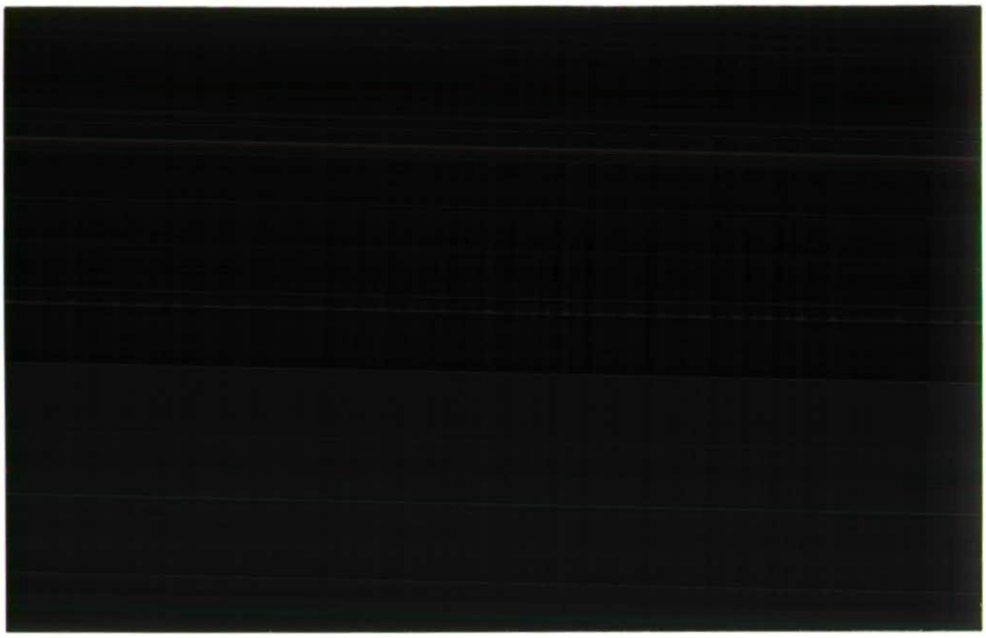
Institute of Hydrology



Centre for Ecology & Hydrology

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FLOOD ESTIMATION FOR PERMEABLE CATCHMENTS

Inception Report

Ministry of Agriculture, Fisheries and Food
Project FD 0423

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Flood Estimation for Permeable Catchments
(MAFF Project FD 0423)

Inception Report

1. GENERAL

Techniques to estimate floods on permeable catchments have received limited attention in the past even though severe floods can occur occasionally in this type of catchment. Conventional methods, such as peaks-over-threshold (POT) analysis, tend to be less suitable for permeable catchments which also often lack suitable data for the application of this method.

The main objective of Project FD 0423, Flood Estimation for Permeable Catchments, is to re-examine and, where possible, improve methods for estimating design floods for engineering works in permeable catchments. This is being undertaken as a desk-study review for which the preliminary scope of work would comprise:

* define the extent of permeable catchments by reference to soil (HOST) mapping and baseflow index (BFI) values derived from daily mean flow data;
* review techniques for the analysis of POT data on permeable catchments;
* review and augment Potter's historical information on floods in Chalk catchments;
* assess the demand for, and nature of, flood estimates on permeable catchments;
* appraise the flood estimation methods used for the design of urban/highway drainage on permeable strata;
* recommend specific lines of research to improve the estimation of design floods on permeable catchments.

This inception report, designated as the September 1996 milestone for this project, summarises progress to date and outlines in more detail the scope of work that will be undertaken.

2. PROGRESS AND OUTLINE SCOPE OF WORK

2.1 Definition and Extent of Permeable Catchments

Permeability, in the context of flooding, can be defined according to the hydraulic characteristics of the soil cover and underlying bedrock and/or by the flow regime. A definition based on the flow regime would produce a clearer indication of the flood characteristics. However, descriptors of the flow regime (in particular the standard percentage runoff, SPR) require appropriate data which are not immediately available for all catchments. The SPR can be estimated by a model based on HOST (Hydrology of Soil Types), although this approach still relies on soils and geology. The HOST model for SPR is generalised for the UK and is not as reliable as direct evaluation from flow data.

The HOST model for SPR was used to identify the most permeable, gauged catchments in the flood peak datasets held at IH. A total of 30 catchments were found with HOST-SPR values of 12.0% or less. Two of these catchments had unusually low BFI values and were subsequently excluded. These gauged BFI values were obtained from the Hydrometric Register and Statistics (1980-85). The locations of the 28 most permeable gauged catchments are shown in Figure 2. All of these catchments are located on the Chalk outcrop, of which over half are situated on the extensive Chalk outcrop (HOST Class 1) in central southern England.

The two other main HOST classes for permeable substrates, which include the Oolitic Limestones and Magnesian Limestone (HOST Class 2) and drift-free areas of the Permo-Trias and Lower Greensand (HOST Class 3), are not represented in the list of the most permeable gauged catchments defined by SPR of < 12.0%. This definition also tends to exclude gauged catchments which have permeable formations in their upper reaches but which because of the gauge location have a high SPR (e.g. R. Pang at Pangbourne). Small ungauged catchments, such as those along the Chalk scarp slopes, are also excluded.

Whilst the response of catchments having both permeable and impermeable surfaces (mixed catchments) is rather complex, a better understanding of the flood response of wholly permeable catchments will assist the analysis of flood events on mixed catchments in future.

We intend to improve the definition of permeable catchments and map their distribution.

2.2 Flood Flow Analysis Techniques

We shall review and assess current methods of estimating flood peaks in permeable catchments. The analysis of flow data, however, has to depend on the available gauged catchments, the most permeable of which are all located on the Chalk and generally have relatively short flow records. Because of their limited record and the relative infrequency of major flood events, information on the more extreme flows may be lacking.

For those catchments having flood peak data, the FSR (I.2.6.3) recommends pooling standardized annual maximum floods (AMFs) for a group of similar catchments to find a regional curve. This approach was used in FSSR4 for a group of permeable catchments.

For ungauged catchments, design flood peaks can be estimated from catchment characteristics (FSR 1.4), or the complete flood hydrograph can be estimated using a rainfall-runoff model (FSR 1.6). However, whilst rainfall-runoff modelling can be difficult for permeable catchments, this approach is sometimes necessary for the design of flood storage schemes.

The FSR recommends standardizing AMFs by their mean, plotting them on a Gumbel scale and fitting a GEV curve (FSR I.2.6.2). A similar procedure was used to derive single-site flood frequency distributions and a pooled distribution for the most permeable catchments (SPR < 12.0) except that the GEV was fitted by the generally favoured probability-weighted moments method.

Inspection of the resulting site curves revealed that some catchments have AMFs that would not be considered as floods: these were either very low flows, or even zero flow in some years for ephemeral streams, such as the Lavant. Using all of the available AMFs without discounting low values tends to produce strongly EV3-shaped curves and consequently relatively modest design floods for long return periods.

Although various ways of removing the influence of these non-flood AMFs were considered, a new, more rigorous approach has been developed as part of this study. This expresses the probability of an AMF in year i exceeding a value X_T with return period T as the product of the probability p of a flood occurring in year i and a conditional exceedance probability. Thus:

$$Pr\ (x_i > X_T) = p\ .\ Pr\ (x_i > X_T \mid \text{year } i \text{ has a flood}).$$

A GEV curve is fitted to the conditional distribution and the return period axis rescaled to give the overall return period of the quantile X_T. This had a significant effect on some flood frequency curves, changing them from an EV3 to an EV2 curve. This would imply that high flows could have shorter return periods. Figure 3 shows an example for the upper Kennet catchment at Marlborough.

This approach helps to ensure that flood frequencies are estimated only from flow data that are more likely to be floods. Currently, work is concentrating on applying this development to pooled flood frequency curves.

To complement the flow data the long-term water level data from Chilgrove (from 1836) and Compton (from 1894) in the Lavant and adjacent Ems catchments respectively will be examined in more detail. A plot of AMF for the Lavant against the water level at Chilgrove on or close to the date of the AMF suggests that flows increase more rapidly when water levels reach a certain elevation: a very similar result was obtained for the Lavant flood event in January 1994. It is hoped that water level data from wells in other permeable catchments with gauged flows can also be used to improve our understanding of the conditions producing 'groundwater floods' in Chalk catchments and their frequency of occurrence.

2.3 Review of Historical Floods on Permeable Catchments.

Relevant information from Potter's 'Use of historical data to augment flood frequency information on Chalk catchments' produced in the mid-1970's has been summarised. There are some 80 events recorded by Potter dating from 1092, although most post-date 1840 and are located in the Chilterns and Yorkshire Wolds. These events have been plotted with dates at a scale of 1:625000. The majority of the flood events recorded by Potter refer to severe summer storms: of 32 events post-1840 only seven are 'winter' events.

It is intended to update Potter's earlier search, although a search of less quantitative sources (such as newspaper reports) will not be undertaken. A series of reports on the groundwater floods in Hampshire during February 1995 has been received from EA Southern Region in response to our article in the June issue of the MAFF Flood and Coastal Defence Newsletter. Reports on other flood events on permeable catchments are being assembled to provide examples of the different types of floods that occur on such catchments. Information and flood investigation reports held by the regional offices of the EA have been requested.

The computerised daily rainfall records will be searched for notable events and unusually wet periods. It is anticipated, however, that the rainfall intensities giving rise to many summer flood events may not be known. Where available, rainfall intensities will be compared to the hydraulic conductivity of Chalk soils, although only limited information is available on the unsaturated hydraulic conductivities (some estimates have been obtained from the SEISMIC database). Runoff from summer storms can be generated from the Lower and Middle Chalk, which are not only less permeable than the Upper Chalk but often form the steep scarp slopes of the Chalk outcrop.

2.4 Engineering Designs

We shall investigate which methods are applied by engineers to estimate the design floods for flood alleviation works or for structures such as culverts or river crossings located in permeable catchments.

Floods on permeable catchments can result from various combinations of circumstances, and this may require different procedures to estimate their magnitude and frequency of occurrence. Climate change could also produce wetter winters and drier summers with more convective storms. A classification of the circumstances that produce floods on permeable catchments will be established.

Flood protection measures range from low cost, local improvements to alleviate shallow groundwater flooding to major flood relief schemes where urban areas are at risk. Databases will be used to identify towns (with a population of more than, say, 10000) occurring within permeable catchments (e.g. Winchester) or at risk from floods on permeable catchments (e.g. Chichester). The urbanisation of permeable catchments (e.g. High Wycombe) will also have an impact on flows, as will the containment of watercourses (e.g. Winchester and Chichester), but these aspects will be considered only summarily in this review.

The presence of permeable substrata with a relatively deep water table (including some alluvial areas) allows soakaways to be used to dispose of runoff from paved and road surfaces. Since this takes place from the road surface, conventional methods of estimating runoff suffice to design gulley inlets. However, there is a concern that the receiving soakaway may sometimes still be full at the time of the next rainfall event.

3. SUMMARY SCOPE OF WORK

The research will:

* improve the definition of a permeable catchment
* identify and classify the different types of flood events
* show the distribution of permeable catchments
* locate urban centres within permeable catchments
* review current methods of flood analysis
* extend the analysis of flow, rainfall and groundwater level data
* assemble flood reports
* identify lines of further research.

A draft final report will be produced in March 1997.

Distribution of SPR (HOST)

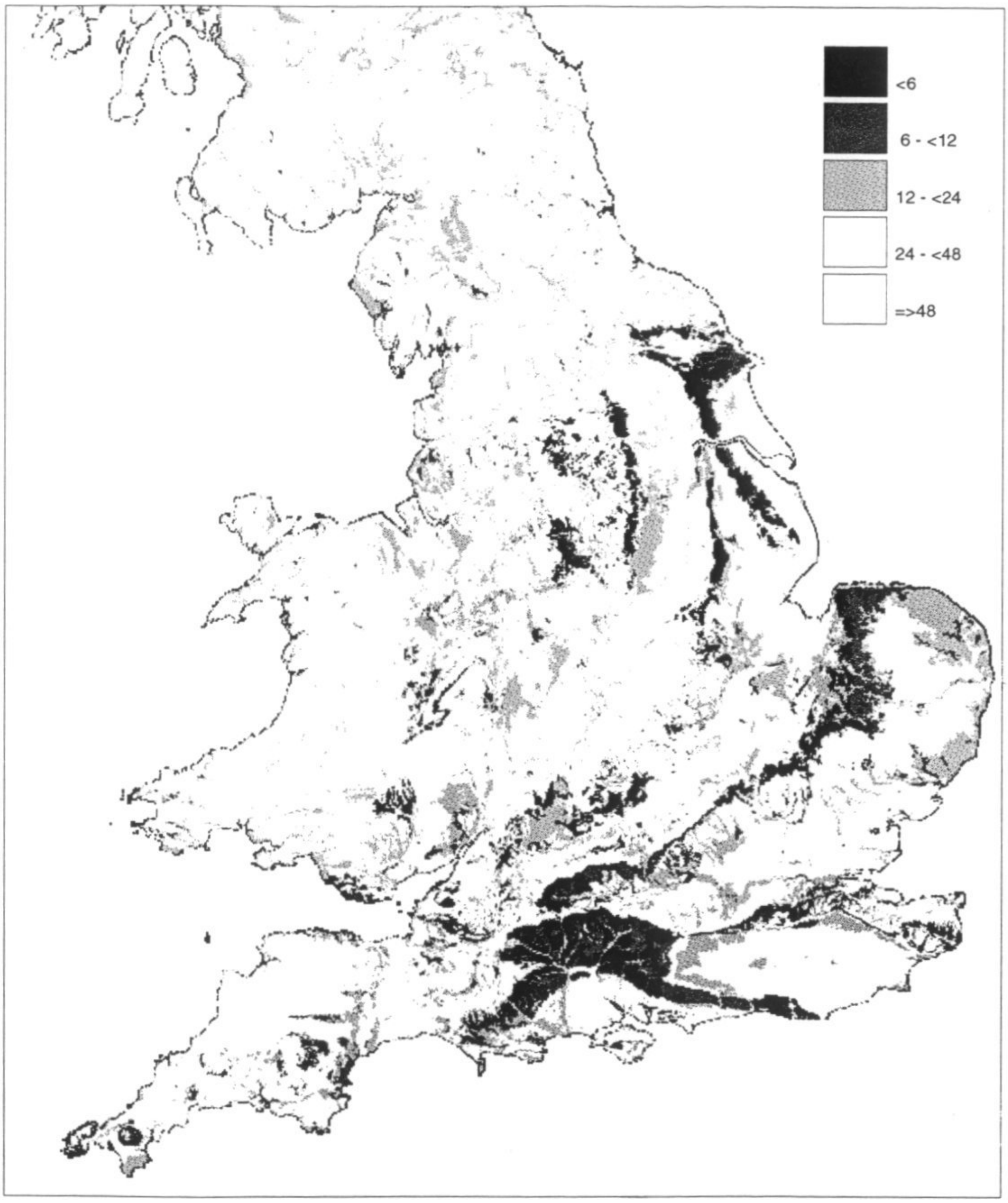

Figure 1

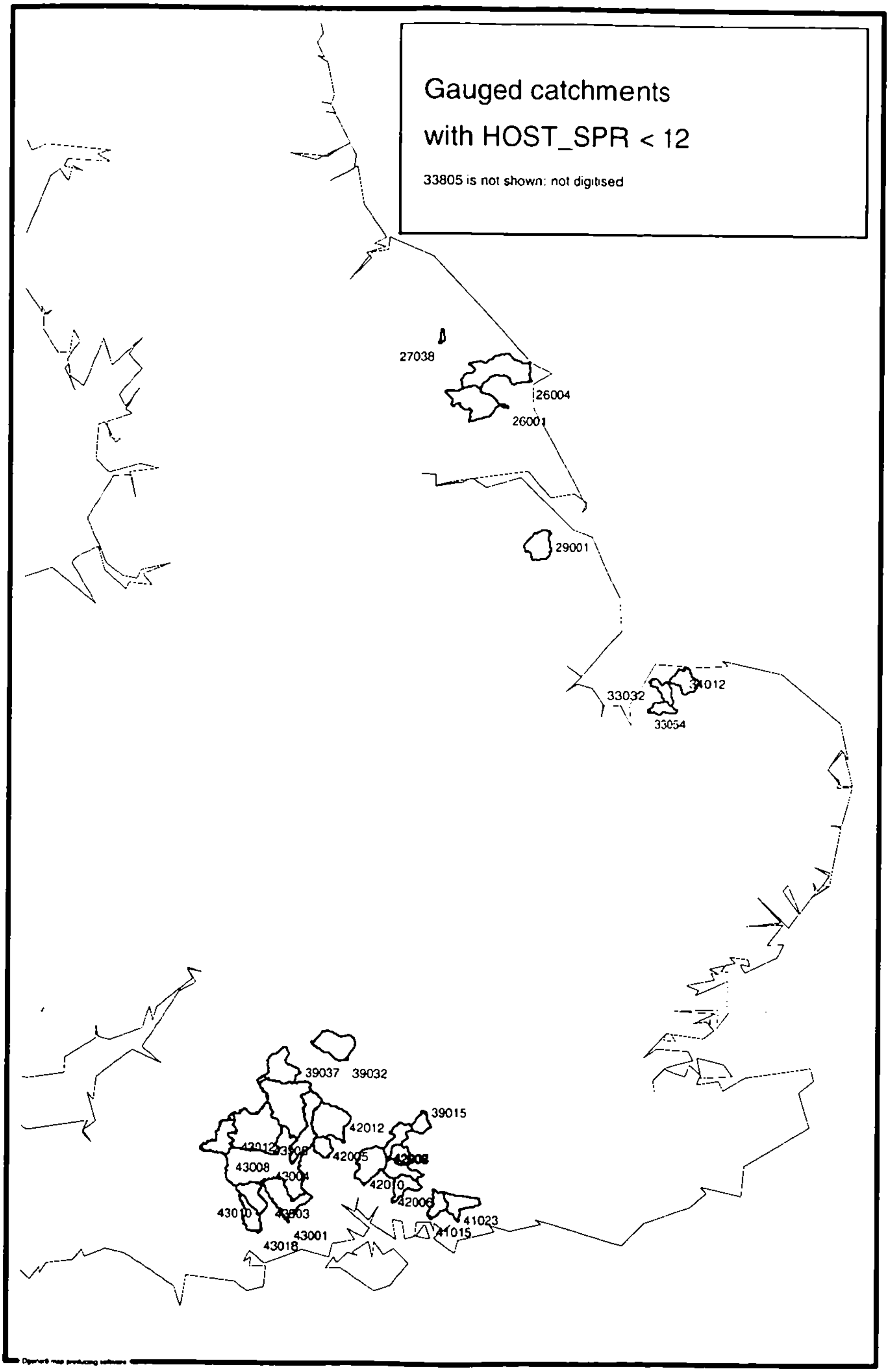
Gauged catchments
with HOST_SPR < 12
33805 is not shown: not digitised
27038
26004
26001
29001
33032
33054
39037
39032
39015
42012
43008
42006
41023
41015
43001
43018

Figure 2

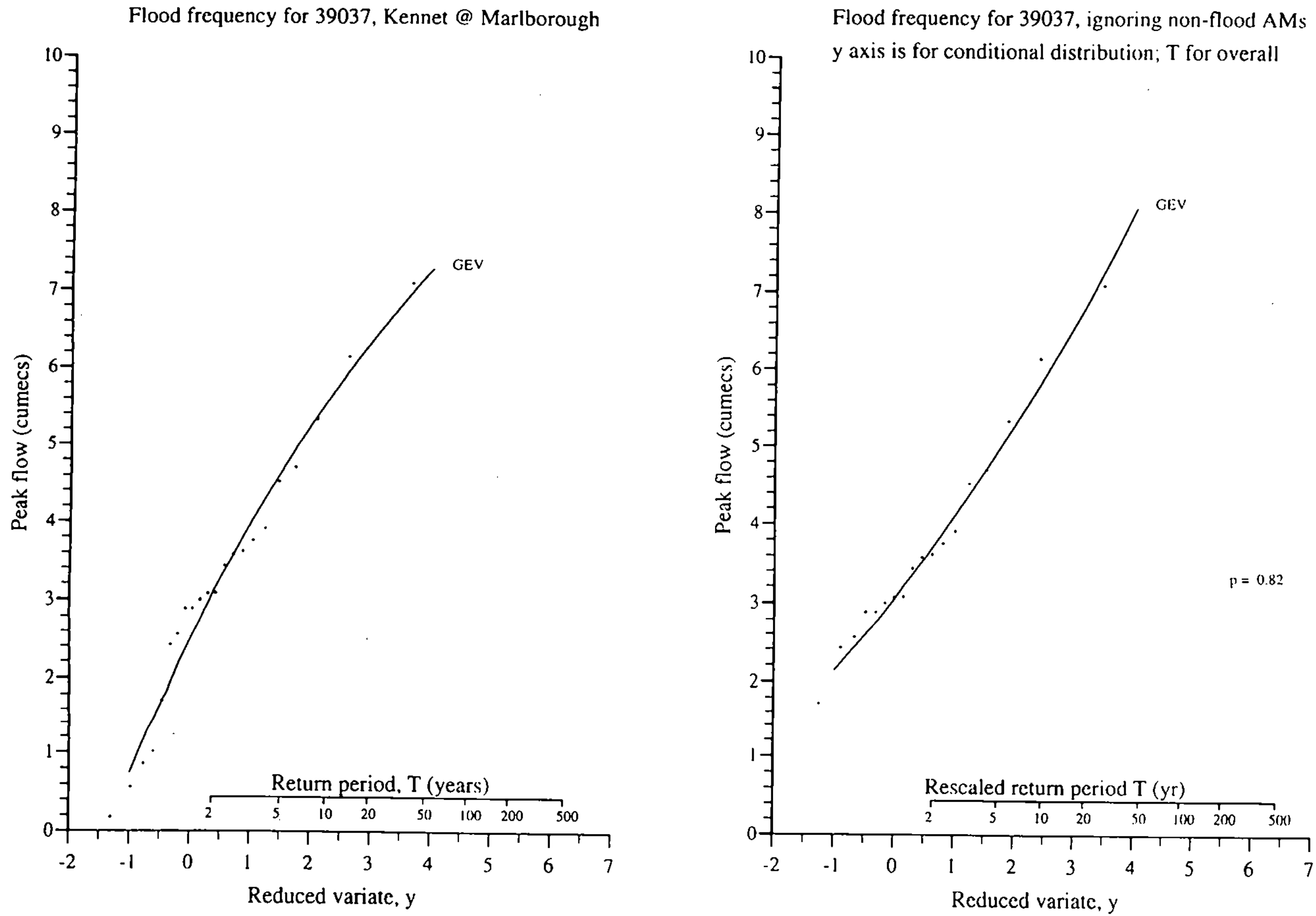
Flood frequency for 39037, Kennet @ Marlborough
Peak flow (cumecs)
GEV
Return period, T (years)
2 5 10 20 50 100 200 500
Reduced variate, y
Flood frequency for 39037, ignoring non-flood AMs
y axis is for conditional distribution; T for overall
Peak flow (cumecs)
GEV
p = 0.82
Rescaled return period T (yr)
2 5 10 20 50 100 200 500
Reduced variate, y

Figure 3