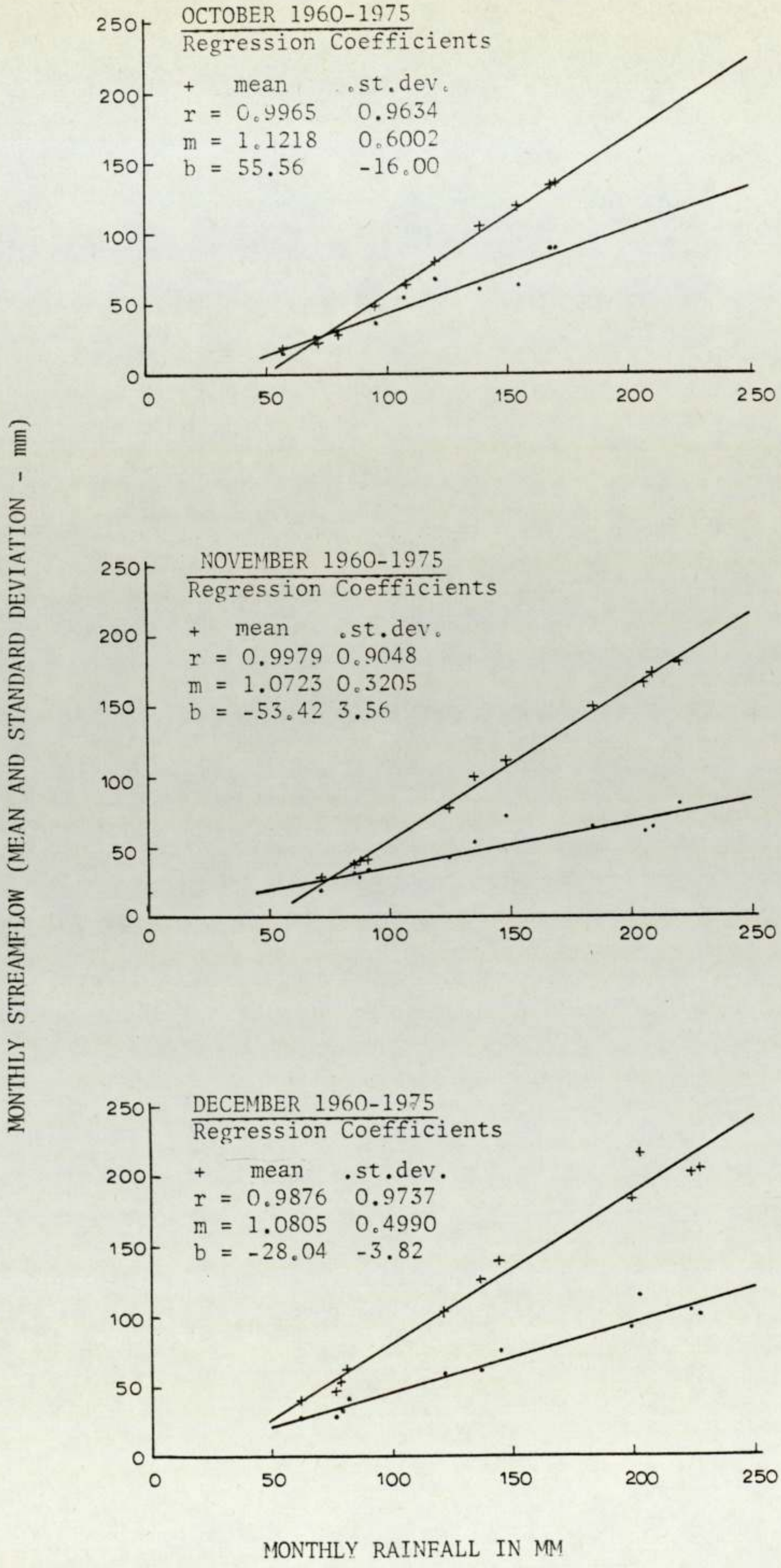


FIGURE 7.36/4 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF SHORT RECORDS

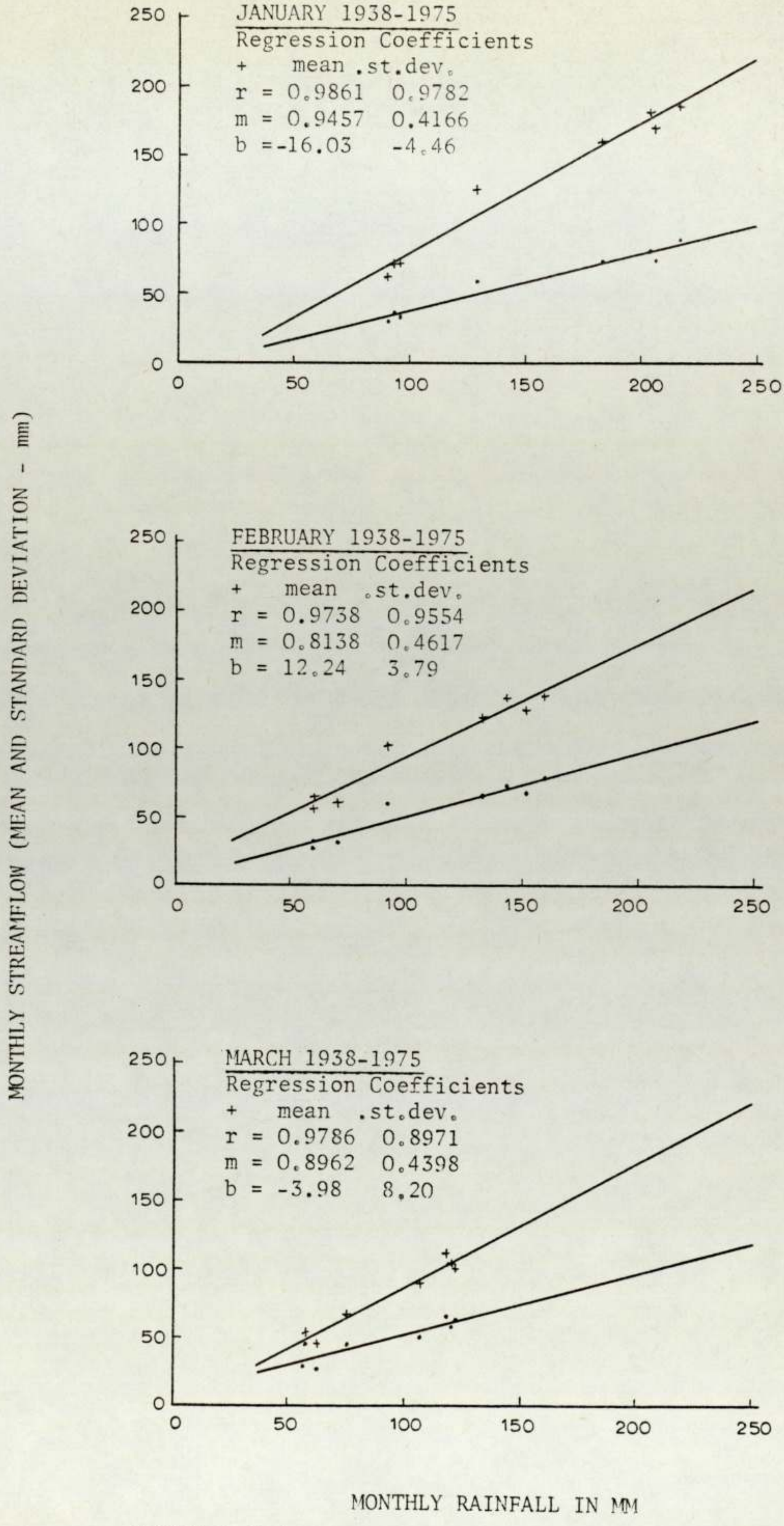


FIGURE 7.37/1 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW (1938-75)

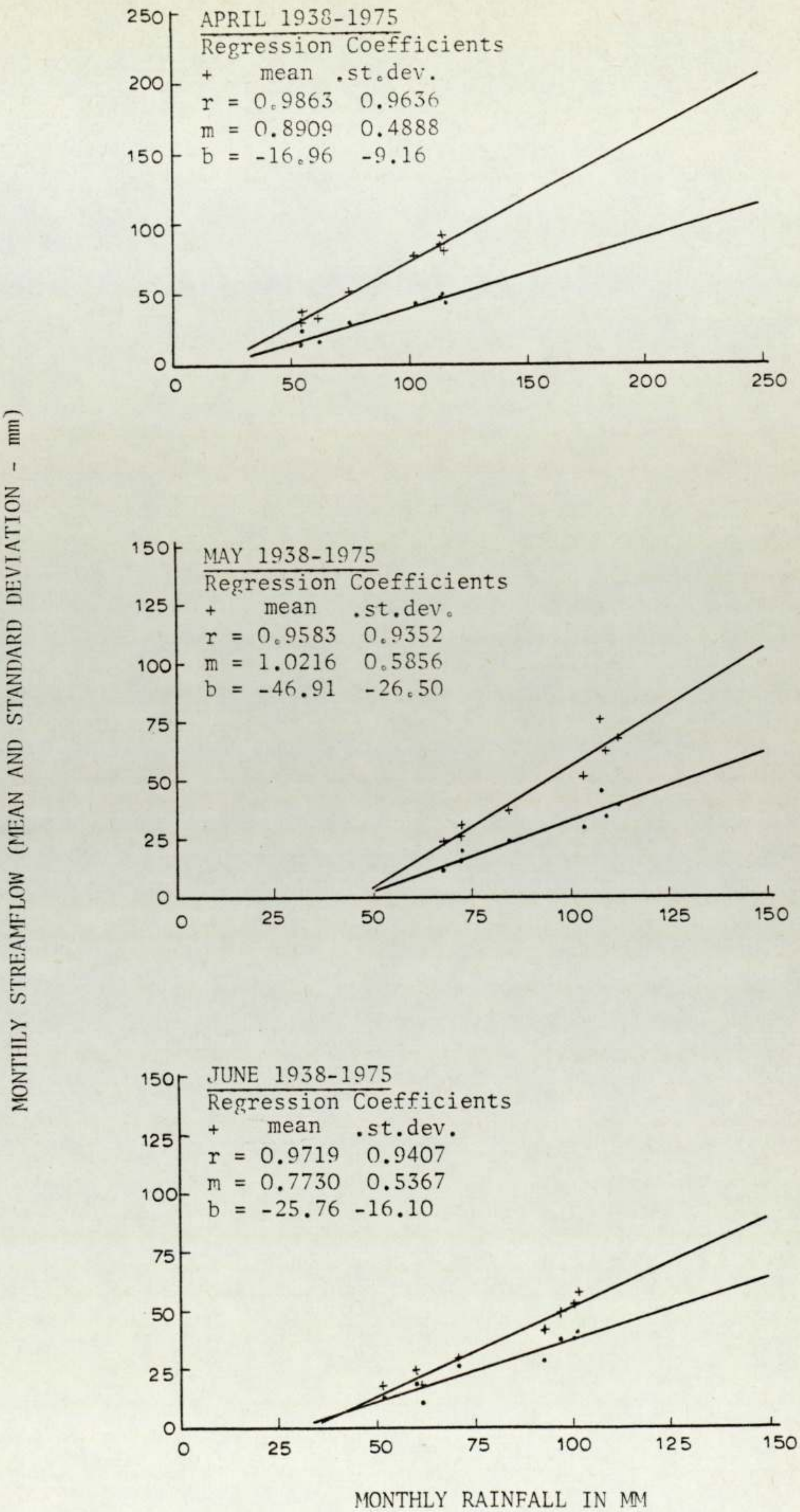


FIGURE 7.37/2 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF LONG RECORDS

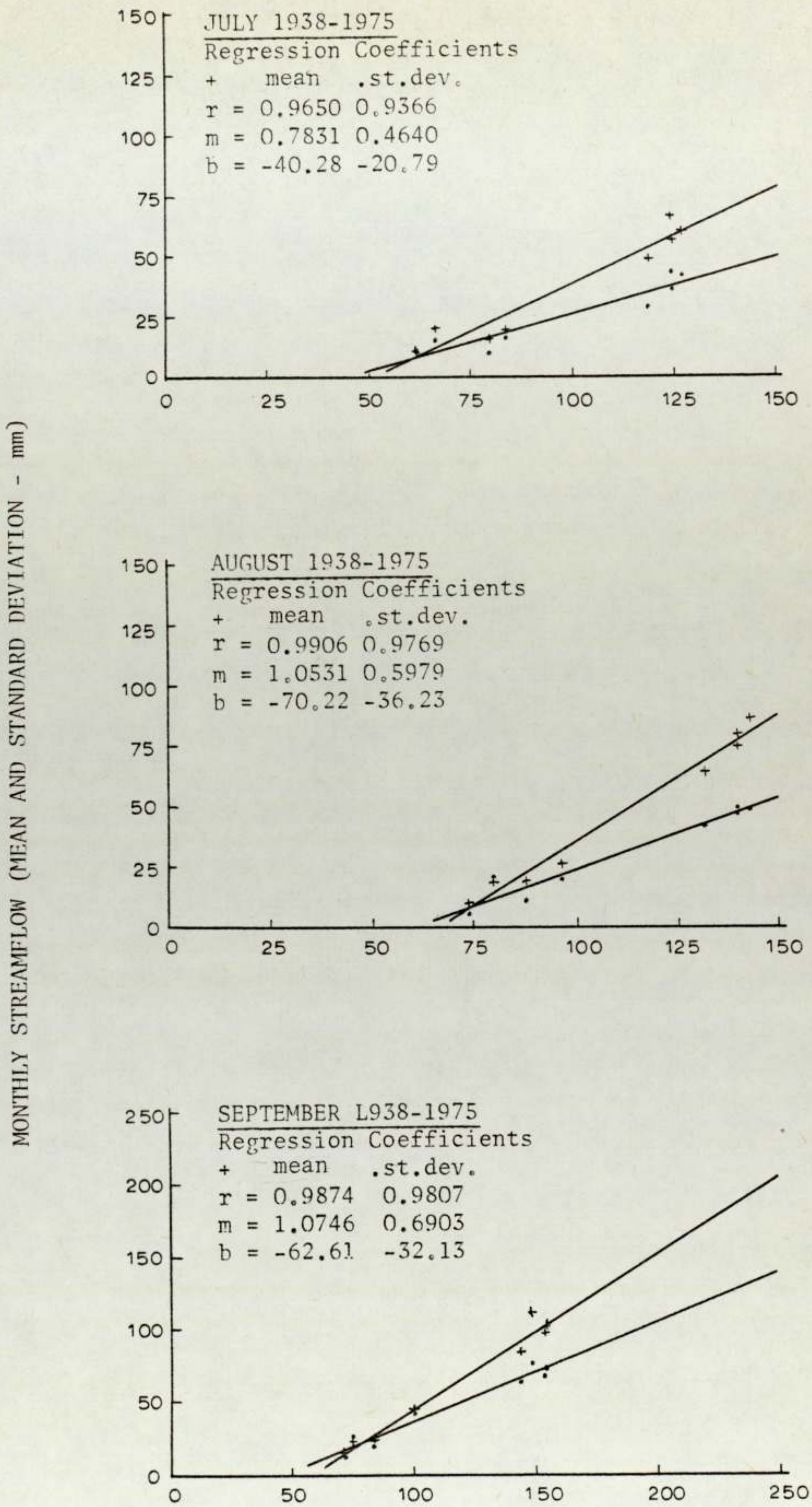


FIGURE 7.37/3 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF LONG RECORDS

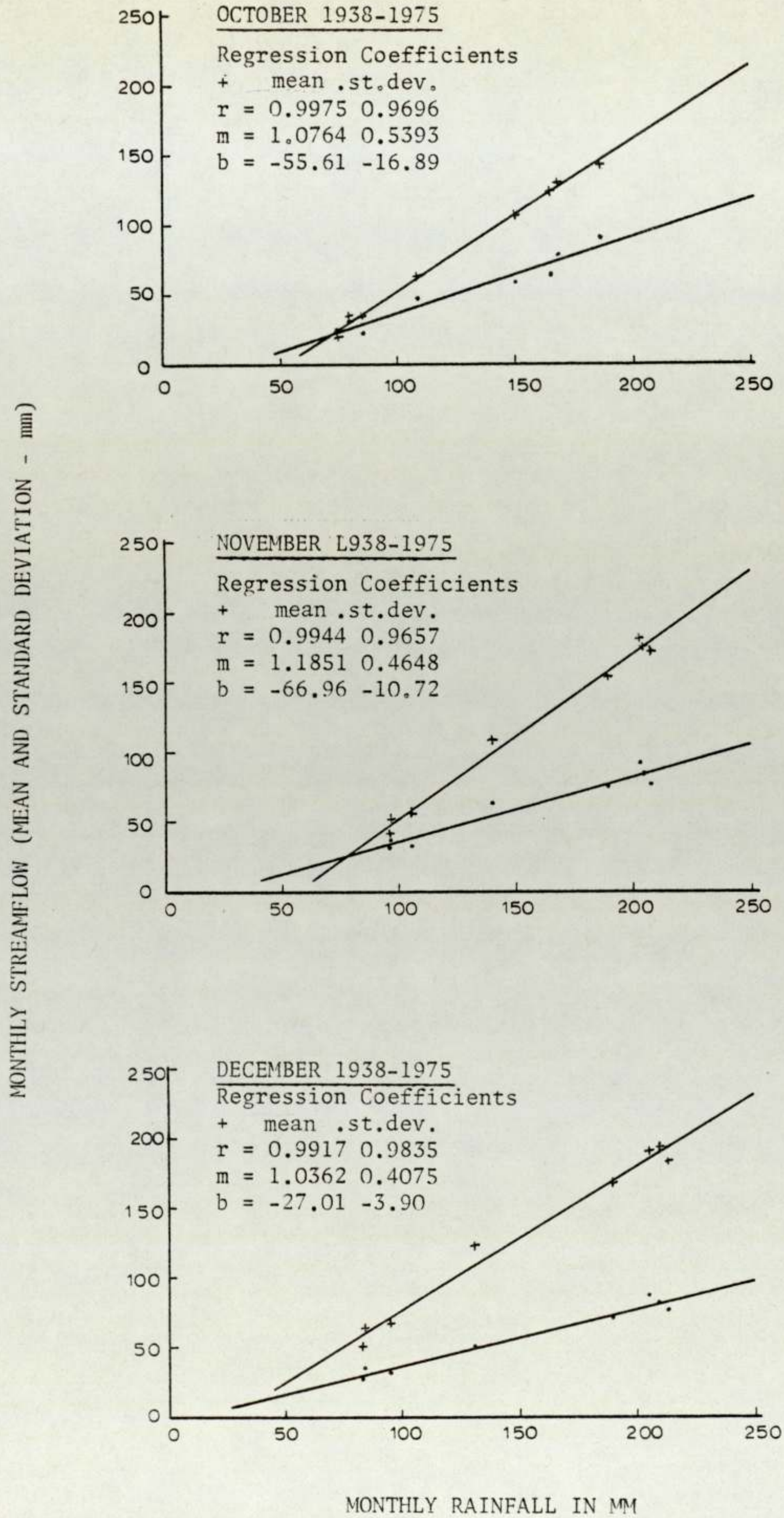


FIGURE 7.37/4 LINEAR REGRESSION OF MONTHLY RAINFALL/ STREAMFLOW OF LONG RECORDS

An equation of the same form was used for the rainfall/standard deviation (S_i) relationship. Although there are clearly other factors involved in the rainfall/streamflow process, the use of simple linear relationships between these primary variables was justified by the sample correlation coefficients which lay between 0.998 and 0.946 for monthly mean flows, and between 0.990 and 0.830 for standard deviations of monthly flow.

Table 7.9 summarises the intercept, slope and regression coefficients for the derived relationships.

Figures 7.38 and 7.39 show the temporal variation of the intercept and slope parameters of the rainfall/streamflow (mean and standard deviation) relationships.

Estimates of the streamflow parameters for ungauged catchments within the Region can be obtained using either:

1) The plotted relationships given in Figures 7.34 to 7.37

or

2) The linear regression equations with smoothed intercept and slope coefficients obtained from Figures 7.38 or 7.39 as appropriate.

The use of smoothed intercept and slope parameters does, however, assume that the long term variation of these is of the smooth cyclic form shown in the graphs. While it may be true that their variation will be relatively smooth, the precise form of the variation may be far more complicated than indicated, since the rainfall/streamflow process involves many seasonally variable factors. Further investigation into this process is needed in order to develop more scientific methods of smoothing these parameters. However, the existing curves provide a useful means of estimating possible long term variations in streamflow, but only time will tell whether

TABLE 7.9 SUMMARY OF THE INTERCEPT (b), SLOPE (m) AND REGRESSION COEFFICIENT (r) FOR THE RAINFALL STREAMFLOW RELATIONSHIPS

Linear Regression coefficients			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Based Upon Annual Rainfall	Short Record (1966-75) Means + St.dev.	b	-32.71 -16.38	-11.34 -7.41	-5.19 -12.69	-29.40 -16.22	-16.53 -2.54	-11.95 -11.54	-20.32 1.83	-45.92 -18.64	-62.22 -33.77	-63.53 -18.52	-71.48 -1.96	-74.62 -26.14
		m	0.1208 0.0550	0.0785 0.0412	0.0610 0.0381	0.0724 0.0364	0.0525 0.0229	0.0322 0.0232	0.0381 0.0128	0.0648 0.0293	0.0869 0.0520	0.1038 0.0542	0.1326 0.0397	0.1549 0.0722
		r	0.9750 0.9790	0.9654 0.9462	0.9794 0.9696	0.9864 0.9362	0.9452 0.9388	0.9558 0.9512	0.9783 0.9020	0.9843 0.9407	0.9947 0.9838	0.9961 0.9409	0.9966 0.8995	0.9949 0.9902
	Long Record (1938-75) Means + St.dev.	b	-34.07 -12.07	-6.86 -6.69	-5.91 -8.84	-16.77 -9.32	-13.59 -7.27	-12.60 -8.67	-31.82 -16.30	-49.33 -24.30	-61.71 -31.35	-68.43 -21.47	-68.84 -11.56	-58.70 -17.35
		m	0.1186 0.0520	0.0787 0.0444	0.0605 0.0276	0.0561 0.0310	0.0439 0.0251	0.0353 0.0253	0.0501 0.0301	0.0706 0.0399	0.0907 0.0581	0.1094 0.0535	0.1353 0.0533	0.1376 0.0548
		r	0.9864 0.9739	0.9794 0.9553	0.9842 0.8303	0.9913 0.9717	0.9662 0.9397	0.9636 0.9499	0.9750 0.9586	0.9880 0.9747	0.9968 0.9875	0.9932 0.9417	0.9933 0.9661	0.9915 0.9875
Based Upon Monthly Rainfall	Short Record (1960-75) Means + St.dev.	b	-17.23 -8.65	1.42 -0.78	-9.58 -15.66	-29.30 -10.08	-45.23 -15.85	-27.69 -22.60	-36.25 -3.66	-61.01 -25.37	-67.03 -36.64	-55.56 -16.00	-53.42 3.56	-28.04 -3.82
		m	0.9703 0.4371	0.8777 0.4675	0.9589 0.6014	0.9841 0.4938	1.0367 0.4602	0.7869 0.5632	0.7474 0.2525	0.9869 0.4462	1.0286 0.6147	1.0218 0.6002	1.0723 0.3205	1.0805 0.4990
		r	0.9889 0.9823	0.9721 0.9556	0.9785 0.9701	0.9944 0.9823	0.9886 0.9609	0.9698 0.9688	0.9575 0.9072	0.9813 0.9453	0.9834 0.9824	0.9965 0.9634	0.9979 0.9048	0.9876 0.9739
	Long Record (1938-75) Means + St.dev.	b	-16.03 -4.46	12.24 3.79	-3.98 8.20	-16.96 -9.16	-46.91 -26.50	-25.76 -16.10	-40.28 -20.79	-70.22 -36.23	-62.61 -32.13	-55.61 -16.89	-66.96 -10.72	-27.01 -3.90
		m	0.9457 0.4166	0.8138 0.4617	0.8962 0.4398	0.8909 0.4888	1.0216 0.5856	0.7730 0.5367	0.7831 0.4640	1.0531 0.5979	1.0764 0.6903	1.0764 0.5393	1.1851 0.4648	1.0362 0.4075
		r	0.9861 0.9782	0.9738 0.9554	0.9786 0.8971	0.9863 0.9636	0.9583 0.9352	0.7917 0.9407	0.9650 0.9366	0.9906 0.9767	0.9874 0.9807	0.9975 0.9696	0.9944 0.9657	0.9917 0.9835

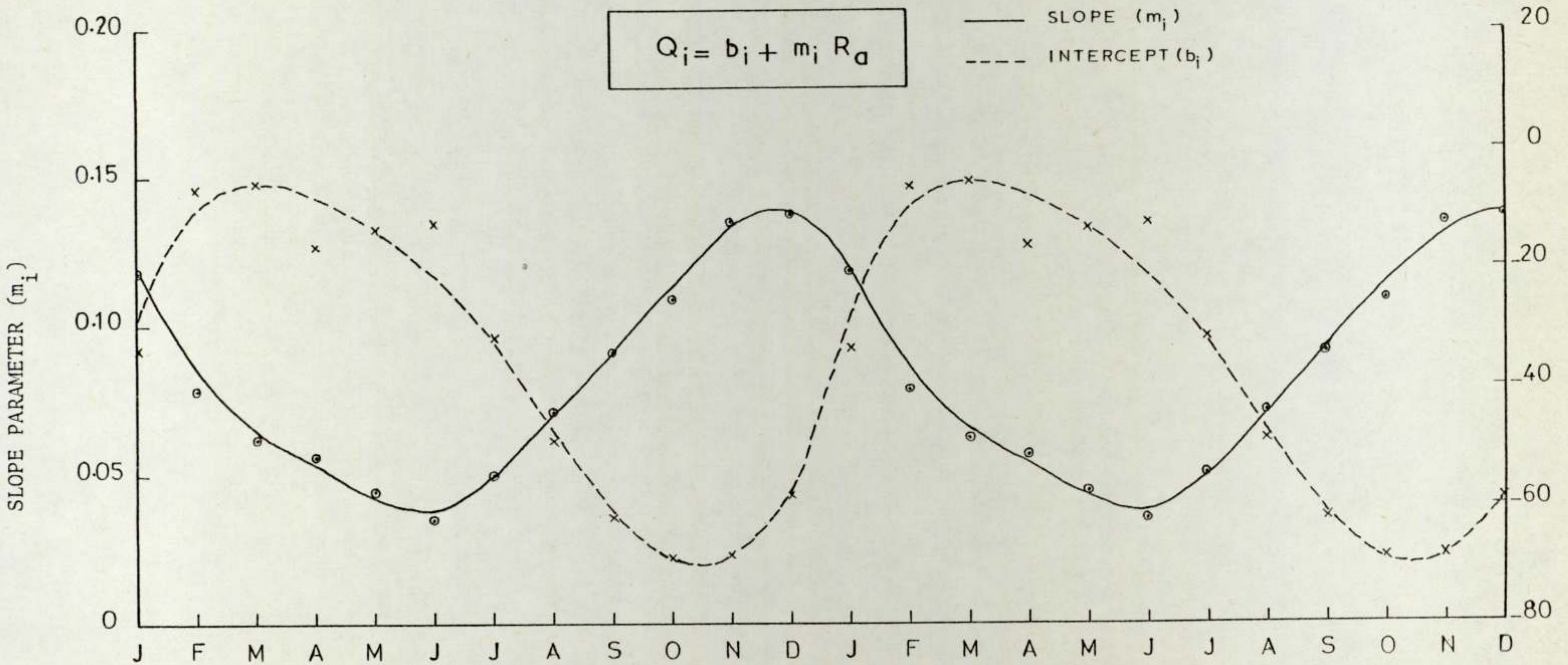


FIGURE 7.38/1 TEMPORAL VARIATION OF THE REGIONAL MEAN MONTHLY STREAMFLOW PARAMETER (b_i, m_i) WITH ANNUAL RAINFALL (1938-75)

[Graph plotted over two year cycle to ensure continuity]

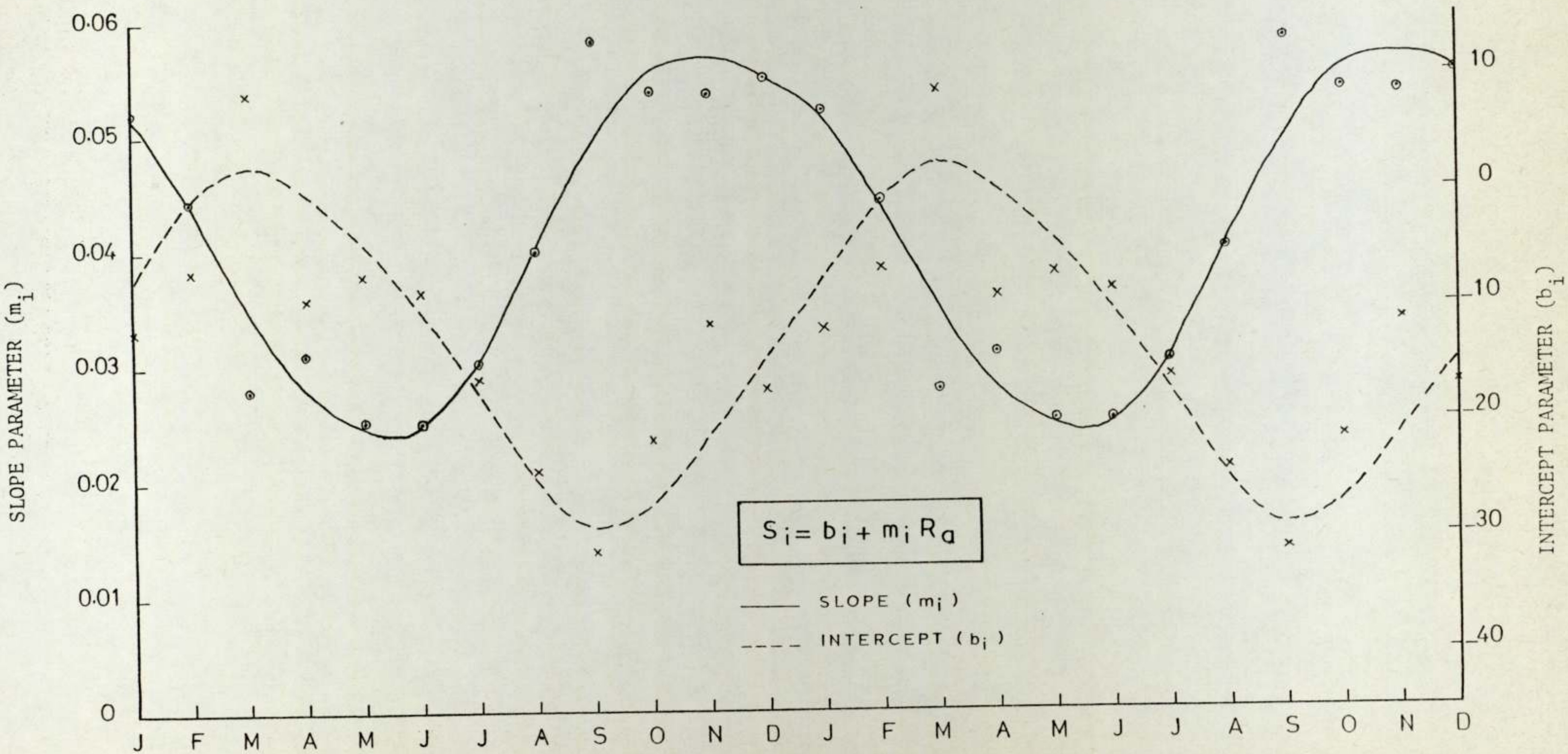


FIGURE 7.38/2 TEMPORAL VARIATION OF THE REGIONAL MONTHLY STANDARD DEVIATION PARAMETERS (b_i, m_i) OF STREAMFLOW WITH ANNUAL RAINFALL (1938-75)

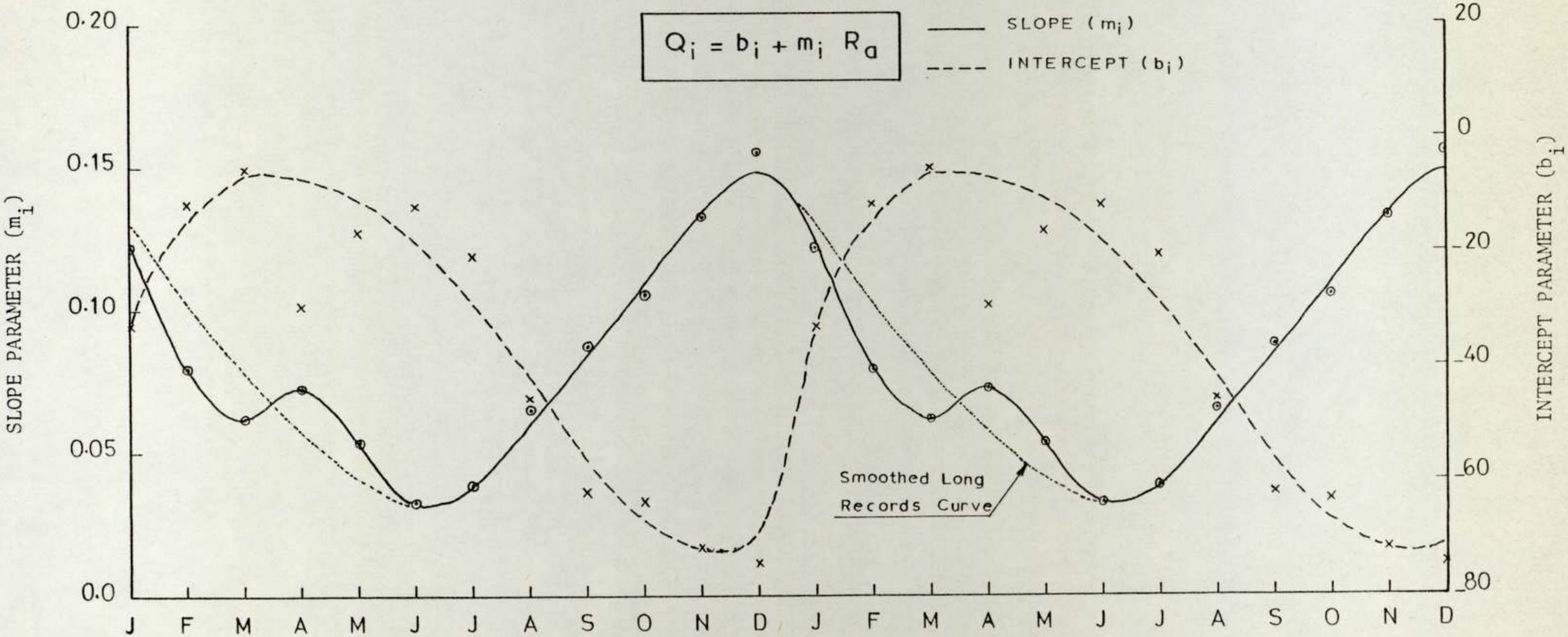


FIGURE 7.39 TEMPORAL VARIATION OF THE REGIONAL MEAN MONTHLY STREAMFLOW AND ANNUAL RAINFALL (1960-75)

[Graph plotted over two year cycle to ensure continuity]

these are valid or not.

The water balance equation for a river catchment states that:

Inflow - Outflow = Increase in Catchment Storage

Therefore, if the catchment is watertight with respect to groundwater flow:

$$R - E - Q = \Delta S \qquad (7.11)$$

where

R = mean areal rainfall (mm) during time interval (t).

E = mean areal evapotranspiration (mm) during time interval (t)

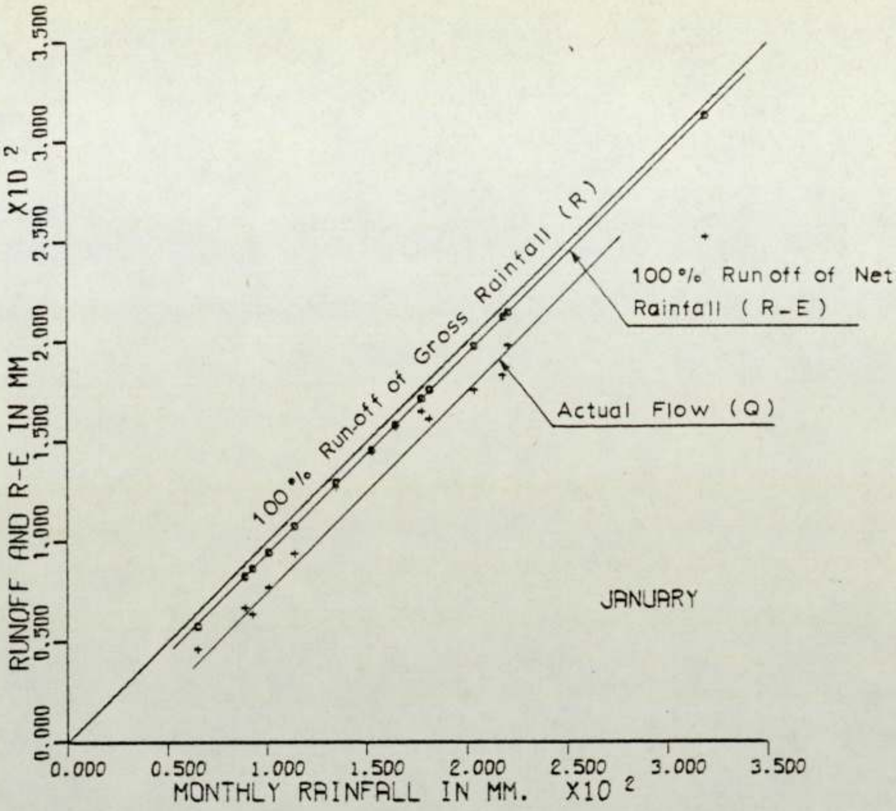
Q = net natural streamflow from catchment during time interval (t)

ΔS = increase in catchment storage (i.e. soil moisture plus groundwater storage) during time interval (t).

Rearranging (7.11) gives

$$Q = R - E - \Delta S \qquad (7.12)$$

So far, this section has described various relationships between measured values of Q and R without reference to the contributions made by E and ΔS. However, a series of graphs relating Q to R and clearly showing the contribution made by E and ΔS for t equal to one month were prepared. Since these are similar in some respects to rainfall/streamflow graphs given earlier, not all of them have been presented. Figure 7.40/1 to 7.40/6 show the theoretical monthly mean flows (R-E) and actual monthly mean flows (Q) against monthly rainfall (R) for each of the months January through to December for the period 1960-75. Also given on each graph is a line representing 100% run-off of the gross rainfall R. Where the actual flow curve



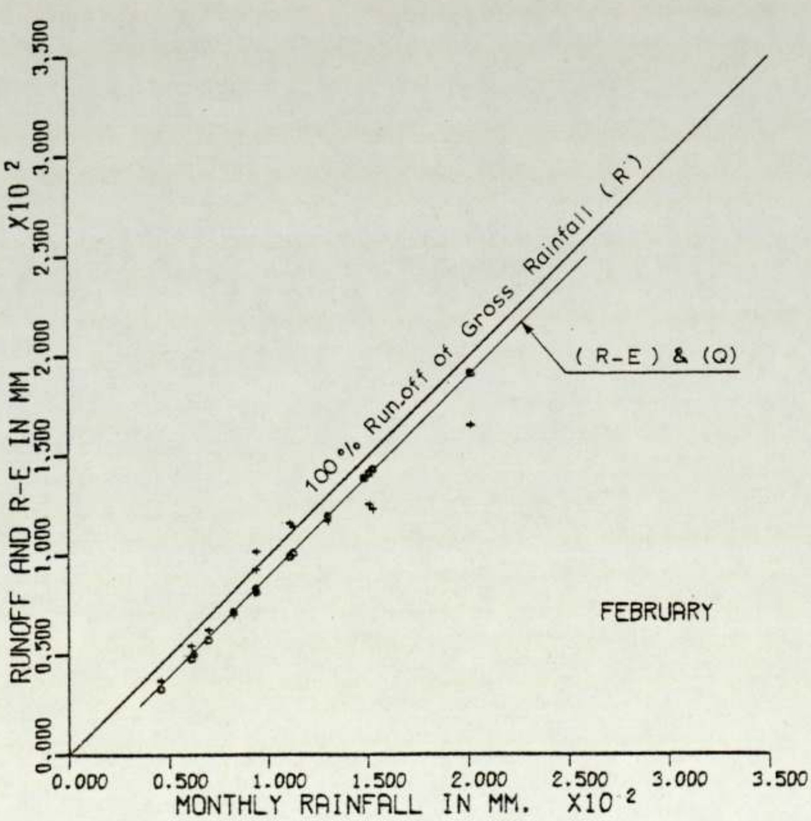
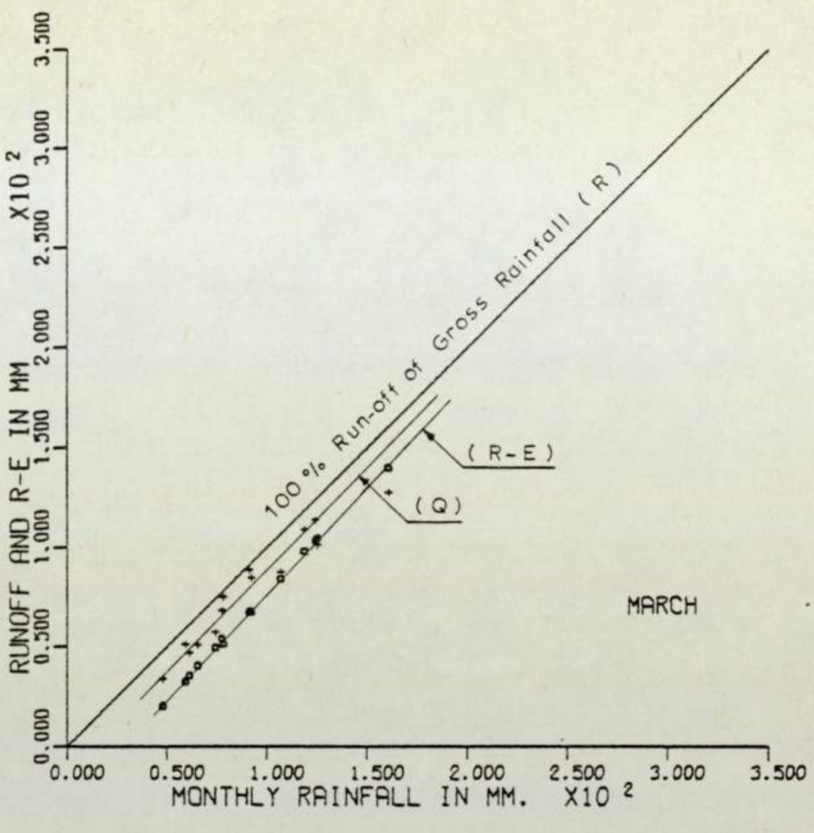


FIGURE 7.40/1 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)



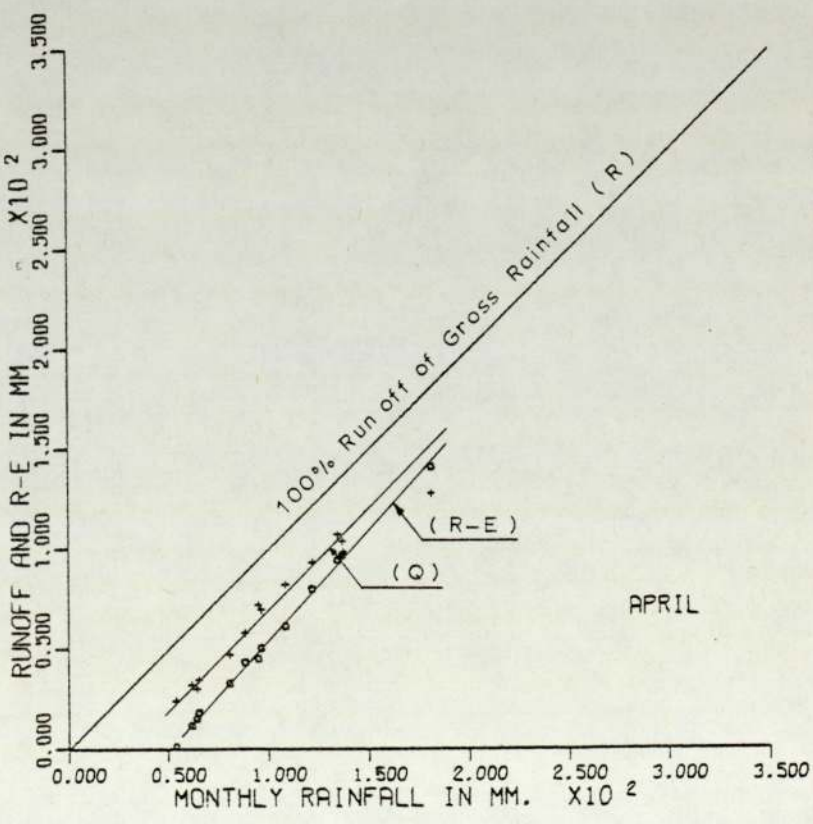
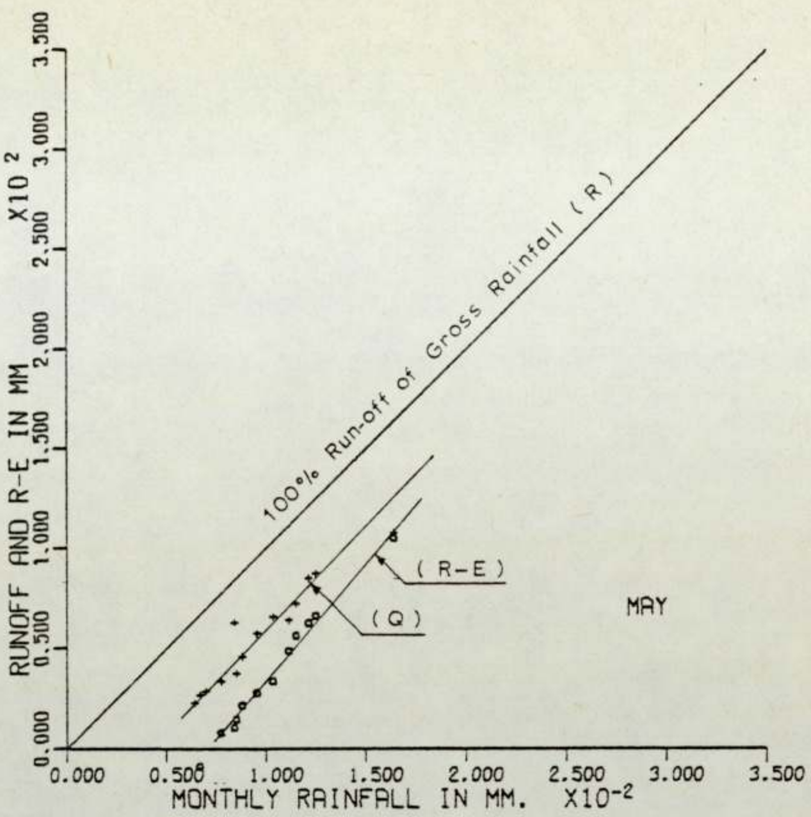


FIGURE 7.40/2 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)



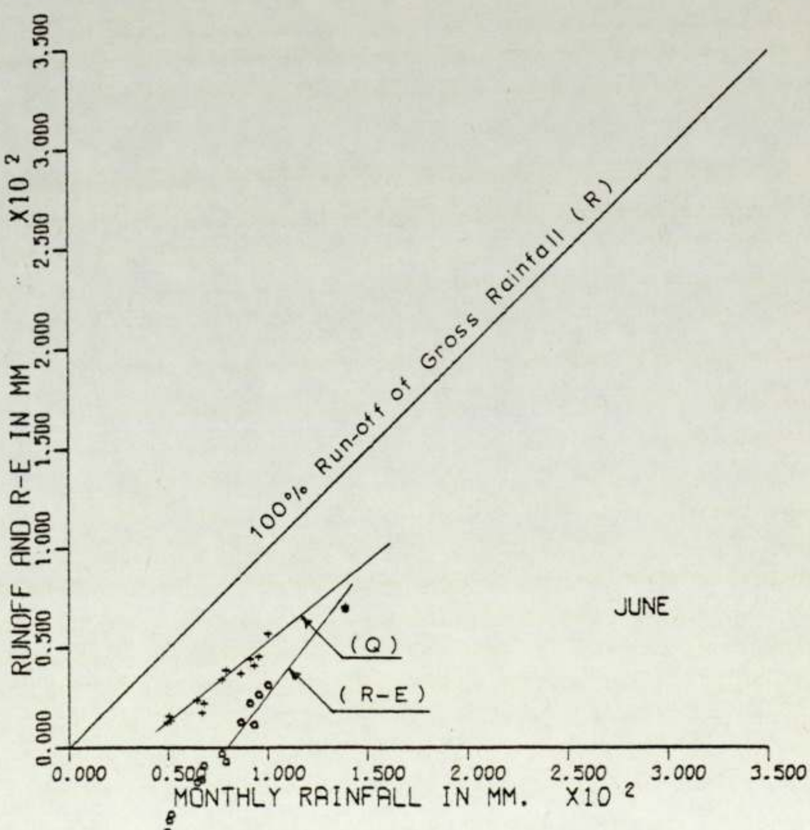
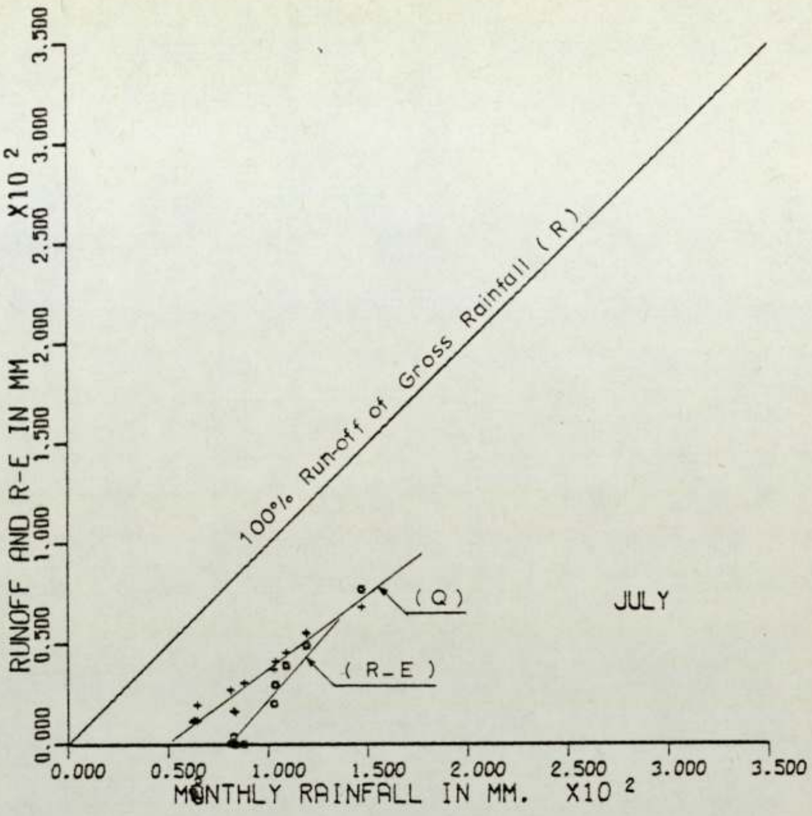


FIGURE 7.40/3 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)



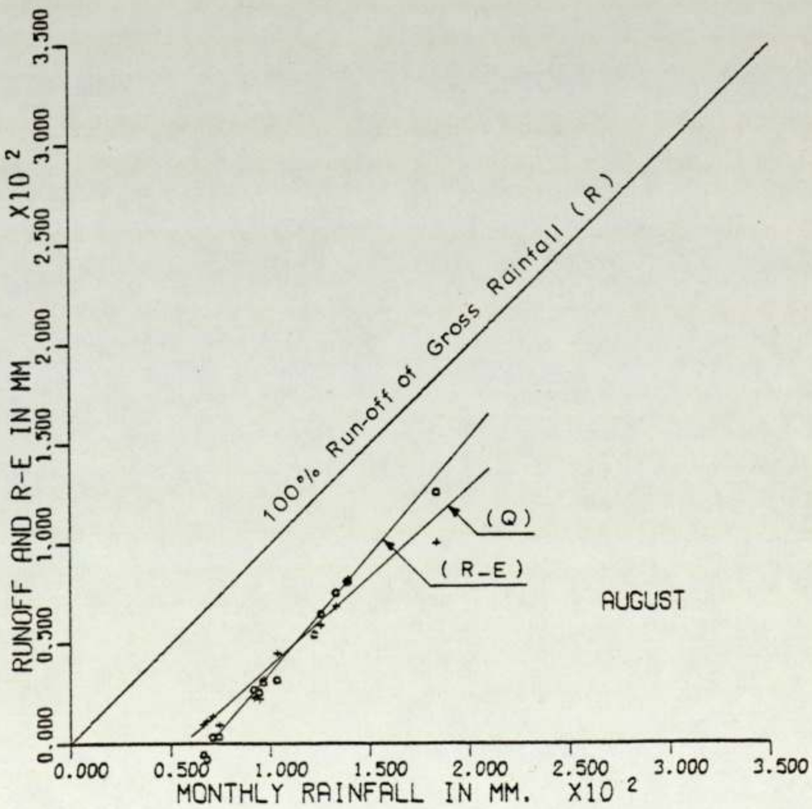
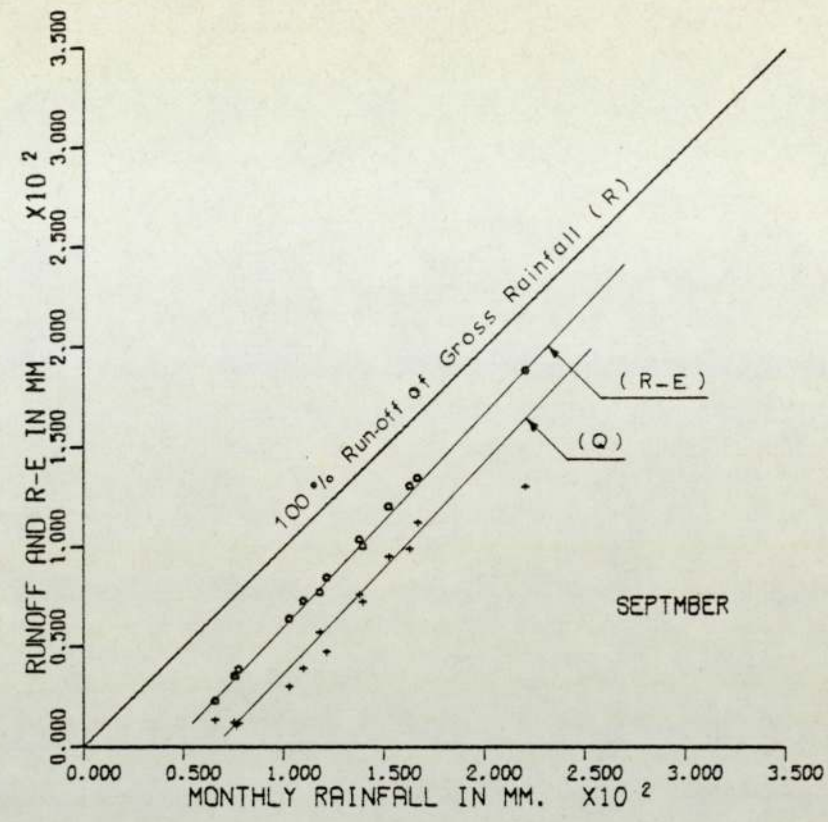


FIGURE 7.40/4 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)



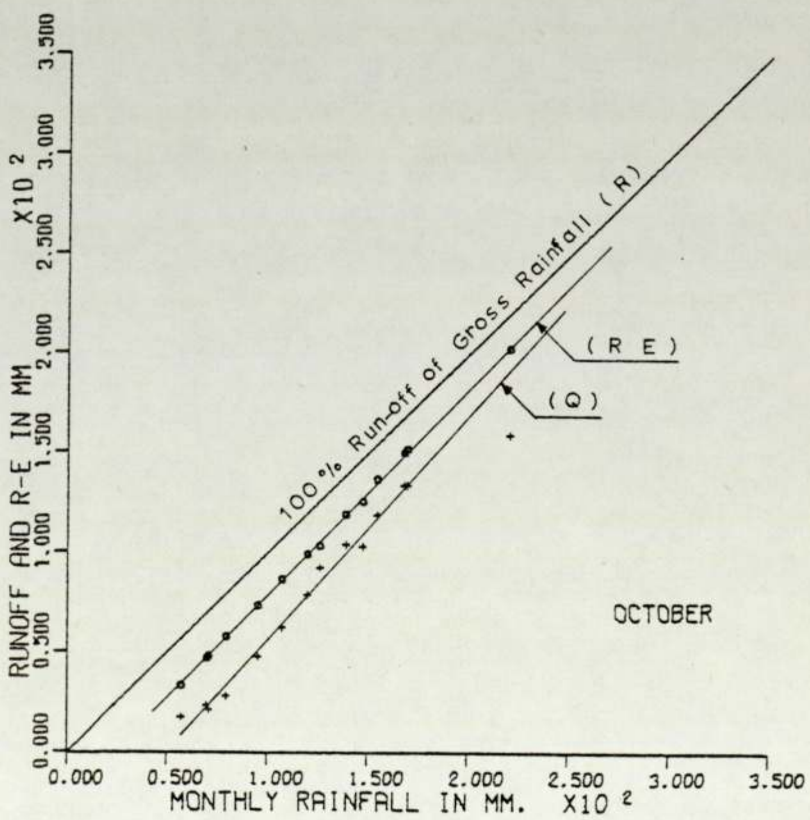
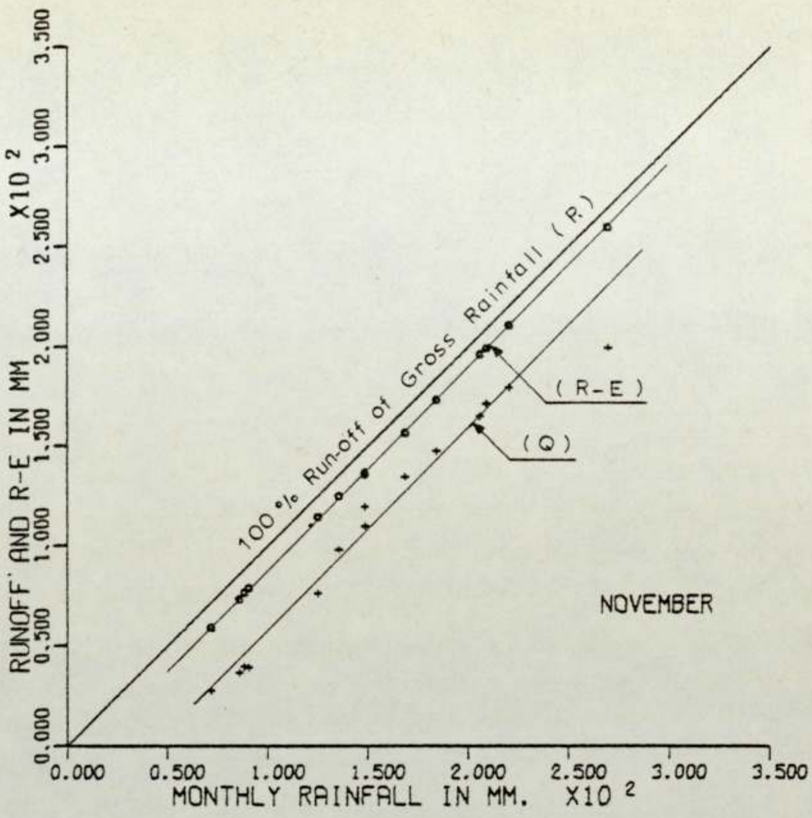


FIGURE 7.40/5 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)



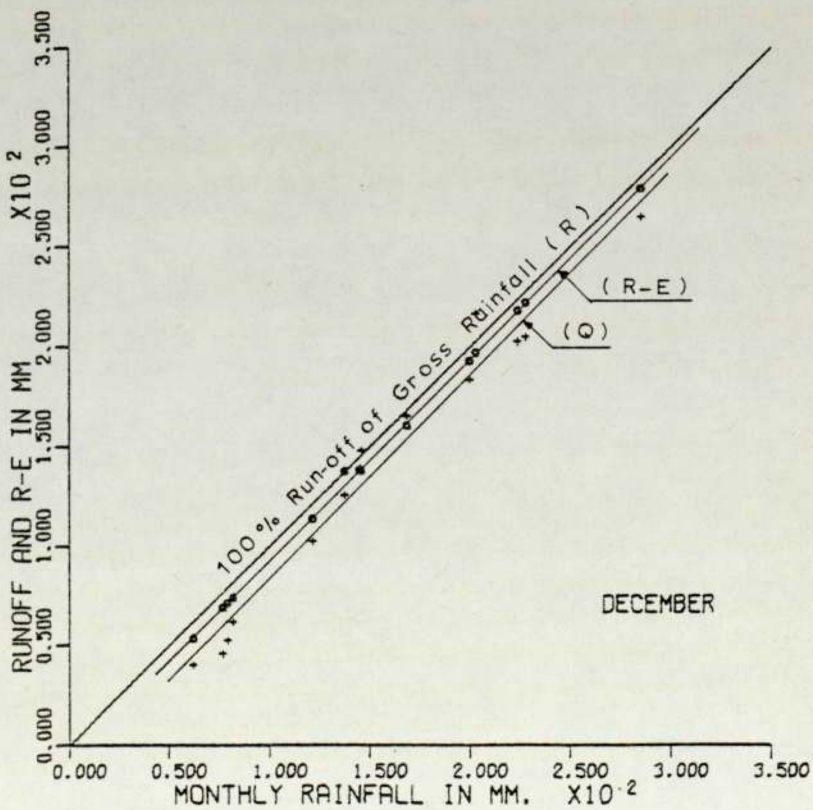


FIGURE 7.40/6 RELATIONSHIP BETWEEN MONTHLY RAINFALL AND MONTHLY STREAMFLOW (1960-75)

(q) is below the 100% (R-E) curve, the difference between them is equal to the increase in catchment storage during the month. Conversely, where the 100% (R-E) curve is below the actual flow curve (Q), the difference between them equal to the decrease in catchment storage during the month. These graphs illustrate various features which are worth noting.

1) During the period March to July the water in storage in the sub-catchments decreased. The maximum rate of decrease occurred in the lowland sub-catchments in June.
2) During the period September to January, the water in storage in the sub-catchments increased. The maximum rate of increase occurred in November and appeared to be the same for all sub-catchments.
3) The lines representing 100% (R-E) and actual flow (Q) coincided in February, indicating that the sub-catchment storage remained constant during that month.
4) In August the lines representing 100% (R-E) and (Q) crossed over, indicating that the mountainous sub-catchments were just starting to increase their storage while the lowland sub-catchments were still losing storage. This feature appears to be due to the decline in evapotranspiration with altitude.
5) In May, June and July the lines representing 100% (R-E) and (Q) differed significantly in slope. This was also due to the decline in evapotranspiration with increased altitude, a characteristic which is particularly significant in the summer months. However, the difference in slope would not be so pronounced if actual evapotranspiration had been used instead of potential evapotranspiration in the evaluation

of (R-E).

Rainfall/streamflow relationships are often expressed in terms of percentage run-off, that is, streamflow expressed as a percentage of rainfall. Consideration was given to using percentage run-off as a parameter in this study, but it was not found to be as useful as the rainfall/streamflow relationships described earlier. However, for completeness, a set of graphs showing the temporal variation of percentage run-off for the Region is given in Appendix IV. The most interesting feature illustrated by these curves is the difference in percentage run-off that existed between high, medium and low rainfall sub-catchments during the months August to November, a feature closely related to the spatial and temporal distribution of soil moisture deficit.

Also for completeness, relationships between mean annual areal rainfall and mean annual streamflow and between mean annual areal rainfall and standard deviation of mean annual streamflow were derived. These are shown in Figure 7.41 and the derived linear regression equationswere:

$$\overline{Q}_a = 0.999\ \overline{R}_a - 439 \qquad (7.13)$$

and

$$S_a = 0.496\ \overline{R}_a - 179 \qquad (7.14)$$

where $\overline{R}_a$, $\overline{Q}_a$ and S_a are the mean annual rainfall, mean annual flow and the standard deviation of the annual flow respectively.

These relationships between $\overline{Q}_a/\overline{R}_a$ and $S_a/\overline{R}_a$ were particularly strong as indicated by their respective correlation coefficients of 0.99 and 0.98.

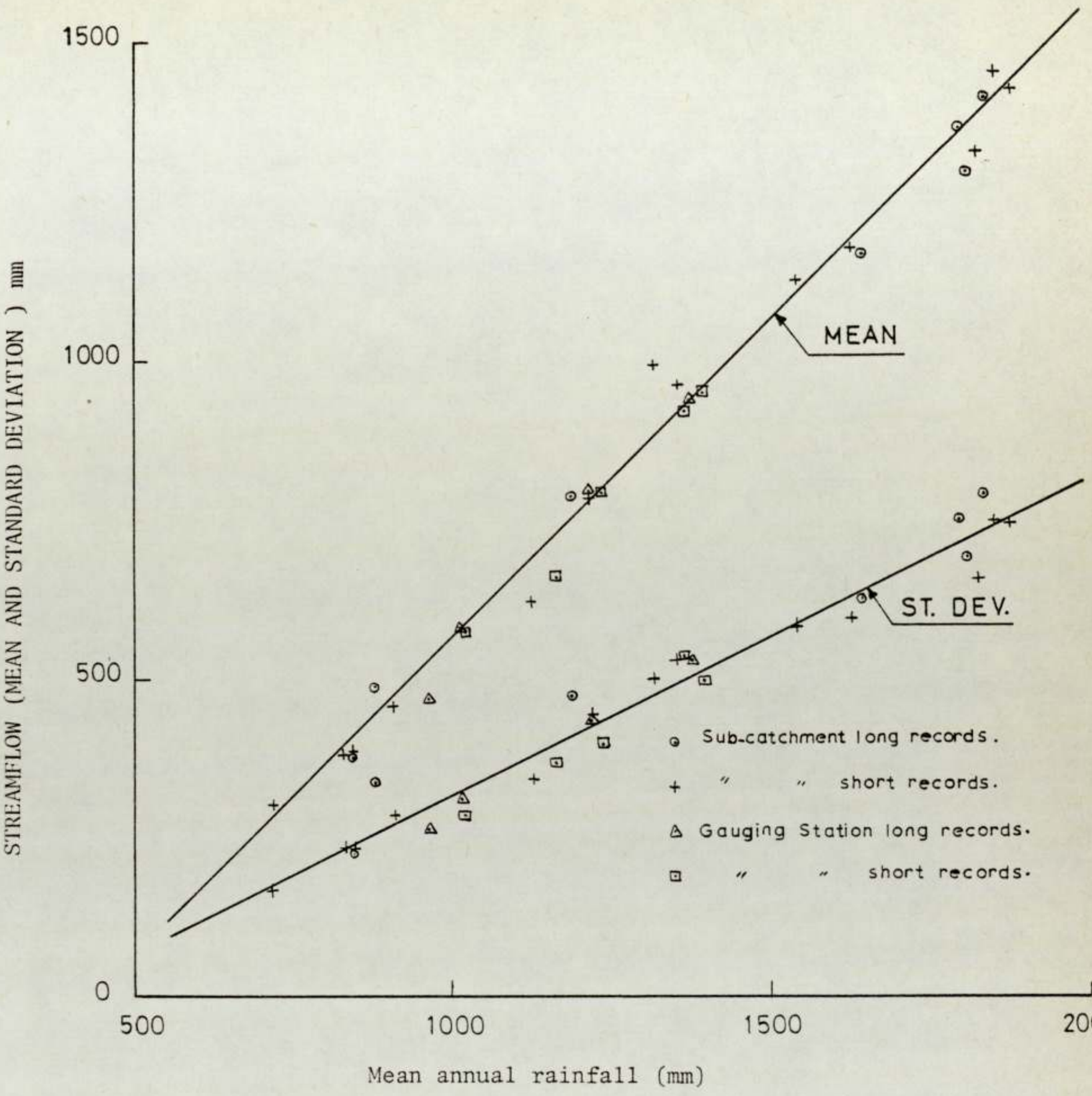


FIGURE 7.41 LINEAR RELATIONSHIPS BETWEEN MEAN ANNUAL RAINFALL/MEAN ANNUAL STREAMFLOW AND MEAN ANNUAL RAINFALL/ANNUAL STANDARD DEVIATION FOR THE REGION

7.9 MONTHLY EVAPOTRANSPIRATION

Most of the evapotranspiration data available in the United Kingdom are those calculated by the Meteorological Office based on the Penman (1948) formula and cover the period 1941-1970. Map No 6 shows the distribution of mean annual evapotranspiration in the Region for a surface with an albedo of 0.25, which is considered representative of most vegetated surfaces, including grass.

Since monthly mean areal evapotranspiration data were not available, it was necessary to devise a means of estimating them. Initially, this was done by estimating the annual mean areal evapotranspiration for each sub-catchment from Map No6, and then distributing these throughout the months of the year using monthly distribution coefficients. These coefficients were evaluated using monthly evaporation data for the County of Hereford which was obtained from the Wye River Authority Report (1972).

This was not a very satisfactory method and an improved procedure was devised which utilised the extensive evapotranspiration data given in the MAFF Bulletin No 34. The mean monthly potential evapotranspiration and altitude data for various climatic regions contained within or bordering on the Region were abstracted from Bulletin No 34 and tabulated (see Table 7.10). These were then used to derive linear regression equations between monthly mean evapotranspiration and altitude for each month of the year. Figure 7.42 shows the altitude/monthly mean evapotranspiration relationships for each month of the year. The derived linear regression equations relating monthly mean potential evapotranspiration, E_p (mm) to altitude, H (m) were:

TABLE 7.10 MEAN MONTHLY POTENTIAL EVAPOTRANSPIRATION AND MEAN ALTITUDE
(Data are taken from MAFF Technical Bulletin 34)

AMFF REGION NO	MEAN ALTITUDE (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
18N	126	1	9	30	55	80	92	91	71	43	20	4	1	497
18S	210	0	8	29	53	79	90	89	70	42	18	3	0	481
19	116	1	8	30	55	80	93	93	72	43	19	4	0	489
25N	117	3	10	32	56	80	93	91	70	44	20	5	0	504
48N	345	-1	5	27	46	72	80	80	65	38	19	4	-1	434
49N	282	0	5	28	48	74	83	84	66	40	19	4	-1	450
49S	309	0	6	27	47	74	83	81	65	39	18	3	0	443
50	123	3	10	32	54	80	89	88	76	47	23	10	1	513

NB Area No 18S South West Shropshire
18N North Shropshire
19 South West Shropshire and North Worcestershire
25N Hereford
48S and 49S Southern Cambrian Hills
49N Northern Cambrian Hills including Snowdonia

Jan	$E_p = 3.4 - 0.0124\ H$	$r = 0.82$
Feb	$E_p = 11.6 - 0.0197\ H$	$r = 0.92$
Mar	$E_p = 33.3 - 0.0191\ H$	$r = 0.92$
Apr	$E_p = 60.2 - 0.0413\ H$	$r = 0.98$
May	$E_p = 84.4 - 0.0345\ H$	$r = 0.97$
Jun	$E_p = 98.2 - 0.0508\ H$	$r = 0.95$
Jul	$E_p = 96.9 - 0.0478\ H$	$r = 0.94$
Aug	$E_p = 76.5 - 0.0352\ H$	$r = 0.88$
Sep	$E_p = 47.6 - 0.0274\ H$	$r = 0.90$
Oct	$E_p = 21.4 - 0.0092\ H$	$r = 0.55$
Nov	$E_p = 6.8 - 0.0105\ H$	$r = 0.45$
Dec	$E_p = 1.18 - 0.0058\ H$	$r = 0.74$

where r is the sample correlation coefficient.

Unfortunately, these equations only apply to the limited altitudinal range of 100 to 350 m, since this was the range of the data used in their formulation. In order to overcome this limitation it was decided to investigate the spatial variation of the monthly evapotranspiration coefficients (i.e. monthly mean evapotranspiration expressed as a decimal fraction of the annual mean evapotranspiration). Table 7.11 shows the evapotranspiration data previously given in Table 7.10 expressed as monthly coefficients. It is immediately apparent from this table that the spatial variation of the monthly evapotranspiration coefficients is so small that for the purpose of this excercise, they could be considered to be constant coefficients equal to the mean values given at the foot of the table.

In order to extend the analysis to cover high altitude regions, use was made of the high altitude evapotranspiration published by the Meteorological Office on the information sheet relating the evapotranspiration map of United Kingdom (see Appendix I). The

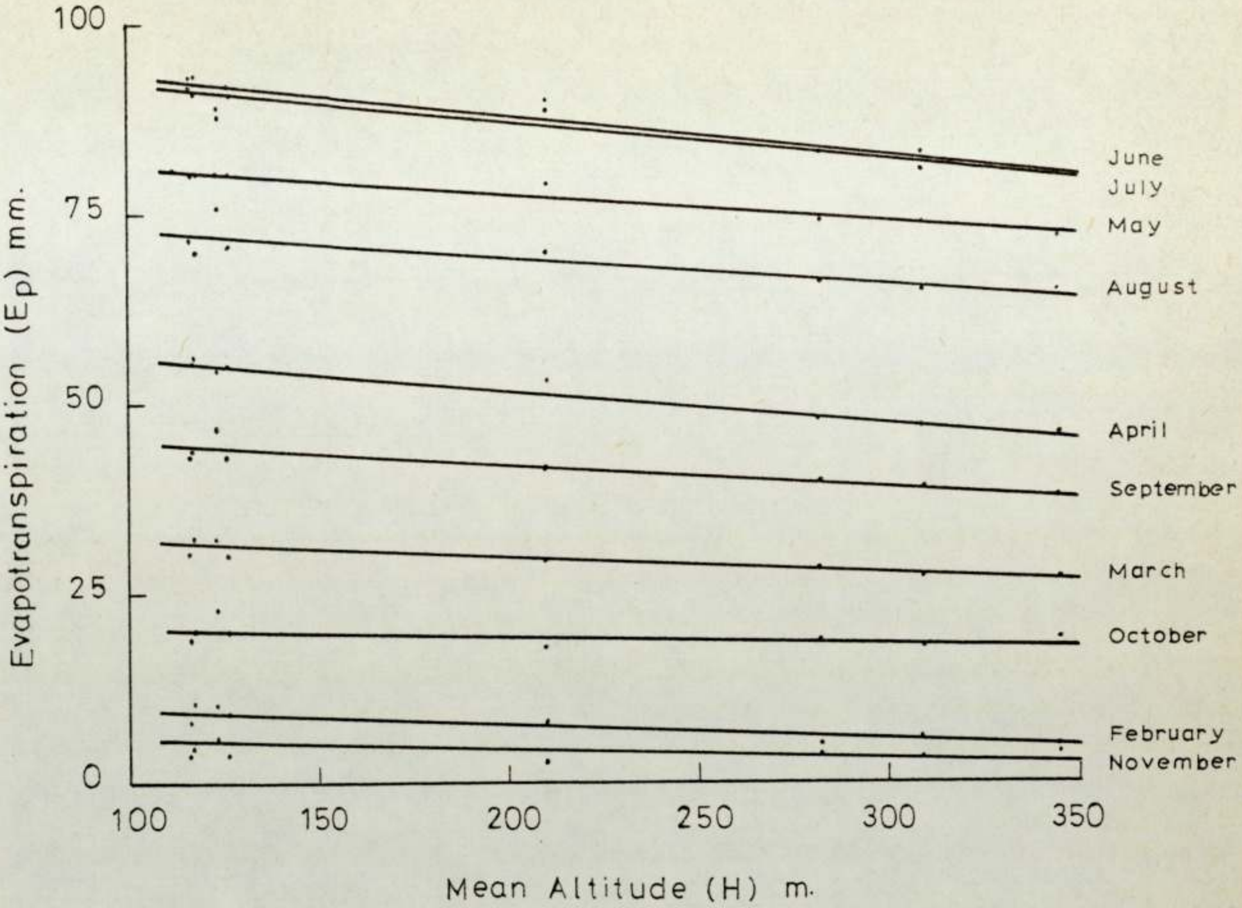


FIGURE 7.42 LINEAR RELATIONSHIP OF MEAN ALTITUDE AND MEAN MONTHLY POTENTIAL EVAPOTRANSPIRATION

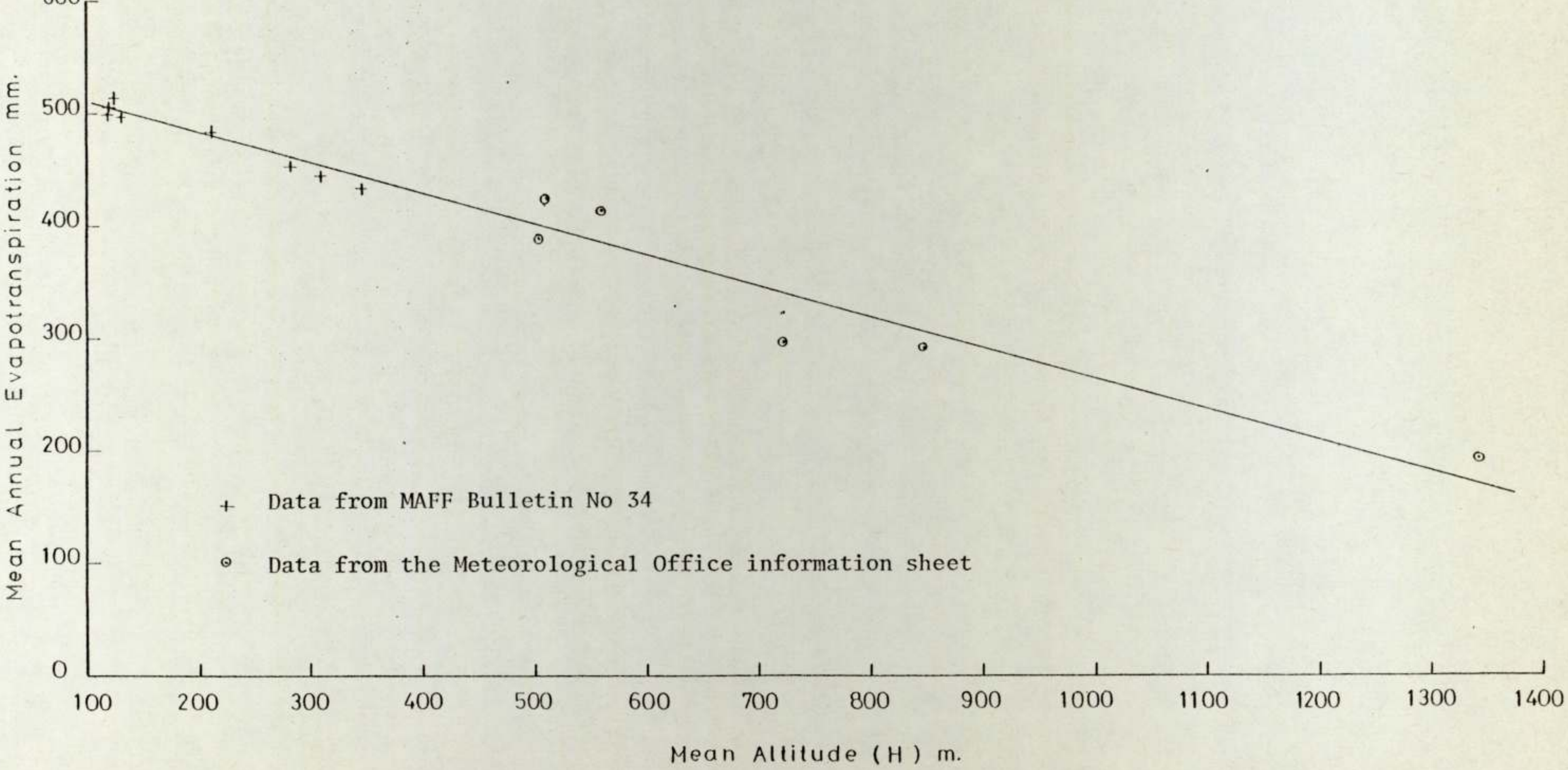


FIGURE 7.43 LINEAR RELATIONSHIP BETWEEN MEAN ALTITUDE AND MEAN ANNUAL EVAPOTRANSPIRATION

TABLE 7.11 MONTHLY EVAPOTRANSPIRATION EXPRESSED AS A PERCENTAGE OF ANNUAL EVAPORATION

MAFF Region No	Mean altitude (m)	Annual potential evaporation (mm)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
18N	126	497	0.00	0.02	0.06	0.11	0.16	0.19	0.18	0.14	0.09	0.04	0.01	0.00
18S	210	481	0.00	0.02	0.06	0.11	0.16	0.19	0.15	0.09	0.04	0.01	0.01	0.00
19	116	498	0.00	0.02	0.06	0.11	0.16	0.19	0.19	0.14	0.09	0.04	0.01	0.00
25N	117	508	0.01	0.02	0.06	0.11	0.16	0.18	0.18	0.14	0.09	0.04	0.01	0.00
48S	345	434	0.00	0.01	0.06	0.11	0.17	0.18	0.18	0.15	0.09	0.04	0.01	0.00
49N	282	450	0.00	0.01	0.06	0.11	0.16	0.18	0.19	0.15	0.09	0.04	0.01	0.00
49S	309	443	0.00	0.01	0.06	0.11	0.17	0.19	0.18	0.15	0.09	0.04	0.01	0.00
50	123	513	0.01	0.02	0.06	0.11	0.16	0.17	0.17	0.15	0.09	0.04	0.02	0.00
Mean	-	-	0	0.02	0.06	0.11	0.16	0.18	0.18	0.15	0.09	0.04	0.01	0.00

high altitude data and the data given in Table 7.10 were used to derive the evapotranspiration/altitude relationship shown in Figure 7.43. The derived linear regression equation for this relationship was:

$$E_p = 532 - 0.268\ H \qquad (7.15)$$

where

E_p = mean annual potential evapotranspiration (mm)

and

H = altitude (m).

This equation and the monthly coefficients given in Table 7.11 can be used to estimate monthly evapotranspiration for any altitude in the range 0 to 1400 m. However, due to shortage of high altitude data this method is most reliable in the altitudinal range 0 to 400 m.

7.10 SOIL MOISTURE DEFICIT

7.10.1 Introduction

Since 1962 the Meterological Office has been publishing maps at regular intervals showing the prevailing soil moisture deficit (SMD) throughout the United Kingdom. The method of preparing these maps has been described by Grindley (1967). Using these data the Meteorological Office has also prepared a set of maps showing average end-of-month soil moisture deficit. These maps were used to evaluate the areal mean end-of-month soil moisture deficit for each of the sub-catchments in the Region as explained in Section 3.6. The results of this analysis were plotted (Figure 7.44) to show the temporal variation of end-of-month soil moisture deficit for each of the sub-catchments. However, it was felt that these were inadequate estimates, because they were prepared from small

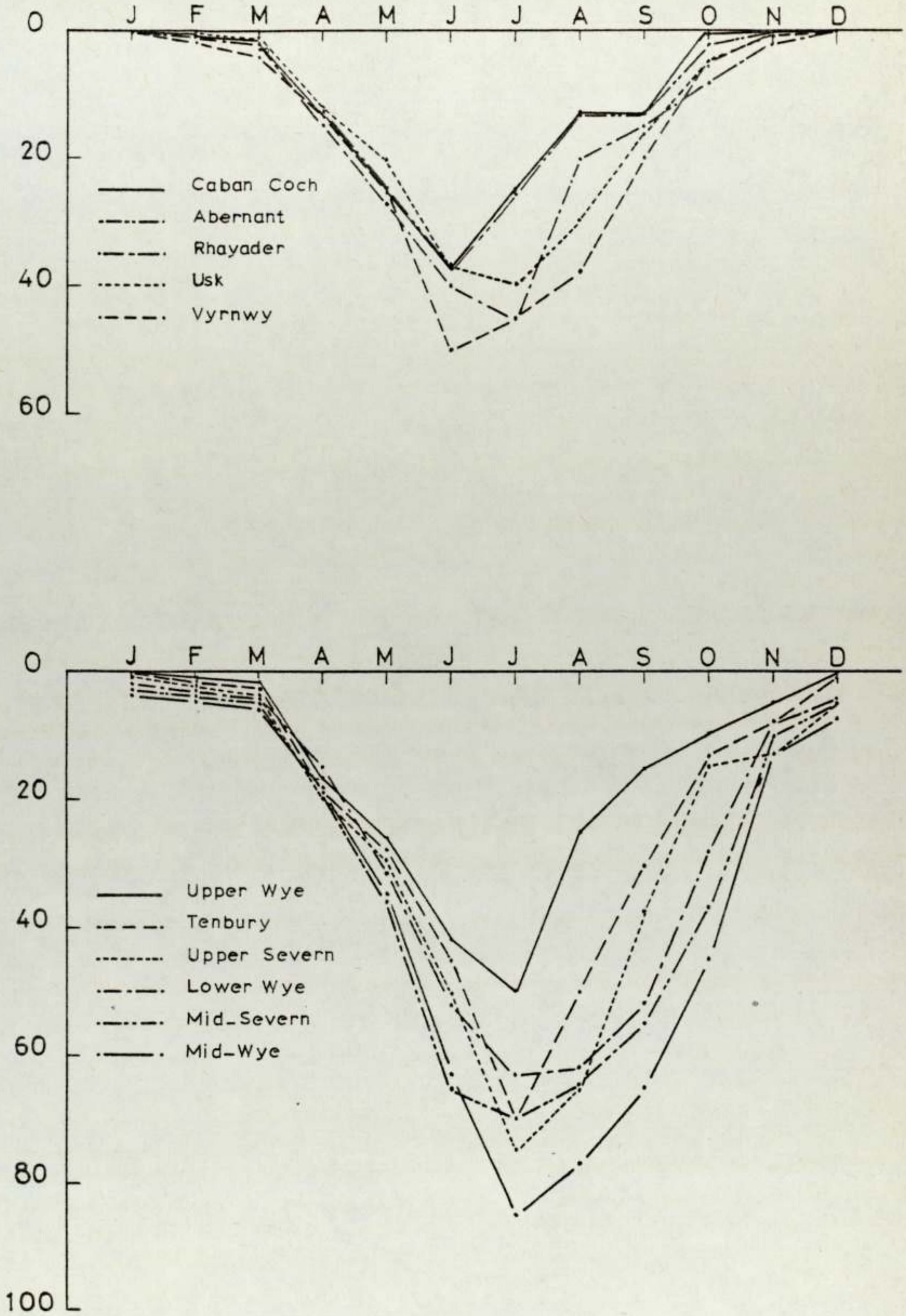


FIGURE 7.44 VARIATION OF MONTHLY SOIL MOISTURE DEFICIT AS ESTIMATED FROM METEOROLOGICAL OFFICE MAP

maps which lacked the necessary detail to enable accurate estimates of areal means to be made, especially in the mountainous regions.

Since fairly reliable rainfall and evapotranspiration statistics had been evaluated for the sub-catchments, it was decided to estimate mean end-of-month soil moisture deficits using a soil moisture simulation model.

7.10.2 Development of Soil Moisture Simulation Model

The simulation model developed for this study was a deterministic, parametric monthly model, which used as input two concurrent streams of climatic data, monthly rainfall and potential evapotranspiration. The model incorporated two separate idealisations of the soil moisture system: Type A and Type B as illustrated in Figure 7.45. Consequently the output from the model was of two types:

1) End-of-month soil moisture deficits (SMD), which were evaluated by the Type A model based upon the assumption that the surplus soil moisture (i.e. in excess of field capacity) immediately drained to the drainage store (DS), and
2) End-of-month soil moisture (SM) which were evaluated by the Type B model based upon the assumption that 85% of surplus soil moisture drained to the groundwater store (GW) during the month.

The difference between the two models was slight but important, because the Type B model allowed soil moisture surplus to accumulate during the winter months whereas the Type A model did not. The Type B model was considered, therefore, to be slightly more realistic than the Type A model, but the Type A model was consistent with the usual assumptions made when evaluating soil moisture deficits, hence both models were retained.

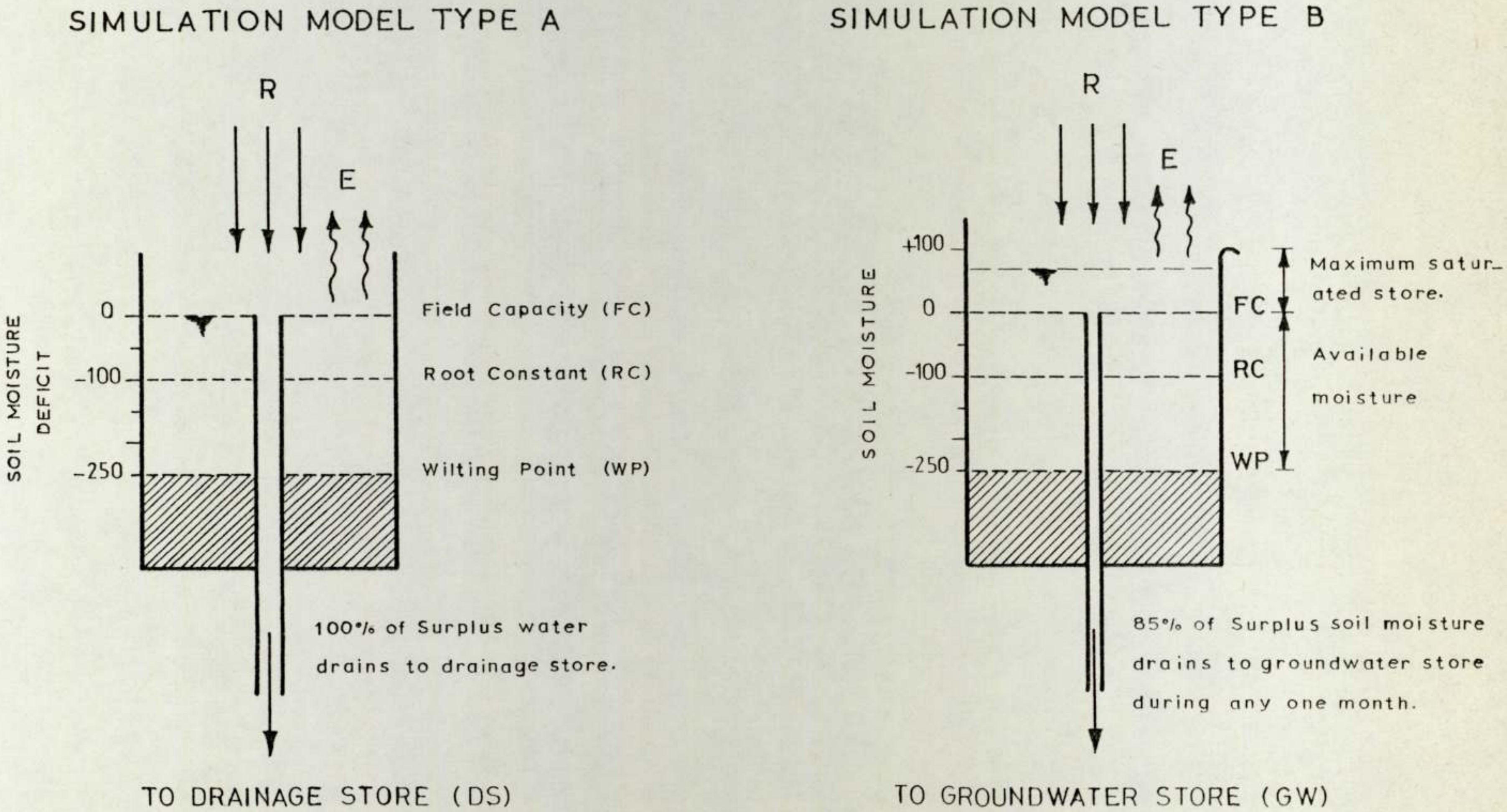


FIGURE 7.45 ILLUSTRATION OF SOIL MOISTURE SIMULATION MODELS

During periods when the soil was adequately, or excessively supplied with water, the Type A model put SMD equal to zero. When, during the summer months, potential evapotranspiration exceeded rainfall, the SMD was allowed to accumulate in the usual way until it reached a deficit of 100 mm. Between this point and a deficit of 250 mm the actual evapotranspiration (E_a) was reduced below the potential rate (E) as follows:

$$E_a = \left(\frac{250 - SMD}{150}\right) E \qquad (7.16)$$

This was equivalent to a linear reduction in actual evapotranspiration from E at a deficit of 100 mm to zero at a wilting point of 250 mm as illustrated in Figure 7.46. Several different values of the constants in Equation (7.16) were tested before the values of 250 and 150 mm were accepted as the most suitable values. The advantages of these values were:

1) They gave mean monthly actual evapotranspirations for lowland sub-catchments during the summer months which compared favourably with values given in various river authority reports;
2) They compared favourably with results and experience gained from other postgraduate research studies in the Department of Civil Engineering in which field measurements near to Birmingham recorded a maximum soil moisture deficit of 216 mm in 1976 (Walley, 1979).

A disadvantage of using these values was that they over-estimated the available soil moisture store in mountainous regions, and hence overestimated actual evapotranspiration at deficits in excess of 100 mm. However, this was a trivial matter because deficit in these regions rarely exceeded 100 mm.

The accumulation of soil moisture deficit in the Type B model was evaluated in the same way as in the Type A model, but it was slightly smaller because the winter surplus had to drain before deficit could start to accumulate. Naturally, a limit had to be set on the amount of surplus that could be stored in the soil, since this could not exceed the storage available between field capacity and saturation. Another important paramater which had to be given a value in the Type B model was the drainage coefficient which governed the proportion of each months surplus rainfall which was allowed to drain during the month. Several simulations were carried out using different values of maximum storage (SATSTR) and drainage coefficient (C2). The resulting winter surpluses were compared with field measurements of soil moisture recorded by other researchers in the Department of Civil Engineering (Walley 1979). The most suitable value of SATSTR and C2 were found to be 100 mm and 0.85, and these values were used in the final simulation study.

A computer program called 'SOIL' was developed to carry out the Type A and Type B soil moisture simulations. Full details of this program, including the Fortran listing, are given in Appendix II.

Ideally, the input data to the program should have been mean areal rainfall and evapotranspiration records corresponding to the short (1960-75) and long (1938-75) records used elsewhere in the study. However, this presented a problem because mean areal evapotranspiration records were not available. Several ways of overcoming this problem were considered including:

1) The estimation of monthly mean areal evapotranspiration data sets from the limited data available from climatological stations;

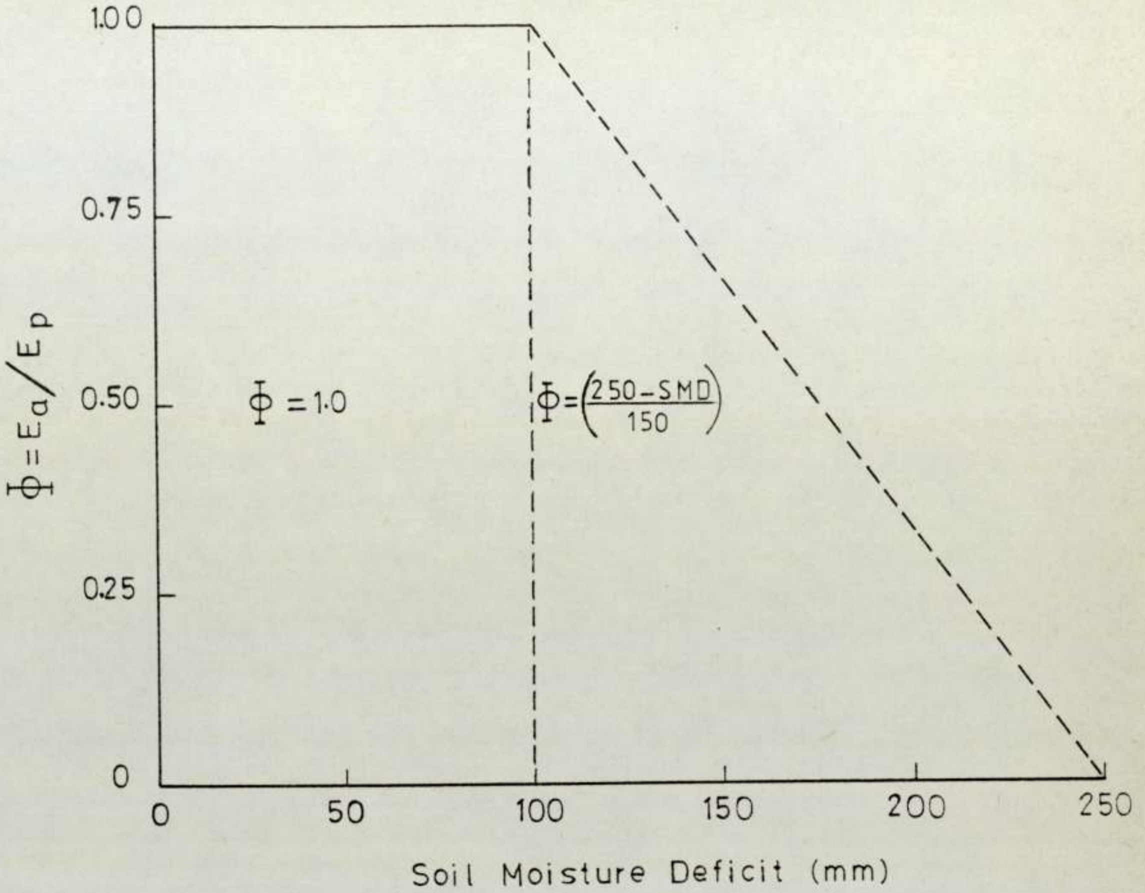


FIGURE 7.46 VARIATION OF E_a/E_p RATIO WITH SOIL MOISTURE DEFICIT

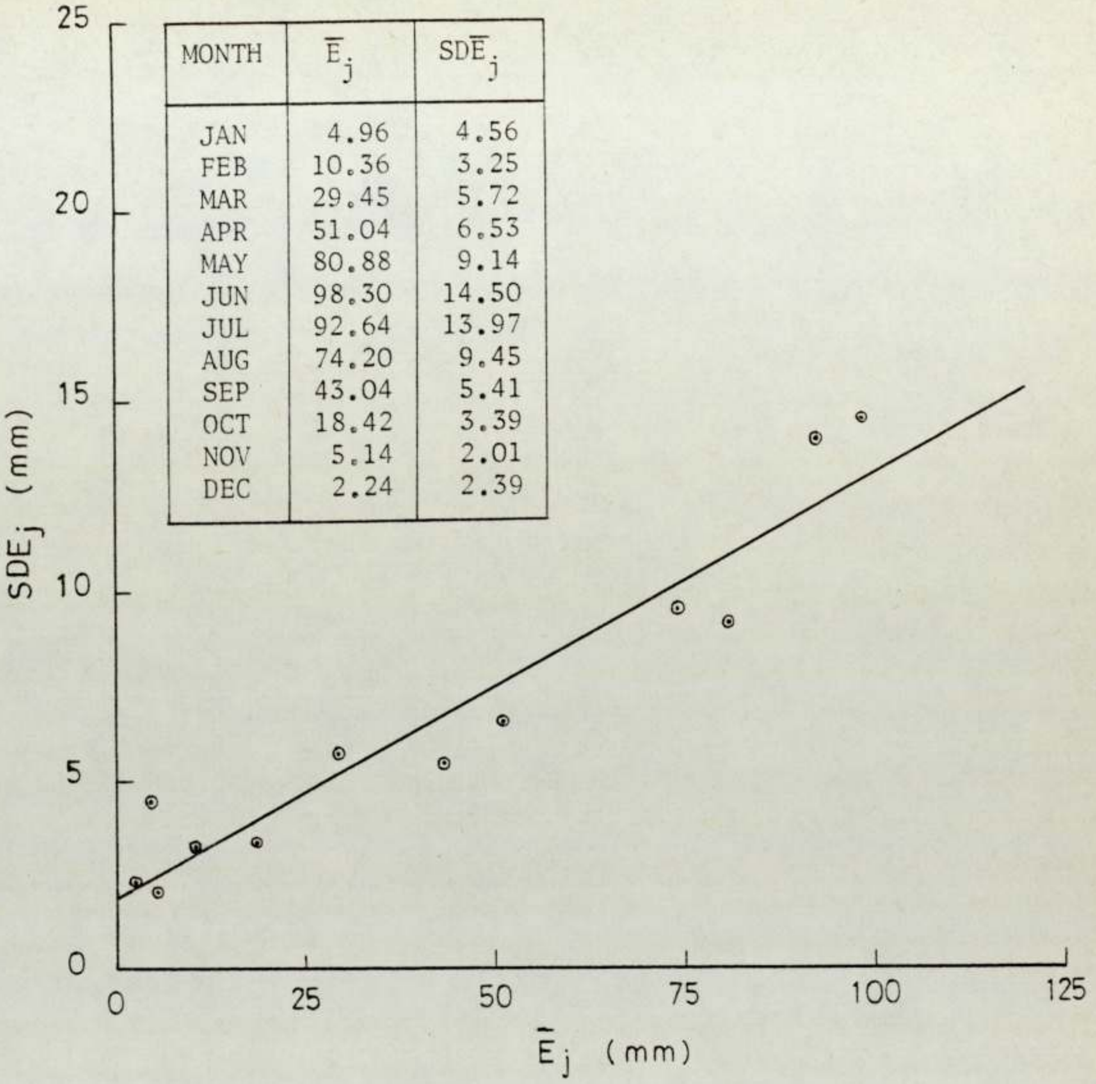
2) The generation of synthetic evapotranspiration data sets for use with the actual rainfall records;

3) The generation of long synthetic data sets of both rainfall and evapotranspiration.

Unfortunately, the most extensive and reliable evapotranspiration record available was that for Edgbaston Observatory, Birmingham, which was not even contained within the Region. Clearly, none of the three possible solutions was without its difficulties, and each could be critisised for lack of rigour, but the variation of soil moisture was thought to be an important factor in the rainfall/streamflow process and worth investigating. It was felt that any investigation was better than none, since nothing could be lost and much could be gained, especially if linked to a study of the variation of ground-water storage. Finally, it was decided to generate long sets of synthetic rainfall and evapotranspiration data for each of the sub-catchments, and to use these to evaluate the mean and standard deviation of end-of-month SMD and SM.

Initially, it was thought that monthly rainfall and potential evapotranspiration for any given month would be inversly correlated, however, an analysis of the Edgbaston rainfall and evapotranspiration data showed this not to be so, nor was there any significant persistence. It also showed that the standard deviation of evapotranspiration was closely related to its mean value (see Figure 7.47). This meant that monthly potential evapotranspiration data could be generated independently of rainfall, using the following simple stochastic model:

$$E_{ij} = \overline{E}_j + \alpha_{ij} S_{ej} \qquad (7.17)$$



MONTH	$\bar{E}_j$	$SD\bar{E}_j$
JAN	4.96	4.56
FEB	10.36	3.25
MAR	29.45	5.72
APR	51.04	6.53
MAY	80.88	9.14
JUN	98.30	14.50
JUL	92.64	13.97
AUG	74.20	9.45
SEP	43.04	5.41
OCT	18.42	3.39
NOV	5.14	2.01
DEC	2.24	2.39

FIGURE 7.47 LINEAR RELATIONSHIP BETWEEN POTENTIAL EVAPOTRRANSPIRATION AND ITS STANDARD DEVIATION

(Data from Edgbaston Observatory)

where

E_{ij} = potential evapotranspiration for the jth month of the ith year.

$\overline{E}_j$ = mean potential evapotranspiration for the jth month obtained using the method described in Section 7.9 and listed in Table 7.12.

S_{ej} = standard deviation of potential evapotranspiration for the jth month, obtained from Figure 7.47 and listed in Table 7.13.

α_{ij} = a normal random deviate (mean = 0, variance = 1) (NB. There was no indication of significant skewness in the Edgbaston data, hence the use of normal deviates)

A similar stochastic model was used for the generation of the rainfall data, but in this case log-normal deviates were used to reproduce the skewness of the historical data. The model used was:

$$R_{ij} = \overline{R}_j + t_{ij} S_{rj} \qquad (7.18)$$

where

R_{ij} = rainfall for the jth month of ith year,

$\overline{R}_j$ = mean rainfall for the jth month

S_{rj} = standard deviation of rainfall for the jth month,

t_{ij} = log-normal random variables.

The log-normal distribution was adopted after a careful investigation of the skewness coefficients evaluated from the historical rainfall data for the Region. The mean monthly skewness coefficient was found to be equal to 0.61. Various numerical tests were performed to ensure that log-normal deviates having skewness coefficient of about 0.61 could be generated.

TABLE 7.12 ESTIMATED MONTHLY POTENTIAL EVAPORANSPIRATION FORTHE SUB-CATCHMENTS WITHIN THE REGION

SUB-CATCHMENT NAME	MONTH												TOTAL
	J	F	M	A	M	J	J	A	S	O	N	D	
Vrynwy	-1	3	25	41	68	75	74	61	36	18	3	-1	402
Rhayader	-1	4	26	44	71	79	78	63	37	18	4	-1	421
Caban Coch	-1	3	25	41	69	76	75	62	36	18	3	-1	405
Abernant	-1	3	25	41	68	75	74	61	36	18	3	-1	412
Usk	0	6	28	47	73	83	82	66	39	19	4	-1	446
Upper Wye	0	6	28	49	75	85	84	67	40	19	4	0	457
Upper Severn	0	7	28	50	76	86	85	68	41	19	4	0	464
Mid Wye	1	8	29	53	78	89	88	69	42	19	4	0	480
Tenbury	1	8	30	53	79	90	89	69	42	19	4	0	484
Lower Wye	1	9	30	54	79	91	89	70	42	19	4	0	488
Mid-Severn	2	9	30	55	80	92	91	71	43	20	4	1	498

TABLE 7.13 ESTIMATED MONTHLY STANDARD DEVIATION OF POTENTIAL EVAPOTRANSPIRATION FOR THE SUB-CATCHMENTS

SUB-CATCHMENT NAME	MONTH											
	J	F	M	A	M	J	J	A	S	O	N	D
Vyrnwy	1.70	2.2	4.6	6.4	9.4	10.25	10.10	8.6	5.9	3.8	2.2	1.70
Rhayader	1.70	2.3	4.7	6.8	9.8	10.60	10.50	8.9	6.0	3.8	2.2	1.70
Caban Coch	1.70	2.2	4.6	6.4	9.5	10.30	10.25	8.8	5.9	3.8	2.2	1.70
Abernant	1.70	2.2	4.6	6.4	9.4	10.25	10.10	8.6	5.9	3.8	2.2	1.70
Usk	1.80	2.5	5.0	7.1	10.0	11.10	11.00	9.2	6.2	4.0	2.3	1.70.
Upper Wye	1.80	2.5	5.0	7.3	10.25	11.30	11.20	9.3	6.3	4.0	2.3	1.80
Upper Severn	1.80	2.6	5.0	7.4	10.30	11.40	11.30	9.4	6.4	4.0	2.3	1.80
Mid-Wye	1.95	2.7	5.2	7.8	10.50	11.80	11.60	9.5	6.5	4.0	2.3	1.80
Tenbury	1.95	2.7	5.2	7.8	10.65	11.90	11.80	9.5	6.5	4.0	2.3	1.80
Lower Wye	1.95	2.8	5.2	7.9	10.65	12.00	11.80	9.6	6.5	4.0	2.3	1.80
Mid Severn	2.02	2.8	5.2	8.0	10.8	12.10	12.00	9.8	6.6	4.1	2.3	1.95

The values of $\overline{R}_j$ and S_{rj} used for the simulations were those listed in Tables 6.10 to 6.20. To ensure that the means and standard deviations used as input statistics were adequately reproduced by the model, simulations were performed on 200 year sequences of synthetic data. Table 7.14 gives details of a comparison made between the input statistics and the corresponding statistics of the generated sequences. It can be seen that these primary statistics were quite faithfully reproduced.

7.10.3 Results of the Soil Moisture Simulations

The results of the soil moisture simulations are given in Tables 7.15 and 7.16 for the Type A and Type B models respectively. Figure 7.48 shows a comparison between the original estimates of soil moisture deficit obtained using the Meteorological Office map and those derived by simulation model Type A.

Inspection of these graphs revealed several features worth noting.

1) The simulated soil moisture deficits for the high rainfall (i.e. mountainous) sub-catchments were much lower than those obtained from the end-of-month SMD maps published by the Meteorological Office. This was due to the fact that the Meteorological Office maps are based upon data obtained from stations which are situated at relatively low altitude and their predictions relate to the valley bottoms and side slopes as opposed to the mean altitudinal level. The simulated values were therefore considered to provide better estimates of mean areal soil moisture deficit for high rainfall sub-catchments than the values based upon the Meteorological Office maps.

FIGURE 7.48 VARIATION OF MEAN MONTHLY SOIL MOISTURE DEFICIT

(Estimated data from Met. Office Map) (Data from simulation model)

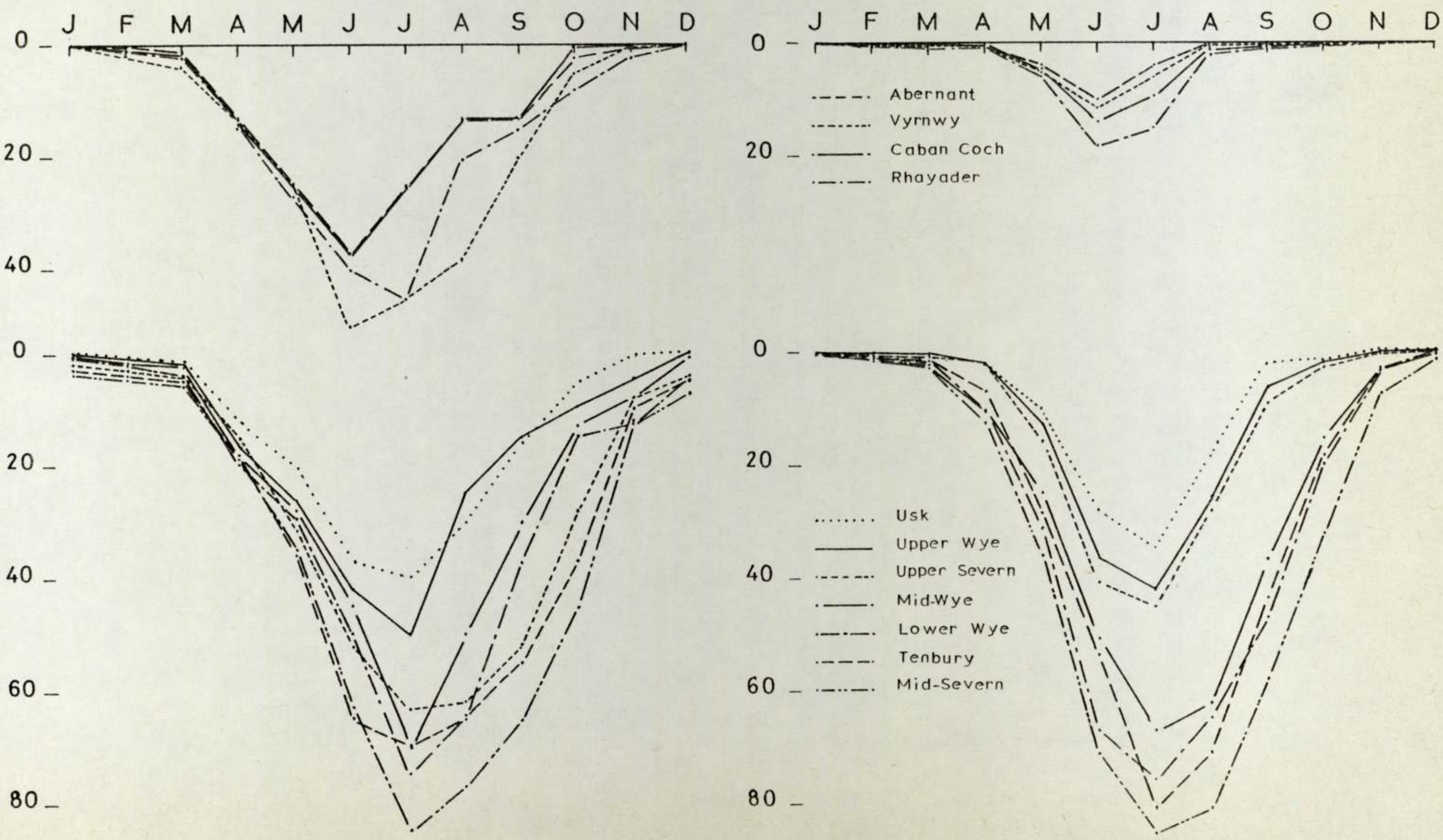


TABLE 7.14 COMPARISON BETWEEN THE SOIL MOISTURE MODEL INPUT STATISTICS AND THE CORRESPONDING STATISTICS OF THE GENERATED SEQUENCES FOR THREE TYPICAL SUB-CATCHMENTS

MONTH			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Vyrnwy	Input stat.	$\bar{R}_j$	203.96	150.90	124.50	134.50	125.30	95.55	119.80	138.70	166.90	170.00	220.60	228.00
		S_{rj}	93.56	82.34	62.73	53.10	61.19	40.77	42.38	49.74	83.64	102.80	87.68	121.10
		$\bar{E}_j$	-1.00	3.00	25.00	41.00	68.00	75.00	74.00	61.00	36.00	18.00	3.00	-1.00
		S_{ej}	1.70	2.20	4.60	6.40	9.40	10.25	10.10	8.60	5.90	3.80	2.20	1.70
	Output stat.	$\bar{R}_j$	203.02	151.66	120.10	131.70	125.14	93.48	117.61	144.45	168.82	177.37	219.40	222.58
		S_{rj}	99.75	83.51	60.28	53.55	63.12	40.92	39.42	50.80	78.64	96.74	83.53	124.86
		$\bar{E}_j$	-1.03	3.24	25.64	41.30	69.02	76.17	73.87	61.89	36.13	18.49	3.07	-1.16
		S_{ej}	1.63	2.22	4.96	6.49	9.25	10.69	12.01	8.44	5.63	3.41	2.05	1.69
Tenbury	Input stat.	$\bar{R}_j$	89.51	62.35	61.37	64.54	69.86	51.33	62.57	74.25	75.42	70.48	88.48	79.15
		S_{rj}	42.65	34.07	24.39	25.95	39.81	21.58	21.66	30.55	37.38	48.35	40.96	36.92
		$\bar{E}_j$	1.00	8.00	30.00	53.00	79.00	90.00	89.00	69.00	42.00	19.00	4.00	0.00
		S_{ej}	1.95	2.70	5.20	7.80	10.65	11.90	11.80	9.50	6.50	4.00	2.30	1.80
	Output stat.	$\bar{R}_j$	89.08	62.67	59.44	63.17	69.97	50.23	61.45	77.78	76.28	74.36	87.96	77.38
		S_{rj}	45.47	34.55	23.92	26.17	40.67	21.66	20.15	31.20	35.15	44.78	38.93	38.29
		$\bar{E}_j$	0.96	8.29	30.72	53.36	80.16	91.36	88.85	69.98	42.15	19.51	4.07	-0.17
		S_{ej}	1.87	2.73	5.61	7.90	10.48	12.41	14.03	9.33	6.21	3.59	2.15	1.79
Lower Wye	Input stat.	R_j	93.44	61.08	59.43	61.89	66.98	50.40	63.18	66.15	76.27	71.44	86.03	76.88
		S_{rj}	44.09	35.26	25.40	30.70	37.07	26.08	42.82	26.22	36.99	53.72	42.05	35.08
		$\bar{E}_j$	1.00	9.00	30.00	54.00	79.00	91.00	89.00	70.00	42.00	19.00	4.00	0.00
		S_{ej}	1.95	2.80	5.20	7.90	10.65	12.00	11.80	9.60	6.50	4.00	2.30	1.80
	Output stat.	$\bar{R}_j$	93.00	61.44	57.46	60.29	67.03	49.12	61.62	69.18	77.18	76.12	85.52	75.20
		S_{rj}	47.01	35.70	24.83	30.93	37.98	26.10	38.61	26.78	34.78	49.15	39.92	36.38
		$\bar{E}_j$	0.96	9.30	30.72	54.36	80.16	92.37	88.85	70.99	42.15	19.51	4.07	-0.17
		S_{ej}	1.87	2.83	5.61	8.01	10.48	12.51	14.03	9.43	6.21	3.59	2.15	1.79

TABLE 7.15 VARIATION OF MEAN AND STANDARD DEVIATION OF END-OF-MONTH SOIL MOISTURE DEFICIT (SMD) AS DERIVED BY THE TYPE A SIMULATION MODEL

SUB-CATCHMENT	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Vyrnwy	Mean	0.00	-0.05	-1.20	-0.40	-5.16	-11.71	-6.40	-1.00	-0.33	-0.99	0.00	0.00
	St.dev.	0.00	0.50	5.20	2.52	14.34	18.67	15.33	4.82	2.80	4.73	0.00	0.00
Abernant	Mean	0.00	-0.05	-0.23	-0.38	-3.85	-10.55	-4.10	-0.11	-0.11	-0.69	0.00	0.00
	St.dev.	0.00	0.50	1.85	2.37	11.56	18.08	11.79	0.93	1.09	3.45	0.00	0.00
Caban Coch	Mean	0.00	-0.05	-0.34	-0.28	-4.48	-14.03	-9.69	-0.70	-0.10	-0.17	0.00	0.00
	St.dev.	0.00	0.50	2.50	1.88	12.30	20.34	18.76	3.48	0.99	1.70	0.00	0.00
Rhayader	Mean	0.00	-0.06	0.43	-0.74	-6.62	-18.76	-15.42	-2.42	-0.28	-0.48	0.00	0.00
	St.dev.	0.00	0.61	2.79	3.90	15.81	23.70	24.05	7.69	2.26	2.78	0.00	0.00
Usk	Mean	0.00	-0.20	-1.45	-2.11	-10.71	-28.64	-35.00	-19.04	-3.73	-2.13	-0.02	0.00
	St.dev.	0.00	1.23	5.70	7.47	19.24	28.58	32.07	26.60	12.21	9.00	0.25	0.00
Upper Wye	Mean	0.00	0.21	-0.92	-2.08	-12.79	-36.93	-41.86	-26.29	-6.78	-2.21	-0.02	0.00
	St.dev.	0.00	1.24	4.05	6.65	19.67	30.10	33.43	30.11	16.40	10.05	0.25	0.03
Upper Severn	Mean	0.00	-0.14	-0.76	-1.94	-16.25	-40.74	-45.19	-28.36	-9.27	-2.48	-0.02	0.00
	St.dev.	0.00	0.01	3.47	5.76	22.85	31.11	34.54	32.20	20.00	11.07	0.25	0.03
Tenbury	Mean	0.00	-0.23	-1.43	-6.84	-28.20	-63.66	-80.72	-70.94	-43.96	-19.17	-2.78	-0.15
	St.dev.	0.00	1.33	5.14	11.49	27.14	27.36	28.98	36.25	39.73	30.72	10.47	2.10
Mid-Wye	Mean	-0.01	-0.44	-2.07	-10.53	-25.81	-51.19	-67.83	-62.83	-37.67	-15.78	-3.19	-0.45
	St.dev.	0.12	2.10	6.60	16.31	27.71	32.19	35.34	38.14	38.91	29.98	12.18	4.25
Lower Wye	Mean	-0.00	-0.37	-1.82	-10.56	-31.67	-67.01	-76.94	-75.27	-47.59	-20.89	-3.52	-0.28
	St. dev.	0.00	1.88	5.98	15.26	28.24	28.24	33.97	37.40	39.49	31.56	12.03	2.41
Mid Severn	Mean	0.00	-0.26	-2.29	-12.70	-36.40	-71.70	-85.62	-81.07	-58.81	-32.57	-7.57	-1.55
	St.dev.	0.02	1.49	6.06	15.15	30.14	26.37	28.32	34.94	42.20	37.36	17.53	6.53

TABLE 7.16 VARIATION OF MEAN AND STANDARD DEVIATION OF END-OF-MONTH SOIL MOISTURE (SM) AS DERIVED BY THE TYPE B SIMULATION MODEL

SUB-CATCHMENT	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Vyrnwy	Mean	36.43	27.73	18.22	16.23	8.64	-1.88	2.64	12.35	21.59	26.77	36.47	39.03
	St.dev.	15.36	12.86	9.74	8.49	15.18	17.25	15.40	9.07	12.18	15.34	12.81	18.98
Abernant	Mean	38.39	27.67	17.62	16.50	8.93	-0.73	4.37	12.91	21.23	26.53	34.74	35.18
	St.dev.	15.47	12.50	6.90	8.82	12.21	17.31	11.46	5.97	10.35	13.74	11.19	14.81
Caban Coch	Mean	38.46	28.34	18.62	16.72	7.64	-4.68	-1.58	10.69	19.30	24.08	33.92	38.09
	St.dev.	15.14	12.09	7.55	8.50	12.25	19.09	18.46	6.84	9.49	10.57	10.12	17.74
Rhayader	Mean	32.38	23.87	15.10	13.22	4.72	-9.75	-7.79	7.51	16.34	21.12	30.07	33.95
	St.dev.	13.47	10.91	6.60	8.72	15.89	22.45	23.50	9.25	9.51	10.68	10.62	16.85
Usk	Mean	28.43	20.14	11.63	7.88	-1.84	-20.91	-28.67	-12.72	8.16	16.14	24.00	25.06
	St.dev.	13.22	10.21	7.65	9.48	19.19	27.56	31.78	27.28	15.99	15.55	11.30	11.66
Upper Wye	Mean	23.73	16.83	9.27	6.06	-5.13	-30.35	-36.23	-20.68	3.15	13.01	21.59	23.44
	St.dev.	10.14	8.57	5.65	8.31	19.66	30.02	33.36	30.25	18.72	14.58	8.83	10.71
Upper Severn	Mean	20.24	14.39	8.50	4.85	-8.92	-34.29	-40.06	-23.09	0.61	10.24	19.60	20.80
	St.dev.	8.05	7.01	5.04	6.88	23.41	31.27	35.52	32.70	22.06	14.34	8.06	9.95
Tenbury	Mean	15.12	10.42	5.35	-1.58	-22.79	-59.33	-77.37	-67.91	-41.25	-13.61	-8.20	-2.73
	St.dev.	6.96	5.37	5.47	11.25	27.68	28.63	30.24	37.72	41.23	33.90	14.66	6.88
Mid Wye	Mean	16.98	11.78	5.95	-3.84	-19.21	-45.77	-63.06	-58.87	-33.47	-7.29	9.34	13.12
	St.dev.	8.15	6.91	7.03	16.16	27.69	32.59	36.50	39.44	40.06	33.24	16.65	9.14
Lower Wye	Mean	15.62	10.15	4.79	-4.90	-26.46	-62.79	-74.20	-72.73	-44.91	-15.40	6.89	12.15
	St.dev.	7.19	5.57	6.15	15.13	28.59	29.15	35.38	38.72	41.30	35.00	16.42	6.74
Mid Severn	Mean	10.62	7.05	2.36	-8.49	-32.18	-68.47	-83.36	-78.99	-57.04	-29.90	-0.85	7.58
	St.dev.	5.17	3.88	5.91	14.88	30.98	27.74	29.69	36.33	43.97	39.71	21.31	10.22

2) The simulated soil moisture deficits for the medium and low rainfall sub-catchments compared very well with the values based upon the Meteorological Office maps. In fact, seasonal variation showed greater consistency and appeared more realistic than those obtained from the maps.

3) Soil moisture deficit commenced at approximately the same time in all sub-catchments; April/May in the high rainfall areas and March/April in the low rainfall areas. The return to field capacity however differed greatly between catchment types. The high rainfall areas reached field capacity in August whereas the low rainfall areas did not return to field capacity until November/December. This is a characteristic of soil moisture deficit which is due to its cumulative nature (i.e. it is a hydrological store and not a process).

From these comparisons it can be concluded that the simulation model provides a valuable means of estimating the temporal variation of soil moisture deficit, and is possibly the most reliable means available.

The results of the simulation study based upon the Type B model are given in Table 7.16 and shown graphically at the top of Figures 7.50/1 to 7.50/3. These results differ from the Type A results in two important respects.

1) Soil moisture content exceeded field capacity during periods of moisture surplus, and thus simulated a condition which is known to exist in the field. To what extent the magnitude and variation of these surpluses simulated actual field conditions, it is difficult to say, because very little field data is available. That data which was available tended to confirm that the magnitude of the surpluses for

the low rainfall sub-catchments were of the correct order.

2) The soil moisture deficits which developed during the summer months were slightly less than those given by the Type A model. This was due to the fact that the winter surplus had to drain away before deficit could commence. This effect was most noticeable in the high rainfall sub-catchments where surpluses of up to 40 mm existed during the winter months.

Although this model was in some respects more realistic than the Type A model, it is felt that the soil moisture surplus part of the model needs further development to allow for the specific soil properties relating to each sub-catchment.

7.11 SOIL MOISTURE VARIATION AND ITS INFLUENCE ON OTHER PARAMETERS

Soil moisture exerts a significant influence upon the hydrological properties of soils. When rainfall reaches the ground, its fate depends upon the state of the soil moisture. If the soil is dry much of the rainfall will infiltrate the ground and thus replenish the soil moisture store. Under these circumstances, surface run-off and natural recharge are negligible. If rainfall continues and the soil reaches field capacity, water continues to infiltrate into the soil but at a much reduced rate. Under these conditions, surplus moisture tends to drain from the soil both vertically (i.e. natural recharge) and laterally (i.e. interflow). The natural recharge adds to groundwater storage and the interflow eventually contributes to streamflow. If the intensity of the rainfall exceeds the infiltration capacity of the soil, water tends to pond on the surface or run-off as overland flow and thus contribute directly to streamflow.

It is therefore apparent that many hydrological processes interact with the soil moisture store as explained and because of the spatial variation of rainfall and evapotranspiration especially in catchments with a large altitudinal range, soil moisture content exhibits considerable spatial and seasonal variation (see Section 7.10).

It follows that the spatial and temporal variation of soil moisture content is likely to be an important factor influencing the spatial and temporal variation of many rainfall/streamflow parameters. Its influence on the variation of some of these parameters is discussed below.

1) Meanflow

The variation of the mean streamflow in the high rainfall regions reaches a minimum in June/July because the effect of soil moisture deficit is very small. However, in the low rainfall regions it reaches a minimum in August/September because the mid-summer soil moisture deficit is high in these regions and has to be replenished before rainfall can begin to cause an increase in streamflow (see Figure 7.9).

2) Standard deviation of monthly flow

The magnitude of the standard deviation of monthly flow (S_i) is closely related to the meanflow (Q_i) but tends to be higher when the soil moisture conditions are most variable. It follows that S_i is not only a function of Q_i but also of the standard deviation of soil moisture deficit. Time did not permit a detailed study of this subject, but it is worthy of further study.

3) Good cross correlation between catchments depends upon soil moisture conditions being similar in each. If they are not similar the cross correlation tends to be weak (see Section 7.7).

4) The spatial and temporal variation of base flow depends upon the spatial and temporal variation of the level of the groundwater store, which in turn depends upon the natural recharge. The spatial and temporal variation of natural recharge does of course depend upon the spatial and temporal variation of soil moisture storage as explained earlier.

To improve methods of predicting rainfall/streamflow parameter, it is therefore necessary to include as far as possible the effects of the variation of soil moisture.

7.12 VARIATION IN CATCHMENT STORAGE

Reference was made in Section 7.8 to the fact that the derived linear relationships between rainfall (R) and streamflow (Q) did not include several of the principal variables which influence the rainfall/streamflow process. However, these relationships had very high correlation coefficients, thus indicating that, provided the rainfall/streamflow regime remained fairly constant, they could be used for prediction purposes with some confidence. Nevertheless, it was felt that an investigation into the relative importance of these other variables could provide a better understanding of the rainfall/streamflow process and lead to improved methods of predicting the various streamflow parameters.

Consideration of the water balance equation (Eqn 7.11) showed that the principal variables to be considered were actual evapotranspiration (E_a) and change in catchment storage (ΔS). The variation of potential evapotranspiration (E) was considered in detail in Section 7.9, and the evaluation of actual evapotranspiration from potential was incorporated into the soil moisture simulation model (Eqn 7.16, Section 7.10.2).

In general, the change in catchment storage over any given time period involves change in the levels of four hydrological stores; the soil moisture store, the groundwater store, lake storage and snowpack storage. In the region covered by this study, changes in lake storage and snowpack storage were small compared with the changes in the other two stores, and have therefore been neglected in the following analysis. (N.B. Man made reservoirs were allowed for in the naturalisation of the flows).

The change in total catchment storage (ΔS) during each month was calculated using:

$$\Delta S = (R - E_a) - Q \tag{7.19}$$

where

R = mean monthly rainfall calculated from the historic data.

Q = mean monthly streamflow calculated from the historic data.

E_a = actual evapotranspiration calculated as explained below.

The actual evapotranspiration was estimated using the soil moisture simulation model. However, due to the inherent errors involved in the measurement of (R) and (Q) and in the estimation of E_a, it was obvious that the summation of the ΔS's would not in general close to zero. However, closure to zero assumes negligible change in catchment storage over the period of the record, in this case sixteen years, and negligible groundwater flow between catchments. Since it was felt that both of these were reasonable assumptions in this case, it was decided to adjust the monthly values of ΔS to ensure closure to zero. This was achieved by distributing the closing error between the monthly values of E_a (i.e. the least reliable variable in equation 7.19) in proportion to their magnitude.

Tables 7.17 to 7.27 give the computed values of monthly mean change in total storage (ΔS) for each of the sub-catchments, and also list the monthly values of Q, R and E_a (N.B. the adjusted value is shown in brackets).

In view of the two different definitions of the soil moisture store (i.e. Type A and Type B models), it was necessary to either abandon one of the models or to adopt two different definitions of groundwater storage. The advantage of the Type A model was that it corresponded to commonly used models of the soil moisture store, but it had the disadvantage of under estimating its total storage capacity because it neglected storage above field capacity. Since both models had their advantages they were both retained.

By summing-up the changes in total storage starting in January and proceeding month by month through to December it was possible to determine the annual variation in total storage (S) relative to the arbitrary datum of zero storage at 1 January. The components contributing to this storage were defined as follows:

Type A model,

$$S = SMD + DS \qquad (7.20)$$

Type B model,

$$S = SM + GW \qquad (7.21)$$

where

SMD = soil moisture deficit (mm),

DS = drainage storage (mm),

SM = soil moisture storage (mm),

GW = groundwater storage (mm).

The term drainage storage was given to the DS component in equation 7.20 because it not only contained that water below the water table but also any surplus water temporarily held above the water table while draining. In the case of Type B model (eqn 7.21), the water table provided a clear boundary between the soil moisture store and the groundwater store and so they were named accordingly.

The mean monthly levels of the various stores for each of the sub-catchments are given in Tables 7.17 and 7.27 and their monthly temporal variations are illustrated in Figures 7.49/1 to 7.49/3 for the Type A model, and Figure 7.50/1 to 7.50/3 for the Type B model.

In order to improve prediction methods using a catchment storage approach it is necessary to devise a means of estimating the temporal variation of total catchment storage for ungauged catchments. Since the temporal variation of the soil moisture components of total storage (i.e. SMD and SM) can be estimated with some degree of confidence, it remains to develop a method of estimating the temporal variation of either groundwater (GW) or drainage storage (DS).

The general form of the temporal variation of both GW and DS was sinusoidal and fairly consistent between the sub-catchments. However, the amplitude of the variations differed considerably between the sub-catchments. Table 7.28 gives the average annual amplitude of the volume of water stored in the various moisture stores. Figures 7.51 and 7.52 show these amplitudes plotted against mean annual rainfall. While there are clearly relationships between mean annual rainfall and the various amplitudes, the degree of scatter, especially in the cases of the groundwater and drainage stores, is so great as to make accurate prediction impossible.

It is apparent that several other factors, such as geology, topography and soil type are of importance in these relationships

TABLE 7.17 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
VYRNWY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	176.10	125.79	113.90	107.47	87.48	45.90	55.67	81.23	112.70	134.35	179.76	205.35	1425.70
Rainfall R (mm)	203.96	150.87	124.52	134.51	125.31	95.55	119.81	138.69	166.92	169.97	220.60	228.00	1878.71
Pot. Evap. E_p (mm)	-1	3	25	41	68	75	74	61	36	18	3	-1	402
Act. Evap E_a (mm)	-1	3	25(28)	41(46)	68(77)	75(85)	74(83)	61(69)	36(41)	18(20)	3	-1	453
$R - E_a$	204.96	147.87	96.52	88.51	48.31	10.55	36.81	69.69	125.92	149.97	217.60	229.00	1425.71
$\Delta S = (R - E_a) - Q$	28.86	22.08	-17.38	-18.96	-39.17	-35.35	-18.86	-11.54	13.22	15.62	37.84	23.65	0.01
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.05	-1.20	-0.40	-5.16	-11.71	-6.40	-1.00	-0.33	-0.99	-0.00	0.00	
Drainage Store (DS	28.86	50.99	34.76	15.00	-19.41	-48.21	172.38	-89.32	-76.77	-60.49	-23.64	0.01	
Model B													
Soil Moisture Store (SM)	36.43	27.73	18.22	16.23	8.64	-1.88	2.64	12.35	21.59	26.77	36.47	39.03	
Groundwater Store (GW)	-7.57	23.21	15.34	-1.63	-33.21	-58.04	-81.42	-102.67	-98.69	-88.25	-60.11	-39.02	
Total in Storage ($\varepsilon\Delta S$)	28.86	50.94	33.56	14.60	-24.57	-59.92	-78.78	-90.32	-77.10	-61.48	-23.64	0.01	

TABLE 7.18 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
CABAN COCH SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	183.27	123.23	101.31	99.03	72.49	44.51	45.85	68.85	95.23	119.51	165.24	203.06	1321.58
Rainfall R (mm)	218.44	153.12	125.31	137.19	115.44	91.25	109.50	133.31	152.63	155.06	206.06	224.13	1821.44
Pot. Evap. Ep (mm)	-1	3	25	41	69	76	75	62	36	18	3	-1	405
Act. Evap. E_a (mm)	-1	3 (4)	25(31)	41(51)	69(85)	76(93)	75(91)	62(76)	36(44)	18(23)	3 (4)	-1	499
$R - E_a$	291.44	149.12	94.31	86.19	30.44	-1.75	18.50	57.31	108.63	132.06	202.06	225.13	1321.44
$\Delta S = (R - E_a) - Q$	36.17	25.89	-7.00	-12.84	-42.05	-46.26	-27.35	-11.54	13.40	12.55	36.82	22.07	-0.14
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.05	-0.34	-0.28	-4.48	-14.03	-9.69	-0.70	-0.10	-0.17	0.00	0.00	
Drainage Store (DS)	36.17	62.11	55.40	42.50	4.65	-32.06	-63.75	-84.28	-71.48	-58.86	-22.21	-0.14	
Model B													
Soil Moisture Store (SM)	38.46	28.34	18.62	16.72	7.64	-4.68	-1.58	10.69	19.30	24.08	33.92	38.09	
Groundwater Store (GW)	-2.29	33.73	36.44	25.50	7.47	-41.41	-71.86	-95.67	-90.88	-83.11	-56.13	-38.23	
Total in Storage ($\varepsilon\Delta s$)	36.17	62.06	55.06	42.22	0.17	46.09	-73.44	-84.98	-71.58	-59.03	-22.21	10.14	

TABLE 7.19 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
RHAYADER SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	161.51	117.22	87.57	93.75	64.31	37.25	41.54	59.18	76.21	104.57	147.76	183.64	1174.51
Rainfall R (mmO	181.94	130.38	107.00	122.00	111.75	86.69	103.87	125.75	137.94	139.25	184.44	199.87	1630.88
Pot. Evap. E_p (mm)	-1	4	26	44	71	79	78	63	37	18	4	-1	421
Act. Evap. E_a (mm)	-1	4	26(28)	44(48)	71(77)	79(86)	78(85)	63(68)	37(40)	18(20)	4	-1	457
$R - E_a$	182.94	126.38	79.00	74.00	36.75	0.69	18.87	57.75	97.94	119.25	180.44	200.87	1174.88
$\Delta S = (R - E_a) - Q$	21.43	9.16	-8.57	-19.75	-27.56	-36.56	-22.67	-1.43	21.73	14.68	32.68	17.23	0.23
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD	0.00	-0.06	-0.43	-0.74	-6.62	-18.76	-15.42	-2.42	-0.28	-0.48	0.00	0.00	
Drainage Store (DS)	21.43	30.65	22.45	3.01	-18.67	43.09	-69.10	-83.53	-63.94	-49.06	-16.88	0.23	
Model B													
Soil Moisture Store (SM)	32.38	23.87	15.10	13.22	4.72	-9.75	-7.79	7.51	16.34	21.12	30.07	33.95	
Groundwater Store (GW)	-10.95	-6.72	6.92	-10.95	-30.01	-52.10	-76.73	-93.46	-80.56	-70.66	-46.93	-33.72	
Total in Storage ($\epsilon\Delta S$)	21.43	30.59	22.02	2.27	-25.29	-61.85	-84.52	-85.95	-64.22	-49.54	-16.86	0.23	

TABLE 7.20 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
ABERNANT SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	198.30	139.14	108.90	104.32	85.36	57.32	55.92	82.78	99.34	134.29	171.29	216.70	1453.98
Rainfall R (mm)	220.87	148.56	118.94	137.06	121.75	100.25	119.37	139.31	163.12	168.50	209.19	203.13	1850.06
Pot Evap. Ep (mm)	-1	3	25	41	68	75	74	61	36	18	3	-1	402
Act. Evap. E_a (mm)	-1	3	25	41(40	68(67)	75(74)	74(73)	61(60)	36(35)	18	3	-1	396
$R - E_a$	221.87	145.56	93.94	97.06	54.75	26.25	46.37	71.31	128.12	150.50	206.19	204.13	1454.05
$\Delta S = (R - E_a) - Q$	23.57	6.42	-14.96	-7.26	-30.61	-31.07	-9.55	-3.47	28.78	16.21	34.58	-12.57	0.07
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.05	-0.23	-0.38	-3.85	-10.55	-4.10	-0.11	-0.11	-0.69	0.00	0.00	
Drainage Store (DS)	23.57	30.04	15.26	8.15	-18.99	-43.36	-59.36	-66.82	-38.04	-21.25	12.64	0.07	
Model B													
Soil Moisture Store (SM)	38.39	27.67	17.62	16.50	8.93	-0.73	4.37	12.91	21.23	26.53	34.74	35.18	
Groundwater Store (GW)	-14.82	2.32	-2.59	-8.73	-31.77	-53.18	-67.83	-79.84	-59.38	-48.47	-22.10	-35.11	
Total in Storage ($\varepsilon\Delta S$)	23.57	29.99	15.03	7.77	-22.84	-53.91	-63.46	-66.93	-38.15	-21.94	12.64	0.07	

TABLE 7.21 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
UPPER SEVERN SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	93.29	70.38	57.28	47.61	37.68	17.83	16.82	22.21	30.20	48.33	76.49	102.65	621.72
Rainfall R (mm)	114.66	82.59	74.47	81.11	85.46	66.97	84.10	94.60	103.11	95.77	125.20	121.84	1129.89
Pot. Evap. Ep (mm)	0	7	28	50	76	86	85	68	41	19	4	0	464
Act. Evap. E_a (mm)	0	7(8)	28(31)	50(55)	76(84)	84(93)	83(92)	68(75)	41(45)	19(21)	4	0	508
$R - E_a$	114.66	74.59	43.47	26.11	1.46	-26.03	-7.90	19.60	58.11	74.77	121.20	121.84	621.88
$\Delta S = (R - E_a) - Q$	20.37	4.21	-13.76	-21.50	-36.22	-43.86	-24.72	-2.61	27.91	26.44	44.71	19.19	0.16
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.14	-0.76	-1.94	-16.25	-40.74	-45.19	-28.36	-9.27	-2.48	-0.02	0.00	
Drainage Store (DS)	20.37	24.72	11.58	-8.74	-30.65	-50.02	-70.29	-89.73	-80.91	-61.26	-19.01	0.16	
Model B													
Soil Moisture Store (SM)	20.24	14.39	8.50	4.85	-8.92	-34.29	-40.06	-23.09	0.61	10.24	19.60	20.80	
Groundwater Store (GW)	0.13	10.19	2.32	-15.53	-37.98	-56.47	-75.42	-95.00	-90.79	-73.98	-38.63	-20.64	
Total in Storage ($\varepsilon\Delta S$)	20.37	24.58	10.82	-10.68	-46.90	-90.76	-115.48	-118.09	-90.18	-63.74	-19.03	0.16	

TABLE 7.22 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORE
UPPER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	127.73	92.96	68.26	58.76	46.05	22.40	17.08	23.09	39.39	62.94	98.42	125.91	782.99
Rainfall R (mm)	135.46	94.13	77.66	88.85	88.34	67.92	88.13	91.86	110.12	107.76	135.83	137.67	1218.47
Pot. Evap. Ep (mm)	0	6	28	49	75	85	84	67	40	19	4	0	457
Act. Evap. E_a (mm)	0	6	28(27)	49(47)	75(71)	84(80)	83(78)	67(64)	40(38)	19(18)	4	0	433
$R - E_a$	135.46	86.13	50.66	41.58	17.34	-12.08	5.13	27.86	72.12	89.76	131.83	137.67	783.46
$\Delta S = (R - E_a) - Q$	7.73	-6.83	-17.60	-17.18	-28.71	-34.48	-11.95	4.77	32.73	26.82	33.41	11.76	0.47
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.21	-0.92	-2.08	-12.79	-36.93	-41.86	-26.29	-6.78	-2.21	-0.02	0.00	
Drainage Store (DS)	7.73	1.11	-15.78	-31.80	-49.80	-60.14	-67.16	-77.96	-64.74	-42.49	-11.27	0.47	
Model B													
Soil Moisture Store (SM)	23.73	16.83	9.27	6.06	-5.13	-30.35	-36.23	-20.68	3.15	13.01	21.59	23.44	
Groundwater Store (GW)	16.00	15.93	-25.97	-39.94	-57.46	-66.72	-72.79	-83.57	-74.67	-57.71	-32.88	-22.97	
Total in Storage ($\varepsilon\Delta S$)	7.73	0.90	-16.70	-33.88	-62.59	-97.07	-109.02	-104.25	-71.52	-44.70	-11.29	0.47	

TABLE 7.23 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
USK SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	157.86	116.26	88.58	70.19	57.49	34.23	27.49	32.52	47.61	79.18	110.14	139.73	961.28
Rainfall R (mm)	165.37	111.44	91.44	96.82	95.83	77.07	81.74	96.56	121.84	120.50	148.75	145.33	1352.70
Pot. Evap. Ep (mm)	0	6	28	47	73	83	82	66	39	19	4	-1	446
Act. Evap. E_a (mm)	0	6(5)	28(25)	47(41)	73(65)	83(73)	81(72)	66(58)	39(34)	19(17)	4(3)	-1	391
$R - E_a$	165.37	106.44	66.44	55.82	30.83	4.93	9.74	38.56	87.84	103.50	145.75	146.33	961.55
$\Delta S = (R - E_a) - Q$	7.51	-9.82	-22.14	-14.37	-26.66	-29.30	-17.75	6.04	40.23	24.32	35.61	6.60	0.27
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.20	-1.45	-2.11	-10.71	-28.64	-35.00	-19.04	-3.73	-2.13	-0.02	0.00	
Drainage Store (DS)	7.51	-2.11	-23.00	-36.71	-54.77	-66.14	-77.53	-87.45	-62.53	-39.81	-6.31	0.27	
Model B													
Soil Moisture Store (SM)	28.43	20.14	11.63	7.88	-1.84	-20.91	-28.67	-12.72	8.16	16.14	24.00	25.06	
Groundwater Store (GW)	20.92	-22.45	-36.08	-46.70	-63.64	-73.87	-83.86	-93.77	-74.42	-58.08	-30.33	-24.79	
Total in Storage ($\varepsilon\Delta S$)	7.51	-2.31	-24.45	-38.82	-65.48	-94.78	-112.53	-106.49	-66.26	-41.94	-6.33	0.27	

TABLE 7.24 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
MID-SEVERN SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	46.71	36.95	34.00	24.79	22.64	12.77	12.14	11.15	13.62	17.94	24.84	40.38	300.93
Rainfall R (mm)	65.55	45.73	48.11	54.37	64.46	49.32	64.99	67.97	65.92	57.66	71.94	62.35	718.35
Pot. Evap. Ep (mm)	2	9	30	55	80	92	91	71	43	20	4	1	498
Act. Evap. E_a (mm)	2	9(8)	30(27)	55(49)	79(71)	82(73)	78(70)	65(58)	42(37)	20(18)	4(3)	1	417
$R - E_a$	63.55	37.73	21.11	5.37	-6.54	-23.68	-5.01	9.97	28.92	39.66	68.94	61.35	301.37
$\Delta S = (R - E_a) - Q$	16.84	0.78	-12.89	-19.42	-29.18	-36.45	-17.15	-1.18	15.30	21.72	41.10	20.97	0.44
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.26	-2.29	-12.70	-36.40	-71.70	-85.62	-81.07	-58.81	-32.57	-7.57	-1.55	
Drainage Store (DS)	16.84	17.88	7.02	-1.99	-7.47	-8.62	-11.85	-17.58	-24.54	-29.06	-12.96	1.11	
Model B													
Soil Moisture Store (SM)	10.62	7.05	2.36	-8.49	-32.18	-68.47	-83.36	-78.99	-57.04	-29.90	-0.85	7.58	
Groundwater Store (GW)	6.22	10.57	2.37	-6.20	-11.69	-11.85	-14.11	-19.66	-26.31	-31.73	-19.68	-7.14	
Total in Storage ($\Sigma\Delta S$)	16.84	17.62	4.73	-14.69	-43.87	-80.32	-97.47	-98.65	-83.35	-61.63	-20.53	0.44	

TABLE 7.25 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
MID-WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	77.16	62.63	50.89	35.41	33.83	23.96	20.09	13.74	11.96	28.81	39.34	61.95	459.77
Rainfall R (mm)	101.62	69.45	65.41	65.53	77.65	64.26	65.06	71.04	77.67	79.99	90.74	82.07	910.49
Pot. Evap. Ep (mm)	1	8	29	53	78	89	88	69	42	19	4	0	480
Act. Evap E_a (mm)	1	8	29(28)	53(51)	78(74)	85(81)	78(74)	66(63)	41(39)	19(18)	4	0	441
$R - E_a$	100.62	61.45	27.41	14.53	3.65	-16.74	-8.94	8.04	38.67	61.99	86.74	82.02	459.49
$\Delta S = (R - E_a) - Q$	23.46	-1.18	-23.48	-20.88	-30.18	-40.70	-29.03	-5.70	26.71	33.18	47.40	20.12	-0.28
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	-0.01	-0.44	-2.07	-10.53	-25.81	-51.19	-67.38	-62.83	-37.67	-15.78	-3.19	-0.45	
Drainage Store (DS)	23.47	22.72	0.87	-11.55	-26.45	-41.77	-54.61	-64.86	-63.31	-52.02	-17.21	0.17	
Model B													
Soil Moisture Store (SM)	16.98	11.78	5.95	-3.84	-19.21	-45.77	-63.06	-58.87	-33.47	-7.29	9.34	13.12	
Groundwater Store (GW)	6.48	10.50	-7.15	-18.24	-33.05	-47.19	-58.93	-68.82	-67.51	-60.51	-29.74	-13.40	
Total in Storage ($\varepsilon\Delta S$)	23.46	22.28	-1.20	-22.08	-52.26	-92.96	-121.99	-127.69	-100.98	-67.80	-20.40	-0.28	

TABLE 7.26 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
LOWER WYE SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	63.96	54.72	51.29	32.84	26.75	15.89	12.68	9.82	10.67	21.83	36.64	45.86	382.95
Rainfall R (mm)	93.44	61.08	59.43	61.89	66.98	50.40	63.18	66.15	76.27	71.44	86.03	76.88	833.17
Pot. Evap. Ep (mm)	1	9	30	54	79	91	89	70	42	19	4	0	488
Act. Evap. E_a (mm)	1	9	30	54	78	83(82)	70(69)	65(64)	41	19	4	0	450
$R - E_a$	92.44	52.08	29.43	7.89	-10.02	-31.60	-5.82	2.15	35.27	52.44	82.03	76.88	383.17
$\Delta S = (R - E_a) - Q$	28.48	-2.64	-21.86	-24.95	-36.77	-47.49	-18.50	-7.67	24.60	30.61	45.39	31.02	0.22
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.37	-1.82	-10.56	-31.67	-67.01	-76.94	-75.27	-47.59	-20.89	-3.52	-0.28	
Drainage Store (DS)	28.48	26.21	5.80	-10.41	-26.07	-38.22	-46.79	-55.81	-59.21	-55.30	-27.28	0.50	
Model B													
Soil Moisture Store (SM)	15.62	10.15	4.79	-4.90	-26.46	-62.79	-74.20	-72.73	-44.91	-15.40	6.89	12.15	
Groundwater Store (GW)	12.86	15.69	-0.81	-16.07	-31.28	-42.44	-49.53	-58.67	-61.89	-60.79	-37.69	-11.93	
Total in Storage ($\varepsilon\Delta S$)	28.48	25.84	3.98	-20.97	-57.74	-105.23	-123.73	-131.40	-106.80	-76.19	-30.80	0.22	

TABLE 7.27 EVALUATION OF SEASONAL CHANGE IN MOISTURE STORES
TENBURY SUB-CATCHMENT

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Run-off Q (mm)	67.23	50.26	47.08	30.62	28.67	13.70	11.52	9.44	12.47	24.12	39.76	52.84	387.71
Rainfall R (mm)	89.51	62.35	61.37	64.54	69.86	51.33	62.57	74.25	75.42	70.48	88.48	79.15	849.33
Pot. Evap. E_p (mm)	1	8	30	53	79	90	89	69	42	19	4	0	484
Act. Evap. E_a (mm)	1	8	30	53	79	84	79	65	41	19	4	0	463
$R - E_a$	88.51	54.35	31.37	11.54	-9.14	-32.67	-16.43	9.25	34.42	51.48	84.48	79.15	386.31
$\Delta S = (R - E_a) - Q$	21.28	4.09	-15.71	-19.08	-37.81	-46.37	-27.95	-0.19	21.95	27.36	44.72	26.31	-1.40
<u>Moisture in Storage</u>													
Model A													
Soil Moisture Deficit (SMD)	0.00	-0.23	-1.43	-6.84	-28.20	-63.66	-80.72	-70.94	-43.96	-19.17	-2.78	-0.15	
Drainage Store (DS)	21.28	25.60	11.09	-2.58	-19.03	-29.94	-40.83	-50.80	-55.83	-53.26	-24.93	-1.25	
Model B													
Soil Moisture Store (SM)	15.12	10.42	5.35	-1.58	-22.79	-59.33	-77.37	-67.91	-41.25	-13.61	8.20	-2.73	
Groundwater Store (GW)	6.16	14.95	4.31	-7.84	-24.44	-34.27	-44.18	-53.83	-58.54	-58.82	-35.91	-14.13	
Total in Storage ($\epsilon\Delta S$)	21.28	25.37	9.66	-9.42	-47.23	-93.60	-121.55	-121.74	-99.79	-72.43	-27.71	-1.40	

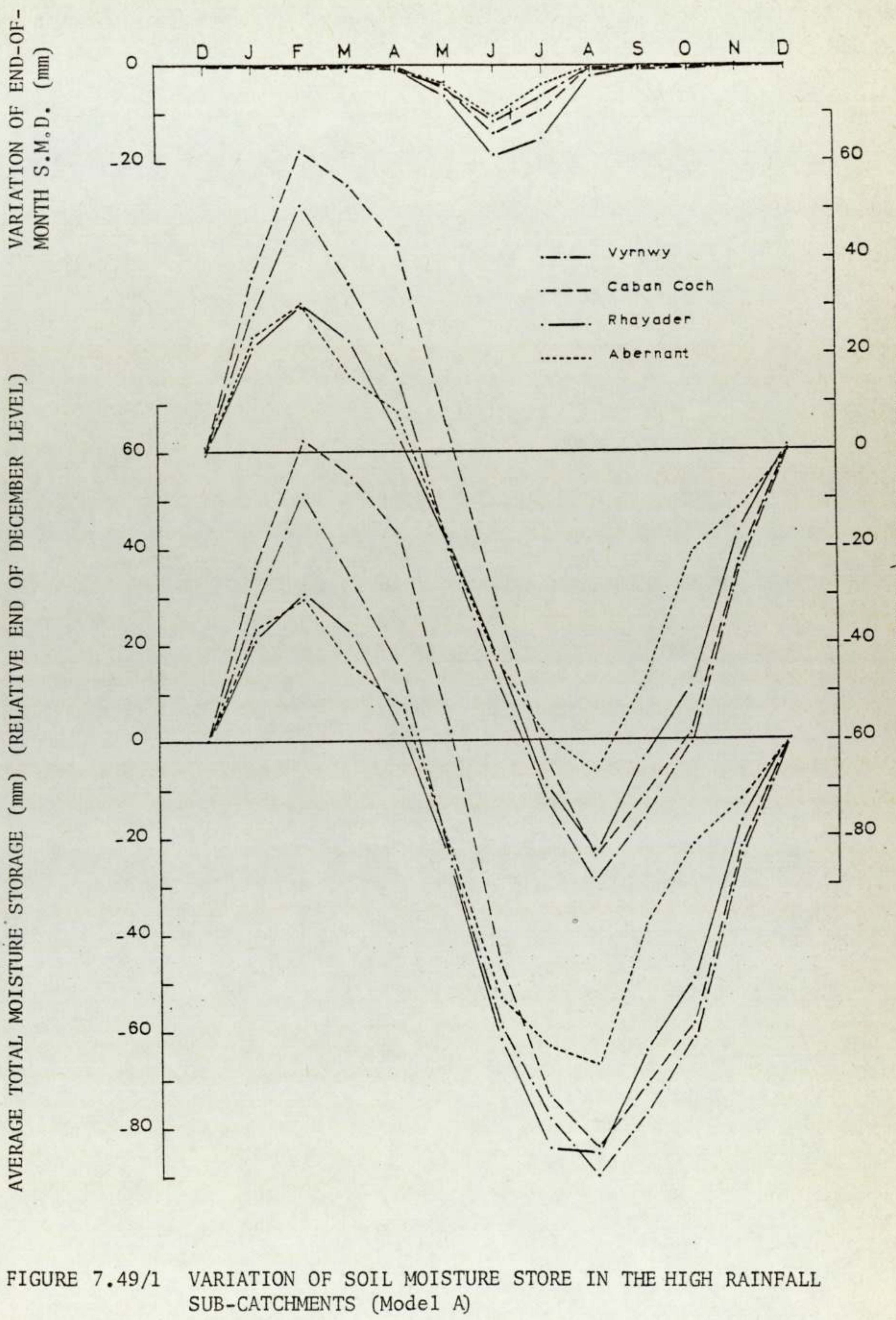


FIGURE 7.49/1 VARIATION OF SOIL MOISTURE STORE IN THE HIGH RAINFALL SUB-CATCHMENTS (Model A)

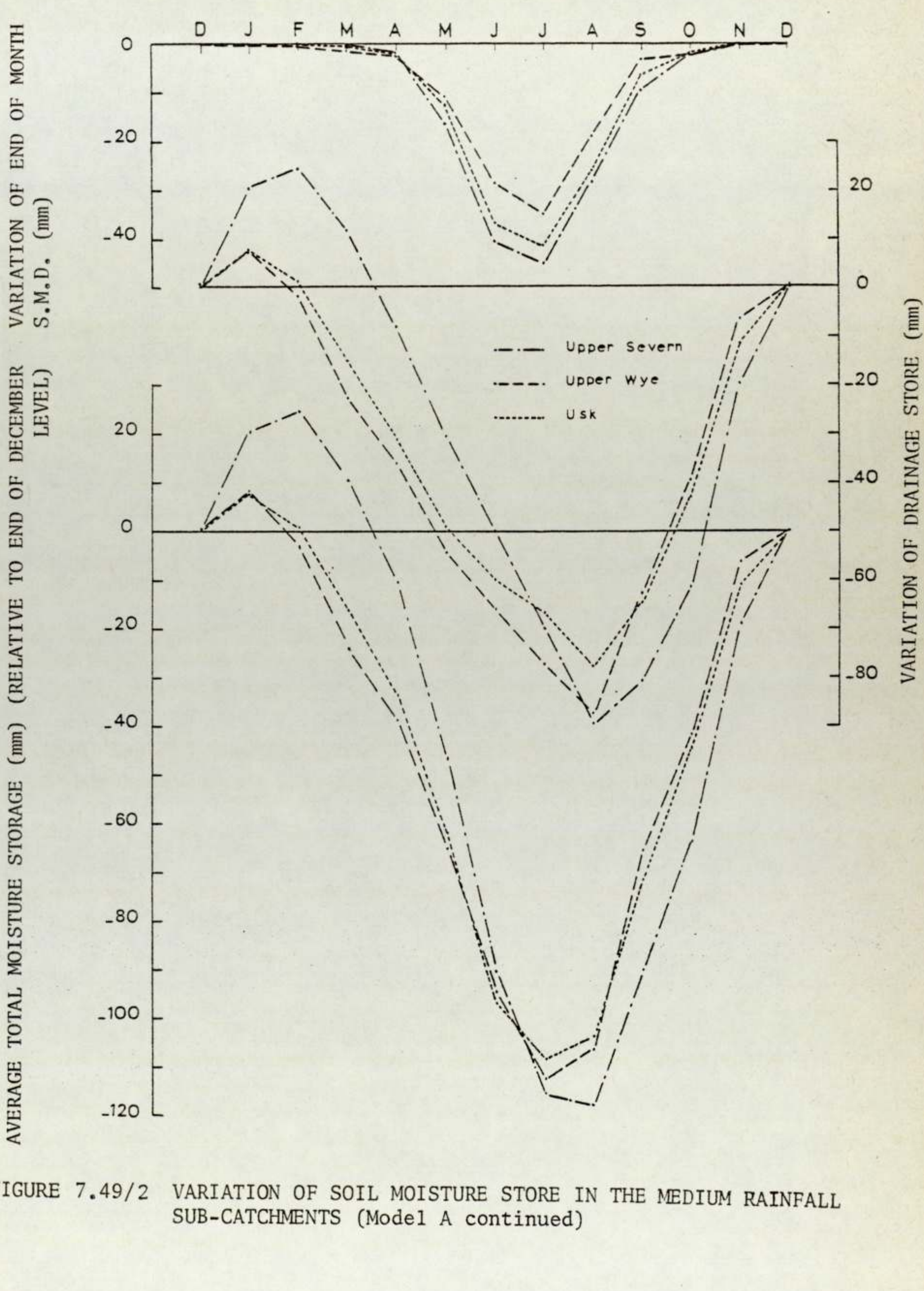


FIGURE 7.49/2 VARIATION OF SOIL MOISTURE STORE IN THE MEDIUM RAINFALL SUB-CATCHMENTS (Model A continued)

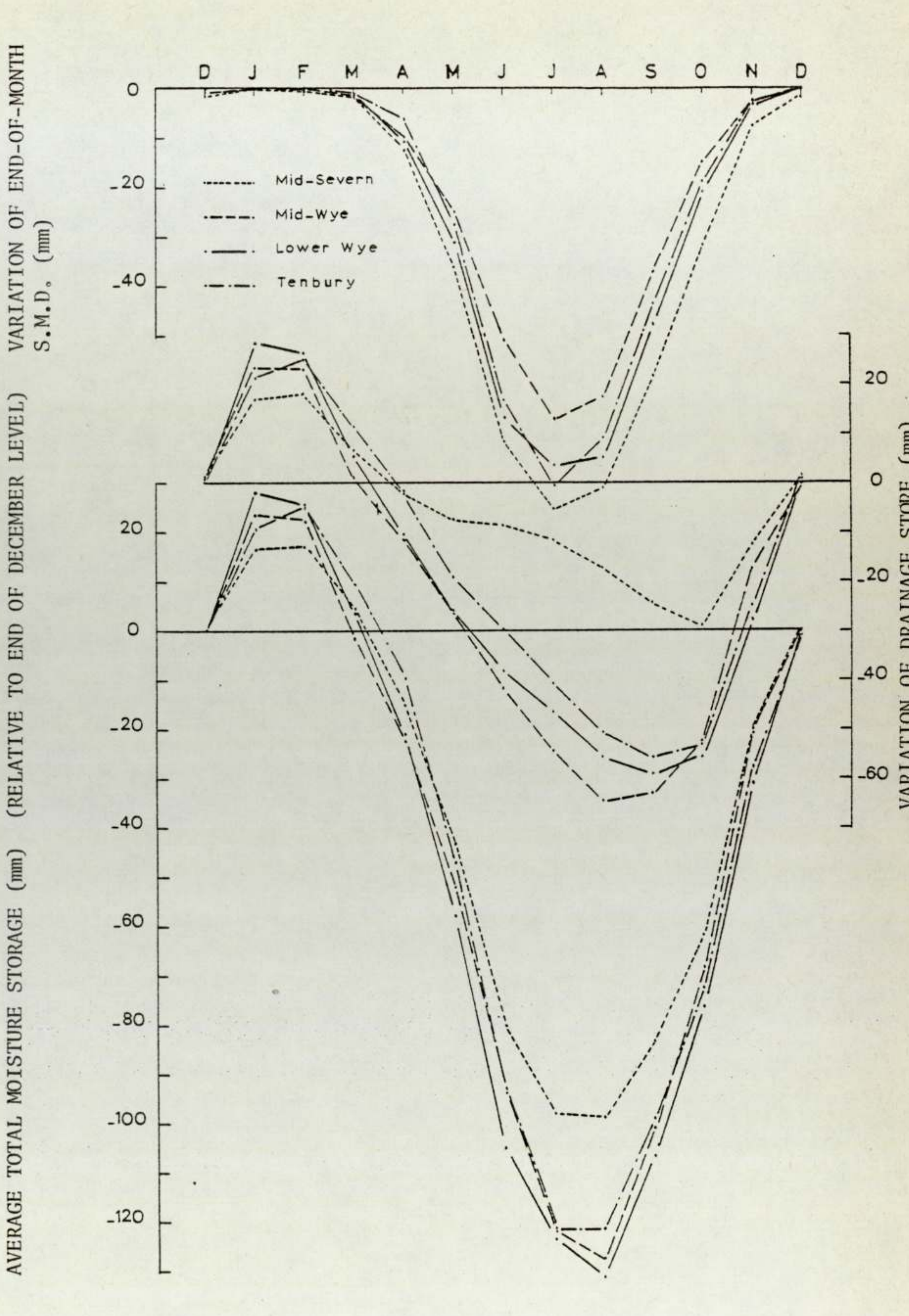


FIGURE 7.49/3 VARIATION OF SOIL MOISTURE STORE IN THE LOW RAINFALL SUB-CATCHMENTS (Model A continued)

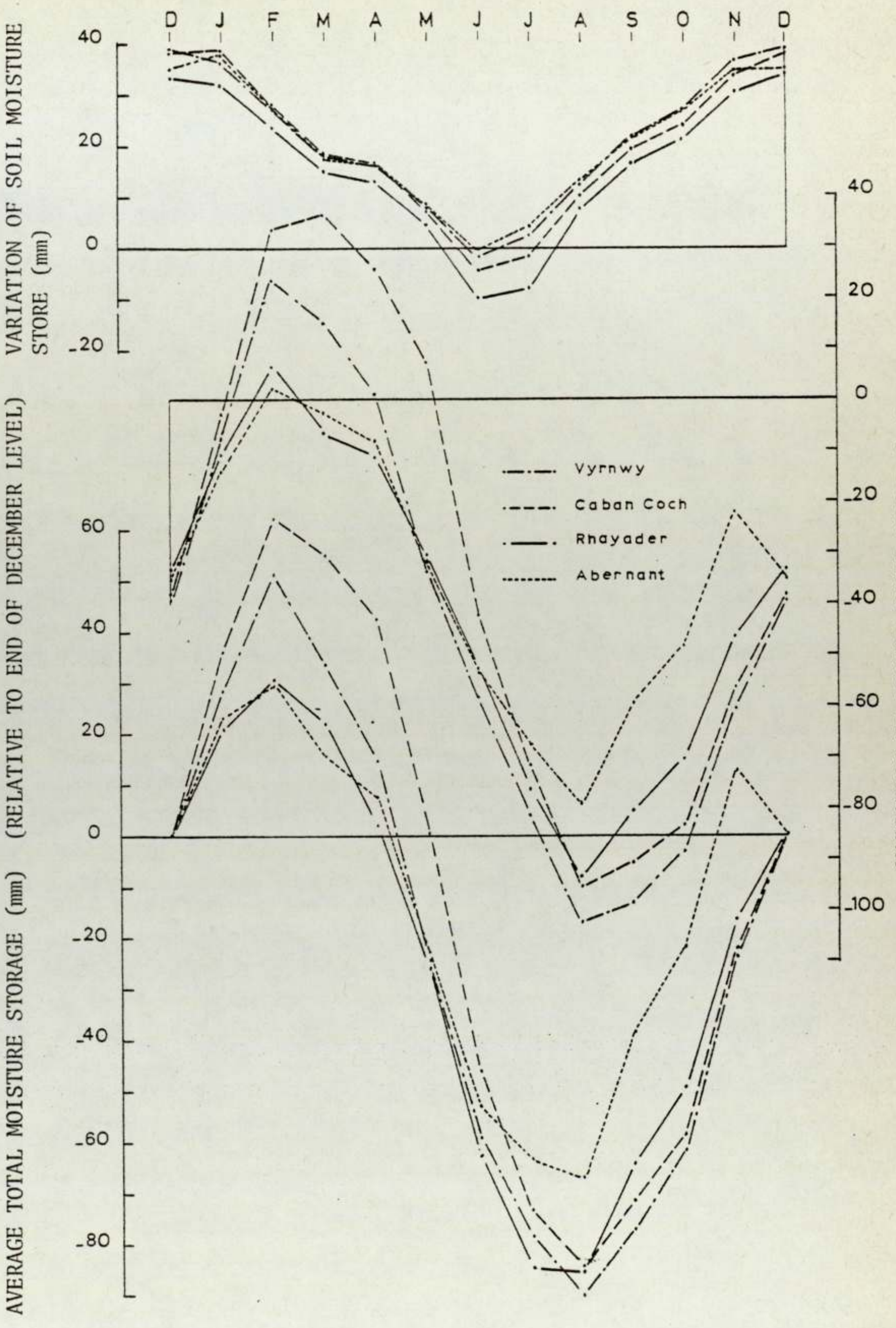


FIGURE 7.50/1 VARIATION OF SOIL MOISTURE STORE IN THE HIGH RAINFALL SUB-CATCHMENTS (Model B)

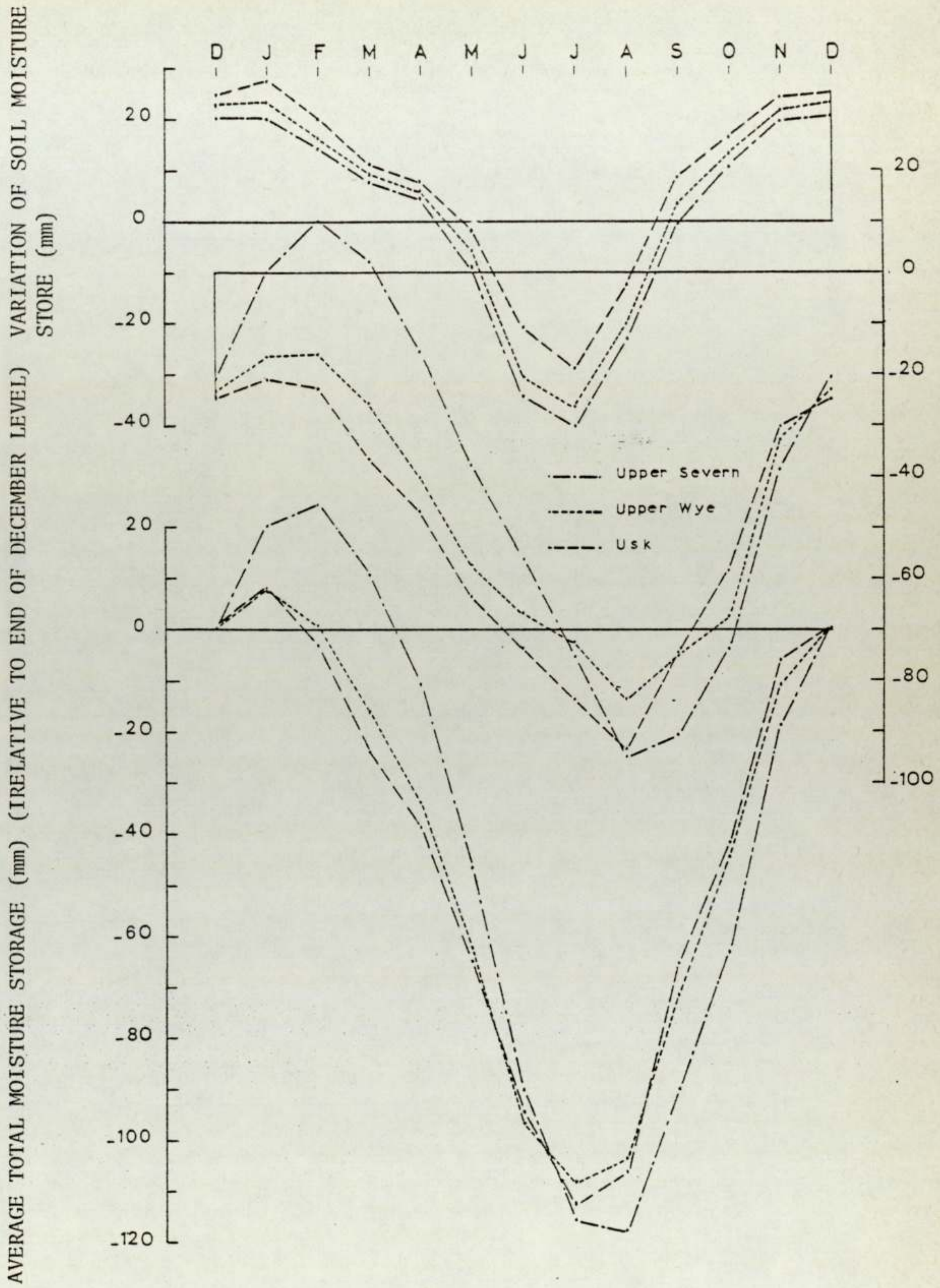


FIGURE 7.50/2 VARIATION OF SOIL MOISTURE STORE IN THE MEDIUM RAINFALL SUB-CATCHMENTS (Model B continued)

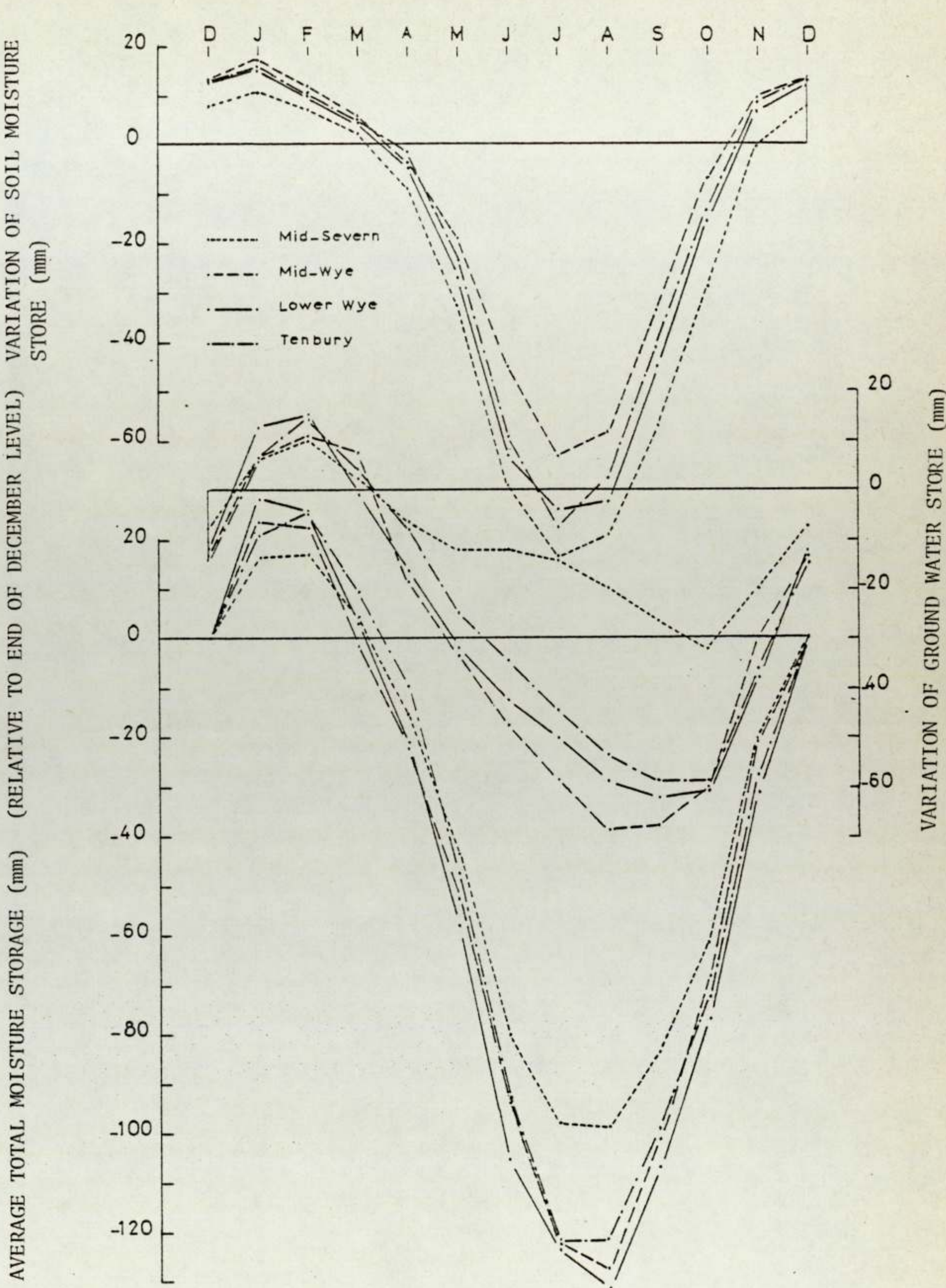


FIGURE 7.50/3 VARIATION OF SOIL MOISTURE STORE IN THE LOW RAINFALL SUB-CATCHMENTS (Model B continued)

TABLE 7.28 AVERAGE ANNUAL AMPLITUDE OF THE VOLUME OF WATER STORED IN THE VARIOUS MOISTURE STORES

Sub-catchment Name	Amplitude (mm equivalent rainfall)				
	Type A Model		Type B Model		Total Catchment Storage
	Soil Moisture Deficit	Drainage Store	Soil Moisture	Groundwater Store	
Vyrnwy	11.71	140.21	40.91	125.88	141.26
Rhayader	18.76	114.06	43.70	100.38	116.54
Caban Coch	14.03	146.29	43.14	132.11	147.04
Abernant	10.55	96.76	35.91	82.16	96.92
Upper Severn	45.19	114.45	60.86	105.19	142.67
Upper Wye	41.86	85.69	59.67	67.57	116.75
Usk	35.00	94.96	53.73	72.85	120.04
Mid-Severn	85.62	46.42	93.98	42.30	116.27
Tenbury	80.72	80.97	92.49	73.77	147.11
Mid-Wye	67.38	88.31	80.04	79.32	151.15
Lower Wye	76.94	87.69	89.82	77.58	159.88

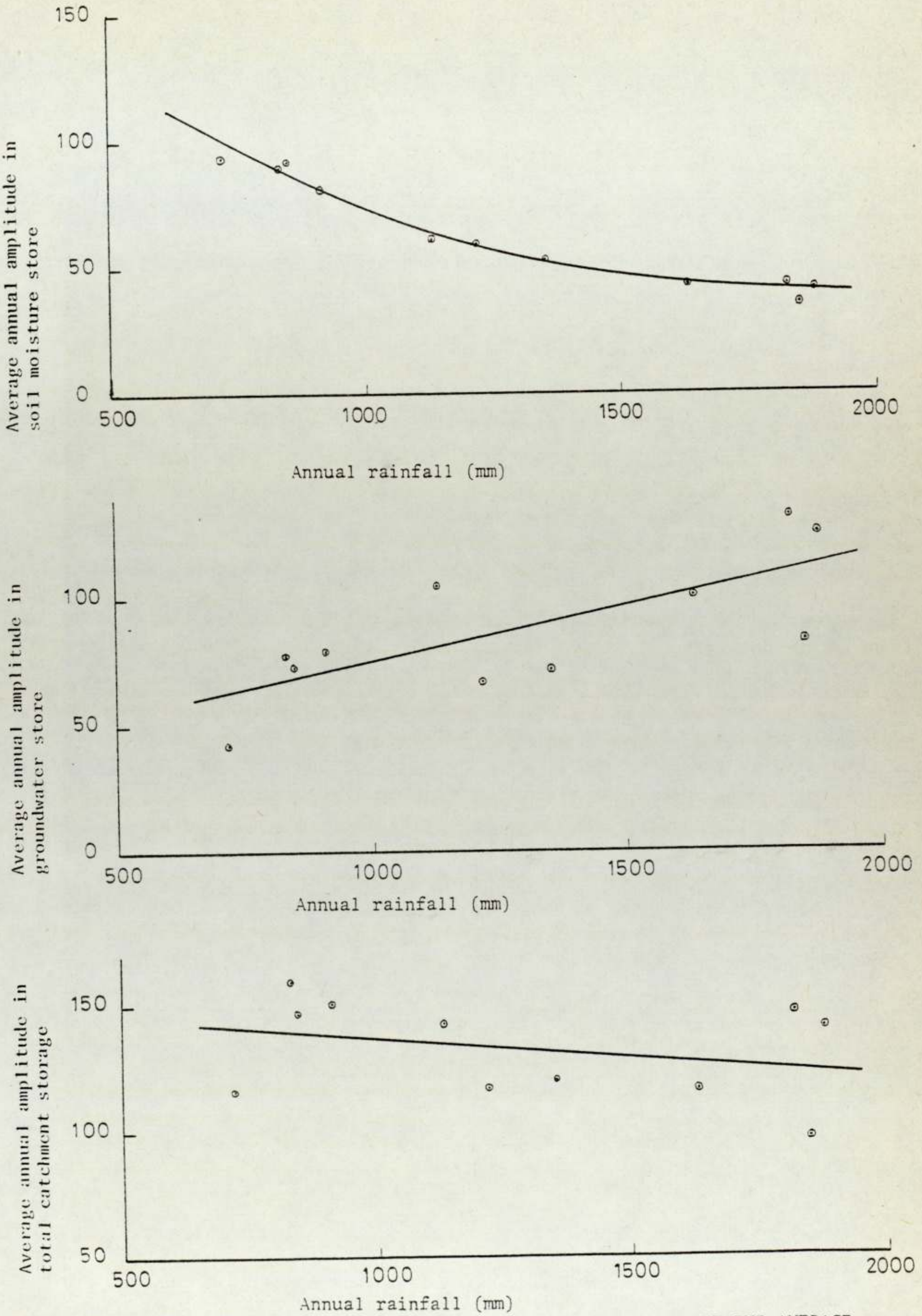


FIGURE 7.51 RELATIONSHIPS BETWEEN MEAN ANNUAL RAINFALL AND THE AVERAGE ANNUAL AMPLITUDE OF THE VOLUME OF WATER IN THE VARIOUS STORES (Type B Model)

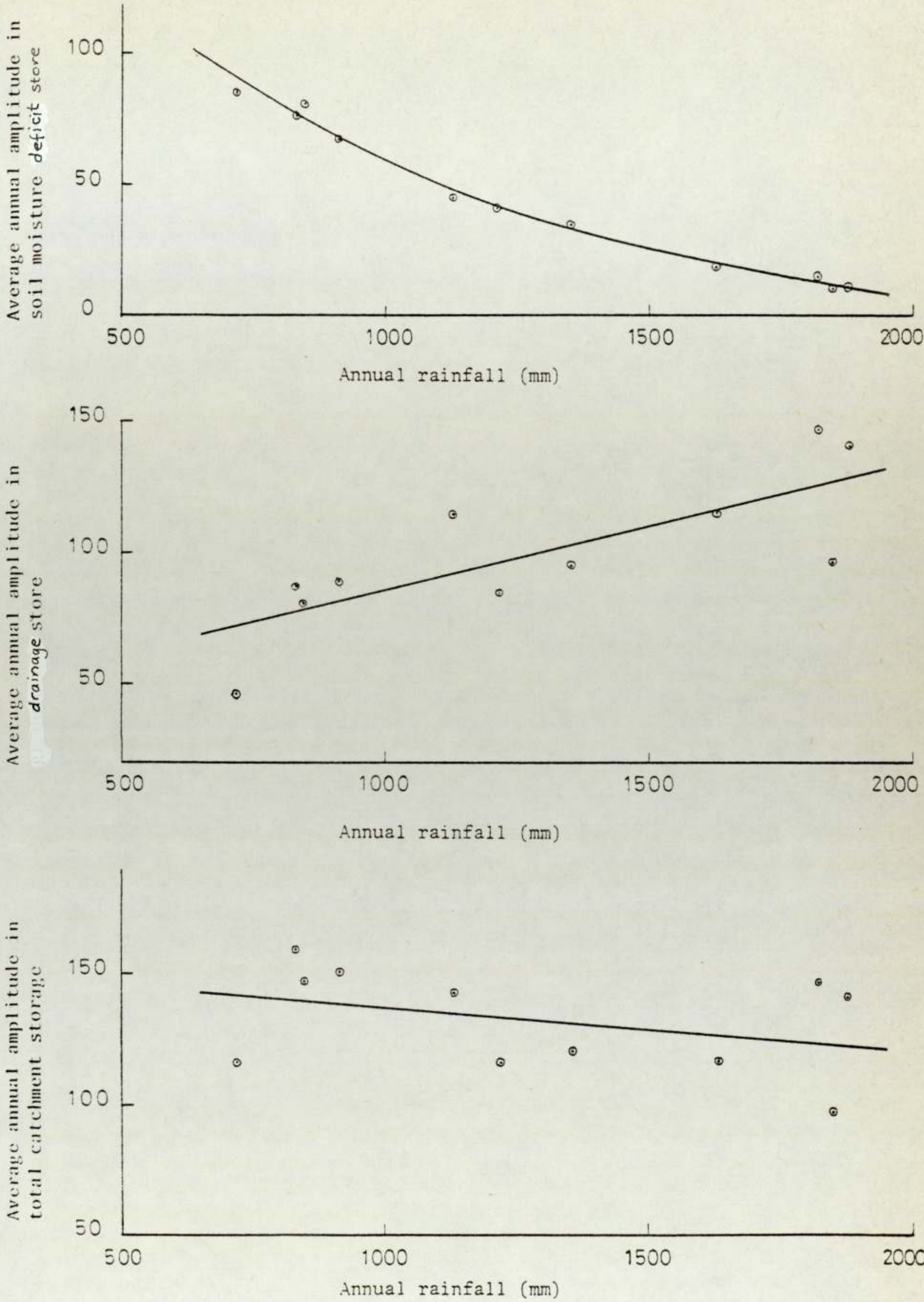


FIGURE 7 52 RELATIONSHIPS BETWEEN MEAN ANNUAL RAINFALL AND THE AVERAGE ANNUAL AMPLITUDE OF THE VOLUME OF WATER IN THE VARIOUS STORES (Type A Model) and that further investigation beyond the scope of this project, is necessary if a reliable method of predicting the temporal variation of catchment storage is to be developed.

CHAPTER EIGHT
THE ESTIMATION OF MONTHLY STREAMFLOW PARAMETERS FOR UNGAUGED CATCHMENTS

8.1 INTRODUCTION

Since a primary objective of this study was to develop methods of estimating monthly flow parameters for ungauged catchments, it was necessary to demonstrate how the derived relationships could be used for this purpose and to test the precision of the estimates.

In order to obtain a comparison between the estimated flow parameters and their values obtained from historical records, three gauged catchments which had not previously been included in the study were chosen and treated as if they were ungauged catchments. The choice was apparently limited to catchments which had been excluded from the analysis because their flow records were either too short or of doubtful precision. However, one good quality flow record, namely Llandewi which had previously been overlooked was discovered and used in this test. The other two flow records used were Lugwardine, which was originally excluded because of its doubtful precision, and Trallong which was excluded because its record was too short. It was discovered that the lack of precision of the Lugwardine gauge was limited to flood flows, so it was decided to use it here in the hope that its precision with respect to monthly mean flows was not seriously in doubt. These three catchments, Lugwardine, Llandewi and Trallong, have mean areal rainfalls (1916-50) of 836 mm, 1202 mm and 1708 mm and are fairly representative of the different types of catchment in the Region.

8.2 THE CATCHMENTS

8.2.1 Lugwardine Catchment

This catchment is located in the north-east of the River Wye catchment and has an area above the Lugwardine gauging station (G.R. SO 548405) of 886 km^2. The Lugg is the main river in this catchment and after rising at 510 metres above sea level, on the slopes of Beacon Hill, flows in a generally south-easterly direction to meet on its right bank the River Arrow. It then flows in a southerly direction to join the River Wye near Hereford. The general topography is low with rolling hills except at the source of the rivers Lugg and Arrow where it is bordered by mountains.

The solid geology of the catchment is predominantly Old Red Sandstone with some Silurian rocks which form the hills at the source of the rivers Lugg and Arrow. The superficial deposits are fairly extensive, particularly around the middle and lower reaches of the Lugg and consists almost entirely of alluvium and glacial sand and gravel.

8.2.2 Llandewi Catchment

This catchment is located in the Upper Wye region and has an area above Llandewi gauging station (G.R. SO 105638) of 111.4 km^2. The Ithon is the main river and flows in a southerly direction to join the River Wye approximately half way between the Rhayader and Erwood gauging stations. The area above Llandewi is generally mountainous being surrounded by the Rhyddhywel, Cilfaesty and Beacon hills, but the rainfall is relatively low (1202 mm) due to the considerable rainshadow effect created by mountain ranges to the north, west and south. The solid geology of the catchment is quite different from the other catchments in the Region since it consists almost entirely of Silurian rock which is not extensive in any of the other catchments. However, it is relatively impermeable and should not therefore make the catchment behave differently from the others. The superficial deposits in this area are limited to small amounts of boulder clay in the valley bottoms.

8.2.3 Trallong Catchment

This catchment is located at the upper end of the River Usk and has an area above the Trallong gauging station (G.R. SN 947295) of 184 km^2. The catchment is mountainous being surrounded by the Mynydd Eppynt in the north and Brecon Beacons in the south. The rainfall over this area is generally high because the prevailing west and south-westerly air stream is forced to rise over the mountain barrier formed by the Brecon Beacons. The solid geology is predominantly Old Red Sandstone which is relatively impermeable. The superficial deposits are small in area and consists of boulder clay, glacial sand and gravel.

8.3 THE PROCEDURE

One of the specific aims of this study, as defined in Section 1.3, was to develop methods of estimating the streamflow parameters for ungauged catchments using only limited meteorological data. Four categories of available data were specified:

1) mean annual areal rainfall estimated from the Annual Rainfall Map (Map No 3);
2) mean annual areal rainfall estimated from local rain-gauge records;
3) mean monthly areal rainfall estimated from local rain-gauge records: and

4) any one of (1), (2) and (3) above plus mean annual areal evapotranspiration.

The various rainfall/streamflow relationships derived during this project may be used to estimate streamflow parameters from data limited to category (1), (2) and (3) above. However, the change in catchment storage approach to the estimation of streamflow parameters, which utilised data in category (4), cannot be used because the method requires further development (see Section 7.12).

The streamflow parameters for the three test catchments were therefore evaluated using:

1) mean annual areal rainfall only;

2) mean monthly areal rainfalls.

Since the differences between the mean annual areal rainfalls derived from Map No 3 and those derived from areal rainfall data provided by the Welsh National Water Development Authority (see Table 8.1 to 8.3) were very small, it was decided to perform only one set of estimates based upon annual rainfall. These were carried out using the means derived from the WNWDA data for the period 1960-75. The mean monthly areal rainfalls were also derived from the WNWDA data (1960-75).

The means and standard deviations of monthly streamflow for each of the test catchments were evaluated using the derived rainfall/streamflow relationships as defined below.

1) The streamflow/annual rainfall relationships (Figures 7.34/1 to 7.34/4) using the derived mean annual areal rainfalls.

2) The streamflow/monthly rainfall relationships (Figures 7.36/1 to 7.36/4) using the derived mean monthly areal rainfalls.

TABLE 8.1 STATISTICAL PARAMETERS FOR LUGWARDINE CATCHMENT

	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL	RAINFALL (R)												
	Mean	89.91	61.44	59.69	63.75	70.06	53.19	59.81	69.25	75.13	72.81	87.06	77.56
	STREAMFLOW (Q)												
	Mean (mm)	67.63	55.07	50.42	32.79	30.77	16.15	14.72	11.28	12.58	24.64	40.78	53.63
	Stan. dev. (mm)	26.72	28.04	22.37	14.28	18.80	7.93	13.94	3.48	7.14	26.75	33.20	34.37
	Skew. coeff.	-1.00	-0.07	0.64	0.93	1.43	1.58	3.78	-0.60	0.97	2.02	1.83	1.33
	Ratio (mean/st.dev.)	2.53	1.96	2.26	2.30	1.64	2.04	1.06	3.24	1.76	0.92	1.23	1.56
	Lag-one coeff.												
	Correlation	-0.09	0.66	0.12	0.28	0.12	0.74	0.28	0.24	0.45	0.42	0.78	0.37
	Regression	-0.07	0.76	0.09	0.19	0.15	0.32	0.47	0.06	0.95	1.15	0.99	0.37
PREDICTED	RAINFALL (R)												
	Mean (mm)	88.43	60.47	58.19	61.88	70.23	53.24	64.60	70.55	75.91	70.87	86.46	78.26
	STREAMFLOW (Q)												
	Mean (mm) (1)	69.91	55.35	47.66	33.44	27.40	14.17	8.45	7.33	10.25	26.12	39.93	55.76
	Stan. dev. (mm) (1)	30.61	27.94	20.24	21.40	16.39	7.36	11.44	5.53	9.54	27.70	31.46	34.88
	Mean (mm) (2)	68.76	54.60	46.05	31.42	27.57	15.10	11.68	8.51	10.78	23.84	39.90	55.50
	Stan. dev. (mm) (2)	29.20	27.20	19.31	14.36	16.70	7.95	12.58	5.97	9.91	27.01	31.39	34.51
	Skew. coeff.	0.38	0.76	0.29	0.53	1.21	0.90	2.12	1.49	1.92	2.18	1.69	1.26
	Ratio (mean/st.dev.)	2.31	2.01	2.38	2.19	1.65	1.90	0.93	1.43	1.09	0.88	1.27	1.61
	Lag-one coeff.												
	Correlation	0.01	0.50	0.02	0.15	0.08	0.60	0.45	0.20	0.25	0.47	0.50	0.35
	Regression	0.01	0.46	0.01	0.11	0.09	0.29	0.71	0.09	0.41	1.28	0.58	0.38

Long Term Annual Rainfall = 836 mm (1916-50)   Annual Rainfall = 840 mm (1960-75)

(1) Based upon monthly rainfall/monthly flow relationships using historical (1960-75) monthly rainfall data.

(2) Based upon annual rainfall/monthly flow relationships using historical (1960-75) mean annual rainfall.

TABLE 8.2 STATISTICAL PARAMETERS FOR LLANDEWI CATCHMENT

	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL	RAINFALL (R)												
	Mean (mm)	132.50	94.25	80.62	86.69	94.69	67.25	85.44	97.44	104.37	102.37	129.25	127.37
	STREAMFLOW (Q)												
	Mean (mm)	113.63	82.87	62.75	48.81	43.69	19.50	15.44	22.94	39.44	62.02	92.94	108.25
	Stan. dev. (mm)	54.33	48.42	29.29	22.25	29.49	14.62	14.98	15.80	34.10	48.14	46.82	50.82
	Skew. coeff.	-0.41	0.55	1.56	0.20	1.19	1.17	2.46	0.61	0.71	1.31	1.03	0.85
	Ratio (mean/st. dev)	2.09	1.71	2.14	2.19	1.48	1.33	1.03	1.45	1.16	1.29	1.99	2.13
	Lag-one coeff.												
	Correlation	-0.11	0.41	-0.23	-0.02	-0.06	0.42	0.37	-0.22	0.32	0.55	0.02	-0.06
	Regression	-0.12	0.36	-0.14	-0.01	-0.08	0.21	0.38	-0.23	0.68	0.77	0.02	-0.07
PREDICTED	RAINFALL (R)												
	Mean (mm)	133.61	92.98	81.07	88.42	88.51	69.19	82.66	94.22	106.36	104.24	131.46	129.34
	STREAMFLOW (Q)												
	Mean (mm) (1)	111.33	84.14	67.73	56.01	52.94	25.23	27.61	35.15	40.32	59.28	85.17	109.60
	Stan. dev. (mm) (1)	49.27	43.28	32.82	32.73	27.73	15.28	17.91	18.11	27.52	45.44	44.98	59.75
	Mean (mm) (2)	112.49	83.02	68.13	57.62	46.58	26.75	25.48	41.97	42.23	61.42	87.91	111.57
	Stan. dev. (mm) (2)	49.73	42.11	33.11	27.53	24.99	16.35	17.22	16.58	28.73	46.63	45.76	60.64
	Skew. coeff.	0.44	0.81	0.69	0.66	0.95	1.22	1.43	0.86	1.44	1.63	0.87	0.97
	Ratio (mean/st.dev.)	2.26	1.97	2.06	2.09	1.86	1.64	1.48	1.93	1.47	1.32	1.92	1.84
	Lag-one coeff.												
	Correlation	0.04	0.40	-0.08	0.15	0.10	0.50	0.42	0.10	0.25	0.45	0.30	0.15
	Regression	0.03	0.34	-0.06	0.12	0.09	0.33	0.44	0.10	0.43	0.73	0.29	0.20

Long Term Annual Rainfall = 1166 mm (1916-50) Annual Rainfall = 1202 mm (1960-75)

(1) Based upon monthly rainfall/monthly flow relationships using historical (1960-75) monthly rainfall data.

(2) Based upon annual rainfall/monthly flow relationships using historical (1960-75) mean annual rainfall.

TABLE 8.3 STATISTICAL PARAMETERS FOR TRALLONG CATCHMENT

	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL	RAINFALL (R)												
	Mean (mm)	226.18	141.00	109.91	109.45	112.64	105.36	107.82	121.18	156.00	150.64	175.64	207.73
	STREAMFLOW (Q)												
	Mean (mm)	195.64	133.18	92.43	74.10	74.67	48.46	37.99	51.82	77.90	99.71	128.47	202.34
	Stan. dev. (mm)	98.26	78.26	21.25	41.27	38.14	28.31	17.76	25.33	59.31	93.74	52.97	104.08
	Skew. coeff.	0.38	0.63	0.96	1.14	0.28	0.64	0.73	0.32	1.52	2.74	2.11	0.75
	Ratio (mean/st.dev.)	1.99	1.70	4.35	1.80	1.96	1.71	2.13	2.04	1.32	1.06	2.42	1.94
	Lag-one coeff.												
	Correlation	-0.37	0.30	0.05	0.49	0.42	0.42	0.29	-0.05	0.28	0.43	-0.01	-0.05
	Regression	-0.35	0.26	0.01	0.99	0.38	0.38	0.17	-0.07	0.67	0.65	-0.01	-0.01
PREDICTED	RAINFALL (R)												
	Mean (mm)	199.63	140.48	114.50	127.19	115.23	91.04	109.06	128.82	150.85	153.02	197.21	203.98
	STREAMFLOW (Q)												
	Mean (mm) (1)	202.23	125.18	95.81	78.41	81.91	55.22	44.33	58.58	93.43	113.43	134.92	196.41
	Stan. dev. (mm) (1)	90.21	65.14	50.44	43.97	40.59	36.74	23.56	28.70	59.25	74.41	59.85	99.84
	Mean (mm) (2)	176.39	124.54	100.40	95.92	74.35	43.79	45.63	66.25	88.20	116.33	158.05	193.51
	Stan. dev. (mm) (2)	78.83	63.91	53.26	46.79	37.10	28.62	23.99	32.08	56.24	75.30	66.76	98.84
	Skew. coeff.	0.47	0.83	0.91	0.71	0.77	1.36	0.90	0.68	1.31	1.35	0.30	0.82
	Ratio (mean/st.dev.)	2.24	1.95	1.89	2.05	2.00	1.53	1.90	2.07	1.57	1.54	2.37	1.96
	Lag-one coeff.												
	Correlation	0.05	0.30	-0.35	0.15	0.12	0.35	0.25	-0.18	0.25	0.40	-0.01	-0.15
	Regression	0.04	0.24	-0.29	0.13	0.10	0.27	0.21	-0.24	0.44	0.54	-0.01	-0.22

Long Term Annual Rainfall = 1708 mm (1916-75)　　Annual Rainfall = 1731 mm (1965-75)

(1) Based upon monthly rainfall/monthly flow relationships using historical (1960-75) monthly rainfall data.

(2) Based upon annual rainfall/monthly flow relationships using historical (1960-75) mean annual rainfall.

The skewness coefficients of the monthly flows were estimated using the derived CS(J)/RATIO(J) relationship (Equation 7.4). The required values of Ratio (i.e. mean/standard deviation) were calculated from the monthly means and standard deviations estimated earlier.

The monthly serial correlation and regression coefficients were estimated from the derived average curves for high, medium and low rainfall regions. This was achieved by linear interpolation between the derived curves based upon mean annual areal rainfall.

The monthly cross correlation coefficients were estimated using the procedure described in Section 7.7. That is, the winter maximum (γ_m) and summer depression (γ_d) were first estimated using Equation 7.8 and 7.9 and then the seasonal variation was plotted as illustrated in Figure 8.5.

The estimation of the mean monthly rainfalls from mean annual rainfall was not a principal aim of this study, but it could be of value in the development of a prediction method based upon change in catchment storage. It was therefore decided to include the estimation of mean monthly rainfalls in this series of tests. This was done by comparing the monthly means derived from the WNWDA data with values estimated from the series of monthly rainfall/annual rainfall regression lines developed in Section 7.2 (Figure 7.1/1 to 7.1/4).

8.4 THE RESULTS

Tables 8.1 to 8.3 give the predicted mean monthly rainfall and mean monthly streamflow statistics and the corresponding statistics derived from the historical data. Figure 8.1 shows comparisons between the predicted and historical mean monthly rainfalls for each

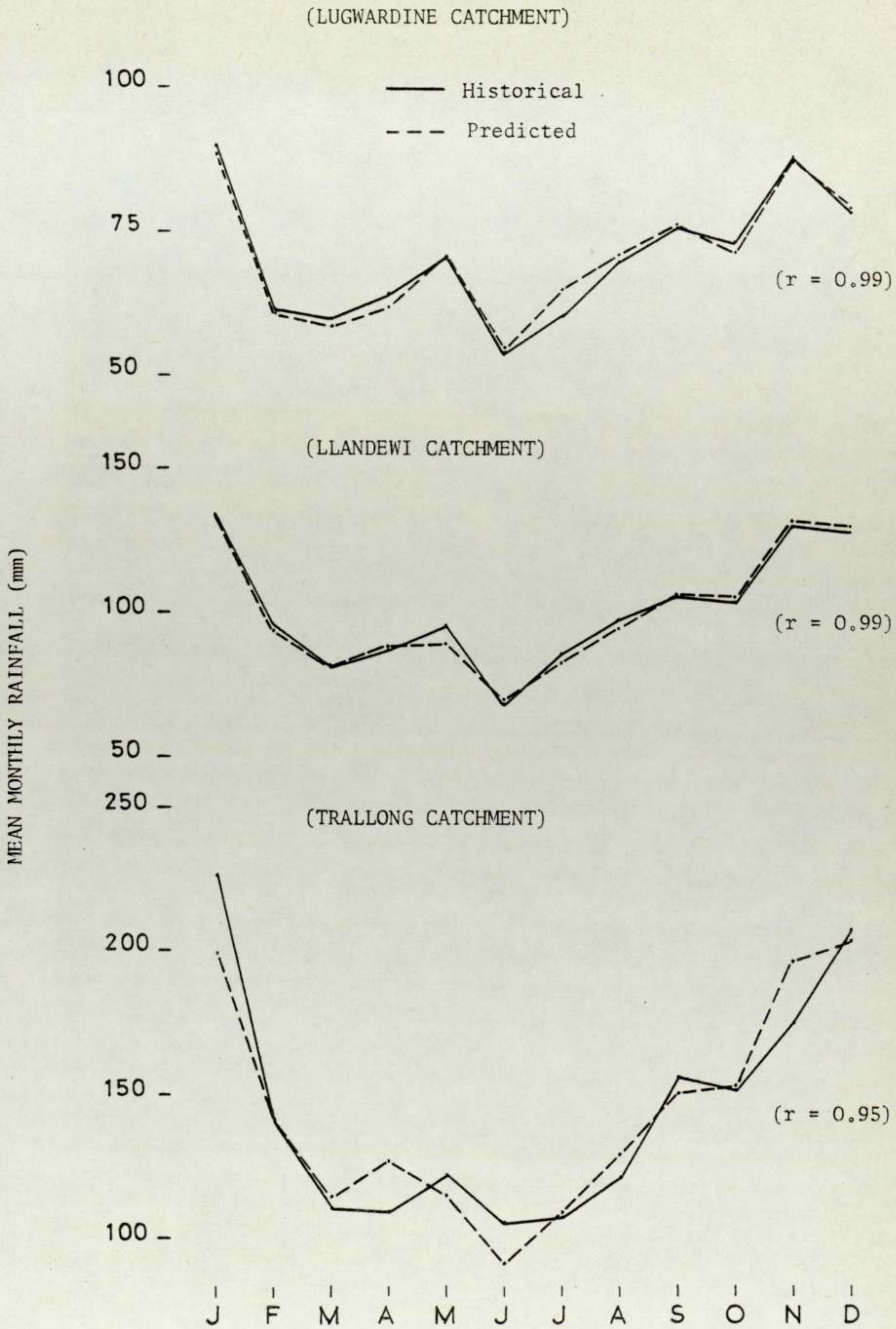


FIGURE 8.1 COMPARISON BETWEEN THE PREDICTED AND HISTORICAL MEAN MONTHLY RAINFALLS (1960-75)

of the three test catchments, and comparisons between the predicted and historical streamflow statistics are shown in Figures 8.2 to 8.4.

The results of the cross correlation test are given in Tables 8.4 and 8.5 and illustrated in Figure 8.5.

8.5 DISCUSSION OF RESULTS

The comparisons made between the predicted and historical mean monthly rainfalls (Fig 8.1) showed that the predicted means were almost identical to the historical means for the Lugwardine and Llandewi catchments, but less precise for the Trallong catchment. This fact was confirmed by the correlation coefficients between the predicted and historical values. They were 0.99, 0.99 and 0.95 for Lugwardine, Llandewi and Trallong catchments respectively. It appears, therefore, that the regional monthly rainfall/annual rainfall linear regression lines derived in Section 7.2 provide a reliable means of predicting the seasonal distribution of annual rainfall for any catchment within the Region. However, this is only of secondary interest to this project, the real test is the precision of the predicted streamflow statistics.

Inspection of the graphs showing the comparisons between the predicted and historic streamflow statistics (Figure 8.2 to 8.4) showed that:

1) the predicted values of both mean and standard deviation were very good (correlation coefficients between 0.99 and 0.97 for means, and 0.98 and 0.91 for standard deviations);
2) there was very little difference in precision between the means and standard deviations predicted using mean annual rainfall and those using mean monthly rainfalls;

TABLE 8.4 COMPARISON BETWEEN THE CALCULATED AND PREDICTED CROSS CORRELATION VALUES OF THE TESTED CATCHMENTS USING EQUATION 7.8 AND 7.9 AND FIGURE 7.32 AND 7.33

Sub-catchment Combinations	Mean Annual Rainfall R_a	Difference in mean Annual Rainfall	Distance Apart (Km)	γ_m		γ_d	
				Calculated	Predicted	Calculated	Predicted
Lugwardine Llandewi	1021.0	362	40	0.74	0.76	0.63	0.41
Lugwardine Trallong	1285.5	891	65	0.68	0.71	0.62	0.51
Llandewi Trallong	1466.5	529	40	0.84	0.83	0.56	0.33

TABLE 8.5 COMPARISON BETWEEN THE MONTHLY CALCULATED AND PREDICTED LAG-ZERO CROSS CORRELATION OF THE TEST CATCHMENTS (1964-75)

	Sub-catchment Combinations	MONTH											
		J	F	M	A	M	J	J	A	S	O	N	D
Historical	Lugwardine Llandewi	0.72	0.82	0.37	0.74	0.76	0.61	0.84	0.45	0.80	0.86	0.62	0.69
Historical	Lugwardine Trallong	0.59	0.80	-.08	0.77	0.62	0.55	0.59	0.73	0.79	0.86	0.54	0.66
Historical	Llandewi Trallong	0.85	0.82	0.56	0.86	0.75	0.70	0.53	0.45	0.79	0.88	0.83	0.89
Predicted		F	M	A	M	J	J	A	S	O	N	D	J
Predicted	Lugwardine Llandewi	0.74	0.74	0.73	0.72	0.70	0.66	0.66	0.70	0.72	0.73	0.74	0.74
Predicted	Lugwardine Trallong	0.68	0.68	0.67	0.67	0.66	0.63	0.63	0.66	0.67	0.67	0.68	0.68
Predicted	Llandewi Trallong	0.84	0.83	0.82	0.80	0.74	0.59	0.59	0.74	0.80	0.82	0.83	0.84

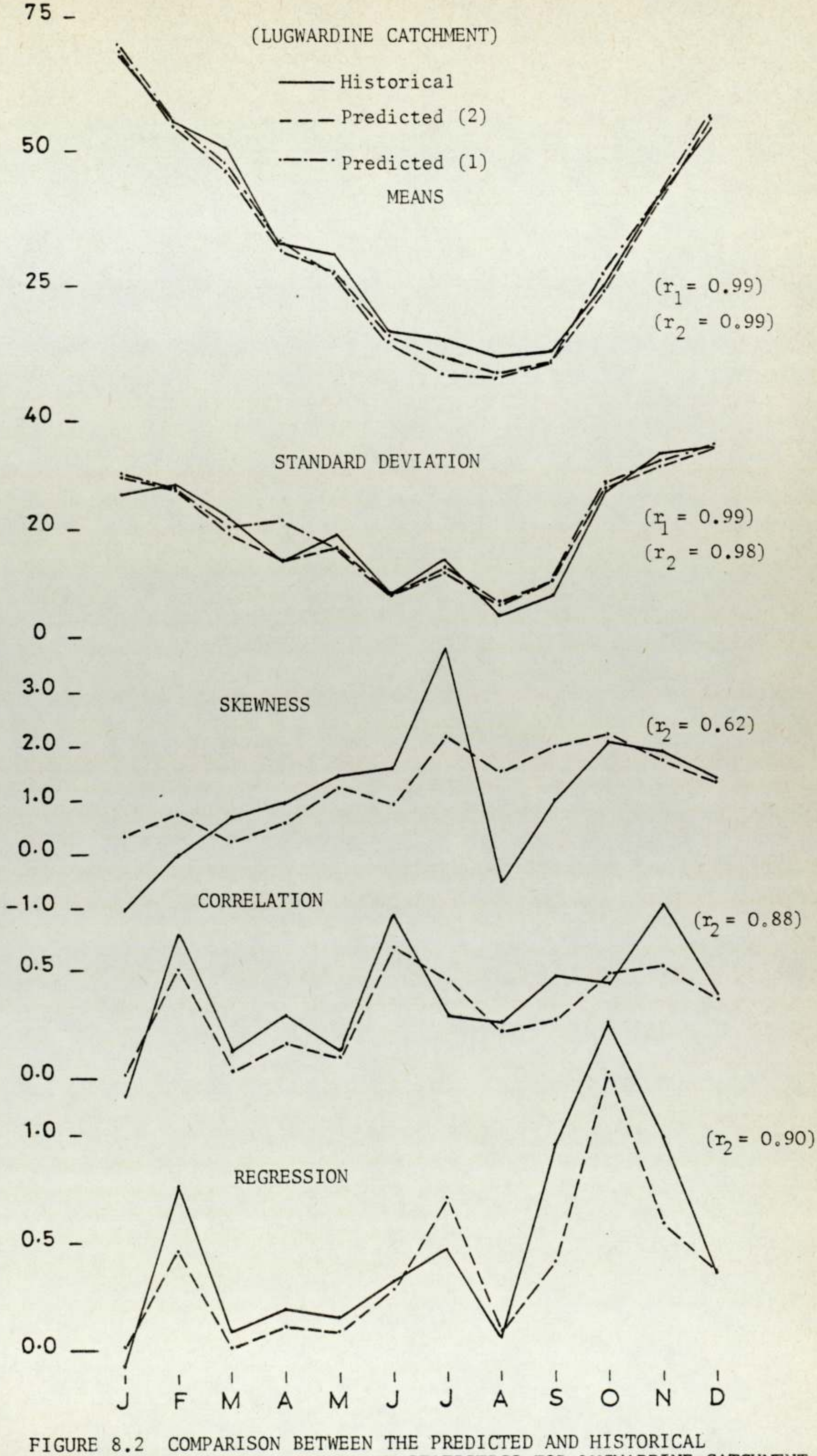


FIGURE 8.2 COMPARISON BETWEEN THE PREDICTED AND HISTORICAL (1960-75) STREAMFLOW STATISTICS FOR LUGWARDINE CATCHMENT

(LLANDEWI CATCHMENT)

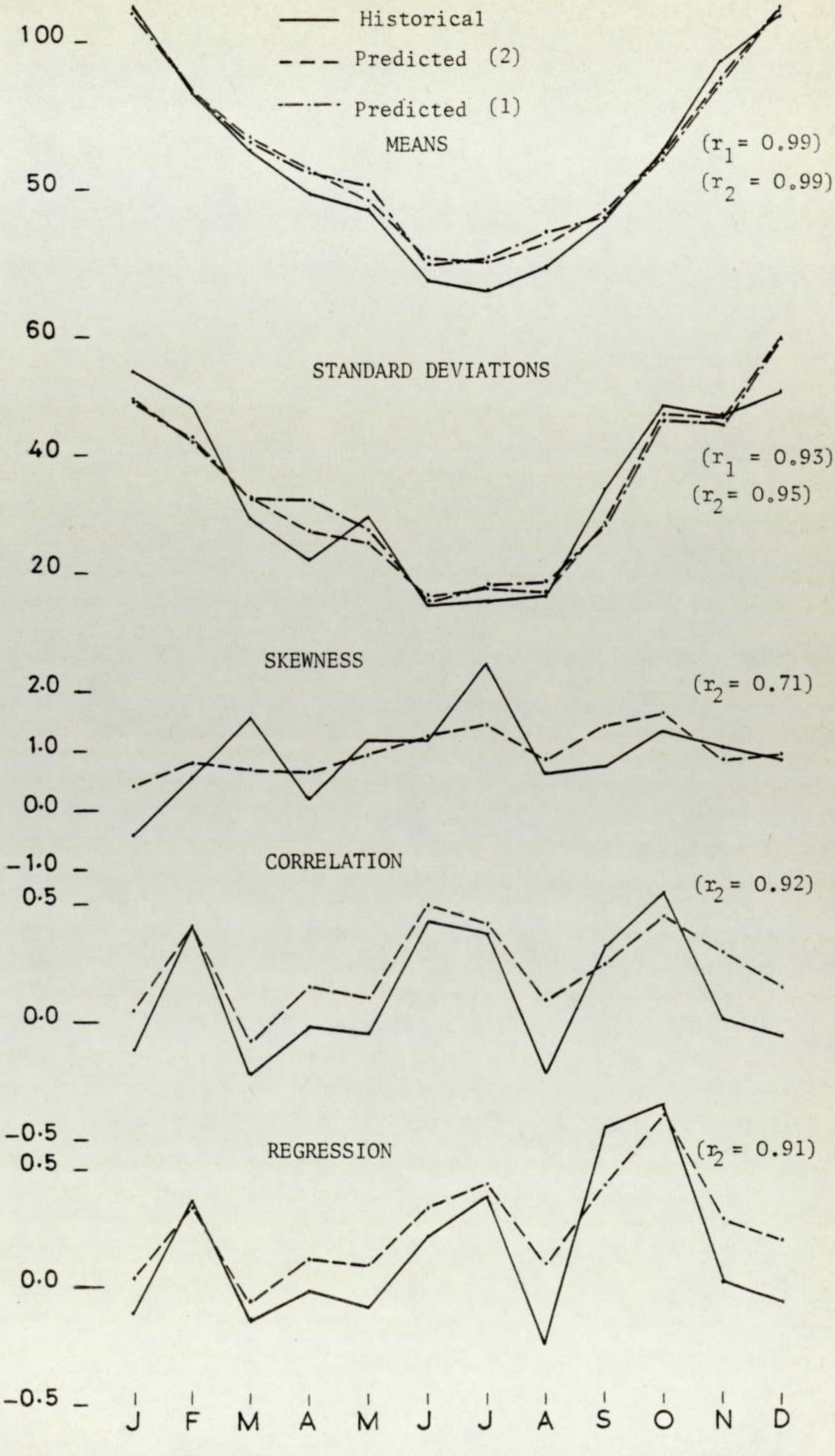


FIGURE 8.3 COMPARISON BETWEEN THE PREDICTED AND HISTORICAL (1960-75) STREAMFLOW STATISTICS FOR THE LLANDEWI CATCHMENT

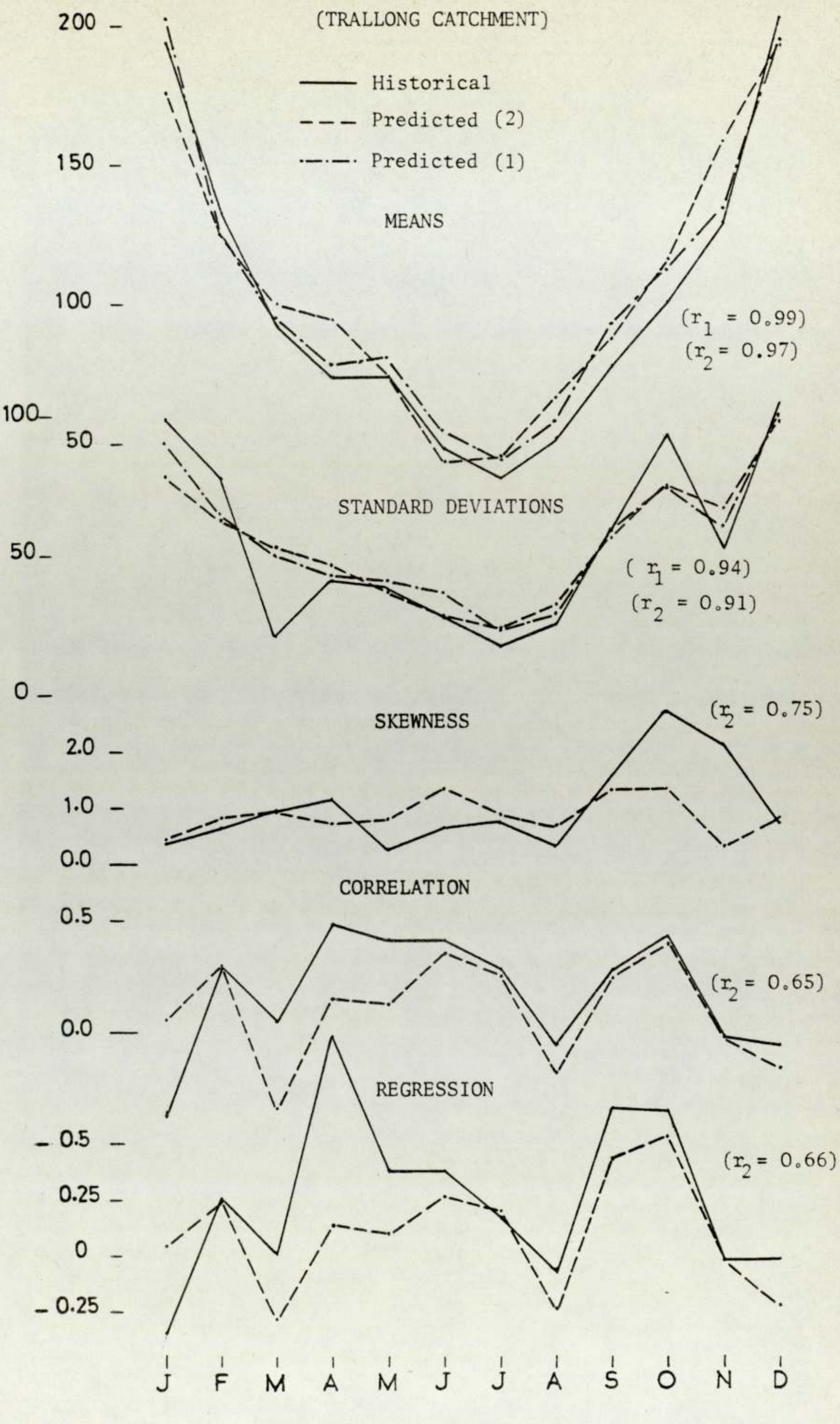


FIGURE 8.4 COMPARISON BETWEEN THE PREDICTED AND HISTORICAL (1960-75) STREAMFLOW STATISTICS FOR TRALLONG CATCHMENT

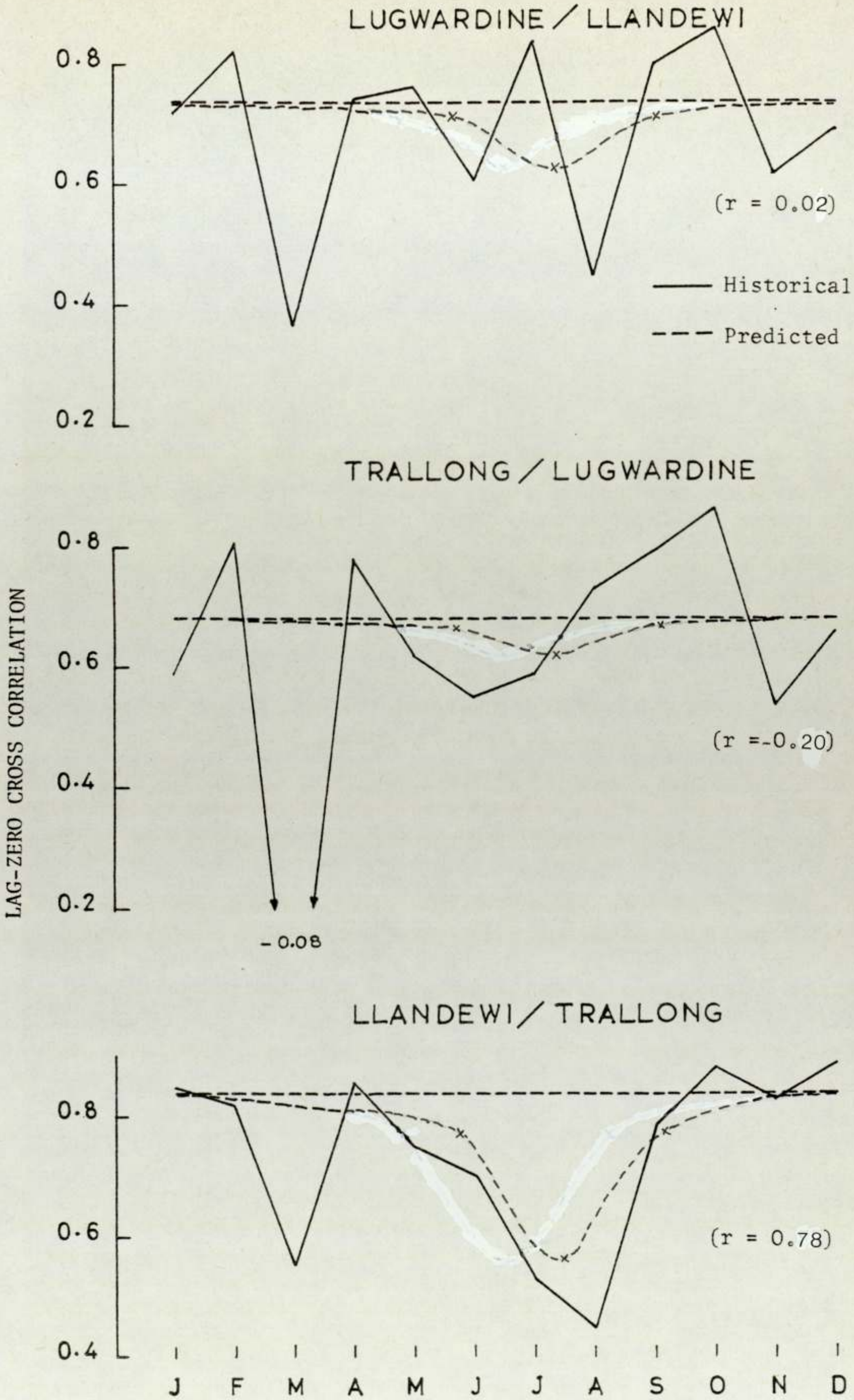


FIGURE 8.5 COMPARISON BETWEEN THE PREDICTED AND HISTORICAL MONTHLY STREAMFLOW LAG-ZERO CROSS CORRELATION (1964-75)

4) the predicted skewness coefficients were the least precise of all the streamflow statistics (correlation coefficients 0.62 to 0.75);

5) in general the predicted values of the statistics for the Trallong catchment were less precise than those for the other two catchments.

The relatively low precision of the skewness coefficients was only to be expected, because of the fact that it is a third order moment of the distribution and therefore more prone to error than the other statistics. In fact, bearing this point in mind, the predicted and historical skewness coefficients are remarkably similar. A further point which is relevant to this matter relates to the nature of the correlation coefficients themselves. It is that correlation between two variables, one of which is almost constant is bound to be very low, because a relationship cannot exist between a variable and a constant. It follows, therefore, that where the predicted parameter shows very little seasonal variation, as is the case with skewness coefficient, its correlation with values derived from historic records is likely to be poor. Under these circumstances, the cross correlation coefficient is highly sensitive to sampling errors and is therefore an inadequate indicator of reliability. The relative low precision of the predicted statistics for the Trallong catchment is almost certainly due to the fact that the historical statistics in this case were based upon a very limited historical record (1964-75).

The correlation coefficients between the predicted and historical lag-zero cross correlation coefficients (Fig 8.5) were extremely low for two of the combinations (i.e. Lugwardine/Llandewi, $r = 0.02$; Trallong/Lugwardine, $r = -0.20$), but much higher for the other combination (i.e. Llandewi/Trallong, r = 0.78). However, this was only to be expected bearing in mind:

i) the sensitivity of lag-zero cross correlation coefficient to sampling errors and length of record (NB. Due to the limited Trallong record only 12 years of data were used in the evaluation of the historical values).

ii) the fact that the predicted values for the Lugwardine/ Llandewi and Trallong/Lugwardine combinations showed very little seasonal variation.

The latter point concerns the nature of correlation analysis and is the same as that stated earlier when considering skewness coefficients. The one combination for which the predicted cross correlation coefficients showed a significant amount of seasonal variation (i.e. Llandewi/Trallong) did, in fact, produce an acceptable correlation coefficient.

8.6 CONCLUSION

The principal aim of this chapter was to show that the regional relationships derived during the course of this project could be used with confidence to predict the streamflow parameters for any ungauged catchment within the Region.

The results of the tests carried out on the Lugwardine, Llandewi and Trallong catchments, which were totally independent of the original analysis, indicate that to a large extent this aim has been achieved. The correlation coefficients between the predicted and historic parameters, which are summarised in Table 8.6, show that:

1) the predicted means and standard deviations were very reliable (r = 0.91 to 0.99);

Catchments	Lugwardine	Llandewi	Trallong
Monthly Rainfall	0.99	0.99	0.95
Monthly Streamflow			
Mean (1)	0.99	0.99	0.99
(2)	0.99	0.99	0.97
Stand. Dev. (1)	0.96	0.93	0.94
(2)	0.98	0.95	0.91
Skewness Coefficient	0.62	0.71	0.75
Lag-one corr. coeff.	0.88	0.92	0.65
Lag-one reg. coeff.	0.90	0.91	0.66
Catchment combination	Lug/Llan	Llan/Trall	Trall/Lug
Cross corr. coeff.	0.02	0.78	-0.20

TABLE 8.6 SUMMARY OF CORRELATION COEFFICIENTS BETWEEN PREDICTED AND HISTORICAL STATISTICS

2) the predicted lag-one correlation and regression coefficients were fairly reliable (r = 0.65 to 0.92); and

3) the skewness coefficient and cross correlation coefficients were the least reliable of the predicted parameters.

However, it could be argued that, in view of their sensitivity and the size of sample used, the predicted values of skewness and cross correlation coefficient are better indicators of their long term values than those derived from the historic data.

In fact, when compared with the results of a prediction technique developed by Barton (1970), based upon computer optimisation of a simple conceptual model, the results of these tests show that the method developed here is superior both in terms of simplicity and reliability. The reason for this is that this method is based upon regional empirical relationships and does not therefore suffer from the inadequacies inherent in simple conceptual models of complicated systems. Until conceptual models of the rainfall/run-off process have been shown to simulate the real system more faithfully, empirical methods, based upon the analysis of all the available historical data, will remain the most reliable means of predicting long term parameters.

CHAPTER NINE

DISCUSSION AND CONCLUSION

9.1 GENERAL

This project tackled the basic problem of how best to use the limited available hydrometeorological data for the calibration of monthly streamflow models. It was assumed from the start that in some cases streamflow parameters would be required for ungauged catchments. The basic approach was to use all the available data from a region to develop regional relationships, which were then used for prediction purposes . This philosophy was tested and proven using data from the region of England and Wales which contains the rivers Teifi, Tywi, Usk, Wye, Teme and Upper Severn. The score matrix method of data verification, which was developed and computerised as part of this project, proved to be a most effective data validation procedure. The correction of errors was not automated and it is not recommended that it should be. This is because some of the data which are identified as probably errors are not in fact errors, but are due to either localised storms, which can be identified by inspection of the rainfall data, or distortions of the error identifier (r_{ij}) which tend to occur when flows are extremely low.

The use of two separate record lengths, that is the long record (1938-75) and the short record (1960-75), was adopted in this study in order to make the maximum possible use of the available data. The nine long records provided fewer plotting points than the fourteen short records, but their statistics were of course more reliable. The use of both long and short records had the disadvantage of greatly increasing the amount of analysis, but had the advantage of providing a convenient check on the sensitivity of the various parameters to the length of record.

The analysis of the results produced many interesting spatial and temporal relationships and revealed a number of noteworthy features, which to the author's knowledge have not previously been described. The most notable of these were:

1) the distinct effect of snowmelt in March on the temporal variation of skewness coefficient and the lag-one serial correlation and regression coefficients, particularly in the mountainous regions;
2) the relationship between skewness coefficient and the parameter Ratio (i.e. mean/standard deviation);
3) the relationship between rainfall and serial correlation coefficient which showed that the low rainfall (i.e. lowland) regions produced the highest coefficients, presumably because of their slower response to rainfall events;
4) the spatial and temporal variation of cross correlation coefficients which were found to be far more dependent upon the difference in altitude (i.e. rainfall and possibly soil moisture deficit) between the two catchments than the distance between them;
5) the important role which the spatial and temporal variation of soil moisture deficit appeared to play in the corresponding variations of several streamflow parameters.

One odd feature, which was apparent in the results of both the lag-one serial correlation and the cross correlation analyses, was the peculiar behaviour of the Mid-Wye sub-catchment with respect to these parameters. This sub-catchment displayed higher than average serial correlation for most months of the year and extremely low, even negative, cross correlation with other catchments in the summer months. No conclusive explanation has been found for this, but it is thought that it is probably related to excessive bank storage which tends to fill during wet months and drain during dry months, thus affecting both serial and cross correlation coefficients.

The method which was used for the prediction of the streamflow parameters was based primarily on the linear regression equations which were derived between rainfall and the various parameters. The use of these relationships for prediction purposes was justified by the fact that the correlation coefficients for most of them, particularly those for mean flow and standard deviation, were exceptionally high. However, this does mean that this method of prediction, using these empirical relationships, can only be used with confidence in the region for which it was developed. The results of the test based upon three independent catchments, in which the predicted parameters were compared with the parameters derived from the historic records, showed that the method could in fact be used with confidence. In these tests the linear regression relationships corresponding to the short record (1960-75) were used for prediction purposes. This was done to enable a fair comparison to be made with the parameters derived from historic records covering the period 1960-75. However, it is recommended that any future practical applications of this method should be based upon the relationships derived from the long record (1938-75), because these will provide better estimates of long term behaviour.

A start was made on a method of calculating mean monthly streamflow from mean monthly rainfall, mean monthly evapotranspiration and mean monthly change in catchment storage. The soil moisture simulation model provided a satisfactory means of predicting the mean monthly changes in the soil moisture store, but more work needs to be done if a reliable method of predicting mean monthly change in groundwater storage is to be developed. The many hydrometeorological and geomorphic factors which influence the temporal variation of groundwater storage will have to be fully investigated and quantified. Once this has been done, it should be possible to predict mean monthly flows, and possibly other flow parameters, for any point in the British Isles. The input data would include mean monthly rainfall, mean monthly evapotranspiration and various geomorphic parameters relating to soil type, rock type and slope.

9.2 RECOMMENDATIONS FOR FURTHER STUDY

It is possible to identify several topics relating to this study which are worthy of further investigation.

1) The score matrix method of data validation could be extended to include one or more additional error identifiers. For example the streamflow/rainfall ratio. The method could also be developed to incorporate primary, secondary and even tertiary verification using progressively more sensitive identifiers.
2) The effect which the spatial and temporal variation of soil moisture deficit has upon the spatial and temporal variations of the principal streamflow parameters is a topic requiring a more detailed investigation than was possible during the course of this project.
3) The spatial and temporal variation of the cross correlation coefficient between streamflow records is a subject requiring further research of both a theoretical and empirical nature.

4) The peculiar behaviour of the Mid-Wye sub-catchment with respect to serial and cross correlation coefficients is a topic which could form the basis of a detailed field study.

5) A detailed investigation into the causes of the spatial and temporal variation of catchment storage is essential to the further development of this project. In particular it is necessary to investigate the hydrometeorological and geomorphic factors influencing the temporal variation of groundwater storage.

6) This project could be extended to other regions. This would enable comparisons to be made between regions, and would give some indication of the sensitivity of the derived relationships to regional location. It would also help to build up a set of regional relationships for the British Isles.

9.3 FINAL CONCLUSIONS

An extensive statistical analysis has been carried out on the available monthly rainfall and streamflow data for the region of England and Wales containing the Rivers Teifi, Tywi, Usk, Wye, Teme and Upper Severn.

During the course of the project several rainfall/streamflow relationships, which have not previously been described, have been identified. Explanations of these relationships in terms of the physical processes involved have been given wherever possible.

A new method of evaluating the principal streamflow parameters required for the calibration of synthetic streamflow models has been developed, tested and proven.

A soil moisture simulation model has been successfully developed as part of an investigation of the spatial and temporal variation of catchment storage. An investigation into the variation of groundwater storage showed that this is a complex problem requiring further research.

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APPENDIX I

METEOROLOGICAL DATA

- Naturalised streamflow records of verified data
- Areal rainfall records
- Meteorological Office information sheet relating to the evapotranspiration map of the United Kingdom

NATURALISED STREAMFLOW RECORDS OF VERIFIED DATA

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400100 RIVER SEVERN AT BEWDLEY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	136.808	90.771	70.016	63.355	27.431	47.186	84.933	23.476	37.171	33.852	129.626	112.894
1937	140.261	154.763	132.587	59.513	28.600	20.237	15.912	10.358	10.732	12.341	29.638	77.223
1938	121.544	55.724	33.268	15.508	7.326	28.553	30.409	27.550	12.978	88.736	118.006	119.166
1939	252.538	76.784	88.702	51.461	22.904	11.523	50.806	48.189	15.214	21.871	121.111	127.892
1940	47.815	170.505	79.202	49.810	50.497	20.943	21.914	9.042	14.422	41.381	245.055	79.294
1941	63.216	196.482	105.266	56.553	32.631	40.189	12.655	23.745	17.453	54.274	49.914	63.084
1942	86.158	101.334	58.705	62.071	36.289	24.073	17.846	23.050	26.026	48.646	22.378	79.767
1943	131.776	124.445	23.519	22.987	49.670	46.686	23.088	21.377	60.378	51.350	59.492	65.177
1944	118.285	52.654	53.937	23.801	14.625	21.262	19.911	13.623	40.918	91.653	137.776	120.866
1945	49.669	193.397	53.610	58.528	30.828	43.439	21.144	15.869	33.301	70.116	42.636	94.012
1946	101.402	233.686	43.891	21.625	15.894	32.055	18.525	44.924	121.725	45.755	137.243	126.029
1947	110.582	29.510	261.923	112.419	49.957	23.597	23.987	12.167	7.787	7.079	44.543	55.227
1948	234.008	118.004	32.044	40.437	20.105	30.630	17.465	32.108	38.776	30.443	57.486	89.112
1949	127.134	42.812	51.724	81.474	29.020	23.351	7.893	9.398	7.083	47.433	94.003	143.356
1950	42.345	214.641	53.701	48.791	31.208	9.701	18.647	42.959	104.698	65.770	96.276	96.287
1951	134.535	129.833	141.665	88.752	50.744	26.330	14.871	23.809	43.051	22.432	174.395	136.383
1952	138.452	81.284	44.584	33.389	41.033	26.346	15.260	23.910	19.608	73.831	78.816	120.100
1953	43.356	84.448	45.129	66.989	41.005	23.681	33.280	27.233	48.252	29.373	87.472	37.548
1954	65.122	117.669	82.227	47.732	26.281	70.097	35.936	59.237	50.216	134.561	209.842	177.590
1955	100.094	77.324	107.810	51.061	91.023	88.551	22.158	12.416	11.856	16.534	33.316	72.065
1956	134.622	49.785	52.485	24.164	17.688	12.532	23.669	55.032	69.612	44.911	35.566	95.627
1957	99.421	129.579	87.783	25.259	20.388	13.451	34.773	88.236	130.711	71.217	108.426	68.301
1958	117.119	172.790	59.296	27.921	41.060	48.903	52.018	61.306	120.206	122.414	58.843	85.801
1959	185.816	44.316	49.526	83.818	42.447	22.087	23.701	15.574	7.334	29.846	66.432	163.559
1960	193.886	147.738	78.721	62.835	23.192	15.376	19.199	34.717	76.314	133.854	205.921	178.369
1961	117.572	118.620	35.736	59.834	54.708	15.716	14.102	23.050	21.040	65.214	47.601	115.052
1962	141.755	84.394	37.180	99.648	39.276	16.084	11.157	39.842	56.832	25.230	59.267	83.507
1963	22.285	29.591	139.348	79.118	40.720	23.277	27.241	16.707	27.609	27.241	136.884	41.569
1964	30.129	37.067	64.874	36.359	37.860	19.567	16.792	11.638	9.033	26.391	40.785	131.601
1965	164.596	29.251	80.288	53.321	46.057	33.895	23.962	18.768	66.460	40.380	75.799	299.662
1966	97.405	155.115	74.238	111.681	58.568	31.925	20.157	32.846	28.782	67.753	93.965	189.843
1967	77.608	107.625	100.334	32.296	89.900	33.053	16.979	24.613	45.547	150.204	84.789	104.319
1968	185.580	60.427	76.590	44.854	70.636	35.916	94.159	26.850	70.906	76.341	81.305	87.369
1969	120.801	109.842	106.950	38.283	132.602	48.338	17.456	22.623	16.782	15.965	88.230	90.866
1970	106.943	154.660	85.134	89.950	30.793	14.503	14.828	34.560	31.199	33.930	154.832	79.100
1971	114.139	85.071	65.323	42.074	25.365	30.831	15.886	37.538	15.500	53.698	67.090	54.441
1972	114.822	94.555	72.247	88.594	43.735	52.000	31.116	33.712	15.599	14.249	61.904	148.686
1973	47.580	77.544	46.134	41.730	46.409	19.101	29.768	61.622	39.074	64.580	50.050	70.190
1974	147.410	148.950	59.560	21.340	14.270	14.810	21.980	23.500	77.680	55.816	118.429	120.729
1975	129.956	71.045	57.528	50.930	33.440	11.795	13.530	8.860	15.846	22.286	34.347	44.646
1976	81.786	56.120	45.398	23.294	17.497	9.020	5.555	3.645	31.699	109.054	56.809	83.129

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400300 RIVER VYRNWY AT VYRNWY RESERVOIR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	7.403	3.016	4.489	2.505	0.848	3.101	5.981	1.404	4.332	3.727	7.381	7.921
1937	8.209	9.670	4.832	3.437	0.979	1.733	0.912	0.407	0.556	1.362	1.976	5.508
1938	10.524	3.111	2.137	0.658	1.358	4.401	3.876	3.353	0.902	10.671	8.761	5.907
1939	10.435	5.848	5.051	2.370	0.837	1.174	7.798	2.184	0.709	1.684	10.765	6.199
1940	1.389	7.412	4.417	3.766	1.746	0.250	1.436	0.853	2.307	6.806	13.994	5.297
1941	1.424	9.567	4.551	2.132	2.457	0.911	0.431	3.195	1.342	6.086	4.311	5.420
1942	5.782	3.880	3.502	4.464	3.367	0.715	1.851	4.028	3.079	5.783	1.185	5.920
1943	10.261	3.830	1.153	1.725	4.801	4.951	2.513	3.825	6.040	4.810	4.069	3.724
1944	8.659	3.013	1.454	1.537	1.198	2.554	2.290	1.103	5.446	8.546	10.754	7.402
1945	5.589	10.757	2.277	3.463	2.912	4.553	1.984	1.923	3.630	6.280	1.086	6.435
1946	8.912	12.340	2.800	0.710	0.570	3.875	1.448	3.264	8.114	2.117	9.575	7.118
1947	6.545	0.783	12.673	5.024	2.683	1.705	1.867	0.405	0.743	0.599	7.794	5.260
1948	15.867	7.000	2.804	2.854	1.343	0.832	1.606	3.225	4.361	2.590	4.773	6.169
1949	5.188	3.393	2.220	5.966	2.504	1.812	0.815	1.050	0.466	7.080	8.394	9.482
1950	3.195	11.401	3.817	3.885	1.557	0.621	3.756	6.171	10.434	4.347	5.585	4.186
1951	7.174	6.871	6.554	4.753	2.064	0.827	0.652	3.424	5.293	1.521	11.350	10.166
1952	6.498	4.347	3.398	1.928	2.084	1.570	0.958	2.474	1.893	9.234	4.054	6.287
1953	2.144	4.590	3.642	3.542	2.052	1.835	4.617	3.056	5.409	2.206	9.033	2.457
1954	4.009	5.937	5.131	2.247	2.508	3.649	3.657	4.281	6.370	13.066	10.894	8.241
1955	4.847	3.266	3.819	2.460	6.469	4.424	1.083	0.296	0.360	1.653	3.307	6.821
1956	7.812	1.309	2.979	0.844	1.084	0.898	3.452	6.372	4.556	3.669	2.733	7.525
1957	9.042	4.563	6.159	0.792	1.369	0.493	5.561	3.901	7.976	5.496	4.153	4.980
1958	6.464	9.232	2.003	1.459	5.201	2.826	2.460	3.820	8.161	4.511	2.296	4.369
1959	7.692	1.111	3.019	4.885	1.069	1.104	2.525	0.670	0.180	4.397	5.954	13.345
1960	9.150	7.541	3.498	4.044	0.775	1.107	3.070	3.761	5.127	5.977	12.579	8.549
1961	7.064	6.494	1.333	4.468	2.983	0.537	0.912	3.268	3.065	7.750	5.580	6.770
1962	8.894	5.164	2.023	7.458	2.830	0.801	0.842	6.029	4.896	2.049	4.526	5.588
1963	0.756	0.600	10.105	5.241	3.871	2.364	2.215	2.338	3.355	2.810	11.339	2.248
1964	2.070	2.154	2.985	2.801	3.298	1.315	2.178	1.201	1.477	3.518	4.361	13.298
1965	8.182	1.299	4.421	3.408	3.703	3.970	2.106	2.273	5.222	3.021	4.730	14.053
1966	4.117	9.107	3.694	5.877	3.714	2.175	1.533	2.912	2.810	4.295	5.793	10.320
1967	4.037	7.193	3.383	2.164	6.421	1.038	1.610	3.693	7.214	13.712	3.756	6.969
1968	9.350	2.637	8.142	2.608	3.688	2.141	3.509	1.390	7.220	6.700	4.077	4.565
1969	6.538	3.487	4.337	3.724	4.903	1.708	0.547	0.890	1.205	1.337	8.297	6.570
1970	5.870	7.942	3.837	6.348	1.357	0.851	1.586	3.074	4.058	6.475	11.356	3.721
1971	6.385	4.640	3.022	1.721	0.760	2.185	0.828	3.368	1.118	6.732	5.344	2.872
1972	6.107	4.236	4.508	6.023	4.797	4.041	2.217	3.300	0.647	0.724	6.356	10.010
1973	2.533	4.461	2.947	3.054	3.397	1.006	2.250	5.187	4.775	4.250	4.120	5.430
1974	8.920	7.300	3.090	0.630	0.580	1.080	4.090	2.300	9.820	3.790	7.771	10.249
1975	9.192	3.532	2.807	3.064	2.203	0.358	1.934	0.815	3.604	2.540	4.730	4.450
1976	6.660	3.970	3.070	1.490	1.310	0.490	0.290	0.000	0.000	7.100	3.860	3.380

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400500 RIVER SEVERN AT MONTFORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.171	62.222	17.010
1954	41.580	77.034	44.311	23.888	8.595	48.923	29.490	47.260	44.275	110.244	130.220	108.938
1955	50.320	39.643	50.363	23.963	44.805	47.425	7.335	2.718	2.537	5.110	14.696	45.122
1956	84.335	21.242	28.224	9.599	5.538	3.457	11.502	34.669	43.375	29.506	20.737	65.667
1957	64.761	81.128	54.255	10.415	10.177	7.031	26.709	66.488	94.154	47.997	64.761	45.647
1958	78.778	107.520	25.953	10.993	30.016	36.869	35.425	43.155	80.137	67.479	29.818	47.204
1959	104.688	18.114	23.718	44.656	19.646	9.718	14.784	7.654	2.435	22.560	49.102	114.372
1960	115.080	84.101	45.590	38.115	10.514	6.980	12.185	25.497	46.581	74.077	129.069	108.001
1961	72.180	71.047	16.540	34.858	33.018	4.862	5.709	18.083	16.701	53.774	37.350	87.556
1962	99.303	60.287	23.427	74.729	25.089	8.523	5.683	32.678	45.789	16.061	42.306	63.458
1963	13.830	14.553	99.704	54.312	28.544	15.824	18.015	13.479	22.608	20.216	117.572	27.467
1964	21.663	25.621	38.823	23.730	27.584	13.691	13.822	9.460	6.439	21.705	35.141	120.347
1965	125.133	17.489	53.604	38.030	35.566	26.802	19.822	18.570	51.310	29.385	58.833	204.425
1966	60.316	103.982	44.884	70.074	33.813	19.198	10.828	17.589	17.126	43.611	66.723	131.537
1967	48.481	78.311	60.437	20.580	62.097	17.944	9.743	13.530	41.042	126.323	57.233	72.638
1968	119.622	33.073	55.966	27.346	41.768	19.592	49.599	12.095	47.914	54.432	51.237	55.526
1969	77.710	62.643	62.668	38.048	74.453	23.095	6.172	9.067	6.242	15.822	62.340	59.565
1970	57.707	105.978	48.233	61.575	16.067	6.835	7.281	18.923	21.446	28.547	119.293	48.229
1971	70.442	54.431	35.024	21.049	13.913	14.996	8.897	24.647	9.017	38.136	44.815	33.279
1972	66.685	53.831	41.470	63.936	27.569	35.221	17.836	21.062	8.032	5.769	41.212	103.420
1973	26.503	51.853	27.346	23.704	26.655	9.807	17.096	45.236	30.195	47.332	33.555	49.338
1974	106.781	105.343	53.505	9.905	6.254	6.898	14.058	14.113	43.000	43.198	93.597	98.308
1975	102.298	43.145	35.239	28.616	19.889	8.344	8.180	7.335	11.289	13.276	23.745	33.358
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING

05400800 RIVER TEME AT TENBURY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	15.871	29.393	17.871	6.577	3.304	2.121	1.838	16.702	25.032	11.282	26.189	14.828
1958	23.827	42.004	14.286	7.332	4.314	8.182	6.637	8.035	29.695	36.105	13.585	21.124
1959	35.793	10.154	11.628	17.318	9.047	3.676	2.283	1.574	1.086	1.350	8.275	38.175
1960	51.704	36.530	21.195	16.007	4.793	2.640	1.707	2.082	10.528	43.195	50.229	42.061
1961	25.829	21.617	7.944	16.586	15.174	3.494	2.411	1.690	1.529	8.381	6.858	19.414
1962	35.651	14.524	9.005	21.062	8.957	4.490	3.021	5.967	11.702	7.921	15.908	15.426
1963	9.709	8.826	45.180	21.717	8.534	4.583	5.701	2.632	2.465	2.133	24.542	10.188
1964	6.201	9.507	20.588	10.332	7.377	5.392	3.264	1.855	1.495	1.668	3.154	16.413
1965	28.314	8.024	19.442	10.071	7.451	5.315	4.260	2.910	11.231	10.037	16.328	57.376
1966	25.514	40.898	21.013	26.402	22.267	7.553	4.725	5.840	6.339	20.809	30.200	31.340
1967	19.085	31.652	24.037	8.148	19.831	9.600	5.644	4.246	7.885	25.945	19.848	20.965
1968	40.160	15.423	15.315	12.011	16.960	8.168	21.955	5.204	8.962	13.690	17.180	22.230
1969	30.500	29.190	31.810	6.690	35.380	13.089	4.487	4.569	3.233	2.463	15.343	21.353
1970	35.427	37.987	20.392	15.753	7.939	3.671	2.385	7.208	4.864	2.474	30.193	17.030
1971	32.419	17.264	17.176	9.366	5.902	4.709	2.368	3.441	1.706	5.290	9.046	11.538
1972	35.555	28.816	24.677	12.303	10.528	10.664	6.001	5.636	3.534	3.216	10.607	39.918
1973	12.560	14.778	9.882	8.897	11.749	6.458	5.390	7.275	3.668	6.558	6.338	10.204
1974	40.182	41.064	14.419	6.313	4.041	2.972	2.583	1.864	6.906	8.129	19.631	17.251
1975	26.894	17.364	17.172	12.824	7.553	3.269	2.256	1.527	1.373	1.576	3.089	5.574
1976	8.847	9.130	7.432	4.701	2.575	1.563	1.012	0.746	6.988	31.770	15.794	26.268

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500100 . RIVER WYE AT CADORA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28.611	128.546	138.430
1937	195.017	207.727	179.811	82.787	34.821	19.869	17.914	12.047	12.491	17.321	37.493	89.588
1938	142.588	71.335	42.490	18.488	21.100	38.655	43.005	26.115	14.764	87.458	137.133	156.506
1939	244.958	116.998	99.414	69.731	26.147	14.375	77.090	46.156	16.716	19.630	181.843	132.104
1940	64.561	164.327	93.107	56.497	56.040	19.835	31.670	11.866	15.727	44.336	245.068	87.684
1941	87.684	213.624	132.762	59.874	37.377	46.782	17.452	38.403	23.938	56.497	63.793	90.502
1942	93.759	86.690	70.100	80.941	59.132	31.896	22.518	22.065	28.603	60.726	32.806	112.990
1943	196.802	178.337	31.044	22.470	44.820	38.881	20.435	21.650	69.163	66.039	85.553	70.752
1944	108.334	52.715	22.696	19.746	12.624	13.102	16.574	10.320	37.635	101.091	159.514	143.924
1945	67.343	191.500	48.739	48.171	33.064	65.586	40.559	35.780	59.106	109.071	68.253	154.517
1946	157.274	225.217	33.741	30.223	29.424	62.300	29.566	82.571	177.125	54.819	199.880	153.549
1947	139.263	43.768	332.610	135.429	60.300	28.830	23.275	12.371	9.925	9.050	57.670	58.826
1948	230.780	124.154	39.217	60.787	37.709	49.877	24.134	31.676	67.022	48.268	67.022	155.361
1949	129.719	53.439	61.843	79.491	34.692	24.938	9.050	9.050	9.352	64.761	131.252	135.629
1950	51.921	221.719	66.740	51.242	35.447	12.834	24.196	51.495	104.926	69.600	120.632	99.214
1951	150.683	144.576	147.816	117.908	48.455	27.231	13.002	20.324	40.300	18.147	210.247	124.041
1952	136.081	94.132	57.633	30.390	70.015	31.728	16.747	41.243	31.870	73.900	87.700	153.900
1953	57.300	81.100	51.000	83.300	43.100	23.400	27.100	29.100	53.300	38.851	93.361	52.556
1954	68.272	128.049	86.933	57.285	24.208	86.707	39.021	74.757	47.771	125.076	234.040	203.401
1955	104.575	91.389	93.333	56.691	91.351	135.837	28.204	13.116	14.150	16.458	48.455	89.299
1956	142.246	53.657	53.709	25.274	17.063	14.170	19.640	50.275	84.302	52.132	35.396	115.052
1957	107.944	184.655	100.639	29.959	21.402	12.505	27.261	54.878	110.946	58.333	106.529	87.245
1958	124.085	210.903	63.288	31.177	36.104	53.264	38.001	47.346	111.173	153.223	75.606	93.758
1959	202.297	44.797	64.308	83.450	52.103	23.056	21.226	11.038	5.748	35.679	85.461	220.844
1960	208.272	180.776	114.202	113.155	28.082	18.443	21.464	25.307	59.183	177.236	255.844	203.344
1961	150.816	134.704	41.286	97.352	67.734	18.632	15.659	21.133	22.328	83.620	49.073	116.581
1962	162.483	92.540	30.271	99.732	43.891	15.880	10.786	48.988	61.363	37.888	61.618	80.958
1963	24.494	29.874	204.392	100.044	57.568	29.620	34.065	20.705	30.129	31.064	155.828	51.084
1964	31.857	42.306	81.326	44.797	39.757	30.214	20.635	15.758	10.910	33.184	49.951	126.945
1965	162.426	35.453	83.563	38.163	45.534	38.001	30.271	27.465	78.693	46.393	73.029	251.333
1966	112.758	173.137	89.576	109.341	82.368	37.323	21.228	37.581	39.640	87.669	105.622	171.856
1967	98.402	144.394	108.454	36.329	86.423	37.803	21.620	39.446	61.165	178.833	110.332	108.058
1968	182.936	72.548	82.091	55.314	77.855	47.986	98.223	25.018	47.765	83.246	96.139	130.747
1969	168.891	124.978	116.647	61.267	108.682	57.424	18.100	33.184	17.145	17.511	85.105	103.632
1970	162.903	192.047	95.027	85.725	39.217	17.145	19.609	30.167	29.614	33.499	175.488	81.966
1971	155.522	104.886	86.326	42.007	28.659	56.808	21.117	32.190	15.586	48.268	62.346	63.361
1972	152.345	145.113	108.602	104.429	67.876	68.580	33.184	24.134	15.586	12.067	76.373	206.646
1973	66.368	91.849	49.776	43.642	54.301	24.938	24.134	43.743	26.497	46.759	52.994	75.418
1974	206.646	225.446	67.876	26.497	22.625	21.821	33.184	30.167	88.843	61.843	116.898	134.244
1975	158.378	96.358	79.943	57.670	33.184	14.028	16.592	10.550	21.821	22.625	45.201	54.301
1976	67.876	54.321	40.726	26.497	18.100	9.352	6.033	3.017	31.173	147.820	82.608	125.194

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500200 RIVER WYE AT BELMONT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	96.979	55.829	38.664	43.427	18.624	25.530	72.501	19.504	24.073	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.281	25.258	66.581
1938	105.284	45.030	24.679	8.242	8.026	27.157	39.812	21.239	9.851	77.243	106.530	94.537
1939	138.516	77.000	66.865	41.627	12.508	6.464	60.937	31.870	7.684	8.558	137.249	84.543
1940	34.137	84.375	56.844	35.578	30.192	10.646	23.470	6.122	9.205	32.801	176.262	66.228
1941	39.465	122.394	74.876	31.865	22.218	21.902	7.195	33.050	14.475	53.820	45.083	67.911
1942	65.000	50.075	40.349	33.594	48.150	20.740	18.983	18.204	22.781	59.196	23.207	78.757
1943	110.444	105.326	11.572	14.202	38.019	34.363	17.589	19.398	62.000	54.972	71.841	47.150
1944	85.254	33.853	12.881	13.107	8.500	10.220	15.096	7.016	32.548	88.373	115.388	93.417
1945	42.442	120.916	24.963	31.723	17.515	43.947	21.350	17.747	34.047	64.876	30.223	87.379
1946	92.518	165.363	31.055	15.164	15.806	49.159	24.848	66.970	127.402	38.150	137.948	99.803
1947	86.747	21.124	199.201	75.260	29.734	10.546	9.946	4.586	4.413	3.829	47.718	49.165
1948	182.537	84.286	22.523	40.170	17.478	37.335	15.296	21.939	50.995	38.413	48.623	105.100
1949	81.566	30.024	37.992	53.273	22.723	14.559	3.676	5.228	4.123	53.241	97.442	109.665
1950	35.410	144.507	36.514	35.384	22.639	6.590	19.614	51.853	94.664	51.516	88.199	70.142
1951	101.470	85.254	89.420	73.403	26.726	11.077	6.401	16.106	37.056	12.823	132.146	82.019
1952	83.213	60.021	34.021	28.803	37.651	19.861	9.930	27.762	22.055	53.383	52.731	86.416
1953	31.412	52.421	34.247	47.318	23.559	11.251	22.807	23.196	42.016	28.073	69.093	32.451
1954	50.121	79.486	48.054	35.793	13.167	48.479	29.421	61.505	42.391	117.799	143.057	113.863
1955	55.300	48.700	49.700	31.500	58.900	74.000	14.200	4.300	8.100	15.600	35.900	61.000
1956	92.313	26.915	45.270	14.048	8.773	8.597	14.014	43.297	57.568	35.906	26.598	78.835
1957	69.093	108.143	64.619	14.962	13.997	9.786	26.468	50.914	90.728	45.505	67.394	54.737
1958	79.684	122.103	30.667	16.121	22.883	31.035	26.004	38.539	69.263	85.206	43.268	51.027
1959	106.075	20.567	36.444	33.689	25.497	10.659	13.847	5.978	2.591	30.044	65.667	133.147
1960	118.025	102.791	36.577	64.931	13.853	10.647	15.594	18.052	43.552	86.905	133.628	122.669
1961	89.991	80.958	18.970	33.926	37.605	6.745	8.492	15.220	14.847	74.417	39.389	86.367
1962	108.500	66.800	15.900	67.100	30.000	10.100	6.300	39.800	55.400	27.400	44.100	60.500
1963	21.901	14.922	120.687	38.871	40.465	22.404	32.083	21.192	27.309	29.450	118.167	28.430
1964	19.898	27.487	42.447	25.896	29.082	24.469	19.476	14.116	8.063	27.666	41.049	104.279
1965	108.900	21.100	47.400	35.800	30.800	24.800	19.900	19.200	52.600	30.900	56.500	182.500
1966	67.293	105.974	55.135	64.134	54.473	26.662	16.817	35.705	31.291	73.174	66.775	135.731
1967	59.986	89.773	34.534	22.067	55.503	25.187	17.640	27.714	55.000	128.342	62.162	68.176
1968	113.009	35.370	30.921	32.843	47.956	31.014	45.417	9.019	35.735	59.814	55.236	68.352
1969	98.082	65.200	52.333	37.365	69.802	30.944	8.527	21.935	12.000	12.496	67.663	75.851
1970	87.253	114.682	54.315	60.036	18.940	6.809	13.117	22.061	21.996	29.590	126.760	48.439
1971	98.312	62.179	47.816	21.119	12.613	30.913	7.094	18.444	7.330	36.178	49.113	42.563
1972	95.057	77.347	36.750	77.701	35.469	43.981	19.153	13.478	8.063	6.384	61.574	129.816
1973	39.725	69.114	34.050	29.321	35.469	11.728	15.606	35.460	19.792	34.050	38.850	63.135
1974	143.205	137.442	34.760	13.194	9.222	12.461	23.409	23.400	76.235	48.238	88.696	112.791
1975	118.466	48.694	41.144	35.185	20.572	5.864	9.222	4.966	16.127	17.734	38.117	44.691
1976	56.041	41.707	26.247	14.660	13.478	6.597	2.838	1.419	16.127	83.707	48.380	65.263

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500500 RIVER WYE AT RHAYADER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	14.202	6.207	4.173	1.738	1.121	4.763	5.855	3.115	1.352	8.970	14.676	10.527
1939	18.313	10.433	7.039	3.214	1.557	0.772	8.471	4.049	1.094	1.806	22.013	11.337
1940	1.931	8.057	5.357	3.476	2.180	0.965	4.173	0.872	3.154	6.229	19.310	8.721
1941	3.364	12.207	6.354	3.218	2.990	1.995	0.685	5.046	2.382	8.222	5.214	7.475
1942	8.347	5.635	7.911	3.407	4.298	1.159	2.803	2.803	3.476	10.589	2.124	9.094
1943	11.960	9.793	1.370	2.124	3.987	5.536	2.429	3.551	9.011	6.727	9.140	5.855
1944	12.583	5.393	1.869	2.060	1.308	2.253	2.492	1.059	5.407	12.271	13.260	10.340
1945	6.104	14.414	2.865	4.184	2.741	4.055	2.118	2.056	3.540	6.229	1.995	8.098
1946	10.029	18.000	1.620	1.139	1.121	4.763	3.052	9.032	16.800	3.675	12.101	9.530
1947	7.973	1.448	17.068	5.021	2.865	1.480	2.554	0.810	0.901	0.747	9.719	8.596
1948	20.930	8.257	3.426	4.827	1.931	5.536	2.928	4.360	6.887	4.423	6.694	9.406
1949	9.780	3.793	3.544	7.788	3.052	1.674	1.121	2.056	1.352	9.406	13.710	16.320
1950	5.170	16.689	4.111	5.922	2.492	0.772	2.429	8.658	15.770	6.852	10.106	7.849
1951	11.275	10.620	12.209	8.689	2.305	1.287	0.997	2.616	5.278	1.744	16.735	12.209
1952	11.088	7.357	4.173	2.575	3.177	3.090	1.308	3.426	4.119	6.665	7.273	10.839
1953	3.737	7.034	6.229	4.699	2.367	1.223	5.170	4.983	6.630	3.177	10.556	3.488
1954	7.973	8.806	5.357	5.021	1.495	5.664	6.540	8.471	7.595	15.510	15.384	14.202
1955	6.167	5.241	3.606	4.892	6.977	7.788	1.682	0.436	1.867	3.177	5.342	8.534
1956	12.707	2.197	6.665	1.545	1.121	1.094	3.177	9.032	8.110	5.855	4.634	10.839
1957	9.530	10.552	8.347	1.223	1.682	1.287	5.419	10.340	14.740	8.970	7.981	9.032
1958	10.963	16.069	3.177	2.000	3.800	3.991	3.924	5.232	8.883	8.783	5.021	5.544
1959	13.704	1.793	4.236	6.437	2.554	1.674	3.301	0.872	0.322	7.288	10.106	17.005
1960	14.451	9.538	5.544	7.402	1.184	1.287	4.485	4.672	8.432	8.160	14.997	14.701
1961	9.593	9.034	2.305	6.308	3.987	0.579	1.184	4.423	2.832	9.530	6.823	8.970
1962	12.396	9.724	1.931	10.234	3.239	1.030	0.685	6.977	7.209	3.052	5.085	9.655
1963	2.616	1.362	13.455	8.046	5.419	2.768	2.928	3.488	5.471	5.544	15.963	1.931
1964	2.492	3.396	4.049	2.639	4.049	2.124	3.426	3.239	1.995	6.354	8.496	15.884
1965	12.084	1.793	4.672	5.214	4.360	3.154	2.616	2.803	7.853	3.675	5.278	23.919
1966	6.354	11.379	5.606	6.050	4.796	4.570	2.429	3.862	3.218	6.354	8.303	19.933
1967	6.291	9.793	5.731	3.283	7.101	1.802	2.305	5.232	7.080	17.379	7.917	10.029
1968	17.130	3.795	7.101	4.699	6.790	3.540	4.423	0.934	5.342	7.973	5.214	6.977
1969	10.839	6.138	6.478	6.244	7.350	3.476	0.872	3.924	2.124	2.990	11.007	10.153
1970	8.285	16.207	7.039	11.007	1.744	0.708	2.928	4.423	3.862	8.160	19.053	7.039
1971	10.465	8.276	5.046	1.995	1.121	3.862	0.685	3.115	1.159	6.727	8.947	5.108
1972	10.402	7.524	6.291	11.972	4.236	5.600	2.928	2.056	0.901	0.685	9.398	13.143
1973	5.668	11.172	4.423	5.342	5.170	1.480	2.678	5.731	5.664	7.724	7.595	11.150
1974	17.005	13.655	3.613	0.965	0.872	1.931	5.295	3.613	11.843	6.852	11.779	17.130
1975	15.074	5.934	4.049	5.214	2.803	0.451	1.495	0.623	3.605	3.115	6.501	7.537
1976	10.029	6.792	3.737	2.124	2.056	0.644	0.436	0.187	1.609	9.157	5.793	6.914

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500600 RIVER ELAN AT CABAN COCH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	11.930	6.315	4.950	5.590	2.285	5.148	9.390	2.019	5.516	6.434	13.057	13.833
1937	17.650	17.152	11.018	9.427	1.991	1.506	2.061	0.479	2.313	3.843	3.458	11.004
1938	16.101	5.918	3.619	1.920	1.883	7.572	7.176	4.109	2.087	14.328	16.611	12.881
1939	16.653	11.502	7.388	4.788	1.195	1.011	10.885	3.732	0.951	2.200	23.826	10.715
1940	4.078	11.279	6.507	4.392	2.330	0.442	7.813	0.895	3.424	9.036	23.257	9.778
1941	3.322	16.374	8.730	3.786	4.834	2.322	1.017	8.750	1.880	8.778	8.167	10.418
1942	11.044	7.436	5.856	5.692	7.946	1.215	4.726	4.112	6.082	12.624	2.441	13.618
1943	15.710	10.331	1.560	2.886	7.076	5.491	3.231	5.035	10.817	9.036	11.641	6.388
1944	12.151	5.510	1.945	2.212	1.665	2.447	4.134	1.390	7.872	15.741	15.883	12.089
1945	7.450	14.512	3.664	4.044	3.792	6.776	3.616	2.747	6.697	7.200	2.149	11.356
1946	11.882	21.455	3.003	1.351	1.819	6.948	3.466	10.925	16.421	4.497	17.037	12.266
1947	9.741	1.130	24.490	6.348	3.671	2.046	3.224	0.704	1.162	1.167	12.955	9.767
1948	23.470	9.332	4.302	5.102	2.398	7.590	3.697	5.028	8.947	6.890	6.706	14.333
1949	8.994	3.366	6.606	7.074	5.523	1.451	0.320	1.225	0.883	11.303	14.380	15.543
1950	5.565	16.537	4.918	5.822	2.719	0.710	3.071	9.851	15.027	6.454	12.271	9.473
1951	12.445	12.229	12.371	10.520	3.024	1.167	0.867	5.044	8.258	1.872	21.850	13.407
1952	11.750	7.474	5.165	3.382	4.802	3.971	1.720	5.840	5.260	9.604	8.268	12.965
1953	5.107	7.858	7.253	7.469	3.829	2.072	6.569	5.640	8.579	4.794	11.463	4.723
1954	9.231	11.279	6.810	5.796	2.736	8.877	8.719	10.571	8.733	18.743	20.997	16.359
1955	7.985	6.187	8.436	6.292	9.313	9.546	1.453	0.249	2.608	5.675	7.911	10.609
1956	14.722	2.677	8.295	2.324	1.215	1.362	3.624	12.902	10.009	6.479	5.576	13.360
1957	9.274	13.615	8.920	1.005	2.200	1.484	8.804	13.601	19.901	9.481	9.622	9.362
1958	11.760	18.049	3.200	2.345	5.029	6.026	4.848	6.493	11.160	12.236	7.419	7.561
1959	15.152	2.118	6.428	9.424	2.679	1.286	3.763	0.714	0.096	11.423	12.972	18.225
1960	17.641	13.901	6.250	8.269	1.815	1.826	5.338	4.330	9.752	11.468	19.196	17.472
1961	12.485	10.154	2.724	9.888	4.086	0.787	2.897	5.032	4.732	14.750	7.566	10.432
1962	15.603	11.389	2.506	12.202	5.615	1.198	0.824	9.902	11.001	4.474	6.932	11.672
1963	1.065	0.719	19.111	9.410	6.513	3.610	3.296	4.590	7.629	6.632	16.529	2.246
1964	3.673	4.276	6.462	3.806	4.627	2.721	3.684	3.981	2.353	8.838	9.917	20.235
1965	15.639	2.302	7.125	7.085	4.876	4.299	2.908	4.013	13.640	4.809	8.402	29.081
1966	8.278	13.340	6.767	7.931	6.227	5.641	3.173	5.729	4.777	8.725	10.080	25.830
1967	8.519	11.028	5.565	3.194	9.412	1.633	2.336	7.213	11.642	18.823	9.938	12.434
1968	19.441	4.406	9.274	5.182	7.213	4.756	4.534	1.374	8.093	9.537	6.507	8.297
1969	14.201	8.481	7.260	7.102	7.980	4.941	1.076	5.924	2.149	3.486	13.694	13.731
1970	12.777	15.453	9.127	11.650	2.070	0.767	4.474	6.309	4.780	9.333	20.725	6.946
1971	12.440	9.171	6.612	2.911	1.917	7.034	0.854	3.613	1.116	8.038	11.855	6.389
1972	14.405	10.428	7.488	10.648	5.977	6.886	3.366	2.885	1.349	0.950	13.891	16.532
1973	7.102	10.376	4.522	5.673	6.548	1.343	3.619	5.604	5.343	8.072	9.551	14.682
1974	21.022	16.309	5.839	0.923	1.924	2.840	6.526	4.534	14.694	8.862	13.133	18.068
1975	17.037	5.324	4.740	6.531	2.817	0.284	1.511	0.618	5.040	4.603	9.725	9.137
1976	11.541	8.386	4.946	2.414	3.229	0.639	0.275	0.069	3.407	14.083	7.809	8.244

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500400 RIVER WYE AT ABERNANT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	6.880	2.830	1.523	0.702	0.870	3.597	3.726	1.931	0.955	6.200	11.661	4.759
1939	7.315	4.396	3.343	1.883	0.408	0.871	6.173	2.040	0.618	0.952	8.964	4.759
1940	1.523	4.157	3.127	1.939	0.761	0.225	1.387	0.218	0.646	3.236	8.093	3.535
1941	1.387	5.118	3.018	1.349	1.468	1.152	0.408	2.583	0.702	3.426	2.979	3.698
1942	3.345	2.198	2.012	2.332	3.263	0.590	1.061	2.040	2.304	3.916	1.096	5.112
1943	5.683	3.523	0.462	0.618	2.284	2.108	1.197	1.904	3.962	3.535	4.046	2.230
1944	4.569	1.948	0.625	0.927	0.517	0.927	1.849	0.897	3.035	6.336	6.941	4.813
1945	2.828	6.563	2.012	2.248	1.632	3.035	1.251	1.115	2.838	2.719	0.871	4.269
1946	4.514	7.677	1.115	0.450	0.598	2.810	1.278	3.073	5.564	1.686	6.070	4.025
1947	3.617	0.632	8.131	2.838	1.197	0.759	0.734	0.218	0.365	0.489	3.934	3.154
1948	9.509	3.663	1.414	1.855	0.843	3.007	1.332	2.067	4.749	3.046	3.119	6.554
1949	4.106	2.288	2.556	3.288	1.768	1.152	0.190	0.517	0.422	3.997	6.098	6.581
1950	2.665	8.430	2.937	2.385	1.496	0.590	2.556	4.569	7.699	3.018	5.648	3.916
1951	6.227	4.426	4.704	4.665	1.142	0.787	0.354	2.257	4.243	0.843	8.121	5.955
1952	5.439	3.808	2.991	1.883	2.237	1.546	0.979	2.556	1.742	4.052	3.400	5.248
1953	1.931	3.372	2.311	2.838	1.577	0.899	2.040	2.203	3.765	2.257	5.367	1.985
1954	3.454	5.269	2.991	2.220	1.142	3.962	2.801	4.677	3.513	8.539	7.868	6.282
1955	3.562	2.649	3.154	2.473	4.133	4.018	0.952	0.218	0.422	1.822	2.894	5.140
1956	5.547	1.192	2.638	0.815	0.816	0.955	1.278	4.351	3.850	2.638	1.770	5.058
1957	5.384	5.961	4.569	0.618	1.061	0.534	3.046	4.025	8.037	4.215	3.625	3.726
1958	5.320	7.587	1.197	0.731	2.311	2.023	1.822	2.665	3.513	4.786	2.782	2.937
1959	6.363	0.783	2.638	3.822	0.952	0.365	0.979	0.290	0.141	3.154	5.451	8.267
1960	6.934	6.192	2.475	3.175	0.925	1.236	1.876	2.284	3.962	4.269	8.514	6.309
1961	5.602	4.576	0.925	4.215	2.257	0.393	0.897	1.840	2.248	7.179	3.203	5.384
1962	6.708	4.185	0.870	4.440	2.910	0.787	0.544	4.133	4.946	2.148	3.484	3.943
1963	1.033	1.204	8.104	3.625	3.073	1.995	2.284	1.659	2.332	2.910	6.323	1.278
1964	1.274	2.035	2.774	1.855	2.475	1.180	1.441	1.006	1.124	3.481	3.878	7.859
1965	6.853	1.024	2.991	2.726	2.300	3.300	3.000	2.020	4.500	1.958	2.248	12.591
1966	3.861	7.358	3.889	4.833	4.133	2.164	1.251	3.644	2.304	4.079	3.962	11.367
1967	4.161	3.389	2.883	1.433	3.753	1.012	1.169	3.454	4.580	10.877	4.637	5.847
1968	8.403	2.703	3.861	2.136	3.209	2.641	2.175	0.780	3.344	4.514	3.681	3.345
1969	5.248	3.071	2.311	2.389	3.345	1.686	0.544	2.012	1.040	1.251	5.957	5.847
1970	5.547	5.901	3.698	4.637	1.169	0.506	1.632	1.985	2.108	3.073	8.008	2.828
1971	5.983	3.462	2.910	1.321	0.897	2.866	0.625	1.822	0.506	3.073	3.934	2.801
1972	5.547	3.750	3.209	4.974	2.774	3.653	1.876	1.550	0.674	0.680	5.564	8.185
1973	2.230	4.396	2.067	2.136	2.067	0.702	1.061	3.997	1.770	3.100	3.597	5.547
1974	8.892	8.159	2.447	0.506	0.789	1.265	2.883	3.318	6.744	3.726	5.901	7.886
1975	7.886	2.559	2.012	2.529	1.006	0.309	1.006	0.462	2.501	2.040	4.215	3.290
1976	3.753	3.198	1.795	1.096	1.142	0.422	0.381	0.190	1.658	5.357	3.400	3.290

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500700 RIVER WYE AT ERWOOD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.792	15.650	44.014
1938	88.027	34.782	20.175	6.465	6.249	21.832	30.009	14.134	6.749	64.555	91.629	77.032
1939	113.095	62.173	50.127	30.192	7.779	4.234	52.337	26.757	5.554	7.811	110.964	64.498
1940	27.352	67.901	39.718	24.127	19.619	4.455	17.494	3.671	8.994	29.003	146.348	56.392
1941	27.062	88.283	52.079	20.514	17.552	18.183	5.701	24.743	11.987	39.549	39.323	54.293
1942	52.221	37.935	28.493	40.317	34.589	12.145	13.034	13.391	17.905	43.715	15.196	63.619
1943	91.802	83.439	10.304	10.688	26.021	23.975	11.382	16.842	51.884	48.539	63.141	40.118
1944	74.423	29.287	11.051	11.287	6.680	8.605	12.771	6.012	27.977	74.055	94.327	75.018
1945	36.908	96.168	19.604	26.578	15.985	35.720	14.806	12.813	28.551	58.491	26.610	80.009
1946	89.477	142.635	20.903	9.725	8.363	30.334	14.522	42.269	94.127	24.075	99.003	67.959
1947	56.960	9.404	134.813	42.926	19.440	9.373	9.888	3.387	3.902	3.902	41.280	41.901
1948	143.035	60.390	17.200	28.409	13.086	28.288	12.723	18.031	39.381	27.320	33.963	81.961
1949	57.838	21.303	27.720	40.344	17.084	11.224	2.388	4.786	3.440	43.263	81.056	92.654
1950	29.571	112.953	29.456	29.513	16.889	4.828	16.163	44.909	79.867	38.645	68.437	50.580
1951	74.618	67.022	67.701	55.656	15.364	7.374	3.713	13.907	32.180	9.162	115.472	76.122
1952	73.035	52.337	26.889	20.577	26.878	15.495	8.463	23.317	21.129	48.733	42.693	66.228
1953	23.596	45.388	31.244	38.697	17.910	8.479	19.035	20.335	37.535	23.690	58.786	24.874
1954	42.504	65.752	36.132	29.931	10.455	43.721	25.007	50.687	34.235	86.905	112.390	88.944
1955	42.589	34.717	36.076	24.715	48.988	52.924	8.501	2.693	6.167	14.223	30.960	54.083
1956	76.323	17.142	32.265	9.684	6.538	6.407	12.382	39.539	53.515	30.639	23.141	66.573
1957	58.106	79.004	51.339	8.226	8.824	5.394	20.643	41.994	83.932	39.191	51.990	42.221
1958	65.016	101.630	20.133	10.817	21.122	26.451	23.401	31.092	59.069	64.081	33.018	38.851
1959	84.271	12.077	28.317	44.996	16.614	7.940	11.924	3.789	1.237	29.789	60.938	109.870
1960	98.628	83.309	40.776	49.385	9.090	7.886	15.336	18.845	42.617	67.310	109.417	92.766
1961	71.217	61.476	13.796	46.581	28.000	5.131	7.977	15.232	15.175	70.594	38.058	66.318
1962	87.103	56.153	13.476	62.694	26.094	7.617	5.142	38.171	51.537	22.824	37.718	53.491
1963	15.293	12.698	96.023	46.440	30.497	15.869	19.952	13.586	22.144	24.084	95.287	17.698
1964	14.394	19.387	30.582	18.746	22.461	13.827	11.470	10.514	6.914	25.806	39.506	95.627
1965	92.144	11.640	36.320	30.724	25.998	20.741	14.337	13.381	50.574	25.282	44.418	147.894
1966	46.242	85.359	35.623	46.650	30.810	18.143	10.286	23.479	18.052	48.746	50.370	117.563
1967	45.400	70.899	37.276	14.815	44.922	10.864	10.992	26.284	52.346	114.165	48.688	58.565
1968	98.925	25.062	43.409	25.302	40.735	24.836	30.672	6.877	32.729	49.938	40.689	51.517
1969	75.886	47.629	39.648	30.627	54.671	21.696	6.032	22.574	9.734	10.992	63.704	66.428
1970	71.207	94.709	45.878	56.296	13.381	4.938	11.947	21.027	21.235	30.585	115.556	39.188
1971	74.074	47.090	35.842	14.321	8.602	24.691	4.779	14.815	4.938	32.497	46.420	34.886
1972	73.118	55.633	43.011	64.691	32.019	36.543	15.293	10.992	5.432	3.823	57.778	101.314
1973	28.196	56.614	24.373	24.691	29.152	7.901	12.425	29.630	19.753	31.063	35.062	61.649
1974	112.784	100.000	29.630	5.926	6.691	9.383	20.550	20.072	70.123	41.577	76.049	100.258
1975	97.491	36.508	29.630	28.642	13.381	2.963	6.213	3.345	16.296	16.726	38.519	39.665
1976	52.569	39.847	24.373	12.346	10.514	3.457	1.912	0.956	13.827	67.384	42.963	52.091

WATER DATA UNIT RETRIEVAL LISTING

05500300 RIVER LUGG AT LUGWARDINE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	11.292	25.302	14.149	7.376	9.256	4.660	4.116	2.530	1.492	1.317	28.088	13.779
1941	14.960	31.601	22.146	11.521	4.990	10.662	4.345	3.979	4.483	4.383	9.214	10.920
1942	12.149	15.705	11.797	11.482	6.229	5.358	2.657	2.123	1.606	1.765	2.595	9.868
1943	22.166	23.963	6.013	2.498	3.218	2.397	1.765	1.439	2.968	4.062	8.688	9.057
1944	10.415	6.326	2.202	1.423	1.058	0.949	1.164	0.938	1.246	6.560	16.008	19.423
1945	8.451	25.017	6.509	4.190	2.015	5.197	2.954	3.526	5.856	12.681	11.076	18.457
1946	21.866	27.992	8.810	4.843	4.301	6.677	3.982	11.557	26.161	8.329	19.828	24.556
1947	21.479	7.993	28.891	21.478	9.541	4.855	2.901	1.810	1.215	1.106	1.651	3.925
1948	23.358	17.547	5.091	6.017	5.066	3.368	1.837	1.973	3.996	3.171	6.982	18.580
1949	17.543	7.437	7.917	9.527	3.865	2.928	1.773	1.076	1.170	5.830	16.420	16.460
1950	7.275	28.785	10.817	6.729	5.019	2.746	2.488	3.348	6.601	6.470	14.277	14.944
1951	21.047	20.786	23.790	16.713	8.014	5.353	2.901	2.599	2.625	2.158	25.918	16.026
1952	21.065	15.034	10.016	7.841	10.077	4.071	2.489	3.229	2.837	8.925	12.620	22.123
1953	9.604	12.006	6.782	12.419	6.105	3.633	2.789	2.647	4.396	4.383	10.859	8.588
1954	7.320	21.325	14.590	8.792	3.917	18.316	4.278	8.985	5.281	12.087	36.479	38.467
1955	18.747	16.856	16.598	9.743	13.770	27.965	5.190	2.862	2.091	0.942	2.184	4.948
1956	10.990	5.937	3.247	2.473	1.779	1.292	1.221	1.850	7.556	7.255	4.272	12.321
1957	16.134	27.533	13.858	6.094	3.676	2.370	1.846	6.070	14.237	8.179	19.485	12.787
1958	18.685	34.341	13.007	7.079	4.624	7.528	7.553	7.741	24.081	27.631	13.582	18.947
1959	31.022	10.078	10.114	11.438	9.596	4.869	3.091	2.348	1.580	1.615	5.375	31.413
1960	33.398	31.970	21.433	19.322	6.087	3.563	2.728	2.520	4.345	31.021	46.704	30.493
1961	23.509	18.857	7.346	15.251	11.844	3.539	2.427	1.822	1.606	5.959	5.984	15.683
1962	24.002	12.565	5.898	13.020	5.949	2.380	2.106	3.225	6.222	5.329	8.504	9.381
1963	5.918	5.575	33.202	17.142	8.553	5.556	6.904	4.785	3.536	1.956	18.230	9.628
1964	4.384	5.099	13.784	7.115	4.399	3.993	2.627	1.666	1.284	1.558	1.851	9.100
1965	20.358	6.210	14.243	7.800	5.509	4.482	5.092	4.425	8.230	9.775	12.491	39.698
1966	21.397	30.306	17.298	21.530	17.052	5.792	3.820	4.945	5.789	15.744	23.073	22.607
1967	15.045	27.140	22.642	6.555	12.174	7.416	4.338	4.309	7.222	26.120	20.563	17.488
1968	29.707	12.901	9.587	7.855	22.757	7.401	21.357	3.940	4.171	8.936	15.578	22.672
1969	30.983	23.380	27.622	9.476	23.933	12.123	4.026	4.814	3.328	2.027	7.798	14.295
1970	29.935	35.253	16.839	10.801	7.338	3.780	2.458	3.463	3.215	2.423	24.409	14.839
1971	26.477	18.437	16.221	8.479	6.138	5.011	3.441	4.190	2.742	4.870	6.122	9.062
1972	29.034	27.567	20.737	13.490	12.470	10.768	4.181	3.426	3.079	2.441	8.156	43.056
1973	12.255	12.125	8.163	5.946	8.474	4.571	3.546	5.363	2.379	3.649	4.658	6.127
1974	28.961	32.644	12.344	5.893	3.868	4.855	6.261	4.518	9.563	6.634	16.512	14.161
1975	22.495	19.778	17.533	9.913	6.285	3.076	2.646	2.316	2.051	1.985	2.393	5.624
1976	6.285	5.658	7.609	4.786	3.308	1.709	0.992	0.662	4.102	26.465	14.357	26.134

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B)

05500900 RIVER MONNOW AT KENTCHURCH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	7.185	4.011	4.672	5.219	1.764	1.497	0.877	0.606	0.678	5.155	9.549	7.692
1950	3.029	17.715	5.428	3.125	2.652	1.268	1.288	2.394	4.693	3.410	10.805	6.367
1951	11.372	16.020	14.215	9.169	7.041	3.246	1.357	1.210	1.713	1.439	21.271	9.009
1952	8.806	5.286	4.113	4.526	8.424	2.307	1.211	5.197	2.064	6.688	6.566	12.525
1953	4.213	4.713	2.194	4.956	2.976	1.599	1.201	1.414	2.381	2.857	5.107	5.092
1954	4.302	12.436	8.798	3.422	1.880	8.268	1.569	2.312	1.674	5.044	21.977	14.557
1955	9.708	6.726	7.343	3.583	7.900	12.653	2.153	1.230	0.723	0.804	4.375	10.110
1956	13.530	4.863	2.844	2.585	1.635	1.137	1.007	1.376	5.487	3.090	1.781	10.681
1957	7.660	16.733	7.563	2.489	1.662	0.948	0.747	2.307	5.721	2.551	7.357	9.114
1958	8.832	20.125	5.818	2.993	2.607	4.344	1.819	2.297	9.113	11.695	4.934	8.653
1959	15.609	3.880	6.161	6.840	6.907	2.662	1.408	1.110	0.628	0.854	6.115	24.376
1960	18.962	15.384	11.521	11.993	2.623	1.239	0.976	0.980	3.483	22.489	25.008	15.871
1961	12.583	10.546	2.904	9.091	4.820	1.374	0.711	0.609	0.602	3.603	2.553	7.497
1962	13.781	4.681	2.547	6.738	2.640	1.414	0.938	1.400	1.934	1.857	3.885	3.826
1963	1.466	2.066	22.600	7.695	3.319	1.485	1.593	0.892	0.944	0.909	13.362	5.521
1964	2.689	4.261	10.245	4.165	2.653	3.230	1.242	0.787	0.643	0.611	0.903	5.774
1965	11.654	3.064	8.920	3.987	2.662	1.756	1.479	0.915	3.231	2.854	6.256	15.007
1966	12.119	17.634	6.646	13.307	6.196	2.051	1.115	1.455	1.258	7.295	9.344	9.796
1967	8.252	15.140	8.877	2.224	8.192	3.067	1.164	0.957	1.624	12.891	9.962	7.436
1968	14.259	7.560	5.826	4.073	5.807	3.265	9.531	1.805	3.099	7.261	9.141	13.215
1969	14.097	11.382	11.435	4.712	9.877	4.409	1.996	1.577	1.695	0.971	3.816	6.207
1970	18.080	13.416	6.076	4.081	3.617	1.605	1.021	1.352	1.582	1.040	13.615	5.985
1971	16.936	7.825	8.198	3.798	2.493	8.183	2.063	3.229	1.370	2.839	2.650	4.391
1972	17.461	17.933	11.996	7.300	7.731	6.060	1.999	1.200	1.102	0.933	3.443	18.261
1973	5.908	5.165	3.066	2.066	3.865	1.928	1.200	1.590	1.102	1.733	2.755	3.066
1974	23.592	20.955	7.331	2.479	2.532	1.791	2.399	1.200	6.887	3.865	9.779	6.798
1975	13.329	9.444	9.463	4.407	2.266	1.102	0.800	0.800	0.964	1.200	1.377	2.266
1976	2.133	3.420	4.532	2.204	1.066	0.689	0.400	0.400	6.336	19.727	7.851	12.929

WATER DATA UNIT RETRIEVAL LISTING

05600100 RIVER USK AT CHAIN BRIDGE

YEAR	JAN	FEB	MAR.	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	53.770	97.300	19.960	9.500	16.930	18.180	11.800	18.000	45.960	74.390	23.040	35.110
1959	88.970	15.160	29.650	39.930	18.350	8.770	8.230	5.650	2.650	11.960	67.060	115.450
1960	80.250	73.710	41.060	46.160	10.370	7.310	7.840	11.740	25.820	64.450	101.720	77.670
1961	60.430	49.780	13.650	34.830	24.900	6.950	5.330	6.850	11.430	48.220	20.070	44.600
1962	66.010	32.030	10.680	35.090	17.430	7.800	5.570	17.980	27.510	18.180	23.920	26.280
1963	16.650	13.040	79.850	32.990	21.240	10.450	13.860	8.400	11.470	15.280	78.040	21.270
1964	11.480	14.230	24.720	16.800	17.190	11.210	8.670	5.840	4.940	10.750	20.550	66.450
1965	70.620	14.550	28.760	20.080	17.780	19.430	11.330	8.710	23.560	19.370	31.150	102.310
1966	42.810	73.760	30.440	43.220	29.210	10.890	7.370	16.620	14.110	37.460	30.820	71.450
1967	44.810	69.680	37.450	13.120	35.430	13.550	7.310	11.340	23.700	89.990	41.280	33.590
1968	44.610	24.420	36.890	21.650	23.370	16.870	27.490	7.570	21.190	37.700	36.310	44.280
1969	61.120	34.320	27.380	16.440	29.630	15.640	7.430	16.340	9.660	6.378	31.569	38.688
1970	66.718	60.554	25.333	27.880	14.461	6.618	7.042	9.685	14.521	13.980	74.290	27.269
1971	61.438	33.051	27.620	13.676	10.010	19.900	7.100	15.771	6.130	19.506	20.456	24.230
1972	50.960	53.732	37.171	37.086	30.298	28.745	10.387	8.750	6.349	5.232	28.392	88.910
1973	21.027	27.819	18.579	14.136	16.510	7.599	5.734	18.016	9.978	12.077	18.234	25.825
1974	95.055	88.577	21.374	8.456	9.127	8.284	13.344	14.239	50.647	26.463	51.389	52.561
1975	72.245	35.202	24.280	16.890	9.500	4.080	6.705	3.800	12.530	11.670	17.960	24.060
1976	23.210	22.220	16.910	10.320	7.159	3.782	3.190	2.080	18.870	64.760	36.000	39.220

WATER DATA UNIT RETIEVAL LISTING

05600400 RIVER USK AT LLANDETTY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	23.370	46.070	13.860	27.760	20.310	7.500	5.140	12.810	10.750	25.340	18.680	49.080
1967	29.860	43.390	20.910	8.210	22.810	7.500	5.150	8.230	19.110	63.280	25.720	25.880
1968	37.300	27.030	27.840	16.230	14.310	12.200	13.730	4.140	17.260	24.700	21.580	25.060
1969	37.050	20.700	15.250	10.790	20.140	9.740	4.030	12.470	6.360	3.820	22.650	30.580
1970	38.490	37.790	18.190	22.500	8.390	3.540	4.520	6.380	10.550	11.680	48.850	17.900
1971	41.530	18.750	16.460	7.570	5.620	11.770	3.600	9.180	3.290	14.310	15.740	16.850
1972	33.010	32.700	21.800	26.960	20.670	18.950	7.350	6.070	3.960	3.370	22.260	60.330
1973	11.880	20.510	12.860	9.810	9.840	4.240	3.290	13.710	7.140	8.940	14.330	20.680
1974	67.710	57.500	12.870	4.570	5.320	5.780	10.090	10.790	36.980	18.919	36.030	41.384
1975	52.223	20.495	14.370	9.684	5.140	2.160	4.580	2.180	9.690	8.060	13.730	17.950
1976	8.160	16.230	9.570	6.340	4.850	2.170	1.200	1.030	7.330	33.740	23.610	23.940

WATER DATA UNIT RETRIEVAL LISTING

05600600 RIVER USK AT TRALLONG

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	2.360	3.360	4.940	3.740	3.050	1.950	2.600	1.690	1.550	3.970	6.900	19.040
1965	16.370	2.470	6.090	4.680	4.400	5.970	3.610	3.040	8.240	4.750	8.030	27.360
1966	8.010	18.030	6.580	10.760	8.020	3.210	2.320	6.500	5.360	10.090	7.050	20.980
1967	11.920	16.030	7.000	3.650	9.390	3.820	2.430	3.970	8.720	25.280	8.800	9.560
1968	13.870	5.430	9.470	5.080	6.050	4.250	4.620	1.760	8.000	9.720	7.830	8.970
1969	13.000	7.080	5.250	4.060	7.650	3.910	1.590	4.150	2.710	1.570	8.880	11.150
1970	14.940	13.280	7.480	9.000	3.060	1.240	2.050	2.850	4.640	4.950	18.610	7.060
1971	14.530	6.730	6.490	2.740	2.270	4.970	1.310	3.270	1.140	6.080	6.590	6.530
1972	12.570	12.080	8.000	9.800	7.850	7.400	3.250	3.210	1.700	1.530	10.110	22.210
1973	4.700	8.180	5.220	4.060	3.880	1.620	0.990	5.570	2.920	3.400	5.640	8.800
1974	26.950	20.640	4.960	1.570	1.870	2.100	4.720	5.870	15.810	7.550	14.380	17.830
1975	22.080	7.080	4.700	4.030	2.060	0.800	1.770	0.870	5.600	3.348	6.609	7.351
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05600700 RIVER USK AT CRAY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.898	0.443	0.467	0.420	0.134	0.172	0.931	0.240	0.252	0.358	0.857	1.0
1937	1.337	1.211	0.646	0.491	0.183	0.164	0.183	0.053	0.101	0.183	0.214	0.854
1938	1.308	0.540	0.211	0.063	0.260	0.659	0.476	0.455	0.134	1.110	1.310	0.825
1939	1.256	0.895	0.435	0.454	0.114	0.223	1.215	0.341	0.113	0.187	1.525	0.809
1940	0.305	0.952	0.553	0.395	0.179	0.050	0.138	0.024	0.126	0.711	1.877	0.580
1941	0.443	1.044	0.589	0.210	0.289	0.164	0.175	0.581	0.113	0.744	0.525	0.825
1942	0.776	0.266	0.366	0.308	0.675	0.134	0.366	0.581	0.559	0.760	0.256	1.158
1943	1.284	0.756	0.126	0.122	0.703	0.554	0.471	0.390	0.790	0.780	0.550	0.431
1944	1.130	0.339	0.118	0.319	0.110	0.172	0.476	0.203	0.764	1.158	1.436	0.915
1945	0.398	1.517	0.443	0.634	0.358	0.937	0.354	0.341	0.844	0.760	0.151	0.959
1946	1.325	0.936	0.343	0.097	0.126	0.823	0.394	0.996	1.474	0.289	1.579	0.943
1947	0.898	0.095	1.666	0.685	0.313	0.185	0.219	0.073	0.097	0.114	1.008	0.569
1948	1.910	0.856	0.321	0.300	0.256	0.743	0.268	0.663	0.970	0.500	0.538	1.496
1949	0.715	0.400	0.382	0.701	0.362	0.193	0.020	0.150	0.105	1.049	0.924	1.179
1950	0.467	1.669	0.630	0.454	0.313	0.172	0.683	0.967	1.369	0.650	0.938	0.642
1951	1.203	0.923	0.764	0.790	0.203	0.193	0.049	0.606	0.790	0.118	1.546	1.171
1952	0.845	0.517	0.756	0.479	0.512	0.382	0.110	0.618	0.248	0.618	0.571	0.829
1953	0.207	0.576	0.520	0.647	0.443	0.185	0.508	0.394	0.701	0.402	1.273	0.329
1954	0.411	1.076	0.630	0.412	0.305	0.659	0.492	0.915	0.823	1.967	1.735	1.134
1955	0.715	0.418	0.492	0.487	0.797	0.714	0.163	0.041	0.088	0.321	0.605	1.093
1956	1.386	0.187	0.411	0.097	0.171	0.256	0.362	0.711	0.735	0.423	0.193	0.963
1957	1.451	1.404	1.077	0.130	0.252	0.055	0.382	0.581	1.457	0.784	0.554	0.642
1958	1.008	1.242	0.236	0.168	0.565	0.323	0.358	0.512	0.995	0.935	0.403	0.630
1959	1.146	0.131	0.642	0.760	0.236	0.227	0.345	0.093	0.008	0.537	1.306	1.715
1960	1.219	1.195	0.492	0.752	0.134	0.223	0.463	0.492	0.676	0.833	1.890	1.435
1961	1.130	1.035	0.154	0.806	0.427	0.076	0.167	0.354	0.496	1.475	0.508	1.045
1962	1.256	0.657	0.219	0.832	0.585	0.122	0.114	0.870	0.844	0.354	0.538	0.520
1963	0.077	0.077	1.577	0.617	0.516	0.298	0.423	0.297	0.407	0.504	1.562	0.236
1964	0.167	0.291	0.443	0.386	0.532	0.223	0.341	0.195	0.172	0.398	0.664	1.695
1965	1.187	0.126	0.524	0.395	0.439	0.689	0.366	0.378	0.739	0.313	0.609	2.187
1966	0.610	1.350	0.427	0.886	0.577	0.315	0.167	0.663	0.508	0.695	0.592	1.772
1967	0.890	1.337	0.431	0.319	0.821	0.160	0.366	0.545	0.836	2.313	0.592	0.784
1968	1.187	0.378	0.813	0.374	0.545	0.563	0.378	0.187	0.802	0.833	0.668	0.687
1969	1.146	0.446	0.378	0.403	0.626	0.370	0.167	0.297	0.281	0.134	0.832	0.854
1970	1.167	1.130	0.532	0.958	0.163	0.088	0.285	0.293	0.487	0.695	1.512	0.532
1971	1.232	0.518	0.520	0.235	0.219	0.550	0.081	0.512	0.126	0.703	0.584	0.545
1972	0.955	0.878	0.683	0.848	0.740	0.760	0.276	0.341	0.118	0.171	1.046	1.727
1973	0.362	0.626	0.451	0.433	0.337	0.155	0.073	0.560	0.353	0.252	0.512	0.679
1974	2.244	1.310	0.402	0.080	0.179	0.231	0.541	0.516	1.218	0.496	0.764	2.028
1975	1.703	0.482	0.350	0.395	0.154	0.042	0.309	0.102	0.727	0.309	0.638	0.496
1976	0.597	0.508	0.370	0.256	0.297	0.097	0.045	0.045	0.428	1.049	0.340	0.537

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

06000100 RIVER TOWY AT TY CASTELL

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	84.977	12.268	33.923	47.657	14.048	4.437	7.071	3.652	1.607	28.600	89.083	96.106
1960	97.268	94.238	32.932	38.880	10.755	9.557	12.771	30.897	61.363	58.161	109.810	87.639
1961	70.706	62.918	18.839	54.083	34.632	8.030	7.400	12.361	25.630	86.903	35.907	52.045
1962	73.368	41.114	9.719	46.070	30.384	7.253	4.777	35.284	59.860	26.097	43.977	37.123
1963	9.487	19.629	78.577	40.607	33.439	16.063	26.313	12.248	20.403	31.868	77.650	19.516
1964	12.687	16.738	27.642	18.010	29.613	12.850	14.177	11.913	10.513	35.639	36.880	97.406
1965	78.197	19.732	34.910	33.060	28.616	39.523	24.300	13.694	48.010	20.984	39.580	128.432
1966	48.961	84.679	42.635	33.380	43.074	22.040	16.726	37.726	24.760	58.700	41.640	105.439
1967	59.839	67.854	41.255	22.840	47.474	14.433	14.968	31.232	49.847	130.658	53.457	60.865
1968	78.239	33.907	40.932	29.790	41.219	31.400	42.197	15.061	33.617	48.116	43.353	55.913
1969	84.577	44.318	25.977	26.650	43.700	27.087	13.206	23.806	12.203	8.168	56.967	68.026
1970	76.916	65.218	38.890	51.093	15.200	5.360	11.168	23.439	24.390	29.329	111.587	40.116
1971	74.200	34.732	36.681	16.240	11.203	27.267	7.206	22.258	5.457	37.503	42.063	40.365
1972	63.445	58.362	43.529	60.107	21.539	40.407	16.739	25.484	7.803	6.281	59.320	105.655
1973	25.404	37.782	27.968	21.817	22.471	7.237	6.948	27.455	14.373	21.752	34.167	59.626
1974	120.710	95.796	25.990	6.867	7.448	6.870	18.910	26.032	74.027	53.965	74.107	80.800
1975	101.313	38.936	24.023	35.873	9.777	3.080	6.894	3.487	17.563	21.597	46.203	40.106
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

06000200 RIVER TEIFI AT GLAN TEIFI

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	72.347	62.218	24.916	31.330	8.205	5.411	5.837	15.844	46.564	47.597	75.896	57.103
1961	45.162	42.283	10.073	32.054	23.649	4.033	5.070	7.638	16.441	69.211	29.676	39.559
1962	55.736	31.315	8.305	29.503	16.110	5.687	2.969	15.677	38.086	24.916	40.188	31.087
1963	7.038	18.095	58.805	30.710	19.746	9.547	14.910	5.837	7.169	15.743	61.178	17.778
1964	9.640	12.051	22.014	17.578	22.548	9.099	8.472	11.774	5.342	22.615	20.060	64.141
1965	54.569	11.152	22.615	20.129	17.278	15.062	11.107	9.073	42.015	21.214	35.053	93.927
1966	38.125	59.361	29.352	35.466	34.322	27.539	17.311	29.319	13.235	44.028	33.674	81.386
1967	41.127	47.638	30.186	14.345	29.219	12.580	8.305	25.016	38.051	81.986	45.772	43.661
1968	56.203	25.315	21.481	21.955	33.822	16.682	25.983	6.671	12.477	29.719	29.538	40.326
1969	59.205	37.298	15.710	16.785	29.152	20.266	6.504	11.040	6.204	6.471	35.225	58.338
1970	57.604	45.791	34.322	41.153	24.916	7.272	6.804	31.420	13.373	26.484	77.688	36.724
1971	47.908	32.866	33.188	20.473	11.708	21.714	7.205	25.049	7.031	18.845	35.776	37.324
1972	51.467	53.126	27.284	36.638	28.819	43.014	25.183	17.511	4.756	3.969	35.604	69.378
1973	20.480	29.469	20.547	14.476	15.577	6.066	5.270	15.076	8.789	19.879	29.917	39.826
1974	90.292	58.347	24.583	7.824	8.639	6.549	10.373	11.774	50.942	52.234	43.325	45.629
1975	67.944	31.131	17.244	29.503	12.708	3.964	3.569	2.935	6.755	12.275	32.261	35.123
1976	30.686	30.735	21.280	13.373	6.871	3.550	1.868	1.134	4.481	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400530 RIVER SEVERN AT UPPER SEVERN IE MONTFORD - VYRNWY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	55.719	76.565	48.096	9.623	8.808	6.538	21.148	60.587	86.178	42.501	60.608	40.667
1958	72.314	98.288	23.950	9.534	24.815	34.043	32.965	39.335	71.976	62.968	27.522	42.835
1959	96.906	17.003	20.699	39.771	18.577	8.614	12.259	6.984	2.255	18.163	43.148	101.027
1960	105.930	76.560	42.092	34.071	9.739	5.873	9.115	21.736	41.454	68.100	116.490	99.452
1961	65.116	64.553	15.207	30.390	30.035	4.325	4.797	14.815	13.636	46.024	31.770	80.786
1962	90.409	55.123	21.404	67.271	22.259	7.722	4.841	26.640	40.893	14.012	37.780	57.870
1963	13.074	13.955	89.599	49.071	24.673	13.460	15.800	11.141	19.253	17.406	106.235	25.219
1964	19.503	23.467	35.838	20.929	24.286	12.376	11.644	8.268	4.962	18.187	30.780	107.049
1965	116.951	16.190	49.183	34.622	31.863	22.832	17.716	16.297	46.088	26.364	54.103	190.372
1966	56.109	94.875	41.190	64.197	30.099	17.023	9.295	14.677	14.316	39.316	60.930	121.217
1967	44.444	71.116	37.054	18.416	55.676	16.906	8.133	9.837	33.828	112.611	53.477	65.669
1968	110.272	30.436	47.824	24.738	38.030	17.451	46.090	10.705	40.694	47.732	47.160	50.961
1969	71.172	59.156	58.331	34.324	69.550	21.387	5.625	8.168	5.037	14.485	54.045	52.995
1970	51.837	98.036	44.396	55.227	14.710	5.984	5.695	15.849	17.388	22.072	107.937	44.508
1971	64.057	49.791	52.002	19.328	13.153	12.811	8.069	21.279	7.899	31.404	39.471	30.407
1972	60.488	49.595	36.962	57.913	22.772	31.180	15.619	17.762	7.385	5.045	34.856	93.410
1973	24.060	47.392	24.399	20.650	23.258	8.801	14.846	40.049	25.420	43.082	29.435	43.908
1974	97.861	98.543	30.415	9.275	5.674	5.818	9.968	11.813	33.180	39.408	85.826	88.059
1975	93.106	39.613	32.432	25.552	17.636	7.986	6.246	6.520	7.685	10.736	19.015	28.908
1976	6.660	3.970	3.070	1.490	1.310	0.490	0.290	0.000	0.000	7.100	3.860	3.380

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400150 . RIVER SEVERN AT MID-SEVERN IE. BEWDLEY - MONTFORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	34.660	48.451	33.528	14.844	10.211	6.420	8.064	21.748	36.557	23.220	43.665	22.654
1958	38.341	65.270	33.343	16.928	11.044	12.034	16.593	18.151	40.069	54.935	29.025	38.597
1959	81.128	26.202	25.808	39.162	22.801	12.369	8.917	7.920	4.899	7.286	17.330	49.187
1960	78.806	63.637	33.131	24.720	12.678	8.396	7.014	9.220	29.733	59.777	76.852	70.368
1961	45.392	47.573	19.196	24.976	21.690	10.854	8.393	4.967	4.339	11.440	10.251	27.496
1962	42.362	24.607	13.753	24.919	14.187	7.561	5.474	7.164	11.043	9.169	16.961	20.049
1963	8.455	15.036	39.644	24.806	12.176	7.453	9.226	3.228	5.001	7.025	19.312	14.102
1964	8.466	11.446	26.051	12.629	10.276	5.876	2.970	2.169	2.594	4.686	5.644	11.254
1965	39.463	11.762	26.684	15.291	10.491	7.093	4.140	0.198	15.150	10.995	16.966	95.237
1966	37.179	51.133	29.354	41.607	24.755	12.727	9.329	15.257	11.656	24.142	27.242	58.306
1967	29.217	29.314	39.897	11.716	27.803	15.109	7.236	11.083	4.505	23.881	27.556	31.681
1968	65.958	27.334	20.624	17.508	28.868	16.324	44.560	14.755	22.992	21.909	30.068	31.843
1969	43.181	47.199	44.282	20.235	58.149	25.243	11.284	13.556	10.540	0.143	25.890	31.301
1970	49.236	48.682	36.901	28.375	14.726	7.668	7.547	15.637	9.753	5.383	35.539	30.871
1971	43.607	30.640	30.290	21.625	11.452	15.833	6.989	12.891	6.483	15.562	22.275	21.162
1972	48.137	40.724	30.777	24.658	16.166	16.779	13.280	12.650	7.567	8.480	20.692	45.266
1973	20.987	23.691	18.788	18.026	19.754	9.294	12.672	16.386	8.879	17.248	16.495	20.852
1974	40.629	43.107	26.055	11.435	8.016	7.912	7.922	9.387	34.680	12.618	24.832	22.421
1975	27.658	27.900	22.289	22.314	13.551	3.451	5.350	1.525	4.557	9.010	10.602	11.288
1976	81.786	56.120	45.398	23.294	17.497	9.020	5.555	3.645	31.699	109.054	56.809	83.129

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05507654 . RIVER WYE AT UPPER WYE IE ERW. ¬(CAB. + RHAY. + ABER.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	50.844	19.827	10.860	2.105	2.375	5.900	13.252	4.979	2.355	35.057	48.681	48.865
1939	70.814	35.792	32.355	18.307	4.619	1.580	26.808	16.936	2.891	2.853	56.161	37.687
1940	19.820	44.408	24.727	14.320	14.348	2.823	4.121	1.686	1.770	10.502	95.688	34.358
1941	18.989	54.384	33.977	12.161	8.260	12.714	3.591	8.364	7.023	19.123	22.963	32.702
1942	29.485	22.646	12.714	26.886	19.082	9.181	4.444	4.436	6.043	16.586	9.535	35.795
1943	58.449	59.292	6.912	5.060	12.674	10.840	4.525	6.352	28.094	29.241	38.314	25.645
1944	45.120	16.416	6.612	6.088	3.190	2.978	4.296	2.657	11.663	39.707	58.243	47.776
1945	20.616	60.679	11.063	16.102	7.820	21.854	7.821	6.895	15.476	42.343	21.604	56.286
1946	63.052	95.503	15.165	6.765	4.825	15.813	6.726	19.239	55.342	14.217	63.795	42.138
1947	35.629	6.194	85.124	28.719	11.707	5.088	3.376	1.655	1.474	1.499	14.672	20.384
1948	89.036	39.118	8.058	16.625	7.914	12.155	4.766	6.576	18.798	12.961	17.444	51.668
1949	34.958	11.356	13.014	22.394	6.741	6.947	0.757	0.988	0.783	18.557	46.868	54.210
1950	16.171	71.297	17.490	15.184	10.182	2.756	8.107	21.831	41.371	22.321	40.412	29.342
1951	44.671	39.747	38.417	31.782	8.893	4.133	1.495	3.990	14.401	4.703	68.766	44.551
1952	44.758	33.198	14.560	12.737	16.642	6.888	4.456	11.486	10.008	28.412	23.754	37.176
1953	12.821	27.124	15.451	23.691	10.137	4.285	5.256	7.500	18.561	13.462	31.400	14.678
1954	21.846	40.308	20.974	16.894	5.032	25.218	6.947	26.968	14.394	44.113	68.141	52.101
1955	24.875	20.640	18.880	11.058	28.565	31.572	4.414	1.790	1.270	3.549	14.813	29.800
1956	43.347	11.076	14.667	5.000	3.386	2.996	4.303	13.254	31.546	15.667	11.161	37.316
1957	33.918	48.876	29.503	5.380	3.881	2.089	3.374	14.028	41.254	16.525	30.762	20.101
1958	36.773	59.925	12.559	5.681	9.982	14.411	12.807	16.702	35.513	38.276	17.796	22.809
1959	49.052	7.383	15.015	25.313	10.429	4.615	3.881	1.904	0.678	7.924	32.409	66.373
1960	59.602	53.628	26.507	30.539	5.166	3.537	3.637	7.559	20.471	43.413	66.710	54.284
1961	43.537	37.712	7.842	26.170	17.670	3.372	2.999	3.928	5.363	39.135	20.466	41.532
1962	52.306	30.855	8.169	35.818	14.330	4.602	3.089	17.150	28.381	13.150	22.217	28.221
1963	10.579	8.913	55.353	25.359	15.492	7.496	11.444	3.840	6.712	8.998	56.472	12.243
1964	7.005	10.180	17.297	10.446	11.310	7.802	2.919	2.288	1.442	7.133	17.215	51.649
1965	57.568	6.321	21.532	15.699	14.462	9.988	5.813	4.545	24.581	14.840	28.490	82.303
1966	27.749	52.782	19.361	27.836	15.654	5.768	3.433	10.244	7.753	29.588	28.025	60.433
1967	26.429	44.689	23.097	6.905	24.656	6.417	5.182	10.385	29.044	67.086	26.196	30.255
1968	53.951	14.158	23.173	13.285	23.523	13.899	19.540	3.780	15.950	27.914	25.287	32.898
1969	45.508	29.939	23.599	14.892	35.996	11.593	3.540	10.714	4.421	3.265	33.046	36.697
1970	44.598	57.143	26.014	29.002	8.398	2.957	2.913	8.310	10.485	10.019	67.770	22.375
1971	45.186	26.181	21.274	8.094	4.667	10.929	2.615	6.265	2.157	14.659	21.684	20.588
1972	42.674	33.981	26.023	37.097	19.032	20.404	7.123	4.501	2.508	1.508	28.925	63.454
1973	13.196	30.170	13.361	11.540	15.367	4.376	5.067	14.298	6.976	12.167	14.319	30.270
1974	65.865	61.377	17.731	3.532	3.106	3.347	5.846	8.607	36.842	22.137	45.236	57.174
1975	57.404	23.591	18.829	14.368	6.755	1.919	2.201	1.642	5.150	6.968	18.078	19.701
1976	27.246	20.971	13.895	6.712	4.087	1.752	0.820	0.510	7.153	38.787	25.961	33.643

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500270 RIVER WYE AT MID-WYE I.E BELMONT - ERWOOD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	17.257	10.248	4.504	1.777	1.777	5.325	9.803	7.105	3.102	12.688	14.901	17.505
1939	25.421	14.827	16.738	11.435	4.729	2.230	8.600	5.113	2.130	0.747	26.285	20.045
1940	6.785	16.474	17.126	11.451	10.573	6.191	5.976	2.451	0.211	3.798	29.914	9.836
1941	12.403	34.111	22.797	11.351	4.666	3.719	1.494	8.316	2.488	14.271	5.760	13.618
1942	12.779	12.140	11.856	13.277	13.561	8.595	5.949	4.813	4.876	15.481	8.011	15.138
1943	18.642	21.387	1.268	3.314	11.998	10.388	6.207	2.556	10.116	6.433	8.700	7.032
1944	10.831	4.566	1.830	1.820	1.820	1.615	2.325	1.004	4.571	14.318	21.061	18.399
1945	5.444	24.748	5.359	5.145	1.530	8.227	6.544	4.934	5.496	6.385	3.613	7.370
1946	3.041	22.728	10.152	5.439	7.443	18.823	10.326	24.701	33.275	14.075	38.945	31.844
1947	29.787	11.720	64.388	32.334	10.294	1.173	0.058	1.199	0.511	-0.073	6.438	7.264
1948	39.302	23.896	5.323	11.761	4.392	9.047	2.573	3.908	11.614	11.093	14.660	23.139
1949	23.728	8.721	10.272	12.729	5.639	3.335	1.288	0.442	0.683	9.978	16.386	17.011
1950	5.839	31.554	7.058	5.871	5.750	1.762	3.451	6.944	14.797	12.871	19.762	19.562
1951	26.852	18.232	21.719	17.747	11.362	3.703	2.688	2.199	4.876	3.661	16.674	5.897
1952	10.178	7.684	7.132	8.226	10.773	4.366	1.467	4.445	0.926	4.650	10.036	20.188
1953	7.816	7.033	3.003	8.821	5.649	2.772	3.772	2.861	4.481	4.383	10.307	7.577
1954	7.617	13.734	11.922	5.862	2.712	4.758	4.414	10.818	8.156	30.894	30.667	24.919
1955	12.711	13.983	13.624	6.785	9.912	21.076	5.699	1.607	1.933	1.377	4.940	6.917
1956	15.990	9.773	13.014	4.364	2.235	2.190	1.632	3.758	4.053	5.267	3.457	12.262
1957	10.987	29.139	13.280	5.836	5.173	4.392	5.825	8.920	6.796	6.314	15.404	12.516
1958	14.668	20.473	10.534	5.304	1.761	4.584	2.603	7.447	10.194	21.125	10.250	12.176
1959	21.804	8.490	8.127	8.693	8.883	2.719	1.923	2.180	1.354	0.255	4.729	23.277
1960	19.307	19.482	15.801	15.546	4.763	2.761	0.258	-0.793	0.935	19.595	24.211	29.903
1961	18.774	19.482	5.174	9.345	9.605	1.614	0.515	-0.012	-0.328	3.823	1.331	20.049
1962	21.307	10.647	2.424	4.406	3.906	2.483	1.158	1.629	3.863	4.576	6.382	7.009
1963	6.608	2.224	24.664	12.431	9.968	6.535	12.131	7.606	5.163	5.366	22.880	10.732
1964	5.504	7.600	11.865	7.150	6.621	10.642	8.006	3.602	1.149	1.860	1.543	8.652
1965	16.756	9.460	11.080	5.076	4.802	4.059	5.563	5.810	2.026	5.618	12.082	34.606
1966	21.051	20.113	19.512	17.484	23.663	8.519	6.531	12.226	13.239	24.428	16.405	18.168
1967	14.586	18.874	17.258	7.252	10.581	14.323	6.648	1.430	2.654	14.177	13.474	9.611
1968	14.174	10.308	7.512	7.541	7.221	6.178	14.745	2.142	3.006	9.876	14.547	16.833
1969	22.196	17.571	12.685	6.738	15.131	9.248	2.495	-0.639	2.266	1.504	3.959	9.423
1970	16.046	19.973	8.437	4.340	5.559	1.871	1.170	1.034	0.761	-0.995	11.204	9.251
1971	24.238	15.089	11.974	6.798	4.011	6.222	2.315	3.629	2.392	3.681	2.693	7.677
1972	21.939	21.664	13.739	13.010	3.450	7.438	3.860	2.486	2.631	2.561	3.796	28.502
1973	11.529	12.500	9.677	4.630	6.317	3.827	3.181	5.830	0.039	2.987	3.788	1.486
1974	30.511	37.442	5.130	7.268	2.531	3.078	2.859	3.337	6.112	6.661	12.647	12.533
1975	20.975	12.186	11.514	6.543	7.191	2.901	3.009	1.621	-0.169	1.008	0.402	5.026
1976	3.472	1.360	1.874	2.314	2.964	3.140	0.926	0.463	2.300	16.323	5.417	13.172

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE H FORMAT)

05500120 RIVER WYE AT LOWER WYE I.E CADORA - BELMONT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	37.304	26.805	17.811	10.246	13.074	11.498	3.193	4.876	4.913	10.215	30.603	61.969
1939	106.442	39.998	32.549	28.104	13.639	7.911	16.153	14.286	9.032	11.072	44.594	47.561
1940	30.424	80.452	36.263	20.919	25.848	9.189	8.200	5.744	6.522	11.535	68.806	21.456
1941	48.219	91.230	57.886	28.009	15.159	24.880	10.257	5.344	9.463	2.677	18.710	22.591
1942	28.759	36.615	29.751	26.447	10.982	11.156	3.535	3.861	5.822	1.530	9.599	34.233
1943	86.358	73.561	19.472	8.268	6.801	4.518	2.846	2.252	7.163	11.067	13.712	23.602
1944	23.080	18.862	9.815	6.639	4.124	2.882	1.478	3.304	5.087	12.718	44.126	50.507
1945	24.901	70.584	23.776	16.448	15.549	21.639	19.209	18.042	25.059	44.195	38.030	67.138
1946	64.756	59.354	22.686	15.059	13.618	13.141	4.718	15.601	49.723	16.669	61.932	53.746
1947	52.516	22.644	133.409	60.169	30.566	18.284	13.329	7.785	5.512	5.221	9.952	9.661
1948	48.243	39.868	16.694	20.617	20.231	12.542	8.838	9.737	16.027	9.855	18.399	50.261
1949	48.153	23.415	23.851	26.218	11.969	10.379	5.374	3.822	5.229	11.520	33.810	25.964
1950	16.511	77.212	30.235	15.858	12.808	6.244	4.582	-0.558	10.262	18.084	32.433	29.072
1951	49.213	59.322	58.396	44.305	21.729	16.154	6.601	4.418	3.244	5.324	78.101	42.022
1952	52.868	34.111	23.612	21.587	32.364	11.867	6.817	13.481	9.815	20.517	34.969	67.484
1953	25.888	28.679	16.753	35.782	19.541	12.149	4.293	5.904	11.284	10.778	24.268	20.105
1954	18.151	48.563	38.879	21.492	11.041	38.228	9.600	13.252	5.380	7.277	90.985	89.538
1955	49.275	43.189	43.633	25.191	32.451	61.837	14.004	8.816	6.050	0.858	12.555	28.299
1956	49.933	26.742	8.430	11.226	8.290	5.573	5.626	6.978	26.734	16.226	8.798	36.217
1957	38.851	76.512	36.020	15.897	7.405	2.719	0.793	3.964	20.218	12.828	39.135	32.508
1958	44.401	88.802	32.621	15.056	13.221	22.229	11.997	8.807	41.910	68.017	32.338	42.731
1959	96.222	24.230	27.864	29.761	26.606	12.397	7.379	5.060	3.157	5.635	19.794	87.697
1960	90.247	77.985	57.625	48.224	14.229	7.796	5.870	7.255	15.631	90.331	122.216	80.675
1961	60.825	53.746	22.316	41.026	30.129	11.907	7.167	5.913	7.481	9.203	9.684	30.214
1962	53.983	25.740	14.371	32.632	13.891	5.780	4.486	9.188	5.963	10.488	17.518	20.458
1963	2.503	14.952	83.705	41.173	17.103	7.216	1.982	-0.487	2.820	1.614	37.661	22.654
1964	11.959	14.319	38.879	18.901	10.675	5.745	1.159	1.642	2.847	5.518	8.902	22.666
1965	53.526	14.353	36.163	22.363	14.734	13.201	10.371	8.265	26.093	15.493	16.529	68.833
1966	45.465	67.213	34.441	45.207	27.895	10.661	4.411	1.876	8.349	14.495	38.847	36.125
1967	38.416	55.125	53.920	14.462	30.920	12.616	3.980	11.732	6.165	50.491	48.170	39.882
1968	69.837	37.178	51.170	22.471	29.899	16.972	52.806	15.999	12.030	23.432	40.903	62.395
1969	70.809	59.778	64.314	23.902	38.880	26.480	9.573	11.249	5.145	5.015	17.442	27.781
1970	75.650	77.365	40.712	25.089	20.277	10.336	6.492	8.106	7.618	3.909	48.728	33.527
1971	57.210	42.707	38.510	20.888	16.046	25.895	14.023	13.656	8.256	12.090	13.233	20.798
1972	57.288	67.768	51.852	26.728	32.407	24.599	14.031	10.656	7.523	5.683	14.799	76.830
1973	26.643	22.735	15.726	14.321	18.832	13.210	8.328	8.274	6.705	12.709	14.144	12.283
1974	63.351	88.004	53.116	13.303	13.403	9.360	9.775	6.758	12.608	13.605	28.202	21.453
1975	39.912	48.164	38.799	22.485	12.612	8.164	7.370	5.593	5.694	4.891	7.084	9.610
1976	11.835	13.114	14.479	11.837	4.622	2.755	3.195	1.598	15.046	64.113	34.228	59.931

WATER DATA UNIT RETRIEVAL LISTING

05600170 RIVER USK AT UPPER USK IE CHIANB. - CRAY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	52.762	96.058	19.724	9.332	16.365	17.857	11.442	17.488	44.965	73.455	22.637	34.480
1959	87.874	15.029	29.008	39.170	18.114	8.543	7.885	5.557	2.642	11.423	65.754	113.735
1960	79.031	72.515	40.568	45.408	10.236	7.087	7.377	11.248	25.144	63.617	99.830	76.235
1961	59.300	48.745	13.496	34.024	24.473	6.874	5.163	6.496	10.934	46.745	19.562	43.555
1962	64.754	31.423	10.461	34.258	16.845	7.678	5.456	17.110	26.666	17.826	23.382	25.760
1963	16.573	12.963	78.273	32.373	20.724	10.152	13.437	8.103	11.063	14.776	76.478	21.034
1964	11.313	13.939	24.277	16.414	16.658	10.987	8.329	5.645	4.768	10.352	19.886	64.755
1965	69.433	14.424	28.236	20.285	17.341	18.741	10.964	8.332	22.821	19.057	30.541	100.123
1966	42.200	72.410	50.013	42.334	28.633	10.575	7.203	15.957	13.602	36.765	30.228	69.678
1967	43.920	68.343	37.019	12.801	34.609	13.390	6.944	10.795	22.864	87.677	40.688	32.806
1968	43.423	24.042	36.077	21.276	22.825	16.307	27.112	7.383	20.388	36.867	35.642	43.593
1969	59.974	33.374	27.002	16.037	29.004	15.270	7.263	16.043	9.379	6.244	30.737	37.834
1970	65.551	59.424	24.801	26.922	14.298	6.530	6.757	9.592	14.034	13.285	72.778	26.737
1971	60.206	32.533	27.100	13.441	9.791	19.350	7.019	15.250	6.004	18.803	19.872	23.685
1972	50.005	52.854	36.488	36.238	29.558	27.985	10.111	8.418	6.231	5.061	27.346	87.183
1973	20.665	27.193	18.128	13.703	16.173	7.444	5.661	17.447	9.625	11.825	17.722	25.146
1974	92.811	87.267	20.972	8.376	8.948	8.053	12.803	13.723	49.429	25.967	50.625	50.533
1975	70.542	34.720	23.930	16.495	9.346	4.038	6.396	3.698	11.803	11.361	17.322	23.564
1976	22.613	21.712	16.540	10.064	6.862	3.685	3.145	2.035	18.442	63.711	35.660	38.683

AREAL RAINFALL RECORDS

WATER DATA UNIT RETRIEVAL LISTING I.C.L. MAG. TAPE TYPE B FORMAT

RAINFALL DATA IN MM.

05400100 RIVER SEVERN AT BEWDLEY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	121.900	63.500	68.600	63.500	38.100	116.800	144.800	25.400	114.300	68.600	104.100	106.700
1937	111.800	152.400	71.100	68.600	63.500	40.600	73.700	38.100	63.500	94.000	48.300	83.800
1938	142.200	38.100	33.000	5.100	73.700	86.400	106.700	109.200	45.700	134.600	149.900	109.200
1939	175.300	83.800	58.400	71.100	27.900	53.300	193.000	63.500	30.500	83.800	177.800	66.000
1940	78.700	91.400	76.200	96.500	63.500	35.600	91.400	12.700	66.000	134.600	243.800	76.200
1941	81.300	94.000	81.300	45.700	81.300	33.000	61.000	129.500	30.500	104.100	81.300	55.900
1942	119.400	30.500	61.000	63.500	124.500	15.200	96.500	96.500	63.500	86.400	25.400	121.900
1943	162.600	78.700	50.500	43.200	94.000	86.400	71.100	101.600	116.800	104.100	83.800	58.400
1944	111.800	53.300	20.300	48.300	55.900	61.000	68.600	88.900	111.800	134.600	154.900	83.800
1945	91.400	111.800	48.300	33.300	91.400	99.100	53.300	91.400	71.100	109.200	12.700	111.800
1946	121.900	134.600	40.600	43.200	63.500	96.500	58.400	160.000	142.200	38.100	180.300	104.100
1947	81.300	55.900	175.300	86.400	76.200	55.900	96.500	15.200	48.300	17.800	96.500	91.400
1948	99.100	71.100	50.800	55.900	55.900	111.800	53.300	114.300	83.800	63.500	81.300	129.500
1949	61.000	40.600	48.300	91.400	76.200	22.900	55.900	50.800	40.600	144.800	124.500	124.500
1950	35.600	170.200	45.700	94.000	38.100	38.100	88.900	137.200	162.600	50.800	116.800	73.700
1951	96.500	106.700	134.600	76.200	88.900	33.000	53.300	109.200	78.700	33.000	190.500	132.100
1952	124.500	30.500	50.800	55.900	68.600	58.400	35.600	91.400	66.000	152.400	78.700	96.500
1953	30.500	53.300	61.000	88.900	63.500	53.300	101.600	86.400	91.400	53.300	86.400	38.100
1954	81.300	86.400	78.700	20.300	76.200	96.500	88.900	119.400	94.000	172.700	205.700	104.100
1955	81.300	61.000	81.300	43.200	134.600	106.700	25.400	40.600	43.200	55.900	71.100	114.300
1956	124.500	17.800	45.700	43.200	17.800	58.400	96.500	132.100	96.500	63.500	40.600	94.000
1957	83.800	83.800	73.700	7.600	50.800	45.700	139.700	157.500	167.600	78.700	61.000	68.600
1958	88.900	137.200	30.500	20.300	78.700	104.100	129.500	94.000	167.600	88.900	53.300	94.000
1959	119.400	10.200	66.000	104.100	50.800	66.000	73.700	30.500	5.100	96.500	111.800	172.700
1960	154.900	83.800	45.700	50.800	45.700	63.500	96.500	127.000	129.500	149.900	162.600	124.500
1961	99.100	66.000	15.200	101.600	45.700	30.500	76.200	83.800	71.100	114.300	58.400	88.900
1962	116.800	50.800	43.200	94.000	73.700	22.900	66.000	127.000	116.800	33.000	61.000	81.300
1963	33.000	22.900	94.000	76.200	53.300	88.900	45.700	66.000	68.600	50.800	157.500	20.300
1964	22.900	33.000	73.700	58.400	55.900	55.900	63.500	45.700	30.500	72.000	62.000	136.000
1965	114.000	14.000	89.000	70.000	72.000	88.000	92.000	54.000	150.000	36.000	108.000	211.000
1966	56.000	126.000	50.000	102.000	81.000	84.000	73.000	85.000	51.000	118.000	106.000	142.000
1967	52.000	107.000	61.000	29.000	157.000	35.000	64.000	56.000	124.000	174.000	57.000	102.000
1968	106.000	36.000	73.000	71.000	101.000	85.000	129.000	66.000	134.000	83.000	67.000	79.000
1969	85.000	96.000	73.000	66.000	186.000	36.000	49.000	93.000	42.000	22.000	140.000	80.000
1970	99.000	101.000	81.000	87.000	25.000	54.000	62.000	123.000	57.000	63.000	179.000	42.000
1971	114.000	42.000	67.000	58.000	44.000	92.000	38.000	121.000	32.000	89.000	99.000	41.000
1972	108.000	73.000	83.000	68.000	85.000	82.000	79.000	49.000	44.000	49.000	89.000	127.000
1973	38.000	55.000	28.000	81.000	98.000	33.000	119.000	92.000	93.000	70.000	60.000	64.000
1974	138.000	96.000	48.000	10.000	39.000	62.000	77.000	63.000	145.000	78.000	117.000	87.000
1975	115.000	32.000	62.000	63.000	42.000	20.000	67.000	53.000	70.000	33.000	64.000	59.000
1976	72.000	55.000	62.000	17.000	71.000	17.000	33.000	14.000	209.000	129.000	62.000	77.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400300 RIVER VYRNWY AT VYRNWY RESERVOIR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	238.800	27.900	119.400	170.200	50.800	96.500	170.200	35.600	15.200	243.800	199.400	431.800
1960	284.500	229.100	76.700	130.600	59.900	89.700	191.000	173.500	167.100	203.200	398.800	271.800
1961	238.800	177.800	40.600	165.100	86.400	53.300	106.700	180.300	147.300	271.800	177.800	198.100
1962	292.100	137.200	88.900	188.000	127.000	58.400	76.200	251.500	180.300	88.900	114.300	182.900
1963	63.500	58.400	266.700	167.600	144.800	139.700	71.100	149.900	142.200	101.600	360.700	76.200
1964	58.400	58.400	91.400	121.900	121.900	73.700	127.000	83.800	83.800	140.000	157.000	446.000
1965	328.000	26.000	154.000	136.000	150.000	171.000	121.000	118.000	194.000	122.000	177.000	491.000
1966	119.000	283.000	135.000	160.000	151.000	117.000	116.000	104.000	118.000	153.000	225.000	313.000
1967	136.000	226.000	111.000	70.000	249.000	54.000	132.000	146.000	274.000	468.000	125.000	217.000
1968	269.000	36.000	262.000	102.000	128.000	123.000	124.000	108.000	277.000	230.000	130.000	154.000
1969	151.000	187.000	103.000	143.000	207.000	93.000	49.000	88.000	80.000	64.000	279.000	188.000
1970	190.000	277.000	158.000	231.000	58.000	88.000	103.000	144.000	155.000	217.000	333.000	116.000
1971	212.000	142.000	95.000	66.000	52.000	131.000	73.000	177.000	57.000	237.000	196.000	73.000
1972	194.000	124.000	163.000	190.000	198.000	151.000	127.000	99.000	42.000	65.000	246.000	283.000
1973	88.000	143.000	78.000	124.000	163.000	41.000	137.000	213.000	204.000	130.000	153.000	173.000
1974	311.000	221.000	88.000	16.000	61.000	106.000	211.000	97.000	346.000	154.000	281.000	328.000
1975	328.000	68.000	101.000	141.000	48.000	39.000	152.000	86.000	203.000	74.000	176.000	137.000
1976	226.000	106.000	112.000	42.000	111.000	31.000	59.000	7.000	274.000	224.000	134.000	115.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05400500 RIVER SEVERN AT MONTFORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	118.400	170.900	35.600	29.500	104.400	103.100	134.900	96.300	194.100	94.000	63.500	106.700
1959	147.300	15.200	68.600	119.400	61.000	76.200	96.500	30.500	7.600	137.200	124.500	228.600
1960	182.900	116.800	53.300	71.100	43.200	68.600	116.800	147.300	132.100	162.600	215.900	170.200
1961	132.100	83.800	22.900	104.100	55.900	35.600	76.200	106.700	86.400	157.500	88.900	109.200
1962	157.500	76.200	61.000	116.800	86.400	30.500	68.600	147.300	139.700	48.300	68.600	119.400
1963	38.100	30.500	129.500	101.600	73.700	104.100	50.800	88.900	88.900	58.400	226.100	33.000
1964	35.600	38.100	76.200	71.100	66.000	61.000	83.800	58.400	53.300	95.000	90.000	209.000
1965	165.000	17.000	104.000	89.000	96.000	111.000	91.000	67.000	156.000	55.000	128.000	289.000
1966	74.000	163.000	65.000	115.000	94.000	88.000	76.000	85.000	64.000	130.000	140.000	182.000
1967	69.000	149.000	79.000	38.000	179.000	42.000	87.000	74.000	160.000	243.000	69.000	138.000
1968	149,000	39.000	114.000	85.000	118.000	102.000	141.000	94.000	169.000	111.000	86.000	98.000
1969	114.000	117.000	94.000	85.000	194.000	47.000	50.000	95.000	69.000	33.000	176.000	106.000
1970	119.000	144.000	100.000	113.000	37.000	67.000	70.000	134.000	78.000	97.000	220.000	55.000
1971	142.000	62.000	66.000	58.000	36.000	103.000	45.000	131.000	39.000	114.000	121.000	54.000
1972	124.000	89.000	103.000	108.000	107.000	106.000	96.000	58.000	41.000	52.000	126.000	163.000
1973	49.000	76.000	36.000	97.000	115.000	30.000	134.000	129.000	127.000	86.000	71.000	87.000
1974	187.000	131.000	52.000	10.000	47.000	77.000	106.000	67.000	198.000	93.000	163.000	139.000
1975	163.000	40.000	73.000	75.000	49.000	20.000	80.000	64.000	96.000	52.000	85.000	77.000
1976	110.000	68.000	74.000	19.000	79.000	17.000	41.000	10.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING

05400800 RIVER TEME AT TENBURY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	58.400	81.300	61.000	7.600	45.700	48.300	83.800	165.100	160.000	50.800	71.100	66.000
1958	109.200	7.600	68.600	101.600	53.300	55.900	58.400	35.600	2.500	91.400	121.900	182.900
1959	73.700	132.100	38.100	12.700	68.600	109.200	109.200	76.200	170.200	88.900	58.400	86.400
1960	157.500	96.500	58.400	53.300	40.600	53.300	86.400	119.400	106.700	182.900	160.000	116.800
1961	86.400	53.300	5.100	114.300	38.100	27.900	53.300	63.500	66.000	111.800	50.800	83.800
1962	121.900	35.600	45.700	94.000	71.100	12.700	63.500	124.500	119.400	25.400	68.600	55.900
1963	25.400	35.600	104.100	78.700	50.800	71.100	50.800	61.000	45.700	40.600	147.300	22.900
1964	22.900	40.600	73.700	58.400	43.200	53.300	43.200	35.600	22.900	59.000	48.000	103.000
1965	89.000	10.000	81.000	55.000	60.000	70.000	71.000	44.000	130.000	26.000	93.000	161.000
1966	51.000	116.000	45.000	97.000	87.000	70.000	55.000	81.000	48.000	121.000	104.000	98.000
1967	53.000	104.000	38.000	28.000	133.000	35.000	56.000	57.000	124.000	153.000	49.000	88.000
1968	82.000	32.000	70.000	72.000	90.000	73.000	116.000	51.000	116.000	81.000	60.000	82.000
1969	85.000	99.000	76.000	54.000	174.000	37.000	47.000	91.000	39.000	21.000	116.000	78.000
1970	118.000	82.000	74.000	73.000	27.000	58.000	52.000	127.000	54.000	38.000	169.000	43.000
1971	120.000	32.000	69.000	46.000	43.000	80.000	22.000	108.000	28.000	81.000	79.000	44.000
1972	122.000	84.000	82.000	60.000	86.000	72.000	67.000	40.000	46.000	49.000	79.000	131.000
1973	36.000	43.000	24.000	79.000	94.000	32.000	91.000	62.000	75.000	44.000	46.000	49.000
1974	154.000	102.000	42.000	9.000	43.000	59.000	61.000	60.000	116.000	60.000	93.000	67.000
1975	108.000	32.000	74.000	61.000	37.000	17.000	66.000	63.000	70.000	34.000	53.000	43.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (MONTHLY RAINFALL DATA)

05500100 RIVER WYE AT CADORA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	150.000	69.000	79.000	69.000	41.000	119.000	157.000	13.000	94.000	66.000	112.000	150.000
1937	155.000	163.000	102.000	71.000	58.000	30.000	89.000	38.000	64.000	112.000	46.000	84.000
1938	135.000	38.000	8.000	5.000	71.000	64.000	94.000	97.000	46.000	127.000	147.000	122.000
1939	185.000	81.000	56.000	81.000	23.000	58.000	173.000	56.000	23.000	84.000	198.000	61.000
1940	89.000	84.000	66.000	86.000	64.000	25.000	104.000	10.000	46.000	132.000	241.000	76.000
1941	117.000	104.000	84.000	36.000	74.000	53.000	69.000	122.000	36.000	91.000	94.000	74.000
1942	107.000	18.000	79.000	61.000	130.000	10.000	64.000	102.000	64.000	79.000	23.000	142.000
1943	193.000	71.000	30.000	33.000	102.000	69.000	53.000	81.000	104.000	99.000	86.000	56.000
1944	97.000	30.000	13.000	41.000	33.000	53.000	56.000	79.000	86.000	145.000	155.000	89.000
1945	69.000	84.000	38.000	41.000	84.000	104.000	74.000	112.000	64.000	127.000	20.000	142.000
1946	114.000	122.000	30.000	53.000	97.000	79.000	56.000	180.000	145.000	38.000	208.000	102.000
1947	89.000	56.000	213.000	94.000	81.000	51.000	64.000	23.000	48.000	18.000	94.000	89.000
1948	216.000	64.000	51.000	71.000	89.000	91.000	38.000	109.000	86.000	84.000	61.000	188.000
1949	46.000	43.000	46.000	81.000	84.000	18.000	30.000	48.000	64.000	180.000	132.000	99.000
1950	28.000	180.000	53.000	74.000	46.000	46.000	104.000	137.000	137.000	51.000	152.000	64.000
1951	104.000	117.000	127.000	84.000	89.000	23.000	33.000	107.000	86.000	28.000	231.000	109.000
1952	107.000	30.000	58.000	64.000	89.000	64.000	38.000	145.000	79.000	135.000	94.000	97.000
1953	28.000	53.000	61.000	89.000	56.000	43.000	94.000	94.000	102.000	76.000	76.000	43.000
1954	81.000	89.000	84.000	18.000	69.000	124.000	71.000	127.000	86.000	142.000	224.000	107.000
1955	99.000	56.000	81.000	46.000	142.000	137.000	28.000	25.000	51.000	66.000	97.000	127.000
1956	132.000	13.000	43.000	51.000	20.000	64.000	102.000	114.000	109.000	56.000	43.000	124.000
1957	84.000	109.000	84.000	5.000	56.000	41.000	99.000	130.000	175.000	74.000	79.000	99.000
1958	97.000	173.000	38.000	25.000	86.000	97.000	112.000	84.000	185.000	109.000	74.000	109.000
1959	142.000	10.000	86.000	107.000	64.000	64.000	79.000	25.000	5.000	109.000	147.000	231.000
1960	168.000	124.000	66.000	81.000	46.000	61.000	97.000	102.000	127.000	203.000	206.000	142.000
1961	119.000	76.000	13.000	145.000	43.000	41.000	53.000	71.000	84.000	142.000	61.000	109.000
1962	135.000	41.000	46.000	94.000	79.000	18.000	66.000	137.000	127.000	33.000	71.000	84.000
1963	30.000	46.000	130.000	97.000	66.000	84.000	53.000	74.000	61.000	56.000	193.000	30.000
1964	28.000	43.000	81.000	61.000	58.000	61.000	51.000	48.000	33.000	79.000	74.000	145.000
1965	124.000	10.000	91.000	66.000	66.000	81.000	97.000	51.000	145.000	43.000	103.000	206.000
1966	70.000	141.000	55.000	111.000	90.000	75.000	61.000	93.000	56.000	137.000	114.000	145.000
1967	80.000	127.000	71.000	30.000	165.000	28.000	63.000	79.000	141.000	215.000	66.000	103.000
1968	117.000	38.000	85.000	82.000	99.000	90.000	122.000	51.000	127.000	109.000	79.000	97.000
1969	120.000	89.000	79.000	63.000	159.000	53.000	53.000	87.000	48.000	27.000	119.000	93.000
1970	157.000	112.000	75.000	82.000	37.000	63.000	68.000	104.000	70.000	66.000	198.000	48.000
1971	157.000	48.000	78.000	48.000	53.000	104.000	31.000	111.000	38.000	90.000	90.000	53.000
1972	134.000	108.000	94.000	94.000	102.000	84.000	47.000	42.000	53.000	55.000	115.000	169.000
1973	50.000	62.000	29.000	80.000	100.000	36.000	85.000	75.000	84.000	52.000	69.000	80.000
1974	208.000	139.000	48.000	9.000	56.000	74.000	83.000	77.000	164.000	69.000	120.000	111.000
1975	147.000	44.000	83.000	63.000	32.000	15.000	83.000	65.000	102.000	45.000	67.000	59.000
1976	64.000	59.000	64.000	16.000	62.000	17.000	30.000	0.000	39.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500200 RIVER WYE AT BELMONT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	173.000	71.000	89.000	76.000	56.000	132.000	178.000	20.000	112.000	86.000	135.000	193.000
1937	191.000	196.000	112.000	89.000	64.000	38.000	94.000	43.000	76.000	124.000	51.000	102.000
1938	170.000	53.000	13.000	8.000	84.000	81.000	112.000	107.000	51.000	160.000	185.000	140.000
1939	208.000	112.000	71.000	97.000	25.000	69.000	203.000	64.000	25.000	91.000	244.000	76.000
1940	97.000	94.000	84.000	86.000	64.000	25.000	130.000	18.000	66.000	147.000	282.000	104.000
1941	112.000	117.000	102.000	43.000	86.000	48.000	76.000	147.000	41.000	119.000	107.000	97.000
1942	130.000	23.000	86.000	74.000	147.000	15.000	94.000	104.000	79.000	109.000	25.000	165.000
1943	211.000	94.000	53.000	38.000	109.000	94.000	69.000	107.000	132.000	124.000	112.000	69.000
1944	132.000	41.000	18.000	48.000	41.000	66.000	66.000	89.000	102.000	178.000	188.000	109.000
1945	89.000	117.000	51.000	48.000	102.000	127.000	71.000	117.000	76.000	142.000	23.000	150.000
1946	140.000	165.000	36.000	53.000	97.000	99.000	71.000	201.000	178.000	48.000	241.000	119.000
1947	107.000	61.000	239.000	104.000	79.000	56.000	71.000	18.000	61.000	25.000	119.000	117.000
1948	259.000	81.000	64.000	81.000	89.000	112.000	51.000	122.000	102.000	97.000	74.000	218.000
1949	58.000	51.000	56.000	94.000	102.000	20.000	36.000	61.000	66.000	188.000	163.000	145.000
1950	41.000	208.000	58.000	94.000	48.000	51.000	114.000	165.000	180.000	69.000	168.000	76.000
1951	130.000	127.000	145.000	104.000	89.000	30.000	43.000	127.000	97.000	33.000	251.000	140.000
1952	135.000	46.000	64.000	71.000	91.000	81.000	46.000	147.000	89.000	150.000	97.000	127.000
1953	41.000	66.000	84.000	97.000	61.000	43.000	117.000	107.000	117.000	84.000	99.000	48.000
1954	104.000	109.000	97.000	25.000	76.000	140.000	94.000	150.000	114.000	180.000	259.000	137.000
1955	107.000	69.000	94.000	58.000	155.000	152.000	30.000	33.000	66.000	81.000	99.000	147.000
1956	152.000	15.000	53.000	51.000	23.000	76.000	114.000	135.000	127.000	69.000	56.000	140.000
1957	107.000	124.000	104.000	10.000	64.000	51.000	127.000	157.000	206.000	102.000	91.000	117.000
1958	117.000	196.000	38.000	33.000	102.000	112.000	135.000	94.000	208.000	124.000	79.000	124.000
1959	163.000	15.000	94.000	127.000	74.000	81.000	99.000	28.000	8.000	145.000	165.000	264.000
1960	193.000	155.000	71.000	102.000	51.000	71.000	124.000	114.000	137.000	201.000	254.000	185.000
1961	152.000	94.000	23.000	145.000	56.000	41.000	66.000	97.000	104.000	188.000	86.000	127.000
1962	175.000	71.000	51.000	124.000	99.000	28.000	71.000	163.000	157.000	46.000	76.000	107.000
1963	36.000	53.000	155.000	117.000	86.000	97.000	61.000	81.000	79.000	71.000	236.000	36.000
1964	36.000	51.000	81.000	74.000	71.000	69.000	71.000	61.000	46.000	104.000	104.000	198.000
1965	165.000	10.000	104.000	84.000	81.000	97.000	97.000	69.000	160.000	59.000	125.000	276.000
1966	80.000	166.000	73.000	127.000	108.000	92.000	80.000	100.000	72.000	154.000	137.000	202.000
1967	99.000	158.000	83.000	39.000	181.000	63.000	99.000	95.000	171.000	270.000	84.000	133.000
1968	152.000	41.000	117.000	93.000	115.000	115.000	127.000	69.000	148.000	126.000	89.000	109.000
1969	150.000	109.000	86.000	77.000	176.000	61.000	59.000	108.000	56.000	38.000	149.000	127.000
1970	165.000	155.000	94.000	110.000	36.000	63.000	80.000	101.000	86.000	100.000	232.000	58.000
1971	176.000	64.000	84.000	53.000	63.000	110.000	41.000	130.000	40.000	110.000	111.000	69.000
1972	152.000	120.000	114.000	122.000	114.000	104.000	55.000	53.000	56.000	56.000	147.000	198.000
1973	59.000	89.000	36.000	94.000	112.000	35.000	100.000	97.000	99.000	62.000	90.000	109.000
1974	253.000	168.000	57.000	11.000	69.000	88.000	104.000	88.000	108.000	91.000	147.000	164.000
1975	194.000	49.000	90.000	77.000	35.000	16.000	93.000	76.000	121.000	58.000	93.000	76.000
1976	88.000	73.000	70.000	19.000	73.000	20.000	43.000	31.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING

05500300 RIVER LUGG AT LUGWARDINE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	124.000	61.000	69.000	64.000	33.000	112.000	130.000	10.000	81.000	48.000	94.000	99.000
1937	109.000	132:000	84.000	48.000	53.000	25.000	74.000	36.000	48.000	107.000	41.000	69.000
1938	99.000	23.000	5.000	3.000	61.000	48.000	76.000	76.000	41.000	94.000	112.000	97.000
1939	147.000	53.000	41.000	64.000	20.000	48.000	145.000	48.000	20.000	66.000	178.000	51.000
1940	91.000	74.000	48.000	71.000	56.000	28.000	89.000	8.000	36.000	109.000	208.000	56.000
1941	104.000	81.000	74.000	33.000	71.000	56.000	64.000	102.000	30.000	74.000	79.000	51.000
1942	86.000	15.000	64.000	48.000	104.000	8.000	46.000	79.000	51.000	58.000	20.000	112.000
1943	160.000	51.000	25.000	28.000	76.000	56.000	43.000	66.000	84.000	86.000	61.000	46.000
1944	69.000	25.000	13.000	38.000	23.000	41.000	51.000	76.000	71.000	112.000	119.000	64.000
1945	56.000	66.000	28.000	28.000	84.000	91.000	69.000	109.000	56.000	107.000	15.000	114.000
1946	89.000	86.000	23.000	51.000	86.000	69.000	53.000	168.000	112.000	28.000	163.000	74.000
1947	71.000	48.000	180.000	71.000	69.000	43.000	56.000	20.000	38.000	15.000	69.000	71.000
1948	160.000	48.000	58.000	61.000	76.000	66.000	30.000	107.000	69.000	66.000	53.000	155.000
1949	36.000	33.000	41.000	64.000	74.000	18.000	28.000	41.000	58.000	160.000	107.000	69.000
1950	20.000	147.000	41.000	56.000	33.000	43.000	94.000	109.000	107.000	38.000	130.000	48.000
1951	81.000	86.000	112.000	66.000	84.000	18.000	36.000	94.000	64.000	23.000	196.000	74.000
1952	81.000	23.000	53.000	51.000	71.000	51.000	30.000	122.000	66.000	117.000	76.000	84.000
1953	20.000	46.000	46.000	76.000	46.000	41.000	76.000	84.000	86.000	58.000	56.000	38.000
1954	66.000	71.000	69.000	13.000	66.000	112.000	51.000	119.000	66.000	102.000	183.000	71.000
1955	84.000	48.000	79.000	33.000	130.000	127.000	30.000	20.000	28.000	48.000	84.000	94.000
1956	107.000	13.000	50.000	48.000	15.000	56.000	102.000	104.000	89.000	46.000	30.000	99.000
1957	53.000	84.000	64.000	8.000	51.000	41.000	74.000	122.000	150.000	43.000	71.000	71.000
1958	71.000	142.000	43.000	15.000	76.000	94.000	114.000	76.000	173.000	89.000	71.000	94.000
1959	114.000	8.000	71.000	86.000	58.000	66.000	61.000	30.000	5.000	79.000	122.000	191.000
1960	157.000	91.000	61.000	61.000	46.000	56.000	76.000	107.000	117.000	203.000	163.000	112.000
1961	86.000	53.000	3.000	147.000	36.000	38.000	46.000	53.000	74.000	112.000	46.000	94.000
1962	99.000	20.000	41.000	79.000	58.000	10.000	74.000	119.000	99.000	20.000	64.000	58.000
1963	23.000	41.000	107.000	79.000	56.000	74.000	46.000	58.000	41.000	41.000	152.000	30.000
1964	18.000	38.000	81.000	51.000	51.000	51.000	38.000	30.000	23.000	66.000	46.000	94.000
1965	89.000	5.000	81.000	53.000	56.000	66.000	79.000	36.000	130.000	32.000	91.000	143.000
1966	53.000	106.000	41.000	102.000	81.000	68.000	48.000	86.000	43.000	125.000	102.000	85.000
1967	56.000	111.000	58.000	22.000	136.000	34.000	45.000	66.000	126.000	168.000	50.000	89.000
1968	88.000	32.000	56.000	71.000	92.000	81.000	126.000	42.000	105.000	87.000	65.000	86.000
1969	96.000	92.000	82.000	51.000	169.000	41.000	43.000	73.000	37.000	21.000	103.000	79.000
1970	129.000	94.000	66.000	60.000	33.000	52.000	55.000	112.000	56.000	38.000	175.000	35.000
1971	125.000	32.000	65.000	45.000	52.000	91.000	29.000	110.000	35.000	76.000	71.000	43.000
1972	119.000	90.000	77.000	71.000	88.000	72.000	44.000	36.000	50.000	51.000	83.000	135.000
1973	39.000	40.000	21.000	69.000	90.000	32.000	71.000	55.000	64.000	38.000	53.000	50.000
1974	152.000	98.000	42.000	8.000	47.000	72.000	67.000	64.000	122.000	51.000	87.000	68.000
1975	108.000	40.000	73.000	51.000	30.000	13.000	70.000	61.000	80.000	36.000	42.000	40.000
1976	41.000	44.000	61.000	12.000	50.000	14.000	29.000	31.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500400 RIVER WYE AT ABERNANT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	241.000	86.000	117.000	102.000	66.000	152.000	257.000	41.000	175.000	152.000	229.000	297.000
1937	312.000	305.000	145.000	165.000	74.000	64.000	99.000	48.000	150.000	104.000	61.000	160.000
1938	338.000	124.000	48.000	20.000	122.000	175.000	180.000	94.000	79.000	287.000	328.000	180.000
1939	269.000	188.000	137.000	117.000	25.000	122.000	284.000	86.000	28.000	94.000	419.000	160.000
1940	99.000	140.000	160.000	94.000	56.000	23.000	183.000	43.000	109.000	211.000	371.000	175.000
1941	109.000	183.000	112.000	58.000	122.000	48.000	97.000	226.000	30.000	201.000	147.000	173.000
1942	193.000	48.000	124.000	99.000	224.000	20.000	168.000	165.000	124.000	193.000	36.000	279.000
1943	193.000	48.000	124.000	99.000	224.000	20.000	168.000	165.000	124.000	193.000	36.000	279.000
1944	224.000	71.000	23.000	76.000	71.000	109.000	114.000	107.000	170.000	277.000	277.000	183.000
1945	145.000	198.000	94.000	79.000	127.000	170.000	89.000	107.000	142.000	140.000	28.000	196.000
1946	208.000	302.000	38.000	51.000	91.000	165.000	109.000	236.000	244.000	71.000	328.000	203.000
1947	152.000	74.000	315.000	155.000	97.000	74.000	104.000	20.000	102.000	46.000	203.000	178.000
1948	437.000	127.000	97.000	94.000	89.000	201.000	109.000	165.000	196.000	137.000	119.000	302.000
1949	122.000	71.000	107.000	150.000	145.000	25.000	36.000	97.000	64.000	218.000	234.000	246.000
1950	99.000	302.000	102.000	163.000	64.000	79.000	142.000	241.000	305.000	94.000	229.000	152.000
1951	221.000	170.000	198.000	173.000	79.000	46.000	61.000	183.000	145.000	43.000	325.000	234.000
1952	224.000	127.000	104.000	99.000	94.000	117.000	74.000	168.000	117.000	198.000	107.000	198.000
1953	76.000	112.000	137.000	119.000	94.000	66.000	185.000	147.000	160.000	119.000	193.000	69.000
1954	147.000	183.000	150.000	46.000	104.000	185.000	160.000	201.000	196.000	320.000	356.000	221.000
1955	142.000	99.000	137.000	117.000	193.000	224.000	28.000	48.000	135.000	137.000	124.000	229.000
1956	224.000	23.000	109.000	53.000	43.000	104.000	130.000	229.000	183.000	117.000	104.000	196.000
1957	196.000	175.000	175.000	18.000	81.000	64.000	201.000	221.000	323.000	183.000	112.000	175.000
1958	191.000	284.000	38.000	61.000	142.000	127.000	160.000	130.000	264.000	185.000	112.000	160.000
1959	221.000	30.000	147.000	191.000	41.000	84.000	145.000	13.000	15.000	239.000	236.000	358.000
1960	292.000	251.000	71.000	135.000	71.000	102.000	175.000	165.000	183.000	206.000	371.000	267.000
1961	244.000	168.000	48.000	191.000	84.000	64.000	107.000	155.000	163.000	292.000	155.000	173.000
1962	279.000	122.000	74.000	185.000	173.000	64.000	84.000	241.000	249.000	91.000	109.000	188.000
1963	46.000	81.000	175.000	173.000	135.000	132.000	99.000	137.000	130.000	114.000	290.000	41.000
1964	61.000	74.000	117.000	99.000	107.000	86.000	122.000	109.000	94.000	163.000	191.000	302.000
1965	272.000	18.000	132.000	142.000	117.000	150.000	135.000	127.000	236.000	108.000	179.000	412.000
1966	118.000	273.000	140.000	185.000	170.000	121.000	133.000	143.000	117.000	192.000	194.000	196.000
1967	182.000	210.000	115.000	69.000	229.000	45.000	144.000	146.000	261.000	447.000	141.000	206.000
1968	287.000	59.000	196.000	133.000	146.000	161.000	97.000	113.000	215.000	202.000	116.000	143.000
1969	223.000	129.000	123.000	119.000	177.000	108.000	70.000	140.000	82.000	81.000	222.000	225.000
1970	247.000	219.000	162.000	219.000	31.000	74.000	141.000	125.000	125.000	187.000	347.000	93.000
1971	268.000	127.000	122.000	65.000	87.000	154.000	60.000	157.000	53.000	167.000	187.000	100.000
1972	219.000	163.000	170.000	209.000	154.000	165.000	102.000	93.000	68.000	82.000	271.000	271.000
1973	98.000	159.000	57.000	132.000	133.000	43.000	137.000	171.000	140.000	119.000	150.000	213.000
1974	367.000	270.000	89.000	19.000	92.000	110.000	174.000	129.000	289.000	153.000	228.000	297.000
1975	331.000	54.000	112.000	118.000	42.000	25.000	130.000	78.000	205.000	92.000	196.000	123.000
1976	142.000	167.000	86.000	43.000	101.000	22.000	85.000	26.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05300500 RIVER WYE AT RHAYADER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	244.000	89.000	102.000	97.000	66.000	175.000	221.000	33.000	142.000	150.000	201.000	279.000
1937	246.000	257.000	135.000	122.000	56.000	89.000	102.000	48.000	84.000	97.000	66.000	142.000
1938	297.000	107.000	53.000	15.000	99.000	142.000	160.000	109.000	56.000	267.000	254.000	170.000
1939	267.000	180.000	107.000	112.000	36.000	84.000	284.000	97.000	30.000	91.000	381.000	124.000
1940	117.000	119.000	107.000	104.000	76.000	30.000	180.000	41.000	112.000	180.000	381.000	170.000
1941	107.000	145.000	114.000	58.000	109.000	38.000	81.000	218.000	53.000	206.000	119.000	142.000
1942	203.000	41.000	97.000	104.000	185.000	30.000	150.000	124.000	137.000	193.000	30.000	218.000
1943	234.000	145.000	46.000	48.000	140.000	140.000	97.000	168.000	221.000	165.000	191.000	86.000
1944	241.000	79.000	28.000	66.000	71.000	102.000	99.000	97.000	157.000	241.000	267.000	147.000
1945	135.000	193.000	81.000	66.000	112.000	168.000	71.000	114.000	112.000	157.000	33.000	185.000
1946	229.000	310.000	41.000	53.000	94.000	145.000	107.000	246.000	272.000	76.000	297.000	170.000
1947	137.000	69.000	310.000	117.000	97.000	86.000	119.000	13.000	79.000	30.000	193.000	203.000
1948	386.000	124.000	109.000	107.000	89.000	157.000	79.000	150.000	142.000	140.000	97.000	262.000
1949	104.000	84.000	81.000	150.000	124.000	25.000	76.000	84.000	74.000	229.000	236.000	274.000
1950	69.000	284.000	84.000	142.000	43.000	58.000	142.000	226.000	323.000	112.000	224.000	119.000
1951	183.000	183.000	203.000	147.000	97.000	38.000	84.000	170.000	142.000	51.000	318.000	244.000
1952	211.000	86.000	69.000	79.000	94.000	97.000	69.000	142.000	142.000	173.000	132.000	191.000
1953	76.000	94.000	145.000	124.000	76.000	46.000	203.000	168.000	157.000	97.000	165.000	58.000
1954	168.000	155.000	145.000	53.000	102.000	160.000	170.000	196.000	198.000	287.000	305.000	241.000
1955	112.000	97.000	112.000	114.000	183.000	180.000	30.000	48.000	122.000	119.000	104.000	191.000
1956	236.000	30.000	107.000	58.000	38.000	94.000	135.000	211.000	170.000	114.000	104.000	180.000
1957	165.000	157.000	160.000	15.000	84.000	76.000	201.000	231.000	305.000	185.000	117.000	180.000
1958	163.000	267.000	48.000	56.000	130.000	130.000	170.000	124.000	249.000	152.000	99.000	155.000
1959	218.000	28.000	117.000	160.000	74.000	117.000	142.000	23.000	13.000	218.000	183.000	300.000
1960	249.000	178.000	74.000	127.000	56.000	86.000	183.000	150.000	155.000	178.000	310.000	264.000
1961	193.000	137.000	53.000	135.000	76.000	46.000	84.000	150.000	107.000	231.000	119.000	155.000
1962	229.000	135.000	71.000	183.000	130.000	38.000	69.000	211.000	206.000	74.000	81.000	168.000
1963	41.000	58.000	201.000	155.000	122.000	137.000	58.000	135.000	130.000	97.000	300.000	28.000
1964	61.000	58.000	81.000	89.000	99.000	79.000	109.000	107.000	66.000	147.000	160.000	292.000
1965	241.000	18.000	124.000	132.000	117.000	117.000	109.000	107.000	206.000	77.000	143.000	451.000
1966	95.000	224.000	106.000	120.000	132.000	139.000	113.000	119.000	100.000	159.000	188.000	355.000
1967	120.000	193.000	111.000	63.000	211.000	48.000	151.000	120.000	216.000	329.000	130.000	197.000
1968	235.000	48.000	173.000	110.000	159.000	126.000	90.000	81.000	190.000	157.000	90.000	129.000
1969	195.000	120.000	111.000	123.000	201.000	90.000	65.000	139.000	71.000	61.000	221.000	156.000
1970	156.000	242.000	130.000	206.000	25.000	80.000	109.000	129.000	115.000	179.000	300.000	104.000
1971	195.000	113.000	101.000	56.000	62.000	127.000	49.000	137.000	43.000	156.000	184.000	94.000
1972	195.000	131.000	148.000	196.000	136.000	120.000	75.000	81.000	55.000	63.000	210.000	227.000
1973	95.000	168.000	58.000	135.000	144.000	30.000	149.000	139.000	152.000	105.000	145.000	169.000
1974	341.000	214.000	72.000	13.000	75.000	102.000	150.000	105.000	266.000	142.000	235.000	284.000
1975	270.000	49.000	98.000	109.000	43.000	22.000	99.000	93.000	129.000	73.000	135.000	125.000
1976	158.000	97.000	94.000	26.000	96.000	22.000	52.000	18.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500600 RIVER ELAN AT CARAN COCH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	231.000	97.000	104.000	104.000	71.000	163.000	226.000	36.000	155.000	170.000	216.000	287.000
1937	305.000	269.000	122.000	162.000	64.000	66.000	91.000	33.000	107.000	119.000	38.000	165.000
1938	312.000	119.000	51.000	25.000	112.000	170.000	178.000	122.000	71.000	274.000	287.000	213.000
1939	282.000	221.000	114.000	127.000	33.000	91.000	264.000	99.000	30.000	102.000	437.000	157.000
1940	104.000	132.000	130.000	109.000	61.000	20.000	234.000	53.000	119.000	213.000	376.000	183.000
1941	109.000	193.000	137.000	66.000	124.000	46.000	94.000	241.000	38.000	193.000	147.000	173.000
1942	213.000	53.000	127.000	117.000	216.000	23.000	173.000	137.000	132.000	229.000	33.000	269.000
1943	272.000	157.000	53.000	64.000	168.000	135.000	122.000	165.000	101.000	168.000	196.000	104.000
1944	226.000	97.000	28.000	66.000	89.000	97.000	114.000	94.000	170.000	292.000	284.000	196.000
1945	142.000	213.000	81.000	84.000	119.000	178.000	86.000	114.000	130.000	145.000	28.000	198.000
1946	218.000	318.000	46.000	61.000	91.000	137.000	112.000	269.000	264.000	84.000	320.000	206.000
1947	157.000	79.000	351.000	137.000	102.000	79.000	114.000	20.000	102.000	43.000	213.000	185.000
1948	411.000	135.000	112.000	112.000	89.000	191.000	99.000	157.000	170.000	145.000	109.000	290.000
1949	127.000	81.000	114.000	155.000	163.000	20.000	48.000	99.000	69.000	236.000	257.000	292.000
1950	107.000	284.000	97.000	157.000	51.000	64.000	130.000	231.000	323.000	107.000	234.000	152.000
1951	198.000	201.000	224.000	178.000	94.000	41.000	79.000	178.000	140.000	51.000	353.000	251.000
1952	226.000	130.000	91.000	86.000	102.000	112.000	69.000	160.000	142.000	198.000	137.000	203.000
1953	86.000	99.000	160.000	127.000	94.000	58.000	198.000	140.000	180.000	107.000	175.000	71.000
1954	157.000	175.000	142.000	66.000	104.000	178.000	191.000	185.000	208.000	287.000	323.000	257.000
1955	140.000	102.000	122.000	124.000	188.000	191.000	33.000	43.000	137.000	147.000	117.000	203.000
1956	244.000	41.000	135.000	74.000	43.000	94.000	130.000	246.000	178.000	127.000	122.000	213.000
1957	188.000	180.000	163.000	15.000	89.000	74.000	231.000	287.000	345.000	191.000	112.000	193.000
1958	196.000	279.000	48.000	66.000	122.000	132.000	145.000	124.000	239.000	193.000	107.000	163.000
1959	236.000	33.000	132.000	183.000	56.000	94.000	142.000	20.000	15.000	267.000	216.000	348.000
1960	282.000	249.000	89.000	157.000	64.000	86.000	191.000	150.000	155.000	196.000	328.000	277.000
1961	201.000	155.000	66.000	165.000	69.000	58.000	127.000	147.000	127.000	262.000	147.000	165.000
1962	277.000	163.000	76.000	196.000	142.000	51.000	71.000	226.000	224.000	81.000	102.000	213.000
1963	69.000	109.000	244.000	178.000	132.000	132.000	64.000	150.000	150.000	112.000	290.000	30.000
1964	76.000	66.000	114.000	102.000	94.000	89.000	117.000	114.000	89.000	165.000	188.000	295.000
1965	264.000	23.000	127.000	145.000	119.000	112.000	107.000	117.000	231.000	97.000	163.000	434.000
1966	119.000	244.000	119.000	147.000	135.000	137.000	119.000	117.000	122.000	165.000	206.000	422.000
1967	155.000	196.000	127.000	64.000	213.000	43.000	122.000	150.000	249.000	343.000	150.000	218.000
1968	297.000	53.000	180.000	142.000	147.000	135.000	104.000	99.000	203.000	186.000	107.000	150.000
1969	219.000	135.000	127.000	132.000	185.000	107.000	62.000	156.000	77.000	74.000	227.000	214.000
1970	237.000	260.000	178.000	217.000	31.000	75.000	126.000	140.000	122.000	193.000	331.000	106.000
1971	222.000	143.000	120.000	69.000	76.000	141.000	50.000	149.000	49.000	165.000	205.000	101.000
1972	234.000	157.000	173.000	205.000	145.000	148.000	66.000	96.000	60.000	76.000	262.000	260.000
1973	116.000	178.000	62.000	127.000	151.000	31.000	144.000	147.000	150.000	129.000	172.000	243.000
1974	399.000	261.000	91.000	14.000	98.000	95.000	164.000	112.000	266.000	146.000	230.000	337.000
1975	328.000	58.000	112.000	135.000	46.000	20.000	118.000	63.000	168.000	91.000	189.000	121.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

05500700 RIVER WYE AT ERWOOD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	183.000	69.000	86.000	81.000	58.000	135.000	188.000	25.000	130.000	137.000	173.000	221.000
1937	221.000	224.000	112.000	109.000	53.000	58.000	84.000	36.000	91.000	104.000	51.000	119.000
1938	231.000	79.000	25.000	10.000	97.000	104.000	127.000	97.000	48.000	206.000	224.000	150.000
1939	218.000	147.000	84.000	102.000	28.000	74.000	229.000	74.000	25.000	81.000	305.000	104.000
1940	89.000	104.000	104.000	89.000	61.000	25.000	150.000	25.000	74.000	165.000	318.000	127.000
1941	97.000	137.000	102.000	48.000	99.000	43.000	76.000	175.000	43.000	147.000	122.000	119.000
1942	155.000	28.000	94.000	86.000	170.000	18.000	112.000	112.000	94.000	137.000	30.000	191.000
1943	224.000	114.000	36.000	46.000	122.000	104.000	84.000	127.000	145.000	140.000	142.000	79.000
1944	157.000	53.000	18.000	53.000	56.000	74.000	74.000	89.000	122.000	213.000	216.000	135.000
1945	107.000	145.000	58.000	58.000	107.000	142.000	66.000	104.000	89.000	147.000	25.000	165.000
1946	170.000	226.000	38.000	51.000	94.000	112.000	79.000	206.000	106.000	58.000	264.000	147.000
1947	119.000	64.000	267.000	109.000	86.000	61.000	79.000	15.000	71.000	28.000	145.000	142.000
1948	312.000	99.000	76.000	91.000	91.000	130.000	61.000	117.000	114.000	104.000	84.000	239.000
1949	74.000	58.000	71.000	112.000	117.000	23.000	36.000	76.000	61.000	203.000	193.000	198.000
1950	58.000	239.000	66.000	114.000	46.000	53.000	119.000	178.000	218.000	79.000	185.000	94.000
1951	152.000	140.000	165.000	130.000	81.000	33.000	53.000	147.000	104.000	38.000	279.000	168.000
1952	168.000	64.000	71.000	76.000	91.000	89.000	53.000	135.000	107.000	165.000	102.000	152.000
1953	53.000	79.000	112.000	104.000	66.000	46.000	142.000	124.000	135.000	86.000	124.000	51.000
1954	119.000	127.000	109.000	36.000	86.000	155.000	119.000	178.000	140.000	213.000	274.000	163.000
1955	109.000	76.000	109.000	76.000	168.000	165.000	36.000	41.000	84.000	94.000	99.000	165.000
1956	180.000	20.000	71.000	53.000	28.000	86.000	114.000	165.000	142.000	81.000	71.000	152.000
1957	127.000	137.000	122.000	10.000	71.000	58.000	140.000	180.000	246.000	122.000	104.000	127.000
1958	140.000	221.000	38.000	41.000	109.000	122.000	142.000	104.000	211.000	140.000	84.000	140.000
1959	178.000	18.000	104.000	147.000	74.000	89.000	112.000	23.000	8.000	173.000	180.000	282.000
1960	213.000	170.000	76.000	112.000	51.000	76.000	142.000	124.000	140.000	193.000	279.000	213.000
1961	175.000	109.000	30.000	147.000	66.000	41.000	79.000	112.000	117.000	216.000	104.000	137.000
1962	206.000	91.000	61.000	145.000	114.000	36.000	74.000	188.000	188.000	58.000	76.000	130.000
1963	36.000	56.000	165.000	124.000	99.000	114.000	64.000	97.000	97.000	81.000	254.000	33.000
1964	46.000	48.000	81.000	79.000	81.000	69.000	86.000	74.000	58.000	122.000	130.000	231.000
1965	201.000	13.000	109.000	104.000	97.000	107.000	99.000	84.000	173.000	68.000	133.000	338.000
1966	84.000	190.000	86.000	125.000	116.000	105.000	95.000	98.000	85.000	153.000	153.000	262.000
1967	110.000	169.000	91.000	45.000	187.000	40.000	122.000	116.000	190.000	296.000	99.000	157.000
1968	192.000	42.000	139.000	97.000	128.000	123.000	103.000	79.000	161.000	137.000	87.000	112.000
1969	166.000	103.000	91.000	95.000	178.000	72.000	63.000	120.000	60.000	47.000	174.000	146.000
1970	163.000	199.000	109.000	145.000	29.000	65.000	93.000	108.000	98.000	128.000	260.000	75.000
1971	186.000	87.000	91.000	52.000	61.000	111.000	36.000	126.000	39.000	131.000	138.000	80.000
1972	163.000	121.000	131.000	158.000	121.000	114.000	64.000	66.000	53.000	58.000	189.000	209.000
1973	72.000	124.000	45.000	110.000	117.000	28.000	121.000	115.000	141.000	84.000	110.000	142.000
1974	286.000	199.000	62.000	12.000	72.000	91.000	128.000	95.000	227.000	118.000	191.000	230.000
1975	234.000	46.000	84.000	93.000	38.000	17.000	98.000	77.000	139.000	64.000	126.000	96.000
1976	123.000	90.000	75.000	25.000	80.000	19.000	49.000	18.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B)

05500900 RIVER MONNOW AT KENTCHURCH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	163.000	81.000	89.000	69.000	41.000	119.000	163.000	10.000	81.000	53.000	99.000	124.000
1937	157.000	152.000	122.000	69.000	71.000	25.000	86.000	43.000	53.000	124.000	53.000	81.000
1938	102.000	28.000	5.000	5.000	71.000	53.000	89.000	97.000	58.000	99.000	130.000	132.000
1939	198.000	64.000	48.000	91.000	23.000	64.000	175.000	53.000	23.000	107.000	196.000	46.000
1940	89.000	91.000	56.000	94.000	74.000	23.000	81.000	8.000	46.000	142.000	226.000	61.000
1941	155.000	109.000	86.000	38.000	66.000	64.000	76.000	104.000	36.000	61.000	89.000	61.000
1942	99.000	10.000	86.000	51.000	124.000	15.000	46.000	104.000	66.000	74.000	23.000	140.000
1943	201.000	56.000	33.000	28.000	107.000	69.000	41.000	76.000	89.000	91.000	76.000	58.000
1944	79.000	23.000	10.000	43.000	18.000	53.000	56.000	86.000	89.000	147.000	150.000	79.000
1945	64.000	69.000	25.000	38.000	81.000	104.000	84.000	119.000	74.000	145.000	20.000	155.000
1946	94.000	79.000	36.000	61.000	119.000	76.000	58.000	180.000	137.000	41.000	206.000	91.000
1947	91.000	64.000	224.000	97.000	81.000	64.000	69.000	25.000	51.000	1.000	1.000	1.000
1948	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	89.000	64.000	196.000
1949	38.000	46.000	46.000	79.000	84.000	15.000	36.000	43.000	79.000	211.000	122.000	74.000
1950	23.000	185.000	56.000	66.000	56.000	41.000	107.000	130.000	112.000	51.000	155.000	46.000
1951	97.000	130.000	135.000	79.000	114.000	28.000	30.000	114.000	86.000	36.000	239.000	91.000
1952	89.000	18.000	64.000	66.000	107.000	76.000	41.000	193.000	84.000	135.000	107.000	86.000
1953	23.000	48.000	53.000	94.000	58.000	48.000	89.000	104.000	99.000	89.000	58.000	48.000
1954	81.000	84.000	86.000	8.000	69.000	135.000	53.000	114.000	69.000	119.000	246.000	89.000
1955	114.000	53.000	76.000	28.000	163.000	152.000	15.000	18.000	38.000	61.000	130.000	142.000
1956	132.000	13.000	33.000	64.000	18.000	71.000	114.000	94.000	119.000	46.000	30.000	140.000
1957	71.000	117.000	76.000	3.000	61.000	30.000	91.000	122.000	173.000	53.000	79.000	114.000
1958	84.000	170.000	46.000	18.000	97.000	104.000	102.000	84.000	196.000	114.000	71.000	112.000
1959	152.000	8.000	102.000	117.000	91.000	74.000	76.000	30.000	5.000	89.000	160.000	264.000
1960	160.000	122.000	89.000	86.000	48.000	58.000	84.000	94.000	142.000	272.000	201.000	132.000
1961	112.000	71.000	5.000	163.000	36.000	48.000	43.000	64.000	79.000	127.000	48.000	107.000
1962	127.000	23.000	48.000	79.000	74.000	15.000	56.000	122.000	114.000	25.000	76.000	76.000
1963	30.000	76.000	137.000	99.000	53.000	79.000	46.000	66.000	46.000	56.000	206.000	38.000
1964	20.000	58.000	102.000	66.000	53.000	69.000	41.000	36.000	28.000	71.000	58.000	109.000
1965	104.000	8.000	114.000	58.000	64.000	76.000	86.000	43.000	152.000	31.000	108.000	155.000
1966	94.000	148.000	39.000	137.000	74.000	66.000	48.000	101.000	43.000	166.000	111.000	96.000
1967	80.000	143.000	72.000	28.000	180.000	25.000	41.000	63.000	124.000	199.000	59.000	85.000
1968	91.000	47.000	80.000	88.000	96.000	81.000	151.000	38.000	139.000	114.000	97.000	113.000
1969	118.000	105.000	96.000	58.000	167.000	51.000	53.000	68.000	66.000	22.000	115.000	83.000
1970	201.000	100.000	73.000	61.000	50.000	49.000	54.000	99.000	64.000	45.000	208.000	39.000
1971	176.000	36.000	80.000	54.000	66.000	130.000	37.000	128.000	42.000	81.000	67.000	48.000
1972	154.000	139.000	93.000	86.000	113.000	74.000	37.000	39.000	63.000	59.000	84.000	176.000
1973	47.000	40.000	23.000	73.000	94.000	43.000	67.000	68.000	83.000	40.000	58.000	60.000
1974	235.000	136.000	50.000	8.000	63.000	92.000	69.000	79.000	166.000	56.000	112.000	70.000
1975	139.000	53.000	100.000	55.000	25.000	16.000	75.000	74.000	101.000	39.000	43.000	38.000
1976	32.000	49.000	69.000	10.000	56.000	21.000	29.000	52.000	1.000	1.000	1.000	1.000

WATER DATA UNIT RETRIEVAL LISTING

05600100 RIVER USK AT CHAIN BRIDGE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	199.000	85.000	107.000	77.000	47.000	117.000	221.000	26.000	104.000	83.000	149.000	241.000
1937	250.000	217.000	143.000	100.000	61.000	44.000	96.000	42.000	68.000	118.000	59.000	113.000
1938	217.000	61.000	15.000	7.000	105.000	92.000	116.000	112.000	61.000	195.000	212.000	162.000
1939	237.000	121.000	78.000	104.000	22.000	93.000	256.000	75.000	25.000	116.000	282.000	86.000
1940	93.000	116.000	112.000	100.000	72.000	25.000	111.000	16.000	66.000	193.000	310.000	97.000
1941	143.000	147.000	110.000	41.000	83.000	52.000	91.000	157.000	31.000	130.000	120.000	116.000
1942	136.000	16.000	109.000	78.000	195.000	8.000	90.000	158.000	101.000	114.000	31.000	218.000
1943	284.000	107.000	33.000	43.000	147.000	101.000	76.000	118.000	136.000	137.000	107.000	78.000
1944	155.000	33.000	12.000	84.000	41.000	78.000	77.000	91.000	127.000	201.000	227.000	124.000
1945	105.000	150.000	64.000	71.000	111.000	132.000	90.000	129.000	112.000	175.000	20.000	205.000
1946	184.000	132.000	47.000	55.000	118.000	125.000	69.000	206.000	207.000	47.000	301.000	151.000
1947	138.000	65.000	268.000	148.000	83.000	73.000	74.000	21.000	71.000	31.000	131.000	110.000
1948	299.000	86.000	77.000	89.000	101.000	135.000	51.000	145.000	122.000	120.000	75.000	291.000
1949	57.000	67.000	52.000	123.000	114.000	23.000	30.000	70.000	78.000	259.000	171.000	143.000
1950	45.000	256.000	91.000	101.000	66.000	61.000	151.000	197.000	185.000	78.000	200.000	88.000
1951	169.000	172.000	152.000	123.000	90.000	86.000	35.000	159.000	126.000	41.000	303.000	168.000
1952	150.000	37.000	93.000	95.000	126.000	93.000	56.000	195.000	96.000	164.000	103.000	123.000
1953	36.000	66.000	98.000	111.000	79.000	56.000	130.000	113.000	135.000	104.000	117.000	51.000
1954	102.000	137.000	118.000	21.000	91.000	158.000	88.000	139.000	140.000	230.000	308.000	140.000
1955	117.000	64.000	93.000	60.000	157.000	165.000	36.000	31.000	63.000	87.000	131.000	198.000
1956	170.000	14.000	64.000	46.000	35.000	87.000	116.000	133.000	151.000	71.100	50.800	180.300
1957	170.200	165.100	132.100	10.200	76.200	33.000	124.500	132.100	213.400	104.100	86.400	142.200
1958	129.500	221.000	40.600	33.000	121.900	104.100	109.200	104.100	221.000	147.300	73.700	137.200
1959	175.300	12.700	132.100	139.700	61.000	73.700	104.100	25.800	7.600	149.900	221.000	350.500
1960	190.500	185.400	88.900	124.500	53.300	68.600	127.000	119.400	149.900	256.500	322.600	200.700
1961	185.400	111.300	15.200	175.300	58.400	53.300	63.500	104.100	124.500	218.400	88.900	132.100
1962	198.100	58.400	55.900	124.500	106.700	35.600	73.700	167.600	167.600	45.700	86.400	96.500
1963	30.500	76.200	205.700	124.500	81.300	106.700	66.000	81.300	73.700	78.700	297.200	45.700
1964	27.900	63.500	101.600	86.400	73.700	78.700	76.200	53.300	45.700	94.000	106.000	224.000
1965	177.000	11.000	113.000	83.000	86.000	120.000	99.000	60.000	169.000	61.000	143.000	296.000
1966	107.000	215.000	77.000	163.000	109.000	93.000	75.000	120.000	75.000	184.000	130.000	209.000
1967	130.000	205.000	92.000	36.000	222.000	36.000	72.000	89.000	174.000	325.000	82.000	119.000
1968	141.000	52.000	142.000	101.000	107.000	122.000	137.000	66.000	177.000	157.000	107.000	121.000
1969	172.000	98.000	82.000	73.000	160.000	68.000	61.000	105.000	71.000	31.000	155.000	138.000
1970	243.000	145.000	82.000	100.000	46.000	61.000	85.000	100.000	102.000	102.000	264.000	63.000
1971	249.000	59.000	92.000	61.000	67.000	133.000	35.000	147.000	37.000	120.000	109.000	76.000
1972	191.000	173.000	135.000	135.000	151.000	111.000	46.000	56.000	65.000	72.000	162.000	275.000
1973	63.000	79.000	42.000	97.000	111.000	48.000	83.000	112.000	119.000	51.000	87.000	109.000
1974	331.000	207.000	51.000	11.000	80.000	93.000	102.000	103.000	257.000	87.000	174.000	162.000
1975	239.000	61.000	101.000	70.000	34.000	17.000	119.000	78.000	161.000	64.000	89.000	85.000
1976	80.000	74.000	76.000	19.000	80.000	21.000	39.000	53.000	241.000	250.000	125.000	133.000

WATER DATA UNIT RETIEVAL LISTING

05600400 RIVER USK AT LLANDETTY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	95.000	214.000	84.000	157.000	128.000	102.000	93.000	119.000	89.000	187.000	132.000	272.000
1967	145.000	211.000	98.000	39.000	210.000	37.000	102.000	90.000	190.000	369.000	89.000	142.000
1968	158.000	47.000	166.000	105.000	109.000	135.000	119.000	89.000	183.000	158.000	113.000	123.000
1969	187.000	98.000	84.000	82.000	162.000	74.000	71.000	138.000	75.000	34.000	169.000	162.000
1970	235.000	165.000	99.000	128.000	39.000	71.000	99.000	95.000	106.000	133.000	278.000	69.000
1971	257.000	69.000	98.000	62.000	75.000	127.000	40.000	164.000	38.000	140.000	133.000	83.000
1972	200.000	175.000	151.000	160.000	162.000	123.000	58.000	65.000	61.000	78.000	192.000	306.000
1973	70.000	105.000	51.000	110.000	109.000	47.000	87.000	140.000	132.000	58.000	110.000	130.000
1974	389.000	236.000	54.000	13.000	88.000	117.000	125.000	106.000	271.000	111.000	201.000	214.000
1975	282.000	62.000	96.000	75.000	37.000	18.000	141.000	76.000	189.000	61.000	112.000	102.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING

05600600 RIVER USK AT TRALLONG

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	215.000	14.000	108.000	109.000	113.000	158.000	118.000	88.000	189.000	95.000	149.000	415.000
1966	93.000	241.000	93.000	179.000	143.000	116.000	113.000	135.000	105.000	205.000	148.000	331.000
1967	172.000	231.000	106.000	48.000	230.000	43.000	140.000	110.000	221.000	451.000	106.000	168.000
1968	193.000	49.000	186.000	117.000	132.000	157.000	108.000	117.000	206.000	173.000	135.000	131.000
1969	218.000	105.000	95.000	97.000	182.000	93.000	79.000	140.000	88.000	42.000	184.000	182.000
1970	251.000	197.000	123.000	176.000	42.000	81.000	126.000	105.000	120.000	174.000	314.000	83.000
1971	283.000	83.000	119.000	74.000	80.000	150.000	38.000	184.000	45.000	166.000	167.000	100.000
1972	221.000	184.000	152.000	184.000	175.000	148.000	81.000	85.000	64.000	81.000	236.000	330.000
1973	81.000	123.000	61.000	111.000	120.000	47.000	81.000	168.000	162.000	69.000	128.000	160.000
1974	435.000	257.000	64.000	17.000	88.000	143.000	156.000	121.000	300.000	136.000	229.000	264.000
1975	326.000	67.000	102.000	92.000	44.000	23.000	146.000	80.000	216.000	65.000	136.000	121.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

06000100 RIVER TOWY AT TY CASTELL

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	203.200	25.400	149.900	160.000	35.600	78.700	124.500	30.500	15.200	228.600	261.600	304.800
1960	236.200	221.000	61.000	127.000	61.000	83.800	162.600	177.800	170.200	203.200	322.600	203.200
1961	188.000	119.400	30.500	175.300	76.200	50.800	83.800	137.200	160.000	279.400	104.100	127.000
1962	223.500	78.700	61.000	132.100	147.300	53.300	86.400	188.000	218.400	76.200	111.800	104.100
1963	22.900	61.000	195.600	132.100	109.200	129.500	88.900	116.800	96.500	94.000	243.800	45.700
1964	33.000	53.300	94.000	83.800	91.400	73.700	96.500	94.000	86.400	142.000	130.000	251.000
1965	179.000	10.000	101.000	95.000	98.000	159.000	121.000	105.000	104.000	93.000	142.000	346.000
1966	94.000	211.000	85.000	159.000	143.000	115.000	112.000	131.000	95.000	212.000	140.000	283.000
1967	165.000	175.000	98.000	46.000	212.000	41.000	150.000	109.000	218.000	396.000	104.000	154.000
1968	178.000	50.000	136.000	106.000	120.000	145.000	117.000	103.000	171.000	165.000	105.000	119.000
1969	211.000	82.000	71.000	93.000	160.000	99.000	59.000	121.000	68.000	50.000	192.000	182.000
1970	215.000	142.000	118.000	161.000	30.000	74.000	108.000	115.000	107.000	160.000	273.000	69.000
1971	221.000	72.000	104.000	62.000	70.000	132.000	45.000	145.000	43.000	129.000	167.000	88.000
1972	177.000	145.000	122.000	147.000	133.000	168.000	82.000	89.000	49.000	77.000	215.000	265.000
1973	70.000	105.000	51.000	89.000	109.000	43.000	91.000	140.000	130.000	62.000	117.000	159.000
1974	339.000	225.000	62.000	17.000	71.000	101.000	134.000	131.000	255.000	152.000	181.000	218.000
1975	300.000	58.000	88.000	116.000	27.000	25.000	115.000	56.000	176.000	78.000	153.000	86.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

06000200 RIVER TEIFI AT GLAN TEIFI

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1959	160.000	22.900	114.300	121.900	38.100	58.400	91.400	30.500	10.200	211.000	243.000	223.000
1960	202.000	164.000	53.000	111.000	57.000	66.000	140.000	168.000	171.000	188.000	279.400	167.600
1961	154.900	99.100	25.400	162.600	61.000	50.800	96.500	127.000	147.300	243.800	94.000	111.800
1962	177.800	63.500	50.800	124.500	101.600	48.300	71.100	152.400	198.100	63.500	106.700	106.700
1963	27.900	66.000	180.300	116.800	94.000	114.300	50.800	96.500	86.400	86.400	231.100	27.900
1964	35.600	38.100	76.200	61.000	76.200	71.100	91.400	94.000	53.300	137.000	107.000	209.000
1965	160.000	12.000	98.000	91.000	78.000	106.000	98.000	80.000	179.000	62.000	136.000	315.000
1966	81.000	163.000	64.000	124.000	101.000	101.000	102.000	86.000	80.000	180.000	115.000	242.000
1967	129.000	141.000	70.000	40.000	168.000	40.000	125.000	94.000	183.000	271.000	108.000	140.000
1968	154.000	44.000	88.000	110.000	100.000	105.000	90.000	65.000	134.000	128.000	76.000	119.000
1969	182.000	83.000	66.000	85.000	128.000	90.000	48.000	107.000	52.000	43.000	175.000	169.000
1970	179.000	134.000	113.000	134.000	29.000	75.000	86.000	102.000	83.000	143.000	244.000	66.000
1971	179.000	62.000	89.000	57.000	53.000	130.000	63.000	150.000	42.000	107.000	153.000	99.000
1972	167.000	140.000	107.000	115.000	106.000	147.000	77.000	67.000	44.000	74.000	160.000	196.000
1973	75.000	77.000	43.000	68.000	88.000	22.000	87.000	114.000	113.000	70.000	117.000	134.000
1974	326.000	183.000	67.000	19.000	80.000	80.000	104.000	91.000	210.000	160.000	142.000	156.000
1975	226.000	41.000	66.000	108.000	30.000	19.000	82.000	67.000	119.000	70.000	135.000	79.000
1976	95.000	72.000	83.000	27.000	84.000	17.000	30.000	16.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

DATA IN MM.

05400530 RIVER SEVERN AT UP SEVERN

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	124.183	179.247	37.339	30.941	109.499	108.136	141.489	101.004	203.580	98.591	66.601	111.911
1959	142.831	14.580	66.119	116.919	61.498	75.208	92.900	30.251	7.229	131.993	120.842	218.675
1960	177.538	111.315	52.157	68.194	42.384	67.569	113.176	146.020	130.391	160.617	206.967	165.238
1961	126.735	79.209	22.035	101.121	54.410	34.735	74.710	103.105	83.425	151.917	84.558	104.858
1962	150.926	73.221	59.637	113.322	84.417	29.137	68.229	142.211	137.717	46.317	66.368	116.299
1963	36.859	29.137	122.799	98.376	70.227	102.361	49.808	85.921	86.297	56.290	219.526	30.890
1964	34.486	37.108	75.458	68.619	63.270	60.380	81.690	57.159	51.810	92.802	86.728	197.424
1965	137.039	16.560	101.558	86.704	93.363	108.069	89.535	64.509	154.144	51.728	125.607	279.134
1966	71.802	137.139	61.581	112.802	91.216	86.584	74.046	84.072	61.363	128.877	135.848	175.602
1967	65.728	145.239	77.437	36.437	175.581	41.414	84.802	70.483	154.432	232.010	66.265	134.141
1968	143.139	38.170	106.771	34.179	117.512	100.974	141.830	93.316	163.725	105.188	83.851	95.265
1969	112.193	113.581	93.560	82.167	193.365	44.753	50.049	95.342	68.463	31.486	170.969	101.995
1970	115.532	137.504	98.144	107.237	35.974	65.974	68.388	133.512	74.239	91.139	214.481	52.021
1971	133.581	58.093	64.584	57.609	35.219	101.632	43.632	128.753	38.121	107.992	117.337	53.072
1972	120.581	87.291	100.069	103.995	102.555	103.802	94.486	55.997	40.951	51.365	120.139	157.139
1973	47.095	72.728	33.949	95.681	112.656	29.463	133.853	124.897	123.239	83.851	66.995	82.800
1974	120.944	126.504	50.242	9.707	46.316	75.584	100.872	65.535	190.771	90.021	157.237	129.769
1975	154.941	38.632	71.632	71.776	49.049	19.072	76.483	62.925	90.774	50.925	80.555	74.069
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

DATA IN MM.

05400150 RIVER SEVERN AT MID SEVERN

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1937	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1938	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1941	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1942	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1943	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1944	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1945	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1946	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1947	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1948	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1958	62.927	107.529	26.010	12.200	56.073	104.980	124.746	91.975	144.268	34.410	44.320	82.818
1959	94.336	5.798	63.711	90.629	41.820	57.020	53.626	30.500	2.899	60.666	100.618	123.484
1960	130.248	54.746	39.009	32.927	47.901	59.010	78.627	109.127	127.211	138.713	115.673	84.264
1961	70.046	50.328	8.421	99.399	36.720	26.010	76.200	63.638	57.629	76.265	31.547	71.027
1962	36.966	28.437	27.528	73.926	62.518	16.209	63.711	109.127	96.638	19.529	54.309	47.755
1963	28.510	16.209	62.745	53.837	35.339	75.517	41.210	45.838	50.727	44.109	97.102	9.118
1964	11.718	28.510	71.499	47.218	47.008	51.410	45.627	34.518	10.426	51.750	37.348	71.728
1965	69.098	11.359	75.793	53.272	50.870	67.750	92.880	42.554	144.717	19.272	90.391	142.326
1966	40.152	93.424	36.793	90.554	69.554	80.478	70.359	85.000	39.554	107.435	76.065	106.783
1967	37.033	70.022	45.152	21.076	137.630	26.837	43.750	40.152	92.304	113.250	46.435	70.304
1968	68.141	33.359	36.902	58.674	86.033	70.033	118.435	41.348	103.185	58.348	50.272	62.272
1969	59.467	77.511	54.511	49.272	178.957	26.315	48.120	91.239	18.228	12.315	102.304	57.109
1970	81.591	63.141	64.272	64.109	14.435	42.554	54.957	113.315	38.511	33.065	142.902	30.554
1971	89.348	24.391	67.880	58.000	51.043	82.315	31.837	112.196	25.837	66.989	79.630	29.554
1972	95.913	58.913	65.391	32.783	65.630	60.870	64.033	41.076	46.641	46.359	56.424	95.304
1973	28.315	36.511	20.957	66.913	83.033	35.641	105.793	59.424	63.065	55.913	50.315	43.750
1974	94.859	65.185	44.478	10.000	31.957	48.793	51.467	59.478	98.337	64.793	76.500	41.217
1975	72.739	24.957	52.315	61.837	35.837	20.000	55.554	43.315	47.109	20.033	45.511	43.152
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

DATA IN MM.

05507654 RIVER WYE AT UP WYE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	155.942	57.671	76.405	71.181	52.981	119.786	167.593	19.731	118.494	126.129	153.595	189.141
1937	190.426	201.075	102.590	90.366	48.279	49.754	77.730	33.294	83.928	102.145	45.737	101.195
1938	191.743	61.171	12.037	4.966	91.277	76.451	105.163	89.565	38.887	172.705	195.850	130.068
1939	190.438	121.251	68.607	93.427	25.628	64.343	206.149	63.156	22.703	73.454	252.275	84.006
1940	79.497	92.032	93.096	81.375	58.510	25.270	123.369	14.364	54.004	147.897	288.834	102.573
1941	91.468	119.373	91.319	41.351	89.749	42.904	69.390	148.175	43.231	121.099	115.105	98.378
1942	130.021	18.420	83.800	74.756	152.647	14.427	86.794	99.816	74.957	101.653	28.848	161.574
1943	214.398	104.358	22.951	37.259	99.994	97.484	66.207	107.667	122.156	124.647	129.895	55.322
1944	120.209	36.952	13.490	45.758	44.741	60.662	57.178	84.848	100.842	185.201	186.344	115.524
1945	90.836	116.605	45.549	49.092	101.761	126.858	58.792	99.659	71.250	146.079	22.548	151.413
1946	145.027	163.517	34.007	48.468	94.897	95.736	63.943	182.182	162.589	47.828	240.159	125.137
1947	104.560	55.966	236.572	97.544	79.501	51.182	61.607	13.893	60.173	22.870	116.181	117.879
1948	265.804	84.053	60.092	83.136	91.987	105.659	45.288	97.945	89.604	85.420	73.148	218.258
1949	52.742	46.916	56.788	92.178	103.407	23.085	25.656	67.735	56.505	139.604	167.452	159.017
1950	41.584	215.270	52.806	95.189	43.985	47.466	110.223	151.972	167.717	65.315	163.189	71.793
1951	130.267	116.027	142.173	112.763	75.275	29.212	40.726	132.834	85.424	32.264	251.662	129.848
1952	142.466	40.238	64.304	71.323	87.805	80.142	44.681	125.483	91.850	153.574	88.246	129.591
1953	39.508	69.001	93.181	93.913	55.682	41.732	114.499	110.072	118.961	76.564	99.252	43.827
1954	98.961	105.523	91.456	25.419	77.507	146.555	90.183	171.052	109.408	173.689	250.521	122.780
1955	98.975	64.397	103.256	54.852	158.679	151.510	38.487	38.618	60.933	74.137	92.051	146.377
1956	151.672	13.302	47.066	47.528	21.570	81.205	105.134	133.275	125.367	61.677	50.859	129.755
1957	100.692	120.676	101.335	7.279	63.768	50.565	103.472	143.681	206.789	89.798	99.081	98.487
1958	119.204	194.289	33.914	31.031	99.335	117.878	134.390	93.623	193.121	122.493	73.782	130.460
1959	154.151	11.825	91.827	133.027	80.656	82.912	96.943	24.491	4.935	138.513	166.953	257.912
1960	184.518	144.645	74.026	97.491	45.546	69.709	120.734	109.899	130.224	194.169	254.673	184.795
1961	160.079	38.698	16.289	141.742	61.888	34.435	65.366	93.469	112.899	196.782	87.545	124.449
1962	180.124	64.391	54.740	123.294	99.887	30.022	74.766	170.892	171.614	47.163	66.658	99.909
1963	27.108	42.132	140.226	102.248	84.466	104.147	62.198	74.866	76.431	68.449	234.294	33.936
1964	25.384	39.794	70.574	70.432	72.512	61.329	71.834	56.047	46.749	104.450	106.568	199.410
1965	173.705	9.461	100.277	86.550	86.703	100.339	92.290	68.812	148.815	56.644	120.726	289.194
1966	71.478	164.782	70.462	116.168	104.240	90.179	83.137	86.032	71.442	145.955	131.364	215.235
1967	92.307	155.073	77.363	35.395	173.203	37.379	114.500	103.643	166.282	266.710	78.485	131.999
1968	153.085	37.035	118.773	81.777	116.378	116.623	105.820	71.442	141.785	117.100	79.671	97.924
1969	144.173	90.634	76.685	79.595	172.116	57.949	62.232	106.897	52.354	35.610	149.439	122.784
1970	141.377	175.875	85.637	111.441	29.179	59.179	78.748	95.620	87.264	99.157	229.634	61.195
1971	169.532	65.554	80.213	46.477	55.386	97.815	28.438	116.304	34.892	115.803	110.547	71.083
1972	136.817	107.780	115.388	136.219	110.143	101.222	58.212	54.366	49.839	51.135	162.320	189.315
1973	55.896	100.909	37.813	99.634	103.110	25.696	109.274	98.730	137.019	67.307	86.520	109.086
1974	244.226	176.777	51.552	10.783	64.149	86.394	112.109	86.530	205.806	104.368	170.955	190.894
1975	198.633	42.167	72.904	78.770	34.975	14.707	90.806	76.807	129.131	54.090	104.813	82.718
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

DATA IN MM.

05500270 RIVER WYE AT MID WYE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	152.087	75.165	95.251	65.545	51.814	125.713	157.086	9.554	74.390	-20.525	55.617	134.492
1937	123.315	137.491	111.982	47.216	86.963	-3.775	114.869	57.612	44.661	165.749	50.992	66.480
1938	42.577	-1.308	-12.064	3.822	56.836	32.952	80.655	127.867	57.257	63.905	103.520	119.093
1939	137.082	38.885	43.839	36.542	18.731	58.547	148.667	43.105	24.996	111.870	116.565	17.511
1940	113.692	73.100	42.217	79.721	70.255	24.996	88.210	3.378	49.282	109.384	206.770	55.949
1941	143.309	75.212	101.983	32.551	58.836	58.434	75.988	88.499	36.816	60.504	75.656	51.038
1942	77.768	12.554	69.273	48.927	98.942	8.732	56.393	87.275	47.660	50.506	14.554	110.673
1943	163.816	52.216	26.729	21.266	81.832	73.100	37.662	65.214	104.829	90.565	49.328	48.104
1944	79.767	15.932	17.997	37.550	9.667	49.282	49.282	88.986	60.214	104.875	129.493	54.683
1945	51.393	58.504	36.373	27.108	91.541	95.653	81.431	144.131	48.838	131.535	18.819	118.649
1946	77.324	37.578	31.817	57.168	103.250	71.834	54.281	190.525	140.379	27.108	192.926	60.504
1947	31.921	54.725	150.424	93.541	64.368	45.549	54.281	24.262	40.106	18.731	64.681	64.770
1948	143.270	43.395	38.928	60.102	84.809	74.390	30.107	132.422	76.922	82.365	53.103	174.107
1949	24.575	36.373	24.664	56.393	70.657	13.731	35.994	29.663	76.432	156.643	100.320	34.288
1950	5.490	143.224	41.283	52.216	52.169	46.815	103.539	137.823	100.610	48.104	132.469	38.396
1951	84.037	99.829	103.207	49.683	105.693	23.730	22.108	85.210	82.365	22.552	192.482	81.501
1952	66.059	8.460	49.370	60.546	90.985	64.279	31.373	172.037	51.393	118.649	86.542	74.768
1953	15.932	38.839	25.510	82.365	50.548	36.728	64.770	71.479	79.389	79.809	46.773	41.727
1954	72.856	71.390	71.923	2.023	55.103	108.650	41.773	91.499	59.682	111.052	227.631	82.678
1955	102.806	54.370	62.658	20.398	127.825	124.825	17.464	16.287	28.397	53.837	93.984	109.384
1956	73.499	4.555	15.399	46.815	12.554	55.103	113.981	72.324	95.653	43.927	24.664	114.916
1957	65.214	96.530	66.391	9.998	49.370	36.373	99.829	108.940	122.428	60.214	63.835	96.096
1958	68.947	143.757	37.994	16.267	87.364	91.097	120.359	73.100	201.701	90.565	68.545	90.565
1959	131.647	8.732	73.100	85.210	73.988	64.279	71.834	38.438	7.999	86.500	133.646	226.365
1960	151.200	123.648	60.546	81.099	50.992	60.546	86.383	93.097	130.712	217.675	201.747	126.493
1961	103.941	62.658	8.377	140.799	35.106	40.993	38.839	65.657	76.833	129.493	48.394	106.095
1962	110.236	29.219	30.107	80.122	67.657	11.288	64.723	110.762	92.232	20.931	75.988	58.948
1963	35.994	46.726	134.090	102.352	58.836	61.481	54.725	47.572	41.395	50.104	198.369	42.259
1964	15.110	57.257	80.987	63.546	50.104	68.989	39.662	33.840	20.931	66.391	49.683	129.049
1965	89.789	3.733	93.541	42.217	47.572	76.100	92.807	37.662	132.824	40.194	108.272	146.471
1966	71.633	115.850	45.838	131.156	91.275	64.835	48.660	104.161	44.838	156.063	103.562	76.660
1967	76.011	135.001	66.279	26.463	165.440	111.024	50.950	51.127	131.292	215.656	52.660	82.856
1968	63.437	28.905	71.055	84.631	87.831	98.274	177.102	48.104	120.826	103.007	93.162	102.717
1969	116.560	121.513	75.544	39.395	171.794	38.017	50.637	82.921	47.637	19.198	96.764	87.299
1970	169.150	63.083	62.658	36.886	50.613	58.813	52.837	86.364	60.925	41.507	173.486	22.487
1971	155.087	15.955	69.367	55.080	67.167	107.894	51.436	138.333	42.082	66.125	54.594	46.016
1972	129.302	117.892	78.478	46.796	99.362	83.099	36.195	25.842	62.256	51.814	59.261	174.995
1973	31.541	15.890	17.198	60.569	101.540	49.613	56.126	59.392	11.269	16.044	48.216	40.063
1974	164.040	103.231	46.548	8.910	62.723	81.720	53.860	73.367	137.403	34.597	55.084	26.136
1975	110.436	55.257	102.516	43.572	28.729	13.909	82.543	73.899	83.388	45.460	24.066	34.219
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WATER DATA UNIT RETRIEVAL LISTING (I.C.L. MAG. TAPE TYPE B FORMAT)

DATA IN MM.

05500120 RIVER WYE AT LOW WYE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1936	129.662	67.232	70.158	62.810	27.736	107.505	138.431	6.810	78.084	48.315	91.662	111.978
1937	123.167	155.820	93.158	55.084	52.695	22.926	84.579	33.579	53.389	101.389	41.579	68.084
1938	104.052	24.736	3.579	2.347	59.505	48.968	78.084	88.158	41.579	97.820	113.399	106.084
1939	164.662	55.589	42.736	66.852	21.232	48.273	146.473	48.926	21.232	77.810	157.325	47.736
1940	81.926	75.158	50.084	86.000	64.000	25.000	81.010	2.926	28.315	118.736	204.746	51.241
1941	121.421	92.505	68.084	29.810	63.389	57.421	62.810	99.894	31.579	66.241	82.505	53.662
1942	86.662	13.579	72.810	49.505	114.968	5.579	37.473	100.232	50.736	52.473	21.232	121.662
1943	177.084	50.662	27.347	28.579	95.810	46.894	38.852	58.010	79.241	76.894	63.010	44.505
1944	66.052	20.273	8.579	34.810	25.926	41.505	47.158	70.158	71.852	115.820	125.820	71.315
1945	51.315	54.820	26.505	34.810	68.084	83.662	76.653	107.579	53.389	113.736	17.347	134.926
1946	91.010	83.978	24.695	53.000	97.000	61.315	42.736	161.431	115.820	29.158	178.820	86.968
1947	73.084	51.579	190.010	85.158	82.768	46.579	57.810	27.421	36.505	11.810	71.894	64.241
1948	177.978	48.968	39.505	62.158	89.000	72.431	26.505	97.505	71.852	72.505	49.505	161.473
1949	35.389	35.926	37.158	69.505	68.084	16.232	24.695	36.505	62.232	172.926	104.589	58.325
1950	16.505	155.241	48.579	56.315	44.232	41.579	95.158	112.241	98.978	35.084	137.852	53.389
1951	81.010	103.158	111.084	66.315	89.000	16.810	24.158	89.315	76.273	23.579	213.315	81.589
1952	82.241	15.852	52.695	57.810	87.232	48.968	30.926	143.232	70.158	121.736	91.347	70.473
1953	16.505	41.505	40.662	81.926	51.579	43.000	73.662	82.505	88.736	68.926	55.662	38.579
1954	60.662	71.315	72.505	11.810	62.810	109.852	50.662	106.662	61.241	108.399	193.052	80.473
1955	51.926	44.505	69.505	35.389	130.505	123.736	26.232	17.926	37.736	52.736	95.232	109.315
1956	114.315	11.232	34.158	51.000	17.347	53.389	91.389	95.431	93.084	44.505	31.505	109.852
1957	63.662	95.736	66.315	0.579	48.926	32.158	74.241	106.126	147.589	49.241	68.389	83.084
1958	79.315	152.662	38.000	17.926	71.852	83.736	91.662	75.158	164.662	95.736	69.579	95.736
1959	123.431	5.579	78.926	89.315	55.158	48.968	61.315	22.347	2.347	77.167	131.084	201.820
1960	145.894	96.589	61.579	62.431	41.579	52.158	73.126	91.389	118.158	204.768	163.556	103.978
1961	89.820	60.084	4.158	145.000	31.505	41.000	41.505	48.010	66.315	101.325	38.894	93.084
1962	99.610	14.473	41.579	67.473	61.315	9.158	61.579	114.010	100.473	21.505	66.579	63.662
1963	24.695	39.810	107.894	79.315	48.315	72.505	45.926	67.810	45.084	42.736	154.978	24.695
1964	20.926	35.926	81.000	49.505	46.505	53.926	33.315	36.505	21.505	56.894	47.473	98.135
1965	67.746	10.000	79.505	50.084	52.736	66.852	97.000	35.084	131.736	28.852	93.547	144.103
1966	61.158	113.894	39.084	96.852	74.084	59.968	44.199	86.810	41.852	121.968	93.662	94.598
1967	63.199	99.589	60.389	22.042	150.852	-2.948	31.167	64.852	114.473	166.367	50.084	76.473
1968	86.052	55.347	56.704	72.273	84.852	67.894	117.579	35.084	108.431	93.968	70.158	86.389
1969	95.473	71.315	72.810	50.621	143.968	45.926	47.695	68.431	40.926	17.273	92.473	62.936
1970	149.926	73.978	58.199	57.241	37.884	63.000	57.389	106.653	55.852	35.936	167.936	39.158
1971	140.199	53.852	72.895	43.579	44.158	98.695	22.158	94.199	36.232	72.315	71.431	38.852
1972	118.084	97.389	76.315	69.741	91.389	66.315	39.926	32.273	50.347	54.116	86.704	143.357
1973	42.042	38.126	22.810	67.621	89.389	36.884	71.736	55.547	70.736	43.158	50.431	54.357
1974	166.209	113.357	40.042	7.232	44.505	61.621	64.431	67.273	133.936	49.547	96.126	64.135
1975	105.441	39.579	76.810	50.621	29.347	14.116	74.158	55.273	85.199	33.505	44.010	43.968

METEOROLOGICAL OFFICE INFORMATION SHEET RELATING TO THE EVAPOTRANSPIRATION MAP OF THE UNITED KINGDOM

PROVISIONAL AVERAGE ANNUAL POTENTIAL EVAPORATION

The map, which is based on the Penman (1948) formula for calculating evaporation, purports to show average annual potential evaporation for a surface with albedo of 0.25, which is considered representative of many vegetated surfaces, including grass. The number of stations with calculated averages of evaporation is inadequate to prepare a definitive map for the United Kingdom, particularly for altitudes greater than 200 metres.

In Grindley (1970) a map of potential evaporation was presented for England and Wales and it was explained that for many river authority areas, evaporation estimates were prepared at 10 km grid intersections using regression of calculated evaporation mainly on altitude, grid northing and distance from coast. For remaining areas a simple height relationship was used. The relationship, obtained from MAFF Technical Bulletin No 16 (1967), allowed for a variation of about 29 mm evaporation per 100 m.altitude, the quantity to be added or subtracted to the value for a mean county altitude depending on the difference between county altitude and that of the grid intersection. The map now presented is similar to that in Grindley (1970) but nodal estimates have been expressed in mm and different isopleth spacing is used. Major amendments have been made in one or two areas and there are several different points of detail. For Scotland and Northern Ireland the map is based solely on the extrapolation in MAFF Technical Bulletin No 16, and for Scotland nodal values refer to smoothed topography at the node.

One major disadvantage of the map is the lack of a standard period on which the estimates are based. For the regression analysis, averages were mainly based on years within the period 1954-66 and for the simple height relationship the period 1950-1964 was used.

Slightly different versions of the Penman formula were also used in the two periods. A second major disadvantage is the uncertainty of extrapolation with altitude; isopleths at altitudes greater than 200 m, where little factual data exist, must be treated with caution. Considerable modification may be required as data from more stations particularly at greater altitudes become available. Calculated evaporation is available for a few stations at altitudes greater than 500 m. A comparison between calculated values and height adjusted values is:

Station	NGR	Altitude (metres)	Evaporation (mm) calculated	height adjusted
Clee Hill	32/599779	504	386	389
North Hessary Tor	20/577742	510	422	415
Moor House	35/758328	558	411	340
Lowther Hill	26/890107	723	295	294
Great Dun Fell	35/710322	847	290	264
Ben Nevis	27/167713	1341	232	62

Apparently, for great altitudes (above 1250 m) the simple evaporation-height relationship fails, but up to 850 m a fair agreement is discernible. The use of topography-smoothed altitudes in Scotland mitigates the effect of extreme altitude; for the near Ben Nevis node, a height adjusted value of 191 mm was calculated.

In Western Scotland, a discontinuity between isopleths over the mainland and over the Islands is apparent; it is not permissible to interpolate isopleths over the sea. In coastal areas, evaporation values may be a few per cent higher than those shown on the map.

References

Penman H L (1948) Natural evaporation from open water, bare soil and grass. Proc. R.Soc., London A, 193, pp 120-145.

Grindley, J (1970) Estimation and mapping of evaporation. IASH Symp. World Water Balance, Reading, July 1970.

Ministry of Agriculture, Fisheries and Food (1967) Technical Bulletin No 16, Potential Transpiration, London, Her Majesty's Stationery Office.

APPENDIX II

COMPUTER PROGRAMS

1 Program 'STATANAL'

2 Program 'CROSS'

3 Program 'CONSISTENT'

4 Program 'RAIN'

5 Program 'SOIL'

1 Program 'STATANAL'

This program provides comprehensive statistical analyses of specified monthly data sets. These data sets are selected from file storage by specifying their station numbers and length of record in terms of start and finish dates.

The program begins by calling subroutine 'TAPE B' which reads the station number and the appropriate data set. The program then calls subroutine 'MFANAL' (i.e. Monthly Flow Analysis) which forms the major part of the program and calculates the following statistics:

QBAR(J) = mean flow for jth month

SD(J) = standard deviation of jth month flows

CS(J) = skewness coefficient of jth month flows

R(J) = lag-one serial correlation coefficient for jth month

B(J) = lag-one regression coefficient for jth month

RATIO(J) = QBAR(J)/SD(J)

In addition to these monthly statistics two subroutines calculate statistics relating to the mean annual flows. They are:

'BSTAT' (i.e. Basic Statistics) which calculates mean, standard deviation and skewness coefficient; and

'SERCOR' which calculates the serial correlation coefficients from lag-one to lag-fifteen.

Finally the linear regression subroutine 'LINREG' is called to calculate the linear regression coefficients between CS(J) and RATIO(J).

The basic input identifiers are as defined below:

STATION = gauging station number

NYRS = number of years of record

Q(I, J) = Flow in month (J) and year (I)

F19XX, T19XX First and last years of selected record.

Although this program was designed for the analysis of flow data it can, of course be used for the analysis of any set of data, and was in fact used for the analysis of the rainfall data.

```
      MASTER STATANAL
      REAL MEWY,MEW
      COMMON /ROOTS/SKEW,AVAR,RRR,X,MEWY,RAWY,V
      DIMENSION Q(50,12),QBAR(12),SD(12),QYR(600),R(12),B(12),SDR(12),
     1SUM1(12),SUM2(12),SUM3M(12),CS(12),RATIO(12),VAR(12)
      DIMENSION MEW(12),RAW(12),XXX(12),V(12),SQBAR(12),SSD(12),SCS(12)
      CALL TAPED(Q,NYRS)
      IF(NYRS.EQ.0.) STOP
      CALL MFANAL (Q,NYRS)
      STOP 1000
      END


      SUBROUTINE TAPER(Q,NYRS)
      INTEGER F19XX,SKIP,T19XX,STATNO,STATON
      DIMENSION Q(50,12)
      DATA FINISH/'          '/
      WRITE(6,1)
      READ(1,2) STATON
      IF(STATON.EQ.FINISH) GO TO 6
 9    WRITE(6,3)
      READ(1,4) F19XX,T19XX
      IF(F19XX.LT.1936.OR.T19XX.GT.1976.OR.F19XX.GT.T19XX) GO TO 9
      NYRS=T19XX-F19XX+1
7     CALL GAP(2)
      READ(7,5,END=999) STATNO
        WRITE(2,5) STATNO
      IF(STATON.EQ.STATNO) GO TO 8
      CALL GAP(43)
      GO TO 7
 8    SKIP=F19XX-1936+2
      CALL GAP(SKIP)
      READ(7,11) ((Q(I,J),J=1,12),I=1,NYRS)
      WRITE(2,100) ((Q(I,J),J=1,12),I=1,NYRS)
 15   END FILE 7
      RETURN
 6    NYRS=0
      GO TO 15
 999  WRITE(6,12)
      END FILE 7
      STOP 2000
 1    FORMAT(' WHICH STATION NUMBER ?'/)
 2    FORMAT(I8)
 3    FORMAT(' BETWEEN WHAT YEARS (1936-1976) ?'/)
  4   FORMAT(2I0)
5     FORMAT(17X,I8)
 11   FORMAT(10X,12F0.0)
 12   FORMAT(' END OF DATA. INCORRECT STATION NUMBER.'/)
  100 FORMAT(10X,12F0.3)
      END


        SUBROUTINE GAP(J)
        DO 1 I=1,J
        READ(7,2) A
 2        FORMAT(A8)
  1   CONTINUE
        RETURN
        END
```

```
      SUBROUTINE TAPER1(Q,NYRS)
      DIMENSION Q(50,12)
      INTEGER F19XX,T19XX,STATION
      COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
      READ(1,100) STATION
 100  FORMAT(I0)
      WRITE(2,201) STATION
 201  FORMAT(//,5X, 'STATION NO. =',I8,/)
      DO 300 I=1,NST
      IF(NSTAT(I).NE.STATION) GO TO 300
      READ(1,102) F19XX,T19XX
 102  FORMAT(2I0)
C     WRITE(2,202) F19XX, T19XX
 202  FORMAT(5X,'BETWEEN THE YEARS ',I6, ' AND',I6)
      IF(F19XX.LT.1936.OR.T19XX.GT.1976.OR.F19XX.GT.T19XX) GO TO 9
      NYRS=T19XX-F19XX+1
      J1=F19XX-1936+1
      J2=T19XX-F19XX+J1
      DO 301 J=J1,J2
      L=J-J1+1
      DO 302 K=1,12
 302  Q(L,K)=D(I,J,K)
C     WRITE(2,205) (Q(L,K),K=1,12)
 301  CONTINUE
      GO TO 310
 300  CONTINUE
      GO TO 310
C     WRITE(2,200)
 200  FORMAT(//,' STATION NOT AVAILABLE')
 205  FORMAT(10X,12F6.3)
 310  RETURN
      END
```

```
        SUBROUTINE GAP(J)
        DO 1 I=1,J
        READ(7,2) A
 2        FORMAT(A8)
 1    CONTINUE
        RETURN
        END
```

```
      SUBROUTINE MEANAL (Q,NYRS)
      REAL NEWY,NEW
      COMMON /ROOTS/SKEW,AVAR,RRR,XBAR,X,NEWY,RAWY,V
      DIMENSION Q(50,12),QBAR(12),SD(12),QYR(600),R(12),B(12),SDR(12),
     1SUM1(12),SUM2(12),SUM3(12),SUM3M(12),CS(12),RATIO(12),VAR(12)
      DIMENSION NEW(12),RAW(12),XXX(12),V(12),RC(16),RNEW(50,12)
      DIMENSION SQBAR(12),SSD(12),SCS(12)
      L=0
      DO 4 I=1,NYRS
      DO 4 J=1,12
      L=L+1
4     QYR(L)=Q(I,J)
      NDAT=NYRS*12
      CALL BSTAT (QYR,NDAT,AA1,AA2,AA3)
C
C     CALC. MONTHLY MEAN FLOWS
C
      DO 6 J=1,12
      SUM1(J)=0.0
      DO 5 I=1,NYRS
5     SUM1(J)=SUM1(J)+Q(I,J)
      QBAR(J)=SUM1(J)/NYRS
    6 CONTINUE
C
C     CALC. YEARLY FLOWS, MEAN AND STAND. DEV. OF YEARLY FLOWS
C
      DO 17 I=1,NYRS
      QYR(I)=0.0
      SUM4=0.0
      DO 16 J=1,12
16    QYR(I)=QYR(I)+Q(I,J)
17    SUM4=SUM4+QYR(I)
      QYRBAR=SUM4/NYRS
      SUM5=0.0
      DO 18 I=1,NYRS
18    SUM5=SUM5+(QYR(I)-QYRBAR)**2
      A3=SUM5/(NYRS-1)
      SDQYR=SQRT(A3)
C
C     CALC. MONTHLY STAND. DEV. SD(J) AND MONTHLY SKEWNESS COEFF. CS(J)
C
      DO 7 J=1,12
      DO 7 I=1,NYRS
7     Q(I,J)=Q(I,J)-QBAR(J)
      DO 9 J=1,12
      SUM2(J)=0.0
      SUM3M(J)=0.0
      DO 8 I=1,NYRS
      SUM2(J)=SUM2(J)+Q(I,J)*Q(I,J)
8     SUM3M(J)=SUM3M(J)+Q(I,J)**3
      AM2=SUM2(J)/NYRS
      AM3=SUM3M(J)/NYRS
      CS(J)=NYRS*NYRS*AM3/((NYRS-1)*(NYRS-2)*AM2**1.5)
      VAR(J)=SUM2(J)/(NYRS-1.)
9     SD(J)=SQRT(VAR(J))
```

```
C
C     CALC. MONTHLY RATIO OF MEANS/STAND. DEV.
C
      DO 3 J=1,12
 3    RATIO(J)=QBAR(J)/SD(J)
C
C     CALC R(J) CORRELATION COEFF MONTH 1 WITH MONTH 12 OF PREVIOUS YEAR
C
      SUM3(1)=Q(2,1)*Q(1,12)
      DO 10 I=3,NYRS
 10   SUM3(1)=SUM3(1)+Q(I,1)*Q(I-1,12)
      A=SUM2(1)*SUM2(12)
      R(1)=SUM3(1)*NYRS/(SQRT(A)*(NYRS-1))
C
C     CALC. R(2) TO R(12) - CORRELATION COEFF'S MONTH J WITH MONTH J-1.
C
      DO 11 J=2,12
 11   SUM3(J)=0.0
      DO 13 J=2,12
      DO 12 I=1,NYRS
 12   SUM3(J)=SUM3(J)+Q(I,J)*Q(I,J-1)
      A1=SUM2(J)*SUM2(J-1)
 13   R(J)=SUM3(J)/SQRT(A1)
C
C     CALC. B(1) TO B(12)
C
      B(1)=R(1)*SD(1)/SD(12)
      DO 14 J=2,12
 14   B(J)=R(J)*SD(J)/SD(J-1)
C
C     CALC. MONTHLY STAND. DEV. OF RESIDUALS SDR(J)
C
      DO 19 J=1,12
        RJ=R(J)
        FNYRS=NYRS
        A2=(FNYRS-1.)*(1.-RJ*RJ)/FNYRS
 19   SDR(J)=SD(J)*SQRT(A2)
C
C     CALC. STANDARDIZED MONTHLY MEAN, STAND. DEV. AND SKEW. COEFF.
C
      DO 31 J=1,12
 31   SQBAR(J)=QBAR(J)/AA1
      DO 32 J=1,12
 32   SSD(J)=SD(J)/AA2
      DO 33 J=1,12
 33   SCS(J)=CS(J)/AA3
C
C     RESET Q(I,J) TO TRUE VALUES
C
      DO 20 I=1,NYRS
      DO 20 J=1,12
 20   Q(I,J)=Q(I,J)+QBAR(J)
C
C     PRINT RESULTS
C
      WRITE(2,50)
 50   FORMAT(//,5X,5HMONTH,6X,2H 1,7X,2H 2,6X,2H 3,6X,2H 4,6X,2H 5,6X,
     12H 6,6X,2H 7,6X,2H 8,6X,2H 9,6X,2H10,7X,2H11,7X,2H12)
      WRITE(2,51) (QBAR(J),J=1,12)
 51   FORMAT(/,5X,9HMEAN FLOW,(12(2X,F6.2)))
```

```
      WRITE(2,52) (SD(J),J=1,12)
52    FORMAT(/,5X,9HSTAND DEV,(12(2X,F6.2)))
      WRITE(2,53) (SDR(J),J=1,12)
53    FORMAT(/,5X,3HSDR,6X,(12(2X,F6.2)))
      WRITE(2,54) (R(J),J=1,12)
54    FORMAT(/,5X,1HR,8X,(12(2X,F6.2)))
      WRITE(2,55) (B(J),J=1,12)
55    FORMAT(/,5X,1HB,8X,(12(2X,F6.2)))
      WRITE(2,58) (CS(J),J=1,12)
58    FORMAT(/,5X,2HCS,7X,(12(2X,F6.2)))
      WRITE(2,59) (RATIO(J),J=1,12)
59    FORMAT(/,5X,5HRATIO,4X,(12(2X,F6.2)))
      WRITE(2,49) (VAR(J),J=1,12)
49    FORMAT(/,5X,5HVAR  ,4X,(12(1X,F7.2)))
      WRITE(2,60)
60    FORMAT(//,30X,'STANDARDIZED MONTHLY MEAN FLOW, STAND. DEV.AND SK
     1. COEFF.')
      WRITE(2,50)
      WRITE(2,51) (SQBAR(J),J=1,12)
      WRITE(2,52) (SSD(J),J=1,12)
      WRITE(2,58) (SCS(J),J=1,12)
      WRITE(2,56)
56    FORMAT(//,32X,12H ANNUAL FLOW,//28X,4HYEAR,12X,7H QYR(I))
      DO 15 I=1,NYRS
15    WRITE(2,57) I,QYR(I)
57    FORMAT(23X,I2,12X,F8.2)
      CALL BSTAT (QYR,NYRS,AA1,AA2,AA3)
      NLAG=15
      CALL SERCOR (QYR,NYRS,RC,NLAG)
      N=12
      NRP=1
      CALL LINREG (N,RATIO,NRP,CS)
      RETURN
      END


      SUBROUTINE BSTAT (X,N,XBAR,SD,CS)
C
C     CALC MEAN,STAND. DEV AND SKEWNESS COEFF OF A DATA SET OF LENGTH N
C
      DIMENSION X(600)
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 10 I=1,N
10    SUM1=SUM1+X(I)
      XBAR=SUM1/N
      DO 11 I=1,N
      SUM2=SUM2+(X(I)-XBAR)**2
11    SUM3=SUM3+(X(I)-XBAR)**3
      A=SUM2/(N-1)
      SD=SQRT(A)
      AM2=SUM2/N
      AM3=SUM3/N
      A1=AM3/AM2**1.5
      AN=N
      CS=A1*(AN/(AN-1))*(AN/(AN-2))
      WRITE(2,101) XBAR,SD,CS
101   FORMAT(//10X,7H MEAN =,F10.3,5X,13H STAND.DEV. =,F10.3,5X,
     1'COEFF OF SKEWNESS =',F10.3)
      RETURN
      END
```

```
      SUBROUTINE SERCOR(X,N,CL,LIM)
C
C  CALCS SERIAL CORRELATIONS
C  MAX NO. OF LAGS (LIM) IS 15.  LENGTH OF RECORD = N
C
      DIMENSION X(500),CL(16)
      SUM=0.0
      DO 1 I=1,N
    1 SUM=SUM+X(I)
      RMEAN=SUM/N
      DO 2 I=1,N
    2 X(I)=X(I)-RMEAN
      SUM=0.0
      DO 3 I=1,N
      A=X(I)
    3 SUM=SUM+A*A
      CL(1)=SUM
      DO 4 J=1,LIM
      SUM=0.0
      LJ=J+1
      NJ=N-J
      DO 5 K=1,NJ
      KA=K+J
    5 SUM=SUM+X(K)*X(KA)
      CL(LJ)=SUM/CL(1)
    4 CONTINUE
      CL(1)=1.0
      DO 7 I=1,N
    7 X(I)=X(I)+RMEAN
      NN=LIM+1
      WRITE(2,8)
    8 FORMAT (1H0,19X,33H SERIAL CORRELATION COEFFICIENTS.,//27X,7H
     1I),7X,5H R(I))
      DO 9 I=1,NN
      ILAG=I-1
    9 WRITE(2,10) ILAG,CL(I)
   10 FORMAT (20X,I2,7X,F10.7)
      RETURN
      END
```

```
      SUBROUTINE LINREG(NGAUGE,ZG,NPP,R)
C
C     LINEAR REGRESSION
C
      DIMENSION ZG(12),R(12),A(10),B(10),REG(10)
      SUM1=0.0
      SUM2=0.0
      DO 5 I=1,NGAUGE
    5 SUM1=SUM1+ZG(I)
      ZGBAR=SUM1/NGAUGE
      DO 6 I=1,NGAUGE
    6 SUM2=SUM2+(ZG(I)-ZGBAR)**2
```

```
      DO 10 J=1,NRP
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      DO 7 I=1,NGAUGE
    7 SUM3=SUM3+R(I)
      RBAR=SUM3/NGAUGE
      DO 8 I=1,NGAUGE
      SUM4=SUM4+(ZG(I)-ZGBAR)*(R(I)-RBAR)
    8 SUM5=SUM5+(R(I)-RBAR)**2
      A(J)=SUM4/SUM2
      B(J)=RBAR-A(J)*ZGBAR
      SUMS2=SUM2*SUM5
      REG(J)=SUM4/SQRT(SUMS2)
   10 CONTINUE
      WRITE(2,50)
50    FORMAT(///2X,'RESULTS OF LINEAR REGRESSION BETWEEN MONTHLY SKEW
     1S COEFF. (C3) AND MONTHLY RATIO (IE. MONTHLY MEAN/STAND. DEV.')
      WRITE(2,60) A(1),B(1),REG(1)
60    FORMAT(//10X,7HSLOPE =,F10.5,5X,11HINTERCEPT =,F10.5,5X,18HREGR
     2ION COEFF =,F10.5)
      RETURN
      END

      FINISH
```

142.831	14.580	66.119	116.919	61.498	75.208	92.900	30.251	7.229	131.993	120.842	218.775
177.938	111.315	52.157	68.194	42.384	67.569	113.176	146.020	130.391	160.617	206.967	165.238
126.889	79.209	22.035	101.121	54.410	34.735	74.710	103.105	83.425	151.917	84.552	104.858
150.926	73.221	59.637	113.322	84.417	29.137	68.229	142.211	137.717	46.317	66.[illegible]	116.299
36.859	29.137	122.799	98.376	70.227	102.361	49.808	85.921	86.297	56.290	219.526	30.890
34.486	37.108	75.458	68.619	63.270	60.380	81.690	57.159	51.810	92.802	86.72[illegible]	197.424
157.039	16.560	101.558	86.704	93.363	108.069	89.535	64.509	154.144	51.728	125.607	279.134
71.802	157.139	61.581	112.802	91.216	86.584	74.046	84.072	61.363	128.877	135.848	175.602
65.728	145.239	77.437	36.437	175.581	41.414	84.802	70.483	154.432	232.010	66.265	174.141
143.139	38.170	106.771	84.170	117.512	100.974	141.830	93.316	163.725	105.198	[illegible]3.251	95.265
112.193	113.581	93.560	82.167	193.365	44.753	50.049	95.342	68.463	31.486	170.969	101.995
115.532	137.504	98.144	107.237	35.974	65.974	68.388	133.512	74.239	91.139	214.451	82.021
138.581	58.093	64.584	57.609	35.219	101.632	43.632	128.753	38.121	107.992	117.757	53.072
120.581	87.291	100.069	103.995	102.555	103.802	94.486	55.997	40.951	51.365	120.1[illegible]	157.139
47.095	72.728	33.949	95.681	112.656	79.463	133.853	124.897	123.239	83.851	66.995	82.800

MEAN = 94.968 STAND.DEV. = 46.763 COEFF OF SKEWNESS = 0.867

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MEAN FLOW	109.44	78.06	75.72	88.89	88.91	70.14	84.08	94.37	91.70	101.57	125.77	130.97
STAND DEV	46.56	46.81	28.19	23.06	46.93	29.31	28.71	35.14	49.04	53.64	54.13	68.44
SDR	44.69	44.96	26.69	22.27	43.51	27.35	27.72	33.92	44.48	51.28	51.14	66.64
R	0.11	-0.11	-0.20	-0.03	-0.28	-0.26	-0.03	-0.04	0.34	0.14	-0.21	-0.21
B	0.08	-0.11	-0.12	-0.03	-0.57	-0.16	-0.03	-0.05	0.48	0.16	-0.21	-0.27
CS	-0.52	0.31	-0.27	-0.97	1.19	-0.11	0.72	-0.08	0.04	1.03	0.76	0.6[illegible]
RATIO	2.35	1.67	2.69	3.85	1.89	2.39	2.93	2.69	1.87	1.89	2.32	1.91
VAR	2167.99	2191.32	794.43	531.86	2202.42	859.06	823.98	1234.93	2404.79	2877.22	2930.59	46[illegible]

STANDARDIZED MONTHLY MEAN FLOW, STAND. DEV.AND SKEW. COEFF.

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MEAN FLOW	1.15	0.82	0.80	0.94	0.94	0.74	0.89	0.99	0.97	1.07	1.3[illegible]	1.[illegible]
STAND DEV	1.00	1.00	0.60	0.49	1.00	0.63	0.61	0.75	1.05	1.15	1.16	1.47
CS	-0.60	0.35	-0.32	-1.11	1.37	-0.13	0.83	-0.09	0.05	1.19	0.88	0.7[illegible]

ANNUAL FLOW

YEAR	QYR(I)
1	1079.05
2	1441.97
3	1020.97
4	1087.80
5	988.49
6	906.93
7	1327.95
8	1240.93
9	1283.97
10	1273.91
11	1157.92
12	1194.14
13	944.63
14	1138.37
15	1007.21

MEAN = 1139.616 STAND.DEV. = 154.063 COEFF OF SKEWNESS = 0.328

SERIAL CORRELATION COEFFICIENTS.

LAG(I)	R(I)
0	1.0000000
1	-0.0076460
2	0.1276265
3	-0.2167254
4	-0.4923973
5	-0.0014040
6	-0.2295483
7	0.1327358
8	0.0953465
9	0.0963980
10	0.1763098
11	-0.1662665
12	0.0816855
13	-0.1202504
14	0.0241357
15	-0.0124304

RESULTS OF LINEAR REGRESSION BETWEEN MONTHLY SKEWNESS COEFF. (CS) AND MONTHLY RATIO (IE. MONTHLY MEAN/STAND. DEV.

SLOPE = -0.66703 INTERCEPT = 1.80943 REGRESSION COEFF = -0.62231

2 Program 'CROSS'

This program calculates the monthly lag-zero cross correlation coefficients between two monthly data sets. It repeats the analysis any number of specified combinations of the monthly data sets available on file.

The basic input identifiers are as given below:

NST = Number of stations (i.e. number of monthly data sets).

NCOMB = Number of combinations of data sets to be analysed.

station = Station number

The specified combinations are defined in terms of the required analysis between the specified station number and the other stations covering the same data record. See Section 5.6).

```
      MASTER CROSS
C
C       THIS PROG. READS ANY SPECIFIED NUMBER OF STATIONS AND CALC. THE
C       LAG ZERO CROSS CORRELATION BETWEEN ANY SPECIFIED COMBINATION.
C
      DIMENSION X(50,12),Y(50,12),XBAR(12),YBAR(12),XSD(12),YSD(12)
      COMMON /ALLDATA/D(30,41,12),NSTAT(30),NST
      WRITE(2,105)
      READ(1,100) NST
105   FORMAT(//,40X,' LAG  ZERO  CROSS  CORRELATION ',/)
100   FORMAT(I0)
      DO 300 I=1,NST
      CALL GAP(2)
      READ(7,100) NSTAT(I)
      CALL GAP(2)
      DO 300 J=1,41
      READ(7,101)NY,(D(I,J,K),K=1,12)
300   CONTINUE
101   FORMAT(I0,12F0.0)
      READ(1,100) NCOMB
      DO 302 I=1,NCOMB
      CALL TAPEB1(X,NYRS)
      CALL MEANAL(X,NYRS,XBAR,XSD)
      CALL TAPEB1(Y,NYRS)
      CALL MEANAL(Y,NYRS,YBAR,YSD)
      CALL CORR(X,Y,XBAR,YBAR,XSD,YSD,NYRS)
302   CONTINUE
      STOP
      END


      SUBROUTINE CORR(X,Y,XBAR,YBAR,XSD,YSD,NYRS)
C
C     THIS SUBROUTINE CALC. LAG ZERO CROSS CORRELATION.
C
      DIMENSION X(50,12),Y(50,12),XBAR(12),YBAR(12),ZCR(12),TOTB(12)
      DIMENSION XSD(12),YSD(12)
      DO 1 J=1,12
      TOTB(J)=0.0
      DO 1 I=1,NYRS
      A=X(I,J)-XBAR(J)
      B=Y(I,J)-YBAR(J)
1     TOTB(J)=TOTB(J)+A*B
      DO 2 J=1,12
2     ZCR(J)=TOTB(J)/(XSD(J)*YSD(J)*NYRS)
      WRITE(2,100) (ZCR(J),J=1,12)
100   FORMAT(/,10X,12F9.3)
      RETURN
      END
```

```
      SUBROUTINE TAPER1(Q,NYRS)
      DIMENSION Q(50,12)
      INTEGER F19XX,T19XX,STATION
      COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
      READ(1,100) STATION
 100  FORMAT(I0)
      WRITE(2,201) STATION
 201  FORMAT(//,5X, 'STATION NO. =',I8,/)
      DO 300 I=1,NST
      IF(NSTAT(I).NE.STATION) GO TO 300
      READ(1,102) F19XX,T19XX
 102  FORMAT(2I0)
C     WRITE(2,202) F19XX, T19XX
 202  FORMAT(5X,'BETWEEN THE YEARS ',I6, ' AND',I6)
      IF(F19XX.LT.1936.OR.T19XX.GT.1976.OR.F19XX.GT.T19XX) GO TO 9
      NYRS=T19XX-F19XX+1
      J1=F19XX-1936+1
      J2=T19XX-F19XX+J1
      DO 301 J=J1,J2
      L=J-J1+1
      DO 302 K=1,12
 302  Q(L,K)=D(I,J,K)
C     WRITE(2,205) (Q(L,K),K=1,12)
 301  CONTINUE
      GO TO 310
 300  CONTINUE
      GO TO 310
 9    WRITE(2,200)
 200  FORMAT(//,' STATION NOT AVAILABLE')
 205  FORMAT(10X,12F8.3)
 310  RETURN
      END
```

```
       SUBROUTINE GAP(J)
       DO 1 I=1,J
       READ(7,2) A
 2       FORMAT(A8)
 1    CONTINUE
       RETURN
       END
```

```
      SUBROUTINE MEANAL (Q,NYRS)
      REAL NEWY,NEW
      COMMON /ROOTS/SKEW,AVAR,RRR,XBAR,X,NEWY,RAWY,V
      DIMENSION Q(50,12),QBAR(12),SD(12),QYR(600),R(12),B(12),SDR(12),
     1SUM1(12),SUM2(12),SUM3(12),SUM3M(12),CS(12),RATIO(12),VAR(12)
      DIMENSION NEW(12),RAW(12),XXX(12),V(12),RC(16),RNEW(50,12)
      DIMENSION SQBAR(12),SSD(12),SCS(12)
      L=0
      DO 4 I=1,NYRS
      DO 4 J=1,12
      L=L+1
4     QYR(L)=Q(I,J)
      NDAT=NYRS*12
      CALL BSTAT (QYR,NDAT,AA1,AA2,AA3)
C
C     CALC. MONTHLY MEAN FLOWS
C
      DO 6 J=1,12
      SUM1(J)=0.0
      DO 5 I=1,NYRS
5     SUM1(J)=SUM1(J)+Q(I,J)
      QBAR(J)=SUM1(J)/NYRS
    6 CONTINUE
C
C     CALC. YEARLY FLOWS, MEAN AND STAND. DEV. OF YEARLY FLOWS
C
      DO 17 I=1,NYRS
      QYR(I)=0.0
      SUM4=0.0
      DO 16 J=1,12
16    QYR(I)=QYR(I)+Q(I,J)
17    SUM4=SUM4+QYR(I)
      QYRBAR=SUM4/NYRS
      SUM5=0.0
      DO 18 I=1,NYRS
18    SUM5=SUM5+(QYR(I)-QYRBAR)**2
      A3=SUM5/(NYRS-1)
      SDQYR=SQRT(A3)
C
C     CALC. MONTHLY STAND. DEV. SD(J) AND MONTHLY SKEWNESS COEFF. CS(J)
C
      DO 7 J=1,12
      DO 7 I=1,NYRS
7     Q(I,J)=Q(I,J)-QBAR(J)
      DO 9 J=1,12
      SUM2(J)=0.0
      SUM3M(J)=0.0
      DO 8 I=1,NYRS
      SUM2(J)=SUM2(J)+Q(I,J)*Q(I,J)
8     SUM3M(J)=SUM3M(J)+Q(I,J)**3
      AM2=SUM2(J)/NYRS
      AM3=SUM3M(J)/NYRS
      CS(J)=NYRS*NYRS*AM3/((NYRS-1)*(NYRS-2)*AM2**1.5)
      VAR(J)=SUM2(J)/(NYRS-1.)
9     SD(J)=SQRT(VAR(J))
```

```
C
C      CALC. MONTHLY RATIO OF MEANS/STAND. DEV.
C
       DO 3 J=1,12
 3     RATIO(J)=QBAR(J)/SD(J)
C
C      CALC R(J) CORRELATION COEFF MONTH 1 WITH MONTH 12 OF PREVIOUS YEAR
C
       SUM3(1)=Q(2,1)*Q(1,12)
       DO 10 I=3,NYRS
 10    SUM3(1)=SUM3(1)+Q(I,1)*Q(I-1,12)
       A=SUM2(1)*SUM2(12)
       R(1)=SUM3(1)*NYRS/(SQRT(A)*(NYRS-1))
C
C      CALC. R(2) TO R(12) - CORRELATION COEFF'S MONTH J WITH MONTH J-1.
C
       DO 11 J=2,12
 11    SUM3(J)=0.0
       DO 13 J=2,12
       DO 12 I=1,NYRS
 12    SUM3(J)=SUM3(J)+Q(I,J)*Q(I,J-1)
       A1=SUM2(J)*SUM2(J-1)
 13    R(J)=SUM3(J)/SQRT(A1)
C
C      CALC. B(1) TO B(12)
C
       B(1)=R(1)*SD(1)/SD(12)
       DO 14 J=2,12
 14    B(J)=R(J)*SD(J)/SD(J-1)
C
C      CALC. MONTHLY STAND. DEV. OF RESIDUALS SDR(J)
C
       DO 19 J=1,12
         RJ=R(J)
         FNYRS=NYRS
         A2=(FNYRS-1.)*(1.-RJ*RJ)/FNYRS
 19    SDR(J)=SD(J)*SQRT(A2)
C
C      CALC. STANDARDIZED MONTHLY MEAN, STAND. DEV. AND SKEW. COEFF.
C
       DO 31 J=1,12
 31    SQBAR(J)=QBAR(J)/AA1
       DO 32 J=1,12
 32    SSD(J)=SD(J)/AA2
       DO 33 J=1,12
 33    SCS(J)=CS(J)/AA3
C
C      RESET Q(I,J) TO TRUE VALUES
C
       DO 20 I=1,NYRS
       DO 20 J=1,12
 20    Q(I,J)=Q(I,J)+QBAR(J)
C
C      PRINT RESULTS
C
       WRITE(2,50)
 50    FORMAT(//,5X,5HMONTH,6X,2H 1,7X,2H 2,6X,2H 3,6X,2H 4,6X,2H 5,6X,
      12H 6,6X,2H 7,6X,2H 8,6X,2H 9,6X,2H10,7X,2H11,7X,2H12)
       WRITE(2,51) (QBAR(J),J=1,12)
 51    FORMAT(/,5X,9HMEAN FLOW,(12(2X,F6.2)))
```

```
      WRITE(2,52) (SD(J),J=1,12)
52    FORMAT(/,5X,9HSTAND DEV,(12(2X,F6.2)))
      WRITE(2,53) (SDR(J),J=1,12)
53    FORMAT(/,5X,3HSDR,6X,(12(2X,F6.2)))
      WRITE(2,54) (R(J),J=1,12)
54    FORMAT(/,5X,1HR,8X,(12(2X,F6.2)))
      WRITE(2,55) (B(J),J=1,12)
55    FORMAT(/,5X,1HB,8X,(12(2X,F6.2)))
      WRITE(2,58) (CS(J),J=1,12)
58    FORMAT(/,5X,2HCS,7X,(12(2X,F6.2)))
      WRITE(2,59) (RATIO(J),J=1,12)
59    FORMAT(/,5X,5HRATIO,4X,(12(2X,F6.2)))
      WRITE(2,49) (VAR(J),J=1,12)
49    FORMAT(/,5X,5HVAR  ,4X,(12(1X,F7.2)))
      WRITE(2,60)
60    FORMAT(//,30X,'STANDARDIZED MONTHLY MEAN FLOW, STAND. DEV.AND SK
     1. COEFF.')
      WRITE(2,50)
      WRITE(2,51) (SQBAR(J),J=1,12)
      WRITE(2,52) (SSD(J),J=1,12)
      WRITE(2,58) (SCS(J),J=1,12)
      WRITE(2,56)
56    FORMAT(//,32X,12H ANNUAL FLOW,//28X,4HYEAR,12X,7H QYR(I))
      DO 15 I=1,NYRS
15    WRITE(2,57) I,QYR(I)
57    FORMAT(23X,I2,12X,F8.2)
      CALL BSTAT (QYR,NYRS,AA1,AA2,AA3)
      NLAG=15
      CALL SERCOR (QYR,NYRS,RC,NLAG)
      N=12
      NRP=1
      CALL LINREG (N,RATIO,NRP,CS)
      RETURN
      END


      SUBROUTINE BSTAT (X,N,XBAR,SD,CS)
C
C     CALC MEAN,STAND. DEV AND SKEWNESS COEFF OF A DATA SET OF LENGTH N
C
      DIMENSION X(600)
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 10 I=1,N
10    SUM1=SUM1+X(I)
      XBAR=SUM1/N
      DO 11 I=1,N
      SUM2=SUM2+(X(I)-XBAR)**2
11    SUM3=SUM3+(X(I)-XBAR)**3
      A=SUM2/(N-1)
      SD=SQRT(A)
      AM2=SUM2/N
      AM3=SUM3/N
      A1=AM3/AM2**1.5
      AN=N
      CS=A1*(AN/(AN-1))*(AN/(AN-2))
      WRITE(2,101) XBAR,SD,CS
101   FORMAT(//10X,7H MEAN =,F10.3,5X,13H STAND.DEV. =,F10.3,5X,
     1'COEFF OF SKEWNESS =',F10.3)
      RETURN
      END
```

```
      SUBROUTINE SERCOR(X,N,CL,LIM)
C
C  CALCS SERIAL CORRELATIONS
C  MAX NO. OF LAGS (LIM) IS 15.  LENGTH OF RECORD = N
C
      DIMENSION X(500),CL(16)
      SUM=0.0
      DO 1 I=1,N
    1 SUM=SUM+X(I)
      RMEAN=SUM/N
      DO 2 I=1,N
    2 X(I)=X(I)-RMEAN
      SUM=0.0
      DO 3 I=1,N
      A=X(I)
    3 SUM=SUM+A*A
      CL(1)=SUM
      DO 4 J=1,LIM
      SUM=0.0
      LJ=J+1
      NJ=N-J
      DO 5 K=1,NJ
      KA=K+J
    5 SUM=SUM+X(K)*X(KA)
      CL(LJ)=SUM/CL(1)
    4 CONTINUE
      CL(1)=1.0
      DO 7 I=1,N
    7 X(I)=X(I)+RMEAN
      NN=LIM+1
      WRITE(2,8)
    8 FORMAT (1H0,19X,33H SERIAL CORRELATION COEFFICIENTS.,//27X,7H
     1I),7X,5H R(I))
      DO 9 I=1,NN
      ILAG=I-1
    9 WRITE(2,10) ILAG,CL(I)
   10 FORMAT (29X,I2,7X,F10.7)
      RETURN
      END
```

```
      SUBROUTINE LINREG(NGAUGE,ZG,NPP,R)
C
C     LINEAR REGRESSION
C
      DIMENSION ZG(12),R(12),A(10),B(10),REG(10)
      SUM1=0.0
      SUM2=0.0
      DO 5 I=1,NGAUGE
    5 SUM1=SUM1+ZG(I)
      ZGBAR=SUM1/NGAUGE
      DO 6 I=1,NGAUGE
    6 SUM2=SUM2+(ZG(I)-ZGBAR)**2
```

```
      DO 10 J=1,NRP
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      DO 7 I=1,NGAUGE
    7 SUM3=SUM3+R(I)
      RBAR=SUM3/NGAUGE
      DO 8 I=1,NGAUGE
      SUM4=SUM4+(ZG(I)-ZGBAR)*(R(I)-RBAR)
    8 SUM5=SUM5+(R(I)-RBAR)**2
      A(J)=SUM4/SUM2
      B(J)=RBAR-A(J)*ZGBAR
      SUMS2=SUM2*SUM5
      REG(J)=SUM4/SQRT(SUMS2)
   10 CONTINUE
      WRITE(2,50)
50    FORMAT(///2X,'RESULTS OF LINEAR REGRESSION BETWEEN MONTHLY SKEW
     1S COEFF. (C3) AND MONTHLY RATIO (IE. MONTHLY MEAN/STAND. DEV.')
      WRITE(2,60) A(1),B(1),REG(1)
60    FORMAT(//10X,7HSLOPE =,F10.5,5X,11HINTERCEPT =,F10.5,5X,18HREGR
     2ION COEFF =,F10.5)
      RETURN
      END

      FINISH
```

3 Program 'CONSISTENT'

This program checks the validity of the historic data using the method described in Chapter 5.

The master segment of the program reads the number of station and the number of combinations involved in the analysis. The program then calls subroutine 'CHECK' which calculates the score matrix between the two specified blocks of data (i.e. X(I,J) and Y(I,J)) for the first combination, and then proceeds to the second combination (i.e. X(I,J) and Z(I,J)) and so on to complete the number of combinations chosen. Later the program calls subroutine 'DATA' to accumulate the score matrices for each station.

The basic input identifiers are as given below:

NST = Number of stations

NCOMB = Number of combinations of data sets to be analysed

STATION = Station number.

```
      MASTER CONSISTENT
C     ********************************************************************
C     *THIS PROGRAM CALC. SCORING MATRIX FOR 7 COMBINED GAUGED STATIONS*
C     ********************************************************************
       INTEGER COMB(50,12,7),WARN(50,12)
       COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
       READ(1,100) NST
 100   FORMAT(I0)
       DO 300 I=1,NST
       CALL GAP(2)
       READ(7,100) NSTAT(I)
       CALL GAP(2)
       DO 300 J=1,41
       READ(7,101)NY,(D(I,J,K),K=1,12)
 300   CONTINUE
 101   FORMAT(I0,12F0.0)
       READ(1,100) NCOMB
       DO 3 K=1,NCOMB
       DO 1 K=1,7
       CALL CHECK(NYRS,WARN)
       DO 2 I=1,NYRS
       DO 2 J=1,12
 2     COMB(I,J,K)=WARN(I,J)
 1     CONTINUE
       CALL DATA(NYRS,7,COMB)
 3 .   CONTINUE
       STOP
       END

      SUBROUTINE CHECK(NYRS,WARN)
C     ********************************************************************
C      * CALC. SCORE MATRIX BETWEEN TWO GAUGED STATIONS                  *
C     ********************************************************************
      INTEGER WARN(50,12),UPPER,LOWER,BLANK,TEXT
       COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
      DIMENSION PERCEN(14)
      COMMON SD,NNN(14)
      DATA SELECT/2.5/
      DATA UPPER,LOWER,BLANK/'**  ','*   ','    '/,IHISTO/14/
      DIMENSION Q(50,12),QBAR1(12),QBAR2(12),AVRAT(12),SUM1(12),
     1SUM2(12),COEFF(50,12),QYR(600),TS(600),CR(12),IND(50,12)
      REAL MRATIO(50,12)
      CALL TAPEB1(Q,NYRS)
      DO 1 J=1,12
      IF(NYRS.EQ.0.) STOP
      SUM1(J)=0.0
      DO 2 I=1,NYRS
 2    SUM1(J)=SUM1(J)+Q(I,J)
      QBAR1(J)=SUM1(J)/NYRS
      DO 7 I=1,NYRS
      MRATIO(I,J)=Q(I,J)
 7    CONTINUE
 1    CONTINUE
      CALL TAPEB1(Q,NYRS)
      DO 3 J=1,12
      SUM2(J)=0.0
      DO 4 I=1,NYRS
 4    SUM2(J)=SUM2(J)+Q(I,J)
```

```
      QBAR2(J)=SUM2(J)/NYRS
      SUM7=0.0
      DO 6 I=1,NYRS
      MRATIO(I,J)=MRATIO(I,J)/Q(I,J)
      SUM7=SUM7+MRATIO(I,J)
    6 CONTINUE
      AVRAT(J)=SUM7/NYRS
      DO 10 I=1,NYRS
      COEFF(I,J)=MRATIO(I,J)/AVRAT(J)
 10   CONTINUE
 3    CONTINUE
      DO 14 J=1,12
      CR(J)=1/AVRAT(J)
 14   CONTINUE
C      WRITE(2,50)
C      WRITE(2,51) (QBAR1(J),J=1,12)
C      WRITE(2,52) (QBAR2(J),J=1,12)
C      WRITE(2,53) (AVRAT(J),J=1,12)
 50   FORMAT(//,3X,5HMONTH,6X,2H 1,7X,2H 2,6X,2H 3,6X,2H 4,6X,2H 5,6X,
     12H 6,6X,2H 7,6X,2H 8,6X,2H 9,6X,2H10,6X,2H11,6X,2H12)
 51   FORMAT(/,5X,'MEAN FLOW 1',(12(2X,F6.2)))
 52   FORMAT(/,5X,'MEAN FLOW 2',(12(2X,F6.2)))
 53   FORMAT(/,5X,'AVER. RATIO',(12(2X,F6.2)),//)
      CENTRE =1.0
      GRPSIZ =0.1
      L=0
      DO 9 J=1,12
      DO 8 I=1,NYRS
      L=L+1
       HOLD=COEFF(I,J)
      QYR(I)=HOLD
      TS(L)=HOLD
  8    CONTINUE
      CALL BSTAT(QYR,NYRS)
  9   CONTINUE
      CALL BSTAT(TS,L)
      CALL HISTO(TS,CENTRE,GRPSIZ,L)
      IHISTO =14
      DO 11 I=2,IHISTO
 11   NNN(I)=NNN(I-1)+NNN(I)
      SAME =100./(FLOAT(12*NYRS))
      DO 12 I=1,IHISTO
      PERCEN(I)=FLOAT(NNN(I))*SAME
 12   CONTINUE
C      WRITE(2,55) (PERCEN(I),I=1,14)
 55   FORMAT(/14(F7.3,'%'))
      SKIP=CENTRE-FLOAT(IHISTO)*GRPSIZ/2.
      READ1=READIT(SELECT,SKIP,1,PERCEN,IHISTO,GRPSIZ,I)
      READ2=READIT(100.-SELECT,SKIP+GRPSIZ,I+1,PERCEN,IHISTO,GRPSIZ,I)-CE
      DOLIM=READ1
      UPLIM=READ2
C      WRITE(2,57) DOLIM,UPLIM,SD
C     WRITE(3,57) DOLIM,UPLIM,SD
 57   FORMAT(/10X,'DOLIM=',F8.3,5X,'UPLIM=',F8.3,5X,'STAN. DEV.=',F8.3)
      DO 13 I=1,NYRS
      DO 13 J=1,12
      HOLD =COEFF(I,J)
      TEXT =BLANK
      IF(HOLD.LT.DOLIM) TEXT=LOWER
      IF(HOLD.GT.UPLIM) TEXT=UPPER
      WARN(I,J)=TEXT
 13   CONTINUE
      DO 56 I=1,NYRS
```

```
C       WRITE(3,58) ((COEFF(I,J),WARN(I,J),J=1,12))
C       WRITE(2,58) ((COEFF(I,J),WARN(I,J),J=1,12))
 56     CONTINUE
 58     FORMAT(6X,12(F5.3,A4))
C       WRITE(2,54)(CR(J),J=1,12)
 54     FORMAT(/,5X,(12(2X,F6.2)),//)
        DO 15 I=1,NYRS
        DO 15 J=1,12
        IF(COEFF(I,J).GE.CR(J)) IND(I,J)=1
 15     CONTINUE
C       WRITE(2,60) ((IND(I,J),J=1,12),I=1,NYRS)
 60     FORMAT(12(I3))
        RETURN
        END


         SUBROUTINE TAPEB1(Q,NYRS)
         DIMENSION Q(50,12)
         INTEGER F19XX,T19XX,STATION
         COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
         READ(1,100) STATION
 100     FORMAT(I0)
         WRITE(2,201) STATION
 201     FORMAT(//,5X,'STATION NO. =',I8,/)
         DO 300 I=1,NST
         IF(NSTAT(I).NE.STATION) GO TO 300
         READ(1,102) F19XX,T19XX
 102     FORMAT(2I0)
C        WRITE(2,202) F19XX, T19XX
 202     FORMAT(5X,'BETWEEN THE YEARS ',I6, ' AND',I6)
         IF(F19XX.LT.1936.OR.T19XX.GT.1976.OR.F19XX.GT.T19XX) GO TO 9
         NYRS=T19XX-F19XX+1
         J1=F19XX-1936+1
         J2=T19XX-F19XX+J1
         DO 301 J=J1,J2
         L=J-J1+1
         DO 302 K=1,12
 302     Q(L,K)=D(I,J,K)
C        WRITE(2,205) (Q(L,K),K=1,12)
 301     CONTINUE
         GO TO 310
 300     CONTINUE
         GO TO 310
 9       WRITE(2,200)
 200     FORMAT(//,' STATION NOT AVAILABLE')
 205     FORMAT(16X,12F9.3)
 310     RETURN
         END


           SUBROUTINE GAP(J)
           DO 1 I=1,J
           READ(7,2) A
 2           FORMAT(A8)
 1       CONTINUE
           RETURN
           END
```

```
      SUBROUTINE BSTAT (X,N)
C
C     CALC MEAN,STAND. DEV AND SKEWNESS COEFF OF A DATA SET OF LENGTH N
C
      DIMENSION X(600)
      COMMON SD
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 10 I=1,N
 10   SUM1=SUM1+X(I)
      XBAR=SUM1/N
      DO 11 I=1,N
      SUM2=SUM2+(X(I)-XBAR)**2
 11   SUM3=SUM3+(X(I)-XBAR)**3
      A=SUM2/(N-1)
      SD=SQRT(A)
      AM2=SUM2/N
      AM3=SUM3/N
      A1=AM3/AM2**1.5
      AN=N
      CS=A1*(AN/(AN-1))*(AN/(AN-2))
C     WRITE(2,101) XBAR,SD,CS
 101  FORMAT(//10X,7H MEAN =,F10.3,5X,13H STAND.DEV. =,F10.3,5X,
     1'COEFF OF SKEWNESS =',F10.3)
      RETURN
      END


      SUBROUTINE HISTO(X,CENTRE,GRPSIZ,NUM)
C
C     PRODUCES HISTOGRAM DATA FOR ANY GIVEN DATA SET.
C
      COMMON SD,NN7,NN6,NN5,NN4,NN3,NN2,NN1,N1,N2,N3,N4,N5,N6,N7
      DIMENSION X(600)
      NN1=0.0
      NN2=0.0
      NN3=0.0
      NN4=0.0
      NN5=0.0
      NN6=0.0
      NN7=0.0
      N1=0.0
      N2=0.0
      N3=0.0
      N4=0.0
      N5=0.0
      N6=0.0
      N7=0.0
      DO 11 I=1,NUM
      A=(X(I)-CENTRE)/(2.0*GRPSIZ)
      IF(A)41,21,21
   21 IF(A-1.0)22,23,23
   22 IF(A-0.5)24,25,25
   24 N1=N1+1
      GO TO 60
   25 N2=N2+1
      GO TO 60
   23 IF(A-1.5)26,27,27
   26 N3=N3+1
      GO TO 60
```

```
27  IF(A-2.0)28,29,29
28  N4=N4+1
    GO TO 60
29  IF(A-2.5)30,31,31
30  N5=N5+1
    GO TO 60
31  IF(A-3.0)32,33,33
32  N6=N6+1
    GO TO 60
33  N7=N7+1
    GO TO 60
41  IF(A+1.0)43,42,42
42  IF(A+0.5)45,44,44
44  NN1=NN1+1
    GO TO 60
45  NN2=NN2+1
    GO TO 60
43  IF(A+1.5)47,46,46
46  NN3=NN3+1
    GO TO 60
47  IF(A+2.0)49,48,48
48  NN4=NN4+1
    GO TO 60
49  IF(A+2.5)51,50,50
50  NN5=NN5+1
    GO TO 60
51  IF(A+3.0)53,52,52
52  NN6=NN6+1
    GO TO 60
53  NN7=NN7+1
60  CONTINUE
11  CONTINUE
    A1=CENTRE-6.0*GRPSIZ
    A2=CENTRE-5.0*GRPSIZ
    A3=CENTRE-4.0*GRPSIZ
    A4=CENTRE-3.0*GRPSIZ
    A5=CENTRE-2.0*GRPSIZ
    A6=CENTRE-1.0*GRPSIZ
    A7=CENTRE+1.0*GRPSIZ
    A8=CENTRE+2.0*GRPSIZ
    A9=CENTRE+3.0*GRPSIZ
    A10=CENTRE+4.0*GRPSIZ
    A11=CENTRE+5.0*GRPSIZ
    A12=CENTRE+6.0*GRPSIZ
C   WRITE(2,55) CENTRE,GRPSIZ
55  FORMAT(15H HISTOGRAM DATA,/8H CENTRE=,F10.5,12H GROUP SIZE=,F10.5)
C   WRITE(2,54)A1,A2,A3,A4,A5,A6,CENTRE,A7,A8,A9,A10,A11,A1,A2,A3,A4,A
   15,A6,CENTRE,A7,A8,A9,A10,A11,A12,A12


54  FORMAT(//2X,6H BELOW,12F8.3,7H ABOVE,/3X,12(2X,3H TO,3X),/14F8.3)
C   WRITE(2,13)NN7,NN6,NN5,NN4,NN3,NN2,NN1,N1,N2,N3,N4,N5,N6,N7
13  FORMAT(/14(2X,I4,2X))
    RETURN
    END
```

```
      FUNCTION READIT(CUT,SKIP,ISCAN,PERCEN,IHISTO,GRPSIZ,I)
      DIMENSION PERCEN(14)
      DO 1 I=ISCAN,IHISTO
      P2 =PERCEN(I)
      IF(CUT.LE.P2) GO TO 2
1     SKIP=SKIP+GRPSIZ
2     P1=0.
      IF(I.NE.1) P1=PERCEN(I-1)
      READIT=SKIP+GRPSIZ*(CUT-P1)/(P2-P1)
      RETURN
      END


      SUBROUTINE DATA(NYRS,NSTATS,COMB)
      INTEGER COMB(50,12,7),SPACE,LINE(12)
      DATA SPACE/'    '/
      DO 11 K=1,NYRS
      DO 8 I=1,12
 8    LINE(I)=0
      DO 9  II=1,NSTATS
      DO 9  J=1,12 .
      IF(COMB(K,J,II).NE.SPACE) LINE(J)=LINE(J)+1
9     CONTINUE
  11  WRITE(2,111) (LINE(J),J=1,12)
111   FORMAT(5X,12I5)
      RETURN
      END

      FINISH
```

4 Program 'RAIN'

This program uses the monthly areal rainfall and monthly naturalised streamflow data for the catchments to compute the corresponding data for the sub-catchments. It is based upon the method described in Section 5.7.

The basic input identifiers are:

NST = Number of stations

A1, A2, A3, A4 and ANEW are the catchment areas involved (i.e. four catchments only) and the sub-catchment area respectively

STATION = Station number.

In case of computing flow record of the sub-catchment, the area parameters must be replaced by unity.

```
      MASTER RAIN
C
C     THIS PROGRAM CALC. RAINFALL DISTRIBUTION OVER A SUB-CATCHMENT WITH
C      RAINFALL RECORD OVER THE WHOLE CATCHMENT.(MAX. OF FOUR CATCHMENTS
C
      COMMON /ROOTS/SKEW,AVAR,RRR,X,MEWY,RAWY,V
      DIMENSION Q(50,12),QBAR(12),SD(12),QYR(600),R(12),B(12),SDR(12),
     1SUM1(12),SUM2(12),SUM3M(12),CS(12),RATIO(12),VAR(12),RNEW(50,12)
      DIMENSION MEW(12),RAW(12),XXX(12),V(12),SQBAR(12),SSD(12),SCS(12)
       COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
       READ(1,100) NST
 100   FORMAT(I0)
       DO 300 I=1,NST
       CALL GAP(2)
       READ(7,100) NSTAT(I)
       CALL GAP(2)
       DO 300 J=1,41
       READ(7,101)NY,(D(I,J,K),K=1,12)
 300   CONTINUE
 101   FORMAT(I0,12F0.0)
      READ (1,102) A1,A2,A3,A4,ANEW
 102  FORMAT(5F0.0)
      CALL TAPEB1 (Q,NYRS)
      DO 1 I=1,NYRS
      DO 1 J=1,12
 1    RNEW(I,J)=Q(I,J)*A1
      CALL TAPEB1 (Q,NYRS)
      DO 2 I=1,NYRS
      DO 2 J=1,12
 2    RNEW(I,J)=RNEW(I,J)-Q(I,J)*A2
      IF(A3) 10,10,11
 11   CALL TAPEB1 (Q,NYRS)
      DO 3 I=1,NYRS
      DO 3 J=1,12
 3    RNEW(I,J)=RNEW(I,J)-Q(I,J)*A3
      IF(A4) 10,10,12
 12   CALL TAPEB1 (Q,NYRS)
      DO 4 I=1,NYRS
      DO 4 J=1,12
 4    RNEW(I,J)=RNEW(I,J)-Q(I,J)*A4
 10   DO 5 I=1,NYRS
      DO 5 J=1,12
 5    RNEW(I,J)=RNEW(I,J)/ANEW
       DO 6 I=1,NYRS
       DO 6 J=1,12
 6    Q(I,J)=RNEW(I,J)
      WRITE(2,200) ((Q(I,J),J=1,12),I=1,NYRS)
 200  FORMAT(10X,12F0.3)
      CALL MFANAL(Q,NYRS)
      STOP
      END
```

```
      SUBROUTINE TAPER1(Q,NYRS)
      DIMENSION Q(50,12)
      INTEGER F19XX,T19XX,STATION
      COMMON /ALLDATA/D(20,41,12),NSTAT(20),NST
      READ(1,100) STATION
 100  FORMAT(I0)
      WRITE(2,201) STATION
 201  FORMAT(//,5X, 'STATION NO. =',I8,/)
      DO 300 I=1,NST
      IF(NSTAT(I).NE.STATION) GO TO 300
      READ(1,102) F19XX,T19XX
 102  FORMAT(2I0)
C     WRITE(2,202) F19XX, T19XX
 202  FORMAT(5X,'BETWEEN THE YEARS ',I6, ' AND',I6)
      IF(F19XX.LT.1936.OR.T19XX.GT.1976.OR.F19XX.GT.T19XX) GO TO 9
      NYRS=T19XX-F19XX+1
      J1=F19XX-1936+1
      J2=T19XX-F19XX+J1
      DO 301 J=J1,J2
      L=J-J1+1
      DO 302 K=1,12
 302  Q(L,K)=D(I,J,K)
C     WRITE(2,205) (Q(L,K),K=1,12)
 301  CONTINUE
      GO TO 310
 300  CONTINUE
      GO TO 310
C     WRITE(2,200)
 200  FORMAT(//,' STATION NOT AVAILABLE')
 205  FORMAT(10X,12F8.3)
 310  RETURN
      END
```

```
      SUBROUTINE GAP(J)
      DO 1 I=1,J
      READ(7,2) A
 2      FORMAT(A8)
 1    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MEANAL (Q,NYRS)
      REAL NEWY,NEW
      COMMON /ROOTS/SKEW,AVAR,RRR,XBAR,X,NEWY,RAWY,V
      DIMENSION Q(50,12),QBAR(12),SD(12),QYR(600),R(12),B(12),SDR(12),
     1SUM1(12),SUM2(12),SUM3(12),SUM3M(12),CS(12),RATIO(12),VAR(12)
      DIMENSION NEW(12),RAW(12),XXX(12),V(12),RC(16),RNEW(50,12)
      DIMENSION SQBAR(12),SSD(12),SCS(12)
      L=0
      DO 4 I=1,NYRS
      DO 4 J=1,12
      L=L+1
 4    QYR(L)=Q(I,J)
      NDAT=NYRS*12
      CALL BSTAT (QYR,NDAT,AA1,AA2,AA3)
C
C     CALC. MONTHLY MEAN FLOWS
C
      DO 6 J=1,12
      SUM1(J)=0.0
      DO 5 I=1,NYRS
 5    SUM1(J)=SUM1(J)+Q(I,J)
      QBAR(J)=SUM1(J)/NYRS
    6 CONTINUE
C
C     CALC. YEARLY FLOWS, MEAN AND STAND. DEV. OF YEARLY FLOWS
C
      DO 17 I=1,NYRS
      QYR(I)=0.0
      SUM4=0.0
      DO 16 J=1,12
 16   QYR(I)=QYR(I)+Q(I,J)
 17   SUM4=SUM4+QYR(I)
      QYRBAR=SUM4/NYRS
      SUM5=0.0
      DO 18 I=1,NYRS
 18   SUM5=SUM5+(QYR(I)-QYRBAR)**2
      A3=SUM5/(NYRS-1)
      SDQYR=SQRT(A3)
C
C     CALC. MONTHLY STAND. DEV. SD(J) AND MONTHLY SKEWNESS COEFF. CS(J)
C
      DO 7 J=1,12
      DO 7 I=1,NYRS
 7    Q(I,J)=Q(I,J)-QBAR(J)
      DO 9 J=1,12
      SUM2(J)=0.0
      SUM3M(J)=0.0
      DO 8 I=1,NYRS
      SUM2(J)=SUM2(J)+Q(I,J)*Q(I,J)
 8    SUM3M(J)=SUM3M(J)+Q(I,J)**3
      AM2=SUM2(J)/NYRS
      AM3=SUM3M(J)/NYRS
      CS(J)=NYRS*NYRS*AM3/((NYRS-1)*(NYRS-2)*AM2**1.5)
      VAR(J)=SUM2(J)/(NYRS-1.)
 9    SD(J)=SQRT(VAR(J))
```

```
C
C     CALC: MONTHLY RATIO OF MEANS/STAND. DEV:
C
      DO 3 J=1,12
 3    RATIO(J)=QBAR(J)/SD(J)
C
C     CALC R(J) CORRELATION COEFF MONTH 1 WITH MONTH 12 OF PREVIOUS YEAR
C
      SUM3(1)=Q(2,1)*Q(1,12)
      DO 10 I=3,NYRS
 10   SUM3(1)=SUM3(1)+Q(I,1)*Q(I-1,12)
      A=SUM2(1)*SUM2(12)
      R(1)=SUM3(1)*NYRS/(SQRT(A)*(NYRS-1))
C
C     CALC: R(2) TO R(12) - CORRELATION COEFF'S MONTH J WITH MONTH J-1:
C
      DO 11 J=2,12
 11   SUM3(J)=0.0
      DO 13 J=2,12
      DO 12 I=1,NYRS
 12   SUM3(J)=SUM3(J)+Q(I,J)*Q(I,J-1)
      A1=SUM2(J)*SUM2(J-1)
 13   R(J)=SUM3(J)/SQRT(A1)
C
C     CALC: B(1) TO B(12)
C
      B(1)=R(1)*SD(1)/SD(12)
      DO 14 J=2,12
 14   B(J)=R(J)*SD(J)/SD(J-1)
C
C     CALC: MONTHLY STAND. DEV. OF RESIDUALS SDR(J)
C
      DO 19 J=1,12
        RJ=R(J)
        FNYRS=NYRS
        A2=(FNYRS-1.)*(1.-RJ*RJ)/FNYRS
 19   SDR(J)=SD(J)*SQRT(A2)
C
C     CALC: STANDARDIZED MONTHLY MEAN, STAND. DEV: AND SKEW. COEFF.
C
      DO 31 J=1,12
 31   SQBAR(J)=QBAR(J)/AA1
      DO 32 J=1,12
 32   SSD(J)=SD(J)/AA2
      DO 33 J=1,12
 33   SCS(J)=CS(J)/AA3
C
C     RESET Q(I,J) TO TRUE VALUES
C
      DO 20 I=1,NYRS
      DO 20 J=1,12
 20   Q(I,J)=Q(I,J)*QBAR(J)
C
C     PRINT RESULTS
C
      WRITE(2,50)
 50   FORMAT(//,5X,5HMONTH,6X,2H 1,7X,2H 2,6X,2H 3,6X,2H 4,6X,2H 5,6X,
     12H 6,6X,2H 7,6X,2H 8,6X,2H 9,6X,2H10,7X,2H11,7X,2H12)
      WRITE(2,51) (QBAR(J),J=1,12)
 51   FORMAT(/,5X,9HMEAN FLOW,(12(2X,F6.2)))
```

```
      WRITE(2,52) (SD(J),J=1,12)
52    FORMAT(/,5X,9HSTAND DEV,(12(2X,F6.2)))
      WRITE(2,53) (SDR(J),J=1,12)
53    FORMAT(/,5X,3HSDR,6X,(12(2X,F6.2)))
      WRITE(2,54) (R(J),J=1,12)
54    FORMAT(/,5X,1HR,8X,(12(2X,F6.2)))
      WRITE(2,55) (B(J),J=1,12)
55    FORMAT(/,5X,1HB,8X,(12(2X,F6.2)))
      WRITE(2,58) (CS(J),J=1,12)
58    FORMAT(/,5X,2HCS,7X,(12(2X,F6.2)))
      WRITE(2,59) (RATIO(J),J=1,12)
59    FORMAT(/,5X,5HRATIO,4X,(12(2X,F6.2)))
      WRITE(2,49) (VAR(J),J=1,12)
49    FORMAT(/,5X,5HVAR  ,4X,(12(1X,F7.2)))
      WRITE(2,60)
60    FORMAT(//,30X,'STANDARDIZED MONTHLY MEAN FLOW, STAND. DEV.AND SK
     1. COEFF.')
      WRITE(2,50)
      WRITE(2,51) (SQBAR(J),J=1,12)
      WRITE(2,52) (SSD(J),J=1,12)
      WRITE(2,58) (SCS(J),J=1,12)
      WRITE(2,56)
56    FORMAT(//,32X,12H ANNUAL FLOW,//28X,4HYEAR,12X,7H QYR(I))
      DO 15 I=1,NYRS
15    WRITE(2,57) I,QYR(I)
57    FORMAT(23X,I2,12X,F8.2)
      CALL BSTAT (QYR,NYRS,AA1,AA2,AA3)
      NLAG=15
      CALL SERCOR (QYR,NYRS,RC,NLAG)
      N=12
      NRP=1
      CALL LINREG (N,RATIO,NRP,CS)
      RETURN
      END


      SUBROUTINE BSTAT (X,N,XBAR,SD,CS)
C
C     CALC MEAN,STAND. DEV AND SKEWNESS COEFF OF A DATA SET OF LENGTH N
C
      DIMENSION X(600)
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 10 I=1,N
10    SUM1=SUM1+X(I)
      XBAR=SUM1/N
      DO 11 I=1,N
      SUM2=SUM2+(X(I)-XBAR)**2
11    SUM3=SUM3+(X(I)-XBAR)**3
      A=SUM2/(N-1)
      SD=SQRT(A)
      AM2=SUM2/N
      AM3=SUM3/N
      A1=AM3/AM2**1.5
      AN=N
      CS=A1*(AN/(AN-1))*(AN/(AN-2))
      WRITE(2,101) XBAR,SD,CS
101   FORMAT(//10X,7H MEAN =,F10.3,5X,13H STAND.DEV. =,F10.3,5X,
     1'COEFF OF SKEWNESS =',F10.3)
      RETURN
      END
```

```
      SUBROUTINE SERCOR(X,N,CL,LIM)
C
C  CALCS SERIAL CORRELATIONS
C  MAX NO. OF LAGS (LIM) IS 15.  LENGTH OF RECORD = N
C
      DIMENSION X(500),CL(16)
      SUM=0.0
      DO 1 I=1,N
    1 SUM=SUM+X(I)
      RMEAN=SUM/N
      DO 2 I=1,N
    2 X(I)=X(I)-RMEAN
      SUM=0.0
      DO 3 I=1,N
      A=X(I)
    3 SUM=SUM+A*A
      CL(1)=SUM
      DO 4 J=1,LIM
      SUM=0.0
      LJ=J+1
      NJ=N-J
      DO 5 K=1,NJ
      KA=K+J
    5 SUM=SUM+X(K)*X(KA)
      CL(LJ)=SUM/CL(1)
    4 CONTINUE
      CL(1)=1.0
      DO 7 I=1,N
    7 X(I)=X(I)+RMEAN
      NN=LIM+1
      WRITE(2,8)
    8 FORMAT (1H0,19X,33H SERIAL CORRELATION COEFFICIENTS.//27X,7H
     1I),7X,5H R(I))
      DO 9 I=1,NN
      ILAG=I-1
    9 WRITE(2,10) ILAG,CL(I)
   10 FORMAT (29X,I2,7X,F10.7)
      RETURN
      END
```

```
      SUBROUTINE LINREG(NGAUGE,ZG,NPP,R)
C
C     LINEAR REGRESSION
C
      DIMENSION ZG(12),R(12),A(10),B(10),REG(10)
      SUM1=0.0
      SUM2=0.0
      DO 5 I=1,NGAUGE
    5 SUM1=SUM1+ZG(I)
      ZGBAR=SUM1/NGAUGE
      DO 6 I=1,NGAUGE
    6 SUM2=SUM2+(ZG(I)-ZGBAR)**2
```

```
      DO 10 J=1,NRP
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      DO 7 I=1,NGAUGE
    7 SUM3=SUM3+R(I)
      RBAR=SUM3/NGAUGE
      DO 8 I=1,NGAUGE
      SUM4=SUM4+(ZG(I)-ZGBAR)*(R(I)-RBAR)
    8 SUM5=SUM5+(R(I)-RBAR)**2
      A(J)=SUM4/SUM2
      B(J)=RBAR-A(J)*ZGBAR
      SUMS2=SUM2*SUM5
      REG(J)=SUM4/SQRT(SUMS2)
   10 CONTINUE
      WRITE(2,50)
50    FORMAT(///2X,'RESULTS OF LINEAR REGRESSION BETWEEN MONTHLY SKEW
     1S COEFF. (CS) AND MONTHLY RATIO (IE. MONTHLY MEAN/STAND. DEV.')
      WRITE(2,60) A(1),B(1),REG(1)
60    FORMAT(//10X,7HSLOPE =,F10.5,5X,11HINTERCEPT =,F10.5,5X,18HREGR
     2ION COEFF =,F10.5)
      RETURN
      END

      FINISH
```

5 Program 'SOIL'

This program is used to simulate the monthly sequences of rainfall, potential evapotranspiration, end-of-month soil moisture deficit (SMD) and end-of-month soil moisture (SM). The simulation models used were described in detail in Section 7.10.

The master segment reads the historical mean monthly rainfalls and their standard deviations, and mean monthly evapotranspiration and their standard deviations. The program then calls the main subroutine 'MONFLO' which in turn calls 'LNDEV' to generate log-normal random numbers from a skewed distribution having the same skewness as the historic rainfall data. It then proceeds to call 'NRDEV' to generate normal random deviates which are for the simulation of monthly evapotranspiration. The required synthetic rainfall and evaporation data are then generated and their monthly means, standard deviations and skewness coefficients evaluated. These are printed out so that the statistics of the historic and synthetic sequences can be compared.

The synthetic rainfall and evaporation data sets are then used as input to the Type A and Type B soil moisture models which were described in Section 7.10. For the sake of computer efficiency these two models have not been treated separately within the program, but operated concurrently in order to make best use of DO loops. The simulated soil moisture sequences are then printed together with their monthly means, standard deviations and skewness coefficients.

The basic input identifiers are:

RBAR(J) = Mean monthly rainfalls for jth month of historic data

SDR(J) = Standard deviation of jth month of rainfall

EBAR(J) = Mean monthly evaporation for jth month of historic data

SDE(J) = Standard deviation of jth month of evaporation

NYRS = Number of years to be simulated (200).

N1, N2 = Constants used in generating random numbers

AMEW, SIGMA = Constants used in generating log-normal variables.

C2 = Drainage coefficients (0.85).

SATSTR = Maximum saturated store (100 mm).

```
      MASTER SOIL
C
C      THIS PROG. GENERATS MONTHLY RAINFALL ,EVAPORATION ,STORAGE
C
      DIMENSION R(200,12),E(200,12),SMD(200,12),SM(200,12),RBAR(12)
     1,B(12),SDR(12),EBAR(12),SDE(12),TS(2400)
      READ(1,40) (RBAR(J),J=1,12)
      READ(1,40) (EBAR(J),J=1,12)
      READ(1,40) (SDR(J),J=1,12)
      READ(1,40) (SDE(J),J=1,12)
      READ(1,40) (B(J),J=1,12)
 40   FORMAT(12F0.0)
      READ(1,50) NYRS,N1,N2,C2,AMEW,SIGMA,SATSTR
 50   FORMAT(3I5,4F0.0)
      CALL MONFLO(RBAR,B,SDR,NYRS,N1,N2,R,EBAR,SDE,C2,AMEW,SIGMA,SATSTR)
      STOP
      END

C
      SUBROUTINE MONFLO(RBAR,B,SDR,NYRS,N1,N2,R,EBAR,SDE,C2,AMEW,SIGMA,
     1SATSTR)
C
      REAL MR,ME,MR1,ME1
      DIMENSION R(200,12),E(200,12),SMD(200,12),SM(200,12),RBAR(12),
     1B(12),SDR(12),SD(12),SDS(12),VAR(12),VARS(12),SMDBAR(12),SMBAR(12)
     1,SUM1(12),SUM2(12),SUM3(12),SUM4(12),EBAR(12),SDE(12),TS(2400)
     2,MR(12),ME(12),SR(12),SE(12),SUM5(12),SUM6(12),SUM7(12),SUM8(12)
     3,VARR(12),VARE(12),RJ(200),EJ(200),SMDJ(200),SMJ(200)
     4,CSR(12),CSE(12),CSD(12),CSS(12),EDEF1(12),EDEF2(12)
      CALL LNDV(N1,N2,NYRS,AMEW,SIGMA,TS)
      DELTAR =0.0
      K=0
      DO 12 J=1,12
      SUM1(J)=0.0
   12 SUM2(J)=0.0
C
C      GENERATE MONTHLY RAINFALL
C
      DO 10 I=1,NYRS
      DO 10 J=1,12
      K=K+1
      RAIN=RBAR(J)+TS(K)*SDR(J)
      IF(RAIN .LT. 0.0) RAIN=0.
      R(I,J) =RAIN
```

```
C
C     GENERATE MONTHLY POTENTIAL EVAPORATION
C
      CALL NRDEV(N1,N2,A)
      E(I,J)=EBAR(J)+A*SDE(J)
 10   DELTAR =RAIN -RBAR(J)
C
C     CALC. MONTHLY SOIL MOISTURE DEFICIT
C
      SMDPM,SMPM=0.0
      DO 20 I=1,NYRS
      DO 20 J=1,12
      SOILMD =SMDPM+E(I,J)-R(I,J)
      IF(E(I,J).LT.R(I,J)) GOTO 30
      IF(SOILMD.LE.100) GOTO 30
      PHI=(250-SOILMD)/150
      SUM1(J)=SUM1(J)+(1.0-PHI)*(E(I,J)-R(I,J))
      SOILMD=SMDPM+PHI*(E(I,J)-R(I,J))
 30   CONTINUE
      IF(SOILMD .LT. 0.0) SOILMD=0.
      SMD(I,J)=SOILMD
C
C     CALC. MONTHLY SOIL STORAGE BY SPECIFYING A CONSTANT STORAGE LEVEL
C
      SOILM =SMPM+E(I,J)-R(I,J)
      IF(SOILM.LE.100) GOTO 45
      PHI=(250-SOILM)/150
      SUM2(J)=SUM2(J)+(1.0-PHI)*(E(I,J)-R(I,J))
      SOILM=SMPM+PHI*(E(I,J)-R(I,J))
 45   CONTINUE
      IF(SOILM .GE. 0.0) GOTO 15
      DRAIN=C2*SOILM
      SOILM=SOILM-DRAIN
      IF(SOILM .LT. SATSTR) GOTO 15
      SM(I,J)=SATSTR
 15   SM(I,J)=SOILM
      SMPM =SM(I,J)
 20   SMDPM=SMD(I,J)
C
C     CALC. THE REDUCTION IN ACTUAL EVAPORATION AND SOIL STORAGE
C
      DO 13 J=1,12
      EDEF1(J)=SUM1(J)/NYRS
 13   EDEF2(J)=SUM2(J)/NYRS
      DO 40 J=1,12
      DO 35 I=1,NYRS
      RJ(I)=R(I,J)
      EJ(I)=E(I,J)
      SMDJ(I)=SMD(I,J)
   35 SMJ(I)=SM(I,J)
C
C     CALC. MONTHLY MEANS , ST. DEV. AND SKEW. COEFFICIENT
C
      CALL BSTAT(RJ,NYRS,MR1,SR1,CSR1)
      CALL BSTAT(EJ,NYRS,ME1,SE1,CSE1)
      CALL BSTAT(SMDJ,NYRS,SMDBAR1,SD1,CSD1)
      CALL BSTAT(SMJ,NYRS,SMBAR1,SDS1,CSS1)
```

```
      MR(J)=MR1
      SR(J)=SR1
      CSR(J)=CSR1
      ME(J)=ME1
      SE(J)=SE1
      CSE(J)=CSE1
      SMDBAR(J)=SMDBAR1
      SD(J)=SD1
      CSD(J)=CSD1
      SMBAR(J)=SMBAR1
      SDS(J)=SDS1
40    CSS(J)=CSS1
      WRITE(2,101) (MR(J),J=1,12)
      WRITE(2,102) (SR(J),J=1,12)
      WRITE(2,103) (CSR(J),J=1,12)
      WRITE(2,101) (ME(J),J=1,12)
      WRITE(2,102) (SE(J),J=1,12)
      WRITE(2,103) (CSE(J),J=1,12)
      DO 50 I=1,NYRS
50    WRITE(2,100) (SMD(I,J),J=1,12)
      WRITE(2,101) (SMDBAR(J),J=1,12)
      WRITE(2,102) (SD(J),J=1,12)
      WRITE(2,103) (CSD(J),J=1,12)
      DO 60 I=1,NYRS
60    WRITE(2,100) (SM(I,J),J=1,12)
      WRITE(2,101) (SMBAR(J),J=1,12)
      WRITE(2,102) (SDS(J),J=1,12)
      WRITE(2,103) (CSS(J),J=1,12)
      WRITE(2,101) (EDEF1(J),J=1,12)
      WRITE(2,101) (EDEF2(J),J=1,12)
100   FORMAT(12F8.2)
101   FORMAT(/,5X,'MEAN  ',(12(2X,F6.2)))
102   FORMAT(/,5X,'ST. DEV',(12(2X,F6.2)))
103   FORMAT(/,5X,'SK. COEFF',(12(2X,F6.2)),//)
      RETURN
      END


C
      SUBROUTINE NRDEV(N1,N2,A)
C
C     GENERATES NORMAL RANDOM DEVIATES 'A'
C
      X1=G05AAF(YY)*6.2831853
      X2=G05AAF(YY)
      A=SQRT(-2.0*ALOG(X2))
      A=A*SIN(X1)
      RETURN
      END
```

```
C
      SUBROUTINE LNDV (N1,N2,NYRS,AMEW,SIGMA,TS)
C
      DIMENSION TS(2400)
      CV=SIGMA/AMEW
      CSK=CV**3+3*CV
      A1=CV**2+1.0
      A2=ALOG(A1)
      SIGMAY=SQRT(A2)
      AMEUY=ALOG(AMEW)-A2/2.0
      K=12*NYRS
      DO 10 I=1,K
      CALL NRDEV(N1,N2,A)
      A3=A*SIGMAY+AMEUY
      TN=2.7182818**A3
 10   TS(I)=(TN-AMEW)/SIGMA
      RETURN
      END


      SUBROUTINE DSTAT(X,N,XBAR,SD,CS)
C
C     CALC MEAN,STAND. DEV AND SKEWNESS COEFF OF A DATA SET OF LENGTH N
C
      DIMENSION X(200)
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 10 I=1,N
 10   SUM1=SUM1+X(I)
      XBAR=SUM1/N
      DO 11 I=1,N
      SUM2=SUM2+(X(I)-XBAR)**2
 11   SUM3=SUM3+(X(I)-XBAR)**3
      A=SUM2/(N-1)
      SD=SQRT(A)
      AM2=SUM2/N
      AM3=SUM3/N
      IF(AM2.EQ.0) AM2=1.0
      A1=AM3/AM2**1.5
      AN=N
      CS=A1*(AN/(AN-1))*(AN/(AN-2))
      RETURN
      END

      FINISH
```

APPENDIX III

DATA VALIDATION ANALYSIS

TYPICAL SCORE MATRICES

BEFORE AND AFTER VALIDATIONS

SCORE MATRIX BEFORE VERIFICATION

GAUGING STATION: CADORA

PERIOD: 1950-1962

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	⑤	0	0
0	0	0	0	0	1	2	0	3	0	0	0
0	0	0	0	0	0	0	0	0	⑤	⑤	0
⑤	0	0	0	0	0	4	0	2	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	1	4	3	2	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	0	0	2	0	0
0	0	0	0	0	0	0	0	4	0	0	0
0	0	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	1	1	1	1	1	0	1	0	0

SCORE MATRIX AFTER VERIFICATION

0	0	0	0	0	0	1	3	0	0	0	0
0	0	0	0	0	1	3	0	0	1	0	0
0	0	0	0	1	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	3	4	1	2	1	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	3	1	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	3	1	0	0
0	0	0	1	0	0	0	1	0	1	0	0
0	0	0	0	0	1	0	0	0	0	1	0
0	0	1	0	0	0	1	1	1	0	0	0

SCORE MATRIX BEFORE VERIFICATION

GAUGING STATION: BELMONT

PERIOD: 1950-1962

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	1	0
1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	3	0	⑤	4	3	⑤	0	0	⑤
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	1	0	0	1	3	0	0	0
0	0	0	0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	1	0	1	0	0	0
0	0	2	⑤	⑤	⑤	⑤	4	0	0	0	0

SCORE MATRIX AFTER VERIFICATION

0	0	0	0	0	0	1	2	0	0	0	0
0	0	0	0	0	1	2	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	1	0	1	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	0	0	3	3	1	5	4	2
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	1	0	0	0	0	0
0	0	0	0	2	0	0	0	0	1	0	0
0	0	0	0	1	0	0	2	5	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0

SCORE MATRIX BEFORE VERIFICATION

GAUGING STATION: ABERNANT

PERIOD: 1938-1973

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	1	3	4	1	0	0	0	4	0
0	0	0	0	2	3	1	0	0	0	0	0
0	0	0	0	4	4	2	⑥	2	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	1	2	2	0	0	0	0	0
0	0	0	1	0	1	1	0	1	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	4	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	1	2	0	0	1	0
0	0	0	0	0	2	0	1	1	0	0	0
0	0	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	1	0	1	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3	1	2	1	1
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	⑦	2	1	3	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	3	2	0	0
0	0	0	0	0	⑥	⑦	⑦	⑤	0	1	0
0	0	1	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	0	2	0	0	0	0	0
0	0	0	0	0	0	0	1	0	1	0	0
0	0	0	0	0	0	0	0	0	0	1	0
1	0	1	1	0	2	0	1	0	1	1	1
1	1	1	0	1	1	1	1	0	2	2	1
1	1	1	1	1	0	1	1	1	2	1	3

SCORE MATRIX AFTER VERIFICATION

GAUGING STATION: ABERNANT

PERIOD: 1938-1973

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	1	3	4	1	0	0	0	6	0
0	0	0	0	3	3	1	0	0	0	0	0
0	0	0	0	4	4	2	7	2	0	0	0
1	0	0	0	0	0	1	0	0	0	0	0
1	0	0	0	1	2	2	0	0	0	0	0
0	0	0	2	0	1	1	0	0	0	0	0
0	0	0	1	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	4	0
0	0	0	1	0	0	1	0	1	0	0	0
0	0	0	0	0	1	1	2	0	0	0	0
0	0	0	0	0	2	0	0	1	0	0	0
0	0	1	0	0	0	4	0	0	0	0	0
0	0	0	0	0	1	3	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3	1	1	0	1
0	0	0	0	0	0	1	0	0	0	0	0
0	1	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	7	2	1	3	0	0	0
0	0	0	0	1	1	0	0	0	1	0	0
0	0	0	0	0	0	0	0	2	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
2	3	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	4	2	0	0
0	0	0	0	0	4	6	0	0	0	0	0
0	0	1	0	1	0	0	1	0	0	0	0
0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	0	2	0	0	0	0	0
0	0	0	0	0	0	1	1	0	1	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	1	0
0	0	0	0	0	0	1	1	1	1	0	2

SCORE MATRIX BEFORE VERIFICATION

GAUGING STATION: BELMONT

PERIOD: 1938-1973

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	1	2	1	0	0	0	0	0
0	4	0	0	1	3	0	0	0	2	0	0
0	0	0	0	3	⑤	2	2	1	0	0	0
0	0	0	1	0	1	0	1	2	0	0	0
4	0	0	0	1	4	0	0	0	0	0	0
0	0	0	0	0	1	0	0	⑦	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	2	3	0
0	0	0	2	2	1	2	2	3	2	0	0
0	4	0	1	1	0	0	3	0	1	1	0
0	0	0	0	0	2	0	0	1	0	0	0
0	0	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	1	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	3	2	⑦	⑥	⑤
0	0	1	0	0	0	0	0	0	0	0	0
1	0	0	1	0	1	2	0	0	0	0	0
0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	0	1	1	0	1	4	1	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	1	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
3	2	0	0	0	0	2	1	0	0	0	1
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	3	0	0	0	0	0	0
0	0	0	0	0	0	1	2	0	0	0	0
0	0	0	0	0	0	0	1	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1	0
1	0	1	1	0	1	1	1	0	1	1	1
1	1	1	0	1	1	1	0	0	2	1	1
1	1	1	1	1	0	2	1	1	2	0	1

SCORE MATRIX AFTER VERIFICATION

GAUGING STATION: BELMONT

PERIOD: 1938-1973

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	2	3	1	0	0	0	0	0
0	4	0	0	1	3	0	1	0	2	0	0
1	0	0	0	3	5	3	2	2	0	0	0
1	0	0	1	0	2	2	1	2	0	0	0
4	0	0	0	2	4	0	0	0	0	0	0
0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	4	0
0	0	0	3	2	1	2	2	2	3	0	0
0	5	0	1	0	2	2	3	0	2	0	0
0	0	0	0	0	2	0	0	1	0	0	0
0	0	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	1	0	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	4	1	1	0	1
0	0	1	0	0	1	1	0	0	0	0	0
0	0	0	1	0	1	2	0	0	0	0	0
0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	0	1	1	0	1	4	1	0	0
0	0	0	0	0	1	2	1	0	0	0	0
0	0	0	0	0	1	1	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	2	1	0	0	0	1
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	3	1	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	4	0	0	1	0	0	0
0	0	0	0	0	0	1	2	0	0	0	0
0	0	0	0	0	0	1	2	2	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	1	0	2	0	0
0	0	0	0	0	0	1	0	0	1	0	0

APPENDIX IV

APPENDIX FOR MISCELLANEOUS GRAPHICAL RELATIONS

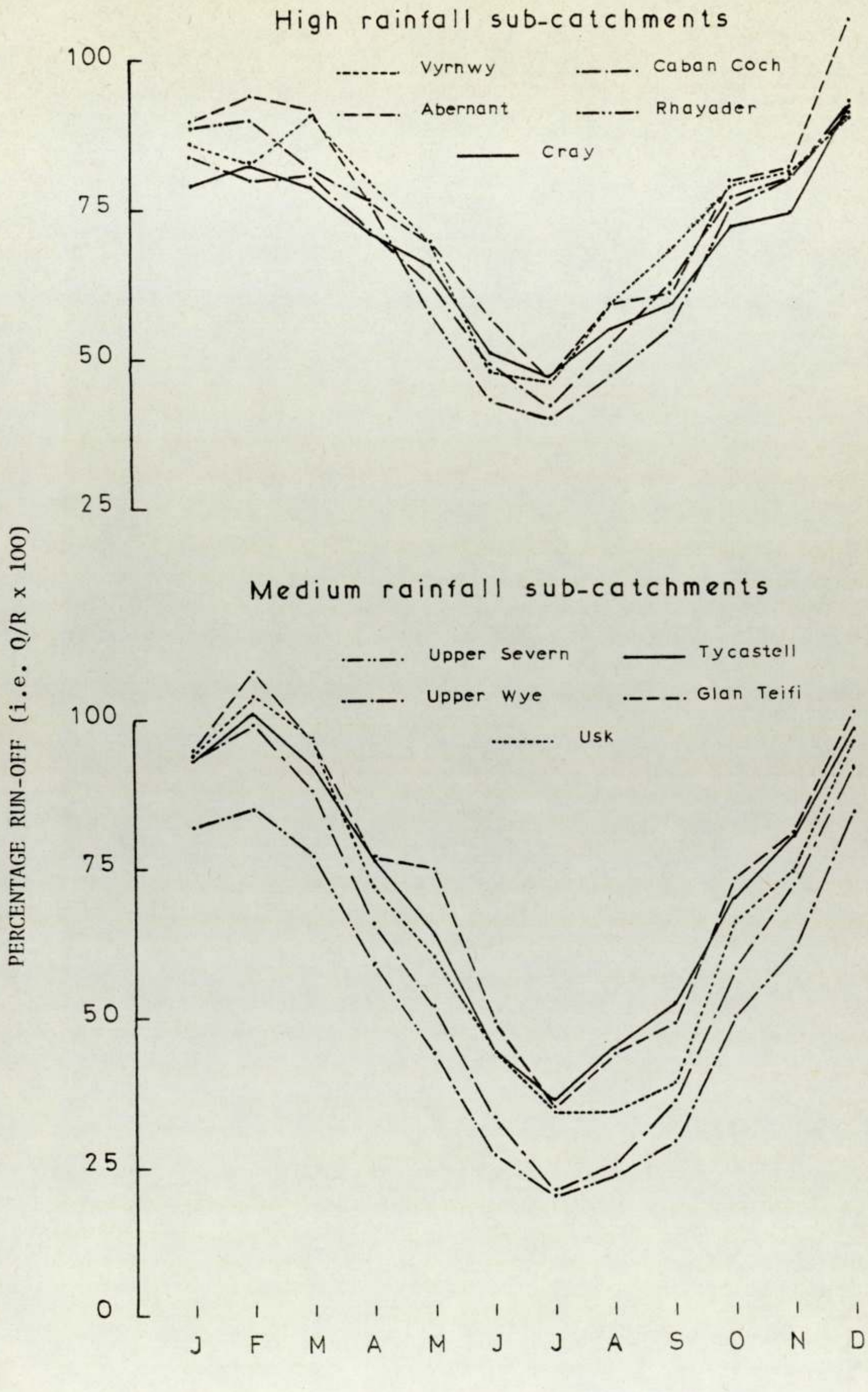


FIGURE A.1/2 VARIATION OF MONTHLY PERCENTAGE RUN-OFF OF THE SUB-CATCHMENT RECORDS (1960-75)

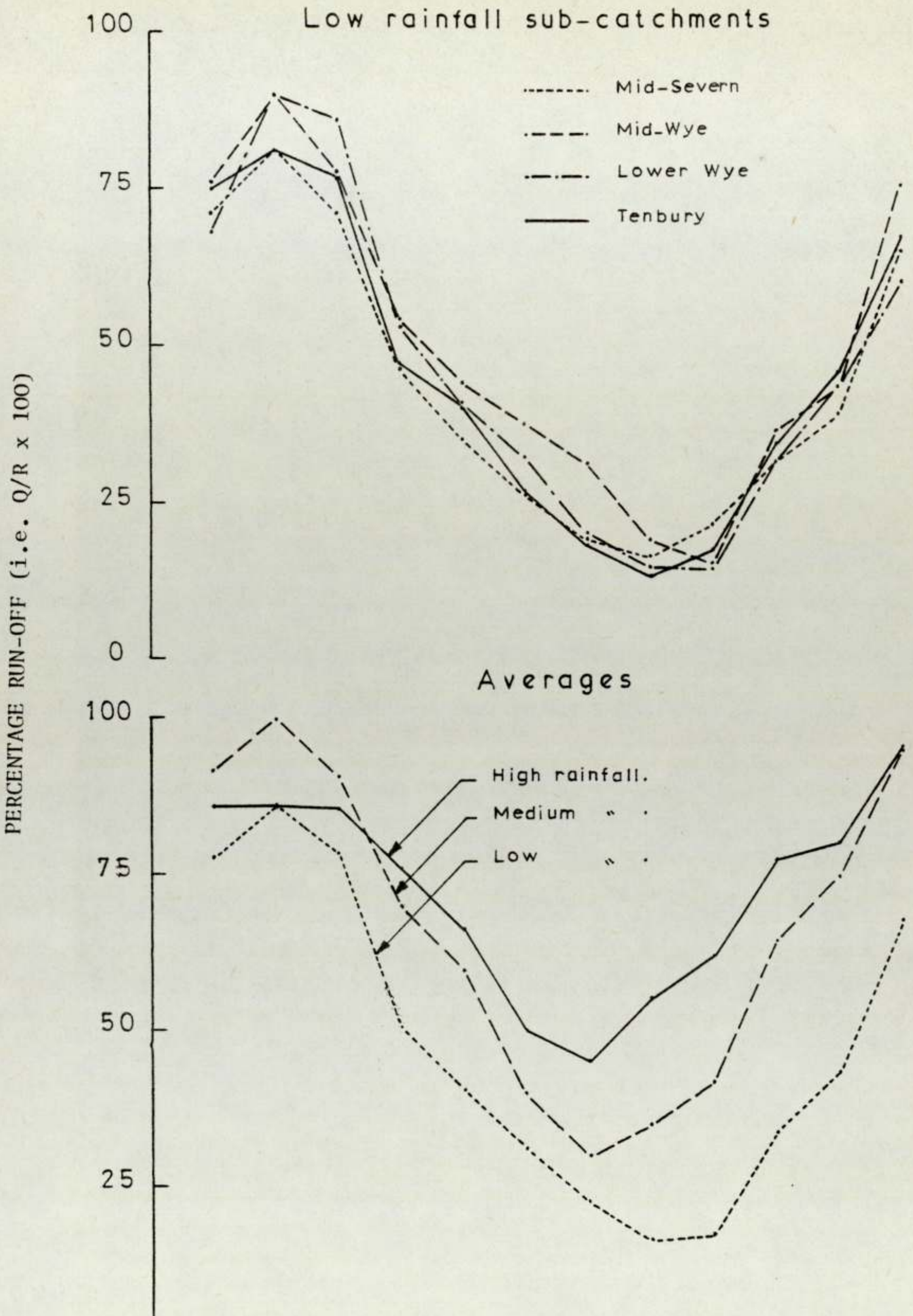


FIGURE A.1/2 VARIATION OF MONTHLY PERCENTAGE RUN-OFF OF THE SUB-CATCHMENT RECORDS (1960-75) (Cont)

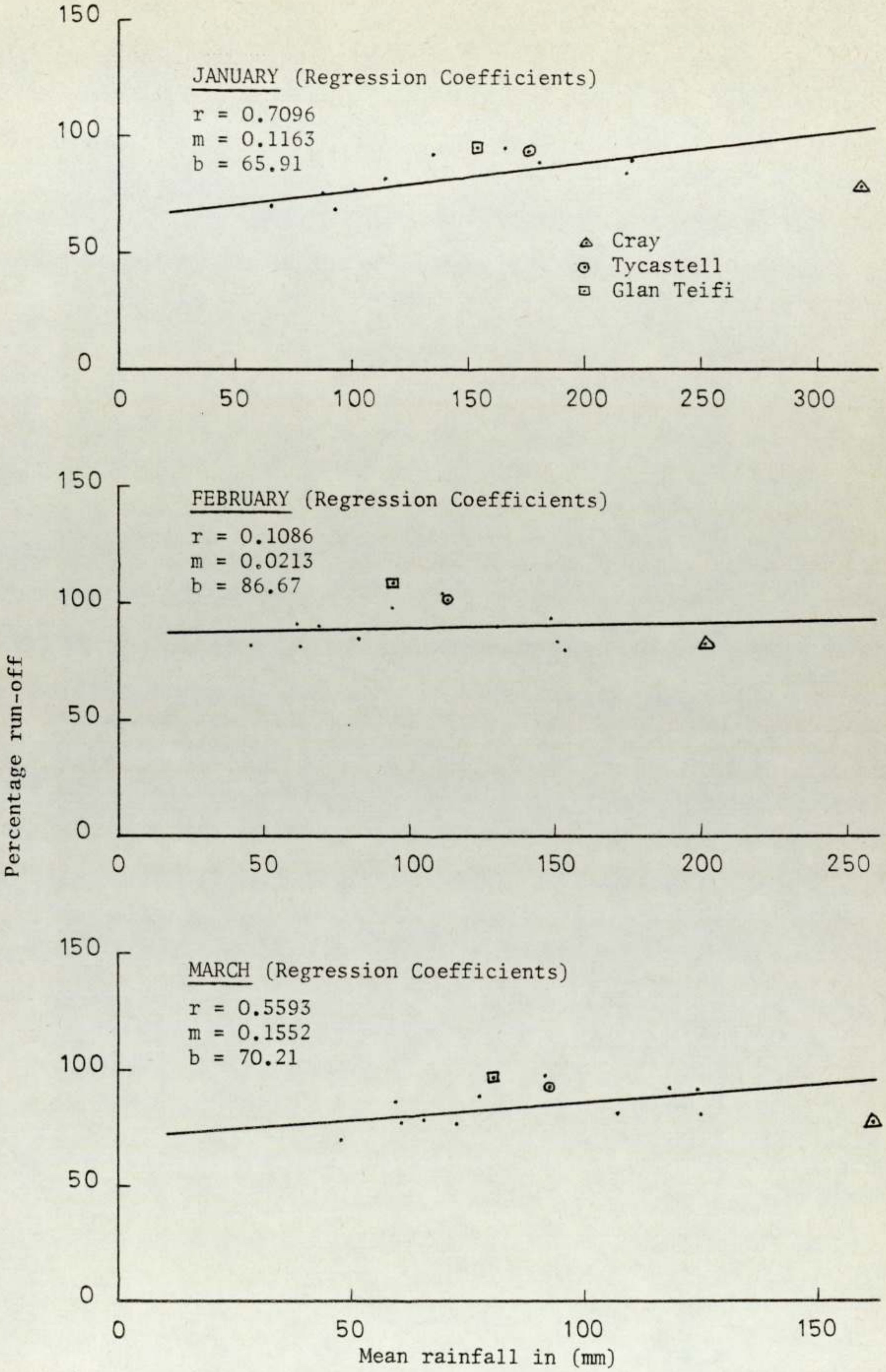


FIGURE A.2/1 LINEAR REGRESSION RELATIONSHIP BETWEEN MEAN MONTHLY RAINFALL AND PERCENTAGE RUN-OFF (1960-75)

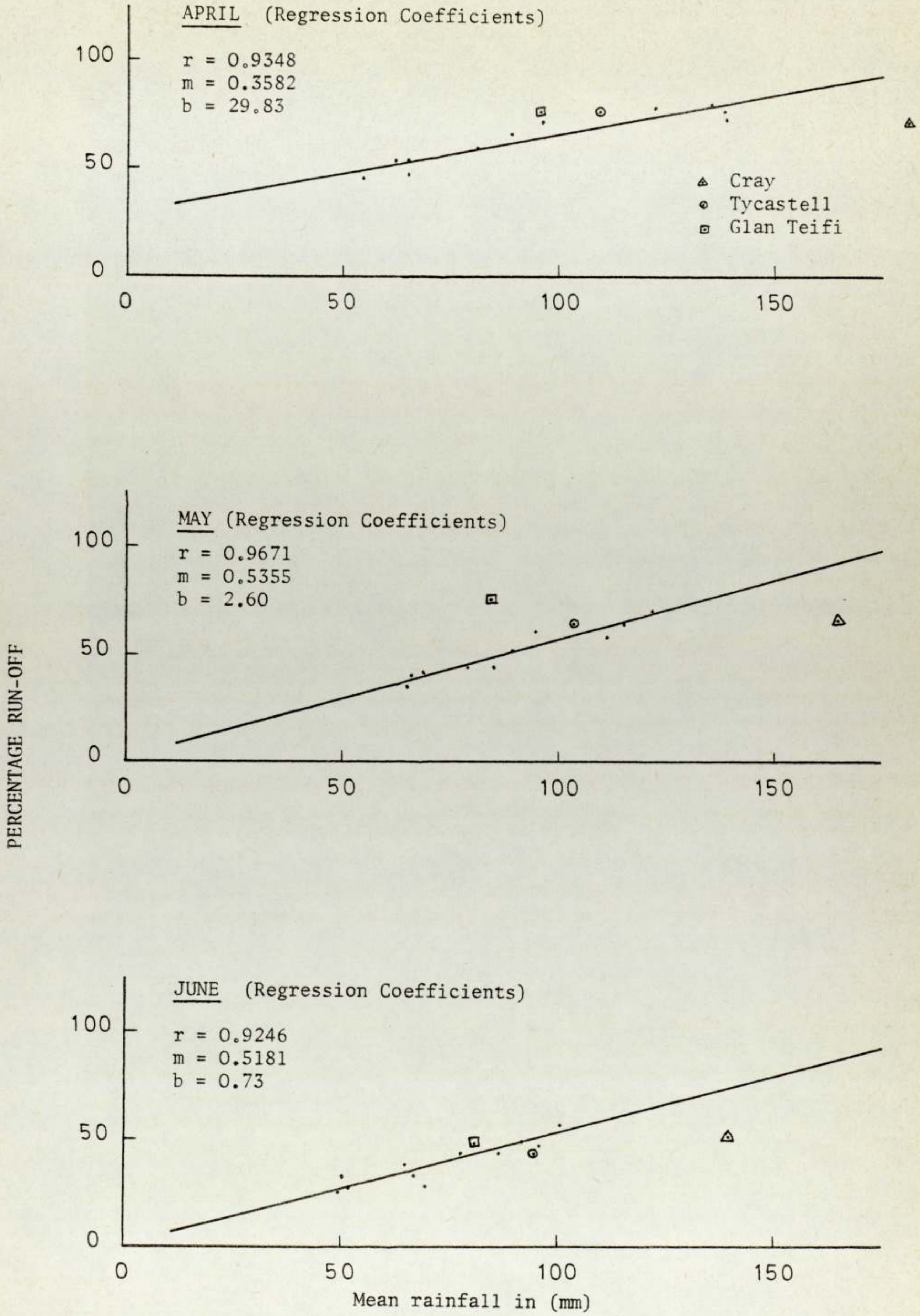


FIGURE A.2/2 LINEAR REGRESSION RELATIONSHIP BETWEEN MEAN MONTHLY RAINFALL AND PERCENTAGE RUN-OFF (1960-75)

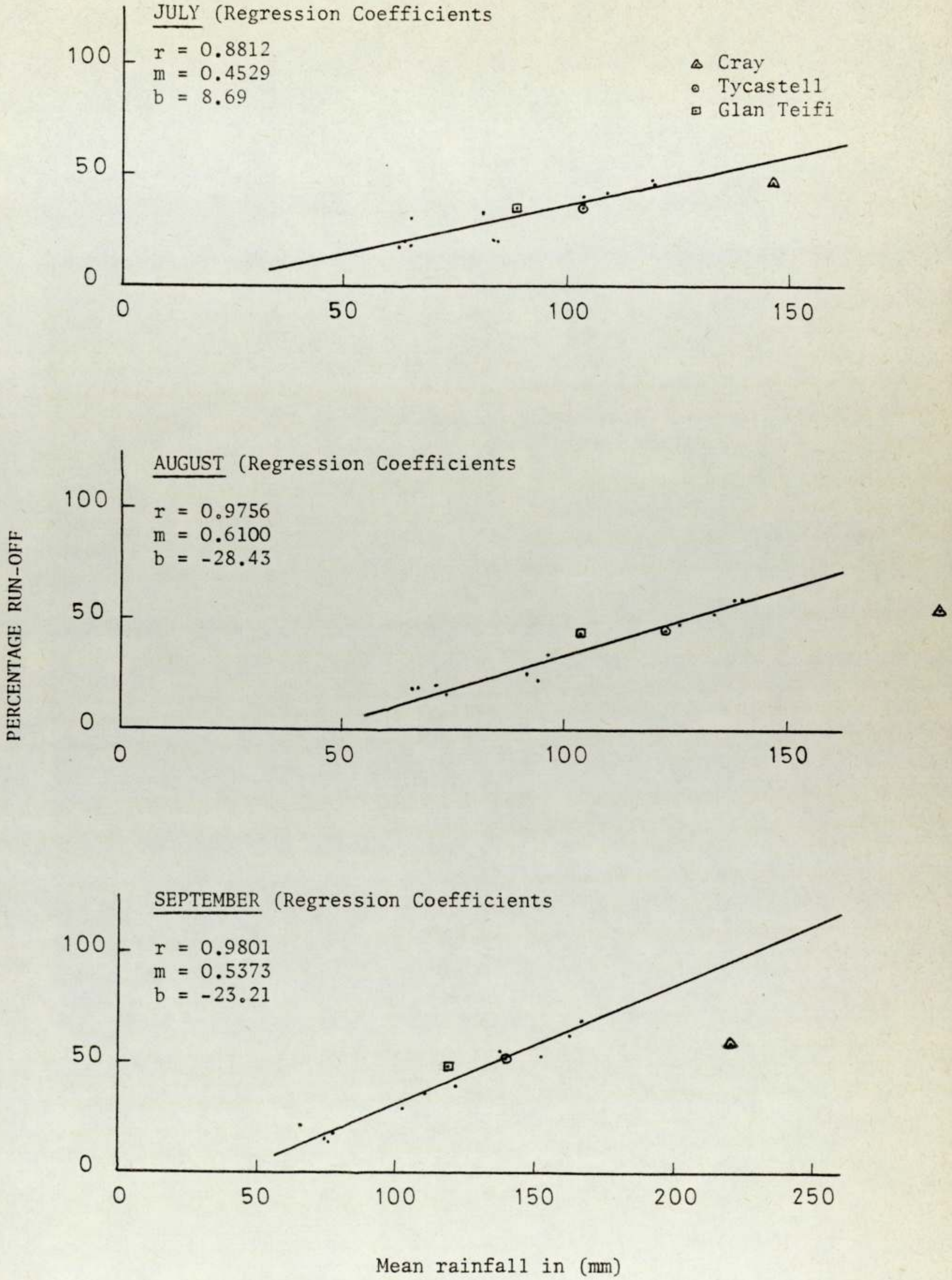


FIGURE A.2/3 LINEAR REGRESSION RELATIONSHIP BETWEEN MEAN MONTHLY RAINFALL AND PERCENTAGE RUN-OFF (1960-75)

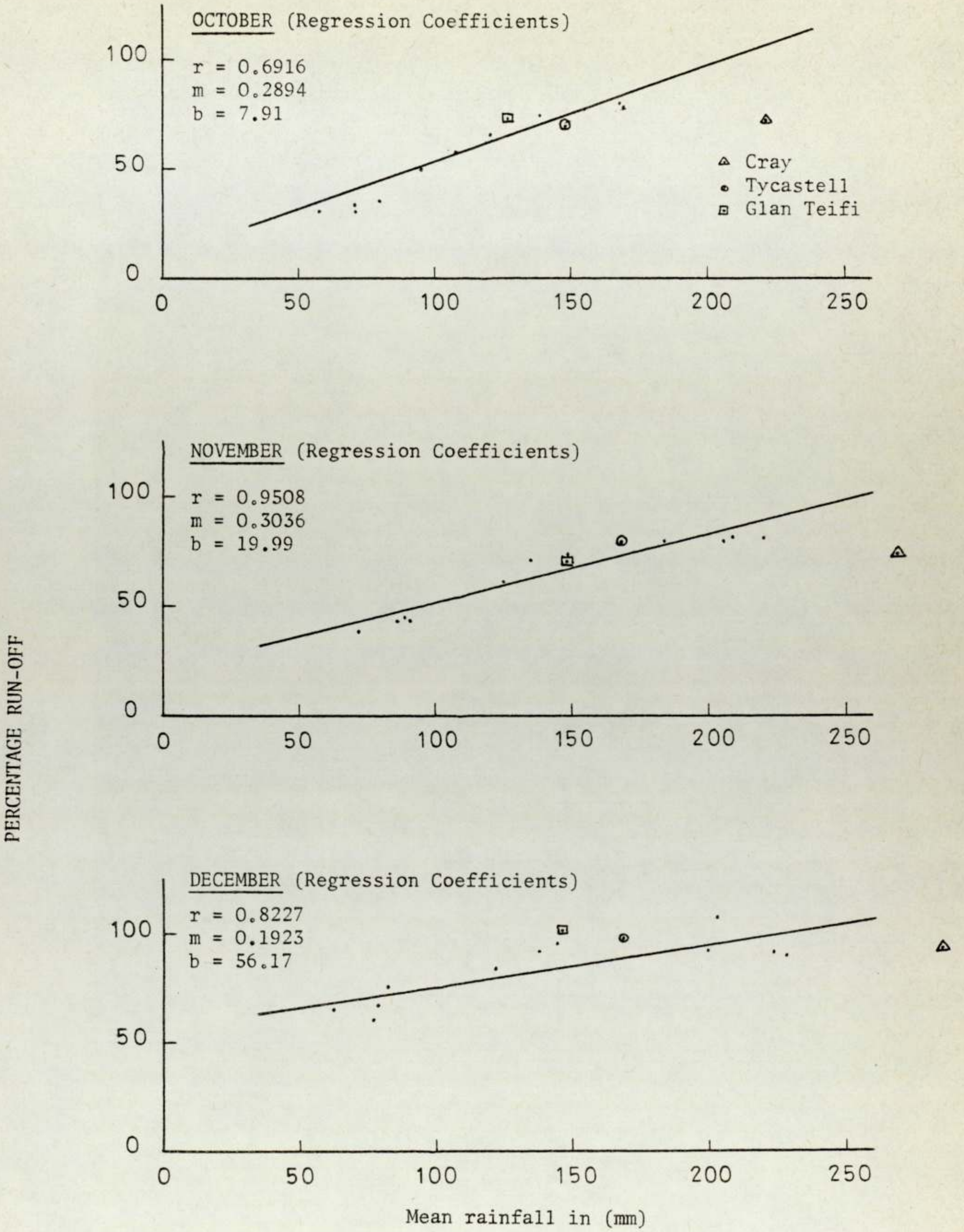
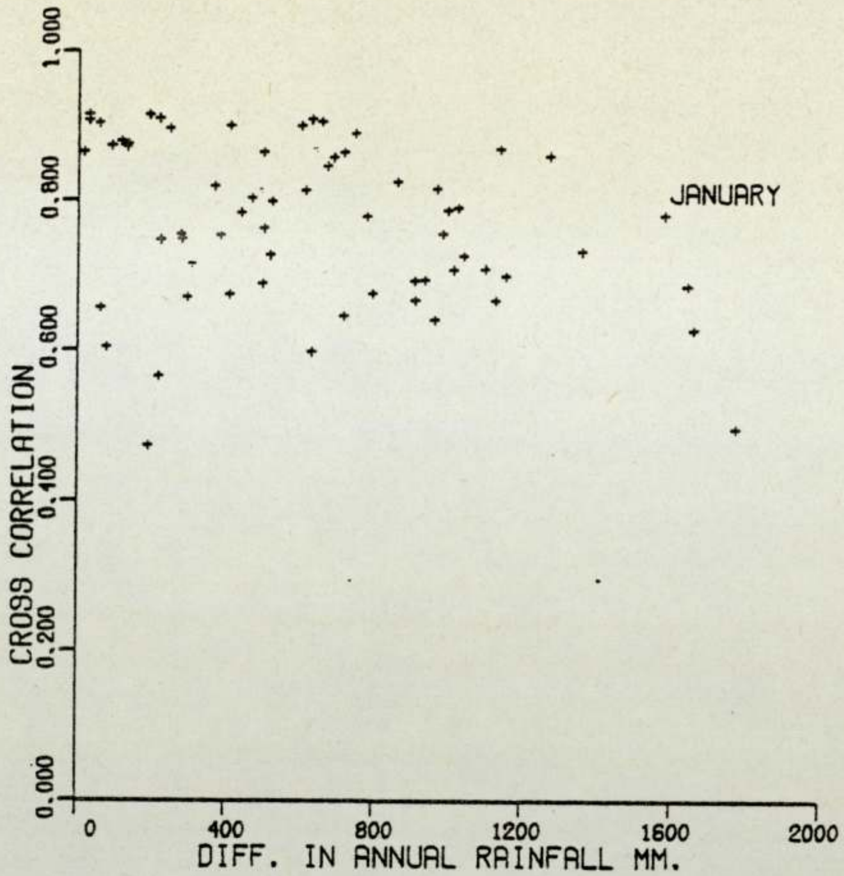


FIGURE A.2/4 LINEAR REGRESSION RELATIONSHIP BETWEEN MEAN MONTHLY RAINFALL AND PERCENTAGE RUN-OFF (1960-75)



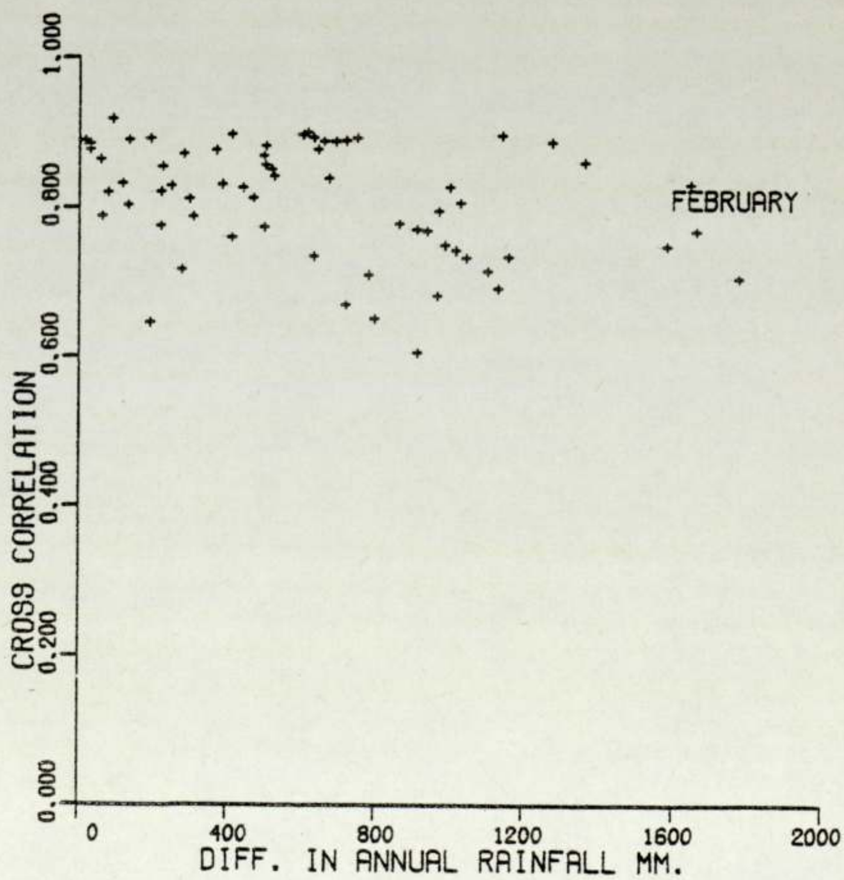
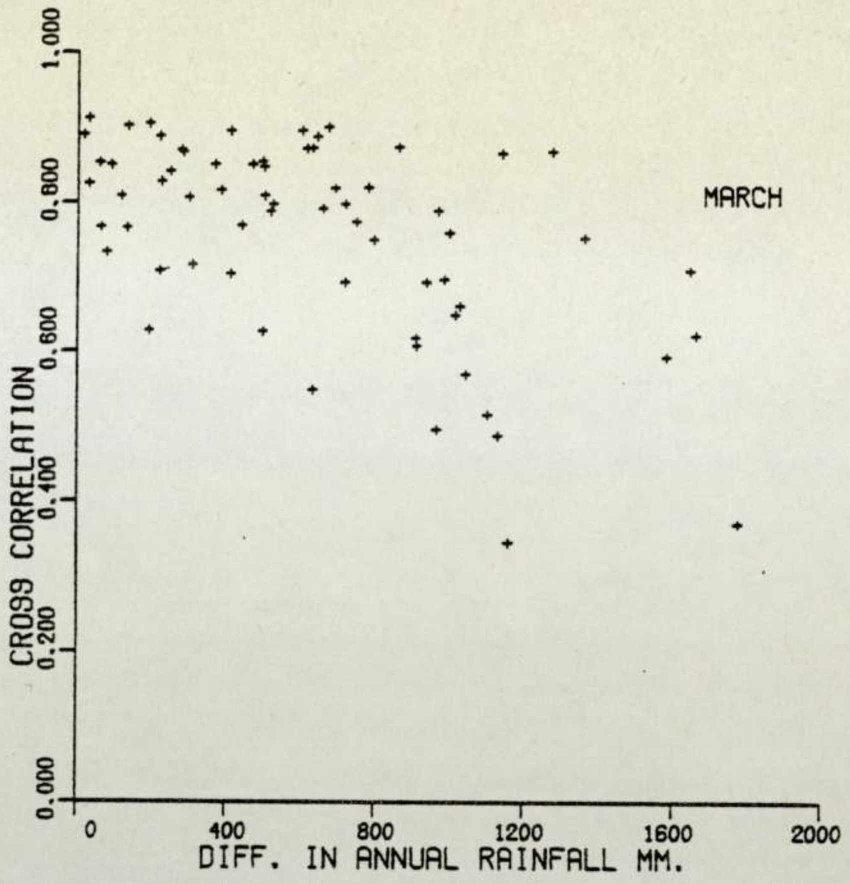


FIGURE A.4/1 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



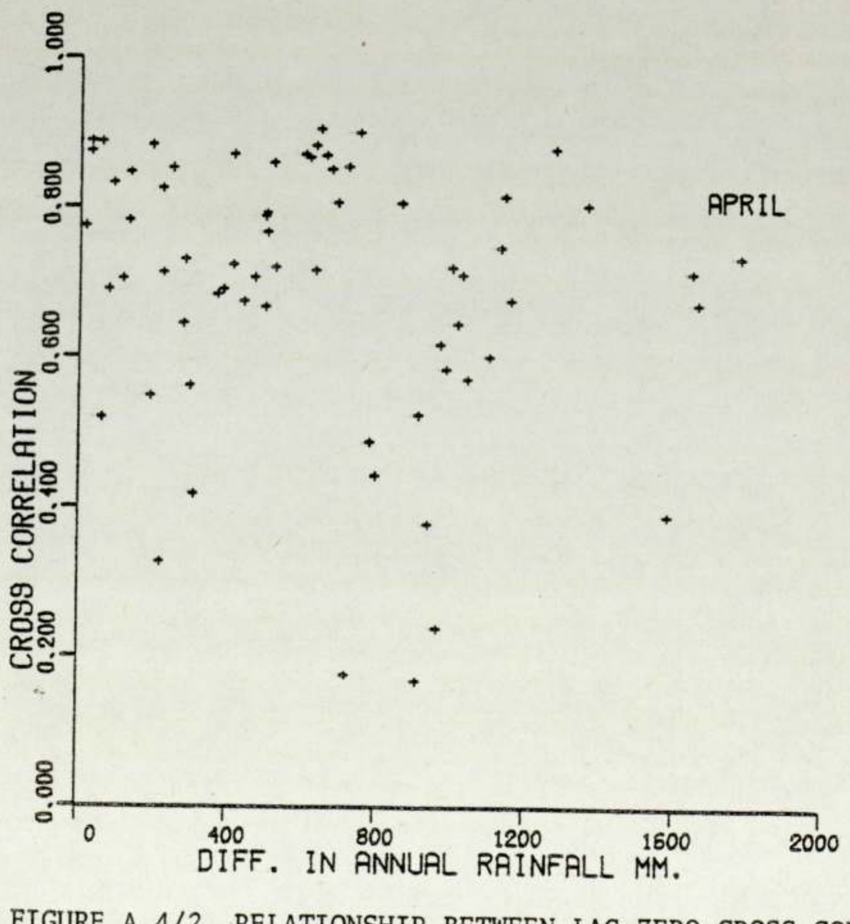
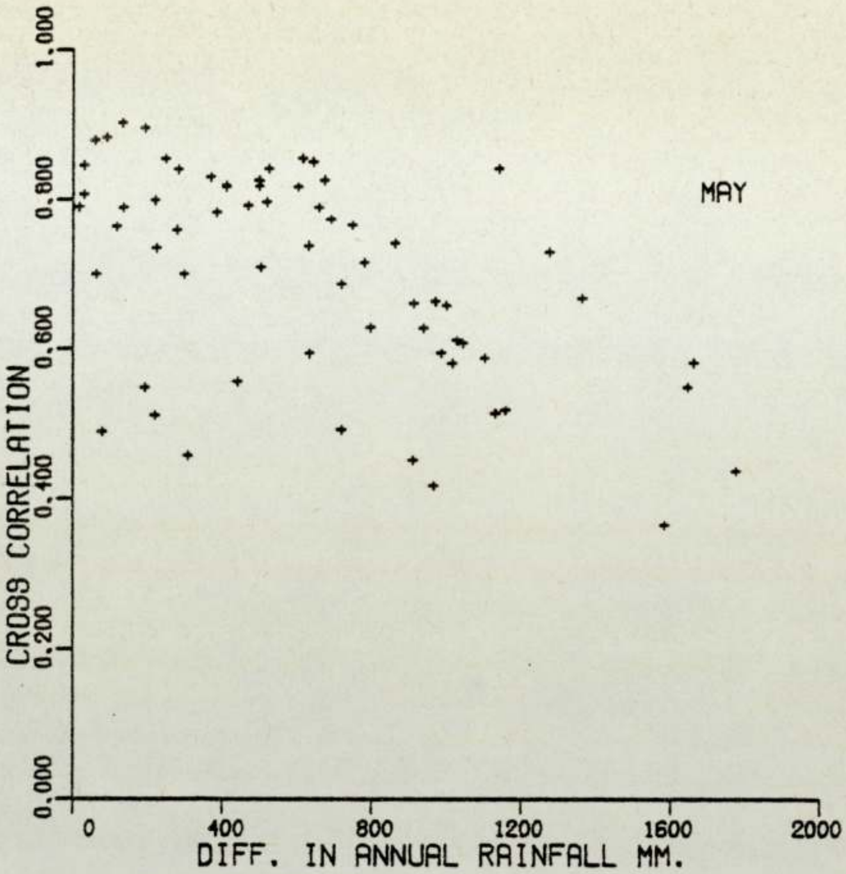


FIGURE A.4/2 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



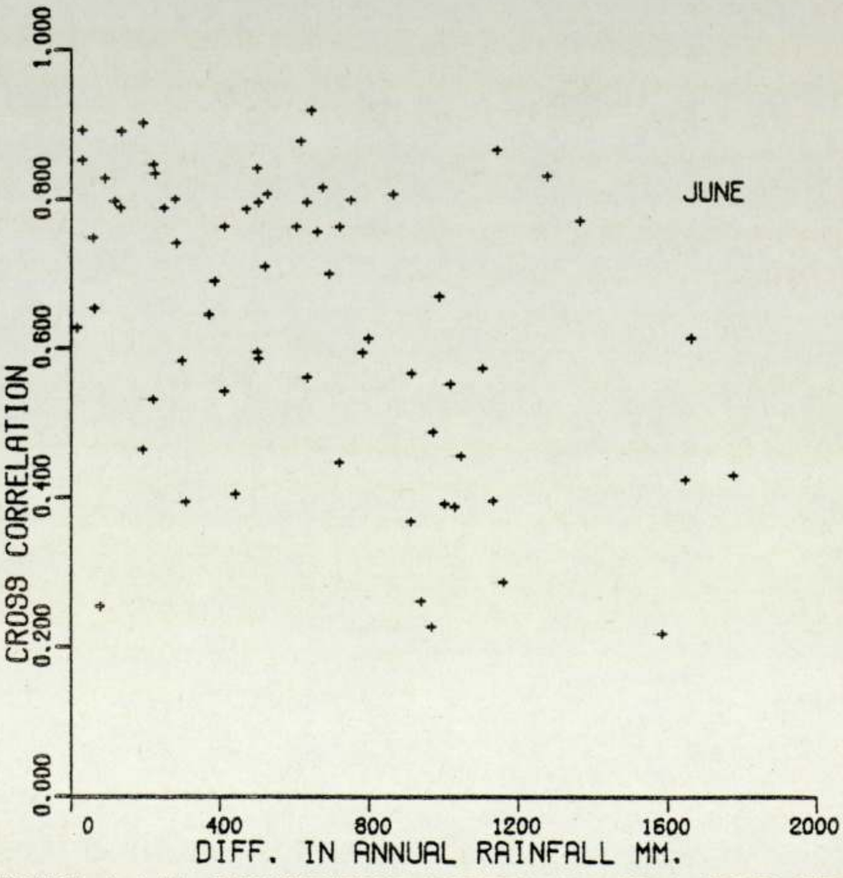
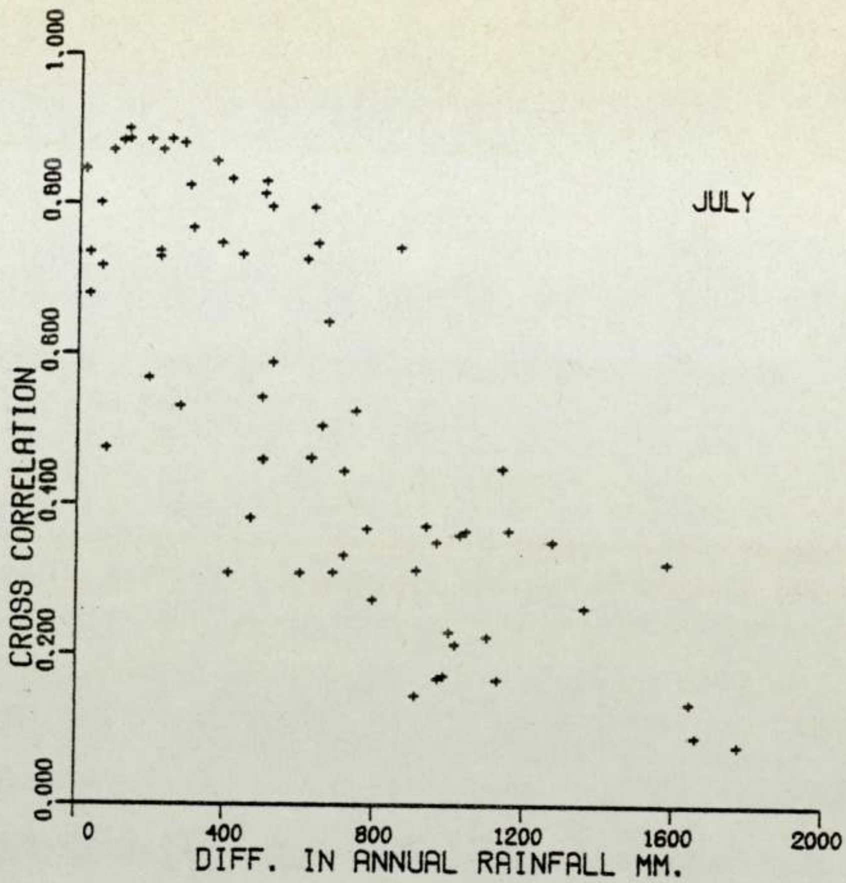


FIGURE A.4/3 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



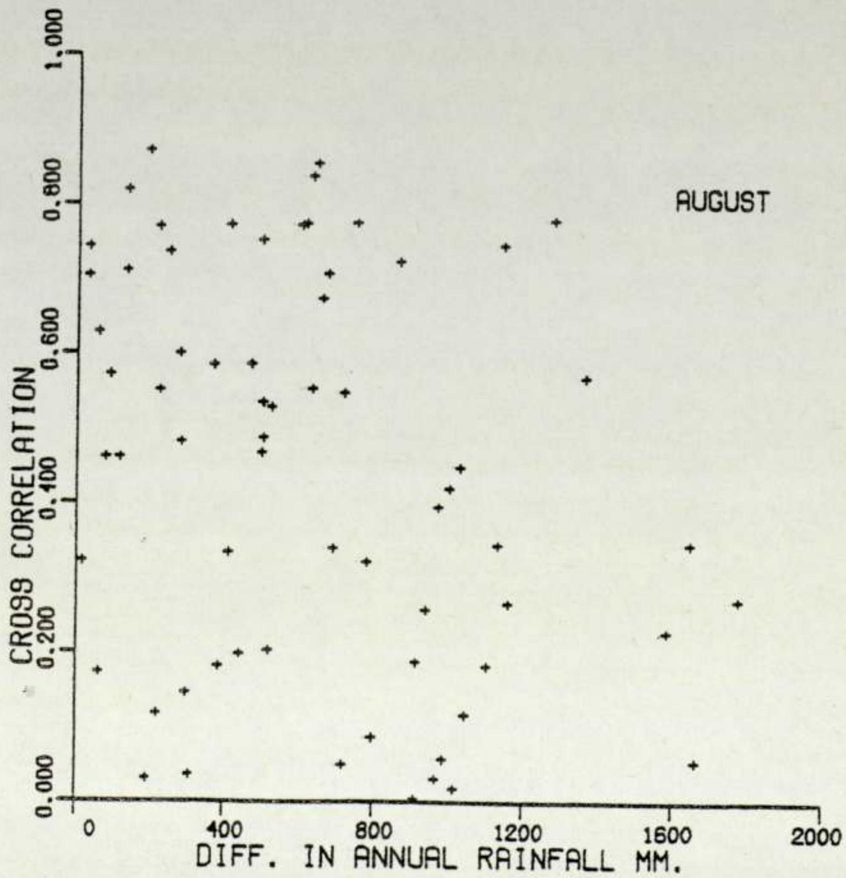
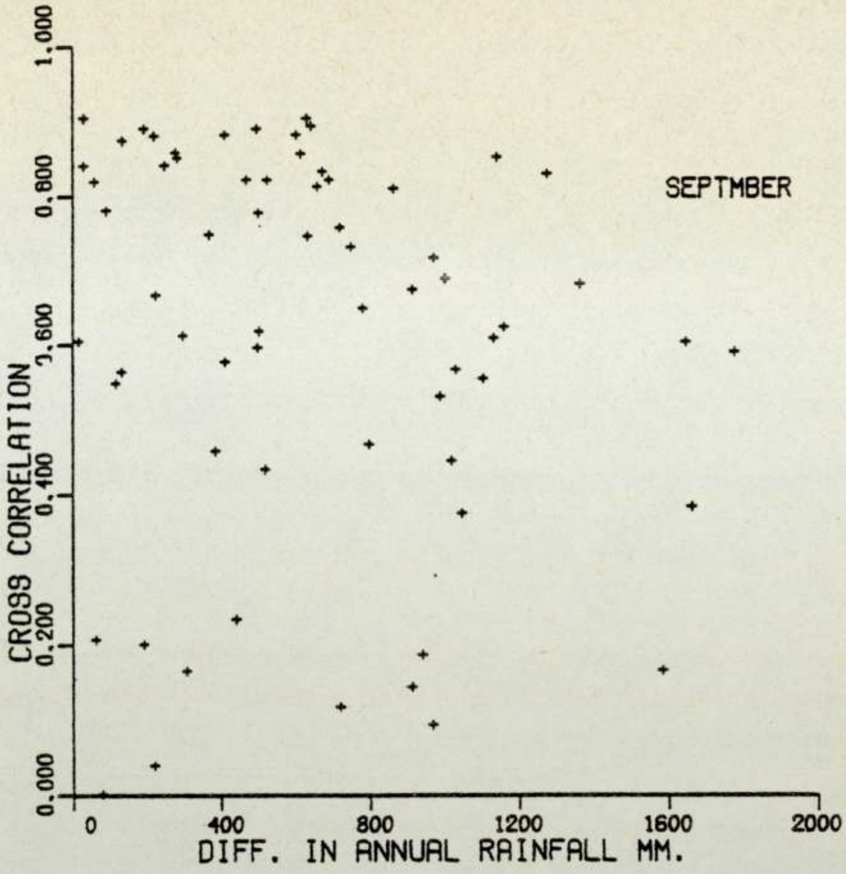


FIGURE A.4/4 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



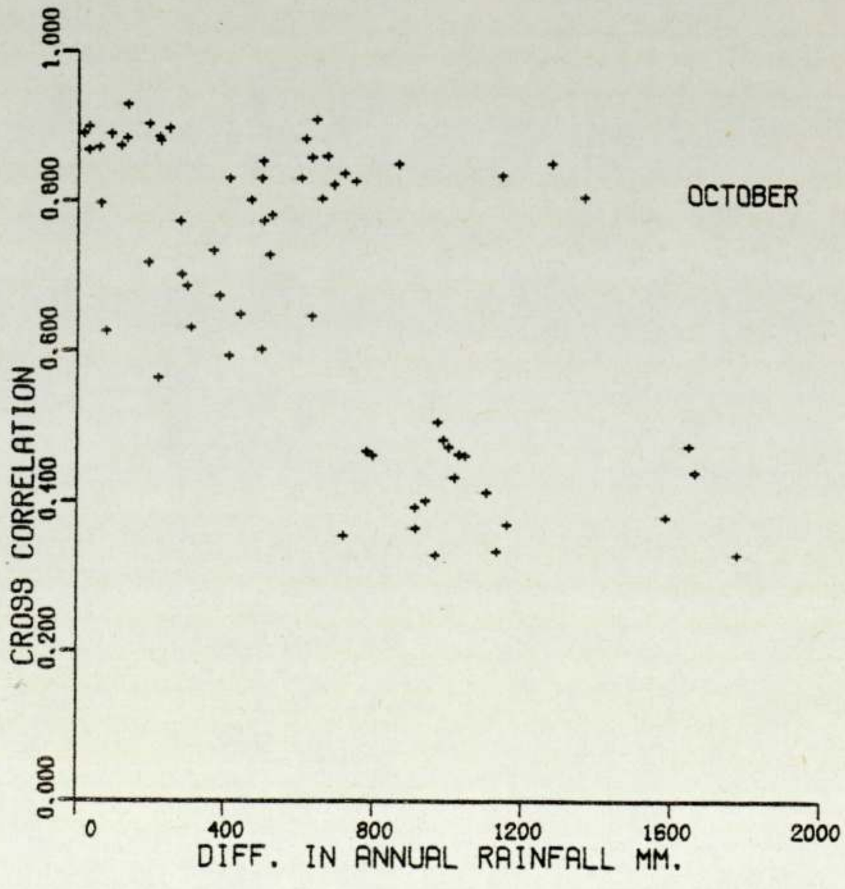
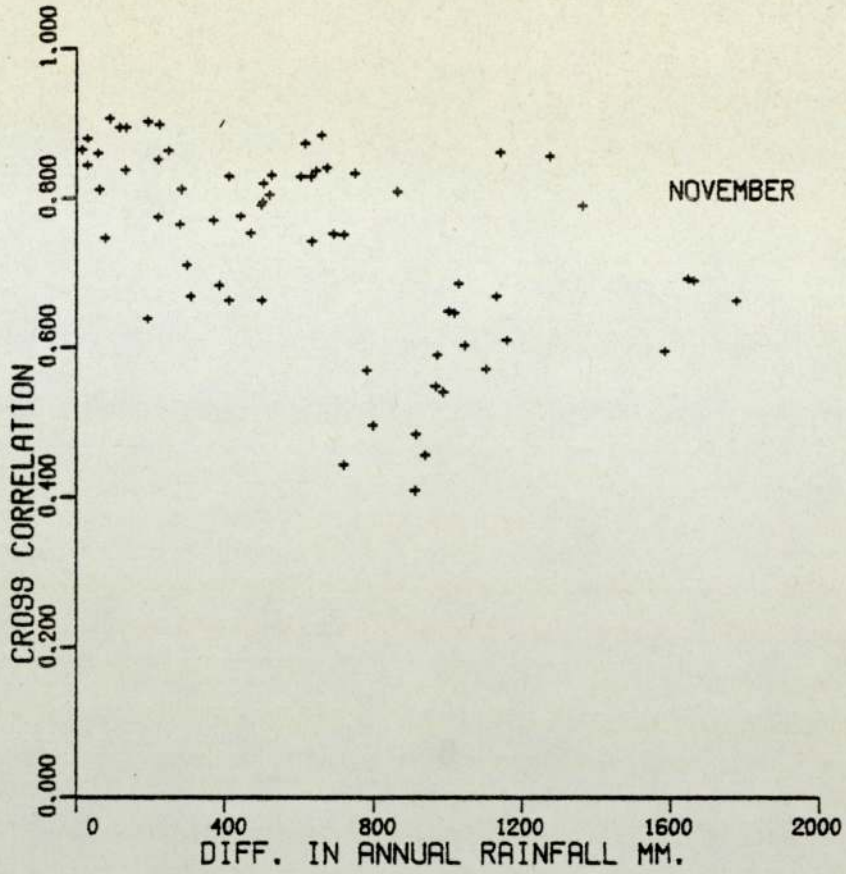


FIGURE A.4/5 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



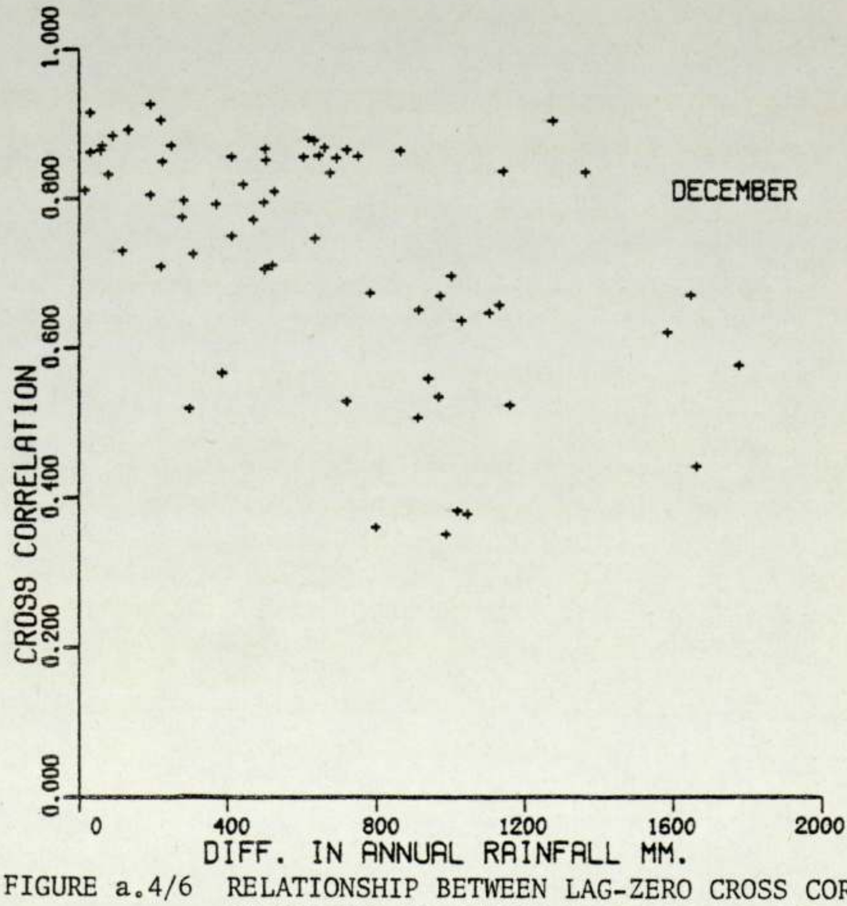
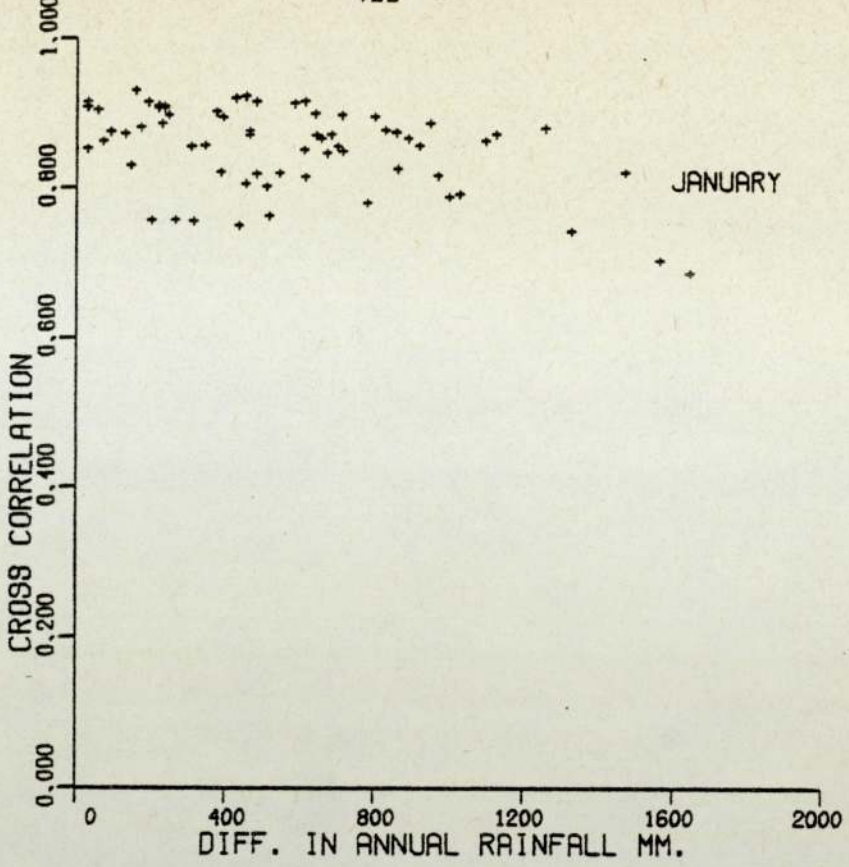


FIGURE a.4/6 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR SUB-CATCHMENTS (1960-75)



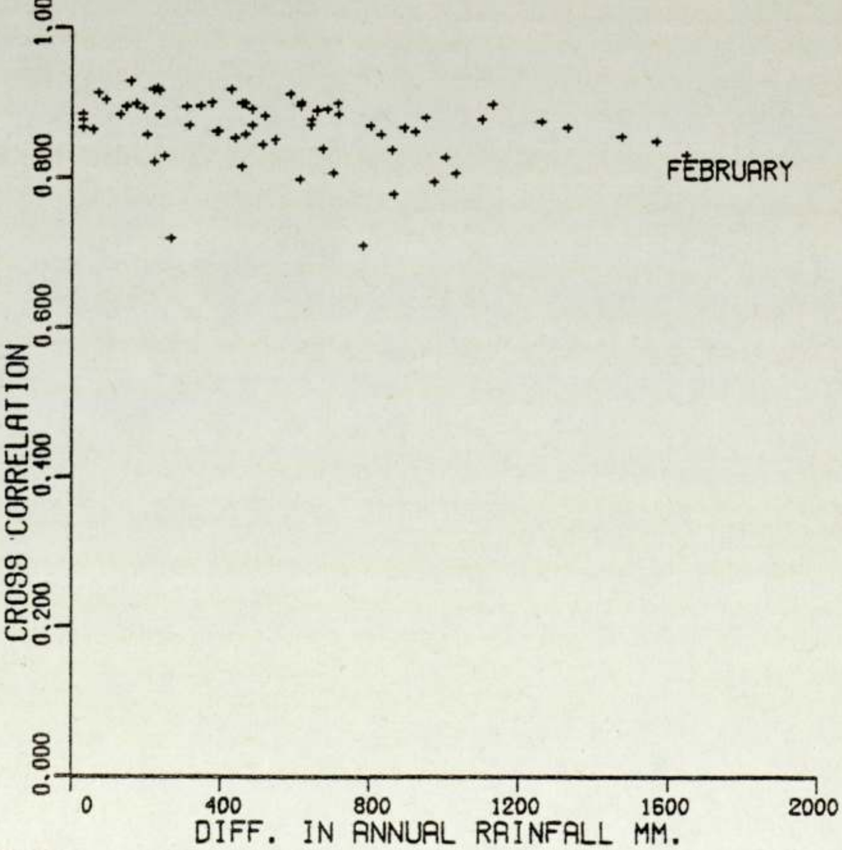
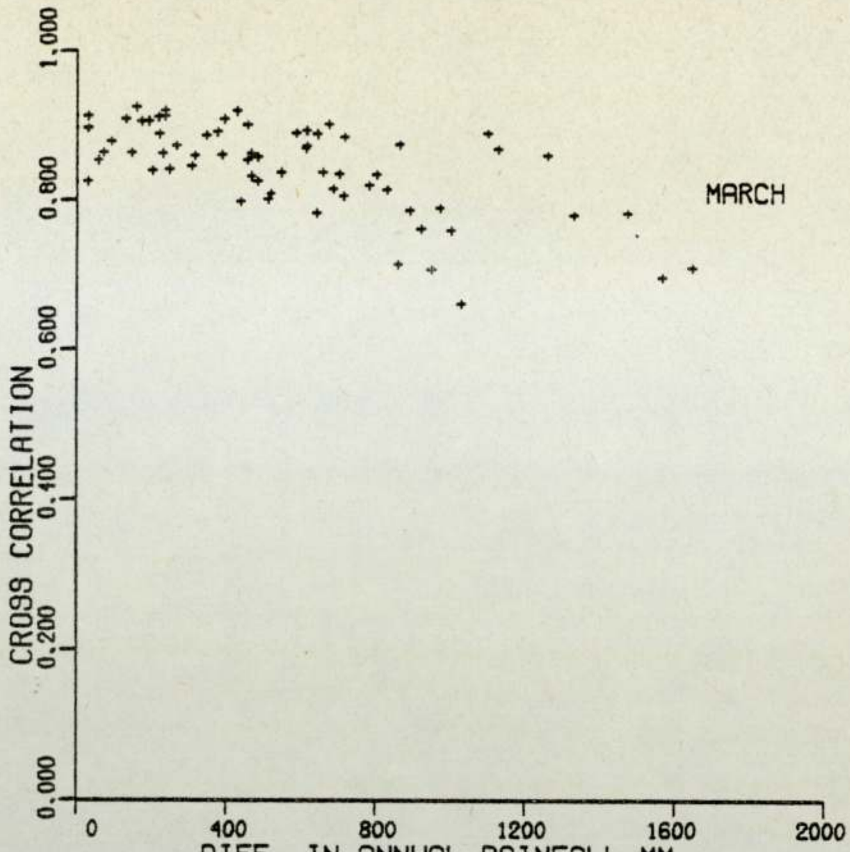


FIGURE A.3/1 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)



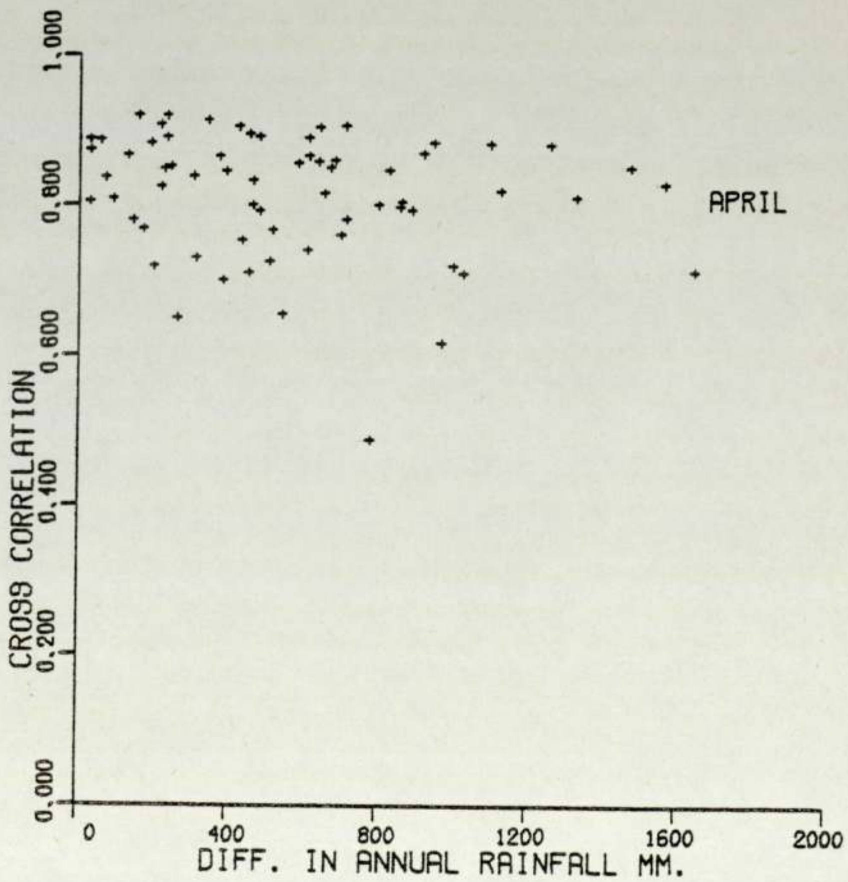
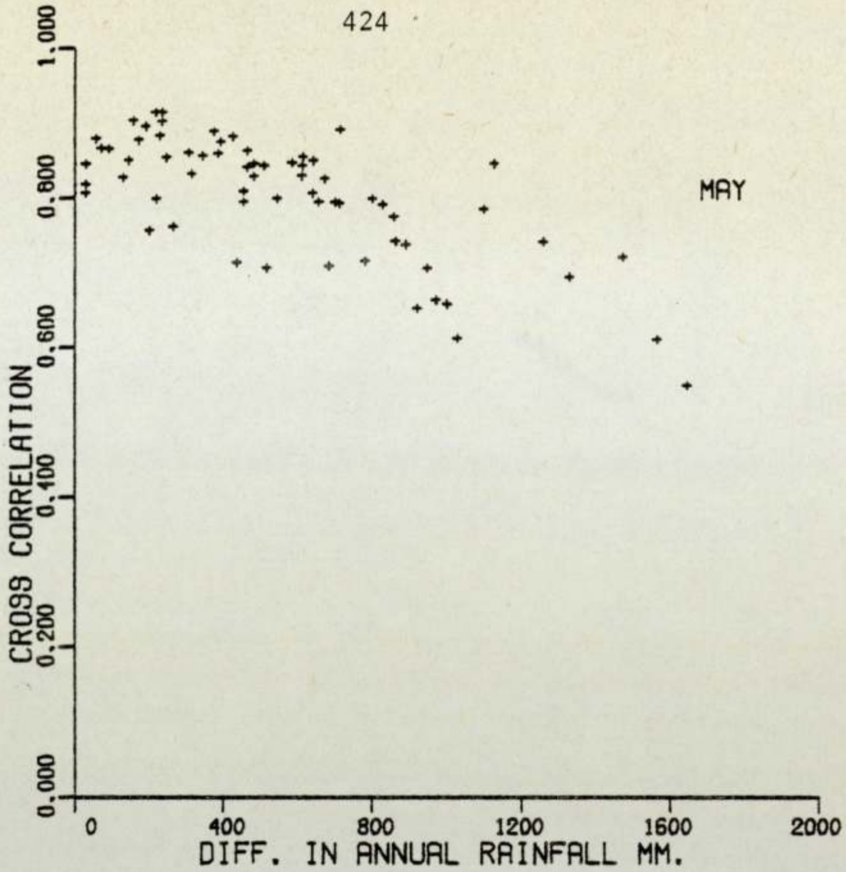


FIGURE A.3/2 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)



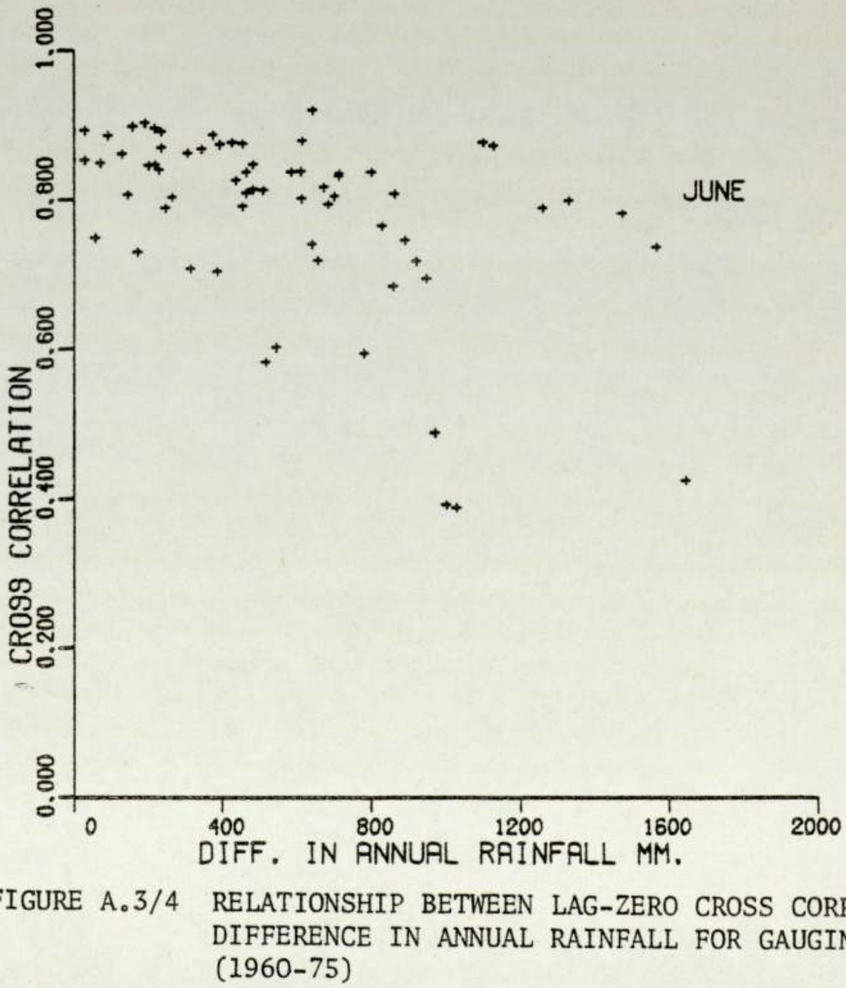
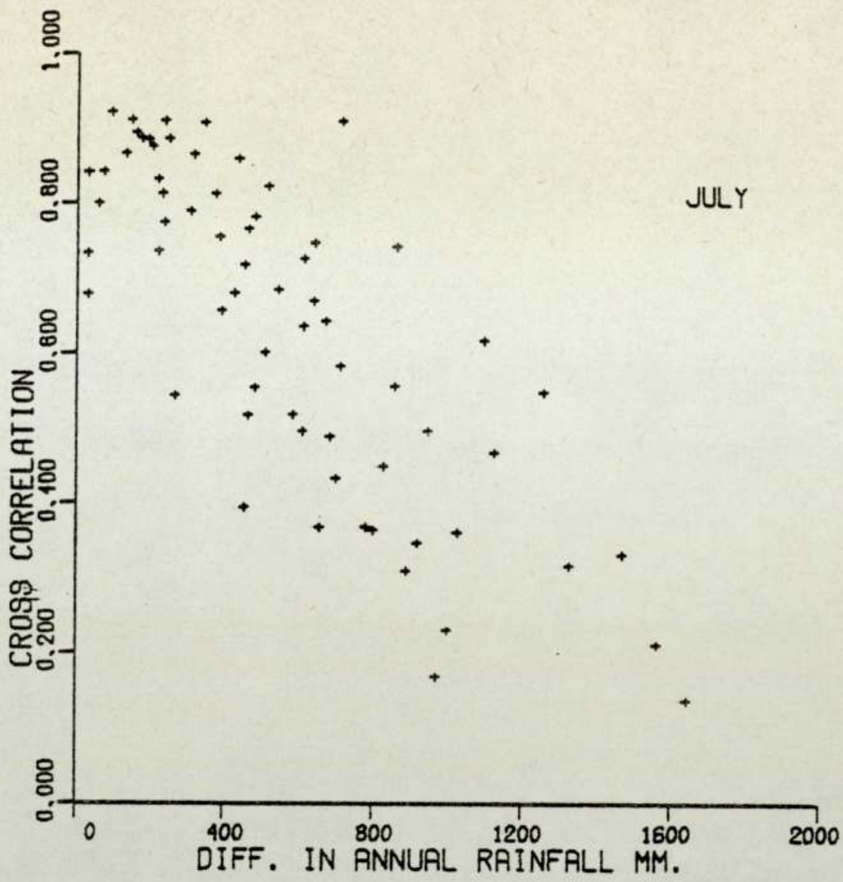


FIGURE A.3/4 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)



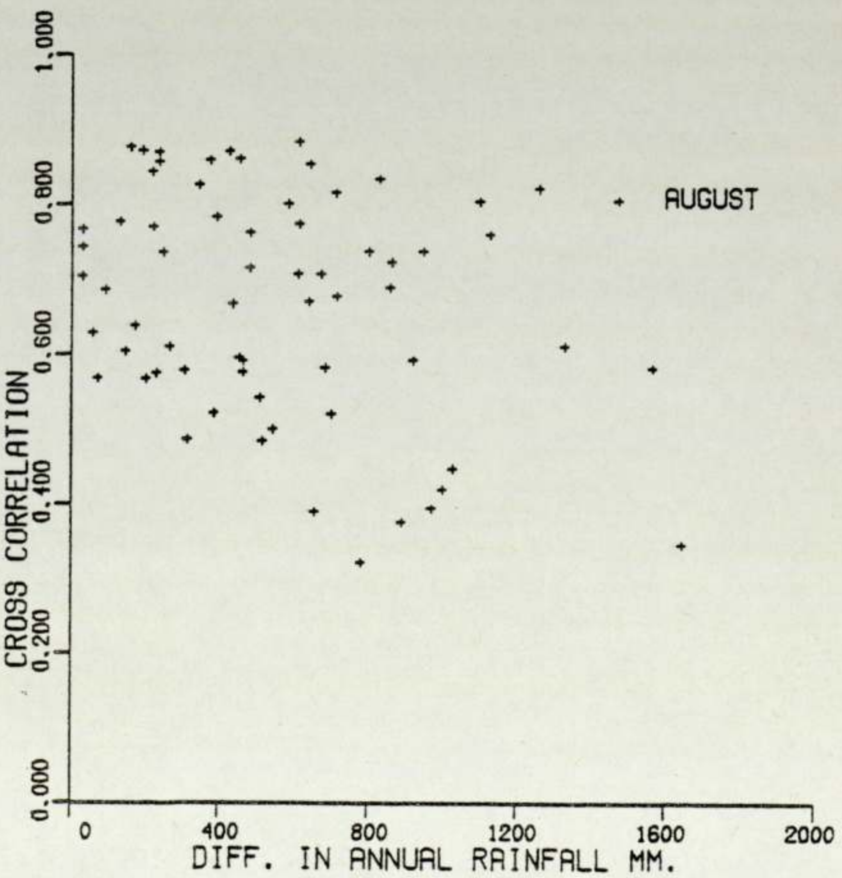
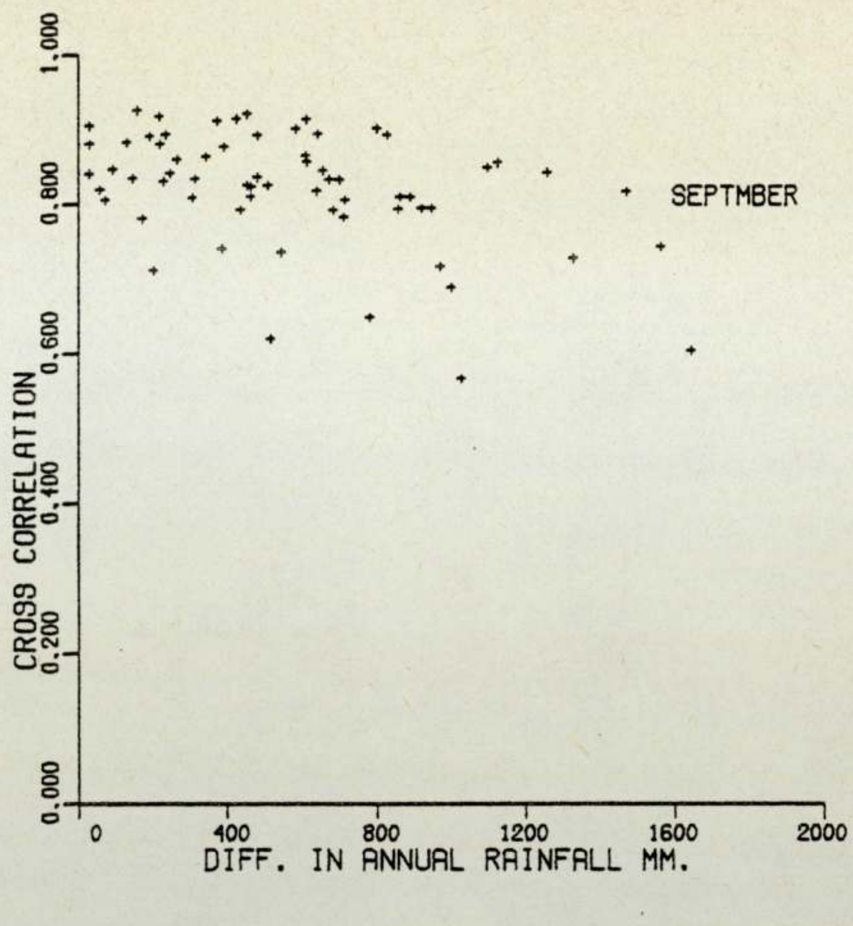


FIGURE A.3/4 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)



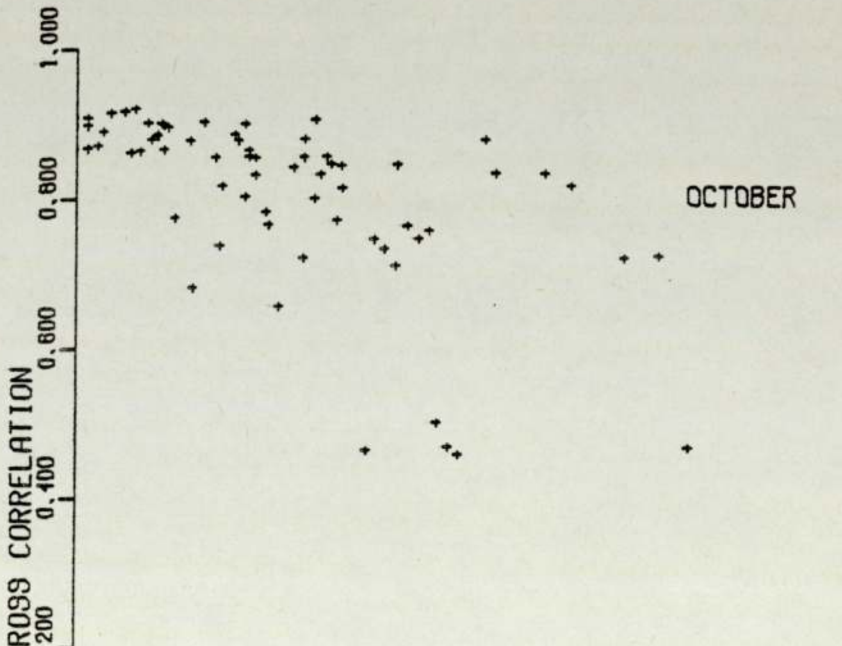
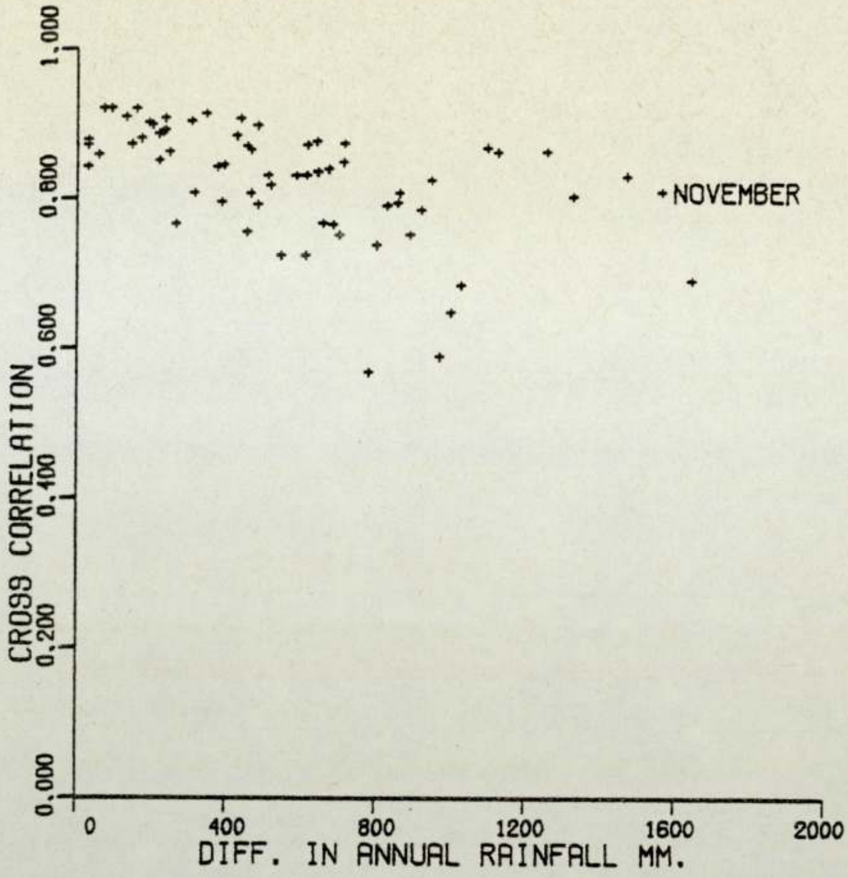


FIGURE A.3/5 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)



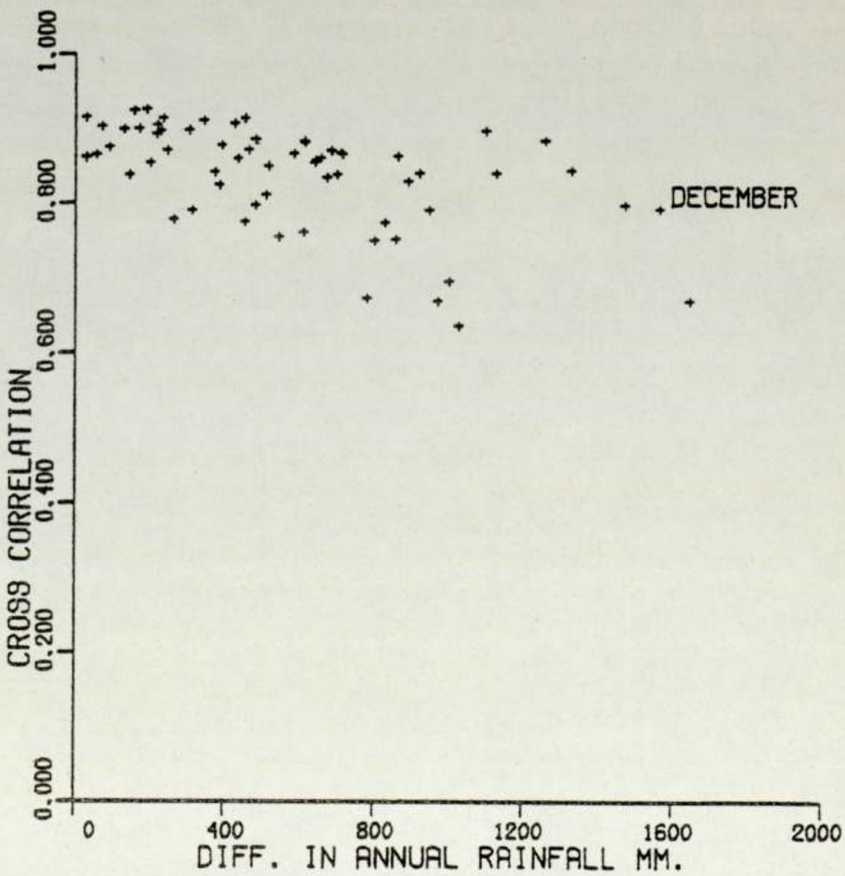
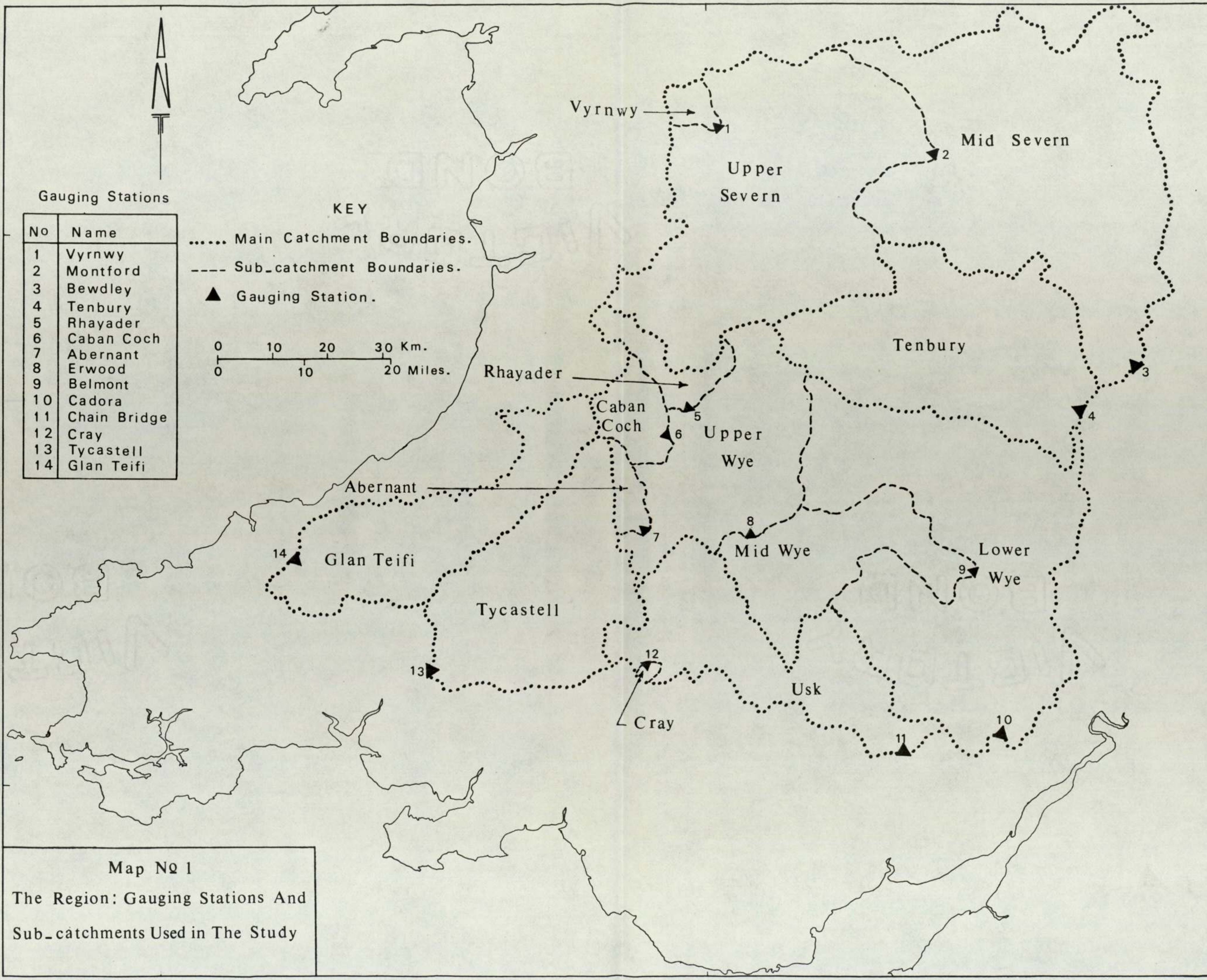
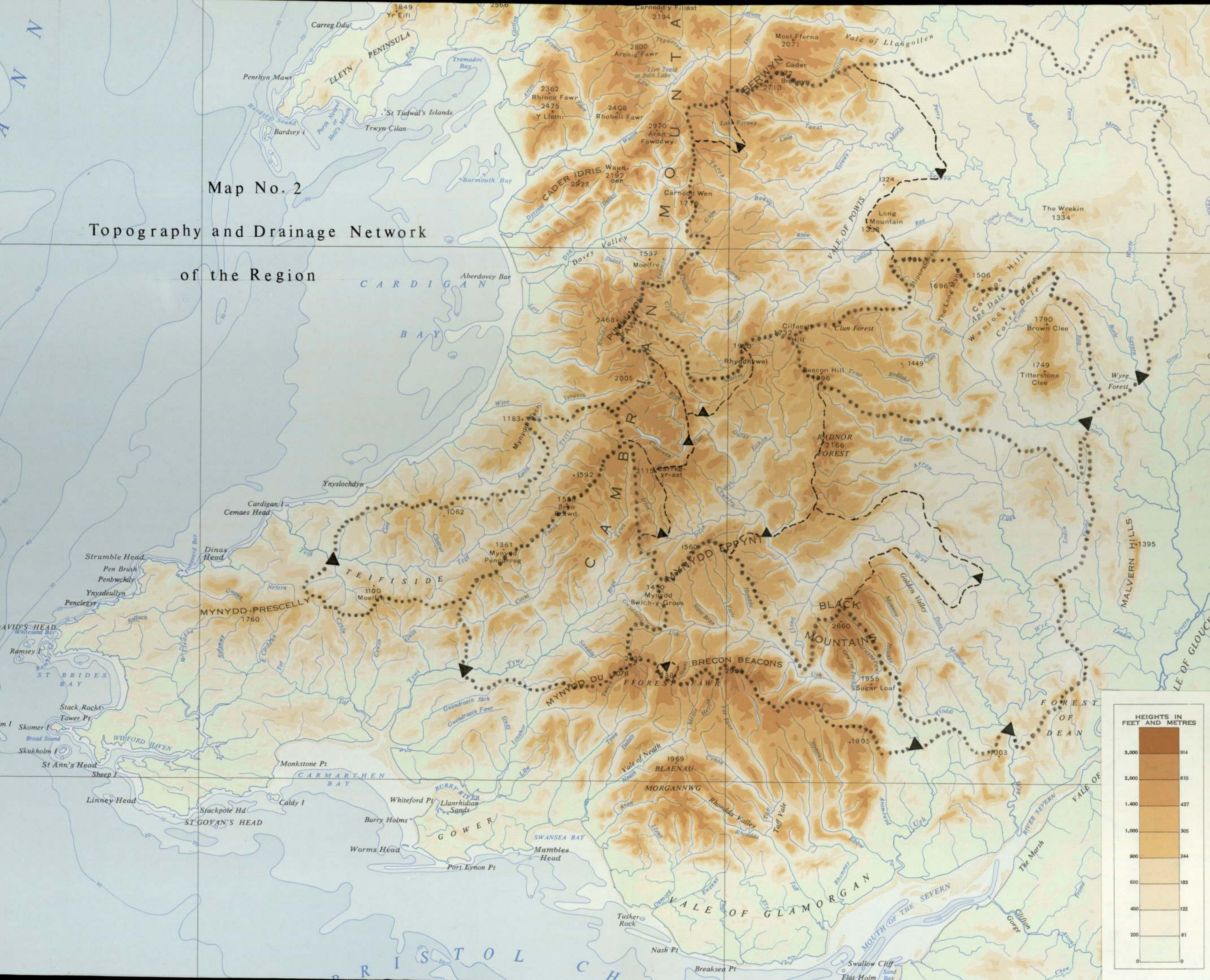


FIGURE A.3/6 RELATIONSHIP BETWEEN LAG-ZERO CROSS CORRELATION AND DIFFERENCE IN ANNUAL RAINFALL FOR GAUGING STATIONS (1960-75)

MAPS

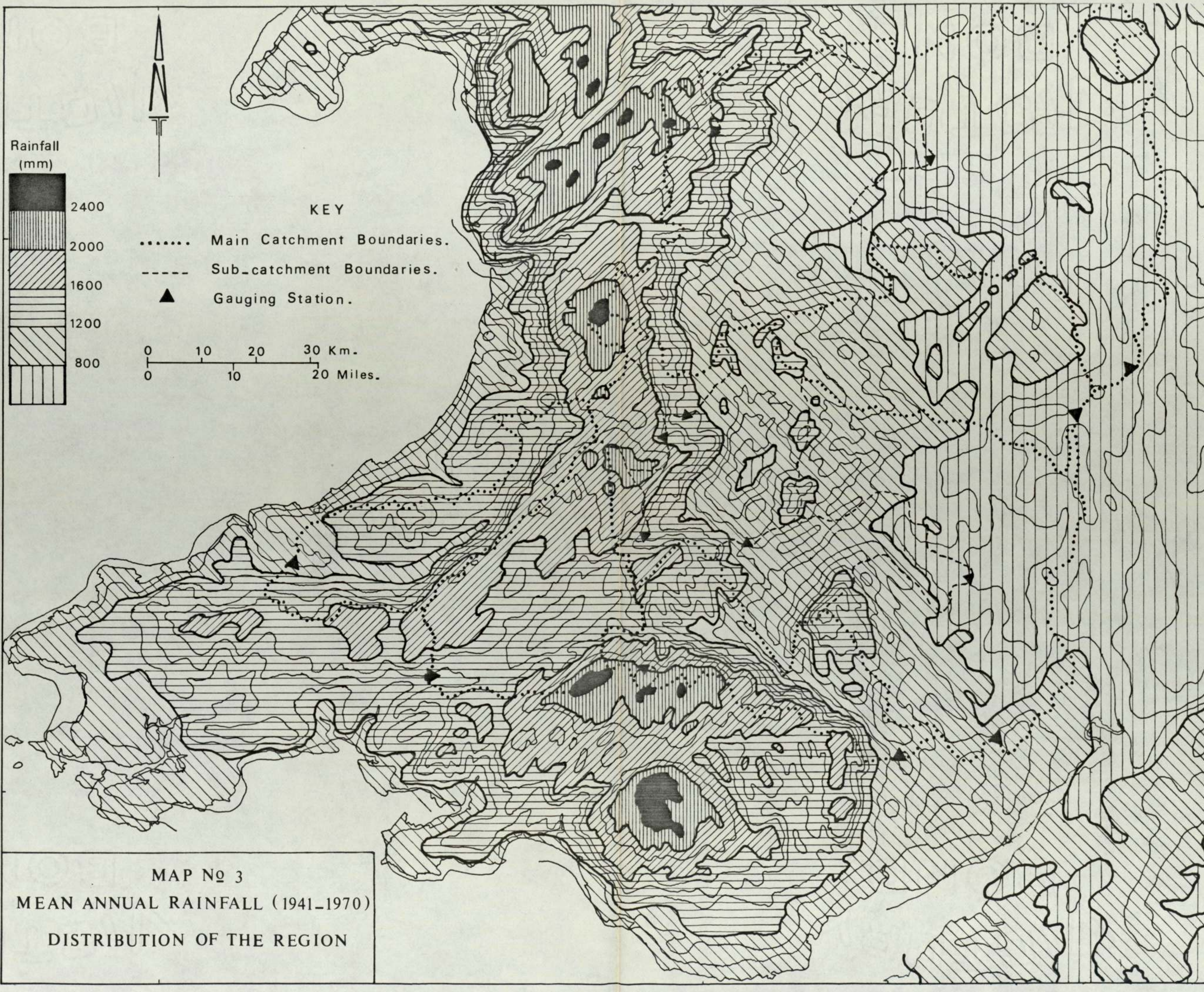


Map No 1
The Region: Gauging Stations And Sub_catchments Used in The Study



Map No. 2

Topography and Drainage Network of the Region



MAP Nº 3
MEAN ANNUAL RAINFALL (1941-1970)
DISTRIBUTION OF THE REGION

MAP NO 4

SOLID GEOLOGY OF THE REGION

SEDIMENTARY FORMATIONS

(All superficial deposits omitted)

System	Symbol	Formation	Division
Jurassic	g^{14}	*Purbeck Beds*	Upper
	g^{13}	*Portland Beds*	
	g^{12}	*Kimmeridge Clay*	
	g^{11}	*Corallian*	
	g^{10}	*Oxford Clay with Kellaways Beds*	
	g^{9}	*Cornbrash*	Middle
	g^{5-8} / g^{6-8}	*Great Oolite Series*	
	g^{5-8} / g^{5}	*Inferior Oolite Series*	
	g^{3-4}	*Upper Lias*	Lower
	g^{2}	*Middle Lias (Marlstone)*	
	g^{1}	*Lower Lias*	
New Red Sandstone	f^{6}	*Keuper Marl (with Rhaetic & Dolomitic Conglomerate)*	Triassic
	f^{1-5} / f^{4-5}	*Keuper Sandstone*	
	f^{1-5} / f^{1-3}	*Bunter Sandstone, Pebble Beds & basal breccias*	
	e	*Sandstones, marls and breccias*	Permian
	e^{5}	*Upper Permian Marl*	
	e^{4}	*Magnesian Limestone (Upper)*	
	e^{3}	*Middle Permian Marl*	
	e^{2}	*Magnesian Limestone (Lower) & Basal Sands*	
Carboniferous	d^{6}	*Barren Upper Coal Measures & Pennant Series*	
	d^{5}	*Productive Coal Measures*	
	d^{4}	*Millstone Grit & Culm Measures*	
	d^{2}	*Carboniferous Limestone Series*	
		Basement Conglomerate	
Devonian	c^{3}	*Upper Old Red Sandstone & Upper Devonian*	
	c^{2}	*Middle Devonian*	
		Limestone	
	c^{2}	*Middle Devonian &* *Brecon & Ditton Series*	*Lower Old Red Sandstone*
	c^{1}	*Downton Series & Lower Devonian*	*Lower Old Red Sandstone*
	c	*Probably Devonian*	
Silurian		*Limestones*	
	b^{6-7} / b^{7}	*Ludlow*	
	b^{6-7} / b^{6}	*Wenlock*	
	b^{5}	*Tarannon & Llandovery*	
Ordovician	b^{1-3} / b^{3}	*Ashgill & Caradoc*	
	b^{1-3} / b^{2}	*Llandeilo (partly volcanic)*	
	b^{1}	*Arenig*	
Cambrian	?a	*Manx Slates & Dodman Series*	
	a / a^{3}	*Upper Cambrian*	
	a / a^{1-2}	*Middle & Lower Cambrian*	
P.C.	x	*Rocks of Anglesey, Charnwood, Longmynd & ?Ingleton*	

IGNEOUS ROCKS

Age, where known, indicated by formation letter, e.g. Ge = Permian Granite

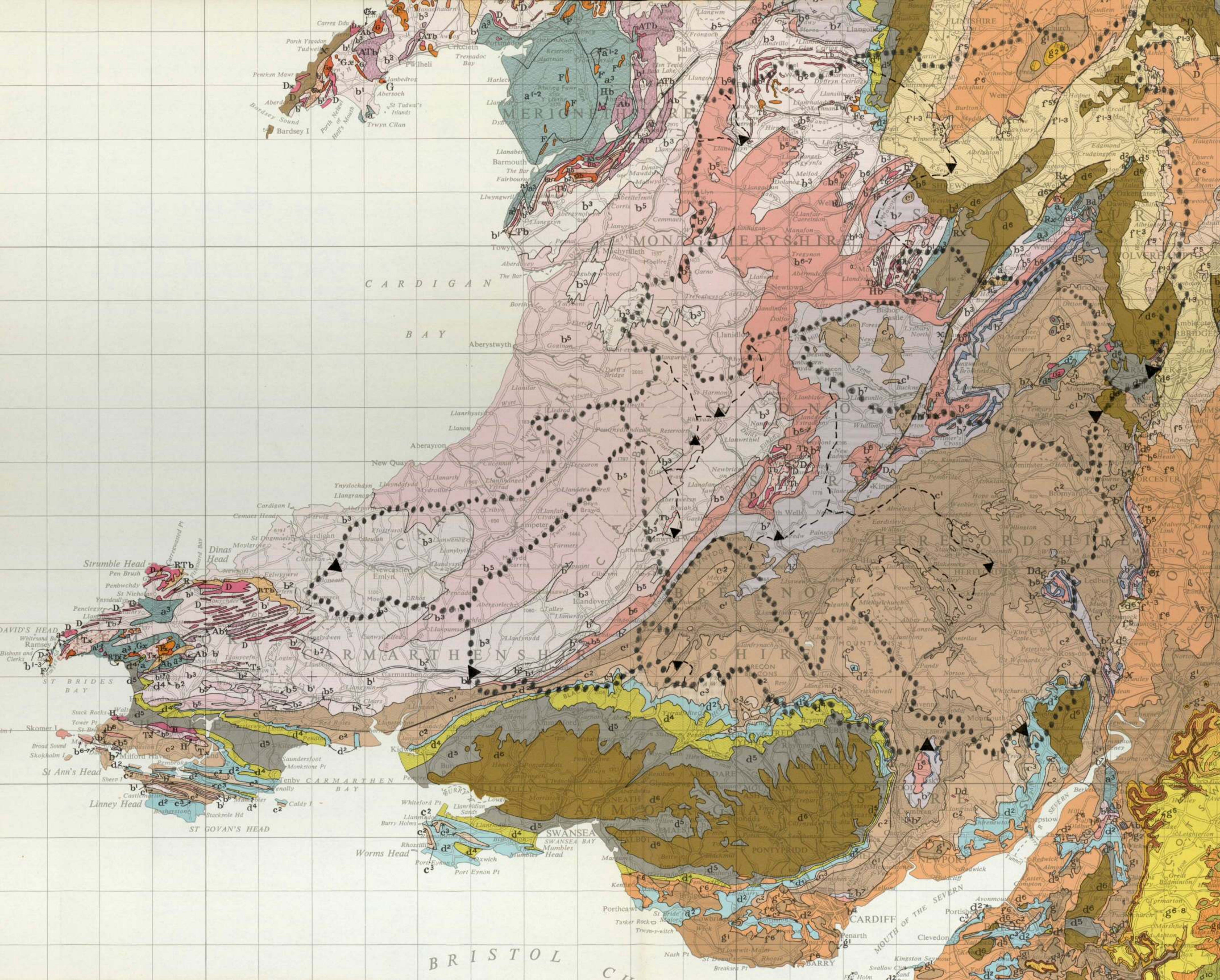
Symbol	Rock
T	*Tuffs, Ashes & Agglomerates*
R	*Rhyolitic & Trachytic Lavas*
A	*Andesitic Lavas*
S	*Spilitic Lavas*
B	*Basaltic Lavas*
G	*Granite & Granophyre*
F	*Syenite, Felsite, Porphyry*
H	*Diorite, Camptonite, Lamprophyre*
D	*Dolerite, Diabase, Greenstone & intrusive Basalt*
E	*Gabbro*
U	*Serpentine, Picrite*

Metamorphic

Symbol	Rock
𝔊	*Gneiss, Mica Schist*
𝔇	*Hornblende Schists*

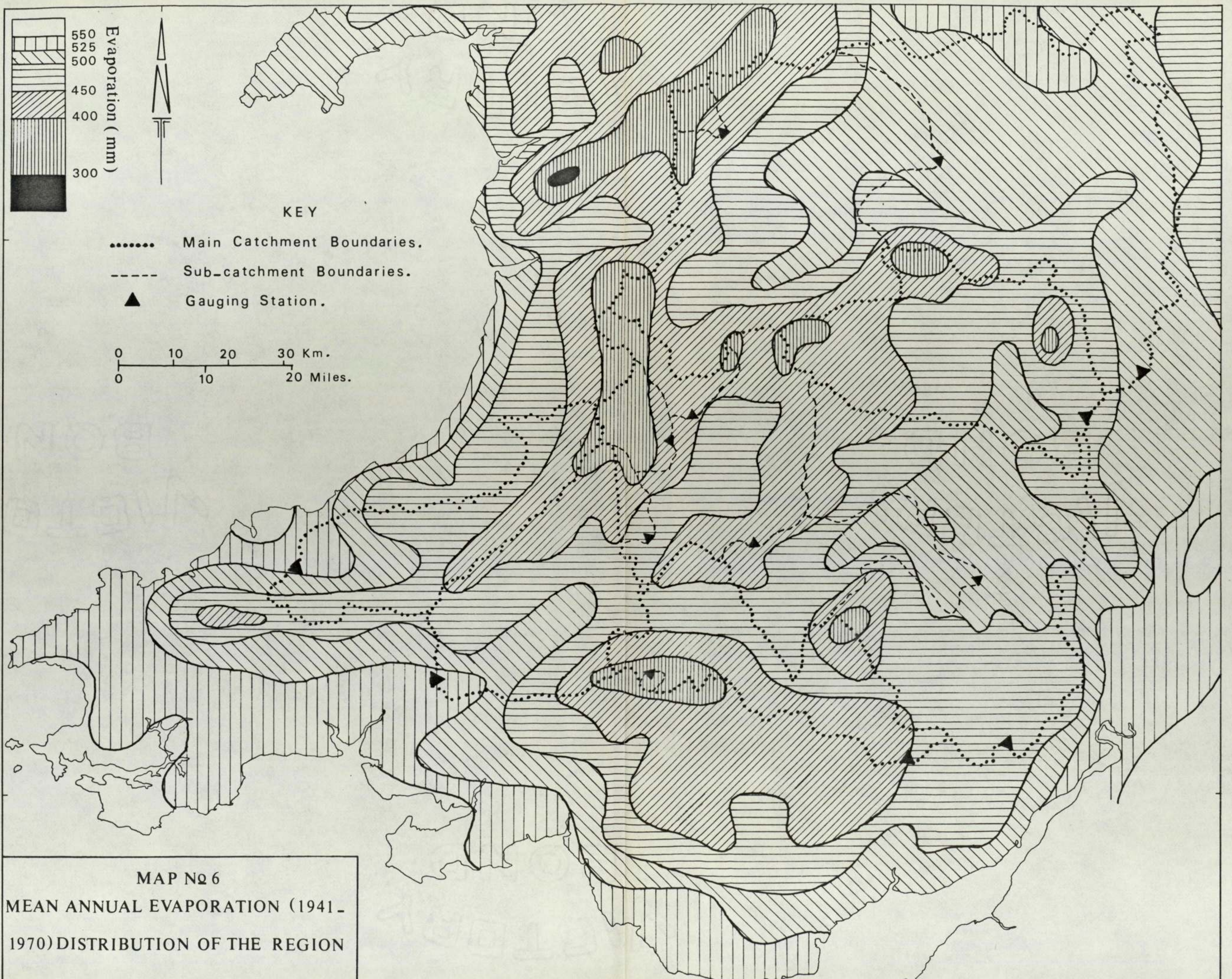
——— *Major Thrusts*

—·—·— *Major Faults*



CARDIGAN
BAY
MERIONETHSHIRE
MONTGOMERYSHIRE
CARDIGANSHIRE
RADNORSHIRE
HEREFORDSHIRE
BRECKNOCKSHIRE
CARMARTHENSHIRE
GLAMORGAN
ST BRIDES BAY
CARMARTHEN BAY
SWANSEA BAY
BRISTOL
MOUTH OF THE SEVERN
Aberystwyth
Aberayron
New Quay
Cardigan
Carmarthen
Llandovery
Lampeter
Newtown
Welshpool
Machynlleth
Towyn
Barmouth
Harlech
Pwllheli
Criccieth
Bala
Swansea
Cardiff
Newport
Neath
Pontypridd
Aberdare
Penarth
Barry
Porthcawl
Hereford
Ledbury
Ross-on-Wye
Monmouth
Chepstow
Builth Wells
Brecon
Crickhowell
Abergavenny
Kington
Leominster
Bromyard
Knighton
Llandrindod Wells
Rhayader
Llanidloes
Bishops Castle
Clun
Ludlow
Church Stretton
Bridgnorth
Kidderminster
Worcester
Malvern
Wolverhampton
Shrewsbury
Oswestry
Whitchurch
Newport
Strumble Head
Dinas Head
St David's Head
Ramsey
Skomer I.
Skokholm I.
Milford Haven
St Ann's Head
Linney Head
St Govan's Head
Tenby
Caldy I.
Saundersfoot
Worms Head
Mumbles Head
Port Eynon Pt
Bardsey I.
Bardsey Sound
Porth Neigwl or Hell's Mouth
St Tudwal's Islands
Abersoch
Llanbedrog
Avonmouth
Portishead
Clevedon
Kingston Seymour
Nash Pt
Breaksea Pt

NOT SURVEYED IN DETAIL
NOT SURVEYED IN DETAIL
CARDIGAN BAY
BRISTOL
SHREWSBURY
BIRMINGHAM
ABERYSTWYTH
KIDDERMINSTER
LEOMINSTER
WORCESTER
CHELTENHAM
SWANSEA
NEWPORT
CARDIFF
BRISTOL
SWINDON



MAP № 6
MEAN ANNUAL EVAPORATION (1941-1970) DISTRIBUTION OF THE REGION