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HYDROLOGICAL ASPECTS OF THE HOST CLASSIFICATION OF SOILS

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)ominant HOST Class on 1km Grid

LRC/MLURI/DANI

Abstract

A hydrologically-based classification of the soils of United Kingdom was developed based on existing data sets that describe both the soils and their distribution, and the hydrological response of catchments. The classification was based on conceptual models of the processes that occur in the soil and, where appropriate, substrate. The resulting scheme has 29 classes, based on eleven response models. Soils are assigned to classes on the basis of their physical properties, and with reference to the hydrogeology of the substrate.

Applications of the classification have been developed that lead to improved estimates of parameters required in low flow and flood estimation procedures. The report contains sufficient detail of the methodologies so that they may be used in combination with soils information obtained from previously published maps. Since the classification is based on soil series it is independent of scale and may be used with many different soil data sets. Access on a national basis to the classification is provided by the 1:250,000 reconnaissance maps produced during the 1980s.

The classification is known by the acronym HOST, standing for Hydrology Of Soil Types.

The map on the previous page shows the distribution of HOST classes on a 1 km grid. For each square only the most extensive class is shown.

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A A brief history of the development of the HOST classification system

B Assignment of HOST classes to map units

C Catchment data used in the development and calibration of HOST

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1 Executive Summary

It is difficult to overstate the importance of soils in influencing hydrological phenomena at both the site and catchment scale. Although much information is available to describe soils and their distribution, most of this requires considerable interpretation before it can be readily used by hydrologists. The Hydrology Of Soil Types (HOST) Project has produced a classification of the soils of the United Kingdom that can be applied via existing national maps to aid hydrological studies and analyses.

The HOST classification is based on conceptual models of the processes taking place within the soil and, where appropriate, substrate. These models have three physical settings:

i) a soil on a permeable substrate in which there is a deep aquifer or groundwater (ie at >2m depth),

ii) a soil on permeable substrate in which there is normally a shallow water table (ie. at <2m depth), and,

iii) a soil (or soil and substrate) which contains an impermeable or semi-permeable layer within 1m of the surface.

Within these situations are variations that allow for different soil properties (eg. a peaty top layer), and wetness regime (eg. as indicated by the presence of gleying), that give rise to a total of eleven models. The eleven models are further sub-divided into 29 HOST classes, based on other properties or the geology of the substrate.

The classification was developed using databases of physical soil properties with feedback from catchment scale hydrological variables, mainly base flow index and standard percentage runoff. The distribution of the soils was taken from the national reconnaissance mapping at a scale of 1:250,000 completed for England, Wales and Scotland in the 1980s. In Northern Ireland a special HOST map was prepared prior to the completion of a 1:250,000 soil map of the province.

The HOST classification is based on the soil series and can therefore be used with many different soil data sets. At the 1:250,000 scale, groups of soil series are combined into map units, which may therefore contain more than one HOST class. Other soil maps are available that show the distribution of individual series and it will be possible to use these with the HOST classification to refine hydrological parameter estimates.

The report contains complete methodologies for the estimation of low flow variables (mean annual minimum and the 95 percentile flow) and the Flood Studies Report standard percentage runoff. Existing users of these methods can use the information contained in this report with previously published maps to obtain HOST-based estimates of model parameters. Other applications of HOST are also described.

A product of the HOST project is a computer data set based on a 1km grid that covers the whole of the UK, although data for Northern Ireland is currently less reliable than for the rest of the UK. Using the data set will greatly speed up the process of abstracting HOST classes for catchments or sites of interest. These data may be leased from any of the collaborating organisations

The HOST Project has been a collaborative venture between the Institute of Hydrology, Soil Survey and Land Research Centre, Macaulay Land Use Research Institute and Department of Agriculture Northern Ireland.

2 Abbreviations, lists of figures and tables

ABBREVIATIONS

a_n	a regression coefficient
AMP(D)	annual D-day minimum flow having probability of exceedance P
BFI	Base flow index
CWI	Catchment wetness index
D	Duration in days
DANI	Department of Agriculture Northern Ireland
DPR_{CWI}	Dynamic contribution to PR from CWI
DPR_{RAIN}	Dynamic contribution to PR from RAIN
fse	factorial standard error
FSR	Flood Studies Report
FSSR	Flood Studies Supplementary Report
GRADMAM	Gradient of duration relationship in low flow frequency
HOST	Hydrology Of Soil Types
$HOST_n$	Fraction of HOST class n
IAC	Integrated air capacity
IH	Institute of Hydrology
LFHG	Low flow HOST group
MAF	Mean annual flood
MF	Mean flow
MAM(D)	Mean annual minimum of duration D days
MLURI	Macaulay Land Use Research Institute
MO	Meteorological Office
NRA	National Rivers Authority
NWA	National Water Archive
P	Exceedance probability
PR	Percentage runoff
Q_x	Flow exceeded by x% of all flows.
$Q_x(D)$	Flow exceeded during x% of all periods of duration D
r^2	Coefficient of determination
$R(Q_{10})$	Q_{10}/Q_{95}
$R(Q_{99})$	Q_{99}/Q_{95}
RAIN	Event rainfall in mm
RPB	River Purification Board
SAAR	Standard period annual average rainfall (mm)
s.e.e.	standard error of estimate
SPR	Standard percentage runoff
SSLRC	Soil Survey and Land Research Centre
SWA	Surface Water Archive
WRAP	Winter rainfall acceptance potential
$WRAP_n$	Fraction of WRAP class n

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3 Introduction

Soils have a major influence on hydrological processes. Their physical properties govern the storage and transmission of water within the soil, and these properties combine with other characteristics of the soil to provide chemical buffers and biological filters. While these effects occur and may be observed at the very small scale, the influence of the soil properties may also be seen in the integrated response of whole catchment systems. Although these effects are recognised, they remain largely unquantified and many hydrologists struggle to interpret the wealth of soils information, in the form of maps, monographs and surveys, that is available to them.

One attempt to classify soils according to their hydrological response was the Winter Rainfall Acceptance Potential (WRAP) scheme developed for the Flood Studies Report (FSR, NERC, 1975) and described in more detail by Farquharson et al (1978). A 1:1,000,000 scale map of the British Isles was produced showing the distribution of the five WRAP classes. This map was enlarged to 1:625,000 for inclusion in FSR Volume V. Although the WRAP system has few classes and limited resolution it has been at the core of the FSR rainfall-runoff method of design flood estimation for almost 20 years and is also engrained in other design procedures (eg. WASSP, Department of the Environment, 1981)

An opportunity to revise the scale of the WRAP map came in the mid-1980s when the Soil Survey of England and Wales, now the Soil Survey and Land Research Centre (SSLRC) and the Soil Survey of Scotland, now based at the Macaulay Land Use Research Institute, (MLURI) completed the national reconnaissance mapping of soils at 1:250,000. However, rather than merely produce a WRAP map at a more detailed scale, it was considered worthwhile to use the large hydrological databases held by the Institute of Hydrology (IH) to assist in the definition of classes. Thus the Hydrology Of Soil Types (HOST) project was born as a collaborative venture between these three organizations. Soil mapping at 1:250,000 has not yet been completed for Northern Ireland but the Department of Agriculture of Northern Ireland has been involved in the HOST project and in the preparation of a HOST map and data set for Northern Ireland.

Since the HOST classification is based on the physical properties of the soils and their effects on the storage and transmission of soil water, it is largely independent of scale and will have a number of applications outwith the prediction of river flows at ungauged sites eg. the evaluation of sewage sludge acceptance potential, the estimation of pesticide residues, and improving predictions of the effects of soil acidification.

3.1 GUIDE TO THE REPORT

It is anticipated that readers of this report will come from a wide variety of backgrounds. Many hydrologists may not have delved more deeply into the hydrological aspects of soils than that presented to them in the WRAP classification. For these readers we include a great deal of information on how soil scientists approach the classification and mapping of soils. On the other hand there may be soil scientists who only consider the influence of soil physics on local hydrological processes, and not at a catchment scale. Since some of the first applications of HOST concern the estimation of parameters on catchments, a full description of these parameters and their importance in applied hydrology is presented. Chapter 4 of the report covers these background issues and shows how the hydrological and soil data sets have been brought together.

Chapter 5 describes the resulting HOST classification, firstly in terms of response models and processes within different soil types, and then in terms of the landscapes and distribution of each HOST class.

Chapter 6 gives details of a number of ways in which HOST has already been used. Two of these applications describe how HOST has been integrated into procedures for the estimation of low flows and flood peaks. Other applications give an insight into how HOST can be used in studies of nitrates, pesticides and slurry acceptance.

Chapter 7 describes how to access the HOST system using existing paper-based maps, or computer data sets.

While this report contains a full description of HOST and how it may be used a great many other potential applications exist, and it is anticipated that further developments of the system will follow; some suggestions of what may be possible are presented in Chapter 8.

Three appendices complete the report. Appendix A gives a brief history of how the HOST classification evolved. Appendix B is the key that allows HOST classes to be derived from the 1:250,000 national soil maps. Appendix C is a complete listing of the catchment based data used in developing and calibrating HOST.

4 From WRAP to HOST

The Winter Rainfall Acceptance Potential (WRAP) classification makes a logical starting point in describing the development of a new classification. The deficiencies of the WRAP system were a major reason for the development of HOST and experiences in using WRAP helped define desirable properties of the replacement classification.

4.1 THE WINTER RAINFALL ACCEPTANCE POTENTIAL CLASSIFICATION

The Winter Rainfall Acceptance Potential classification was based on a theoretical consideration of soil hydrological processes and made use of four main soil and site properties ie. soil water regime, depth to an impermeable layer, the permeability of the soil horizons above this layer, and the slope of the land. The classification scheme is shown in Table 4.1.

Table 4.1 The WRAP classification scheme

Water regime class	Depth to Impermeable horizon (cm)	Slope Classes								
		< 2°			2-8°			> 8°		
		Permeability class (above impermeable horizon)								
		Rapid	Medium	Slow	Rapid	Medium	Slow	Rapid	Medium	Slow
1	> 80	1	1	2	1	1	2	1	2	3
	80-40	1	1	2	2	2	3	3	3	4
	< 40	-	-	-	-	-	-	-	-	-
2	> 80	2	2	3	3	3	4	-	4	5
	80-40	2	3	3	3	4	4	4	4	5
	< 40	3	4	4	4	4	4	4	5	5
3	> 80	4	4	5	5	5	5	-	5	5
	80-40	4	5	5	5	5	5	-	5	5
	< 40	5	5	5	5	5	5	5	5	5

Winter Rain Acceptance Class		Winter Run-off Potential	
1	Very high	1	Very Low
2	High	2	Low
3	Moderate	3	Moderate
4	Low	4	High
5	Very low	5	Very high

The soil water regime classification was based on a system given in the Soil Survey Field Handbook (Hodgson, 1974). The three classes identified are:

1) soils rarely waterlogged within 40cm depth, and for less than 90days within 70cm in

most years.

2) soils commonly waterlogged within 40cm, but for less than 335 days within 70cm in most years, and

3) soils waterlogged within 40cm for more than 180 days, and for more than 335 days within 70cm in most years.

An impermeable layer is defined as a layer with a hydraulic conductivity of less than 0.1m day^{-1}, and should therefore be considered slowly permeable rather than impermeable. Depth to such a layer is often closely related to the water regime class but because of exceptions to this general rule both properties were included.

These two properties were considered the most important in accounting for the variations in the response of soils to rainfall, since, taken together, they indicate if saturation is likely within the soil and the depth at which vertical movement of water stops and horizontal movement begins. However, it was also seen as important to differentiate the soils with no impermeable layer, and also soils where the properties above such a layer were very different. This was achieved by using a simple classification of permeability based on soil structure and particle-size. Slope was used as the final variable since it accentuates the response from soils with a shallow water table.

The classification shown in Table 4.1 using these four variables was based on a theoretical consideration of the movement of water in the soil combined with a general knowledge of the responsiveness of streams, and a small number of catchment studies. The developers of the classification report that "although the directional effects of the the four main parameters are reasonably clear, their relative magnitude is a matter of judgement" (Farquharson et al, 1978). A primary consideration was to produce a system that could be applied consistently by many individual soil scientists in constructing a national map depicting the classes.

Therefore, although the impetus to develop WRAP came from the UK Flood Studies project, little hydrological data were used to develop the classification. The WRAP scheme was applied to the soils of the UK and presented to users as maps at 1:1,000,000 and 1:625,000. To use the system, catchment boundaries were overlain on the WRAP map and the fraction of each class calculated. The five fractions were combined into a soil index:

$$SOIL = 0.15\ WRAP_1 + 0.30\ WRAP_2 + 0.40\ WRAP_3 + 0.45\ WRAP_4 + 0.50\ WRAP_5$$

where $WRAP_1$ etc are the fractions of each WRAP class on the catchment.

The new variable SOIL was then used in multiple regression studies to estimate the mean annual flood (MAF) and standard percentage runoff (SPR). The WRAP system is therefore at the core of the Flood Studies Report methods of design flood estimation, and has been used in many design studies since the publication of the report in 1974. It has also been integrated into other design procedures (eg. WASSP, Department of the Environment, 1981).

Problems encountered in the use of WRAP are easily illustrated by considering the estimation of SPR, which is percentage runoff derived from event data, adjusted to standard rainfall and catchment conditions, and averaged for a catchment (see Section 4.2.2). To estimate SPR at ungauged sites, the FSR assigned the values of about 15%, 30%, 40%, 45% and 50% to the five WRAP classes (actually 0.955 of these values). Across a boundary between WRAP classes 1 and 5, SPR can change by a factor of slightly over three, and this factor will be carried forward in the flood estimate. (Note that within the statistical approach this factor is reduced as the SOIL parameter is raised to the power 0.653.) Where a flood estimate is being made on a small catchment in the region of such a boundary then it is easy to see how the resulting estimate may change if either the dividing line on the soil map or the catchment boundary is mislocated. Clearly mapping at a larger scale would remove some of this uncertainty, but users have also commented on the poor discrimination and limited range of the WRAP classification scheme. Downland chalk catchments have typical responses of just a few percent and some small, upland catchments have a standard response of over 60% (see, for example, Boorman 1985).

Limitiations in using WRAP to estimate SPR were recognised from the start and users were advised to refine estimates of variables obtained from the regression equations by reference to local data from gauged catchments, or by commissioning a more detailed soil survey of the study catchment. Recent research has shown that more accurate estimates of SPR can be obtained by transferring data from similar catchments than is possible using regression equations; however, within this approach WRAP is still used to help define similarity (Burn and Boorman, 1993).

Based on hydrological feedback there have been some changes to the WRAP model within the FSR techniques: minor changes to the WRAP map were introduced in Flood Studies Supplementary Report 7 (FSSR 7, IH, 1978), new coefficients to estimate SPR were presented in FSSR 16 (IH, 1985), and fresh advice on interpreting WRAP in specific locations is contained in FSSR 17 (IH, 1985). It is also worth noting that when the WRAP map appeared in 1975 it left large urban areas unclassified which caused problems for the many flood estimation projects on the urban fringe. One of the revisions to the WRAP map presented in FSSR 7 was the classification of these urban areas mainly through correlations between geology and soil type.

While WRAP has been integrated into procedures for design flood estimation, it was not used in the later development of a methodology for low flow estimation (Low Flow Studies, Institute of Hydrology, 1980) since it was ineffective in distinguishing between responses at the lower end of the WRAP scale. The Low Flow Studies stressed the use of geological maps to aid estimation procedures. It is perhaps because of this need to make a subjective assessment of the soils that meant that the methods of the Low Flow Studies report were not as rapidly or widely adopted as the methods of the FSR

4.2 CATCHMENT-SCALE HYDROLOGICAL VARIABLES

In producing a replacement for WRAP it was seen to be desirable and useful to use hydrological data during the development phase, rather than just calibrating a new classification for specific hydrological purposes. It has already been noted that the areas in which HOST was to be applied immediately were in the estimation of catchment-scale variables.

One approach is, therefore, to use the catchment-scale variables directly to aid in the calibration. This has the obvious benefit of using the information of greatest relevance to the problems being addressed, but could be criticised for being an empirical rather than physically-based approach. The alternative would be to base the classification on hydrologically relevant physical properties of the soil (eg. hydraulic conductivity, storage capacity) and to then use these within a physically based rainfall-runoff model to estimate the response at the catchment outlet and hence the catchment-scale parameter.

While this latter course may be scientifically more rigorous it requires far more elements to be drawn together (eg. a physically based rainfall-runoff model, detailed and widespread measurement of soil physical properties, long-period rainfall and runoff data for validation and calibration, rainfall generator for use in simulation). Within the current project these requirements were considered too demanding and the former approach was adopted. However, in adopting the more empirical approach based on catchment-scale variables it was seen to be important to preserve a structure to the classification that had a sound physical basis.

4.2.1 The hydrological response of catchments

The data that describe the response of a catchment come from a flow gauge at the catchment outlet and raingauges located within or close to the area draining to the outlet. The flow data are, in theory, available at a very fine data interval (typically 15 minute intervals). However, they are often archived as daily mean flows and it is this type of time-series data that are archived by the National Water Archive (NWA) located at IH. The NWA contains daily flow records for well over 1000 UK catchments. Rainfall data are also mainly available on a daily basis, as the majority of gauges are read on a once-a-day basis. Other raingauges can provide data at a finer resolution but the network of these gauges is sparse. Again the main rainfall archive maintained at IH is of daily data.

Daily data are most useful in describing the flow regime of the catchment ie. the general shape of the flow hydrograph, and characteristics of the hydrograph as described by its statistical properties. An example of a daily flow hydrograph for a one-year period is shown in Figure 4.1. The hydrograph contains much information about the nature of response, for example typical response times can be seen, and the seasonal variation in baseflow is apparent. For general water resource purposes a commonly used method of displaying a summary of a long record is as a flow duration curve. Figure 4.2 shows such a curve for the flow gauging station portrayed in Figure 4.1. The x-axis in the diagram is a percentage scale; the flow corresponding to the 50% point is the median flow. It is easy to extract figures corresponding to other percentile flows, so for example it can be seen from Figure 4.2 that the daily flow exceeded 95% of the time (often written as Q_{95}) is approximately 0.8 m^3s^{-1}. Note that in both of these figures the flow is conveniently plotted on a logarithmic scale.

In practice for looking at extreme flows, at both the flood and drought ends of the scale, it is usual to use other parameters. For low flows it is usual to look at durations longer than 1 day, say 5 or 10 days. $Q_{95}(10)$ is therefore the flow not exceeded in 95% of all 10-day periods. For looking at flood flows it is usual to look at data that are at a finer data interval as, in a UK context, daily data hide many of the true variations in the flow hydrograph. Clearly the instantaneous flow peak will usually be larger than the maximum daily mean flow peak, and the difference between the two will be greatest on quickly responding catchments. Statistical analyses of a flow record for flood purposes usually use data describing instantaneous peaks, for example the mean annual flood (MAF) is the arithmetic mean of the largest instantaneous flood peak abstracted from each water year of the station record.

Where a long flow record exists on a catchment then this can be analysed to yield the required parameter. In situations in which it is required to estimate one of these parameters at a site on a river where no data have been recorded, then it is necessary to estimate it from other information. In the Low Flow Studies then the key variable used to link the required statistics to the physical properties of the catchment is the Base Flow Index (BFI). In the

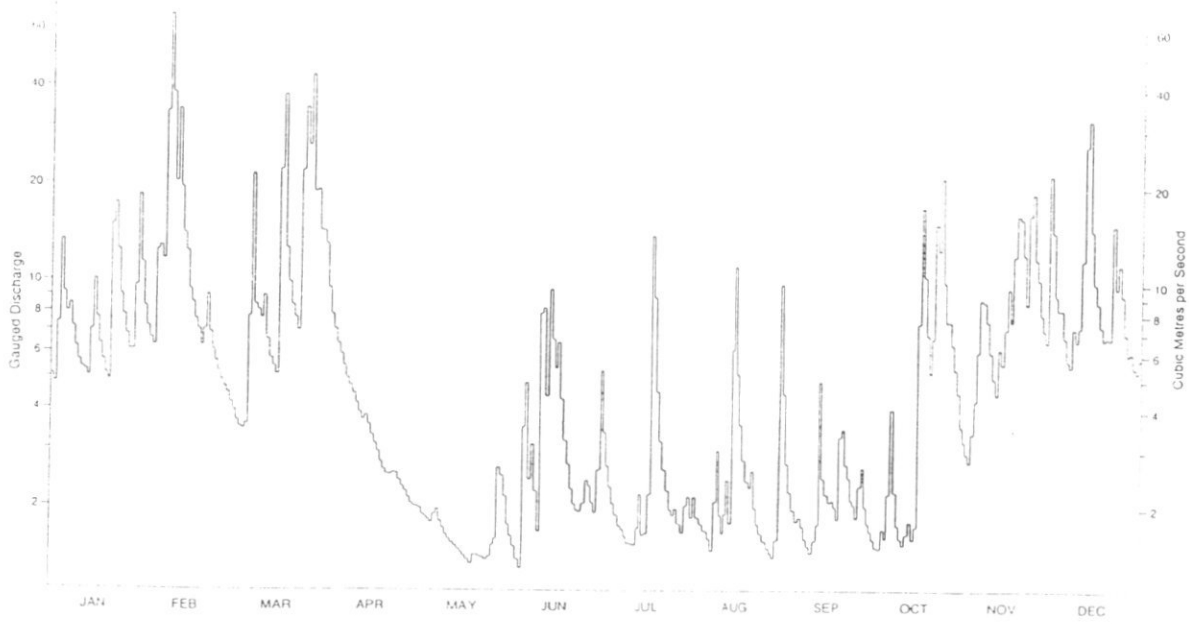


Figure 4.1 Daily flow hydrograph for the River Coquet at Rothbury for 1980

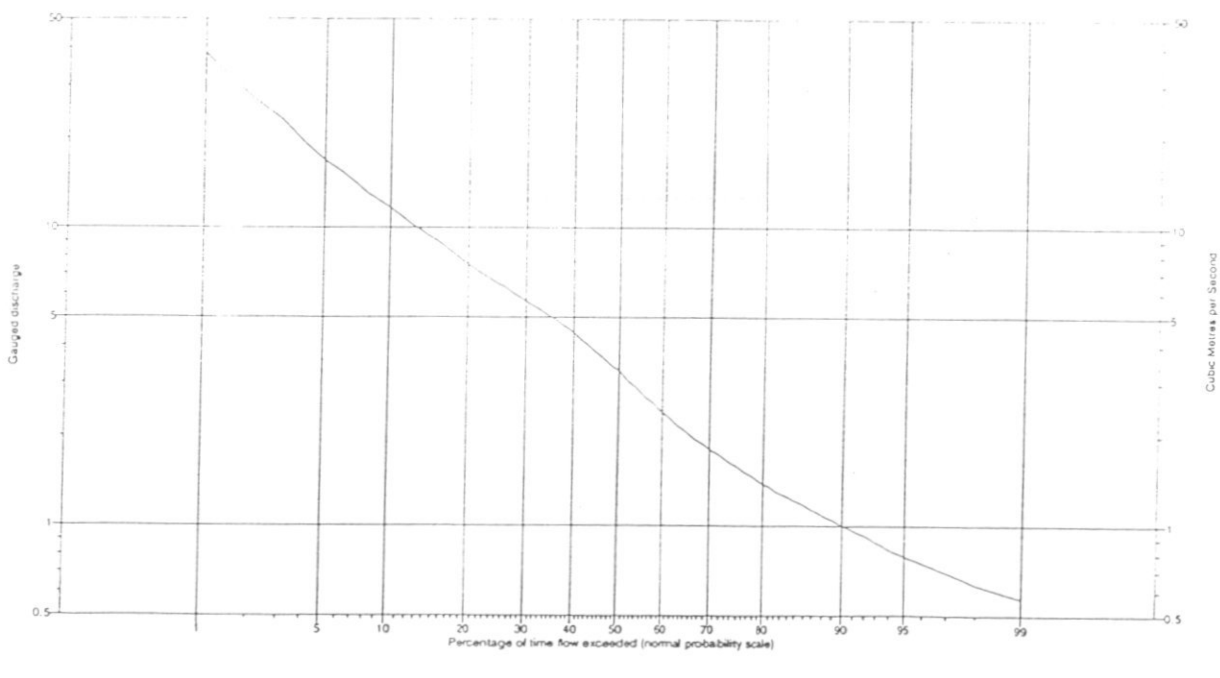


Figure 4.2 Flow duration curve for the River Coquet at Rothbury

rainfall-runoff method of design flood estimation contained in the FSR the most difficult to estimate and single most important parameter is the standard percentage runoff (SPR).

BFI is calculated from daily data and is a dimensionless variable that expresses the volume of baseflow as a fraction of the total flow volume; it is therefore possible to calculate the BFI for many of the catchments for which data are stored in the NWA (approximately 1000 catchments). SPR is derived from a joint analysis of flood events as described by flow data at fine resolution and data describing the rainfall that caused the flood. Like BFI, SPR is a dimensionless variable, but because of its different data requirements it is only available for a set of roughly 200 catchments.

Although BFI and SPR are calculated from different data sets they are well correlated and it was decided to use these two hydrological variables to calibrate and verify the HOST classification. The following sections contain a detailed description of how SPR and BFI are calculated for a catchment with examples that illustrate how these vary between catchments.

4.2.2 Standard percentage runoff

Whereas many parameters describing catchment response can be obtained from flow data alone, such indices do not explicitly account for the rainfall that drives the hydrological response of the catchment. The calculation of SPR is based on the analysis of flood event data ie. collated flow and rainfall data for storm events; simply put, SPR is the percentage of rainfall that causes the short-term increase in flow seen at the catchment outlet. An example of such an event is shown in Figure 4.3.

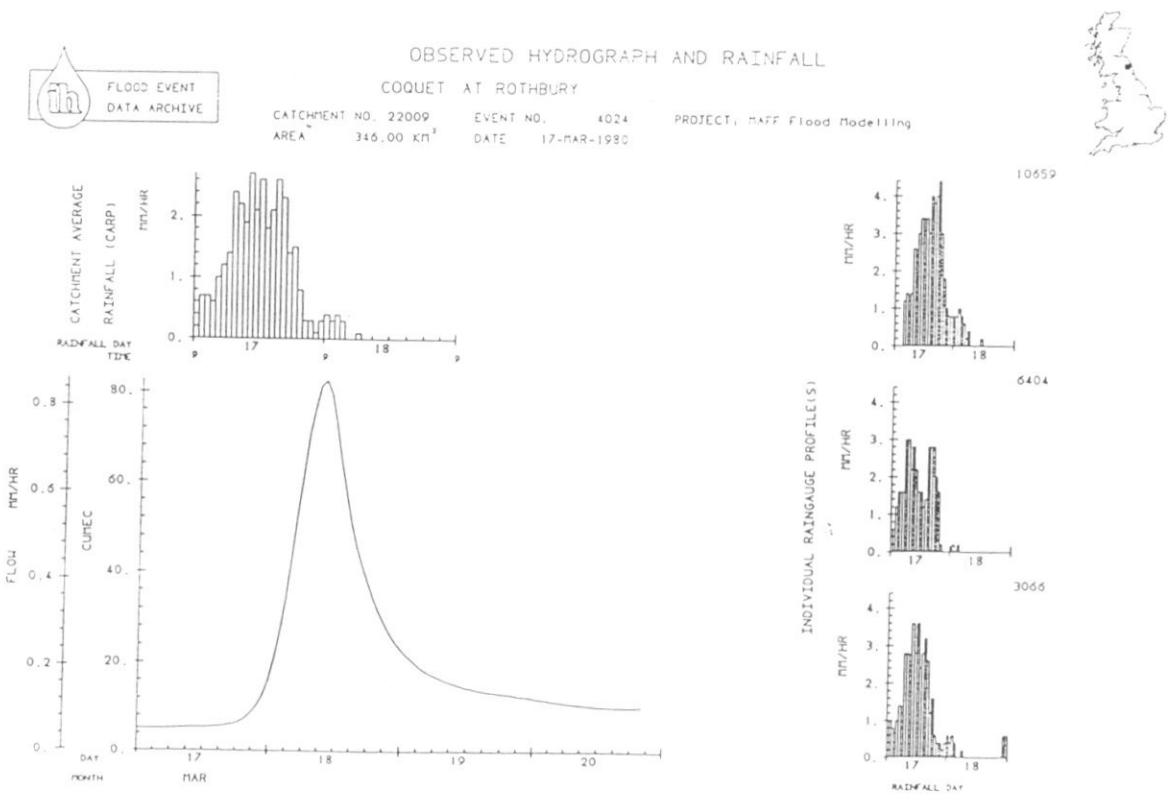


Figure 4.3 An example of a flood event

As shown in Figure 4.3, the flow data are usually at hourly intervals and are most often obtained directly from the operator of the flow gauge (normally the National Rivers Authority, NRA, in England and Wales, and the River Purification Boards, RPBs, in Scotland), although not always in a computer compatible form. The event shown is an ideal one in which the flow prior to the event is low, the flow record (hydrograph) then rises steeply to a well defined peak, after which the flow drops (recedes) to a level similar to that prior to the event. Note that this event is included in the annual hydrograph depicted in Figure 4.1 but, whereas the peak daily mean flow is about $49 m^3 s^{-1}$, the peak from the instantaneous record is just over $80\ m^3 s^{-1}$.

The rainfall series shown above the flow data in Figure 4.3 is a catchment average rainfall profile which is normally derived from a number of individual raingauge records. The volume of rainfall is a weighted average of the totals recorded by the daily gauges located on or near the catchment. This volume is distributed in time according to the weighted average of profiles from recording gauges in the same area, which are shown on the right hand side of Figure 4.3. Figure 4.4 shows the location of all gauges supplying data used to estimate this average profile. The averaging process uses the percentage of the annual average fall in the event, rather than the depth in mm, and symbols are used on the map in Figure 4.4 to indicate these percentage figures. These data are not usually available from the same source; the Meteorological Office (MO) can provide all daily data, but the recording gauge data may be from the same source or from the gauge operator (again normally the NRA or RPB).

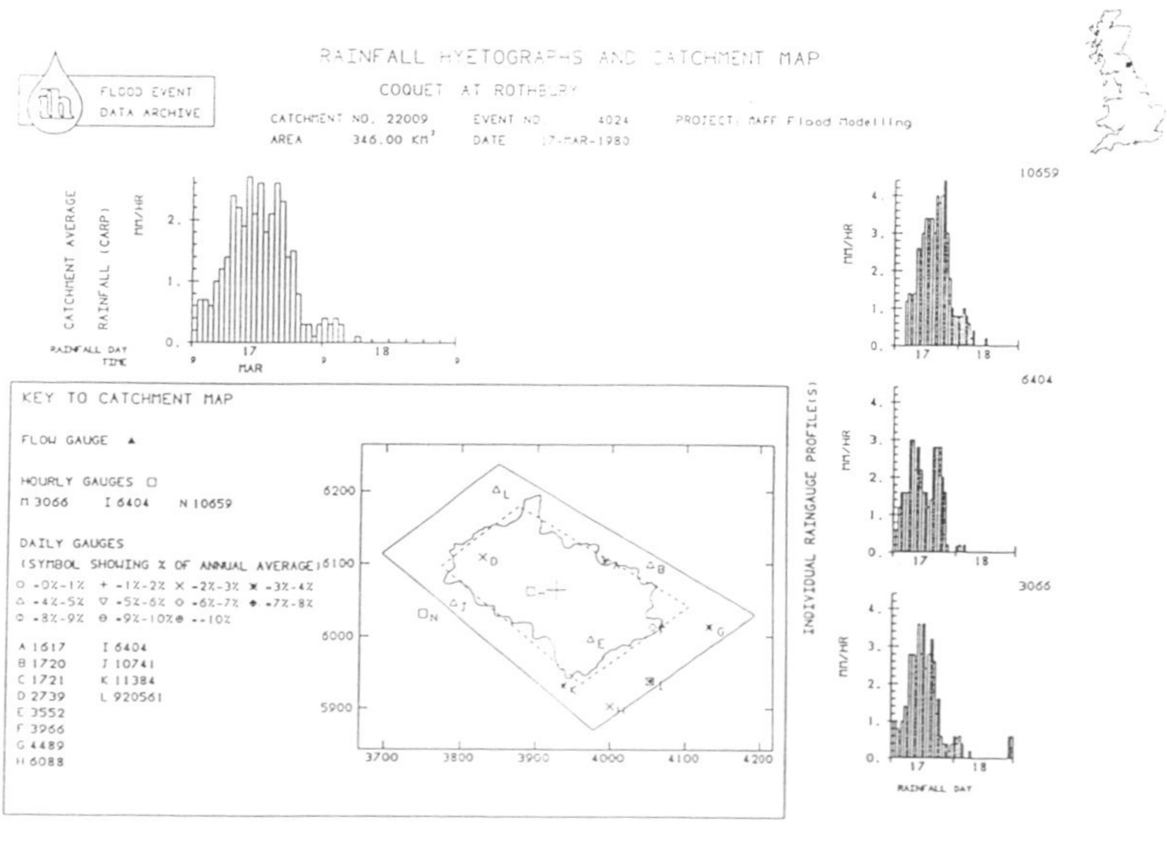


Figure 4.4 Raingauge data used to calculate a catchment average rainfall

Referring again to Figure 4.3 the catchment average rainfall may also be considered ideal because there is a single rainfall burst that starts before the rise in the flow hydrograph, and, because it is perfectly believable that the depicted rise in flow was caused by this rainfall. Because the raingauge network is sparse and for many events the rainfall is spatially variable, the catchment average rainfall calculated from the gauged data does not appear compatible with the flow data and the event has to be rejected from further analysis

To calculate the percentage of the rainfall that contributes to quick response runoff, it is necessary to separate the total flow hydrograph into a quick response component and an underlying baseflow. There are a great many ways of performing this separation that may be justified on the grounds of: physical interpretation, ease of analysis, or robustness in implementation. The event data available for the HOST study had all been previously analysed using the methods of the FSR; Figure 4.5 illustrates how the FSR flow separation is performed. In this procedure the lag between total rainfall and flow peak is derived and the end point of response runoff is taken as four times this lag after the flow peak. In the case of multi-peaked flow events then the centroid of flow peaks is used. The recession prior to the event is continued through the event, and this flow is subtracted from the total flow hydrograph. A straight line is then drawn from beneath the peak flow, or centroid of peaks, to the point already indentified as marking the end of response runoff. The response runoff is the portion of flow above this separation. The Flood Study found this to be a robust procedure that could be reliably applied to individual events. The flow separated by this process should be thought of as quick response runoff, rather than response runoff, since the rainfall will cause an increase in baseflow that may be apparent for a considerable time after the event, but in practice the label 'quick' is often omitted. Percentage runoff (PR) is simply the volume of response runoff expressed as a percentage of total rainfall.

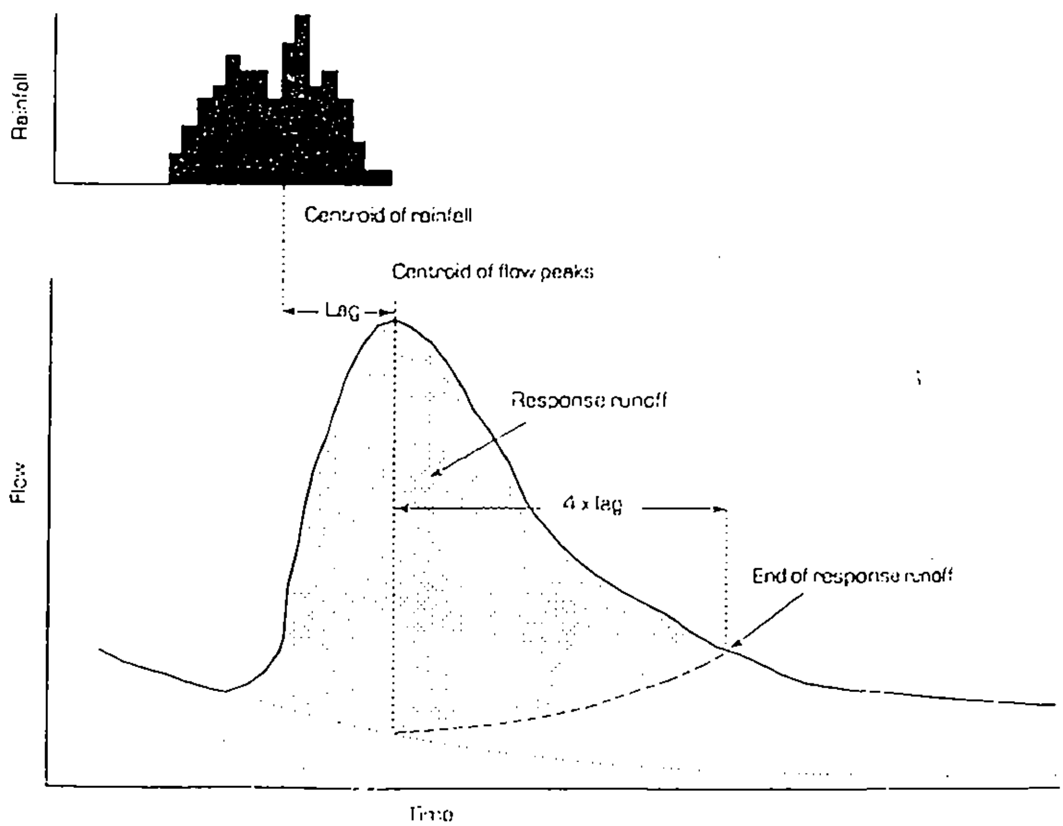


Figure 4.5 The FSR method of flow separation

To see how SPR is derived it is convenient to digress slightly and review how PR is estimated in the design situation. In making a flood estimate using the FSR rainfall-runoff method then PR has to be estimated and a two part model is used. This model divides the percentage runoff from a natural, undeveloped (ie. rural), catchment into two components: a standard term that is fixed for a catchment, and a dynamic component, comprising two terms, that varies between events. The precise form of these terms was revised in FSSR16, but the principle remains the same. The two dynamic terms presented in FSSR16 are given by:

$DPR_{CWI} = 0.25 (CWI - 125)$

$DPR_{RAIN} = 0.45 (RAIN - 40)^{0.7}$ for RAIN > 40.0 otherwise $DPR_{RAIN} = 0$

where
DPR_{CWI} is the dynamic percentage runoff term relating to catchment wetness,
CWI is the Catchment Wetness Index (CWI),
DPR_{RAIN} is the dynamic percentage runoff term dependent on event rainfall, and
RAIN is the rainfall depth in mm.

On rural catchments these dynamic terms are added to the standard percentage runoff to give the (total) percentage runoff:

$PR_{RURAL} = SPR + DPR_{CWI} + DPR_{RAIN}$

On catchments that are not rural then an allowance has to be made for the increased runoff from the developed area. The amount of development is obtained from the urban (pink) area of the Ordnance Survey's 1:50,000 scale map. Using a model that assumes 30% of the depicted area to be "impermeable", and that from this area 70% of the rainfall contributes to quick response runoff, the resulting equation is

$PR = PR_{RURAL} (1.0 - 0.3 URBAN) + 21.0 URBAN$.....

where URBAN is the urbanized fraction taken from the 1:50,000 OS map.

When these equations are applied to an ungauged catchment then URBAN can be taken from a map, RAIN and CWI are calculated from procedures which make use of special maps provided with the FSR, and SPR has until now been derived from the WRAP map.

Returning now to the situation where an event has been analysed and a value of PR obtained, these same equations can be applied in reverse to obtain an SPR value. The observed event PR is adjusted to give the PR_{RURAL} from which the dynamic terms are subtracted to give SPR. It is recommended that at least 5 events are used to give a reliable value of the catchment SPR. It is clear that averaging SPR rather than PR seeks to remove the effects of analysing events that are all drier or wetter than the normal conditions. Figure 4.6 illustrates this calculation for the Mole at Horley. This catchment average value of SPR can, and should when available, be used to replaced the value obtained via the WRAP map.

(a) Equations

PR_{OBS} = (Response runoff/Total rain)x100

PR_{RURAL} = (PR_{OBS}-(21.0xURBAN))/(1-0.3xURBAN)

DPR_{CWI} = 0.25 (CWI - 125)

DPR_{RAIN} = 0.45 (RAIN - 40)$^{0.7}$ for P>40 otherwise DPR_{RAIN}=0

SPR = PR_{RURAL} -DPR_{CWI} -DPR_{RAIN}

(b) Calculation for event of 13 November 1970

Total rain: 60.8mm
Response runoff: 27.5mm
Urban fraction: 0.09
Pre-event CWI: 80

PR_{OBS} = (27.5/60.8)x100
= 45.2

PR_{RURAL} = (45.2-(21x0.09))/(1-0.3x0.09)
= 44.51

DPR_{RAIN} = 0.45 (60.8 - 40)$^{0.7}$
= 3.77

DPR_{CWI} = 0.25 (80 - 125)
= -11.25

SPR = 44.51 + 11.25 - 3.77
= 51.99

(c) Average for catchment

Event	Rainfall	Reponse runoff	CWI	SPR
15-09-68	127.9	54.1	127	30.70
20-02 69	23.3	15.0	124	64.39
13-11-70	60.8	27.5	80	51.99
18-06 71	33 3	18.0	129	52.76
10-02 74	43.8	24.1	136	50.68
14-02-74	26.6	15.5	136	55.02
20-01-75	31.3	17.0	132	52.11
		Catchment average		51.09

Figure 4.6 The calculation of percentage runoff (PR) and standard percentage runoff (SPR) from event data

The catchment average SPR data derived in this way are the data used by the HOST project. From the above description it is seen that the preparation of such data is laborious as the data come from many sources and require careful processing and checking before they can be used. SPR values were available from the 1910 events on 210 catchments described by Boorman (1985), and from an additional 683 events collected subsequently from the same and other catchments. However, for many of these catchments insufficient events are available to give an acceptable value of SPR and less could be used for HOST. The distribution of these catchments in the UK is shown in Figure 4.7; there are no such catchments in Northern

Ireland. Figure 4.8 gives an example event, event SPR and catchment average SPR values for a number of UK catchments that cover a range or response types. In these plots in it is informative to compare the scale of the rainfall axis with the left hand flow axis, as these have the same units, mm hr^{-1}. In the top left hand diagram, for the Conwy, the peak of the rainfall is about 7mm hr^{-1} and the flow peak is just over 4mm hr^{-1}. As the flow response is fast, and because the flow quickly returns to close to the pre-event value, it is no surprise that the standard percentage runoff is about 60%. Compare this with the bottom right hand diagram for the Ems catchment, in which the peak rainfall is almost 4mm hr^{-1} but the peak flow is less than 0.03 mm hr^{-1}. Here the response runoff continues well beyond the duration of the rainfall event, but the standard percentage runoff is less than 0.5%. The other events shown in this figure represent a variety of responses between the two described. In the data set available for HOST, catchment average SPR ranges from 3.8% to 77.5%.

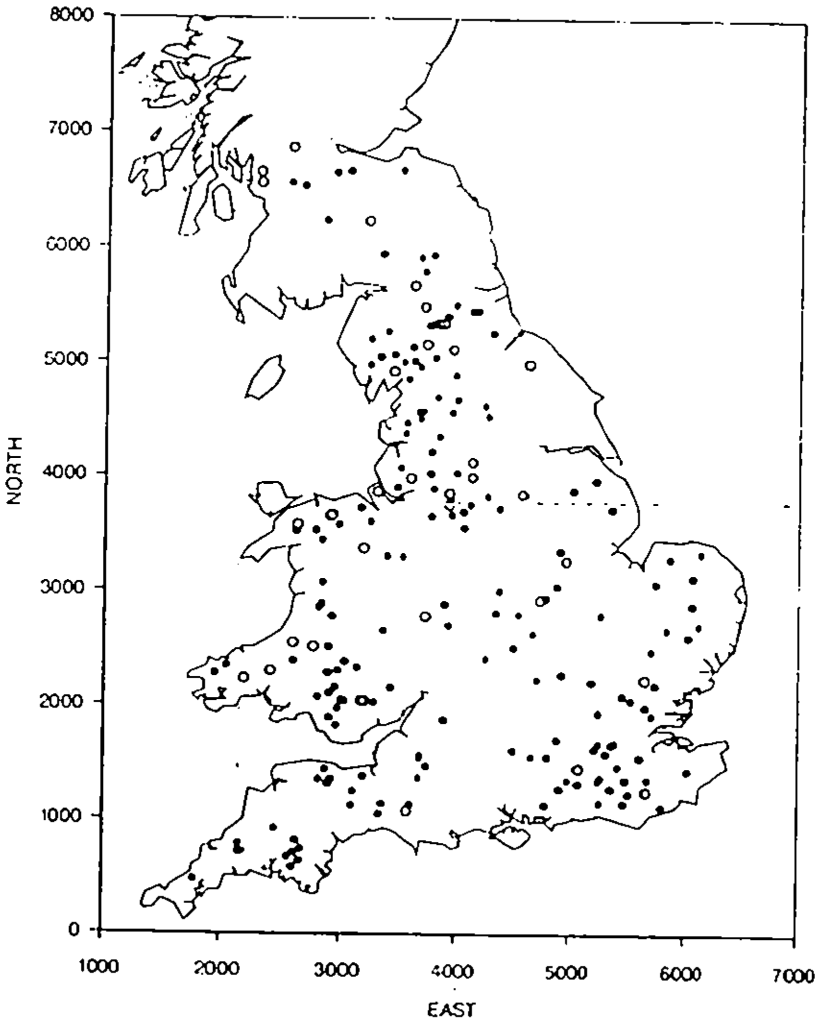


Figure 4.7 The distribution of catchments for which SPR values were available. Dots represent catchments with SPR calculated from five or more events, circles represent other catchments for which a value of SPR was available

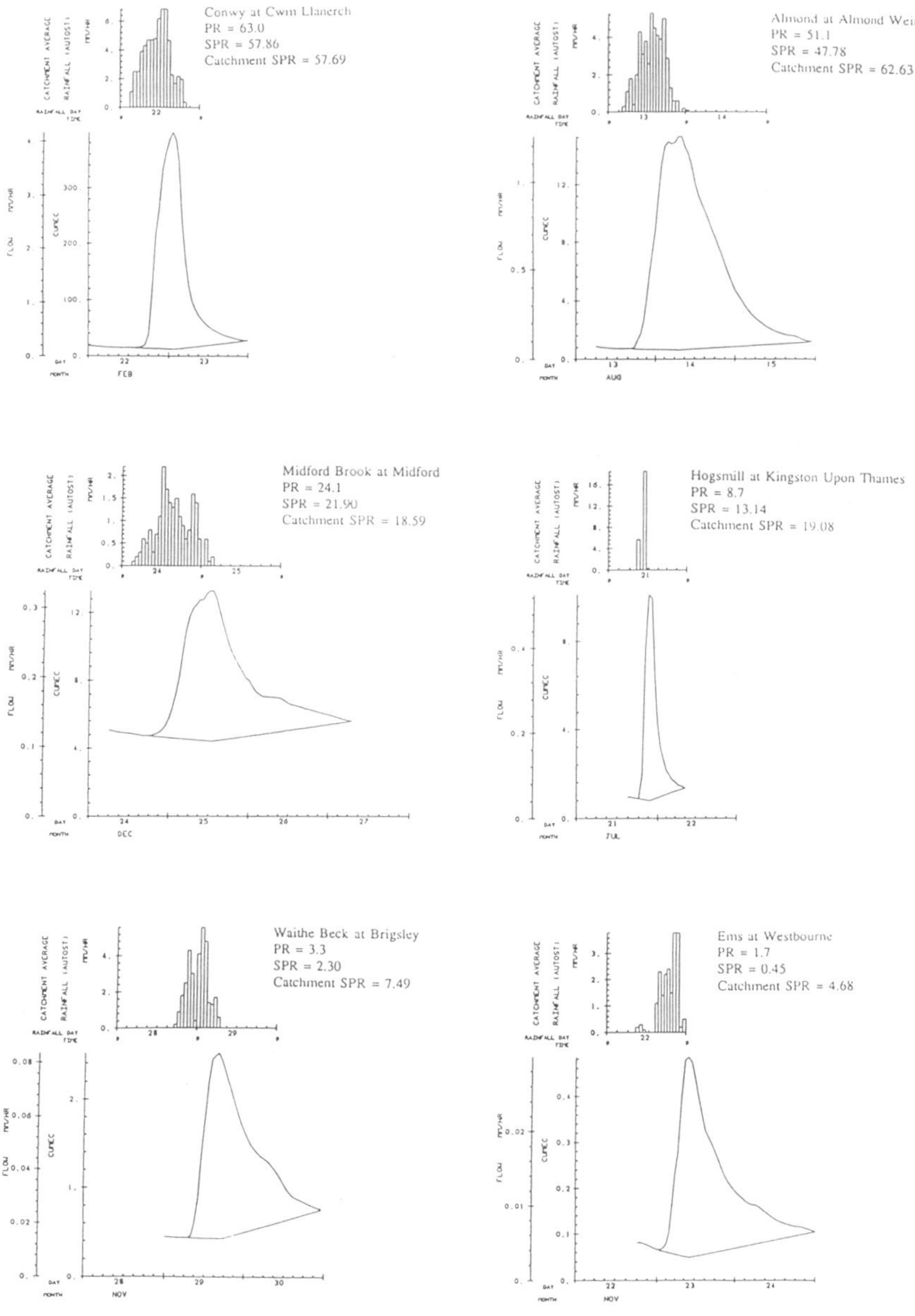


Figure 4.8 Example flow hydrograph separations and SPR values

4.2.3 Base flow index

Whereas the calculation of SPR requires detailed event-based data describing both flow and rainfall, BFI is derived using only daily mean flow data. BFI is the long-term average proportion of flow that occurs as baseflow, and is an index developed in the Low Flow Studies (Institute of Hydrology, 1980). Figure 4.9 illustrates the calculation of BFI for the Coquet at Rothbury which has a BFI for the year of 0.50. Observed values are close to unity on catchments dominated by baseflow but as low as 0.15 on the catchments with the flashiest response. Figure 4.10 presents a selection of annual hydrographs with their BFI separations, and long-term BFI values for the same catchments as are shown in Figure 4.8. The top two hydrographs are for catchments dominanted by the quick flow response, whereas the bottom two are almost entirely dominated by groundwater flow. These latter two hydrographs are quite unusual as the baseflow does not show the expected annual variation; Waithe Beck begins at a lower level than expected but then baseflow recovers at the start of the following winter, and the Ems flow decreases through the summer, but does not recover at the start of the next winter. The two middle plots show catchments with a quick response superposed on seasonal variation.

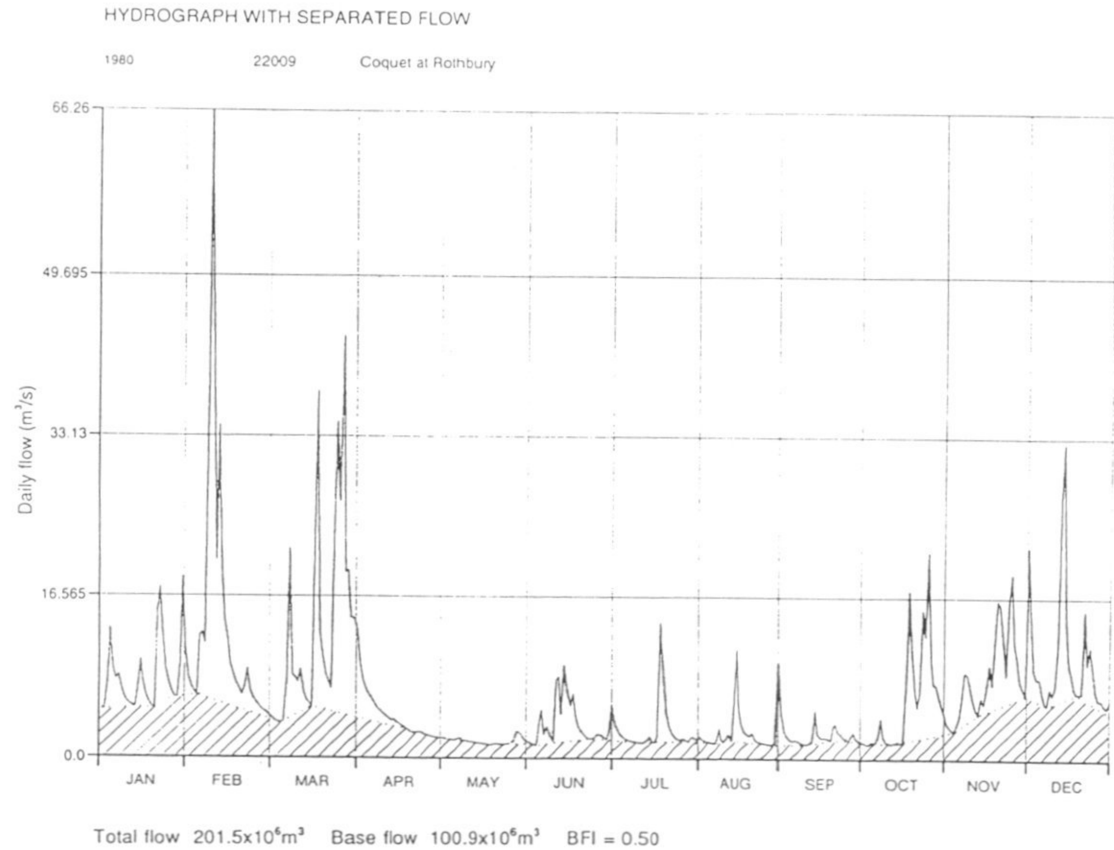
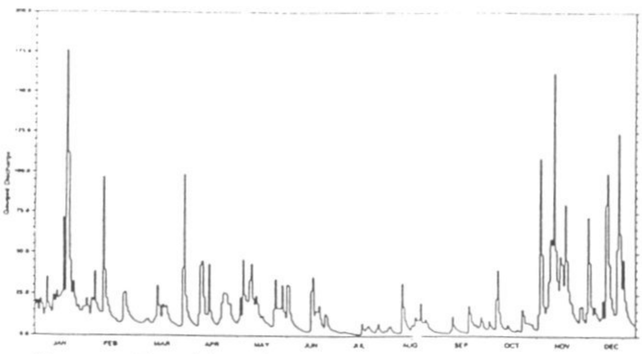


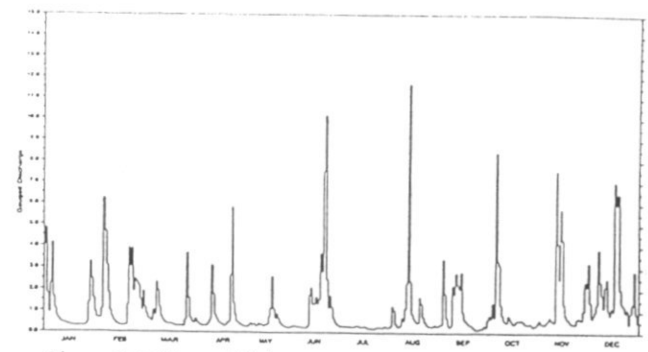
Figure 4.9 The calculation of base flow index BFI from daily mean flow data

BFI has been derived for all of the catchments for which flow data are available in the UK National Water Archive (see, for example, Institute of Hydrology, 1988). However, although values of BFI can be derived for these catchments, many with major artificial influences were rejected. The HOST project was able to draw on station assessments for low flow studies



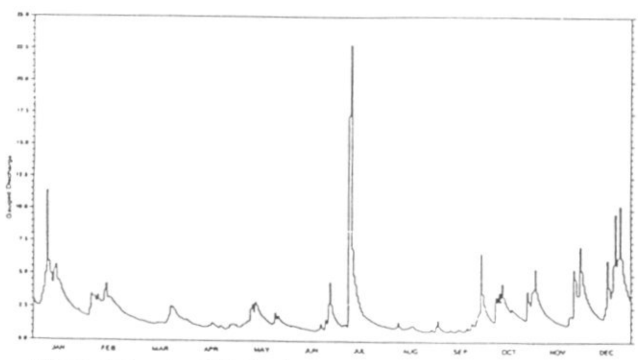
Conwy at Cwm Llanerch

AREA = 344.5 sq.km BFI = .28



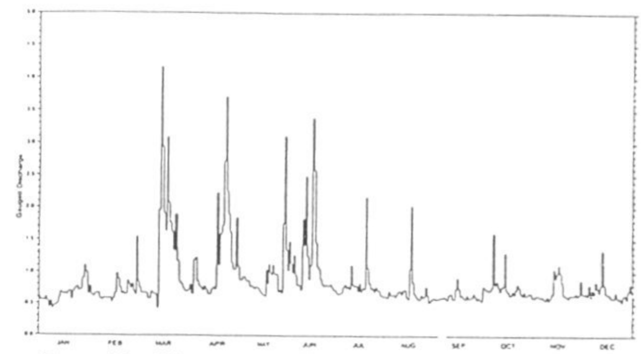
Almond at Almond Weir

AREA = 43.8 sq.km BFI = .34



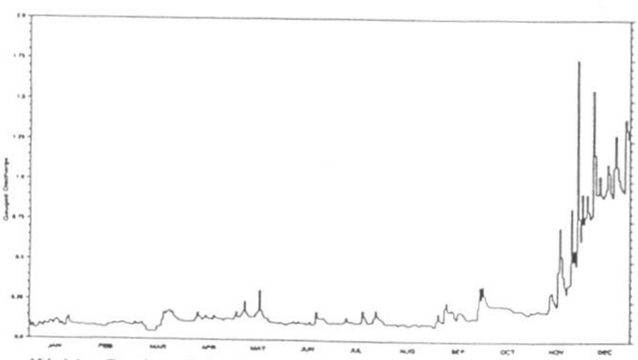
Midford Brook at Midford

AREA = 147.4 sq.km BFI = .62



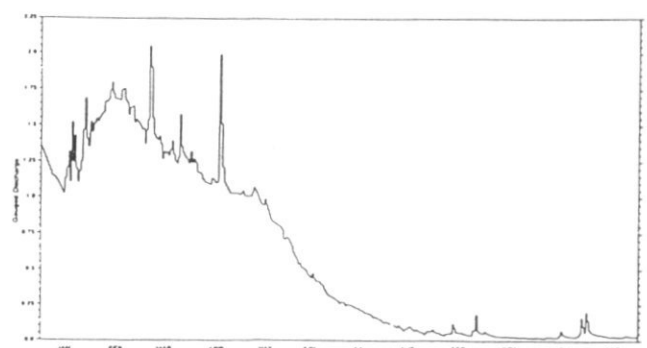
Hogsmill at Kingston upon Thames

AREA = 69.1 sq.km BFI = .74



Waithe Beck at Brigsley

AREA = 108.3 sq.km BFI = .84



Ems at Westbourne

AREA = 58.3 sq.km BFI = .92

Figure 4.10 Example hydrographs and BFI values

(Gustard et al, 1992) which included viewing an arbitrarily chosen annual hydrograph; this simple check revealed many problems in the data. The same assessment exercise sought information of artificial influences from gauging authority staff and files. Two measures of the suitability of catchments were therefore available based on the hydrometric quality of the flow gauge, and degree of artificial influence as summarised in Table 4.2.

Table 4.2 Classification of station suitability (after Gustard et al, 1992)

Grade	Hydrometric Quality	Artificial Influence
A	Accurate low flow measurement.	Gauged Q_{95}/mean flow within 20% of estimated Q_{95}/mean flow.
B	Less accurate or periodic variation in quality	Gauged Q_{95}/mean flow within 50% of estimated Q_{95}/mean flow.
C	Poor accuracy of low flows (eg. through poor control, scatter of gaugings, weed growth, siltation, vandalism)	Gauged Q_{95}/mean flow not within 50% of estimated Q_{95}/mean flow.
U	Unclassified	Unclassified

For the current project this scheme was modified to give a more general indication of the quality of the BFI values. Thus any station graded AA,AB,BA or BB was coded A for this study, catchments graded AC, CA or CC were coded D, and all others were graded Y. There were subsequently some modifications, and additions of catchments, and code B was used for additional good quality stations, and X for stations with poor data. It is notable that the list of quality codes that appears in this report indicates different data qualities to those found in Gustard et al. This is most often because a subsequent examination of the data will have shown that by removing a dubious period of the record the quality of the abstracted parameters can be improved. For example, many values of BFI had to be recalculated for a restricted period (eg. only to include pre-impoundment flows at a now-reservoired site).

Even after this thorough review there were many more values of BFI than SPR; the distribution of the catchments for which BFI data were available is shown in Figure 4.11.

4.2.4 Comparison of BFI and SPR

As noted in IH Report 94 (Boorman, 1985) there is a good correlation between SPR and BFI; on a set of 166 catchments the correlation coefficient was 0.75 and a regression equation was presented for the estimation of SPR from BFI. This equation is:

$$SPR = 72.0 - 66.5\ BFI$$

This relationship is represented for the data available to the HOST project in Figure 4.12.

What the two measures have in common is that they both involve a separation of the hydrograph, but whereas SPR compares the quick response volume to that of the rainfall, BFI compares the remaining, baseflow, volume with the total flow volume. If all of the rain

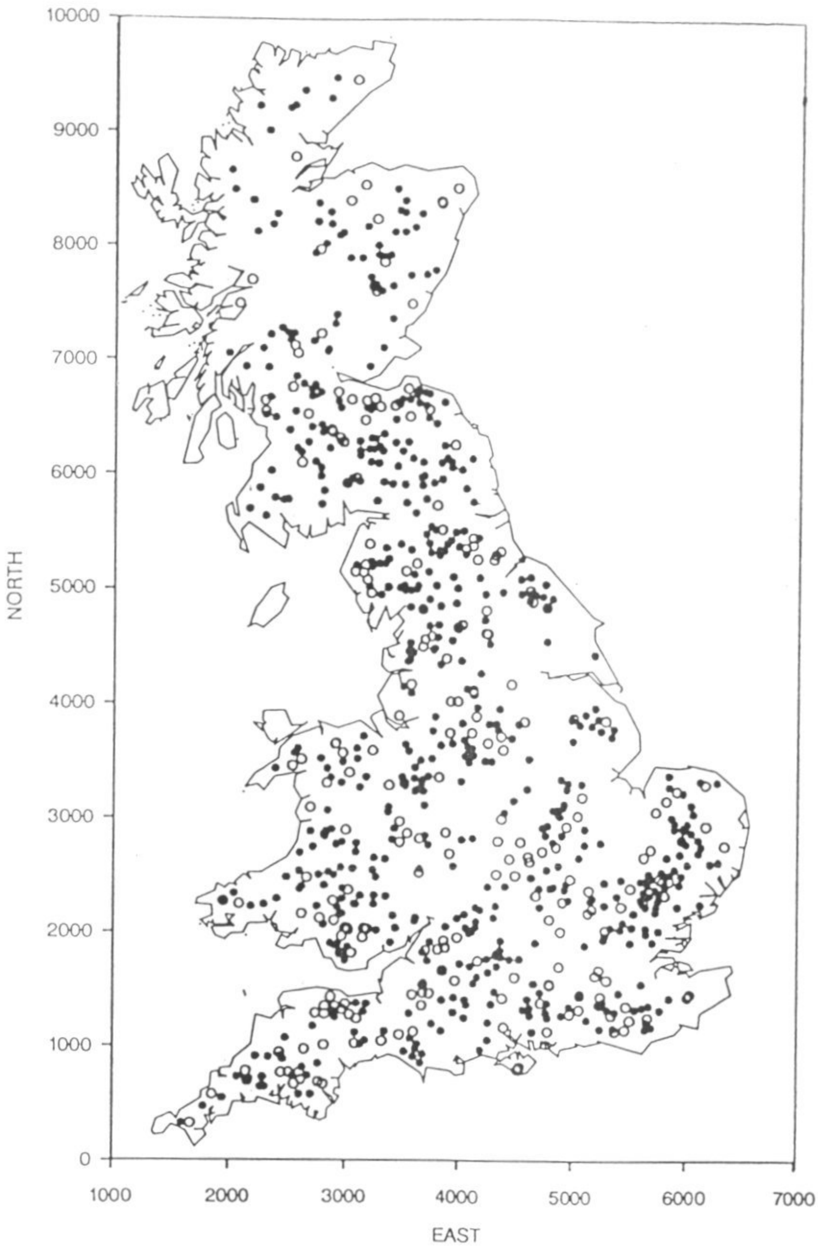


Figure 4.11 The distribution of catchments for which values of BFI are available. Dots represent catchments quality graded A or B, circles represent other catchments for which a value of BFI was available

falling on the catchment leaves the catchment as runoff (ie. none is lost as evaporation or to groundwater) then the flow volume is the same as the rainfall volume and 1-BFI should be equivalent to some form of average percentage runoff.

The other difference between the two measures is the time scale of the response; SPR separates over a period of tens of hours, whereas the BFI separation is over a period of many days. SPR therefore represents a quicker response than BFI.

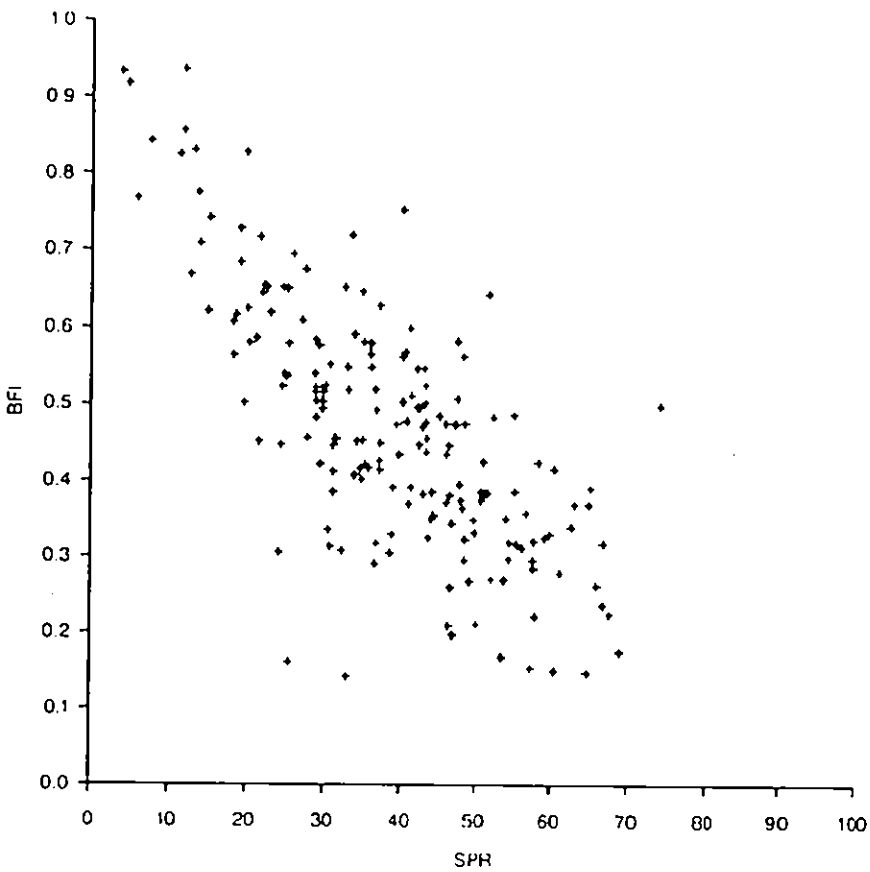


Figure 4.12 Comparison of BFI and SPR values

Because of its greater availability, BFI was the main hydrological variable used in the development of the HOST classification, but limited use was made of SPR and of flow duration curve and flood peak statistics.

It must not be forgotten that SPR and BFI are not observed data but the result of applying models to carefully vetted sets of data.

4.3 SOIL DATA AND MAPS

4.3.1 An introduction to soil surveying

Soil, in general terms, is that part of the earth's surface which supports biological activity. It comprises unconsolidated material within which there has been some degree of internal reorganisation due to soil-forming processes which have acted on the material over a period of time. This unconsolidated material may have been altered by the addition and movement of organic material, the redistribution of mineral material and nutrients, and the effects of climate. These processes often lead to a distinct layering within the soil to form *horizons*. The specific nature and order of these horizons informs pedologists of the dominant soil forming processes, and provides a means of classifying soils. Classification is a vital first step in mapping the spatial distribution of soils.

Although soil classifications are often hierarchical, soils do not, in practice, belong to a series of discrete taxa. The soil seen at a point should be thought of as a sample from a continuously varying medium. The role of the soil surveyor is to define the allowable range in soil properties within the taxa, and then to assign soils to the most appropriate one. By repeating this process over an area the soil surveyor attempts to delineate the distribution of the taxa in the landscape, trying to make sense of what is often a chaotic situation.

The classification schemes used by MLURI (in Scotland) and SSLRC (in England and Wales) are different. Strictly the Scottish Soil Survey has a typological rather than a hierarchical system. Within both systems the *soil series* is the lowest class and represents the individual soil type as defined by the soil forming process, plus other characteristics which are inherited from the parent material, such as soil texture or inherent soil fertility.

Soil science is a field science and as such relies on the recognition of soil properties in the field for classification and mapping. In applying the classification, a soil surveyor has to take account of what it is practical to delineate at the scale being used, and the intended purpose of the map. It is normal to relate a soil mapping unit to the landscape, or some other physical expression of change in soil type, such as vegetation. This approach relies on the skill of the surveyor and his understanding of the local relationship between soils and the environment. Because of these considerations, the soil series cannot always be used as the soil map unit.

A soil map unit will, in general, comprise a dominant soil series combined with other similar or dissimilar soils. The degree to which the map unit is homogeneous depends largely on the scale of the map but, at the reconnaissance scale of 1:250,000, each unit is likely to contain a mixture of soil types. At this scale it should also be recognised that the proportions of the various soil types are likely to change between locations. At a more detailed scale, say 1:25,000, there is an assumption that the soil map units will be much more homogeneous, and usually represent one soil type. In such a case the unit may still represent more than one soil series, but the sub-dominant ones are likely to have properties similar to those of the dominant series. This need not always be the case and expert advice is often required to interpret soil maps.

Throughout this report the term soil series is used exclusively to represent a taxonomic unit and never a soil map unit. Unfortunately, this is not universally the case and can cause a great deal of confusion even among soil scientists.

The use of soil horizons to help classify soils was mentioned above, and it is relevant to say slightly more about horizons and their nomenclature. Since the definition of horizons is common to both the classifications used in England and Wales, and in Scotland, they were a useful handle for the development of a unified approach to the hydrological classification of the soils of the UK.

Topsoil horizons are designated as A horizons with various subhorizons indicated by the addition of lower-case letters such as p for ploughed, or g for gleyed. The immediate subsoil (ie. material in which pedological alteration has occurred and which has no rock structure) is designated B, again with sub-horizons such as s for sesquioxides (iron and aluminium rich). The relatively unaltered parent material is known as a C horizon and again sub-horizons are identified.

4.3.2 The 1:250 000 soil maps

In the late 1970s the two national soil survey organisations began a rapid reconnaissance mapping programme to provide soils information for the whole of Great Britain at a 1:250,000 scale. The projects were concluded in 1981 and 1982 resulting in a series of seven maps covering Scotland, one map for Wales and five for England. Another product of this exercise was an objectively based national soil inventory whereby soil profiles were examined at 5-kilometre grid intervals. Previous detailed mapping at scales ranging from 1:25,000 to 1:63,360 were incorporated into these national maps, and existing profile descriptions and accompanying analyses were added to computerised databases along with the National Inventory data, making a comprehensive spatially referenced soil and environmental information system suitable for resource management and strategic planning on a national scale.

Although differences in soil classification and certain concepts occurred between the two survey organisations, detailed correlation and matching of the map units at the border ensure continuity throughout.

From the general description of soil surveying presented above, it will be appreciated that the unit shown on the 1:250,000 maps will not be a single soil series, but a collection of series that will in many cases have dissimilar properties. So although the maps satisfy one criterion for the development of a national soils classification for hydrological use, namely that they are the most detailed maps with national coverage, they do not directly relate to the physical properties of soils that are likely to influence the hydrological response. It is necessary, therefore, to consider in slightly more detail the classification schemes used by the two national soil surveys, and the ways in which they represent soils on the 1:250,000 maps. As will become clear later, a basic understanding of these issues will help in using HOST in applications.

England and Wales

In England and Wales, soil profile characteristics are used to classify soils at four levels in a hierarchical system. The four levels are labelled: major group, group, subgroup, and series, and they are described in Table 4.3.

Soil map units (also known as associations in England and Wales) are named after their largest component series and assigned a map symbol that is the sub-group number and a code letter allocated to an alphabetical list of all the units with the same sub-group number. The letters are lower case first, then upper case. If the association's name is upper case it implies that the corresponding series is dominant within the association (ie. >50%). Table 4.4 presents examples of this naming convention.

The colours used to depict the map units shown on the soil maps of England and Wales reflect the major soil sub-groups of the most extensive series within the map unit.

1	Terrestrial raw soils	Not mapped at this scale
2	Raw gley soils	pale blue
3	Lithomorphic soils	yellow, orange
4	Pelosols	khaki
5	Brown soils	brown, orange
6	Podzolic soils	red

7	Surface water gleys	green
8	Ground-water gleys	blue
9	Man made soils	grey
10	Peat soils	purple

Table 4.3 The soil classification used by SSLRC in England and Wales

	Properties	Naming convention	No.	Examples
Major group	Predominant pedological characteristics	Named using the features used to distinguish them	10	4. Pelosols 7. Surface water gley soil 10. Peat soils
Group			67	2.2 Unripened gley soils 4.1 Calcareous pelosols 7.1 Stagnogley soils 10.1 Raw peat soil
Sub-group				4.31 Typical argillic pelosols 7.11 Typical stagnogley soils 10.11 Raw oligo-fibrous peat soil
Series	Precisely defined particle-size subgroups, parent material (substrate) type, colour and mineralogical characteristics.	Named after places at which they were first defined	418	431a Worcester 711a Stanway 1011a Longmoss

Table 4.4 Examples of the SSLRC map unit naming convention

Symbol	Name		
343	a	ELMTON1	First map unit (hence letter a) in sub-group 343, brown rendzina, major series Elmton which is dominant within the association
343	b	ELMTON2	2nd in sub-group 343 (letter b), Elmton main series and dominant so named ELMTON2
343	c	Elmton3	3rd in sub-group (c). Elmton main series but not dominant so in lower case.

Scotland

The Scottish soil classification has four categorical levels (Soil Survey of Scotland, 1984) termed: division, major soil group, major soil subgroup and soil series. The last two groups correspond to the lower categories of the soil classification used in England and Wales. Soils at the major soil subgroup level are very similar in appearance and are separated at the soil series level according to their parent material and natural drainage.

In Scotland, the underlying geology has been found to have a profound effect on the soil chemistry and so soils have been grouped according to the rock types which comprise the parent drift. This grouping is called an *association*. Thus all soil types developed on granites belong to the Countesswells Association, and those developed on basalts belong to the Darleith Association. Each association will have a suite of major soil subgroups associated with them. The major soil subgroup, the parent material (or Association) and the natural drainage of the soil all combine to produce what is known as the soil *series*. It is this unit that is represented on all the Soil Survey maps at scales less that 1:63,360. The soil series and associations are named according to the region or farm where they were first encountered and, in essence are short hand ways of describing the pedology of the soil (ie. its major soil subgroup), its natural drainage, and its parent material.

Table 4.5 The soil classification used by MLURI in Scotland

	Properties	Naming convention	No.	Examples
Division	Predominant pedological characteristics	Named using the properties used to distinguish them	5	1. Immature soils 4. Gleys 5. Organic soils
Major soil group	Soil processes and stages of development		12	1.3 Alluvial soils 4.1 Surface water gleys 5.1 Peats
Major soil sub-group	Nature and arrangement of horizons and sub-hoizons.		37	1.3.1 Saline alluvial soils 4.1.6 Peaty gleys 5.1.1 Eutrophic flushed peat
Series	As above but also distinguished by parent material.	Named according to the region or farm at which they were first encountered	516	

The map units are grouped according to the Association (ie. parent material) and listed alphabetically after Alluvial and Organic soils. They are also ordered such that dry soils precede wet soils, lowland soils precede mountain soils, and non-rocky terrain precedes rocky landscapes. The map units are then numbered consecutively (Handbook 8, Soil Survey Scotland), the numbers having no other significance.

The colours used to depict the map units shown on the soil maps of Scotland reflect the major soil groups of the most extensive series within the map unit.

Alluvial soils	yellow
Brown forest soils	brown
Humus-iron and peaty podzols	pink, orange and red
Peaty gleys	green
Mineral gleys	blue

Peats	purple
Rankers, subalpine, alpine soils	grey

4.3.3 Understanding differences in the soil classifications and maps

As the two survey organizations have used different classification schemes, the two sets of 1:250,000 maps appear very different, especially to the non-specialist. The map units in Scotland are largely delineated on the basis of landform, while in England and Wales soils which commonly occur together form the basis of the map unit. This difference is predominantly due to the more complex topography found in Scotland and the recognition that similar landform units recur throughout the country with a similar set of soils despite changes in the geological composition of the drift, e.g. hummocky moraine.

Each survey organisation colour codes the map units in terms of the dominant major soil subgroup. These broadly agree in that brown soils are shown in brown colours and podzolic soils in reds and oranges; however, other differences do occur.

On the 1:250,000 maps there are approximately twice as many map units in Scotland as in England and Wales, even though Scotland has only half of the land area. On average, map units in Scotland cover only 1/4 of the area covered by map units in England and Wales, but note that the average extent of a map unit can be misleading because the variation is extremely large.

The Scottish maps contain a higher total number of series, but because there are many more map units, there are, on average, fewer series in a Scottish map unit (1.8) than in England and Wales (3.5). On average, a soil series occurs in more map units in England and Wales.

Table 4.6 Summary data describing the 1:250,000 soil maps

	England & Wales	Scotland
Area	151,207km^2	77,087km^2
No. of map units	300	590
Approximate average extent of map unit	504 km^2	130km^2
No. of soil series	418	556
Average no. of series in a map unit	3.5	1.8
Average no. of map units in which a series appears	2.5	1.9

Although there are differences between the soil classification systems used in England and Wales and in Scotland, both are intended for general purpose surveys, and rely on the identification and assessment of soil properties in the field. Underlying both systems are similar data bases collected by the two organisations. Data have been abstracted from these and used to create a common database from which the HOST classification has been developed.

4.3.4 Using the soils data in the HOST project

In the preceding sections it has been noted that soil physical properties were available for soil series, and that national maps showed the distributions of map units. The composition of the map units was understood in a qualitative way that allowed the necessary flexibility to assign soils surveyed in the field to a map unit. However, if a classification based on series was to be applied to derive hydrological parameters, then a quantitative breakdown of the map unit by series was required. The most straightforward way of making this breakdown was to assume fixed proportions of soil series in each occurrence of a map unit, and these proportions were derived as an early requirement for HOST. However, in some units proportions often summed to less than unity as small amounts of subsidiary series were omitted. In using the data the proportions were rescaled so that they totalled one.

Within some map units, particularly in Scotland, map units were at first assigned equally to two soil series that had different soil properties. In such cases a 1% adjustment was made to the assignments so that one of these would always appear as the larger series. The exact reason for this concerns the nature of the database management system used to hold these data, and the way in which HOST classes were attached to series and map units. Making this adjustment meant that when these data were used later in the project the same HOST class would consistently appear as the dominant class. This adjustment was also needed on some catchments with more than two component series, and was always made on the basis of an assessment of the soils rather than on an arbitrary basis.

Table 4.7 Example of the breakdown of map units by soil series.

Map symbol	Association	Component series	Attributed %	Rescaled %
343a	ELMTON1	Elmton	40	44.4
		Aberford	30	33.3
		Shippon	10	11.1
		Moreton	10	11.1

One other addition that was required to the existing soils data sets was to ascribe soil map units to the unclassified, mainly urban, areas. For HOST it was seen as important to provide a complete soil classification since the hydrological effects of urbanisation are conditioned by the underlying soils. The urban areas have now been infilled in the national soil maps, mainly using geological correlation techniques. Figure 4.13 shows those areas depicted as unclassified on the 1:250,000 soil maps; they represent 5.1% of the land area in England, Scotland and Wales.

4.3.5 Soil physical properties

In addition to the map data, there exist databases containing information about the physical properties that characterise the soil series, and the proportions of series within the map units. For England and Wales alone there are physical property data for about 4000 soil layers describing over 1000 soil profiles. The physical properties that were available at the start of the HOST project were: depth to a slowly permeable layer, depth to a gleyed layer, the integrated air capacity (IAC) and presence or abscence of a peaty top soil. However, at an

Distribution of urban areas (HOST)

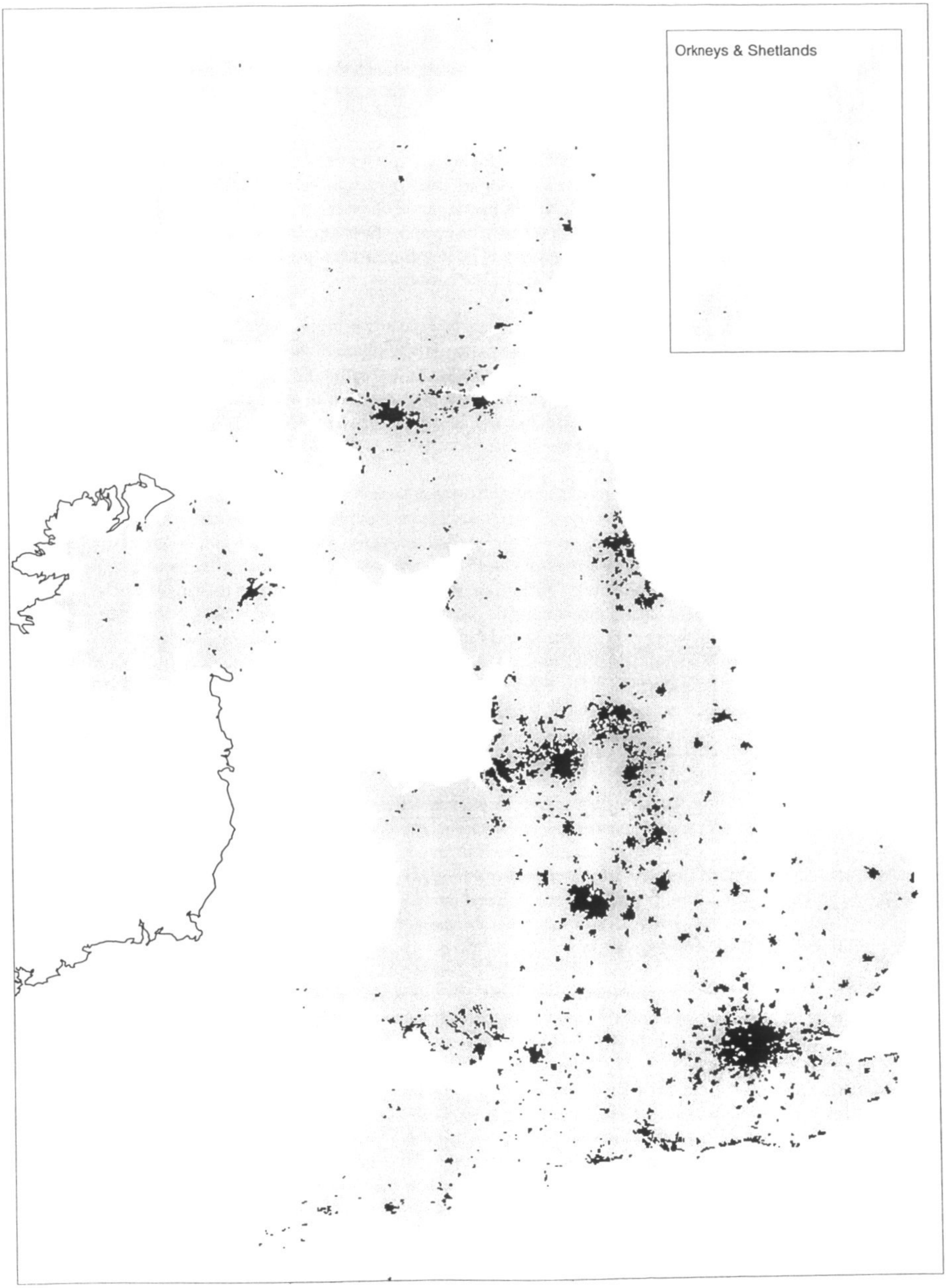


Figure 4.13 Areas shown as unclassified on the 1:250,000 soil maps.

early stage in the project it was seen to be necessary to include a geological component and a soil-hydrogeological classification was derived; where appropriate this also contained information about the depth to an aquifer or groundwater.

Depth to a slowly permeable layer: These soil layers have a lateral hydraulic conductivity of < 10 cm day^{-1} and can be defined in terms of their particular soil textural and structural conditions. Such a layer impedes downward percolation of excess soil water causing periodic saturation in the overlying layer. Storage is reduced and, since there is a decreased acceptance of rainfall, there will increased response. The depth to a slowly permeable layer is only included if such a layer exists within 1m of the surface.

Depth to a gleyed layer. Gleying, the presence of grey and ochreous mottles within the soil, is caused by intermittent waterlogging. The particular definition of gleying used identifies soil layers wet for at least 30 days each year, or soils that are artificially drained. This depth is defined in terms of soil colour, particularly the hue, chroma, density and prominence of mottling (Avery, 1980; MAFF, 1988 and Hollis, 1989). The depth to a gleyed layer is only included if such a layer exists within 1m of the surface.

Integrated air capacity: Air capacity is a measure of the soil macroporosity and is defined as the volume of pores in the soil which are greater than 60μm, i.e. the pores that are unable to retain water against the pull of gravity. The volume of these pores in each soil horizon was integrated over 1 metre (where the soil was deep enough) to give an average percentage volume for the whole soil profile. Although the relevance of this variable to the classification is limited, it provides a useful discrimination between some soils where it acts as a surrogate for hydraulic conductivity in permeable soils and for storage capacity in some impermeable soils (Hollis and Woods, 1989). The air capacity values for 4000 soil horizons held in the soil physical properties database by the SSLRC were used in the assessment of the air capacity values of the HOST soils, again by relating the soil structural and textural conditions to approximate air capacity values. This approach was of particular importance to the classification of the Scottish soils as there were limited soil physical data available.

The presence of a peaty surface layer: Peaty surface layers have more than 20 percent organic matter although in most cases it is much higher. It is indicative of saturated conditions for most of the year. Peaty topsoils are both slowly permeable and yet can store large volumes of water. These layers, therefore, limit infiltration and provide a lateral pathway for rapid response in the uppermost parts of the soil making surface runoff prevalent in soils with these layers. A raw peaty topsoil has specific characteristics of thickness, consistency and fibre composition (Avery, 1980).

Two hydrogeological parameters were used in the development of HOST. These were substrate hydrogeology and the approximate depth to an aquifer or groundwater. Substrate hydrogeology was specifically developed for use in HOST and provides a method of distinguishing between slowly permeable, permeable or impermeable substrates and, in the permeable substrates, between mechanisms of vertical water movement (e.g. intergranular or macroporous flow). Substrate permeability is based on Bell (1985) with permeable substrates having a vertical hydraulic conductivity > 10 cm day^{-1}, slowly permeable between 0.1 and 10 cm day^{-1}, and impermeable < 0.1 cm day^{-1}. The national soil maps provided the description of the underlying substrates (soil parent material) and the classification of rock and drift hydrogeology followed that of the Institute of Geological Sciences (1977) and the British Geological Survey (1988). Table 4.8 shows the full hydrogeological classification. Concurrent with the classification of the hydrogeology was an estimation of the likely

Table 4.8 Soil-geology classes used within the HOST project

Class number	Class description
1	Soft sandstone, weakly consolidated sand
2	Weathered/fissured intrusive/metamorphic rock
3	Chalk, chalk rubble
4	Soft Magnesian, brashy or Oolitic limestone and ironstone
5	Hard fissured limestone
6	Hard coherent rocks
7	Hard but deeply shattered rocks
8	Soft shales with subordinate mudstones and siltstones
9	Very soft reddish blocky mudstones (marls)
10	Very soft massive clays
11	Very soft bedded loams, clays and sands
12	Very soft bedded loam/clay/sand with subordinate sandstone
13	Hard (fissured) sandstones
14	Earthy peat
15	River alluvium
16	Marine alluvium
17	Lake marl or tufa
18	Colluvium
19	Blown sand
20	Coverloam
21	Glaciolacustrine clays and silts
22	Till, compact head
23	Clay with flints or plateau drift
24	Gravel
25	Loamy drift
26	Chalky drift
27	Disturbed ground
34	Sand
35	Cryogenic
36	Scree
43	Eroded Blanket Peat
44	Raw Peat
50	Unsurveyed
51	Lake
52	Sea

presence of an aquifer or groundwater table and, if present, at what depth it was likely to occur. The depth to an aquifer or groundwater indicates the time taken for excess water to reach the water table. Three categories were recognised: >2m, ≤ 2m, and no aquifer or groundwater.

4.4 LINKING THE CATCHMENT AND SOIL DATA

For each catchment a digitised boundary has been overlain on a 1km gridded version of the national soil maps and the total percentage of each soil map unit abstracted. From this the proportion of each component soil series was derived and hence the link established between the catchment response descriptors and soil properties.

The catchment boundaries were digitised from lines drawn by hand mainly on 1:50,000 maps. The construction of the boundaries is easy in upland areas but quite difficult in low lying regions where many ditches exist at right-angles to the expected flow direction. The construction of a hydrologically sound digital elevation model at IH has shown many minor, but very few major, errors in these boundaries. The process of digitisation is unlikely to introduce significant error.

5 The HOST classification system

5.1 THE BASIS OF THE HOST CLASSIFICATION SYSTEM

The HOST classification is based on a number of conceptual models that describe dominant pathways of water movement through the soil and, where appropriate, substrate.

Rain falling at the surface of some soils can drain freely, under the influence of gravity, so that the dominant flow pathway is a vertical one. If the underlying substrate is also permeable this vertical pathway extends into the substrate, perhaps for some considerable depth. Eventually the water will reach a water table and vertical movement will stop. Variations in the level of the water table will cause lateral movement of the water perhaps towards valleys and springs, and after some considerable time the water may emerge to augment streamflow. Clearly the time elapsing between rain falling and flow leaving a catchment may be long, and in such a situation the rain would be expected to have little or no influence on the short term response of the catchment, but low flows will be maintained by the slow passage of water through the ground.

The characteristics of other soils and substrates restrict the vertical drainage, so that the dominant pathway for rain falling at their surface is lateral, as surface, or sub-surface runoff. In such situations a very rapid response to rainfall will be seen at a catchment outlet, and little water will be retained within the catchment to maintain the flow between rainfall events.

These are the two extreme response models within the HOST classification. The first in which water movement in the soil is mainly vertical, and the second where the dominant pathway is lateral and at, or very close to, the surface.

In the majority of soils the situation is, of course, more complex, and a number of other response models are necessary. However in all of these models the basic consideration is the same: at what depth within the soil/substrate profile, and for what reason, does lateral water movement become a significant factor in the response of the soils? A complicating factor is that the flow pathways within soils can depend on soil wetness, for example some soils may under dry conditions have capacity to store water and hence limit response, but under wet conditions the water table may rise close to the surface thereby limiting storage capacity and causing an increase in the short-term response to rainfall.

The models themselves fall into three physical settings.

i) The soil overlies a permeable substrate, in which a ground water table usually exists and is at a depth of greater than 2m.

ii) Again the soil overlies a permeable substrate but there is a shallow water table within 2m, either in the soil or substrate.

iii) There is no groundwater or aquifer but usually a shallow impermeable substrate that impedes vertical movement of water.

These three situations are shown in Figure 5.1

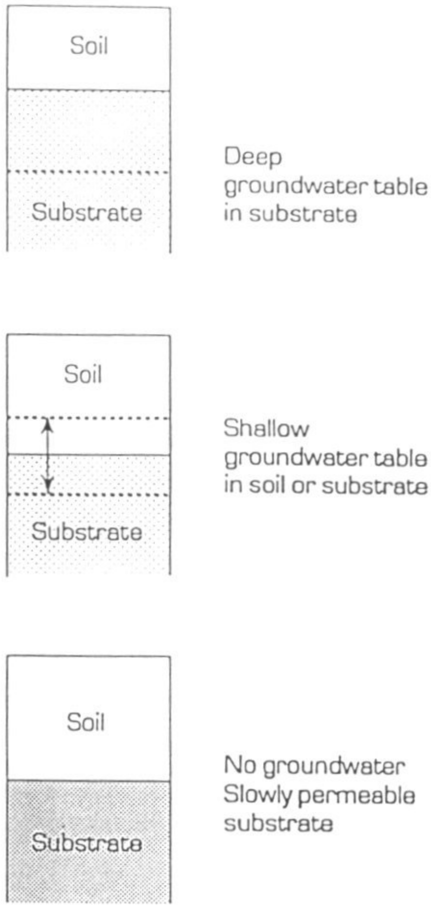


Figure 5.1 Physical settings underlying the HOST response models.

Within the basic physical settings there are variations caused by the nature of the parent material, the organic content of the soil, and the influence of climate. These other factors are indexed by the physical properties described in Section 4.6, namely the presence of an impermeable or gleyed layer within 1m of the surface, the presence of a gleyed layer within 0.4m of the surface and the presence of a peaty surface layer. Figure 5.2 shows the full range of models, and these are described in detail in the next section.

5.2 HOST RESPONSE MODEL DESCRIPTIONS

Model A

Model A describes the dominant water movement in permeable, well drained soils with permeable substrates. The dominant water movement is downwards through the vadose zone to an aquifer or groundwater table at least two metres below the surface. Lateral movement is largely confined to the saturated zone. The base flow of rivers and streams dominated by soils in this group is generally high, with the hydrological response being controlled by the flow mechanisms of the substrate. Four types of flow through the substrate have been recognised.

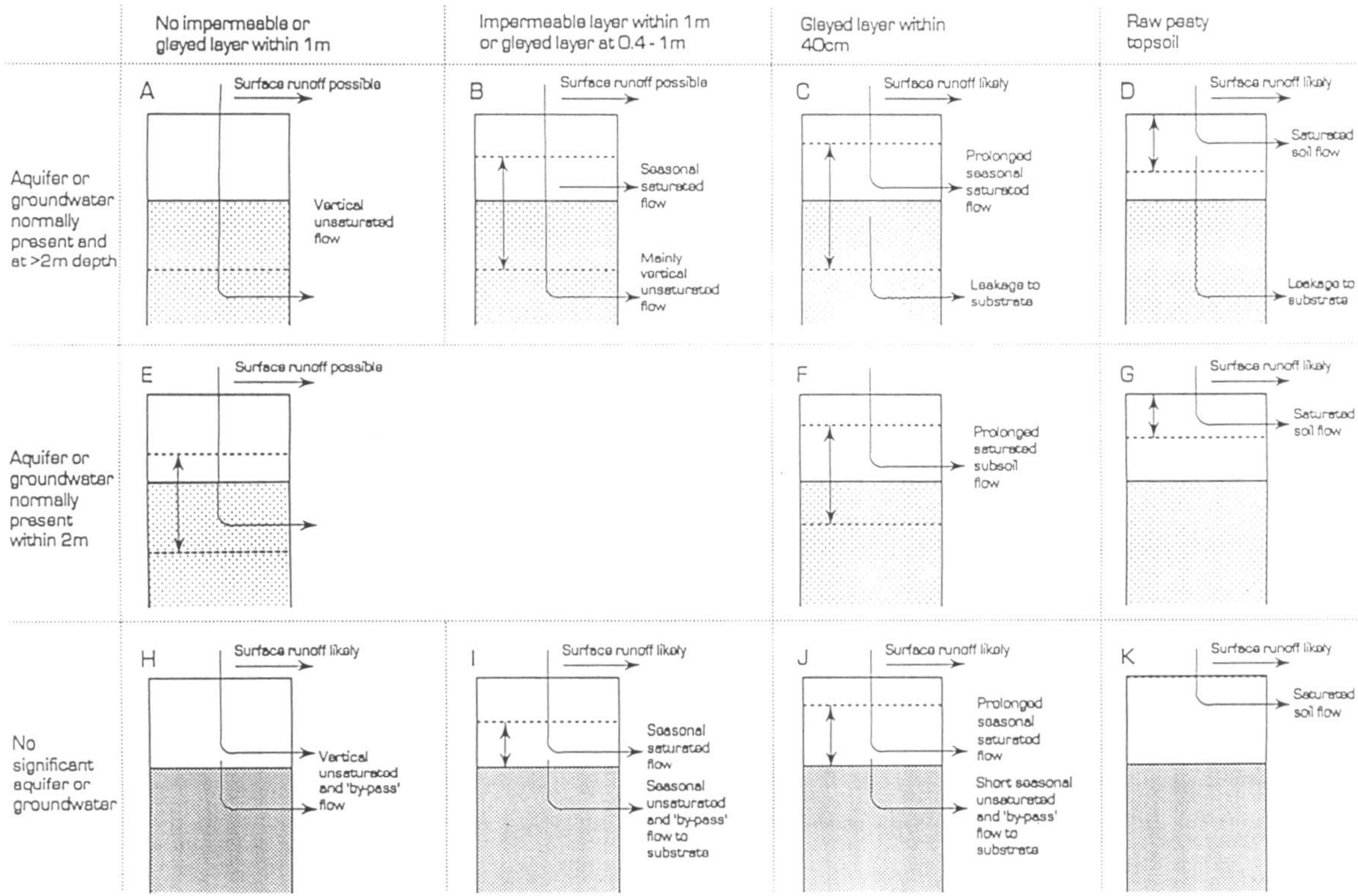


Figure 5.2 The 11 response models used in the HOST classification

i) In weakly consolidated chalky substrates the dominant flow is laminar via small pores, but with some fissure flow.

ii) In unconsolidated sandstones the water flows in large pores between the particles (ie. is intergranular)

iii) Where the rock is more coherent but deeply weathered or fissured, the dominant flow is via the fissures as the bulk of the rock is only slightly porous at best. Aquifers or groundwater are more rarely found in this group than in the others in Model A.

iv) In unconsolidated sands and gravels the flow is largely laminar and intergranular.

Model B

Model B encompasses a wide range of soil types which are of limited geographical extent. Although, as in model A, the flow is dominantly vertical through an unsaturated zone, there is an increased likelihood of some seasonal saturated flow particularly in winter when the soils develop a water table for short periods. These soils may be either weakly gleyed, perhaps due to their position in the landscape, or may have a slowly permeable horizon within the top metre. The underlying substrate may well contain groundwater or an aquifer.

Model C

Model C describes the flow regime in soils and loamy substrates with prolonged seasonal saturation and hence a dominantly horizontal flow with only some leakage through the permeable substrate to groundwater. These soils are mineral or humic gleys developed from loamy or colluvial drifts. They are often associated with concave hollows of springs along footslopes and as such they will have groundwater at depth. Much of the land associated with this HOST class is cultivated and will often have artificial drainage schemes.

Model D

Within this model the raw peaty topsoils dominate the hydrology, although a limited amount of throughflow penetrates to groundwater (where present). The drift is coarse and relatively permeable so the saturated conditions are largely due to climatic wetness rather than fluctuating groundwater tables, and there is likely to be a hydraulic discontinuity between surface saturation and the groundwater table.

Whilst the previous models described flow in soils largely unaffected by groundwater but where the degree of soil wetness was increasing, models E to G describe the conditions of soil response where a true groundwater table is within a short distance of the soil surface (nominally 2 metres). Clearly then the height to which a groundwater table rises will affect the speed of the response as will the fact that these models describe conditions of flow in the riparian environment.

Model E

Model E is indicative of coarse sandy, gravelly or loamy textured alluvial soils where the water table only penetrates the upper portions of the soil profile on rare occasions. Therefore, in the sands and gravels, the dominant flow pathway is vertical and largely laminar or intergranular, and in the more loamy alluvium there will be a component of by-bass flow because of the presence of macropores.

Model F

The saturation is due to a fluctuating groundwater table which comes close to the surface. This means that vertical water movement is restricted to the top few centimetres and rainfall reaches the water table quickly.

Model G

Model G describes the flow regime in drained, cultivated earthy peats (and in lowland basin and valley peats) as well as in small, localised hollows which are permanently saturated but which overlie permeable drifts eg. dune slacks. The dominant hydrological features are the presence of a peaty surface layer (an H horizon) and a water table within a short distance of the surface (nominally 2 metres). Although this will not always hold true for some confined basin peats which have developed as raised mosses, the confined nature of the water table means that these soils are adequately described by this model. Flow is dominantly surface runoff though there will also be saturated throughflow.

Model H

Model H is the first of the models which describes the flow of water through soils which are underlain by either a slowly permeable or an impermeable substrate such as glacial lodgement till or hard coherent rock at depths greater than one metre. However, the soils described by the model have no inhibition to drainage within the first metre and exhibit vertical unsaturated and by-pass flow through the macropores to the depth of the underlying substrates. A groundwater table or aquifer is not normally present in these substrates.

Model I

Model I describes conditions where there is some inhibition to water movement down through the soil profile. In some cases the slowly permeable fine textured glacial till is within one metre of the surface which also leads to the development of perched water tables for a few weeks in the year. In other cases there is solid coherent rock within one metre which leads to lateral water movement along the soil/rock interface. By-pass flow may be a feature of these soils when they are not saturated. When a perched water table forms, the dominant flow regime will be largely saturated lateral flow, however at other times, or where no water table forms, the flow will be predominately vertical, albeit to within a restricted depth.

Model J

Like the previous conceptual model, Model J illustrates the likely flow regime in soils and substrates with seasonal saturation. However, in this case the soils are waterlogged for a longer time and are dominated by prolonged saturated flow controlled by the height and duration of a perched water-table. Some unsaturated and by-pass flow will be apparent in the summer months.

Model K

The flow regime of the soils described by Model K is influenced by the raw peaty topsoil as well as the underlying substrate. Surface runoff is a feature of these soils and the upper soil layers remain saturated for much of the year. There is some lateral flow above the impermeable layer which may be glacial till or hard coherent rock. The rock is often close to the surface further restricting downward percolation. Where there is deep peat, the flow is dominated by surface and immediate subsurface flow, with the underlying substrate having little influence on the hydrological response except where the peat is eroded.

In eroded peat the exposed mineral layers allow deeper infiltration and the large areas of exposed peat may absorb a greater proportion of the precipitation. The intensity of rainfall may also be important in controlling the response in that low intensity rainfall may be more easily absorbed by the exposed peat, but high intensity rainfall may lead to the development of ephemeral streams which could extend into the gullies often found in these soils.

5.3 SUBDIVISIONS WITHIN THE FRAMEWORK OF MODELS

From the above descriptions it will have been noted that the models do not identify groups of soils that can be expected to respond in the same way to rainfall. Indeed this might be expected from the size of some of the groups; in terms of the area covered in England, Wales and Scotland, Model A covers some 19% and Model J roughly 17%. Of course not all of the models are so widespread; Models B and C each cover less than 1% of the area.

Within Model A, six divisions are made according to flow mechanism and geology, as indexed by the soil hydrogeology coding developed for HOST and described in Section 4.3.5.

Table 5.1 Subdivisions within HOST response Model A

	Flow mechanism	Substrate hydrogeology
1	Weakly consolidated, microporous; by-pass flow uncommon (Chalk)	Chalk; chalk rubble Clay with flints or plateau drift Chalky drift
2	Weakly consolidated, microporous, by-pass flow uncommon (Limestone)	Soft Magnesian, brashy or Oolitic limestone and ironstone
3	Weakly consolidated, macroporous, by-pass flow uncommon	Soft sandstone, weakly consolidated sand.
4	Strongly consolidated, non or slightly porous. By-pass flow common	Weathered/fissured intrusive/metamorphic rock Hard fissured limestone Hard (fissured) sandstone
5	Unconsolidated, macroporous, by-pass flow very uncommon	Blown sand Gravel Sand
6	Unconsolidated, microporous, by-pass flow common	Colluvium Coverloam Sand

A subdivision based on flow mechanism is also applied in Model E, but here only two classes are found as shown in Table 5.2

Table 5.2 Subdivisions with HOST response Model E

	Flow mechanism	Substrate hydrogeology
1	Unconsolidated, macroporous, by-pass flow very uncommon	Blown sand Gravel Sand
2	Unconsolidated, microporous, by-pass flow common	Hard but deeply shattered rocks River alluvium Marine alluvium Coverloam Loamy drift Chalky drift

Within Model F the response of the soils depends on their saturated hydraulic conductivity. Soils described by this model are subdivided into those with a low integrated air capacity, $\leq 12.5\%$ (fine textured silty or clayey alluvium), and those whose integrated air capacity is $> 12.5\%$ (coarse textured sandy or gravelly alluvium). Hollis and Woods (1989) found that an integrated air capacity of around 12.5 percent equates with a saturated hydraulic conductivity of 1 m day^{-1}.

Model G is divided according to whether the peat is drained or undrained.

Within each of the models there may be a subdivision according to flow rate and water storage. In theory there is an extremely large number of combination models and properties, but in practice not all combinations are possible. Of those that do occur, some can be expected to give a similar hydrological response and indeed cannot be distinguished using the available hydrological data; in such situations they may be combined in a single HOST class. Other model/property combinations are also indistinguishable using the hydrological data but represent different mechanisms of runoff production or situations in which some differentiation may be required for certain applications; in such cases the soils are assigned to different HOST classes. Various classification schemes were assessed by studying individual catchments and by multiple regression analysis of the response descriptors for the catchment data set.

Models H, I, J and K all apply to impermeable or slowly permeable soils in which there is no significant groundwater or aquifer; soils are further divided according to the substrate geology, as shown in Table 5.3. In practice not all of the substrates occur in each of the model groups.

One further subdivision exists within Model I. Here integrated air capacity is used to index soil water storage capacity and a split is made into those soils with IAC$>$7.5 and those with IAC$\leq$7.5.

The HOST classification is obtained by applying these subdivisions to the response models and results in the 29 class system shown in Figure 5.3.

Table 5.3 Substrate hydrogeology subdivision within Models H to K

	Substrate hydrogeology	Soil hydrogeology class
1	Slowly permeable	Soft shales with subordinate mudstones and siltstones Very soft blocky mudstones (marls) Very soft bedded loams, clays and sands Very soft bedded loam/clay/sand with subordinate sandstone Glaciolacustrine clays and silts Till, compact head Clay with flints or plateau drift
2	Impermeable (hard)	Hard coherent rocks
3	Impermeable (soft)	Very soft massive clays
4	Eroded peat	Eroded blanket peat
5	Raw Peat	Raw peat

5.4 VALIDATION OF THE HOST CLASSIFICATION.

The utility of the HOST classification was verified by using the classification to develop a BFI estimation equation. This analysis took the form of a multiple regression exercise in which BFI is the dependent variable and the independent variables are the fractions of the various classes occurring within the topographic catchment boundary. The relationship sought was of the form

$$BFI = a_1HOST_1 + a_2HOST_2 + a_3HOST_3 + \ldots + a_{29}HOST_{29}$$

where $HOST_1 \ldots HOST_{29}$ are the proportions of each of the HOST classes, and $a_1 \ldots a_{29}$ are the unknown regression coefficients.

Table 5.4 shows the result of such a regression on a set of 575 catchments which were all quality graded A or B, and have an unclassified area of less than 50% on the 1:250,000 soil maps (remember that in the data set used all soils were classified; this was a method of eliminating those most likely to show a strong urban effect).

SUBSTRATE HYDROGEOLOGY	MINERAL SOILS						PEAT SOILS	
	Groundwater or aquifer	No impermeable or gleyed layer within 100cm	Impermeable layer within 100cm or gleyed layer at 40-100cm		Gleyed layer within 40cm			
Weakly consolidated, microporous, by-pass flow uncommon (Chalk)	Normally present and at >2m	[1] 4.31						
Weakly consolidated, microporous, by-pass flow uncommon (Limestone)		[2] 2.12						
Weakly consolidated, macroporous, by-pass flow uncommon		[3] 1.58						
Strongly consolidated, non or slightly porous. By-pass flow common		[4] 3.33	[13] 0.87		[14] 0.66		[15] 9.93	
Unconsolidated, macroporous, by-pass flow very uncommon		[5] 5.07						
Unconsolidated, microporous, by-pass flow common		[6] 2.61						
Unconsolidated, macroporous, by-pass flow very uncommon	Normally present and at ≤2m	[7] 1.01			IAC' < 12.5 (< 1m day⁻¹)	IAC' ≥ 12.5 (≥ 1m day⁻¹)	Drained	Undrained
Unconsolidated, microporous, by-pass flow common		[8] 1.62			[9] 3.68	[10] 2.21	[11] 0.55	[12] 2.93
	No significant groundwater or aquifer		IAC'# > 7.5	IAC'# ≤ 7.5				
Slowly permeable		[16] 0.43	[18] 5.40	[21] 4.02	[24] 13.85		[26] 2.49	
Impermeable (hard)		[17] 9.28	[19] 2.16	[22] 1.10			[27] 0.83	
Impermeable (soft)			[20] 0.69	[23] 1.31	[25] 3.64			
Eroded Peat							[28] 0.59	
Raw Peat							[29] 5.73	

Also unclassified (urban) areas (5.15%) and lakes (0.74%).
* IAC used to index lateral saturated hydraulic conductivity
# IAC used to index soil water storage capacity

No extensive UK soil types exist outside the table or within the shaded portions of the diagram.
Small numbers are HOST class numbers.
Large numbers are percentage land cover in England, Wales and Scotland, on 1:250,000 maps.

Figure 5.3 The HOST Classification

Table 5.4 BFI coefficients from multiple regression analysis

HOST class	BFI coefficient	s.e. of coefficient	HOST class	BFI coefficient	s.e. of coefficient
1	1.034	0.022	16	0.778	0.195
2	1.011	0.039	17	0.613	0.027
3	0.835	0.052	18	0.506	0.039
4	0.790	0.042	19	0.498	0.104
5	1.016	0.065	20	0.526	0.207
6	0.586	0.065	21	0.330	0.025
7	0.725	0.177	22	0.294	0.111
8	0.533	0.216	23	0.198	0.118
9	0.789	0.254	24	0.311	0.019
10	0.437	0.142	25	0.178	0.042
11	0.838	0.213	26	0.247	0.043
12	0.092	0.075	27	0.229	0.193
13	1.005	0.231	28	0.552	0.156
14	0.219	0.225	29	0.232	0.034
15	0.387	0.028			

Standard error of estimate 0.089
Approximate equivalent r^2 0.79

The values of the coefficient of determination, 0.79, and the standard error of estimate, 0.089, indicate that a useful regression was obtained. The table shows that some of the coefficients (classes 1, 2, 5 and 13) are slightly greater than the maximum allowable value for BFI (ie. 1.0), and that one (class 12) is lower than the minimum expected value of BFI (minimum value in data set 0.14). It is easier to assess the BFI coefficients if they are tabulated in a form corresponding to Figure 5.3; this has been done and is shown as Table 5.5.

From this table the general trends of decreasing BFI from top to bottom and left to right are quite clear. Within the impermeable or slowly permeable group at the bottom of the table the decrease in BFI from left to right is very well defined. From this part of the diagram only two coefficients stand out as being different from expected. The coefficient for class 20 appears considerably higher than for classes 23 and 25 which have the same substrate, but the coefficient is consistent with those for the other classes with the same physical properties but different geologies (ie. HOST classes 18 and 19). The other outstanding coefficient is for class 28, which is higher than for other peat soils.

The coefficients for classes 7 to 12 are consistent with their response models, although as already noted the coefficient for class 12 is lower than any observed BFI in the dataset.

Table 5.5 BFI regression coefficients according to HOST framework

<table>
<tr><td>[1] 1.034</td><td colspan="2" rowspan="6">[13] 1.005</td><td colspan="2" rowspan="6">[14] 0.219</td><td colspan="2" rowspan="6">[15] 0.387</td></tr>
<tr><td>[2] 1.011</td></tr>
<tr><td>[3] 0.835</td></tr>
<tr><td>[4] 0.790</td></tr>
<tr><td>[5] 1.016</td></tr>
<tr><td>[6] 0.586</td></tr>
<tr><td colspan="3">[7] 0.725</td><td rowspan="2">[9] 0.789</td><td rowspan="2">[10] 0.437</td><td rowspan="2">[11] 0.838</td><td rowspan="2">[12] 0.092</td></tr>
<tr><td colspan="3">[8] 0.533</td></tr>
<tr><td>[16] 0.778</td><td>[18] 0.506</td><td>[21] 0.330</td><td colspan="2">[24] 0.311</td><td colspan="2">[26] 0.247</td></tr>
<tr><td>[17] 0.613</td><td>[19] 0.498</td><td>[22] 0.294</td><td colspan="2"></td><td colspan="2">[27] 0.229</td></tr>
<tr><td></td><td>[20] 0.526</td><td>[23] 0.198</td><td colspan="2">[25] 0.178</td><td colspan="2"></td></tr>
<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] 0.552</td></tr>
<tr><td colspan="2">[29] 0.232</td></tr>
</table>

Within the top part of the table there are also two anomalies. Firstly it is surprising that the coefficient for class 5 is higher than for class 3. A reducing sequence of BFI coefficients would be expected for the three classes in which macroporous flow dominates (ie. classes 3, 5 and 7). Secondly the physical models imply that class 14 should have a higher BFI coefficient than class 15, but from the regression the reverse is true.

Table 5.4 also shows the standard errors of the coefficients and it will be noted that some of these are relatively large, and that the coefficients are therefore unreliable. This is particular true for classes 12, 14, 20 and 27 for which none of the coefficients is significantly different from zero at the 5% level. It is hardly surprising that some of the coefficients were badly estimated since they have very little areal extent and are therefore very poorly represented in the data set. Table 5.6 shows the way in which HOST classes are represented within the 575 catchment set and, for comparison, the equivalent figure for the whole of the UK. Note that these latter figures differ slightly from those in Table 5.3, since those in Table 5.3 relate to the printed maps of England, Wales and Scotland and have unclassified, mainly urban, areas, but the numbers in Table 5.6 come from the UK HOST data set in which these areas have been infilled with the underlying soil. Although there is some correspondence between the classes for which coefficients are not significant and class with very low coverage this is not always the case.

Overall the results of the regression are encouraging and indicate that the form of the HOST classification, which is based on conceptual models of response, is very useful in the estimation of a catchment-scale hydrological variable, BFI.

In order to fully develop a way of estimating BFI from HOST the regression was repeated with bounds applied to the coefficients so that unacceptably large or small values were excluded. The range of allowable values was specified as 0.170, the minimum reliable BFI coefficient from the unbounded regression, to 1.000, the maximum possible BFI value. Table 5.7 shows the coefficients resulting from this regression, which has a s.e.e. of 0.089.

Table 5.6 Representation of HOST classes in the BFI catchment data set

HOST class	% in UK	Average % on BFI catchment set	Equivalent number of catchments
1	4.17	5.85	33.6
2	2.07	3.17	18.2
3	1.64	1.99	11.4
4	3.22	3.95	22.7
5	5.61	4.07	23.4
6	2.52	2.64	15.2
7	1.04	0.81	4.7
8	1.74	0.88	5.1
9	3.86	0.98	5.6
10	2.14	1.74	10.0
11	0.53	0.30	1.7
12	2.75	1.37	7.9
13	0.85	0.64	3.7
14	0.62	0.55	3.2
15	9.30	10.14	58.3
16	0.61	0.62	2.6
17	8.72	10.02	57.6
18	6.74	5.72	32.9
19	1.94	1.44	8.3
20	0.64	0.97	5.6
21	5.96	6.22	35.8
22	1.01	1.28	7.4
23	1.27	1.46	8.4
24	15.23	15.30	88.0
25	3.82	4.57	26.3
26	3.20	4.88	28.1
27	0.77	0.55	3.2
28	0.57	0.33	1.9
29	6.16	7.19	41.3

It can be seen that imposing these bounds has had little effect on the coefficients, other than for HOST class 12, and that no increase in the standard error of the estimate has resulted.

Because the same inconsistencies between the derived coefficients and the conceptual response models remain, a third regression with additional bounds was performed. In this case the extra constraints set a lower limit on class 3 of 0.9, an upper limit on class 5 of 0.9 (0.9 being between the coefficients derived for these two classes previously and these bounds would ensure the coefficient for class 5 must be less than or equal to that of class 3) and a lower limit on class 14 of 0.38 (the value derived for class 15). Table 5.8 shows the coefficients from this second bounded regression.

The s.e.e. for this regression has increased very slightly from 0.089 for the unbounded case to 0.090, but the coefficients are now in line with the observed range of BFI values, and consistent with the response models.

The quality of this regression is depicted in Figures 5.4 and 5.5 which show the observed and estimated BFI values, and the residuals (observed-estimated) plotted against the estimates. These figures show the values for all 786 catchments (ie. including the poorer quality catchments and those with high urban fractions). Figure 5.7 shows the residuals plotted at catchment centroids for the same catchments. The map shows some clustering of positive and negative residuals, and therefore indicates where BFI estimation using the equation represented by Table 5.8 is likely to be in error. The reasons for these regional clusters are not known at present, but it is hoped they will be explored fully in future work.

Table 5.7 BFI Coefficients from bounded multiple regression analysis

<table>
<tr><td>[1] 1.000</td><td colspan="2" rowspan="6">[13] 1.000</td><td colspan="2" rowspan="6">[14] 0.231</td><td colspan="2" rowspan="6">[15] 0.380</td></tr>
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<tr><td colspan="3">[7] 0.740</td><td rowspan="2">[9] 0.814</td><td rowspan="2">[10] 0.482</td><td rowspan="2">[11] 0.862</td><td rowspan="2">[12] 0.170</td></tr>
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Table 5.8 BFI Coefficients from second bounded multiple regression analysis

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<tr><td colspan="3">[8] 0.560</td></tr>
<tr><td>[16] 0.778</td><td>[18] 0.518</td><td>[21] 0.340</td><td colspan="2">[24] 0.312</td><td colspan="2">[26] 0.244</td></tr>
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<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] 0.581</td></tr>
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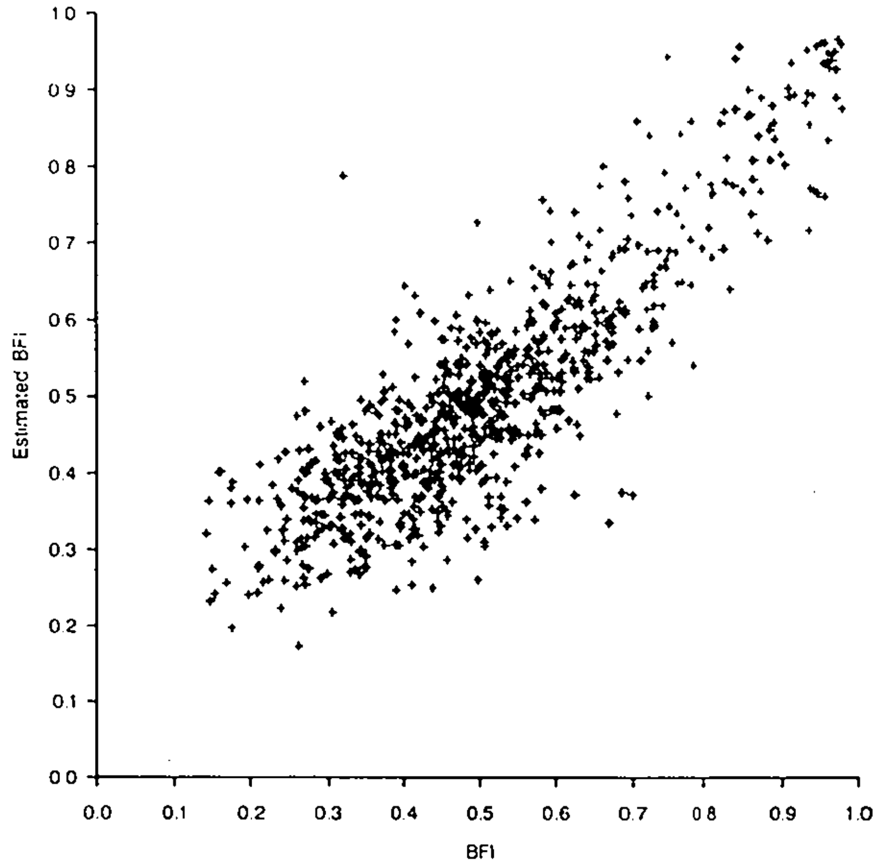

Figure 5.4 Estimated values of BFI against observed BFI

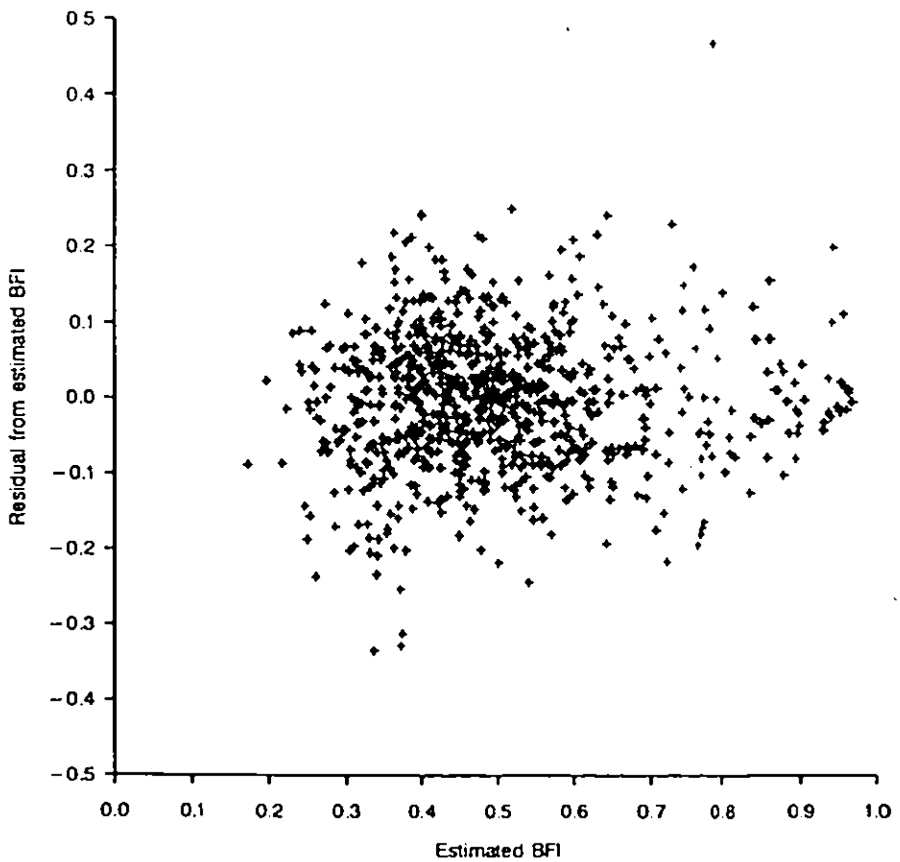

Figure 5.5 BFI residuals (observed-estimated) against estimated values of BFI

catchment centroids for the same catchments. The map shows some clustering of positive and negative residuals, and therefore indicates where BFI estimation using the equation represented by Table 5.8 is likely to be in error. The reasons for these regional clusters are not known at present, but it is hoped they will be explored fully in future work.

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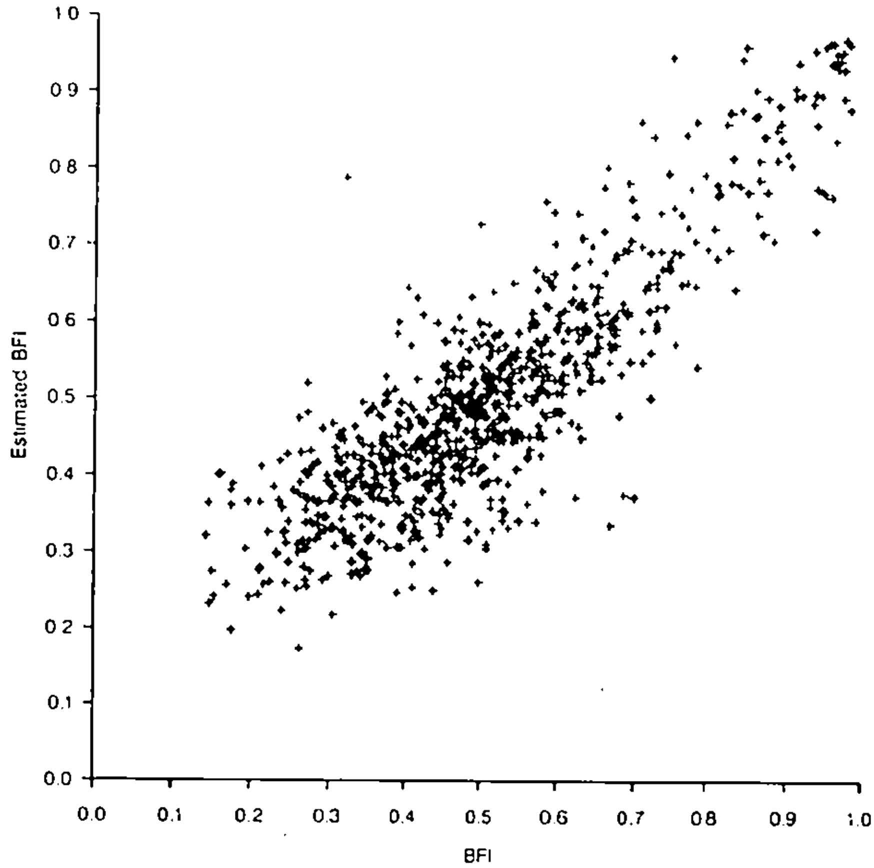


Figure 5.4 Estimated values of BFI against observed BFI

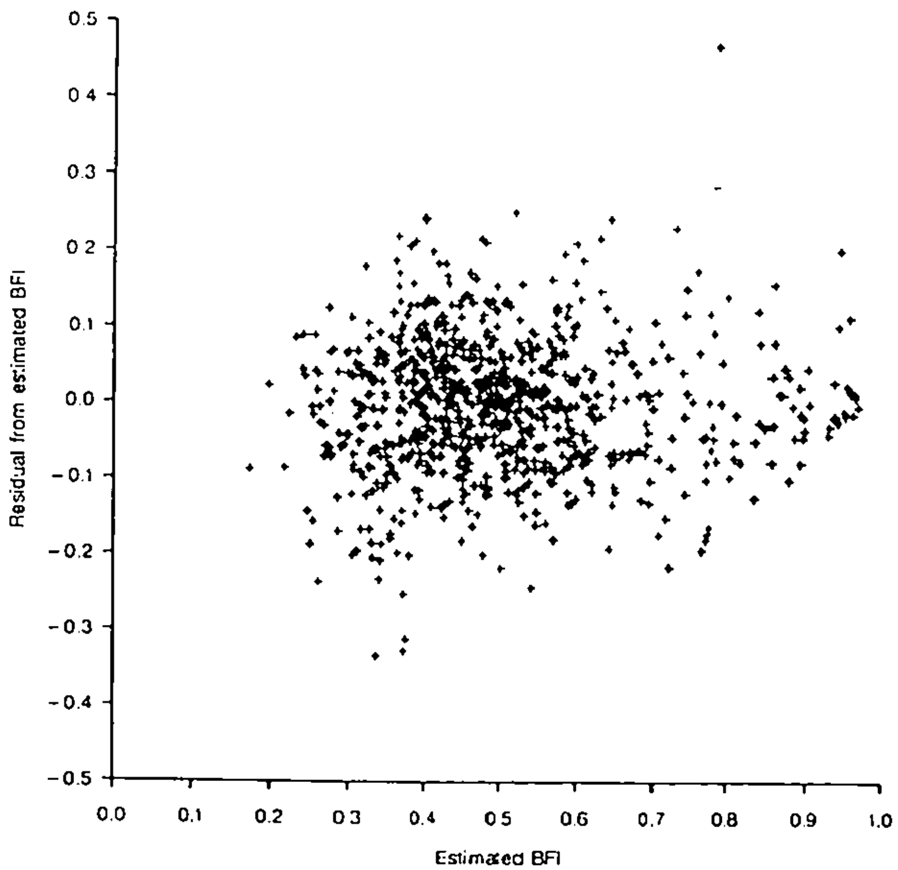


Figure 5.5 BFI residuals (observed-estimated) against estimated values of BFI

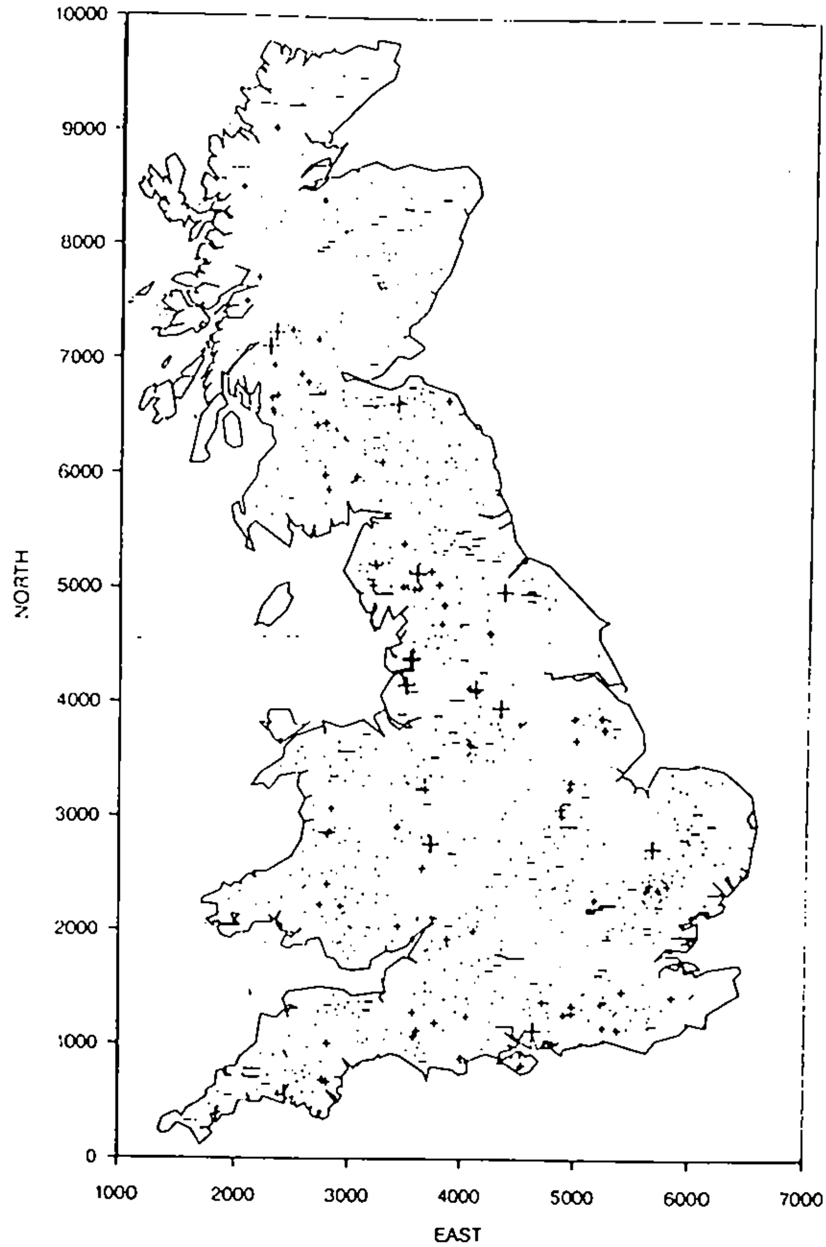


Figure 5.6 The distribution of BFI residuals (observed-estimated)

5.3 HOST CLASS DESCRIPTIONS

HOST classes have been defined using conceptual models of the processes within the soils and physical properties of the soil and substrate. The following descriptions of the HOST classes aim to set these definitions against a more qualitative description of where the classes are to be found, the form of the landscape, the vegetation and the landuse. Appendix D, Figures Di-xxix show the distributions of the HOST classes in the United Kingdom.

HOST class 1

HOST 1 contains freely drained soils overlying chalky substrates which are weakly consolidated (e.g. chalks). The dominant flow is laminar via small pores with some fissure flow.

HOST class 2

HOST 2 is similar to HOST 1 except that the substrate is magnesian, oolitic or brashy limestones.

HOST class 3

The soils of HOST 3 are underlain by soft sandstones and weakly consolidated sands, therefore the dominant flow is intergranular via large pores.

HOST class 4

These first three HOST classes are restricted to England and Wales, however HOST 4 has a wider distribution in that it is found in all three countries albeit in a limited extent in Scotland. The underlying substrates include weathered or fissured, intrusive or metamorphic rocks, hard fissured limestones and sandstones. The dominant flow in the substrate is via these fissures as the bulk of the rock is only slightly porous at best. The intrusive and metamorphic rock types found in this HOST class are restricted to England and Wales where they have undergone substantial chemical weathering. Similar rock types in Scotland were extensively glaciated which removed the weathered overburden. There is a likelihood of groundwater at depths greater than two metres in this class.

The soils comprising HOST class 4 are underlain by hard fissured Dalradian, Cambrian or Ordovician limestones or sandstone and are distributed throughout Scotland in both highland and lowland situations. Much of the topography is very rocky, particularly the limestone regions which have been extensively glaciated. Only rarely is there true karst topography, the land being predominantly undulating with ridges and rock knolls or craggy outcrops on steep-sided valleys. The island of Lismore is composed almost entirely of limestone and has a ridged appearance. Around Tomintoul and upper Deeside the landscape is one of rocky knolls and hollows.

The landscape associated with the sandstones varies from gently undulating lowlands with few rock outcrops to the rock-dominated hill tops of Sutherland and Caithness. In Shetland, the topography can be very rocky with a stepped appearance or strongly undulating lowlands. The largest area, around the Black Isle, is gently to strongly undulating with low ridges.

All the soils are freely drained (wetness class I) and include brown forest soils, humus-iron podzols, brown and podzolic rankers, brown rendzinas and lithosols. They are often shallow. As expected with such a diversity in topography and climate, the vegetation varies from semi-natural grasslands and herb-rich heather moorland in the uplands to arable, improved pastures, coniferous plantation and occasionally broadleaved woodlands in the lowlands.

HOST class 5

HOST 5 comprises soils developed on fluvioglacial sands and gravels or windblown sands.

Found throughout Britain, the flow through these soils and substrates is largely laminar and intergranular. This HOST class often occupies immediate post-glacial terraces (in Scotland at least) along river valleys and the presence of groundwater is therefore very likely. The depth of these deposits may have a bearing on river response times.

The drift comprising HOST class 5 is coarse textured and dominated by rapid infiltration and through flow. The soils are freely drained (wetness class I) and are found throughout Scotland but primarily south and east of the Great Glen. The soil types are mainly humus-iron podzols and brown forest soils with brown calcareous soils, calcareous regosols, alluvial sands and gravel, and regosols. The sand and gravel deposits are associated with a range of geomorphic processes and can be divided into fluvioglacial, raised beach, windblown links and dunes, coarse morainic drift and the specific geomorphology of Glen Roy and Glen Gloy in the Western Highlands. This class is extensive but its importance is limited by its proximity to the sea in many cases.

The fluvioglacial deposits can be either moundy with long sinuous ridges or gently sloping outwash plains (e.g. around Forres in North-east Scotland) and river terraces. The deposits are generally associated with river valleys and vary considerably in thickness.

The raised beach deposits are found around the coast and are generally gently undulating and often terraced. These are areas of former beach but are now above the high water line due to isostatic recovery after the Ice Age.

The windblown coastal sand deposits form areas of gently undulating stable links on which many of the best golf courses are to the found on moundy dune areas with little or no vegetation cover and steep slopes. Again their location limits the impact of these soils on river flow. These areas are extensive e.g. Culbin, Tentsmuir and Gullane.

The coarse morainic drift is a specific case where the deposit grades into fluvioglacial drift and is found around Invergordon in Easter Ross. It can be moundy but in general the topography is gently undulating. The Glen Roy and Glen Gloy areas are world renowned for the series of parallel roads which are former shore lines of a glacial lake. The drift is highly variable ranging from fine silts to coarse gravel with the latter falling into HOST class 5. The slopes on the valley sides are steep and subject to landslippage while the valley floor deposits are gently undulating with terraces.

The diversity of landforms, topography and climate means that the land use of these soils varies from natural marram grassland through heather moorland to coniferous plantation but the dominant land use is arable and permanent pasture.

HOST class 6

HOST class 6 comprises freely drained soils (wetness class I) developed on loamy textured drift underlain by porous rocks such as sandstones. They are found throughout the lowlands of Scotland but most extensively in the east, Caithness and Sutherland. The main soil types are brown forest soils and humus-iron podzols with some subalpine podzols. All are freely drained (wetness class I) and microporous with by-pass flow common along major structural cracks. These soils have the ability to both store water and to allow the rapid transmission of excess rainfall through them to streams and rivers. The landforms associated with these soils are highly variable and encompass undulating non-rocky lowlands, valley sides and hill tops. The land has a wide range of slopes and is occasionally rocky. There are also localised areas of moundy morainic drift. These soils range in altitude from virtually sea level to around 700 m. This is reflected in the vegetation which ranges from cultivated arable land in the lowlands through heather moorland, rough grasslands and semi-natural woodland.

HOST class 7

The soils of HOST class 7 are free and imperfectly drained, coarse textured alluvial soils. Although these soils are underlain by a fluctuating groundwater table generally within two metres they are relatively unaffected as they tend to be found on the very gently undulating higher terraces away from the river in the lowlands or, as in many Highland glens, they occur on outwash alluvial fans of coarse textured sand and gravel deposits, (wetness class I-III).

HOST class 8

The soils of HOST class 8 are found in similar positions in the lowland landscape to the previous HOST class. The soils, however, are more loamy in nature and will have a more well developed structure leading to by-pass flow. These soils are also freely and imperfectly drained and are often intensively cultivated, (wetness class I-III).

HOST class 9

The alluvial soils of HOST class 9 are developed on fine textured (silty or clayey) lacustrine or riverine alluvium. These deposits are found in various positions in the landscape. They can often be associated with loch margins or infilled ox-bow lakes on broad alluvial flood plains. Occasionally they are found as large, relatively stone-free areas of former lake beds which are still prone to seasonal flooding. Therefore the water table is likely to exert a strong influence on both the soil development and its hydrological response. These soils have low integrated air capacities and as such have a low solute transmission rate which will also influence the soils' response.

HOST class 10

HOST class 10 comprises poorly drained alluvial soils and mineral ground water gleys ie. they are influenced by a fluctuating groundwater table, and are found in low lying areas around lochs, between fluvioglacial mounds, along rivers and on raised beaches. It also encompasses the saline alluvial soils of saltings. All have no impermeable horizon within 1 m of the surface and are often very porous (wetness class IV).

These soils are often found in conjunction with freely drained sands and gravels (HOST class 5), interspersed amongst the hummocks and as recent alluvial deposits fringing modern rivers and lakes, and therefore occupy low lying and depressional sites within the landscape.

The raised beach can be either former estuarine alluvium or coarse gravelly beach deposits but the topography is very similar with a level to gently undulating landform with some depressions. In some instances coarse sandy or gravelly deposits are underlain by silts at depth which reduces the infiltration of rainwater. Modern beach areas, particularly dunes, have localised hollows known as slacks. These areas can also carry mineral gley soils.

The large area of HOST class 10 around Glasgow is based on a best estimate of the drainage conditions and deposits under the urban area. This estimate was made on the basis of a detailed soil survey around the urban fringe and extrapolated to unsurveyed areas using the geological drift maps, local knowledge and topographic maps. The land to the south of the River Clyde has fine sandy (HOST class 10) and silty soils (class 9), is low lying and is punctuated by raised mosses (class 12), some of which lie about one metre above the surrounding land. To the north, the floodplain is more constrained and has more topographic expression and consequently better drained soils (class 7 or 8).

Saline alluvial soils occupying the land below the high-water mark are periodically inundated by sea water. Although a specific landform, its affect on river hydrology is negligible.

The vegetation of these areas varies from the halophytic marsh species of the saltings, rush pastures, and sedge mires to permanent pasture and intensive agriculture where the level of the water table can be controlled.

HOST class 12

The soils and landforms of HOST class 12 are similar in many ways to those of class 9. However, these soils have a peaty surface layer and are predominantly peaty gleys, peaty alluvial soils and occasionally peaty podzols. Again, all are porous albeit below the surface organic layer. Low lying hollows amongst fluvioglacial ridges and mounds, dune slacks, gently undulating raised beaches and outwash plains all carry these soil types.

In addition this class also includes confined and semi-confined peats. Confined peats or raised mosses occur in localised depressions that were formerly lakes. These hollows gradually silted up and the vegetation which grew on this material died, however, the anaerobic conditions prevented this plant debris from breaking down and so it accumulated as peat. The peat accumulation continued to the extent that the moss is now well above the underlying lake bed. Semi-confined peats occur in river valleys particularly in the Highlands often associated with either fluvioglacial mounds or moundy moraines. These peats occupy the lowest positions in these landscapes and are therefore more strongly influenced by the underlying water-table than the confined basin peats.

Basin and valley peats form in confined and partially confined basins in either rock controlled topography or in undulating till deposits. In many instances the basin originally held a small loch which has gradually been clogged with partially decayed vegetation. Basin peats can often form dome-shaped raised mosses with the centre considerably higher than the edges. The vegetation varies from heather moorland to *Molinia*-dominated bog and often there are flushed channels of mosses, rushes and sedges. Flanders Moss, Rora Moss and St Fergus Moss are all examples of these lowland basin peats; many others are now exploited for fuel or horticultural peat.

Outwith the lowlands, valley peats are found over a wide altitudinal range, primarily in areas of high rainfall where they form on level or gently sloping sites generally underlain by impermeable substrate. These sites are often flushed and carry *Molinia*-dominated bog vegetation. In many areas, this type of peat can be found interspersed between morainic and fluvioglacial mounds, on the steps of terraced topography. Peat occupies the intervening hollows and, in wide valleys where the mounds are less confined, extensive peat flats can develop, (wetness class V-VI).

HOST class 13

The landscape of HOST class 13 is one of gently to strongly undulating lowland and foothills, some valley-side and hummocky moraines. The land is generally non-rocky. The soils are only weakly gleyed brown forest soils and humus-iron podzols (wetness class II - III) or have an impermeable horizon below 40 cm. This impermeable horizon is generally due to the presence of a hard dense compact layer in the soil (termed induration) which formed under much colder climatic conditions. This layer is found in present day arctic soils. Only rarely does this layer impede the flow of water through the soil to such an extent that gleying occurs.

The main land use is again arable with permanent and semi-natural grasslands, coniferous plantation, broadleaved woodland and moorland.

HOST class 14

HOST class 14 has a wide distribution from Shetland in the north, Lewis in the west to the Border Country. The soils are poorly drained mineral and humic gleys (wetness class IV) and are largely confined to concave slopes or depressional sites in the foothills, valley sides and lowlands. Occasional areas of irregular topography or hummocky moraine also carry these soils. The drift is loamy, locally colluvial in derivation where the soils are often associated with flushes and spring lines.

The soils are generally found below 300 metres altitude and the vegetation is predominantly arable, permanent and long ley pasture. Rush pastures occur in embayments in the foothills along with semi-natural grasslands. Areas of moorland and coniferous plantation are generally restricted to the more irregular topography, e.g. hummocky moraines. In Lewis, the landscape is dominated by the long, narrow fields of the crofting communities.

HOST class 15

HOST class 15 is very extensive throughout Scotland and covers a wide range of landforms and geographical regions from lowland depressional sites to the glacially scoured landscape of north-west Scotland. The soils are those with a peaty surface layer on permeable drift (peaty gleys and peaty podzols) and, occasionally, peaty rankers on porous rock. The wetness class is most likely VI and the peaty surface restricts infiltration as well as retaining large amounts of water.

Soils of this class are found from as far south as Dartmoor and Cornwall, and as far north as Shetland. In Scotland, they are found in the lowlands in either depressions and receiving sites, raised beaches of the west coast fjords or fluvioglacial terraces and hollows. These sites are net receivers of water from a number of sources and are generally gleys. Being difficult to drain, these soils are generally under permanent or rush pastures, occasionally arable or forestry. Limited areas with drier podzolic soils may be cultivated. Omitting the low lying, receiving sites interspersed amongst the lowland hill plain, the soils of HOST class 15 are generally to be found in upland areas where the climate is cold and wet. However, the altitude above which these conditions are conducive for the development of these peaty soils decreases from the south-east to the north-west such that the Outer Hebrides are dominated by HOST class 15, even at sea level. The same holds for Shetland where the topography is described as undulating lowlands.

Much of the area in the north and west of Scotland has peaty soils for the reasons explained earlier. This land has also been extensively glaciated and the resultant ice-scoured landscape is quite distinctive with numerous black, peaty lochans and pockets of drift interspersed between the bare, rounded, striated rock knolls. The landscape is one of desolation and chaos, particularly the drainage pattern, as streams twist tortuously from one lochan to the next.

The extreme diversity of landscapes encompassed in this class means that only a brief description can be given. However, the landforms are described in more detail in the Soil Survey publications.

In the uplands and moorlands of the Midland Valley, peaty gleys predominate, particularly in the west. These areas are often smooth and undulating but locally the topography is stepped and terraced with rock outcrops and crags. The vegetation is primarily heather moorland with some *Molinia* grassland.

One of the most extensive landform units which carries this HOST class is that of hummocky moraine and the associated deeply dissected slope moraines. In narrow, constrained valleys the mounds are lightly packed, almost overlapping, and in these areas the soils are predominantly peaty podzols; where the valleys widen and the mounds are more dispersed, the large areas of intervening hollows often have peaty gleys and peat (the latter belonging to HOST class 12). Above the mounds, on the valley sides, the drift is often eroded and gullied giving a similar pattern of soils to that found in the valley bottom. The vegetation varies from bog and heather moorland to *Molinia* grassland and occasionally broadleaved semi-natural woodland and bracken-infested slopes. Some areas have been planted with conifers.

Footslopes, embayments, spring-lines and flushed sites at valley heads can all have soils in HOST class 15 again, predominantly, peaty gleys. These tend to occur sporadically and are generally of only local significance. The vegetation is often specific to flushed areas with mosses, rushes and sedges.

This class encompasses a wide range of hill slopes and valley sides from concave (peaty gleys) to convex (peaty podzols) and from the Southern Uplands to the rugged topography of West Scotland.

Many of the rounded hills and smooth slopes of the uplands, in particular the Ladder Hills, eastern Grampians, Lammermuirs, Moorfoot and Lowther Hills and the central Southern Uplands have peaty podzols developed on a variety of porous drifts. Where the topography is more irregular, with terraces, rocky knolls and crags, the soils in HOST class 15 are both peaty podzols and peaty gleys with occasional peaty rankers on porous rock. The slopes vary enormously from gentle to very steep and can exhibit a great deal of short range variability eg. in the stepped or terraced topography associated with Basaltic lava flows. Here, the smooth flats carry peaty gleys but there is much bare rock in the form of crags.

HOST class 16

The soils comprising HOST class 16 are all developed on water modified glacial till i.e. the upper layers of the soil have had fine particles of clay and silt removed by water from melting glaciers. They are underlain by the impermeable fine-textured tills at depths greater than one metre. They are all freely drained (wetness class I) and are located in gently to strongly undulating lowlands (and occasionally footslopes) e.g. the Howe of the Mearns and Vale of Strathmore. They tend to be intensively cultivated but long ley pastures and dairying are common in the wetter west. These soils are closely related to those in HOST class 18.

HOST class 17

HOST class 17 is one of the most extensive in Scotland and the UK representing all deep, freely drained soils developed on loamy textured drifts overlying hard, coherent rock at depths greater than one metre. They are found primarily in the foothills of the Grampian mountains, Fife and the Southern Uplands and sporadically throughout the Highlands. Where this class occurs in the Western Highlands it is generally associated with steep valley sides with colluvial drift. Where the slopes become more gentle the soils develop a peaty topsoil and are classified accordingly. The main soil types are brown forest soils, humus-iron podzols, subalpine soils, some brown magnesian soils and alpine soils. As expected with a class with such a wide distribution, the associated landforms are also highly variable and encompass gently undulating non-rocky lowlands: steep, rocky and non-rocky valley sides and hill tops with scattered boulders and rock outcrops. There are also areas of moundy moraines. This class ranges in altitude from virtually sea level to over 900 metres and consequently the vegetation includes the cultivated arable lands of the lowlands, coniferous plantations, semi-natural woodland, heather moorland, rough grasslands and the windclipped moorland and heath reminiscent of the fringes of the arctic tundra.

The alpine soils found on the high mountain summits have a distinct character. The altitude at which these soils occur varies depending on both latitude and exposure, hence in the central Cairngorm mass these soils are found above 700m but in the Orkney Island of Hoy they occur at altitudes of about 275m. The drift is loose and often very stony being essentially frost shattered debris. In many cases the depth of drift is variable but primarily greater than 1m. Continual freezing and thawing within the solum produces this loose fabric which is very porous and often results in the sorting of stones into distinct stripes. On slopes, terracettes can form which are only sparsely vegetated. Boulder lobes and screes are also a feature of this landscape particularly on steep slopes. The alpine soils are invariably freely drained although some exhibit seasonal water logging due to snow-melt. They are also frozen for a large proportion of the year which may lead to direct run-off rather than infiltration. The very severe climate means that the vegetation is rather slow growing and often prostrate. Wind clipped moorland and heath reminiscent of the fringes of the arctic tundra are common and include alpine azalea, lichens and sedges.

HOST class 18

HOST class 18 comprises soils which are weakly gleyed and are waterlogged for at least part of the year. These soils have developed on water-modified glacial tills and are similar to those in HOST class 16 except that the depth of water modification is less. This restricts the volume of soil available to store water as shown by the IAC. At certain times of the year these soils will have predominantly unsaturated vertical flow but, when waterlogged, the dominant flow regime will be largely saturated lateral flow. Freely drained soils with hard coherent rock within a metre of the surface are in HOST class 19. Because they are shallow these soils have limited storage capacity. The dominant flow is vertical unsaturated flow with some lateral flow along the soil/rock interface. This HOST class is found mainly in Scotland, particularly in glacially scoured areas and sporadically in the uplands of north-west England and parts of Wales and the South-west. In contrast, HOST class 20 is found exclusively in England. The soils have a degree of waterlogging due to the impermeable nature of the soils and substrate, however, as they occur in the drier parts of the UK, they tend to be waterlogged for short periods and at depth. The underlying geology is of soft but massive clays. HOST class 21 includes soils developed on slowly permeable glacial lodgement till, soft shales and mudstones. These soils are weakly gleyed despite their low IAC ($\leq 7.5\%$) and shallow depth to the slowly permeable layer. They are found primarily in the drier, warmer areas of the country although not exclusively and it is perhaps this influence of climate that means that soils with low permeability are only weakly gleyed and have a short period of waterlogging. These soils form a progression of increasing wetness with classes 16, 18, 21, 24 and 26. HOST class 22 is more akin to class 19 but here the depth to the slowly permeable rock is less and so the IAC of these soils is lower than 7.5 percent. The soils are freely drained with dominantly vertical unsaturated flow but there is a preferential pathway of lateral water movement along the boundary between the soil and the rock. The class is dominated by shallow soils and occurs mainly in Scotland. HOST class 23 is similar to class 20 in the flow regime exhibited by the soils but they are less permeable and so will be saturated for longer each year.

Many of the soils of HOST class 18 are similar to those in HOST class 16. However, the thickness of the water modified layer is less, and consequently, the soils have an impermeable horizon and gleying within one metre. They are also mineral soils with wetness class II to III.

This class also includes soils with weakly gleyed horizons but with an impermeable layer. In general, these soils have a reddish colour, e.g. the soils found in the Howe of the Mearns.

The topography associated with both these groups of soils is that of undulating lowlands typified by Strathmore and, occasionally, foothills adjoining the Midland Valley.

HOST class 19

Common factors linking the soils of HOST class 19 are the presence of hard, coherent rock within one metre of the soil surface and their free drainage. They are found in undulating, glacially scoured lowlands, in the high undulating mountain plateaux, and in summits with shallow frost-shattered debris and patterned ground. This exceptionally varied landscape includes the craggy, terraced slopes of Mull and encompasses a wide range of slopes from gentle to very steep, but the land is invariably rocky or bouldery with well developed *roches moutonnées* in the Machars of Wigtonshire.

The rockiness, steep slopes and severe climate precludes much of this land from cultivation although some areas support mixed arable and dairy farming. Semi-natural grassland and moorland predominate with occasional areas of broadleaved woodland and conifer plantations.

HOST class 22

In common with HOST classes 17 and 19, the soils of class 22 are shallow and underlain by hard, coherent rock predominantly at depths less than 0.5m. The soils are freely drained and occur in a number of rock dominated landscapes throughout Scotland, from the lowlands of Kirkcudbright to the high tops of the Cairngorms and as far north as Shetland.

Rugged, rocky lowlands such as Ardnamurchan and Sleat are often cultivated providing some improved pastures for crofting communities. However, the majority of the areas where these soils occur carry little or no vegetation, eg. the precipitous rock walls of corries or the undulating rock pavements of mountain plateaux. Areas of terraced land or steep hill slopes with crags and screes will often carry semi-natural grassland or heather moorland and some lowland areas are dominated by gorse or bracken.

HOST Class 23

HOST Class 24

Gleyed mineral soils with wetness class III or IV and developed on fine-textured lodgement till (formerly boulder clay) or glaciolacustrine and estuarine deposits comprise HOST class 24. These soils are found throughout the Midland Valley, Caithness, The Rhins peninsula, the Merse of Berwick, parts of the north-east and sporadically throughout the foothills and uplands.

The landscape is generally of undulating till plains, typified by parts of Ayrshire, with occasional drumlin swarms which are rounded hillocks of till resembling upturned egg cartons. These drumlins underlie much of Glasgow city centre. In the hill areas the till is often found in corrie-like hollows called till embayments and some steep sided valleys. The slopes are invariably concave and, in contrast to the open hill plains, the vegetation is generally semi-natural rush pasture or *Molinia* grassland. The open, hill plain has both arable farming (primarily in the east) and dairying (especially in western areas). In most instances the fields are divided by hedges or wire fences rather than stone dykes. Locally, especially in the south-west and Kintyre, the till is punctuated by rocky knolls but, in the main, the landscape is non-rocky.

Fine-textured glaciolacustrine deposits occur sporadically and vary widely in extent. The landscape is often gently undulating or level. The estuarine silts and clays form a specific and distinct landform associated with the Rivers Tay, Forth and Cree and are known as the Carse lands. These deposits now lie between 15 and 35 metres above sea level due to changes in the relative position of land and sea since the retreat of ice from Britain. Also included in this group are the more recently reclaimed estuarine soils but these are very small in extent. The landscape is gently undulating or level and carries both arable and permanent pasture; stone dykes are absent.

As previously mentioned these soils are primarily cultivated with dairying being a prominent farming system. More locally, semi-natural grassland, rush pasture, broadleaved woodland and conifer plantation can be found.

HOST class 26

The soils of HOST class 26 are formed on similar drift deposits to those of class 24. However, as they tend to occur in areas of excessive wetness, e.g. in the higher rainfall areas of the west, at higher altitudes and in lowland depressions, they develop a peaty surface layer and gleyed subsoil (wetness class V to VI). They are predominantly found on gently undulating hill ground with semi-natural vegetation including rush pasture, *Molinia* bog and heather moorland. Many areas have been planted with conifers due to the inherent poor potential of the soil for agriculture and generally rock-free topography. Occasionally, areas of steep valley sides have these soils, e.g. Glen Roy but these are rare occurrences. The overall impression of this landscape is of wet, gently undulating bog often with open 'sheep drains' and used primarily as rough grazing.

HOST class 27

Rapid runoff and very little storage typifies the hydrological response of HOST class 27. The soils have a thin peaty surface layer underlain by hard coherent rock. Although the landscapes associated with this class vary, they are all rock dominated from rock pavements in the high mountains to the undulating lowlands of north-west Scotland.

Very steep, almost vertical rock walls and corries are distinct landforms found throughout the mountainous regions of Scotland. In many cases the soils comprise a thin organic layer directly on hard rock and this shallowness, combined with the steep slopes, gives rapid runoff and little storage.

Some less steep slopes with very thin drift and rock outcrops typified by much of the west coast fjords also carry thin, peaty soils, although areas between outcrops may have deeper drift (HOST class 15). Where the slopes become more gentle, the rock and thin soils are separated by peat flats (HOST class 29). A similar distribution of soil types and HOST classes is found in stepped and terraced topography with short, steep rocky crags.

Perhaps the most extensive landform associated with this class is that typified by the Assynt region of north-west Scotland. This desolate treeless landscape has been virtually scoured of any soil forming material leaving only pockets of thin drift and ice-moulded rock knolls in an undulating lowland of peat flats and black, dubh lochans.

A very small area of coastal rock platform in the west of Scotland where soils have developed on thin denuded beach deposits is also included in this class.

HOST Class 28

Although eroded peat is found throughout Scotland it has only been delineated in specific localities for the purposes of the 1:250,000 scale map. However, a better appreciation of the extent and distribution of this unit (and hence HOST class 28) can be gained from more detailed, larger scale soil maps.

The main areas shown at the smaller scale include Orkney, Shetland, Sutherland and Caithness, and the Monadhliath, Cairngorm and Eastern Grampian mountain masses. Detailed mapping shows that eroded peat can be found in western Scotland, the Hebridean

Islands and sporadically in the Southern Uplands.

The landscape is undulating plateaux, hill tops and hill sides with slopes generally less than 15°. A characteristic of the peat is that it 'blankets' the existing relief. Because of its widespread distribution, eroded blanket peat is found at a wide range of altitudes from below 60 metres in Shetland to about 800 metres in the Monadhliath mountains. The gullies and channels have two forms: dendritic on gentle slopes and in cols, and radial on steeper slopes. In many instances the peat in the gullies has been totally removed, exposing the underlying solum. The uneroded vegetated haggs often have short, steep slopes of unvegetated black peat which is easily removed by both wind and water. Gullies deeper than 1.5 metres are not uncommon.

The hydrological response of eroded peat differs significantly from that of intact peat. The dendritic and radial drainage pattern would tend to imply a more rapid response in stream levels to incoming rainfall. However, the large expanse of relatively dry, exposed peat may give a larger storage capacity than uneroded peat. Also, in many areas of eroded peat, pools of water form between haggs, again delaying the time taken for rainfall to reach streams and rivers; this may be dependent on the intensity of the rainfall. During heavy rainfall the gullies and channels quickly fill and become extensions of the existing stream pattern. However, in less intense rainfall, absorption by the peat is more likely.

HOST class 29

HOST class 29 is one of the most extensive classes in Britain. It occurs in large areas on its own and in conjunction with other classes in complex soil and landform units. This class encompasses raw organic soils which are uncultivated and carry either semi-natural moorland, scrub or conifer plantation. A few areas will have improved pasture but cultivation is light and often restricted to surface scarification.

Blanket peat is unconfined, ombrogenous, climatic peat and is extensive throughout the hills and uplands of Scotland. The term 'blanket peat' is highly descriptive of how the peat smothers and partially masks the underlying topography. Because of its ubiquitous nature, it has a wide altitudinal range and overlies undulating land with gentle slopes including mountain plateaux. This type of peat only rarely develops on slopes greater than 15 degrees. However, blanket peat also develops on the more gentle slopes within steep, rugged topography. It is climatic in nature i.e. the cold wet conditions of the Scottish uplands favour its development by retarding the breakdown and decay of dead plant material. The peat is generally more than one metre thick and can be considerably deeper. The vegetation is dominantly heather moorland, *Molinia*-dominated bog and the white heads of cotton grass are characteristic as are the herring-bone pattern of open sheep-drains.

6 Applications of the HOST classification

6.1 LOW FLOW ESTIMATION

This describes how the HOST classification can assist in the estimation of low flow indices. The methods described have already been published in Gustard *et al.* (1992), and indeed much of the following has been drawn from that report. These methods were developed before the HOST project was complete using a provisional classification system and data set. Users of the methods should be aware of the following difference between the provisional and final products.

i In the provisional HOST data set, areas remained unclassified (mainly because they were urban). These areas were placed in HOST class 97, which is treated in this section as a separate class.

ii The HOST classes have been renumbered. In Gustard *et al.* (1992) HOST class 2 was numbered class 29, with all class numbers between reducing by one. In the following section this renumbering has been applied and this section is consistent with the remainder of the report. There are, therefore, differences between this report and Gustard *et al.*

iii Some soil series have been reassigned to different HOST classes; the changes affect HOST classes 5, 6, 7, 8, 9, 10, 12, 16, 17, and 29 but are generally small. For small catchments, users should consider referring to the revised assignment of HOST classes to map units presented in this report (Figure 5.3) and calculating new average low flow parameters values for HOST map units. The effect on larger catchments is likely to be insignificant.

iv The provisional HOST data set was based on a single map unit for each 1km square, to which the HOST classes were ascribed. In the new dataset, all map units within each 1km square were used to calculate the HOST classes. The revised data will most affect the percentage coverage on small catchments. It was for this reason that catchments of less than 5 km^2 were omitted in calibrating the low flow methods, but were considered acceptable for other analyses described in the report.

6.1.1 Introduction

A number of studies have identified the key role of catchment hydrogeology in controlling the low flow response of a catchment (Institute of Hydrology 1980, Pirt and Douglas 1980, Gustard *et al.* 1989). Problems of numerically quantifying this role have contributed to the difficulty in estimating low flows at ungauged sites and to the practical utility of applying a consistent method nationally. The Low Flow Studies (1980) report sought to overcome these problems by using the Base Flow Index as a key variable to index hydrological response from which other flow statistics could be derived. Examples were given of how the index could be estimated at an ungauged site from catchment geology and it was anticipated that hydrologists would develop these procedures based on their detailed knowledge of hydrogeology and low flow response. Although some regional relationships were derived between the Base Flow Index and local geology in Southern England (Southern Water Authority 1979), and Scotland (Gustard, Marshall and Sutcliffe, 1987) the lack of a national low flow response map was a major constraint to the practical application of estimation techniques in the UK.

6.1.2 Estimating flow duration curve: 95 percentile and mean annual 7 day minimum

A total of 865 stations have been identified as suitable for inclusion in the Low Flow Study data base. The selected stations have an average record length of 18.6 years of daily mean flow data, and over 16,000 station years of daily data were analysed.

The percentage coverage of the 29 HOST classes and URBAN (97) and LAKE (98) for each of the 865 low flow catchments were derived using the digitised catchment boundary and HOST data bases, (Gustard *et al.*, 1992). Linear least squares multiple regression analysis was used to relate $Q_{95}(1)$ and MAM(7) to the percent coverage of HOST classes. Only a draft HOST data base was available for Northern Ireland so data from Northern Ireland were not used in the analysis. Because different missing data criteria were used, different data sets were available for the $Q_{95}(1)$ calibration (694 stations) compared with the MAM(7) analysis (660 stations). Gauging stations with catchment areas of less than 5 km^2 were omitted because of the possibility of introducing errors in small catchments by using the dominant HOST class within 1 km^2 grids. The estimated $Q_{95}(1)$ parameters for the HOST classes are presented in Table 6.1. The poor representation of certain HOST classes was reflected in the results of the regression analysis with very high standard errors in parameter estimates of $Q_{95}(1)$ and MAM(7). For example, the highest standard errors of the $Q_{95}(1)$ parameters are associated with HOST classes 8 and 11, both of which are very limited in extent. Furthermore, negative parameters are estimated for HOST classes 22, 23, 25 and 27 for both $Q_{95}(1)$ and MAM(7), and additionally for HOST class 9 for $Q_{95}(1)$.

Table 6.1 $Q_{95}(1)$ estimates for HOST classes

HOST class	$Q_{95}(1)$ Parameter	s.e. of Parameter	HOST class	$Q_{95}(1)$ Parameter	s.e. of Parameter
1	37.7	1.8	17	12.3	2.3
2	32.7	2.9	18	14.5	2.8
3	68.8	4.4	19	24.6	9.4
4	26.4	3.2	20	31.4	20.1
5	56.4	4.9	21	12.3	2.2
6	31.6	8.6	22	-3.0	15.2
7	4.8	14.3	23	-12.9	9.1
8	30.0	32.7	24	7.7	1.5
9	-4.3	23.7	25	-2.5	4.3
10	13.2	12.4	26	9.8	3.4
11	44.3	41.0	27	-8.5	11.0
12	16.6	19.2	28	24.7	12.5
13	95.8	15.7	29	5.8	2.7
14	5.4	19.9	97	29.9	2.3
15	12.7	2.6	98	78.3	28.9
16	26.8	13.5			

$r^2 = 0.565$
Standard error of estimate = 7.633

The regression analysis also identified that HOST classes with similar soil and hydrogeological characteristics with respect to their low flow response possess similar parameter estimates. It was thus decided to group the HOST classes into a smaller number of low flow response units. These units were combinations of HOST classes with similar physical characteristics and in some cases these were supported by the results of the regression analysis. A number of different strategies of groupings were investigated and the final assignment of 29 HOST classes to ten Low Flow HOST Groups (LFHG) is shown in Table 6.2. The final assignment of HOST classes to groups is based principally, but not exclusively, upon hydrogeological class. The URBAN (HOST 97) and LAKE (HOST 98) fractions are assigned to individual Low Flow HOST Groups 11 and 12 respectively. Figure 6.1 displays the general distribution of Low Flow HOST Groups in Great Britain based on the dominant HOST class within grid squares of 1 km^2.

Table 6.2 Assignment of HOST classes to Low Flow HOST Groups

LOW FLOW HOST GROUP	CONSTITUENT HOST CLASSES
LFHG1	HOST 1
LFHG2	HOST 2
LFHG3	HOST 3, HOST 5
LFHG4	HOST 4
LFHG5	HOST 6, HOST 13
LFHG6	HOST 7, HOST 8, HOST 9, HOST 10, HOST 11
LFHG7	HOST 12, HOST 16, HOST 17, HOST 18, HOST 19, HOST 21, HOST 22, HOST 24
LFHG8	HOST 20, HOST 23, HOST 25
LFHG9	HOST 15
LFHG10	HOST 12, HOST 26, HOST 27, HOST 28, HOST 29
LFHG11	HOST 97
LFHG12	HOST 98

Table 6.3 presents proportions of the Low Flow HOST Groupings within gauged catchments in the United Kingdom, and the maximum proportion within those gauged catchments.

Using linear least squares multiple regression, $Q_{95}(1)$ and MAM(7) were regressed against the proportional extent of the 12 Low Flow HOST Groupings. Standard errors of parameters are significantly reduced compared with the analysis based on 29 individual HOST classes, no negative parameters are calculated and parameter estimates differ significantly from each other in broad terms.

An analysis of residuals using these relationships identified that there are major differences between the observed and predicted low flow statistics for catchments 26004 and 26005. Both gauging stations are on the Gypsey Race, a bourne stream draining the Yorkshire Wolds, and are controlled by fluctuating groundwater levels and cease to flow each summer when levels fall below that of the channel bed. In the final analyses, these two catchments were omitted from the regional calibration of the Low Flow HOST Groups resulting in minor changes in the parameter estimates and a significant reduction in the overall error of the estimation procedure. The final parameter estimates for $Q_{95}(1)$ and MAM(7) are presented in Tables 6.4 and 6.5. These enable $Q_{95}(1)$ and MAM(7) to be estimated for each soil association in England, Wales and Scotland, calculated from the percentage area of soil series, and thence

Table 6.3 Percentages of Low Flow HOST Groupings in Great Britain and within gauged catchments

Low Flow HOST Group	Mean percentage in Great Britain	Mean percentage in AB graded catchments	Maximum percentage in AB graded catchments
LFHG1	4.53	6.18	100.00
LFHG2	2.24	3.22	90.69
LFHG3	7.01	5.86	98.68
LFHG4	3.50	4.10	77.24
LFHG5	2.69	2.39	45.83
LFHG6	9.67	3.87	37.76
LFHG7	39.75	40.19	100.00
LFHG8	5.92	6.37	95.00
LFHG9	10.44	9.74	86.67
LFHG10	13.10	13.91	100.00
LFHG11	0.57	3.86	97.22
LFHG12	0.57	0.34	10.00

Table 6.4 Final $Q_{95}(1)$ estimates for Low Flow HOST Groups

Low flow HOST grouping	$Q_{95}(1)$ Parameter	s.e. of Parameter
LFHG1	40.8	1.7
LFHG2	31.9	2.6
LFHG3	65.7	2.9
LFHG4	25.0	3.0
LFHG5	49.0	6.8
LFHG6	6.5	5.6
LFHG7	10.7	0.8
LFHG8	1.1	2.0
LFHG9	15.0	2.2
LFHG10	6.8	1.5
LFHG11	29.4	2.1
LFHG12	65.1	25.8

$r^2 = 0.573$
Standard error of estimate = 7.427

***Figure 6.1 (Opposite)** General distribution of Low Flow HOST Groups in Great Britain based on the dominant HOST class in each 1 km² derived by the HOST project*

Dominant Low Flow Group on 1km Grid

IH/SSLRC/MLURI/DANI

Table 6.5 Final MAM(7) estimates for Low Flow HOST Groups

Low flow HOST Grouping	MAM(7) Parameter	s.e. of Parameter
LFHG1	50.8	1.9
LFHG2	40.3	2.8
LFHG3	71.3	3.3
LFHG4	27.5	3.3
LFHG5	53.4	7.5
LFHG6	1.4	6.2
LFHG7	12.4	0.9
LFHG8	0.1	2.3
LFHG9	14.4	2.4
LFHG10	5.9	1.7
LFHG11	33.8	2.4
LFHG12	49.6	28.7

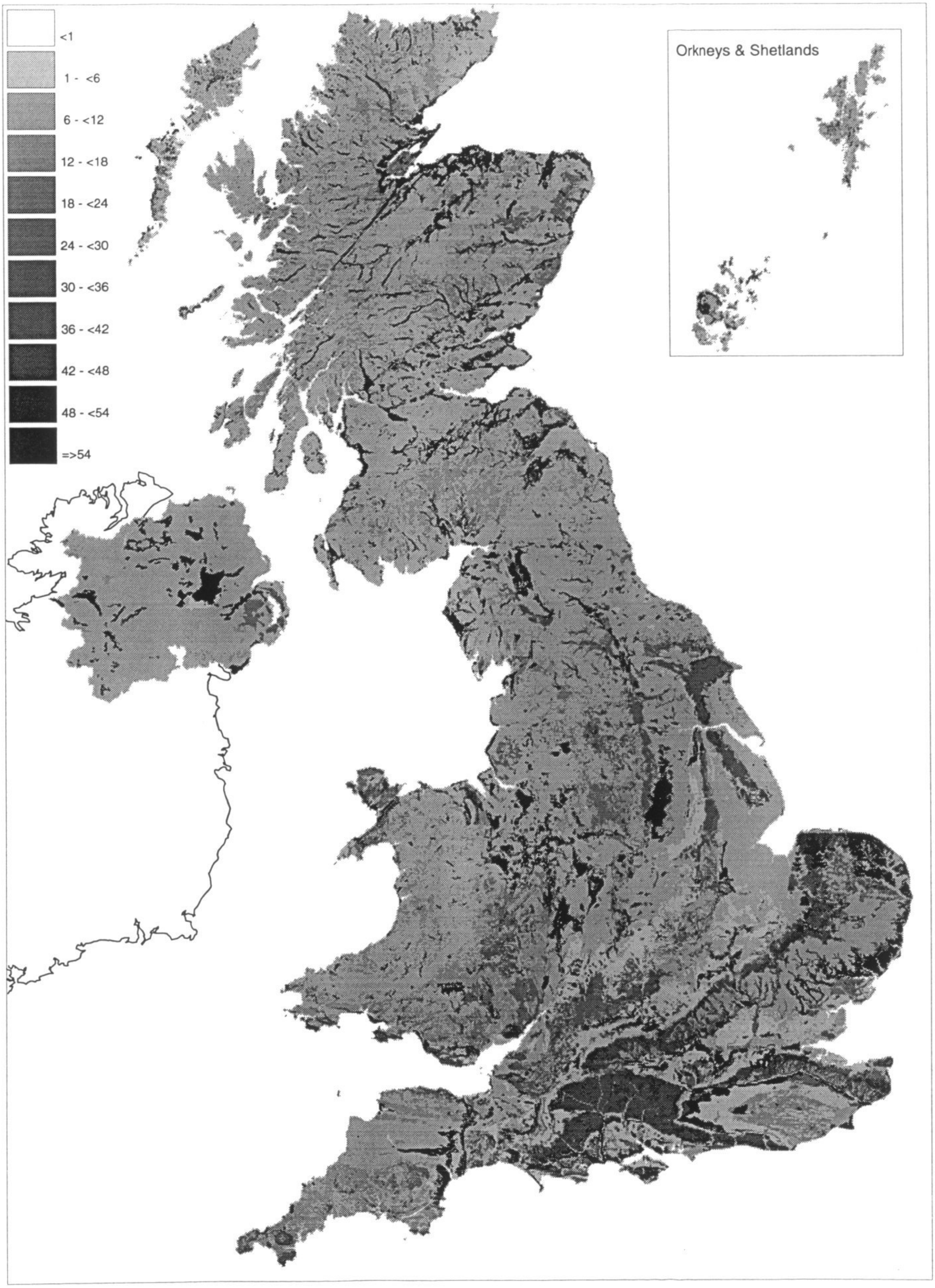
$r^2 = 0.614$
Standard error of estimate = 8.253

HOST and Low Flow HOST Group within each association. For Northern Ireland values of low flow parameters are shown for each of the HOST classes for use with the provisional HOST map of the province. Figure 6.2 displays the general distribution of the estimated $Q_{95}(1)$ and MAM(7) statistics for 1 km^2 grid squares throughout Great Britain. These maps are based on the fractions of soil series within grid squares, which have been assigned to HOST classes and then Low Flow HOST Groups for which $Q_{95}(1)$ and MAM(7) estimates are made.

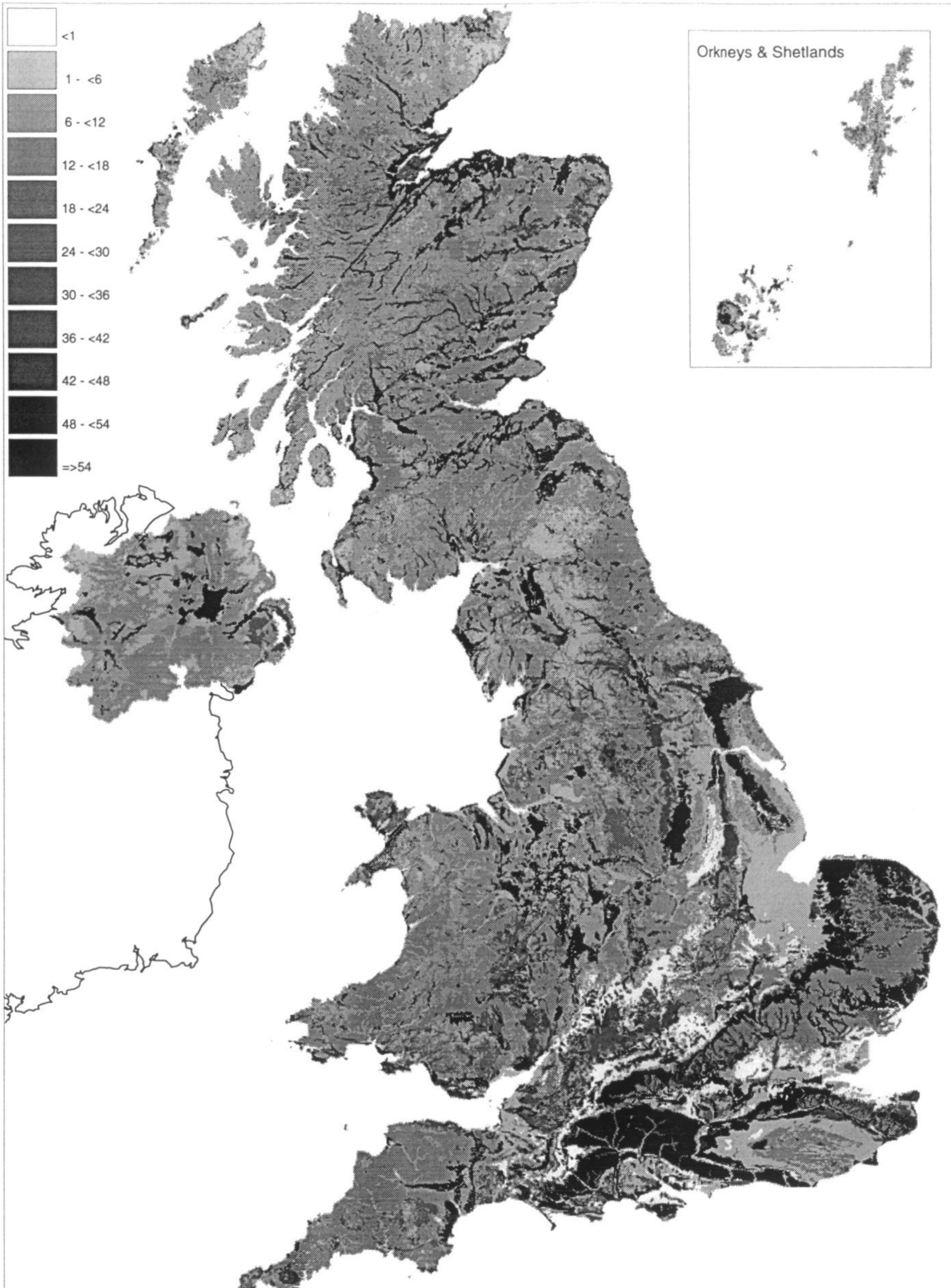
Figure 6.2(i) (Following) *General distribution of estimated $Q_{95}(1)$ in Great Britain based on the proportion of HOST class in each 1 km^2 derived by the HOST project group*

Figure 6.2(ii) (Following) *General distribution of estimated MAM(7) in Great Britain based on the proportion of HOST class in each 1 km^2 derived by the HOST project group*

Distribution of Q95 (HOST)



Distribution of MAM7 (HOST)



6.1.3 Estimation of the flow duration curve at ungagued sites

The initial approach to developing a procedure for estimating the flow duration curve at an ungauged site was to establish which variables controlled the slope of the line. This was investigated by calculating values of Q_{95}, Q_{10} and Q_{99} for each of the 845 time series of daily mean flows having Q_{95} greater than zero. The following ratios were then derived from each flow duration curve:

$$R(Q_{10}) = Q_{10}/Q_{95}$$

$$R(Q_{99}) = Q_{99}/Q_{95}$$

Values of the two ratios were then related to $Q_{95}(1)$, AREA and SAAR. This analysis showed that $Q_{95}(1)$ was the only significant variable in controlling the slope of the flow duration curve, that is there was no significant difference between the gradients of the curve that could be attributed to catchment area or average annual rainfall. Inspection of a number of curves indicated that they did not plot exactly as straight lines using a log normal transformation. It was therefore not possible to use simple relationships based on gradients alone. The procedure adopted was to maintain the shape of the predicted curves by pooling groups of flow duration curves. This was achieved by deriving the 845 curves and pooling them according to their $Q_{95}(1)$ value into one of 15 groups shown in Table 6.6.

Table 6.6 *Number of flow duration curves in each class interval of $Q_{95}(1)$*

$Q_{95}(1)$ % MF	Number of flow duration curves
< 2.5	14
2.5 - 7.5	132
7.5 - 12.5	197
12.5 - 17.5	177
17.5 - 22.5	103
22.5 - 27.5	83
27.5 - 32.5	53
32.5 - 37.5	30
37.5 - 42.5	22
42.5 - 47.5	17
47.5 - 52.5	5
52.5 - 57.5	3
57.5 - 62.5	4
62.5 - 67.5	4
67.5 - 72.5	1

A computer program was used to derive the mean curve for each group of stations by finding the mean discharge (expressed as a percentage of the mean flow, MF) for each of 40 class intervals of x, the plotting position on the frequency axis.

A family of twenty type curves were then interpolated between the pooled curves such that the logarithm of $Q_{95}(1)$ was equally spaced. Thus type curve 0 had a $Q_{95}(1)$ of 1% MF and type curve 19 had a $Q_{95}(1)$ of 79.43% MF. The shape of the curve is therefore entirely dependent on the value of $Q_{95}(1)$. The derived type curves are shown in Figure 6.3 and Table 6.7. In design studies individual curves can be interpolated between the values shown.

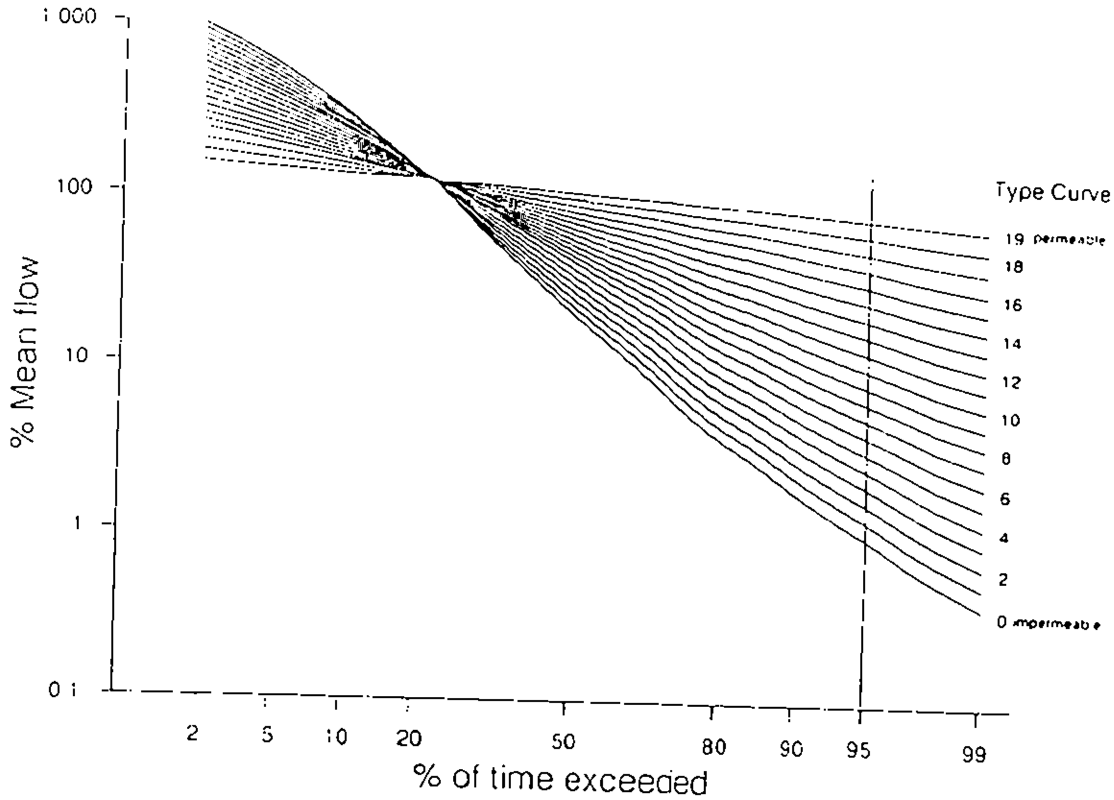


Figure 6.3 Type curves for flow duration curve

Table 6.7 Flow duration type curves (percentage of mean flow)

$Q_{95}(1)$		1.00	1.26	1.58	2.00	2.51	3.16	3.98	5.01	6.30	7.94
Type curve		0	1	2	3	4	5	6	7	8	9
Percentile	2	975.70	904.17	838.77	776.04	719.91	667.48	618.22	572.53	520.00	472.29
	5	577.26	1534.08	511.37	480.48	452.42	425.82	400.44	376.64	350.65	326.46
	50	20.49	22.69	25.10	27.86	30.82	34.11	37.81	41.82	45.10	48.64
	80	3.70	4.42	5.27	6.33	7.54	9.00	10.77	12.86	15.20	17.98
	90	1.73	2.13	2.62	3.25	3.99	4.92	6.07	7.47	9.16	11.22
	95	1.00	1.26	1.58	2.00	2.51	3.16	3.98	5.01	6.30	7.94
	99	0.38	0.51	0.67	0.88	1.16	1.53	2.02	2.65	3.46	4.52

$Q_{95}(1)$		10.00	12.57	15.83	19.93	25.13	31.64	39.81	50.13	63.12	79.43
Type curve		10	11	12	13	14	15	16	17	18	19
Percentile	2	428.96	389.60	353.86	321.39	291.65	264.89	240.09	206.89	178.28	153.69
	5	303.93	282.96	263.44	245.26	228.19	212.45	197.49	176.99	158.62	142.20
	50	52.46	56.57	61.01	65.79	71.00	76.57	82.60	89.91	97.86	106.49
	80	21.25	25.13	29.71	35.12	41.58	49.16	58.08	67.82	79.21	92.46
	90	13.75	16.86	20.66	25.32	31.09	38.10	46.67	56.95	69.50	84.77
	95	10.00	12.57	15.83	19.93	25.13	31.64	39.81	50.13	63.12	79.43
	99	5.89	7.69	10.03	13.08	17.11	22.32	29.13	39.00	52.22	69.85

6.1.4 Estimation of the flow frequency curve at an ungauged site

Duration relationship

To enable mean annual minimum flow frequency curves of other than the 7 day duration to be estimated a study was carried out of the relationship between the mean annual minimum of different durations. Figure 6.4 shows the relationship between minima of different durations for two contrasting catchments. Station 85003 (Falloch at Glen Falloch) is impermeable and has a low value of MAM(7), a high value of MAM(180) and thus a high value of GRADMAM, the gradient of the duration relationship. In contrast station 39019 (Lambourn at Shaw) is permeable and has a higher value of MAM(7) and a lower gradient.

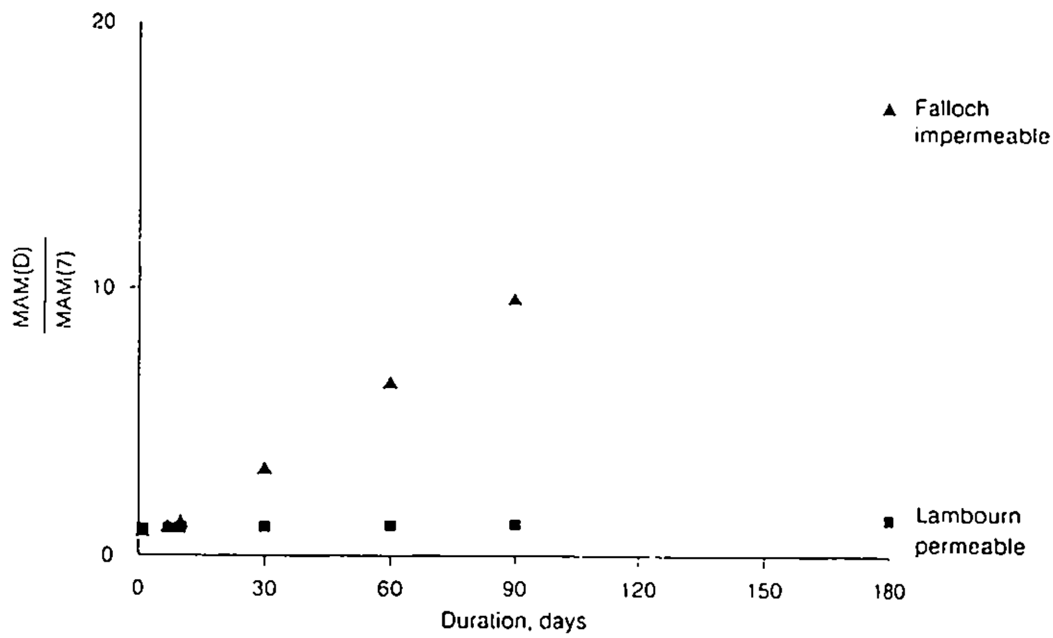


Figure 6.4 Relationship between annual minima of different durations

For each station values of GRADMAM were derived and related to flow and catchment characteristics. MAM(7) and SAAR were found to be the most significant variables enabling the gradient of the duration relationship to be estimated from

$$GRADMAM = 2.12\ .10^{-3}\ MAM(7)^{-1.02}\ SAAR^{0.629} \qquad (1)$$

$$r^2 = 0.916 \qquad fse = 1.29$$

where fse is the factorial standard error from a regression of log(GRADMAN) on log (MAM(7)) and log(SAAR).

From the linear relationship between MAM(D) and D we obtain

$$MAM(D) = MAM(7)\ ((1+(D-7)\ GRADMAM)) \tag{2}$$

This enables the mean annual minimum of any duration up to 180 days (the maximum value used in the analysis) to be estimated.

Frequency relationship

To estimate discharges other than the mean of the annual minima, relationships were derived based on pooled flow frequency curves following a similar procedure to the flow duration curve analysis. Flow frequency curves were derived for annual minima of durations (D) of 1, 7, 30, 60, 90 and 180 days for 680 stations with more than five years of data. A missing year criteria was adopted such that if a year contained more than seven missing days it was rejected. Figure 6.5 illustrates annual minimum plots for two contrasting flow records and for four durations. It can be seen that the curve for the seven day minimum is very much lower for station 85003, the impermeable catchment, than for station 39019 which is a chalk catchment. Differences between durations are greater for the more impermeable catchment. This analysis was repeated on all the flow records, producing 3960 individual flow frequency curves.

Standardisation of individual minima by MAM(D) reduced the variability between minima of different durations and between different stations. Figure 6.6 shows the same data plotted on Figure 6.5 with the annual minima standardised by MAM(D). All stations were then allocated to one of 15 class intervals of MAM(7), Table 6.8 shows the number of stations in each group. For each group of stations, and for each duration, a pooled annual minimum curve was derived resulting in 90 curves. The pooling procedure was carried out by calculating the mean discharge (standardised by MAM(D)) and mean Weibull reduced variate for class intervals of reduced variate. It was found that the range of pooled curves could be described by the family of twelve type curves shown in Figure 6.7 and Table 6.9. These were then overlain on each of the 90 curves to assign a type curve for a given value of MAM(7) and duration (Table 6.10).

The type curves enable the annual minimum (AM) of any probability (P) for any duration (D), AMP(D), to be estimated from the mean annual minimum MAM(D). This is achieved by multiplying the value of MAM(D) by the appropriate type curve factor shown on Table 6.9.

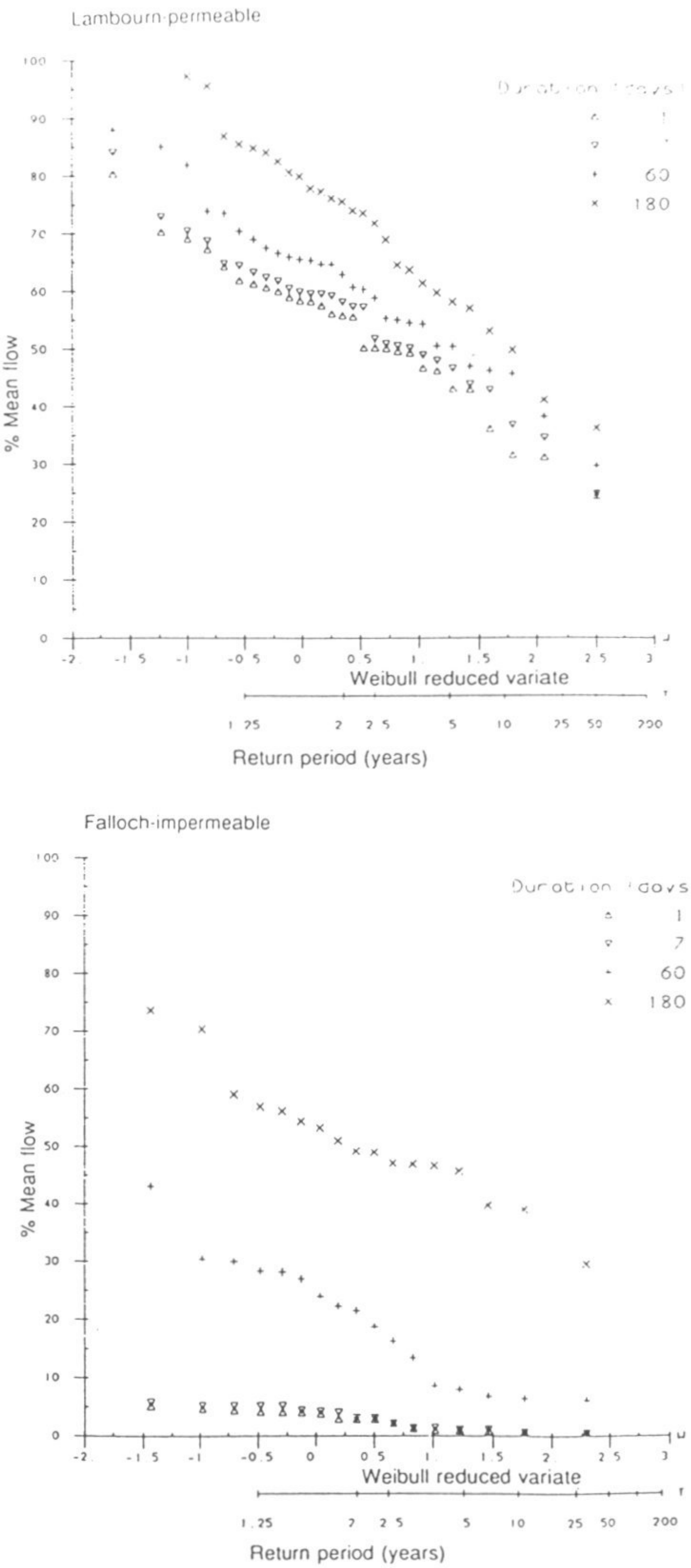
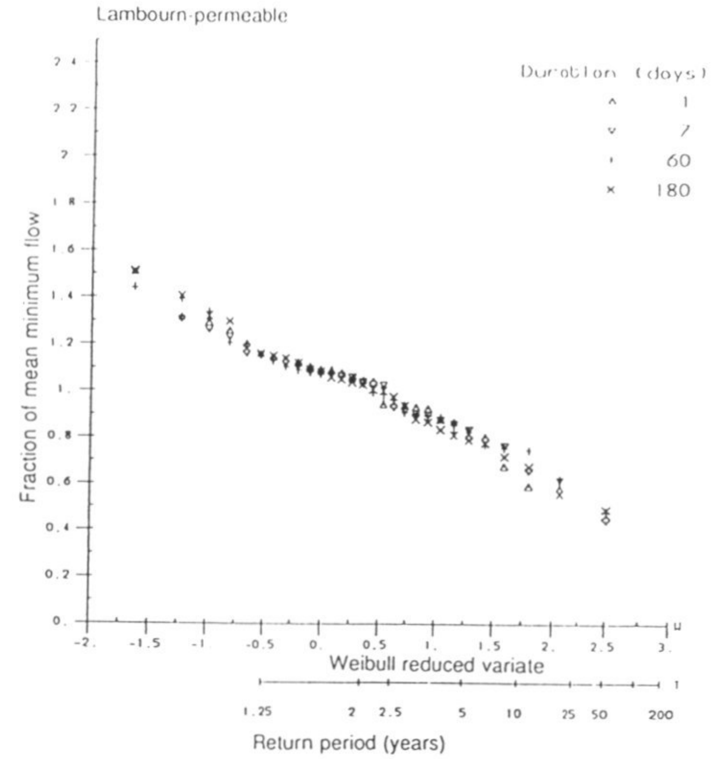


Figure 6.5 Example low flow frequency curves for two contrasting flow records and for four durations



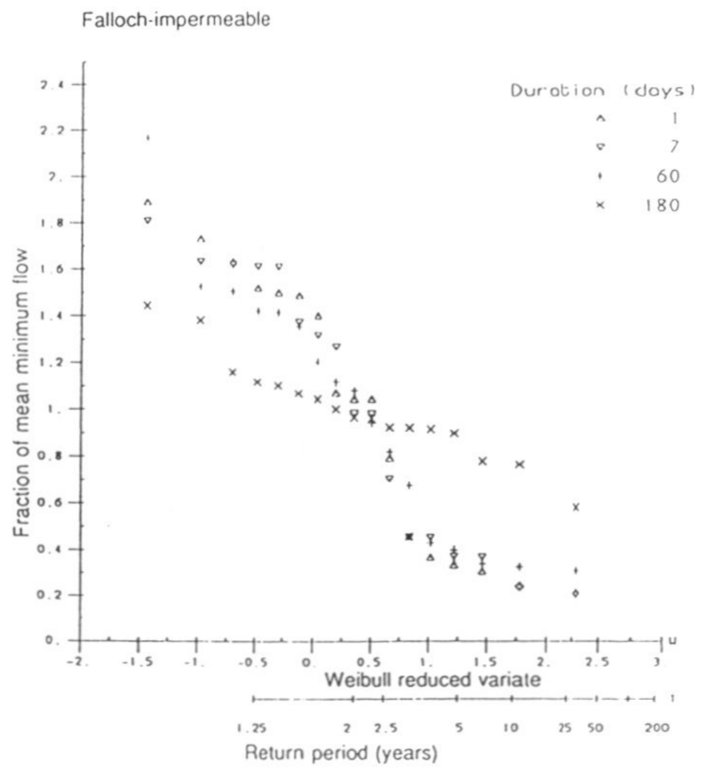


Figure 6.6 Low flow frequency curves standardised by MAM(D)

Table 6.8 Number of low flow frequency curves in each class interval of MAM(7)

MAM(7) % MF	NUMBER OF LOW FLOW FREQUENCY CURVES
< 2.5	16
2.5 - 7.5	87
7.5 - 10.0	69
10.0 - 12.5	59
12.5 - 15.0	83
15.0 - 17.5	64
17.5 - 22.5	90
22.5 - 27.5	66
27.5 - 32.5	50
32.5 - 37.5	35
37.5 - 42.5	13
42.5 - 47.5	16
47.5 - 52.5	12
52.5 - 62.5	11
> 62.5	9

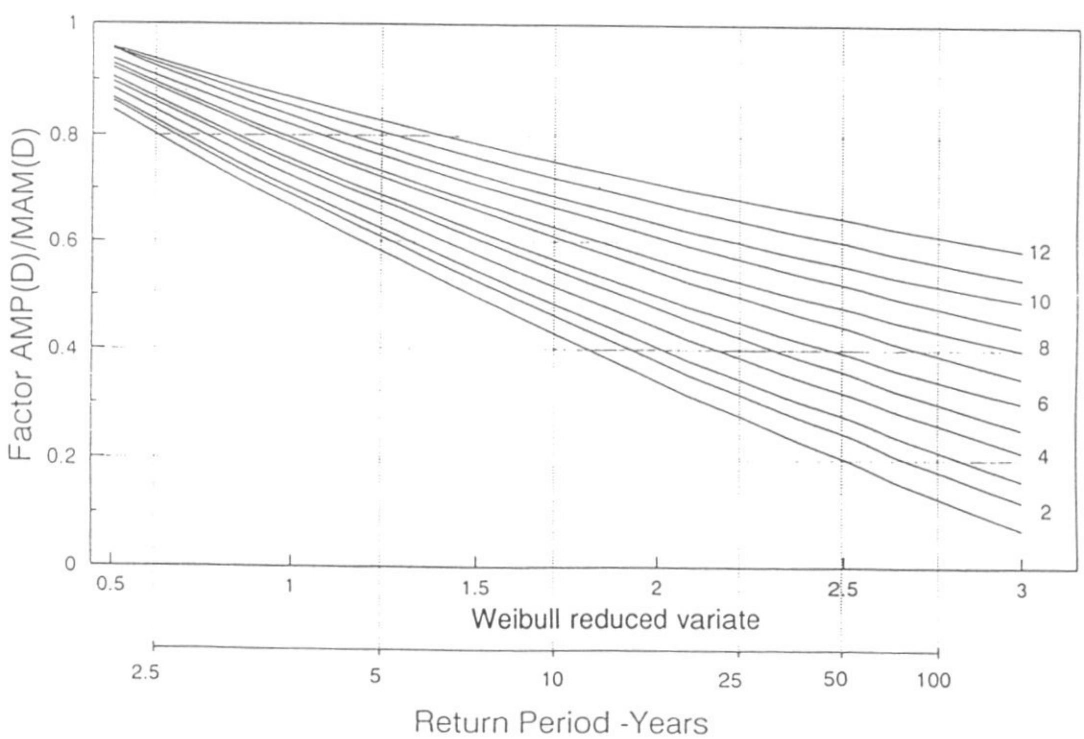


Figure 6.7 *Type curves for low flow frequency curves*

Table 6.9 Type curves for low flow frequency

Plotting position W	TYPE CURVE 1	2	3	4	5	6	7	8	9	10	11	12
0.5	0.85	0.86	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.96	0.96	0.96
1.0	0.66	0.69	0.70	0.72	0.75	0.76	0.79	0.80	0.82	0.84	0.86	0.87
1.5	0.50	0.53	0.55	0.58	0.61	0.62	0.66	0.68	0.71	0.73	0.76	0.79
2.0	0.34	0.38	0.40	0.44	0.48	0.50	0.54	0.57	0.61	0.64	0.68	0.71
2.5	0.20	0.24	0.27	0.32	0.36	0.39	0.44	0.48	0.52	0.56	0.60	0.65
3.0	0.07	0.12	0.16	0.21	0.25	0.30	0.35	0.40	0.44	0.49	0.53	0.59

Table 6.10 Assignment of low flow frequency type curves by MAM(7) and duration

MAM(7) as % MF	Duration days 1	7	60	180
5	2	2	1	1
10	5	5	4	5
15	6	6	5	6
20	7	7	7	7
25	7	7	7	7
30	7	7	7	7
35	7	7	7	8
40	7	7	7	8
45	8	8	8	9
50	7	8	9	10
55	11	11	12	12

6.2 THE ESTIMATION OF STANDARD PERCENTAGE RUNOFF

6.2.1 Introduction

The importance of percentage runoff in the FSR method of design flood estimation, and the form of the FSSR16 percentage runoff model, have already been discussed. In considering how to use HOST to enhance the estimation of PR a number of options were considered.

The most radical of these was to replace the PR estimation method completely. The major disadvantage of this would be a discontinuity with previous methods. The concept of standard and dynamic component models, with each dependent on different factors is conceptually attractive and allows flexibility in application, for example to exploit locally derived data. It was therefore decided to retain this form of model.

Within this framework it would be possible to modify both components. This was an attractive option for two reasons: firstly it would allow the introduction of dynamic terms that differed between soil types, and secondly, as with the calibration of WRAP, it would allow the integrated development of the standard and dynamic component models. These two ideas require expansion.

Very different responses to rainfall would be expected from soils in the different HOST classes. As an approximate guide, the BFI values can be translated to SPRs using the equation presented in Section 4.2.4. A two part PR model adds to this variation in SPR between soil types, with dynamic terms based on wetness and the total event rainfall. In a HOST context it is expected that these dynamic terms would differ markedly between the various HOST classes. For example in classes 21 to 25, in which seasonal variations in the depth to the water table are expected, then a large increase in response with catchment wetness is expected. In contrast the effect of wetness on freely draining soils over permeable substrates is likely to be small. Indeed on some of these soils, dry, baked surface conditions may give rise to a greater response than under normal wetness conditions. The change in response as rainfall increases is also likely to be modest on these soils until very intense rainfall rates are encountered, when overland flow will result. Such soils therefore have a strongly non-linear response to rainfall. This can be contrasted with soils that give a high response to modest rainfall and where when rainfall amounts increase response is likely to increase, possibly to nearly 100%, and thereafter there can be little increase in response even in the most extreme conditions.

Unfortunately while the introduction of such dynamic terms is an exciting prospect, insufficient data are available to calibrate and verify the increased number of sub-models required. It is hoped that this situation can be rectified in future studies.

It was therefore decided that, in this first use of HOST to enhance design flood estimation, only the SPR component of the existing model would be modified, ie. it would be assumed that the dynamic terms and urban adjustment were correct. While this provides a very straightforward means of integrating HOST with existing methods it imposes dynamic terms that were developed in tandem with the old WRAP classification, and which may, therefore, be biassed.

The following sections describe the development of a model of the form

$$SPR = a_1 HOST_1 + a_2 HOST_2 + a_3 HOST_3 + \ldots + a_{29} HOST_{29}$$

Section 6.2.3 describes an approach based on the BFI model derived in Section 4.2.4, then in Section 6.2.4 a model is calibrated directly against SPR data.

6.2.2 The SPR catchment data set

The data required for developing the SPR estimation equation are catchment average values of SPR calculated as described in Section 4.2.3; only the 170 catchment average values coming from at least five events were used in the fitting process, although all catchments 205 were used to assess goodness of fit. The catchments and their SPR values are listed in Table C.2.

6.2.3 Estimating SPR via BFI

In Section 5.3 there is a set of BFI coefficients derived from an analysis of data from 575 catchments, and in Section 4.2.4. there is an equation relating BFI to SPR reproduced from a previous study on a set of 210 catchments. Combining these allows SPR to be estimated using the SPR coefficients given in Table 6.11.

Table 6.11 SPR coefficients derived via BFI

<table>
<tr><td>[1] 5.5</td><td colspan="2" rowspan="6">[13] 5.5</td><td colspan="2" rowspan="6">[14] 46.7</td><td colspan="2" rowspan="6">[15] 46.7</td></tr>
<tr><td>[2] 5.5</td></tr>
<tr><td>[3] 12.2</td></tr>
<tr><td>[4] 19.4</td></tr>
<tr><td>[5] 12.2</td></tr>
<tr><td>[6] 29.1</td></tr>
<tr><td colspan="3">[7] 19.3</td><td rowspan="2">[9] 23.2</td><td rowspan="2">[10] 51.3</td><td rowspan="2">[11] 10.4</td><td rowspan="2">[12] 60.7</td></tr>
<tr><td colspan="3">[8] 34.8</td></tr>
<tr><td>[16] 20.3</td><td>[18] 37.6</td><td>[21] 49.4</td><td colspan="2">[24] 51.3</td><td colspan="2">[26] 55.8</td></tr>
<tr><td>[17] 31.5</td><td>[19] 40.8</td><td>[22] 51.1</td><td colspan="2"></td><td colspan="2">[27] 54.8</td></tr>
<tr><td></td><td>[20] 37.2</td><td>[23] 57.5</td><td colspan="2">[25] 60.7</td><td colspan="2"></td></tr>
<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] 33.4</td></tr>
<tr><td colspan="2">[29] 54.3</td></tr>
</table>

The range of SPR coefficients is from 5.5% (corresponding to BFI of 1.0) to 60.7% (BFI of 0.17), which is greater than with the existing WRAP based method with a range of 10% to 53%, but not as great as for the observed data with a range from 3.8% to 77.5%. Figures 6.8 and 6.9 show plots of the estimated against observed values, and residuals against estimated values, respectively for the 205 catchment set. Figure 6.10 shows the distribution of residuals. The s.e.e. using this estimation procedure is 11.7%.

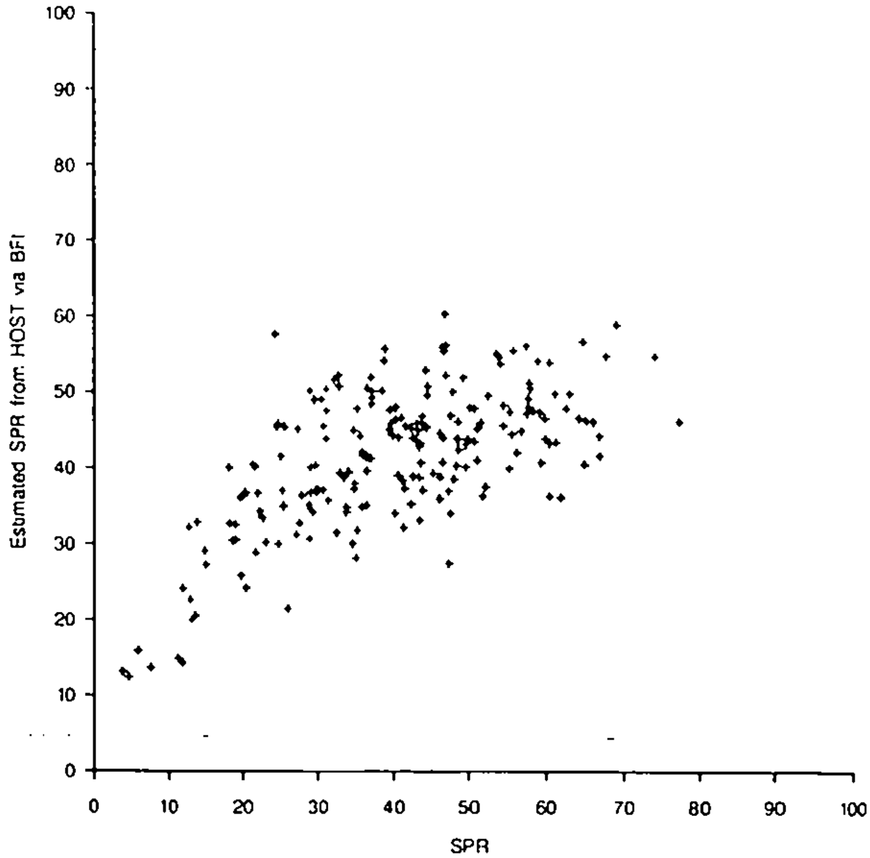


Figure 6.8 Estimated SPR from HOST via BFI against observed values of SPR

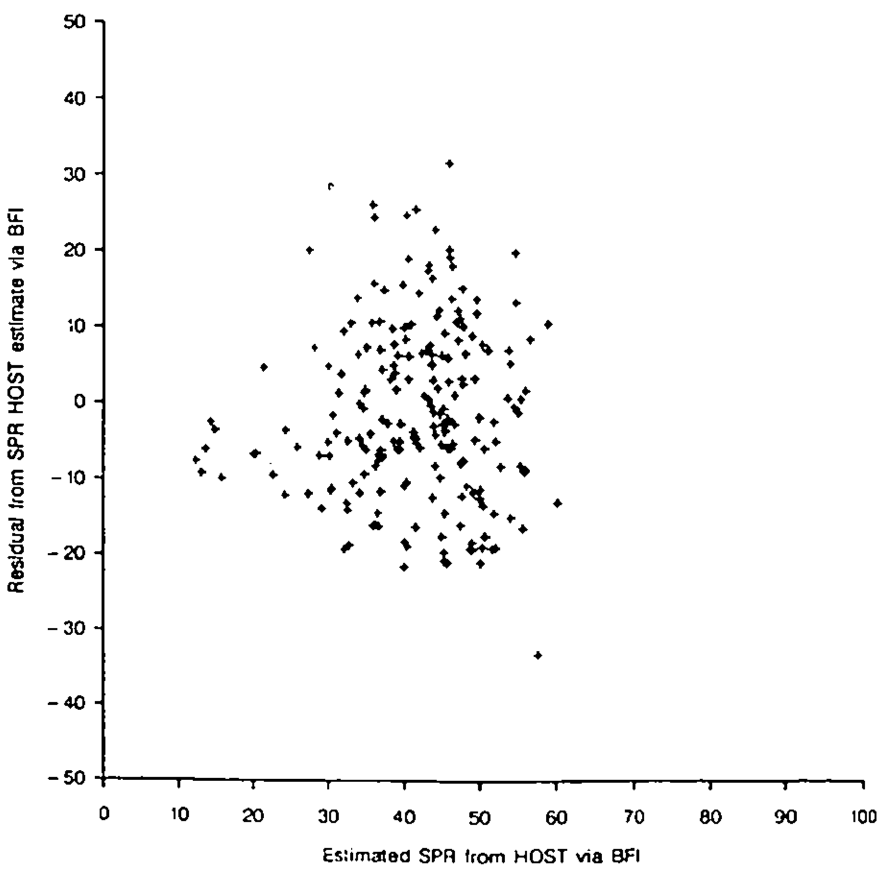


Figure 6.9 Residuals against estimated values of SPR

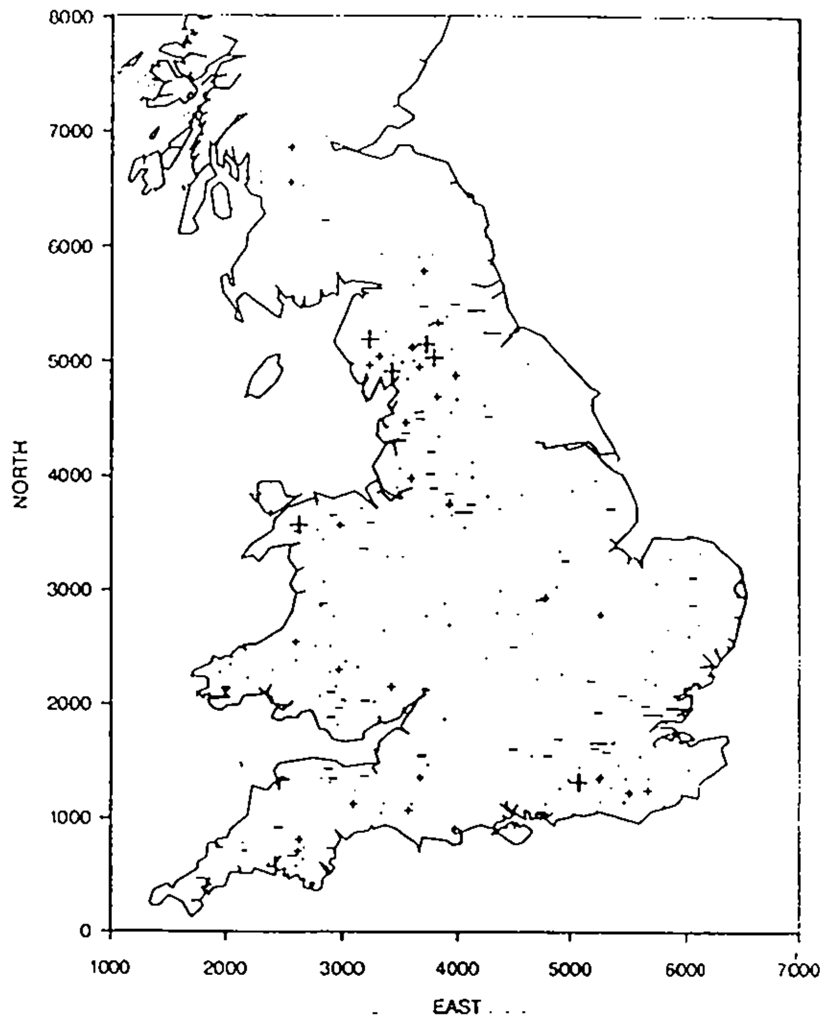


Figure 6.10 Map showing SPR residuals from estimation from HOST via BFI

No equivalent value is available from FSSR16 for comparison and so the WRAP based estimate has been calculated for the same data set; it has an s.e.e of 11.9%, only fractionally worse than from HOST using BFI. Figures 6.11 to 6.13 show the same three plots as above for the estimates obtained from WRAP. Using this method of estimating SPR gives only a very small improvement over WRAP and to see if this can be improved a direct calibration against HOST was performed. This is described in the next section.

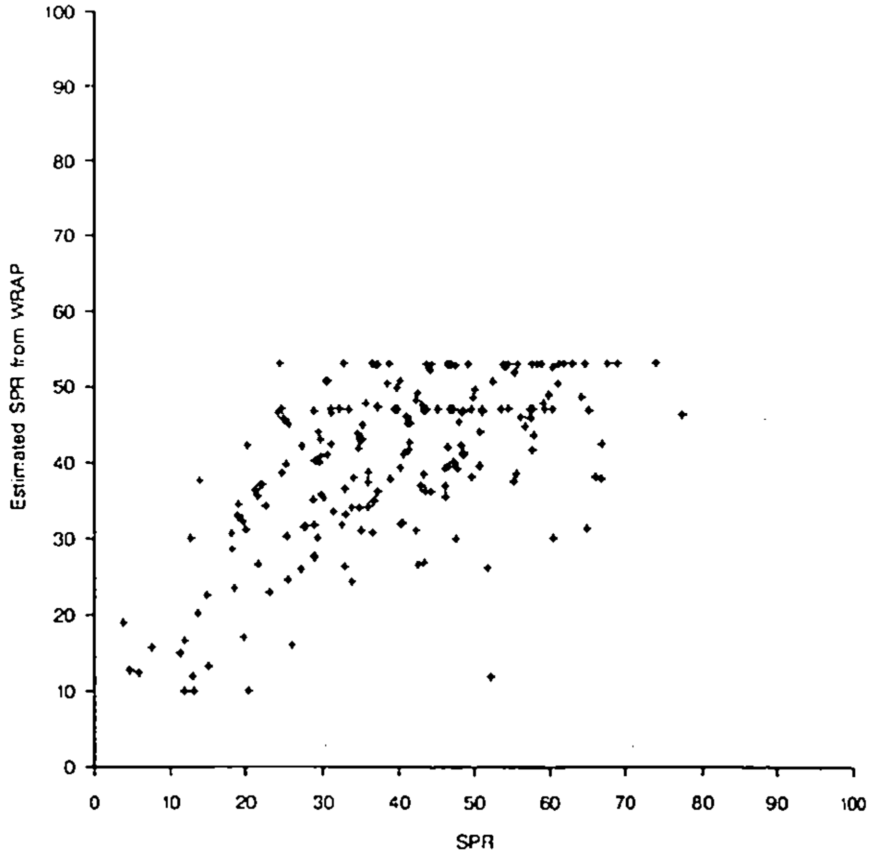


Figure 6.11 Estimated SPR from WRAP against observed values of SPR

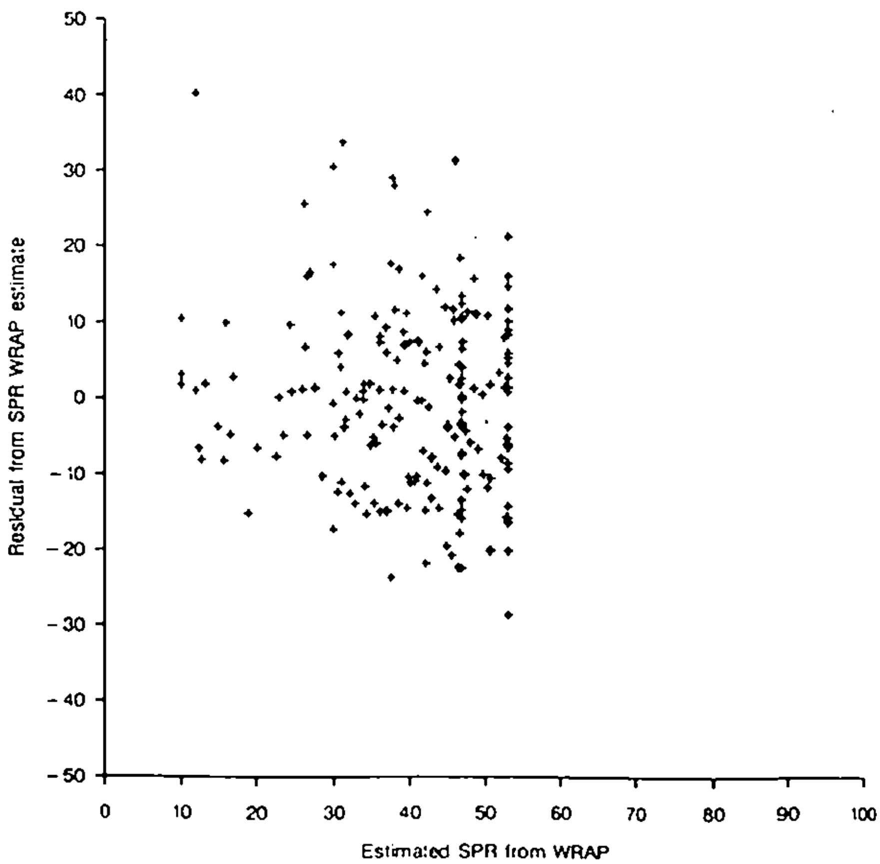


Figure 6.12 Residuals against estimated values of SPR from WRAP

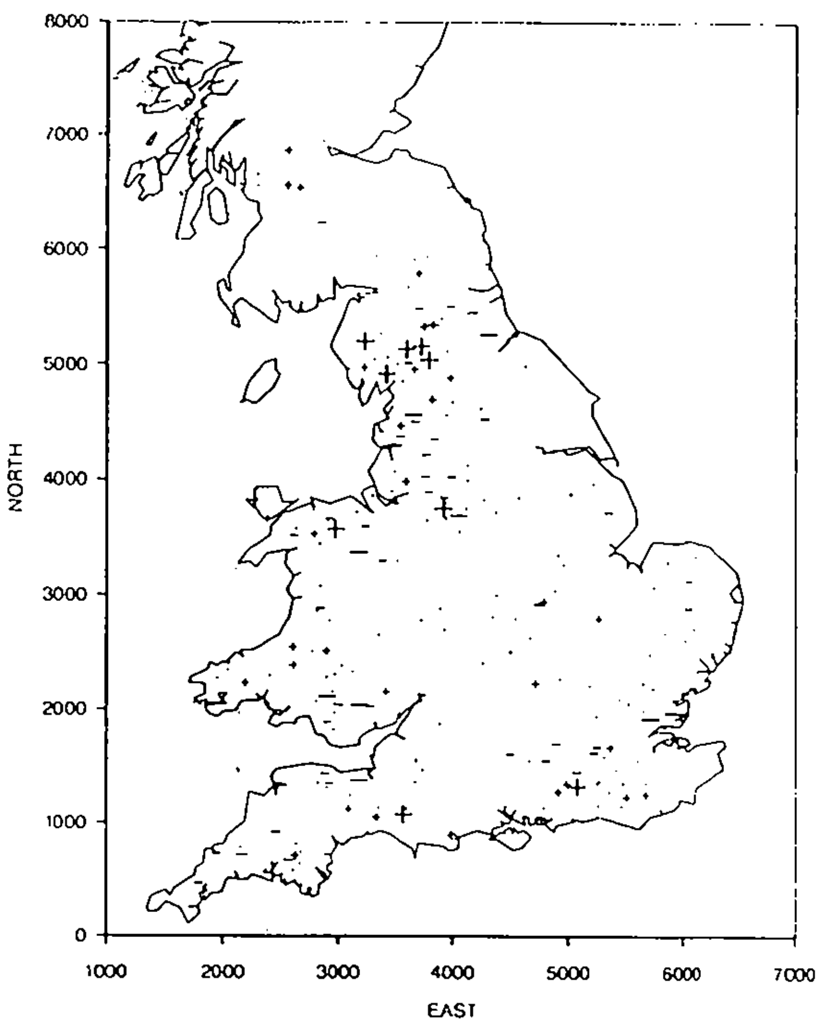


Figure 6.13 Map showing SPR residuals from estimation from WRAP

6.2.4 Direct estimation from HOST

A multiple linear regression of the same type as used to derive BFI coefficients was performed on the 170 catchment SPR data set. The resulting coefficients are shown in Table 6.12. As expected in a multiple regression with only 170 observations and 29 unknowns, the results are not very useful. No HOST class 28 soils are present on any of the 170 catchments, and many others occur in very small percentages, on a limited number of catchments, as can be seen from Table 6.13. 15 coefficients have t-statistics of less than 1.97, suggesting that they are not significantly different from zero at the 5% level. Several have coefficients that are negative or greater than 100%. The resulting model is clearly of no practical use, but its s.e.e. is 9.4% suggesting that even using a more reasonable, and hence less accurate, model some improvement of the estimation of SPR via BFI may be possible.

Two modifications to the analysis were made to obtain a usable regression model. First of all, as with BFI, the coefficients had bounds imposed on them so that they could only take on reasonable values. In percentage runoff terms these bounds could be set at 0% and 100%, but SPR, which represents standard and not extreme runoff, can reasonably be resticted to a smaller range. At the lower end of the scale a value of 2% was chosen on the pragmatic basis that in an application this would ensure some response was produced (perhaps rain falling

Table 6.12 SPR coefficients for HOST classes from multiple regression.

<table>
<tr><td>[1] -8.7</td><td colspan="2" rowspan="6">[13] -94.5</td><td colspan="2" rowspan="6">[14] -25.0</td><td colspan="2" rowspan="6">[15] 51.1</td></tr>
<tr><td>[2] -2.7</td></tr>
<tr><td>[3] 16.3</td></tr>
<tr><td>[4] -4.5</td></tr>
<tr><td>[5] 15.4</td></tr>
<tr><td>[6] 52.0</td></tr>
<tr><td colspan="3">[7] 46.5</td><td rowspan="2">[9] 43.6</td><td rowspan="2">[10] 34.6</td><td rowspan="2">[11] -55.9</td><td rowspan="2">[12] 72.5</td></tr>
<tr><td colspan="3">[8] 25.3</td></tr>
<tr><td>[16] 81.8</td><td>[18] 47.5</td><td>[21] 44.7</td><td colspan="2">[24] 40.2</td><td colspan="2">[26] 56.9</td></tr>
<tr><td>[17] 32.1</td><td>[19] 54.6</td><td>[22] 7.4</td><td colspan="2"></td><td colspan="2">[27] 102.8</td></tr>
<tr><td></td><td>[20] 127.5</td><td>[23] 43.4</td><td colspan="2">[25] 43.1</td><td colspan="2"></td></tr>
<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] None</td></tr>
<tr><td colspan="2">[29] 58.1</td></tr>
</table>

Table 6.13 Occurrence of HOST classes in the SPR data set; values represent equivalent number of catchments.

<table>
<tr><td>[1] 6.4</td><td colspan="2" rowspan="6">[13] 0.4</td><td colspan="2" rowspan="6">[14] 0.1</td><td colspan="2" rowspan="6">[15] 16.8</td></tr>
<tr><td>[2] 4.0</td></tr>
<tr><td>[3] 5.7</td></tr>
<tr><td>[4] 9.0</td></tr>
<tr><td>[5] 5.3</td></tr>
<tr><td>[6] 3.2</td></tr>
<tr><td colspan="3">[7] 1.0</td><td rowspan="2">[9] 2.0</td><td rowspan="2">[10] 4.5</td><td rowspan="2">[11] 0.6</td><td rowspan="2">[12] 1.0</td></tr>
<tr><td colspan="3">[8] 1.4</td></tr>
<tr><td>[16] 1.2</td><td>[18] 10.8</td><td>[21] 8.2</td><td colspan="2">[24] 25.5</td><td colspan="2">[26] 13.4</td></tr>
<tr><td>[17] 13.0</td><td>[19] 1.0</td><td>[22] 1.5</td><td colspan="2"></td><td colspan="2">[27] 1.2</td></tr>
<tr><td></td><td>[20] 2.3</td><td>[23] 3.1</td><td colspan="2">[25] 15.3</td><td colspan="2"></td></tr>
<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] 0.0</td></tr>
<tr><td colspan="2">[29] 11.7</td></tr>
</table>

on the channel itself). The upper bound was set at 60%, this being a rounded upper limit from the well defined coefficients from the unbounded regression (ie. mainly classes 26 and 29, but also class 19).

Secondly some classes were combined where they came from the same underlying response model, in a similar fashion to the way low flow HOST groups were defined in Section 6.1.2.

Thus the following classes were combined: 7 and 8 (both response model E), 9 and 10 (model F), 16 and 17 (model H), 18 and 21 (slowly permeable substrate, model I), 19 and 22 (impermeable [soft] substrate, model I), 20 and 23 (impermeable [hard] substrate, model I). This reduced the number of coefficients to be determined from 29 to 22; remember that the coefficient for HOST class 28 could not be determined analytically either. The resulting derived coefficients are shown in Table 6.14. The s.e.e. from this model is 10.0%.

***Table 6.14** SPR coefficients for HOST classes from bounded multiple regression, with some combined classes.*

[1] 2.0	[13] 2.0		[14] 2.0		[15] 48.5	
[2] 2.0						
[3] 14.4						
[4] 2.0						
[5] 14.4						
[6] 33.8						
[7] 44.1			[9] 25.7	[10] 25.7	[11] 2.0	[12] 60.0
[8] 44.1						
[16] 29.2	[18] 47.2	[21] 47.2	[24] 39.7		[26] 58.6	
[17] 29.2	[19] 60.0	[22] 60.0			[27] 60.0	
	[20] 60.0	[23] 60.0	[25] 49.6			
					[28] None	
					[29] 60.0	

The coefficients now show a good deal of consistency with the response models. However, whereas with the BFI coefficients there was a reduction from the left to the right of the diagram (ie. as the soil becomes increasingly waterlogged close to the surface), a slightly different picture emerges with the same general trend but with the soils with a gleyed layer within 40cm giving a lower response.

One explanation of this is that SPR represents a much faster response to rainfall than BFI. In the imperfectly drained soils they may give an increased response over a longer time period of a few days, than they do in the very short term. In such soils the presence of artificial drainage is likely to increase the volume of quick response runoff.

One concern about the coefficients shown in Table 6.14 is the value of 2% for class 14. The response model of this class (model C) suggests a rapid response mechanism more like models E or F which have SPR coefficients of 25.7% and 48.5% respectively. For this reason it was decided to link the HOST class 14 coefficient with coefficient for classes 9 and 10. For practical applications class 28 requires a value of SPR and a value of 60% was ascribed, in line with the high response from the other peat soils. The final set of coefficients is shown in Table 6.15; there has been no significant change in the s.e.e associated with this set of coefficients (ie. it remains at 10%).

Table 6.15 Final SPR coefficients for HOST classes from bounded multiple regression, with some combined classes.

<table>
<tr><td>[1] 2.0</td><td colspan="2" rowspan="6">[13] 2.0</td><td colspan="2" rowspan="6">[14] 25.3</td><td colspan="2" rowspan="6">[15] 48.4</td></tr>
<tr><td>[2] 2.0</td></tr>
<tr><td>[3] 14.5</td></tr>
<tr><td>[4] 2.0</td></tr>
<tr><td>[5] 14.5</td></tr>
<tr><td>[6] 33.8</td></tr>
<tr><td colspan="3">[7] 44.3</td><td rowspan="2">[9] 25.3</td><td rowspan="2">[10] 25.3</td><td rowspan="2">[11] 2.0</td><td rowspan="2">[12] 60.0</td></tr>
<tr><td colspan="3">[8] 44.3</td></tr>
<tr><td>[16] 29.2</td><td>[18] 47.2</td><td>[21] 47.2</td><td colspan="2">[24] 39.7</td><td colspan="2">[26] 58.7</td></tr>
<tr><td>[17] 29.2</td><td>[19] 60.0</td><td>[22] 60.0</td><td colspan="2"></td><td colspan="2">[27] 60.0</td></tr>
<tr><td></td><td>[20] 60.0</td><td>[23] 60.0</td><td colspan="2">[25] 49.6</td><td colspan="2"></td></tr>
<tr><td colspan="5" rowspan="2"></td><td colspan="2">[28] 60.0</td></tr>
<tr><td colspan="2">[29] 60.0</td></tr>
</table>

For these coefficients estimated SPR values are plotted against observed values in Figure 6.14, and the residuals against the estimates in Figure 6.15. It is clear that there is considerable scatter in these figures, and, as should be expected, the extremes are poorly estimated. Figure 6.16 shows a map of the SPR residuals; two regions show consistent underestimation, the Weald and Cumbria, and in the coastal region of north-west England and North Wales there is a confused picture of poor estimation.

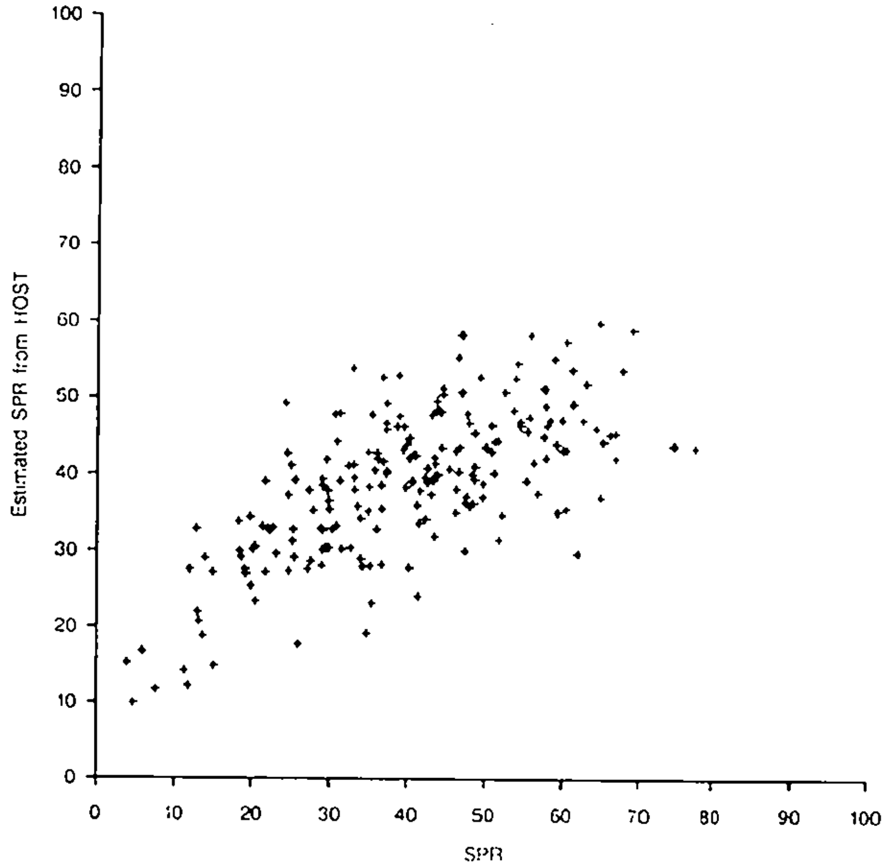


Figure 6.14 Estimated SPR from HOST against observed SPR

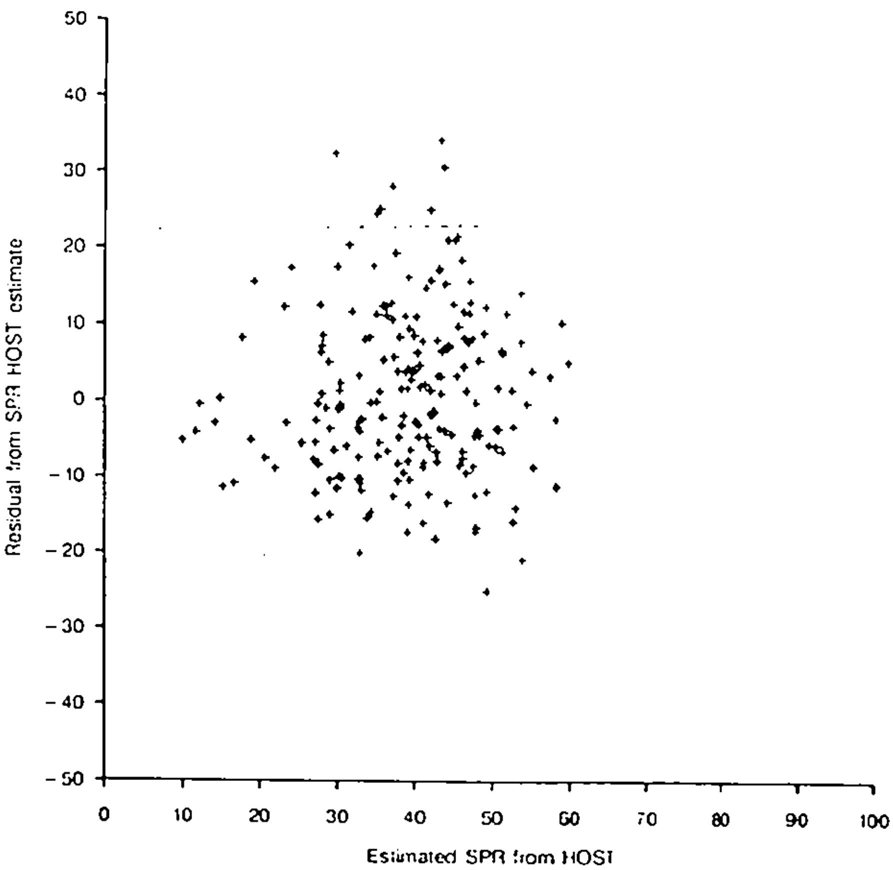


Figure 6.15 Residuals against estimated values of SPR from HOST

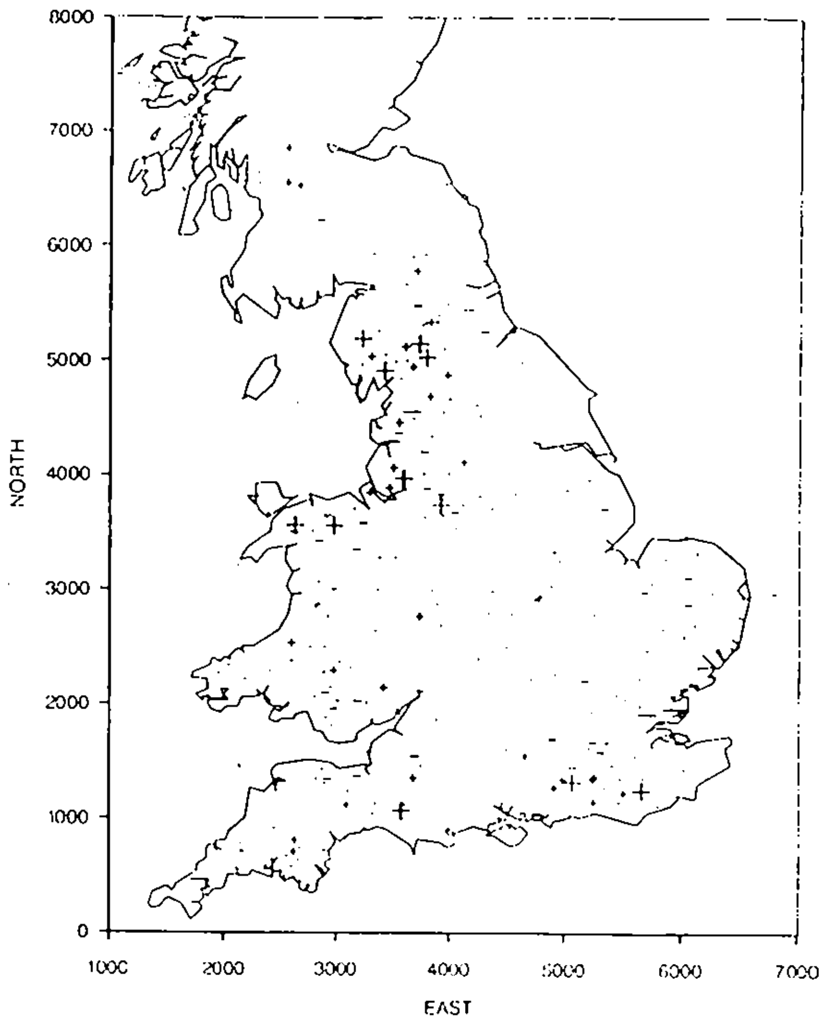


Figure 6.16 Map showing distribution of SPR residuals from estimation from HOST

6.2.5 Comparison of SPR estimation methods

Three ways of estimating SPR have been presented: the method of FSSR16 based on WRAP, a method based on HOST using BFI as an intermediate step, and direct estimation from HOST. The s.e.e. gives an objective method of comparing the goodness of fit: from WRAP s.e.e. is 11.9%, from HOST using BFI s.e.e. is 11.7%, and directly estimating SPR using HOST s.e.e. is 10.0%.

The second of these (ie. estimation via BFI) appears to have no real advantage over using WRAP, since the estimate is likely to be only very slightly more accurate but obtained with far greater effort. However, it may be appropriate, in particular circumstances, to use aspects of this procedure in combination with local data.

In terms of the s.e.e., estimating SPR from HOST offers a small but worthwhile improvement over using WRAP. Part of the explanation for this can be seen by comparing Figures 6.11 and 6.14. In the former, the banding of estimates in the top two WRAP classes is obvious, many catchments have the maximum 53% estimated SPR. In Figure 6.14 a number of catchments have estimated SPR above 53%, but only one with the maximum 60%; at the bottom end of the scale the minimum estimated SPR is about 10%, although a value as low as 2% is possible. Figures 6.13 and 6.16 in which the distributions of residuals are plotted show similar regional trends. However, when the two estimates are plotted against each other as in Figure 6.17 then it is clear that the two methods will produce significantly different estimates on some catchments.

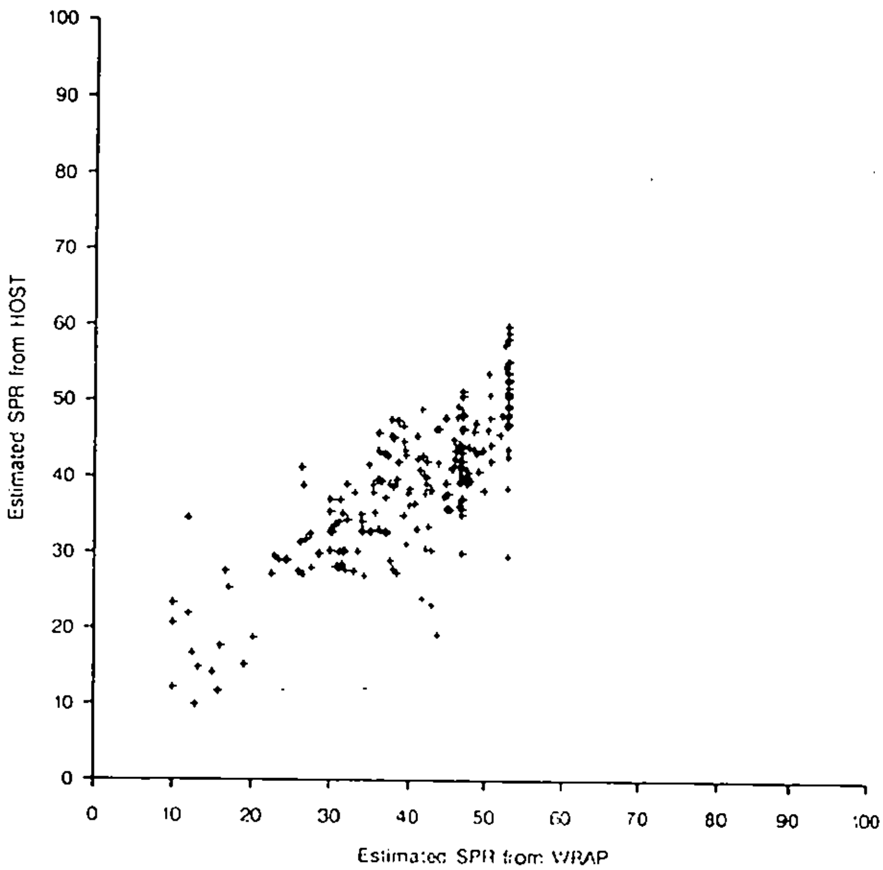


Figure 6.17 SPR estimates from HOST plotted against SPR estimates from WRAP

Two more qualitative benefits accrue from the use of HOST. Firstly the better resolution of both the maps and the classification system mean that, even on small catchments, several HOST classes are likely to be found. In only 13 of the 170 catchments with at least five events was the observed SPR outside the range of the HOST coefficients for classes found on the catchment. Looking at the percentage runoff from all classes may therefore give an indication of the possible range of SPR.

Secondly, HOST provides a means of selecting a suitable catchment from which data may be transferred. It must be remembered that while HOST gives a better estimate than WRAP, it is still a fairly uncertain estimate which should be refined by looking at local data. A comparison of the HOST classes on the study catchment and various neighbouring catchments will indicate the most suitable analogue for the transfer of SPR.

6.2.6 Conclusion and recommendation

The HOST classification provides a step forward towards more accurate estimation of SPR. The recommended coefficients, equivalent to SPR values, for each of the HOST classes are shown again, in class number order, in Table 6.16. Estimates made using these coefficients had a s.e.e. of 10% on the data available for this study. These coefficients have been derived by a mixture of regression analysis and reference to the physical response models at the core of HOST. As well as being useful for direct estimation of SPR, the HOST classification provides a way of selecting analogue catchments for the transfer of local data, and envelope values for the estimate of SPR.

Table 6.16 Recommended SPR values for HOST classes

HOST class	SPR value (%)	HOST class	SPR value (%)
1	2.0	16	29.2
2	2.0	17	29.2
3	14.5	18	47.2
4	2.0	19	60.0
5	14.5	20	60.0
6	33.8	21	47.2
7	44.3	22	60.0
8	44.3	23	60.0
9	25.3	24	39.7
10	25.3	25	49.6
11	2.0	26	58.7
12	60.0	27	60.0
13	2.0	28	60.0
14	25.3	29	60.0
15	48.4		

As a very broad indication, Figure 6.18 shows an outline map of SPR for the United Kingdom.

Figure 6.18 (Following) General distribution of SPR calculated from HOST

Distribution of SPR (HOST)

6.2.7 An example of the calculation of SPR from HOST

The estimation of SPR via HOST is illustrated for the St. Neot at Craigshill Wood catchment (NWA number 48009) which has an area of 22.7km^2. The first stage in making the estimate is to abstract the HOST classes found within the catchment boundary. This can be done either by overlaying the boundary on the soil map manually, or by performing this operation on digital HOST or soil map data sets. These processes are described fully in Section 7. Table 6.17 shows the HOST classes found on the catchment and illustrates how the SPR estimate is made.

Table 6.17 HOST classes for 48009 and the calculation of SPR

HOST class	Fraction	SPR for class	SPR × Fraction
4	13	2.0	0.26
9	.01	25.3	0.25
15	.47	48.4	22.75
17	.21	29.2	6.13
18	.01	47.2	0.47
22	.03	60.0	1.8
29	.14	60.0	8.4
Estimated SPR = ΣSPR×Fraction			40.06

It will be seen from the table that this is a catchment on which the estimated SPR from the component HOST classes ranges from 2% to 60% (ie. the two extreme values). A user should be aware that a different mapping of the soils, or a variation from the nationally assigned proportions of soil series within the map units may lead to a very different flood estimate. The user is therefore made aware of the possibility that the estimate may be particularly unreliable.

In is interesting to compare this HOST based estimate with the one from WRAP. Table 6.18 is the WRAP equivalent of Table 6.17 and again shows a mixture of soil types with very different, but less extreme, SPR values.

This catchment is in fact one of those used in the development of the HOST classification and is one for which SPR has been calculated; from 7 events observed SPR is 37.2%. Although in this case the HOST estimate is a good one, and better than from WRAP, this will not always be the case. Figure 6.16 shows that on many catchments there will be a substantial error in the HOST estimate, and Figure 6.17 implies that in some cases estimates from WRAP will be better than those derived from HOST.

Table 6.18 WRAP classes for 48009 and the calculation of SPR

WRAP class	Fraction	SPR for class	SPR × Fraction
2	.2	30.	6.0
5	.8	53.	42.4
Estimated SPR = ΣSPR × Fraction			48.4

7 Access to the HOST system

The development of the HOST classification required the overlay of catchment boundaries on soil maps. This process was performed automatically by computer. To use HOST in the estimation of hydrological parameters, users will have to perform this overlaying. This section describes three ways in which this can be done: one manual method, and two computer-based overlay procedures using the HOST digital data set and the digitised 1:250,000 soils data set.

7.1 MANUAL OVERLAY

Information provided in this report can be used with the published 1:250,000 national soil maps to help estimate hydrological parameters. Figure 7.1 shows the boundary for the St Neot catchment at Craigshill Wood overlain on the national soil map (England and Wales Sheet 5, Soils of South West England). Table 7.1 shows the areas of the various map units located within the boundary that can be abstracted either using a planimeter or by counting squares on millimetre graph paper. In the example the latter method has been used and the number of squares in each map unit is shown. Two occurrences of each of two units are present, and of course these are added together to obtain the total coverage. As a check that the areas have been abstracted correctly, the total number of squares can be converted to an area in square km by dividing by 16 (1km = 4mm at 1:250,000 and the calculations were done on 1mm graph paper). Thus 383/16 = 23.9km^2 which is larger than the published area of 22.7km^2 but within an acceptable margin of disagreement. It will also be noted that on the catchment is a small lake, but this is totally within an area marked as being map unit 1013b and is therefore counted as being part of that unit.

The table shows that on this relatively small catchment there are seven different soil map units. The component HOST classes for each of these map units are listed in Appendix B and below as Table 7.2. The breakdown of these seven map units by class shows that some map units comprise a single HOST class whereas others can be divided into four classes. If this is related back to the description in Sections 4.3.1 and 4.3.2 of how soils are mapped, then soil map unit 651b (Hexworthy), for example, is seen as one that contains soil series that have similar hydrological properties, whereas in map unit 541j (DENBIGH1) the opposite is true. To calculate the overall cover of each HOST class on the catchment then the information contained in Tables 7.1 and 7.2 must be combined; this calculation is contained in Table 7.3. Summing the HOST class fractions provides a check that no errors have crept into the arithmetic. Once fractions have been rounded the total is slightly less than one and a simple way of adjusting for this, in this instance, would be to add 0.01 to the largest fraction.

These HOST class fractions can now be used for any of the applications described in Section 6.

It should be noted that in performing the overlay on the paper version of the map then "unsurveyed" or "built-up areas" and "lakes" may be found. In the estimation of the low flow variables as described in Section 6.1 these should be calculated and used in the same way as any other map unit. In the estimation of SPR then they should be ignored; this will lead to a total of the HOST class fractions that is less than unity, and the various fractions must be scaled so the correct total of 1.0 is achieved. In the above example is was possible to include the lake as part of one of the mapped units and no scaling was necessary.

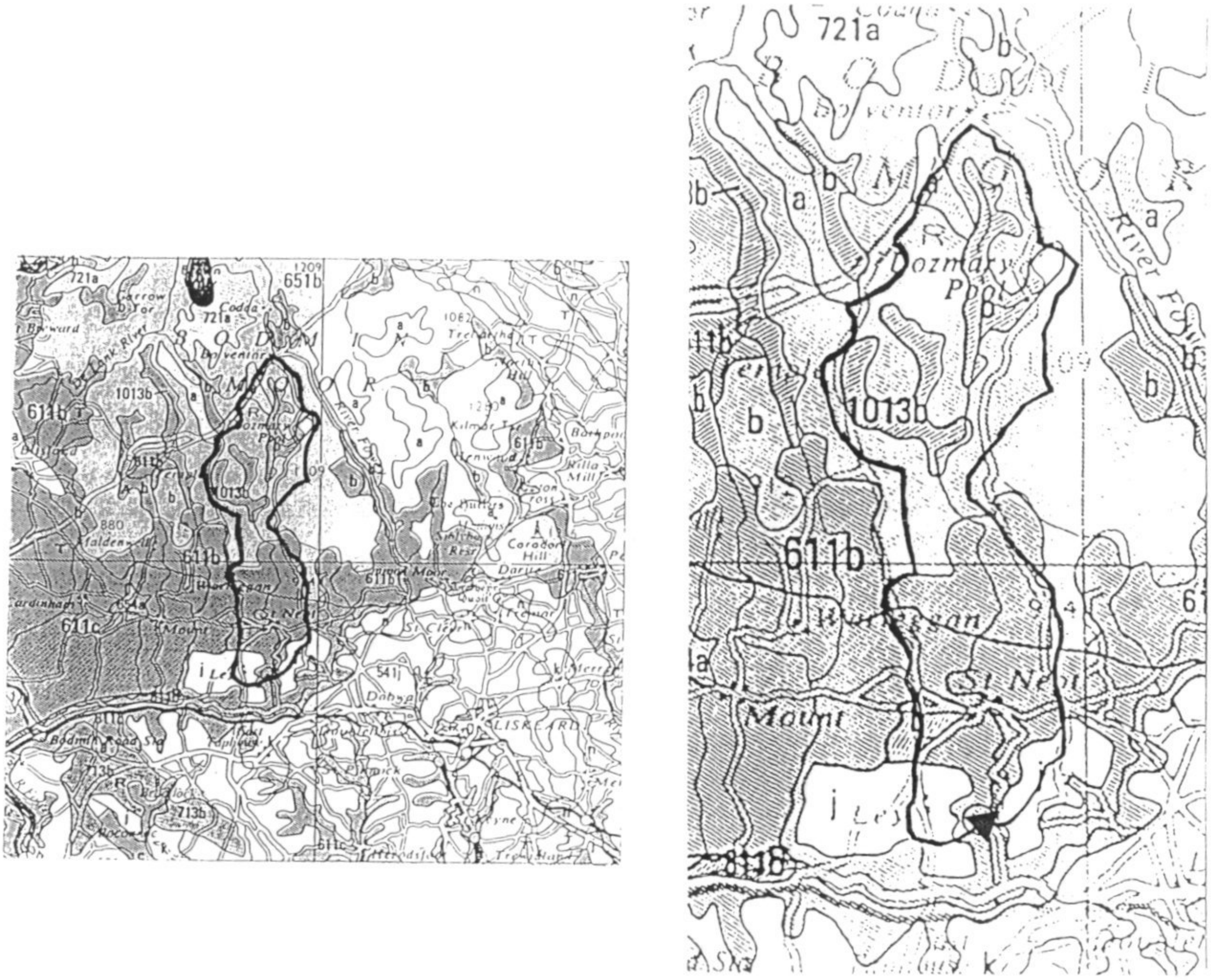


Figure 7.1 Overlay of catchment boundary on soil map. On the left this is shown at the actual size of the 1:250,000 map, on the right this is enlarged for clarity.

Table 7.1 Fractions of soil map units on catchments from manual overlay.

Map unit	Squares on mm paper	Coverage (%)
541j	13+8=21	2.3
611b	44	16.7
611c	73	5.5
651b	162	11.5
713b	10	19.1
721a	9	2.6
1013b	32+27=64	42.3
TOTAL	383	100

Table 7.2 HOST classes in soil map units on catchment

Map unit	Component HOST classes HOST class number (percentage in map unit)
541j	4(13.33), 17(60.00), 18(13.33), 22 (13.33)
611b	4(100)
611c	17(87.5), 22(12.5)
651b	15(100)
713b	9(43.75), 15(18.75), 21(18.75), 24 (18.75)
721a	15(100)
1013b	29(100)

Table 7.3 Calculation of HOST class fractions on catchment 48009

HOST class	Components (percentage HOST class in map unit x percentage map unit in catchment)	Total (sum of components)	Fraction (total adjusted to a fraction)
4	13.33x5.5=73.315 100x11.5=1150.	1223.315	.12
9	43.75x2.6=113.75	113 75	.01
15	100x42.3=4230. 18.75x2.6=48.75 100x2.3=230.	4508 75	.45 (adjust to 0.46 to compensate for rounding errors)
17	60.00x5.5=330. 87.5x19.1=1671.25	2001 25	.20
18	13.33x5.5=73.315	73.315	.01
21	18.75x2.6=48.75	48.75	.00
22	12.5x19.1=238.75 13.33x5.5=73.315	312.065	.03
24	18.75x2.6=48.75	48.75	.00
29	100x16.7=1670.	1670.	.17
TOTAL		9999 945	.99

It will be noted that the calculation of the HOST class fractions has required only this report and the published maps (exactly the same process could have been applied to a Scottish catchment). However, if the exercise had to be undertaken on a large catchment, or repeated on a great many catchments then considerable effort would be expended. The digital versions of the HOST and soil maps can provide relief from this drudgery by handing the task to a computer. Sections 7.2 and 7.3 describe these two digital data sets.

7.2 THE 1:250,000 SOIL DATA SET

Both SSLRC and MLURI have digitised their 1:250,000 soil maps and have them stored on computer databases. The data sets have been constructed by digitising the lines on the maps, forming these into polygons and labelling them with the appropriate map unit. From this vector version of the data set, rastered versions have been produced, in which the map units within 1km or 100m cells have been identified.

To use HOST in estimating catchment parameters, it is clearly possible to overlay the catchment boundary on the digitised map, abstract the map units, and convert these to HOST using a key. For users who are also interested in other properties of soils beyond those offered by HOST, then this may be an attractive route into HOST. Such users should contact SSLRC and MLURI to discuss leasing of the soil map data and HOST key.

For users who only require the HOST data then a derived data set has been prepared and this is described in the next section.

7.3 THE 1KM HOST DATA SET

The HOST data set is the result of applying the HOST classification to the soils of the national maps as represented on a 1km grid. The process was therefore a two stage one: firstly the soil map units in each 1km square were identified, and then the HOST classification was applied to the map units. The percentage of each HOST class was then calculated as the sum of the percentages across all map units.

Since there can be several map units within each 1km (the most found was in fact 7), and several HOST classes represented within a map unit (maximum found was 5), it might be expected that in some 1km squares a great many HOST classes were present. In fact, because many neighbouring map units have some soils in common, this does not happen, and very few 1km squares have more than seven classes. Seven was taken as the maximum number of classes to be stored in the HOST data set, and where more existed, the smallest were ignored and the percentages of the others rounded up to compensate.

A further adjustment of the percentages was made to round them all to the nearest integer, and then to adjust them so the sum of the percentages is 100. These adjustments were considered worthwhile to reduce the storage space of the derived data set. Although there may appear to be some loss of information in this process this is not the case as there are many other sources of uncertainty in compiling the HOST data set including: the accuracy of the underlying soils maps, the use of constant fractions for the series break down of the map units, and neglecting small component series within the map unit.

When a catchment boundary is overlain on this data set then the 1km squares that are completely within the boundary contribute directly to the sum of the HOST classes for the catchment. Where the boundary crosses a square then the proportion of the square within the catchment is found, and all classes within the square are assumed to occur in this portion in the same distribution as in the whole square.

This overlay will therefore give different HOST fractions from those obtained from a manual overlay, but only on very small catchments is the difference likely to be great. As with any other catchment characteristic derived from a map, care is always needed on small catchments both in abstracting the data and in using that information to estimate another parameter. Section 8 describes ways in which a better representation of the HOST classes can be obtained which are particularly applicable to small catchments.

Table 7.4 contains the HOST fractions obtained from the overlay on the 1km data set and should be compared with Table 7.3 which has the corresponding values from a manual overlay. It will be noted that the differences between the two sets of values are relatively minor.

Table 7.4 Fractions of HOST classes on catchment 48009 derived from HOST data set.

HOST class	Fraction
4	.13
9	.01
15	.47
17	.21
18	.01
22	.03
29	.14

8. Conclusions and recommendations

A new soil classification that uses physical property data to define soil classes has been developed for hydrological purposes. The classification, which is known by the acronym HOST (Hydrology Of Soil Types), is based on conceptual models of the processes taking place within the soil and, where appropriate, substrate. Catchment-scale hydrological indices (mainly BFI and SPR) were used in the development of the HOST classification.

The classification is based on soil series and is therefore not limited to application at any one scale. However, applicability throughout the UK is assured by the accessibility to HOST via the national reconnaissance mapping of soils at a scale of 1:250,000 (only a provisional map of Northern Ireland is currently available). For some applications it may be appropriate to access the HOST system through a computer-based data set: a 1km HOST data set has been created for this purpose.

The efficacy of the HOST classification has been demonstrated in estimating important parameters needed for flood and low flow studies. In these catchment-based studies, HOST has so far only been used by abstracting the coverage within the topographic catchment boundary. An alternative strategy for use in design flood estimation, would be to weight the soils within the boundary according to, say, their distance from a river channel, since flood response is thought to be generated predominantly from a riparian zone. It is also hoped to use the HOST classification of soils directly within distributed catchment models.

9. Acknowledgements

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Appendix A A brief history of the development of the HOST classification system

The result of the HOST project is a classification scheme that is defined in terms of physical models with subdivisions based on soil properties or the substrate hydrogeology. This appendix describes the evolution of the classification during the HOST Project.

As described in Section 4, the WRAP classification and map were seen as a logical starting point. The first idea to improve upon WRAP was simply to code the new 1:250,000 soil maps with the appropriate WRAP classes, since this would solve one of the main problems with WRAP, that is that the scale was not adequate to represent the spatial variability of the soils. A modification to this approach was to use a revised WRAP scheme that subdivided the WRAP types 1, 2 and 5 as shown in Table A.1

Table A.1 An early proposal for a divided WRAP classification

WRAP class	New class	Description
1	1	Soil associations over chalk
	2	Soil associations over sand
	3	Soil associations over hard limestone
2	4	Brown earths, moist areas over shale or rock
	5	Groundwater gleys and lowland peat
	6	Argillic brown earths and Paleo-argillics (excluding chalks)
3	7	No change
4	8	No change
5	9	Hill Peat
	10	Humic Rankers

While the notion of bolting-on additions to WRAP to give it greater resolution had appeal as an evolutionary approach, it was seen as limiting the possibilities within a revised scheme.

The first scheme considered that departed from WRAP considered a broad division into four major groups, and 10 classes as shown in Table A.2. The geology of the substrate was seen as being a key differentiating characteristic in one of the groups. In two groups IAC was proposed as a surrogate for permeability. IAC could be calculated for all soils, but in some cases this would be through aggregating air capacities from similar horizons in different soils. These early classification schemes were examined initially by referring to 'benchmark' catchments. If catchments were dominated by soils of a particular class and had similar hydrological characteristics this supported the classification scheme, but where these catchments had very different hydrological properties it was clear that the classification was inadequate.

The use of these benchmark catchments quickly showed that classes D and F contained soils with very different response characteristics. In class D it seemed necessary to divide deep peat soils from thin peat soils over a variety of substrates. Class F appeared to need further division on the basis of substrate geology.

Table A.2 The first proposal to depart from WRAP

Major differentiating characteristics	Class	Class differentiating properties
Soils with a ground water table within 2m depth	A	IAC ≥ 175
	B	175 > IAC ≥ 125
	C	125 > IAC
Soils with evidence of wetness below a peaty or humose surface horizon and no groundwater within 2m depth	D	None
Soils, excluding A, B, C and D that overlay hard or shattered rock or gravelly substrates within 80cm of the soil surface	E	Chalk or soft sandstone substrates
	F	Shattered rock, gravel or fissured limestone
	G	Hard coherent rock substrates
Deep soils, excluding A, B, C and D on very soft or unconsolidated substrates	H	IAC ≥ 175
	I	175 > IAC ≥ 125
	J	125 > IAC ≥ 75
	K	75 > IAC

In retrospect it is difficult to be certain at what stage it became clear that it was impractical to place map units in these classes. In the scheme represented by Table A.1 this was certainly the intention. However, as soon as more physical properties were introduced it became clear that the new classification had to be series-based, since the properties can only be defined in a meaningful sense for soil series. It therefore became important to have figures for the percentages of the different soil series within the map units. While it was clearly a simplification to assume that soil series were represented in the same proportions in all occurrences of a map unit, it was necessary to make such an assumption.

At this stage the classes were allocated to soil series by inspection and it was therefore very laborious to try a different form of classification. If the various soil parameters could be specified for each soil series then the classification could be altered simply be changing a set of class definitions. In the first data set of properties, three soil parameters were included: depth to a gleyed layer (evidence of seasonal waterlogging), depth to an impermeable layer (indicating the vertical movement in the soil prior to a lateral flow) and IAC (useful both as a measure of storage capacity and permeability). Three other properties were seen as important; slope, drainage and climate. At that time overland slope data were not readily available and although some work was done using channel slopes this was not productive and slope was not considered further in the HOST project. Some information was available on drainage and although it was used in the earlier stages of the project it was later disregarded; the possible future use of drainage in some of the final HOST classes is seen as a likely further development of HOST. Climate is one of the important factors influencing the formation of soils, and is clearly important in influencing the hydrological response of basins. There were lengthy discussions about whether the climate should be used to help define the new classification, or whether it should be another input used in applications of the new system. It was agreed to use the annual average rainfall in some studies to ascertain its value when used with the soil data to discriminate between benchmark catchments. Eventually this parameter was also disregarded in the definition of the HOST classification.

A data base of properties was established that contained average proportions of the soil series in each map unit, and the three soil physical properties. Although some analysis work was done using these properties alone it became clear at a very early stage that other information was required. From the above tables it can be seen that important properties in the two schemes are the substrate geology, the soil depth, the presence and, if appropriate, depth to an aquifer or groundwater, and the presence of a peaty top layer to the soil. It was decided to add these to the data held for each series. The geological classification, as described in Section 4, was based on the hydrogeological classification used by BGS, but many other classes were added. Table A.3 shows the nature of the data available to describe all of the soil properties.

Table A.3 Description of data available for each soil series

Property	Nature of data
IAC	Value in cm.
Depth to an impermeable layer	Value in cm (if > 1m then set to -100)
Depth to a gleyed layer	Value in cm (if > 1m then set to -100)
Soil depth	Options: DEEP,SHALLOW
Peaty top layer	Options: YES, NO
Depth to groundwater or aquifer	Options: >2m, <2m, NO
Substrate hydrogeology	See Table 4.8

It is perhaps worth dwelling slightly longer on the hydrogeological classification of the substrate. It was hoped that the new classification could be based as far as possible on physical properties of the soils. While some other properties may appear more appropriate than those in Table A.3, hydraulic conductivity for example, such data were not available. It was hoped that the data that were available would act as surrogates for these more desirable properties. Although substrate geology appeared to be important, it was hoped that some simple properties might be sufficient to represent what geology was thought to be contributing to the classification. Again physical properties relating to the substrate would be most appropriate but all that was available were the inferred properties soil depth, and depth to a water table. It quickly became clear that this was not the case and the descriptive substrate geology classification became an essential element of the project.

Once this data set had been established it become possible to test classifications more easily. One of the first experiments was to partition the continuous variables to form discrete variables and examine all possible combinations of the parameters. Even when this was done using a highly simplified substrate hydrogeology scheme a great many classes result, although very many of these contain no recognised soil series. However, using this type of approach in combination with the benchmark catchments, it was possible to see some aspects of the scheme where distinctions seemed necessary, and others where they did not. In this way it was possible to group soils into roughly 130 classes, but this was clearly far too many classes to form a practical tool for hydrologists, and it was difficult to see any rationale as to why some distinctions seemed necessary but other not.

To take the development further it was necessary to go back and consider the processes occurring in the soil and substrate. By considering these simple physical models it became possible to group the 100 plus classes into a more manageable number. However, using this approach did not lead directly to a unique set of classes; one scheme resulting from this approach is shown in Table A.4. With this type of classification, that has only 26 classes, it is possible to perform multiple regression analyses using BFI as the dependent variable and the fractions of the classes as the independent variables.

Table A.4 An example of a classification based on the soil series properties

Substrate hydro-geology	Subdivision	Further differentiation	Cases
Permeable	Intergranular flow (deep water table)	For each subdivision the following cases are distinguished 1. No gleyed or impermeable layer within 1m 2. Not 1. and IAC>125 3. Not 1. and IAC≤125	3
	Intergranular flow (shallow water table)		3
	Fissure flow		3
	Clay with flints		1
	Any permeable geology with no gleyed or impermeable layer within the top 1m and a peaty top soil		1
Peat	Earthy		1
	Eroded Blanket		1
	Raw		1
Impermeable	Hard	For each subdivision the following cases are distinguished 1. Not gleyed within 40cm, IAC >125 2. Not gleyed within 40cm, 125≥IAC>75 3. Not gleyed within 40cm, 75≥IAC 4. Gleyed within 40cm, no peaty top 5. Gleyed within 40cm, peaty top	4
	Clay		3
	Others		5

Using both the multiple regression studies, and the benchmark catchments, many different classifications were examined to see which variables appeared useful in differentiating catchment-scale parameters, and which were not. For example in the above scheme the 3 classes based on IAC in the impermeable substrate section appeared to contribute little to the resolution of the catchment-scale parameters. In other models a greater division of permeable substrate geology yielded benefits.

While the process of combining or separating classes referred to the hydrological data, it also considered the physical processes at work in the soil. Classes were never merged simply because they did not help the hydrological estimation process but only when the classes represented similar physical models.

Using this approach a classification with about 30 classes seemed inevitable. This was certainly more than had been envisaged at the start of the project when it was thought that a system with around 10 classes would be appropriate. This earlier estimate was based on the expected accuracy in estimating hydrological parameters. While combining then 30 classes into 10 would result in no loss in accuracy in estimating BFI or SPR, it would probably compromise the use of the classification for other purposes. This idea is easily understood by referring back to the table defining the WRAP classification (Table 4.1) which shows that WRAP class 5 covers 2 water regime categories, 3 depth to impermeable layer categories, 3 slope categories, and 3 permeability categories. It is hard to imagine that the same physical processes are dominant within such a diverse collection of soils.

Map units in England and Wales

CODE	MAP_UNIT	CLASS	PERC
0C	CHINA CLAY WORKS	17	100.00
0L	LAKE	98	100.00
0S	SEA	99	100.00
0U	UNSURVEYED	97	100.00
22	UNRIPENED GLEY SOILS	9	100.00
92a	DISTURBED SOILS1	21	100.00
92b	DISTURBED SOILS2	21	100.00
92c	DISTURBED SOILS3	24	100.00
311a	REVIDGE	15	42.86
		29	57.14
311b	SKIDDAW	15	33.33
		27	53.33
		29	13.33
311c	WETTON1	4	41.86
		15	58.14
311d	WETTON2	4	23.08
		15	76.92
311e	BANGOR	27	57.14
		29	42.86
313a	DUNWELL	19	38.89
		22	44.44
		27	16.67
313b	POWYS	17	33.33
		22	66.67
313c	CRWBIN	4	100.00
341	ICKNIELD	1	94.74
		6	5.26
342a	UPTON1	1	100.00
342b	UPTON2	1	100.00
342c	WANTAGE1	1	88.89
		6	11.11
342d	WANTAGE2	1	69.23
		9	30.77
343a	ELMTON1	2	100.00
343b	ELMTON2	2	90.00
		4	10.00
343c	Elmton3	2	56.25
		23	25.00
		25	18.75
343d	SHERBORNE	2	77.78
		23	22.22
343e	MARCHAM	2	100.00
343f	NEWMARKET1	1	100.00
343g	Newmarket2	1	84.21
		5	15.79
343h	ANDOVER1	1	90.00
		6	10.00
343i	ANDOVER2	1	85.00
		6	15.00
346	Reach	9	100.00
361	Sandwich	5	89.47
		10	10.53
372	Willingham	10	85.00
		11	15.00
411a	Evesham1	2	29.41
		23	70.59
411b	EVESHAM2	23	52.94
		25	47.06
411c	EVESHAM3	20	23.08
		23	61.54
		25	15.38
411d	HANSLOPE	21	100.00
421a	STOW	16	16.67
		20	55.56
		21	16.67
		24	11.11
421b	HALSTOW	17	10.99
		21	45.05
		24	43.96
431	WORCESTER	21	100.00
511a	ABERFORD	2	89.47
		6	10.53
511b	Moreton	2	65.96
		23	34.04
511c	PANHOLES	1	90.00
		6	10.00
511d	Blewbury	1	68.75
		13	31.25
511e	SWAFFHAM PRIOR	1	100.00
511f	COOMBE1	1	77.78
		6	22.22
511g	COOMBE2	1	100.00
511h	BADSEY1	5	77.78
		7	11.11
		8	11.11
511i	BADSEY2	5	78.95
		7	10.53
		10	10.53
511j	STRETHAM	18	50.62
		21	49.38
512a	ASWARBY	2	17.65
		13	47.06
		23	17.65
		25	17.65
512b	LANDBEACH	5	13.79
		7	70.11
		8	16.09
512c	RUSKINGTON	7	100.00
512d	GROVE	8	41.18
		10	23.53
		20	23.53
		25	11.76
512e	BLOCK	7	29.07
		8	30.23
		9	11.63
		10	29.07
512f	Milton	5	20.00
		8	80.00
513	CANNAMORE	18	70.00
		21	15.00
		24	15.00
521	METHWOLD	1	100.00
532a	BLACKTOFT	8	89.47
		9	10.53
532b	ROMNEY	8	100.00
541A	BEARSTED1	3	84.21
		8	15.79
541B	BEARSTED2	3	52.94
		10	29.41
		19	17.65
541C	NEWBIGGIN	6	65.00
		18	35.00
541D	OGLETHORPE	5	77.78
		6	22.22
541a	MILFORD	6	10.53
		17	78.95
		21	10.53
541b	BROMSGROVE	3	71.43
		4	14.29
		18	14.29
541c	EARDISTON1	3	14.93
		4	67.16
		18	17.91
541d	EARDISTON2	4	100.00
541e	CREDITON	2	22.22
		3	77.78
541f	RIVINGTON1	4	66.67
		13	33.33
541g	RIVINGTON2	4	83.33
		21	16.67
541h	NEATH	17	25.00
		18	25.00
		21	50.00
541i	MUNSLOW	4	100.00
541j	DENBIGH1	4	13.33
		17	60.00
		18	13.33
		22	13.33
541k	DENBIGH2	6	18.60
		8	17.44

CODE	MAP_UNIT	CLASS	PERC
		9	17.44
		17	46.51
541l	BARTON	4	83.33
		18	16.67
541m	SOUTH PETHERTON	3	80.00
		16	20.00
541n	Trusham	4	68.00
		17	20.00
		22	12.00
541o	MALHAM1	4	15.00
		15	85.00
541p	MALHAM2	4	100.00
541q	WALTHAM	4	55.56
		6	44.44
541r	WICK1	5	75.00
		7	25.00
541s	WICK2	5	37.50
		6	15.63
		8	10.42
		13	36.46
541t	WICK3	5	72.22
		6	27.78
541u	ELLERBECK	5	100.00
541v	RHEIDOL	5	88.89
		8	11.11
541w	Newnham	5	71.43
		8	28.57
541x	EAST KESWICK1	6	52.94
		7	11.76
		21	35.29
541y	EAST KESWICK2	5	15.00
		6	65.00
		17	20.00
541z	EAST KESWICK3	4	37.50
		6	62.50
542	NERCWYS	21	62.50
		24	37.50
543	ARROW	7	75.00
		10	25.00
544	BANBURY	2	83.33
		20	16.67
551a	BRIDGNORTH	3	89.47
		5	10.53
551b	CUCKNEY1	3	55.00
		5	45.00
551c	CUCKNEY2	3	52.94
		10	23.53
		16	23.53
551d	NEWPORT1	5	75.00
		10	12.50
		18	12.50
551e	NEWPORT2	3	26.67
		5	73.33
551f	Newport3	5	60.00
		18	40.00
551g	NEWPORT4	5	100.00
552a	KEXBY	5	33.33
		7	66.67
552b	Ollerton	7	40.59
		13	19.80
		18	39.60
554a	FRILFORD	3	89.47
		13	10.53
554b	WORLINGTON	1	50.00
		5	30.00
		16	20.00
555	Downham	5	21.05
		10	42.11
		13	36.84
561a	WHARFE	8	88.89
		10	11.11
561b	TEME	8	80.00
		9	20.00
561c	ALUN	8	81.25
		10	18.75
561d	LUGWARDINE	8	88.89

CODE	MAP_UNIT	CLASS	PERC
		9	11.11
571A	Rowton	5	53.33
		18	33.33
		24	13.33
571a	STON EASTON	2	66.67
		4	16.67
		23	16.67
571b	BROMYARD	4	15.58
		18	84.42
571c	MALLING	1	11.11
		2	16.67
		3	16.67
		16	38.89
		18	16.67
571d	FYFIELD1	3	66.67
		16	22.22
		18	11.11
571e	FYFIELD2	3	100.00
571f	FYFIELD3	3	77.78
		15	22.22
571g	FYFIELD4	3	70.00
		18	20.00
		24	5.00
		25	5.00
571h	ARDINGTON	3	23.53
		16	64.71
		24	11.76
571i	HARWELL	4	10.00
		16	55.00
		24	35.00
571j	FRILSHAM	1	100.00
571k	MOULTON	1	80.00
		5	20.00
571l	CHARITY1	1	40.00
		6	60.00
571m	CHARITY2	1	58.82
		6	41.18
571n	TATHWELL	1	89.47
		18	10.53
571o	MELFORD	1	100.00
571p	ESCRICK1	6	62.50
		18	21.88
		24	15.63
571q	ESCRICK2	5	20.00
		6	60.00
		18	20.00
571r	HUNSTANTON	1	68.42
		5	15.79
		6	15.79
571s	EFFORD1	5	39.60
		6	40.59
		8	14.85
		9	4.95
571t	Efford2	5	36.05
		10	11.63
		18	34.88
		25	17.44
571u	SUTTON1	5	100.00
571v	SUTTON2	5	77.78
		6	22.22
571w	Hucklesbrook	5	90.00
		7	10.00
571x	Ludford	5	73.33
		6	26.67
571y	HAMBLE1	1	13.33
		6	40.00
		8	26.67
		18	20.00
571z	HAMBLE2	6	53.33
		8	46.67
572a	YELD	2	22.22
		4	16.67
		18	61.11
572b	MIDDLETON	18	85.88
		24	14.12
572c	HODNET	3	11.76

CODE	MAP_UNIT	CLASS	PERC
		13	11.76
		18	64.71
		21	11.76
572d	Whimple1	5	34.07
		6	29.67
		21	36.26
572e	WHIMPLE2	3	23.53
		21	76.47
572f	WHIMPLE3	21	82.35
		24	17.65
572g	DUNNINGTON HEATH	18	71.43
		21	28.57
572h	OXPASTURE	20	52.50
		23	12.50
		25	35.00
572i	CURTISDEN	3	9.46
		16	9.46
		18	54.05
		24	27.03
572j	Bursledon	10	17.24
		13	17.24
		18	34.48
		25	31.03
572k	BIGNOR	4	11.24
		16	33.71
		18	32.58
		24	22.47
572l	FLINT	18	87.50
		24	12.50
572m	SALWICK	5	25.00
		8	20.00
		18	55.00
572n	BURLINGHAM1	5	37.50
		18	62.50
572o	BURLINGHAM2	6	15.79
		18	63.16
		24	21.05
572p	BURLINGHAM3	1	30.00
		5	30.00
		18	40.00
572q	ASHLEY	18	64.71
		21	23.53
		24	11.76
572r	Ratsborough	18	37.50
		24	35.71
		25	26.79
572s	Bishampton1	5	21.05
		6	26.32
		18	36.84
		24	15.79
572t	BISHAMPTON2	18	44.44
		20	11.11
		24	27.78
		25	16.67
573a	WATERSTOCK	5	11.76
		6	17.65
		7	23.53
		8	35.29
		9	11.76
573b	Wix	5	23.53
		7	64.71
		25	11.76
581a	NORDRACK	4	100.00
581b	SONNING1	5	88.89
581b	SONNING1	18	11.11
581c	SONNING2	5	62.50
		18	12.50
		25	25.00
581d	CARSTENS	1	88.89
		6	11.11
581e	MARLOW	1	73.33
		18	26.67
581f	BARROW	1	55.00
		5	45.00
581g	STONE STREET	1	27.78
		3	38.89

CODE	MAP_UNIT	CLASS	PERC
		5	33.33
582a	BATCOMBE	1	18.75
		18	81.25
582b	Hornbeam1	1	26.67
		5	40.00
		18	33.33
582c	HORNBEAM2	1	37.50
		18	62.50
582d	HORNBEAM3	18	70.59
		21	17.65
		24	11.76
582e	TENDRING	5	32.61
		8	45.65
		24	21.74
611a	MALVERN	4	28.57
		19	71.43
611b	MORETONHAMPSTEAD	4	100.00
611c	MANOD	17	87.50
		22	12.50
611d	WITHNELL1	4	55.56
		17	33.33
		21	11.11
611e	WITHNELL2	4	83.33
		19	16.67
612a	PARC	15	11.76
		17	70.59
		26	17.65
612b	MOOR GATE	4	87.50
		15	12.50
631a	ANGLEZARKE	4	60.00
		15	40.00
631b	DELAMERE	3	100.00
631c	SHIRRELL HEATH1	3	44.44
		10	22.22
		13	16.67
		18	16.67
631d	SHIRRELL HEATH2	3	100.00
631e	GOLDSTONE	3	78.57
		4	21.43
631f	Crannymoor	5	72.94
		10	27.06
633	LARKBARROW	4	50.55
		15	49.45
634	SOUTHAMPTON	5	87.01
		24	12.99
641a	SOLLOM1	5	31.58
		10	68.42
641b	Sollom2	3	22.22
		5	11.11
641b	Sollom2	10	50.00
		18	16.67
641c	HOLME MOOR	5	12.50
		7	66.25
		10	21.25
643a	Holidays Hill	3	23.53
		10	11.76
		13	11.76
		18	29.41
		25	23.53
643b	Poundgate	18	23.53
		24	64.71
		26	11.76
643c	Bolderwood	5	16.67
		24	83.33
643d	Felthorpe	7	26.67
		10	73.33
651a	BELMONT	4	18.75
		15	81.25
651b	Hexworthy	15	100.00
651c	EARLE	15	68.75
		27	31.25
652	MAW	15	100.00
654a	HAFREN	15	86.67
		26	13.33
654b	LYDCOTT	15	88.89
		26	11.11

CODE	MAP_UNIT	CLASS	PERC
654c	Gelligaer	15	100.00
711a	STANWAY	18	20.00
		24	80.00
711b	BROCKHURST1	21	20.00
		24	80.00
711c	BROCKHURST2	9	13.33
		24	86.67
711d	MARTOCK	24	100.00
711e	WICKHAM1	20	11.76
		24	17.65
		25	70.59
711f	WICKHAM2	20	16.67
		23	11.11
		25	72.22
711g	WICKHAM3	10	15.79
		18	10.53
		25	73.68
711h	WICKHAM4	25	100.00
711i	WICKHAM5	18	12.99
		20	12.99
		24	12.99
		25	61.04
711j	KINGSTON	3	17.65
		16	11.76
		18	23.53
		24	47.06
711k	VERNOLDS	9	21.43
		18	21.43
		24	57.14
711l	CLAVERLEY	19	25.00
		24	75.00
711m	SALOP	18	18.75
		24	81.25
711n	CLIFTON	10	10.53
711n	CLIFTON	18	21.05
		24	68.42
711o	RUFFORD	10	45.00
		24	55.00
711p	DUNKESWICK	24	100.00
711q	PINDER	18	22.22
		24	77.78
711r	BECCLES1	24	100.00
711s	BECCLES2	10	15.79
		24	84.21
711t	BECCLES3	18	25.00
		21	15.00
		24	60.00
711u	HOLDERNESS	18	32.61
		24	67.39
711v	GRESHAM	10	15.79
		14	63.16
		24	21.05
711w	CROFT PASCOE	4	10.00
		9	20.00
		13	20.00
		14	50.00
712a	DALE	24	100.00
712b	DENCHWORTH	20	14.29
		23	14.29
		25	71.43
712c	WINDSOR	23	10.00
		25	90.00
712d	HALLSWORTH1	24	100.00
712e	HALLSWORTH2	24	100.00
712f	CREWE	24	100.00
712g	RAGDALE	21	22.22
		24	77.78
712h	FOGGATHORPE1	24	100.00
712i	FOGGATHORPE2	24	100.00
713a	BARDSEY	4	29.41
		21	11.76
		24	58.82
713b	SPORTSMANS	9	43.75
		15	18.75
		21	18.75
		24	18.75
713c	FFOREST	21	10.53
		24	78.95
		26	10.53
713d	CEGIN	17	11.76
		18	11.76
		24	76.47
713e	BRICKFIELD1	24	68.75
		26	31.25
713f	BRICKFIELD2	6	20.00
		21	26.67
		24	53.33
713g	BRICKFIELD3	24	100.00
714a	DUNKESWELL	18	10.53
		24	63.16
		26	26.32
714b	OAK1	24	100.00
714c	OAK2	18	33.33
		24	66.67
714d	ESSENDEN	18	20.00
714d	ESSENDEN	24	60.00
		25	20.00
721a	PRINCETOWN	15	100.00
721b	ONECOTE	26	100.00
721c	WILCOCKS1	10	11.11
		26	88.89
721d	WILCOCKS2	15	11.11
		26	55.56
		29	33.33
721e	WENALLT	26	84.21
		29	15.79
811a	ENBORNE	8	21.05
		9	15.79
		10	63.16
811b	CONWAY	8	23.53
		9	76.47
811c	HOLLINGTON	8	11.11
		9	88.89
811d	ROCKCLIFFE	8	11.11
		9	55.56
		10	33.33
811e	TANVATS	9	61.11
		10	38.89
812a	FROME	10	95.00
		11	5.00
812b	WISBECH	8	31.25
		9	68.75
812c	AGNEY	9	100.00
813a	MIDELNEY	9	83.33
		10	16.67
813b	FLADBURY1	8	15.00
		9	85.00
813c	FLADBURY2	8	23.53
		9	76.47
813d	FLADBURY3	9	88.89
		10	11.11
813e	COMPTON	9	100.00
813f	WALLASEA1	9	100.00
813g	WALLASEA2	8	12.77
		9	87.23
813h	Dowels	9	100.00
814a	THAMES	8	8.89
		9	91.11
814b	Newchurch1	8	25.32
		9	74.68
814c	NEWCHURCH2	9	100.00
815	HORMOOR	9	100.00
821a	EVERINGHAM	7	26.32
		10	73.68
821b	BLACKWOOD	7	9.52
		10	90.48
831a	YEOLLANDPARK	8	17.65
		9	70.59
		24	11.76
831b	SESSAY	9	55.00
		10	15.00

CODE	MAP_UNIT	CLASS	PERC
		24	30.00
831c	WIGTON MOOR	7	11.11
		8	16.67
		9	44.44
		10	27.78
832	KELMSCOT	7	12.50
		9	12.50
		10	75.00
841a	Curdridge	10	80.00
		25	20.00
841b	HURST	7	13.33
		8	13.33
		10	73.33
841c	SWANWICK	10	100.00
841d	SHABBINGTON	7	13.33
		8	26.67
		9	46.67
		25	13.33
841e	PARK GATE	8	22.22
		9	77.78
851a	DOWNHOLLAND1	9	64.71
		10	17.65
		11	17.65
851b	DOWNHOLLAND2	9	71.43
		10	28.57
851c	DOWNHOLLAND3	9	50.00
		10	20.00
		11	30.00
861a	Isleham1	10	80.00
		29	20.00
861b	Isleham2	7	20.00
		10	50.00
		11	30.00
871a	LAPLOYD	10	23.53
		12	64.71
		29	11.76
871b	HENSE	3	10.00
		10	70.00
		12	20.00
871c	HANWORTH	10	70.00
		11	30.00
872a	PEACOCK	9	15.00
		11	16.67
		25	68.33
872b	Clayhythe	9	15.79
		10	63.16
		11	10.53
		25	10.53
873	IRETON	10	100.00
1011a	LONGMOSS	12	100.00
1011b	WINTER HILL	29	100.00
1013a	CROWDY1	15	11.11
		26	16.67
		29	72.22
1013b	CROWDY2	29	100.00
1021	TURBARY MOOR	11	80.00
		12	20.00
1022a	ALTCAR1	11	100.00
1022b	ALTCAR2	11	100.00
1024a	ADVENTURERS'1	11	100.00
1024b	ADVENTURERS'2	10	20.00
		11	80.00
1024c	ADVENTURERS'3	9	23.53
		10	23.53
		11	52.94
1025	Mendham	9	38.89
1025	Mendham	11	61.11

Map units in Scotland

CODE	MAP_UNIT	CLASS	PERC
1	ALLUVIAL SOILS	7	35.00
		8	15.00
		9	10.00
		10	20.00
		12	20.00
2	ALLUVIAL SOILS	10	100.00
3	ORGANIC SOILS	12	100.00
4	ORGANIC SOILS	29	100.00
5	ABERLOUR	14	70.00
		15	30.00
6	ABERLOUR	13	40.00
		17	60.00
7	ABERLOUR	15	50.51
		29	49.49
9	ABERLOUR	12	35.00
		15	65.00
10	ABERLOUR	15	50.51
		17	49.49
11	ABERLOUR	15	50.51
		29	49.49
12	ABERLOUR	17	100.00
13	ABERLOUR	17	50.51
		29	49.49
14	ABERLOUR	17	100.00
15	ABERLOUR	22	75.00
		27	25.00
16	ARBIGLAND	18	25.00
		24	75.00
17	ARDVANIE	5	100.00
18	ARKAIG	17	100.00
19	ARKAIG	14	50.51
		15	49.49
20	ARKAIG	13	49.49
		17	50.51
21	ARKAIG	15	100.00
22	ARKAIG	15	50.51
		29	49.49
23	ARKAIG	15	65.00
		29	35.00
24	ARKAIG	15	100.00
25	ARKAIG	17	100.00
26	ARKAIG	12	35.00
		15	65.00
27	ARKAIG	17	100.00
28	ARKAIG	15	50.51
		17	49.49
29	ARKAIG	12	49.49
		15	50.51
30	ARKAIG	15	50.00
		22	25.00
		27	25.00
31	ARKAIG	15	70.00
		27	30.00
32	ARKAIG	12	30.30
		15	35.35
		27	34.34
33	ARKAIG	19	100.00
34	ARKAIG	19	50.51
		29	49.49
35	ARKAIG	19	100.00
36	ARKAIG	22	49.49
36	ARKAIG	27	50.51
37	ARRAN	24	100.00
38	ARRAN	26	100.00
39	ASHGROVE	24	100.00
40	ASHGROVE	24	100.00
41	BALROWNIE	18	100.00
42	BALROWNIE	24	100.00
43	BALROWNIE	4	100.00
44	BALROWNIE	6	50.51
		13	49.49
45	BALROWNIE	15	100.00
46	BALROWNIE	12	49.49
		26	50.51
47	BALROWNIE	24	100.00

CODE	MAP_UNIT	CLASS	PERC
48	BALROWNIE	26	100.00
49	BALROWNIE	6	100.00
50	BALROWNIE	12	49.49
		26	50.51
51	BARGOUR	24	100.00
52	BARNCORKRIE	16	50.51
		24	49.49
53	BEMERSYDE	17	100.00
54	BEMERSYDE	17	100.00
55	BEMERSYDE	15	100.00
56	BENAN	6	100.00
57	BENAN	6	100.00
58	BENAN	24	100.00
59	BERRIEDALE	6	100.00
60	BERRIEDALE	14	100.00
61	BERRIEDALE	15	70.00
		29	30.00
62	BERRIEDALE	12	49.49
		15	50.51
63	BERRIEDALE	6	100.00
64	BERRIEDALE	15	80.00
		29	20.00
65	BERRIEDALE	15	100.00
66	BERRIEDALE	4	34.34
		6	35.35
		17	30.30
67	BERRIEDALE	6	50.51
		29	49.49
68	BLAIR	24	100.00
69	BLAIR	24	35.35
		26	34.34
		29	30.30
70	BOGTOWN	24	100.00
71	BRAEMORE	6	50.51
		13	49.49
72	BRAEMORE	6	35.35
		13	34.34
		14	30.30
73	BRAEMORE	14	100.00
74	BRAEMORE	6	100.00
75	BRAEMORE	15	34.34
		26	35.35
		29	30.30
76	BRIGHTMONY	16	100.00
77	CAIRNCROSS	6	50.51
		24	49.49
78	CANISBAY	6	100.00
79	CANISBAY	24	85.00
		26	15.00
80	CANISBAY	6	29.29
		15	20.20
		24	30.30
		26	20.20
81	CANISBAY	15	100.00
82	CANISBAY	26	100.00
83	CANISBAY	24	100.00
84	CANONBIE	16	50.51
		24	49.49
85	CANONBIE	24	100.00
86	CANONBIE	6	100.00
87	CANONBIE	26	100.00
88	CANONBIE	12	49.49
		26	50.51
89	CARPOW	5	100.00
90	CARTER	6	30.00
		14	70.00
91	CARTER	14	30.00
		24	70.00
92	CARTER	6	30.00
		24	70.00
93	CARTER	15	100.00
94	CARTER	24	49.49
		26	50.51
95	CARTER	26	50.51
		29	49.49
96	CORBY	17	100.00

CODE	MAP_UNIT	CLASS	PERC
97	CORBY	5	100.00
98	CORBY	5	70.00
		7	10.00
		8	5.00
		9	5.00
		10	5.00
		12	5.00
99	CORBY	5	100.00
100	CORBY	5	100.00
101	CORBY	15	100.00
102	CORBY	7	10.10
		8	5.05
		9	5.05
		10	5.05
		12	39.39
		15	35.35
103	CORBY	5	50.51
		12	49.49
104	CORBY	12	85.00
		15	15.00
105	CORBY	5	50.51
		15	49.49
106	CORBY	12	50.51
		15	49.49
107	CORRIEBRECK	14	15.00
		17	85.00
108	CORRIEBRECK	17	100.00
109	CORRIEBRECK	12	30.00
		15	70.00
110	CORRIEBRECK	15	100.00
111	CORRIEBRECK	12	49.49
		15	50.51
112	CORRIEBRECK	17	100.00
113	COUNTESSWELLS	17	100.00
114	COUNTESSWELLS	17	100.00
115	COUNTESSWELLS	17	100.00
116	COUNTESSWELLS	14	100.00
117	COUNTESSWELLS	15	100.00
118	COUNTESSWELLS	15	50.51
		29	49.49
119	COUNTESSWELLS	15	50.51
		29	49.49
120	COUNTESSWELLS	12	49.49
		15	50.51
121	COUNTESSWELLS	17	70.00
		22	30.00
122	COUNTESSWELLS	17	100.00
123	COUNTESSWELLS	12	35.00
		15	65.00
124	COUNTESSWELLS	12	85.00
		27	15.00
125	COUNTESSWELLS	17	100.00
126	COUNTESSWELLS	15	50.51
		17	49.49
127	COUNTESSWELLS	12	49.49
		15	50.51
128	COUNTESSWELLS	17	50.51
		22	49.49
129	COUNTESSWELLS	15	49.49
		27	50.51
130	COUNTESSWELLS	15	70.00
		29	30.00
131	COUNTESSWELLS	15	70.00
		27	30.00
132	COUNTESSWELLS	12	49.49
		15	50.51
133	COUNTESSWELLS	27	100.00
134	COUNTESSWELLS	17	100.00
135	COUNTESSWELLS	17	50.51
		29	49.49
136	COUNTESSWELLS	17	100.00
137	COUNTESSWELLS	22	100.00
138	CRAIGDALE	15	49.49
		17	50.51
139	CRAIGDALE	24	50.51

CODE	MAP_UNIT	CLASS	PERC
		26	49.49
140	CRAIGELLACHIE	18	100.00
141	CREETOWN	17	100.00
142	CREETOWN	17	100.00
143	CREETOWN	24	50.51
		26	49.49
144	CROMARTY	13	100.00
145	CROMARTY	18	100.00
146	CROMARTY	14	49.49
		15	50.51
147	DARLEITH	17	100.00
148	DARLEITH	24	100.00
149	DARLEITH	24	100.00
150	DARLEITH	17	100.00
151	DARLEITH	19	100.00
152	DARLEITH	15	50.51
		19	49.49
153	DARLEITH	15	100.00
154	DARLEITH	15	70.00
		29	30.00
155	DARLEITH	15	50.51
		29	49.49
156	DARLEITH	15	49.49
		17	50.51
157	DARLEITH	12	35.00
		15	65.00
158	DARLEITH	19	100.00
159	DARLEITH	15	50.51
		19	49.49
160	DARLEITH	15	50.51
		29	49.49
161	DARLEITH	17	100.00
162	DARLEITH	17	50.51
		29	49.49
163	DARVEL	5	100.00
164	DARVEL	5	70.00
		7	5.00
		8	10.00
		9	5.00
		10	5.00
		12	5.00
165	DEECASTLE	4	100.00
166	DEECASTLE	4	49.49
		15	50.51
167	DEECASTLE	4	100.00
168	DOUNE	5	100.00
169	DREGHORN	5	100.00
170	DREGHORN	10	100.00
171	DRONGAN	24	100.00
172	DULSIE	16	100.00
173	DULSIE	15	100.00
174	DULSIE	12	49.49
		15	50.51
175	DULSIE	15	100.00
176	DUNNET	15	100.00
177	DUNNET	15	100.00
178	DUNNET	17	100.00
179	DURISDEER	6	50.51
		18	49.49
180	DURISDEER	18	49.49
		24	50.51
181	DURNHILL	14	50.51
		15	49.49
182	DURNHILL	15	100.00
183	DURNHILL	15	50.51
		29	49.49
184	DURNHILL	15	50.51
		29	49.49
185	DURNHILL	12	35.00
		15	65.00
186	DURNHILL	17	100.00
187	DURNHILL	15	70.00
		27	30.00
188	DURNHILL	12	30.00
		15	70.00
189	DURNHILL	27	100.00

CODE	MAP_UNIT	CLASS	PERC
190	DURNHILL	15	70.00
		27	30.00
191	DURNHILL	15	70.00
191	DURNHILL	27	30.00
192	DURNHILL	17	85.00
		27	15.00
193	DURNHILL	17	50.51
		29	49.49
194	DURNHILL	17	100.00
195	DURNHILL	22	100.00
196	ECKFORD	5	100.00
197	ECKFORD	5	70.00
		12	30.00
198	ECKFORD	5	70.00
		7	10.00
		8	20.00
199	ECKFORD	10	100.00
200	ECKFORD	5	70.00
		10	30.00
201	ELGIN	14	50.51
		15	49.49
202	ELGIN	6	60.00
		13	40.00
203	ELGIN	15	100.00
204	ETHIE	19	100.00
205	ETTRICK	16	100.00
206	ETTRICK	17	100.00
207	ETTRICK	19	100.00
208	ETTRICK	17	100.00
209	ETTRICK	13	49.49
		24	50.51
210	ETTRICK	14	49.49
		24	50.51
211	ETTRICK	12	70.00
		17	30.00
212	ETTRICK	12	49.49
		15	50.51
213	ETTRICK	12	70.00
		15	30.00
214	ETTRICK	12	35.00
		15	50.00
		17	15.00
215	ETTRICK	12	85.00
		27	15.00
216	ETTRICK	15	70.00
		29	30.00
217	ETTRICK	15	100.00
218	ETTRICK	15	70.00
		29	30.00
219	ETTRICK	12	25.00
		15	25.00
		26	50.00
220	ETTRICK	15	25.00
		26	25.00
		29	50.00
221	ETTRICK	17	100.00
222	ETTRICK	19	100.00
223	ETTRICK	19	70.00
		22	30.00
224	ETTRICK	17	34.34
		19	30.30
		22	35.35
225	ETTRICK	17	70.00
		24	30.00
226	ETTRICK	15	70.00
		17	30.00
227	ETTRICK	17	100.00
228	ETTRICK	15	100.00
229	ETTRICK	15	100.00
230	ETTRICK	15	100.00
231	ETTRICK	15	100.00
232	ETTRICK	14	50.51
		17	49.49
233	ETTRICK	14	50.51
		15	49.49
234	ETTRICK	15	65.00

CODE	MAP_UNIT	CLASS	PERC
		29	35.00
235	ETTRICK	22	100.00
236	ETTRICK	17	100.00
237	FORFAR	16	45.00
		18	55.00
238	FORFAR	24	100.00
239	FORFAR	16	50.51
		18	49.49
240	FOUDLAND	17	100.00
241	FOUDLAND	14	100.00
242	FOUDLAND	14	100.00
243	FOUDLAND	17	100.00
244	FOUDLAND	15	100.00
245	FOUDLAND	15	50.51
		29	49.49
246	FOUDLAND	15	70.00
		29	30.00
247	FOUDLAND	15	70.00
		29	30.00
248	FOUDLAND	12	49.49
		17	50.51
249	FOUDLAND	12	49.49
		15	50.51
250	FOUDLAND	17	100.00
251	FOUDLAND	17	100.00
252	FOUDLAND	15	50.51
		17	49.49
253	FOUDLAND	15	100.00
254	FOUDLAND	15	100.00
255	FOUDLAND	17	100.00
256	FOUDLAND	17	70.00
		29	30.00
257	FOUDLAND	17	100.00
258	FOUDLAND	22	100.00
259	FRASERBURGH	5	100.00
260	FRASERBURGH	5	100.00
261	FRASERBURGH	5	70.00
		10	30.00
262	FRASERBURGH	10	100.00
263	FRASERBURGH	12	100.00
264	GLENALMOND	16	100.00
265	GLENALMOND	24	100.00
266	GLENALMOND	24	100.00
267	GLENALMOND	6	100.00
268	GLENALMOND	15	100.00
269	GLENALMOND	15	34.34
		24	30.30
		26	35.35
270	GLENALMOND	26	50.51
270	GLENALMOND	29	49.49
271	GLENALMOND	6	100.00
272	GLENALMOND	15	100.00
273	GLENEAGLES	5	100.00
274	GOURDIE	6	30.00
		18	70.00
275	GOURDIE	24	51.02
		26	48.98
276	GOURDIE	6	100.00
277	GOURDIE	6	49.49
		15	50.51
278	GRULINE	5	100.00
279	GRULINE	5	25.00
		12	75.00
280	GRULINE	12	30.00
		27	70.00
281	HATTON	24	50.51
		26	49.49
282	HATTON	6	100.00
283	HATTON	15	100.00
284	HATTON	15	50.51
		29	49.49
285	HATTON	6	49.49
		15	50.51
286	HATTON	15	100.00
287	HAYFIELD	16	51.02
		24	48.98
288	HAYFIELD	6	70.00
		24	30.00
289	HAYFIELD	24	100.00
290	HAYFIELD	15	100.00
291	HINDSWARD	24	100.00
292	HINDSWARD	24	100.00
293	HINDSWARD	26	50.51
		29	49.49
295	HOBKIRK	16	100.00
296	HOBKIRK	6	100.00
297	HOBKIRK	6	70.00
		14	30.00
298	HOBKIRK	14	100.00
299	HOBKIRK	6	49.49
		15	50.51
300	HOBKIRK	6	49.49
		15	50.51
301	HOBKIRK	15	100.00
302	HOBKIRK	15	50.51
		29	49.49
303	HOLYWOOD	16	49.49
		18	50.51
304	HOLYWOOD	18	50.51
		24	49.49
305	HOLYWOOD	6	100.00
306	HOLYWOOD	6	100.00
307	INCHKENNETH	6	100.00
308	INCHKENNETH	24	100.00
309	INCHKENNETH	24	100.00
310	INCHKENNETH	26	100.00
311	INCHKENNETH	26	100.00
312	INCHKENNETH	26	100.00
313	INCHKENNETH	6	100.00
314	INCHNADAMPH	4	100.00
315	INCHNADAMPH	4	34.34
		15	35.35
		29	30.30
316	INSCH	17	100.00
317	INSCH	15	30.00
		24	70.00
318	INSCH	17	100.00
319	INSCH	15	100.00
320	INSCH	15	50.51
		29	49.49
321	INSCH	14	49.49
		17	50.51
322	INSCH	12	30.00
		15	70.00
323	INSCH	17	70.00
		22	30.00
324	INSCH	17	100.00
325	INSCH	15	70.00
		29	30.00
326	INSCH	17	49.49
		22	50.51
327	INSCH	12	49.49
		15	50.51
328	INSCH	15	30.00
		17	70.00
329	INSCH	17	50.51
		29	49.49
330	INSCH	17	100.00
331	KILMARNOCK	24	100.00
332	KILMARNOCK	24	100.00
333	KINTYRE	24	100.00
334	KINTYRE	26	100.00
335	KINTYRE	24	100.00
336	KINTYRE	26	50.51
		29	49.49
337	KIPPEN	13	50.51
		17	49.49
338	KIPPEN	24	100.00
339	KIPPEN	6	100.00
340	KIPPEN	24	100.00
341	KIPPEN	6	100.00
342	KIPPEN	15	100.00

CODE	MAP_UNIT	CLASS	PERC
343	KIPPEN	15	65.00
		29	35.00
344	KIPPEN	15	50.51
		29	49.49
345	KIPPEN	15	100.00
346	KIPPEN	12	30.00
		15	70.00
347	KIPPEN	15	100.00
348	KIRKCOLM	5	100.00
349	KIRKWOOD	6	50.51
		24	49.49
350	KIRKWOOD	24	50.51
		26	49.49
351	KNOCKSKAE	14	100.00
352	KNOCKSKAE	17	70.00
		22	30.00
353	KNOCKSKAE	17	100.00
354	KNOCKSKAE	15	100.00
355	KNOCKSKAE	12	35.00
355	KNOCKSKAE	15	65.00
356	KNOCKSKAE	17	100.00
357	KNOCKSKAE	15	70.00
		29	30.00
358	KNOCKSKAE	15	70.00
		27	30.00
359	LANFINE	24	100.00
360	LANFINE	24	100.00
361	LANFINE	26	100.00
362	LAUDER	6	100.00
363	LAUDER	24	100.00
364	LAUDER	6	100.00
365	LAUDER	6	30.30
		15	35.35
		24	34.34
366	LAUDER	6	50.51
		15	49.49
367	LAUDER	15	50.51
		29	49.49
368	LAURENCEKIRK	6	24.49
		17	24.49
		18	51.02
369	LESLIE	17	100.00
370	LESLIE	24	100.00
371	LESLIE	17	100.00
372	LESLIE	24	100.00
373	LESLIE	22	30.00
		24	70.00
374	LETHANS	6	100.00
375	LETHANS	24	100.00
376	LETHANS	6	49.49
		15	50.51
377	LETHANS	15	100.00
378	LETHANS	15	100.00
379	LINFERN	12	49.49
		15	50.51
380	LINKS	5	100.00
381	LINKS	5	50.51
		10	49.49
382	LINKS	12	100.00
383	LINKS	5	100.00
384	LINKS	12	100.00
385	LOCHINVER	14	100.00
386	LOCHINVER	17	100.00
387	LOCHINVER	17	70.00
		22	30.00
388	LOCHINVER	14	65.00
		17	35.00
389	LOCHINVER	17	100.00
390	LOCHINVER	15	50.51
		29	49.49
391	LOCHINVER	12	49.49
		15	50.51
392	LOCHINVER	15	50.51
		29	49.49
393	LOCHINVER	14	15.00
		17	85.00

CODE	MAP_UNIT	CLASS	PERC
394	LOCHINVER	12	49.49
		15	50.51
395	LOCHINVER	12	34.34
		15	35.35
395	LOCHINVER	27	30.30
396	LOCHINVER	15	70.00
		27	30.00
397	LOCHINVER	17	50.51
		29	49.49
398	LOCHINVER	17	80.00
		22	20.00
399	LYNEDARDY	24	49.49
		26	50.51
400	LYNEDARDY	15	50.51
		26	49.49
401	MAUCHLINE	18	100.00
402	MAUCHLINE	24	100.00
403	MAUCHLINE	26	100.00
404	MAUCHLINE	6	70.00
		14	30.00
405	MILLBUIE	14	100.00
406	MILLBUIE	6	30.00
		18	70.00
407	MINTO	24	100.00
408	MINTO	24	100.00
409	MINTO	24	100.00
410	MINTO	15	49.49
		24	50.51
411	MINTO	15	70.00
		29	30.00
412	MINTO	15	100.00
413	MOUNTBOY	16	100.00
414	MOUNTBOY	6	30.00
		18	70.00
415	MOUNTBOY	24	70.00
		26	30.00
416	MOUNTBOY	6	100.00
417	MOUNTBOY	15	100.00
418	MOUNTBOY	6	50.51
		15	49.49
420	NIGG	5	100.00
421	NIGG	10	100.00
422	NOCHTY	5	70.00
		7	10.00
		8	5.00
		9	5.00
		10	5.00
		12	5.00
423	NORTH MORMOND	24	100.00
424	NORTH MORMOND	24	100.00
425	NORTH MORMOND	6	50.51
		13	49.49
426	NORTH MORMOND	15	100.00
427	ORDLEY	24	50.51
		26	49.49
428	ORDLEY	6	65.00
		13	35.00
429	PETERHEAD	24	100.00
430	PETERHEAD	24	100.00
431	RACKWICK	12	49.49
		15	50.51
432	REPPOCH	6	100.00
433	REPPOCH	24	100.00
434	REPPOCH	6	49.49
		15	50.51
435	REPPOCH	15	70.00
		29	30.00
436	REPPOCH	15	50.51
		29	49.49
437	RHINS	17	100.00
438	RHINS	24	100.00
439	RHINS	19	49.49
		24	50.51
440	RHINS	24	100.00
441	RHINS	19	85.00

CODE	MAP_UNIT	CLASS	PERC
		22	15.00
442	RHINS	24	100.00
443	RHINS	17	100.00
444	ROWANHILL	18	100.00
445	ROWANHILL	24	100.00
446	ROWANHILL	24	100.00
447	ROWANHILL	6	100.00
448	ROWANHILL	4	85.00
		13	15.00
449	ROWANHILL	15	100.00
450	ROWANHILL	15	50.51
		29	49.49
451	ROWANHILL	6	25.00
		14	25.00
		15	50.00
452	ROY	5	50.51
		24	49.49
453	ROY	15	30.00
		26	70.00
454	SABHAIL	4	49.49
		13	50.51
455	SABHAIL	15	100.00
456	SABHAIL	15	50.51
		29	49.49
457	SABHAIL	13	49.49
		15	50.51
458	SHAWHILL	6	100.00
459	SKELBERRY	14	49.49
		15	50.51
460	SKELBERRY	15	100.00
461	SKELBERRY	15	100.00
462	SKELMUIR	24	100.00
463	SKELMUIR	26	100.00
464	SMAILHOLM	17	100.00
465	SORN	18	100.00
466	SORN	24	100.00
467	SORN	24	100.00
468	SORN	6	24.74
		15	24.74
		24	25.77
		26	24.74
469	SORN	15	50.51
		26	49.49
470	SORN	14	49.49
		26	50.51
471	SORN	6	50.51
		14	49.49
472	SOURHOPE	17	100.00
473	SOURHOPE	24	100.00
474	SOURHOPE	19	100.00
475	SOURHOPE	17	100.00
476	SOURHOPE	15	100.00
477	SOURHOPE	15	50.51
		29	49.49
478	SOURHOPE	15	50.51
		29	49.49
479	SOURHOPE	19	100.00
480	SOURHOPE	15	65.00
		29	35.00
482	SOURHOPE	22	100.00
483	STAFFIN	24	100.00
484	STAFFIN	24	100.00
485	STAFFIN	26	50.51
		29	49.49
486	STAFFIN	26	50.51
		29	49.49
487	STIRLING	24	100.00
488	STIRLING	24	100.00
489	STIRLING	26	100.00
490	STONEHAVEN	6	30.00
		18	70.00
491	STONEHAVEN	24	100.00
492	STONEHAVEN	6	100.00
493	STONEHAVEN	6	49.49
		13	50.51
494	STONEHAVEN	15	100.00

CODE	MAP_UNIT	CLASS	PERC
495	STONEHAVEN	6	100.00
496	STONEHAVEN	6	100.00
497	STRICHEN	14	49.49
		24	50.51
498	STRICHEN	17	100.00
499	STRICHEN	15	100.00
500	STRICHEN	15	50.51
		29	49.49
501	STRICHEN	15	50.51
		29	49.49
502	STRICHEN	15	50.51
		29	49.49
503	STRICHEN	15	15.00
		17	85.00
504	STRICHEN	12	30.00
		15	70.00
505	STRICHEN	17	100.00
506	STRICHEN	15	50.51
		17	49.49
507	STRICHEN	12	49.49
		15	50.51
508	STRICHEN	17	65.00
		22	35.00
509	STRICHEN	15	49.49
		22	50.51
510	STRICHEN	15	70.00
		27	30.00
511	STRICHEN	12	30.30
		15	35.35
		27	34.34
512	STRICHEN	19	100.00
513	STRICHEN	19	30.00
		29	70.00
514	STRICHEN	19	100.00
515	STRICHEN	22	75.00
		27	25.00
516	SYMINGTON	5	100.00
517	TARVES	13	49.49
		17	50.51
518	TARVES	15	49.49
		24	50.51
519	TARVES	14	50.51
		17	49.49
520	TARVES	17	100.00
521	TARVES	15	100.00
522	TARVES	15	50.51
		29	49.49
523	TARVES	12	49.49
		15	50.51
524	TARVES	12	30.00
		15	70.00
525	TARVES	17	100.00
526	TARVES	14	49.49
		17	50.51
527	TARVES	15	49.49
		17	50.51
528	TARVES	12	49.49
		15	50.51
529	TARVES	17	49.49
		22	50.51
530	TARVES	17	49.49
		22	50.51
531	TARVES	15	50.51
		27	49.49
532	TARVES	17	50.51
		29	49.49
533	TARVES	17	49.49
		29	50.51
534	TARVES	17	100.00
535	THURSO	4	30.00
		6	70.00
536	THURSO	24	100.00
537	THURSO	24	100.00
538	THURSO	24	100.00
539	THURSO	6	100.00
540	THURSO	12	49.49

CODE	MAP_UNIT	CLASS	PERC
		15	50.51
541	THURSO	15	100.00
542	THURSO	15	100.00
543	THURSO	15	100.00
544	THURSO	12	49.49
		15	50.51
545	TIPPERTY	24	100.00
546	TOROSAY	17	70.00
		22	30.00
547	TOROSAY	12	49.49
		15	50.51
548	TOROSAY	15	50.51
		29	49.49
549	TOROSAY	15	50.51
		17	49.49
550	TOROSAY	15	35.35
		27	34.34
		29	30.30
551	TOROSAY	19	50.51
		29	49.49
552	TORRIDON	14	100.00
553	TORRIDON	14	49.49
		17	50.51
554	TORRIDON	12	35.00
		15	65.00
555	TORRIDON	17	70:00
		22	30.00
556	TORRIDON	15	50.51
		29	49.49
557	TORRIDON	12	49.49
		15	50.51
558	TORRIDON	12	34.34
		15	35.35
		27	30.30
559	TORRIDON	15	100.00
560	TORRIDON	19	50.51
		29	49.49
561	TORRIDON	17	25.00
		19	50.00
		22	25.00
562	TYNEHEAD	6	50.51
		13	49.49
563	TYNEHEAD	24	100.00
564	TYNEHEAD	15	100.00
565	TYNET	14	100.00
566	TYNET	6	100.00
567	TYNET	15	100.00
568	WALLS	29	100.00
569	WALLS	14	49.49
		15	50.51
570	WALLS	15	100.00
571	WALLS	15	50.51
		29	49.49
572	WALLS	4	30.00
		15	70.00
573	WALLS	17	100.00
574	WHITSOME	16	30.00
		24	70.00
575	WHITSOME	24	100.00
576	YARROW	5	100.00
577	YARROW	5	100.00
578	YARROW	5	35.35
		12	64.65
579	YARROW	5	70.00
		7	10.00
		8	5.00
		9	5.00
		10	5.00
		12	5.00
580	YARROW	5	70.00
		12	30.00
600	BUILT_UP_AREA	97	100.00
601	LAKE	98	100.00
602	SEA	99	100.00
731	ORGANIC SOILS - 3D	12	100.00
732	ORGANIC SOILS - 3E	28	100.00

CODE	MAP_UNIT	CLASS	PERC
733	ORGANIC SOILS - 3DE	28	100.00
741	ORGANIC SOILS - 4D	29	100.00
742	ORGANIC SOILS - 4E	28	100.00
743	ORGANIC SOILS - 4DE	28	100.00
800	BARE ROCK - X	17	40.00
		22	60.00

Appendix C Catchment data used in the development and calibration of HOST

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
2001												5			51		2											2	36	3
3001												7	2		34		3		5								1	12	27	8
3003												7			42		3		4								2	12	27	1
3803												7			31				1										59	1
4003				2		5						5	5		28		8		2					1					41	2
5802												12			38		4		32								2		5	5
6003					2							18			38		6		18			1					3		9	5
6006												23			29		1		5										35	6
6008												19	7		41		23		1			1					2		5	2
7001					2		1	1		1		2		1	14	1	2		9			7					4	39	18	
7002					7		1					3		1	26	1	2		5			4					3	22	23	
7003					22	8	2	1	1	1		2	9	3	14		12							1					23	
7004				2	20	1	1	1	1	1		3	2	2	19	5	2	5	2			2					2	23	5	2
7005					2							2		2	41	4	5					1		1			1		38	1
8001					9		1	1		1		4	3	1	23	2	16		7			6		1			3	7	14	
8002					7		2	1	1	1		7			24	2	9		15			7					6	11	9	1
8004				1	1	1						1	4	1	20		32		1			5		2		2	1	4	24	
8005					11		1	1		1		6			23	2	10		13			9					5	9	8	1
8006					8		1	1		1		4	3	1	23	2	17		7			5		1			3	7	14	
8009					6		1	1		1		4			30	6	15		6			2					2	19	8	
8010					11		2	1		1		6	1		25	3	10		11			7					4	9	8	1
8011				1											24		45					2		2		2			22	
9001					3	2	1					1	5	2	13		47							5					20	
9002					3	2	1			1		2	4	7	13		46							9					11	
9003						4	1	1		1		1	4	13	20		32							14					9	
9004					3	6						2	4	3	10		63							2		1			6	
10001					2	4	1					1	9	5	6		68							4						
10002					5	1	1			1		7	9	9	8		36							17		3			2	
10003					2	3	1					1	12	4	7		63							6						
11001					3	1	1	1		1		1	9	3	15		56							3					4	
11002					3	1	1			1		1	11	3	20		48							2					7	
11003					2	2	1						13		21		46							2			1		11	
11801							1	1		1		1		4	10		76							6						
12001					5		1					1	5	1	22		37		5			8		1			1	2	11	
12002					5		1					1	4	1	22		39		4			6		1			1	1	13	
12003					3							1	4		22		28		10			16					1		14	
12004					1								8	4	53		21					2		2			4		5	
12005					1							2	6		24		33		1					2			1	19	8	2
12006					1								3	1	28		35	1	4			1		3					22	
12007												1	2		18		21		10			28							19	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
13001					6	24	1	1		1		1			9		11	38						3					5	
13002					2	20	3	1	1	1		1			11	3	19	33											4	
13005					10	3	2	1	1	1		1				14		67						1						1
13007					6	8	1	1		1		1		1	24	3	17	17	2					2				7	8	
13008					6	2	2	1	1	1		1	1	2	12	6	28	19	5			3		3				3	7	
14001					16	7	1			5		1	4			1	37	9						18						
14002					1	11	2	1		1		1	5			3	8	67						1						
15001					3							3		2	18		27		14			3						2	26	
15002					1							5		5	16		48		1			1		6					17	
15004					4	2	1							4	28		53	1	2					4					1	
15005					2	1						2	1	5	29		41							7		2			5	3
15010				1	10	8	1					1	1	5	13		28	11	4			1		6		2			7	1
15013					8	3						3		1	15	4	20	13	1			1		6		2			22	
15017					3							2		10	29		29					1		10					14	1
15023					3							2		10	28		30					1		10					13	1
15024					2		1					11			34		22		10			1					2		16	
15809					2							2		9	22		45		6					9					3	1
16001				3	4	4	2	1	1	1		5	1	2	13	1	22	14	3			1		4		1			14	2
16003					1	7						7	6	5	10		19	6	4					3		3			29	
17004												3					2	18	2					73						2
17005					7							3			4		6	19						54					5	1
18001				3	13	4	2	1	1	1		2	4		11		3	24						4					27	
18003				1	3	3	1					5	1	6	20		28	5	4			1		3		1			12	5
18005				2	12	3	2	1		1		1	3		12		2	30	2					6					23	
18008							1					5		4	25		41		8			1		3					9	3
18011				1	3	4	1					7	1	3	14		20	12	3			1		13		2			11	3
18017												23			42		20		4										11	
18018												11			16		53		13										6	
19001					1		1					2		1	10		2	32						41		1			9	
19002												9			11		1	31						36					11	
19003															30									41					29	
19004					24	7	1	2	1	1		10		1	13	6	6	10	4					9		1			4	
19006					4	4		1						8	9		2	35						24		8			2	2
19007					25	13		1				5	3	1	7	1	6	8	3					22		1			3	1
19010														1	4		31	49						13		1				1
19011					25	5	1	1	1	1		6	1	1	13	4	5	10	7					16		2			3	
19805					2	14									50			32												
20001					12	6	1	1	1	1		1	3	1	2		10	11						49					2	
20003					15	9	1	2	1	1		1	4		1		8	9						44					2	
20005					16	7	1	2	1	1		1	5	1	2		14	3						42					3	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
20006					13	17	1	2					1	2	11		20							31						
20007					18	5							2	2	6		25	2						37					3	
20804					18	77	1																	3					1	
20806					2					2														96						
20807					28	65									3											1			3	
20808																								100						
20809					49	14	3	7	3	3		3	14											3						
21001														9	52		16		1			1							16	5
21002														1	57		25							1					14	2
21005					5	1	2	1	1	1		1		4	34		40	1	1			1		3					4	1
21006					4	1	1	1		1		1	1	4	28	1	38	1	2			1		6		1			7	
21007					2		1	1		1		1		5	34		29		3			1		8		1			12	1
21008					3	15	1	1		1		1		10	14		11		17			4		14		3			6	
21009				1	6	7	2	1		1		1	2	5	16	1	22	1	8			2		16		1			6	
21010					4	4	1	1		1		1	3	4	22	1	39	1	2			1		8		1			7	
21011					2		1			1		1		3	30		33		1			2		7					18	1
21012							1	1		1		1		11	28		22		13			5		10		2			6	
21013							1			1		1	3	3	12		63		1					5					9	
21015					1	20	1			1		1	6	3	5		43							8					10	
21016					6	15							10	1	9	4	35							19						
21017														1	58		24		1			1		8		1			7	
21018					8	5	2	1		1		3		5	23	9	26	5						7		2			1	
21019					5		1	1		1		1		2	37		36		3			3		1					9	
21020							1			1		1		1	35		24		1			2		6					26	2
21021					3	8	1	1		1		1	2	6	18		28		7			2		11		1			6	
21022					7	24	1	1				1	1	2	21	2	20							12					8	
21023						3										10	7							80						
21024						27								9	11		7		10					9		9			15	
21025						6							1	10	14		4		21			3		24		5			11	1
21026												2		15	63		5							2		4			8	
21027					6	40						1		5	16	1	8							18					3	
21028														7	83		6												2	2
21030							2	1		1		1		1	40		21		2			3				1			28	
21031				7	16		5	4		2					12			1	18		1	6		19		1	3		6	
21032				5	6		3	2		1		1			11				38			17		5			4		6	
21805					3	18	1	1					1	1	29		29							3		1			13	1
22001				7	3		1	1	1	2					11				9			2		43		7	2		9	
22002				11											19				34			9		1		1	8		17	
22003				2											17				12			8					7		54	
22004				13	6		2			2					8				2		1			58		8				

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
22006				1						1	1										2			93						
22007				3	3		1			3		3	1		3									64		19				
22008				7											3				34			20		2			9		23	
22009				9	1		1	1	2	3			1		15				14			4		25		7	3		15	
23001				1	3			2	1	5		2			3						2			31		31			18	1
23002				3				1		4			1		8									29		31			19	4
23004				1	2			2		3		3									1			36		24			27	
23005				1				1		5					5									7		39			37	4
23006				1				1		3		1												25		22			47	
23007				3	2		1	1		3			1		5									54		20			10	2
23008				3	1			1	2	7					10									17		43			15	
23009				2		1				2														20		12			63	
23010				2	1		1		1	7					10									4		55			19	
23011				2						3					11									5		23			56	
23012					2					3											5			46		27			16	
23013								3		4											1			29		33			30	
23014				2						3				1	9									11		26			48	
24001				3	2	2	1	1		3					4		1				1			50		18			13	
24002		1		2	5	1	2			1					1									83		4				
24003					1	5				3					2		1							25		27			36	
24004				14						4					11						3			24		30			15	
24005				2				1		1			1											91		4				
24006				1		2				5					6		1							16		37			31	
24007				3						2			2											78		15				
24008				4	2	3		1		3					6		1				1			33		26			19	
24009		1		3	3	2		2		2					3						1			62		13			9	
25002				1	3					2					1				2					13		12			65	1
25003																										4			96	
25004		3			4	1	2		2	1	2							1		1	3		1	75	4					
25005					4	2			3						4	2		5		5	2			71		3			1	
25006				1						2		24												17		14			41	
25007				2	17	9	7	1	1	1											8			50		4				
25011										2														6		12			81	
25012										3														25		22			50	
25019					28										21	3				10	3			22		14				
25020		6			7	1	3		2	1	3										4			73						
25021		9			11	1	6		3	1											9			59						
25810										11																88			1	
26007					1		5		1	2								30						61						
27001		3		9	2	4		2	1	2			1		4			2			1			43		13			13	1

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
27008		1		3	7	7	3	2	3	4	1				5			2			6			37		9			10	
27009		1		4	7	8	3	2	2	5					5			3			5			35		10			11	
27010				1	1	4									9	2	1			8	2			20		31			19	
27014		12		15		1		1	4	2			6		12	1				4	1		1	18	3	14			3	
27015	4	11	2	13	4	1	4	2	4	3	1		5		9			1		2	2		1	17	4	8			1	
27024				7	1	4	1	1		3					15						3			8		21			36	
27026				30		1							4		2						7			53		1			1	
27027				9	3	1		1		4					17									11		29			23	
27031				38	1	4		1	1	1			13		7		1				2			10		8			12	1
27032										5					2											42			51	
27034				4	3	11	3	1		4					9						7			9		24			24	
27035				6		7		1	4	3					13						9			33		20			3	
27040		11		9		1			2				1								3			72						
27041	4	11	2	14	4	1	4	2	4	2	1		5		10			1		2	1		1	17	4	8			1	
27042		3		14	1	5		1					5		11	2	1			8	2			19	1	20			5	
27043				9	4	1		1		4					18									9		29			24	
27044	10				1	2	3		1	15								2		2	50		2	3	9					
27047				6		1				3					9									10		50			21	
27050				2	4										9	2		1		6	2			26		40			7	
27051										1														91		8				
27052				36		1							7		2						8			41		2			2	
27054				5	1	2									25	1	1			4	1			17		32			10	
27055		6		8									1		14	3				9	3			22		29			4	
27056		21	3	31	2								7		23									4		8				
27057		5	2	10				1	1				3		18	1				5	1		1	20	4	23			7	
27058		15		12				1	2	3			3		29					1			1	12	4	17				
27059				6	7	4	3			2			3		6						8			38		16			6	
27061				36	1	3				1			4		8		1				5					12			25	2
27062		2		8	3	6	1	2	1	2			1		4			4			1			42		12			12	
27064		20		24		4			2				4								6			39						
27065				37	1	4				1			15		10		1				1			5		11			11	1
27066				18	1	4							9		4		1							61		1				
27067				16						1			2		4						4			62		10			1	
27069					5	1	1		5	4								6		1	2			73						
27071		1		3	7	7	3	2	3	4	1				5			2			6			37		9			10	
27072				13						3			2		7						1			24		27			22	1
27074				17									5								1			77						
28002			6	1	3		8	2	4	5								10		1	9		1	44	4					2
28008			4	42				1	2						5			1			3			31		9			1	
28016		29	13	6	15	4	1	1	2	4			2					1			1			21						

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
28018			9	23	1		2	2	4	1					3		1	3			10			34		6				
28021			1	37	2	3		2	1	1			1		9		2	4			6			22		2			6	
28023				74						1					15		1					1				6			3	
28025			2		5		3	2	4	1								17			21			45						
28026			2	2	6		4	1	3	1			1				1	13			24	1		41						
28029					2		1	1	3									21		1	26		2	37	8					
28030									2									3	17					78						
28031				30					1	1			1		4						4			33	1	23			1	
28033				17											41						2			11		18			11	
28037				13	1	4		1							27		4	2			4			10		3			30	2
28038				20				1	3				3		3					1	6		1	28	3	28			3	
28039			8	1	5				12	7			2					19			7			38					1	1
28041				2						2											1			46		49				
28046				68											13						4			11		2			1	
28048				25		1			2				3								6			61		1				1
28049		45		11	2	5	1		1				4								2			28						
28055			2	23	2	1			2									1			3			65						
28058			5	18	1				1									1			2			71						
28060			38		24				1	1	1		3					16			15			1'						
28066					3		7	1	5	2								1			12			70						
28070				27						3					21											27			22	
28075				6											27											2			65	
28079			29	2	8		2	2	3	6	1							5			19			23						
29001	75					10			1									8						5	1					
29002	51	1				5	3		1	1								5		3			2	16	11					
29003	68					6												8						18						
29004		28					2	2	6	4			1							2			6	34	14					
29005	11				4	1	21		1	12								1		5			4	13	25					
29009		43					3	1	4	5			1							2			7	21	13					
30001		40					1	1	2	8										6	4		8	9	22					
30002	3	21					3	1	4	3			1					2		1			2	51	5					
30003	51		1			3	7	1	3	4						1		13		2	3		1	4	7					
30004	11	1	22			1		1	3	10						10				7			5		31					
30011	65					8	11		1	4								1		2			1		7					
30012	23						6	1	4	2								8		4	2		3	30	17					
30013		88								2	1		3							2			1	1	3					
30014					12		2		2	2										3	14		3	49	13					
31005		8						1	5									1		14	17		7	12	33					
31006		48							1									1		4	10		4	13	11					8
31007		7						1	5									1		15	18		7	12	34					

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
31010		35																1		10	4		8	12	31					
31011		26								7											11		7	39	9					
31016		66																		3	11			19						
31020		58																		13			5	1	23					
31021		2						1	5									2		14	19		7	12	38					
31022																				10	43		6		40					
31023		1																			22			77						
31025									1											4	31		4	42	18					
31026		32																		12	14		6		29					7
31027		2			20		3		1	31	2		6							2	2		4	6	21					
32001		25			3		1	1	4									2		8	27		9	7	11					1
32002		11			1				1												30		26	29	2					
32003		12							1											6	41		6	30	4					
32004		30							3											10	36		6	3	11					
32006		13			5		1	1	3									5		19	9		7	5	32					
32007		30			1				1									4		11	26		4	2	18					2
32008		9			9		2		2									10		16	8		6	8	29					1
32020		85			2															1			7	1	3					
32023		17			1	1	1	2	2									3		3	44		9	16	2					1
32027		4																		7	64		20		5					
32031		16			3	1	1		1									8		4	35		3	19	7					
32801		16																7		18	9		8	5	37					
33001	5	5	3		4	2		2	4									5		6	33		13	7	10					
33002	1	11	2		1	1		2	4									5		4	31		8	13	13					
33003	40				3			7	4									1		2	36		6		2					
33005		19			2	2		1	3									11		4	17		5	16	20					
33006	36				17		5			7	4		1			4		11						15						
33007	40				28		2			4	3					1		6						16						
33008	26				18		3			5	3		1			3		13			2			24						
33011	18				25		2			4	2					2		13						33						
33012					2	2		1												8	48		12		29					
33013	24				14	1			1	1	1					2		15			8			32						
33014	48				13				1	1	3					2		6			23			3						
33015	8		5		1	1	2	4	4	2								6		8	24		15	9	11					
33018		10							1											6	16		5	42	20					
33019	22				19		6			8	5		1			4		14						21						
33020									1											12	45		31	2	8					
33022	23		12		8	1		2	5	1			1					11		4	18		10	2	3					
33024	43				1			3	3									1			48			1						
33026	6	6	4		4	2		2	4									5		5	32		11	8	11					

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
33027	37				1			4	3									2		7	24		18		4					
33029	65				9		2			4	3					3		6		1				4	3					
33030					4													9		7	41		18	15	4					
33031			22					2	1				1					4		12	21		11	6	18					
33033	50				8	1			7									15			17			1						
33034	26				19		3			5	3		1			3		13			2			24						
33035	35				10		2	2	6	5	7					2		4		1	13		2	6	3					
33037		14			1	1		1	4									7		4	28		5	19	17					
33039	1	10	2		2	2		2	4									5		5	31		11	12	13					
33044	18				19		6			8	5		1			3		15						23						
33045					25		2			5	3							16						48						
33046	5				16		7			7	4		2			2		22						35						
33048	45				20		5			12	7					10														1
33049	41				14		10			9	5		3			9		7						2						
33062	80				4			16																						
33063	14				22		2			3	2					2		15						40						
33065	87				6													7												
33066	24				2																72			2						
33067	74				5				21																					
33809																		46		2	36		5	10	1					
34001					19		2			5	3							30						41						
34002					10		1			3	2							17						68						
34003					50	17		3		7	3		10	1				5						5						
34004	12				35	1	2			5	3							23						18						
34005					30		2			4	3							30						32						
34006	6				4				2		2							10			6			69						
34007	10				1				1									17			6			64						
34008					55	22		2		10	4		7																	
34010	3				9		1		2		4							8			2			70						
34011	38				42		1			3	2							7						7						
34012	67				32	1																								
34014	17				31		2			5	3							22						20						
34019					46	16	1	4		10	4		13					3						3						
35002	3		1		5				3	1								4			33			50						
35004	7				7				1		2							9			40			34						
35008					2				3	1								26			37			32						
35013					1				2		2							1			30			65						
36001	5				17	6		1	2									11			54			4						
36002	1				9	3															88									
36003	2				20	7												34			31			6						

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
36004	14				1													2			81			1						
36005					8	3												20			60			9						
36006	5				17	6		1	3									7			59			3						
36007	11				16	6												5			59			4						
36008	1				9	3			1									2			80			3						
36009																		30			64			6						
36010					7	2															91									
36011					6	2															88			3						
36012					7	3												6			77			8						
36015	6				12	4			2									4			70			2						
37001					1	3		3	2									11			42		3	6	30					
37003					12	8		3										14			56			5	1					
37005					22	7	3	1										22			33			10	1					
37006					1	2		1		1			1					17			25		4	9	38					
37007					1	1				1			1					6			4		7	14	64					
37008					21	8												7			65									
37009					28	10												3			56			3						
37010					17	7		1										13			50			9	3					
37011					16	6															78									
37012	1				8	3												4			84			1						
37013					6	1				2			1					10			1		7	4	64					5
37016					10	4															87									
37017					20	7												9			59			5						
37019					12		4	3		14								2			2		5	8	50					
37020					19	7												1			74									
37021					15		36	2										14			8		1	9	14					
37022					20		9	23															4	11	34					
37024					20	7												16			47			9						
37025					18	7												36			18			21						1
37030					20		9	23															4	11	34					
37031																		8					8	9	75					
38002	24									1			1					2			70				3					
38003	39				5	2			1									49			3			2						
38007	4																				91		1		5					
38014						4	1	4		3								5			2		7	12	64					
38018	37				6	4		2	1									33			3		1	5	7					
38020																					27		7	1	64					
38021						4		3										6			2		6	17	61					
38022						4	1	4		3								4			1		7	8	68					
38024						24	1	24	10									3			1		3	7	25					2

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
38026						1												23			75									
38029	17																				83									
38030	15				9	3			1									23			48			1						
39002	2	38	2		5	1	1	2	5	3						1		1		6			10	2	21					
39004	60		3		5	3	1			1								26												
39005	17		2				3	3	1	24			1					8							41					
39006		66			3			1	5											2			12		9					
39007	15		11		11	3	1	1	3	15			4					10						1	23					
39008	1	46	1		6		2	1	4	4								1		3			14	1	16					
39011	34		29	1	2	6	1	1	1	3			3			4		2		1			2	3	9					
39012	36		2		1	2	2	2	3	11								5					1		35					
39015	81					10				3															6					
39016	52		1		6	6			1	5			2			1		12						1	13					
39017		2																		11	1		20	4	62					
39019	63				2	9				2								21							2					
39020		82																		1			13		4					
39022	37		1		1	5			3	2	2		1					2							46					
39025	23				12	2				5			1			2		6						3	45					
39026		17							2											17	2		10	5	45					
39027	50				3	5			2	1								17							20					
39028	46		3			8				4			4			5		24						1	6					
39029	11		79				1	2	3				1					1							2					
39031	72					10				1								17												
39032	75					11												14												
39033	51		1		1	4				1								35							5					
39034		52			1	2		1	4									3		9	1		7	4	17					
39036			97										1												2					
39037	83	1				7				3			6																	
39038	14	7	1			3	2	5	5	3						1		4		7			11	2	32					
39040		42		1	6		1		2	5								1		4			18		19					2
39042		76			4		1	1		2													14		1					
39044	8		15		7	2			5	9	1		7					16						1	29					
39051		58							2											15	2		4		18					
39052			9		2					8			4					12							66					
39053			18					1	3							7		18		5			2	14	31					
39054			17						2							6		11		7			2	13	41					
39055																							5		95					
39061	91					6												3												
39065	86																	14												
39068	3		14				1	2	4							4		11		7			2	13	40					

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
39069			12				1	2	5							6		18		6			2	15	32					
39073		79								1													19							
39074		61			3		1		1	5													26		3					
39075		39			14		2	1		2								1					25		17					
39076		73			1				3											2			13		7					
39077	88					8							4																	
39078	66			1	3	13	1	1					1			5				1			1	3	4					
39081	10	14	13	1		1	1	7	3	6						4		4		7			3	6	19					
39091	39					14				4								42						1						
39092																							10	1	89					
39097	2	44	1		5		1	1	3	4								1		3			16		17					
39101	88					9												3												
39813			43													14		23		1				13	6					
39814			12													10		50						26	2					
39830	2		75							1															21					
39831			75															1							24					
40004			5						3							5		26		6			1	21	34					
40005	2	1	2				1	3	6							3		8		8				16	50					
40006	17	5	17		3	1	1	1								11		7		5			1	5	26					
40007			6						2							6		36		3				29	15	2				
40008	21	3	16			3		3	9	1						8		9		4			2	3	20					
40009			6						1							6		37		3				25	17					3
40010	3		11		1		1	2	4							3		14		6			1	15	39					
40011	32	2	11			6		3	7	1						5		15		2			1	2	13					
40017			7													7		38		4			3	20	21					
40020			8													7		40		3				25	17					
40021			6													6		32		5				23	28					
40024			7													7		40		3				25	18					
41001			5													5		28		6				22	34					
41002			5													5		29		5				23	32					
41005			10					1	1							8		44		2				25	9					1
41006			6					1								6		36		4				24	22					
41007			11				1	2	5							2		7		9			1	11	48					
41010			3						1							1		6		11				17	61					
41011	13		35	2		1		1	1	1			2			9		7		3			2	6	17					
41013			5													5		31		5				23	30					
41014			12				1	2	5							2		7		9			2	11	48					
41015	78					15		1		1								1							5					
41018			2				3	7	12									5		9			2	9	52					
41020	11		2					1								1		5		9			2	16	52					

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
41021			1													1		2		11				19	66					
41022			21				3	7	12									3		7				8	39					
41024			9													9		50		1				26	3					3
41025			8				1	1	2									5		11			3	10	59					
41026			7													7		39		3				28	16	1				
41027	15		27	2		1				5			4			12		5		3			3	8	15					
41028	14		20													2		8		6			4	11	36					
41801			3													3		28		8				18	39					
41806	46		1			1										1		2		7			6	4	33					
42001	48		3			5				3			1					3					2		35					
42003			2		3		3	3		24			2					10						14	40					
42004	75		1		2	12			1	2	1							1							5					
42005	87					12																								
42007	90					8				2																				
42008	84					13				2																				
42009	87					12				2																				
42010	83					11			1	2	1														1					
42012	79		2			16				1	1							1												
42014	16		10		2	2	1	1	1	9			1					8						2	49					
42019			12		1	1				14			1					13						1	58					
43003	69	1	4		1	7			1	5			2			3		1	1	1				1	2					
43005	66		5			5		1	4	2			2			11								2						
43006	41	7	13	1		4			3	5			1					1	3	4			3		13					
43007	34	6	3		5	5		1	4	3			1			1		2		5			7	1	23					
43008	81		2			9				4			1			1			1											
43009	6	12	2		1	1		1	4	2			1			2		2		9			13		43					
43011	81		1			9				5			4			1														
43012	63		8			11				8			4			3			2					1						
43013			5		28	16	4	9	2	22			2					3						3	6					
43014	38		13			2	1	2	4	3			3			28		1	1					5						
43021	62	1	4		4	6			1	7			2			2		1	1	1				2	5					
44001	41		6		7	6		1		11			2			1		17						1	4					
44003	8	15	33							3						8		5	2	2			13		11					
44004	48		4		1	6				6		1	4			1		23	1	1			1		4					
44006	60					1							12					26												
44008	56				4	6												32						1						
44009	31	35			1	5														3			9		15					
45001		2	7	3	1			1	2						8		38	7			10	5		9		4			2	
45002				4					1						11		46	6			5	7		8		6			3	
45003	2	2	20	2	1		1	2	9	11		2					1	13	1		16			14		1				

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
45004	8		6			9	1	1	3	7		1				3		16	1	4	13		3	8	16	1				
45005	2		17	2	8			4	4	6		1						10	2		28			15		2				
45008	3		10		4			2	2	9		1						14	3		31			18		3				
45009				9					1			1			7		57	7				11				3			3	1
45010				11				1	3						2		59	9				11								4
45011				1											28		42	1				6				14			8	
45012		5	20	3					4								20	8			24	2		14						
45013	1		10	1	12			7	6	4		1						5			37			16						
46002			1	39				2		2		3			9		21	3		1	4	4		5	3				2	
46003				30						1		2			30		19	2				3							13	
46005				14						1		2			39														44	
46007				9						1		3			58														29	
46008				21				2	4						11		35	7				8		1					10	
46802															69														30	
46805				8											43														49	
46812		2	7	27					2								41	9				9		2						
46818				14													60	13				13								
47001				7		2		3	4						4		28	8	1		14	4		25					1	
47004				16				1	3						23		39	7				9		1					2	
47005				1		3		4	8						4		19	7			20			31		1			1	
47006				8		1		1	2						4		34	9			11	6		23		1			1	
47007				19		3		5	6						9		32	5				6		3		3			8	
47008				3													23	10			21	3		39						
47009				16													59	10				13								
47011				15											41		26	1				4				1			12	
47014				43								1			15		20	3				4							14	
47015				30					2						10		29	4			1	7		1		2			15	
47016				25				1	7						3		39	7			2	11		2		2			1	
47017				2													20	14			25	2		37						
48002				15		1		1	3						32		35	1			1	5		1					6	
48003				5		4		4	6	2		6			13		53	1				4				1			1	
48004				22					1						40		22					3							12	
48005				3		11		10	18						3		42	3			3	3		3						
48006				59		3		3	3	1		3			14		13					1								
48009				13					1						47		21	1				3							14	
48010				18		2		2	2						7		50	8				10								
49001				11		8		8	9						24		32					2				1			5	
49002				24		7		7	8						2		48					5								
49003				4											83														13	
49004				2		13		13	19						1		45	2			1	3		2						

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
50001			2	3		1		2	1						4		32	9			15	4		24		1			1	
50002			1	2		1		3	1						2		19	11			23	1		31	1	2			1	
50006				5		1		3	2						9		42	8			6	7		15		2				
50007		2	6	11				3		1		2			6		17	6			12	2		25					6	
50012				7											15		31	8			3	7		25		3			1	
51001		3	18	11	4	3		1							2		28	1			20	2	2	3	1					
51002				40											40		2				6					8			3	
51003		1	2	3		4									2		77				4	7								
52003		3	18	2	7	6		1	3				2				21	10			22	1		6						
52004	6	2	8			7	1	1	4	2						4		20		7			5	8	24					
52005		2	11	3	5	4		1	4	2		1					23	6			21	2		13						1
52006	1	23	9		2	1	1	2	2	1						4		6		4			22	2	18					
52007		16	19	1												8		2		8			25	2	20					
52009		18		31	5	6			3								10	1			18		5	1						
52010		21	8	1	3			1	1	1						2		5		7			22	8	19					
52011		23	1		2			2	9							1		2		10	7		29	8	6					
52014		1	2	5		2			1						1		55	6			10	6		8						2
52016			1	20	9	5		2					1		14		26	3			9	2		8						
52020	2	8	7							4								8	2	8			26		35					
53002	18	5	5				1	2	4	3			2			10		2		6			8	2	31					
53003	4	28	3	3	2		1	1	2	2			1			1	1	3		3	2		20	2	21					
53005		40	3	2					1				1				1	7			17		23	5						
53006		3	1	3					2								3	6		4	25		8	23	21					
53007	2	19	4	16		2		1		2						1	5		1	3	1		19	5	17					
53008		49		1					1	2								2		2			27		16					
53009		44	4	3													1	2			24		21	2						
53013	18	10	8			1	1	1	1	4			2					4		7			8		34					
53016	15		26			13				10			3			19			6	1				4	3					
53017		28	1													1		8		2	11		28	9	10					
53018	4	28	3	3	2		1	1	2	3			1			1	1	3		3	2		19	2	21					
53022	4	28	3	3	2		1	1	2	2			1			1	1	3		3	2		20	2	21					
53023		63		1																1			32		3					
53024		69		3																			28							
53025		22		36		1									1		10				2		13	11	3					
53026		5	1	5				1	3								3	6		3	24		8	24	16					
53029	11	11	3				1	2	5	4			1			4		1		6			12	1	37					
54001			6	6	10	1	1	3	2	2	2				3		14	13			2	2		28		3			3	
54004			15	2	7		3		1									12			24			35						
54006		1	30	3	14			1	1	5			1					15			2			26						
54008		1		29	5	4		5	4						1		12	24	2			2		10		2			1	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
54010		16			1	1												1		14	2		19	3	43					
54011			21	3	4		1	1	2	2								6			44			14						
54012			16	2	19		2	1	1	6	5							14			3			32						
54013															28		40					6		3		11			7	4
54014				2	1			3	2						8		34	4				5		26		9			4	
54015			1	1					3									12		5	17		10	29	22					
54016			6	2	28		2		2	5	7							10			1			36						
54018				20	4			1	3		1						4	16	2			1		46						
54019		1			5		10	1	3	3								13		4	7		4	30	19					
54020			2		33	1	4		1	3	11						1	10			2			33						
54022															58		1									15			26	
54025										1					4		45	1				6		24		16			3	
54027		64																3					23	10						
54029		1		26	4	4		5	3						1		9	32	2			1		9		2			1	
54032			7	10	9	1	1	3	2	2	1				2		11	17	1		4	2		22		2			2	
54034				58									1					13			12			15						
54038				1	1			2	2						10		43	3				6		18		3			8	
54041			26	3	17		3	1		5	2							10			7			26						
54043			7	10	9	1	1	3	2	2	1				2		11	17	1		4	2		22		2			2	
54044			34	6	15		5	1		4	1							7			9			17						
54048		8			3		1											2		7	3		30	6	41					
54049		1			3		3		1	1								3		9	11		16	7	43					1
54052					31		3	1		8	2							12			2			41						
54053		1		28	1	3		13	2				1					40						9		1				
54054		1		36	4			1	3								2	15	8					27						
54055			1	15		9		4	1				1					54	3		1			7		6				
54057		1	5	7	8	1	2	3	3	1	1				1		7	13	1	1	7	1	4	21	7	2			2	
54059			63		9		1			5	4							3			2			12						
54060			33		12		1	2		12	1							12						26						
54062			65	5	3					1								6			3			17						
54065			6	2	26		2		3	4	9							9			1			38						
54066			35		15		1			11	2							9						26						
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54085				29													18	1			8			44						
54087			70		6		1			6	4							2			3			9						
54088		25	3	5					1							1		8		3	11		12	19	14					
54090															76											14			11	
54091															43		3									15			40	
54092															64											14			22	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
54818					9		1		1		40							9						39						
55002				2	1	6		3	2						11		33	6	1		1	3		17		8			5	
55004				1				2							30		27		2			4		4		10			20	
55005										1					24		34					5		9		21			4	
55008															64		13					2				12			9	
55009				21	2	5		4	2						3		1	55						3		1			1	
55010															61		16					2				14			6	
55011				1					1	1					7		27	3				4		22		24			8	
55012				1	1			1		1					19		35	1	1			5		12		15			8	
55013				14		20	3		1						6		22	9			12	4		7		2				
55014				15	5	6	1	1	4						4		34	13			5	6		4		1				
55015				45	5	1									28									1		4			15	
55016				2				2	2						4		29	6	1			4		35		11	1		3	
55017				1											15		29	4				4		21		15			12	
55018			1	16		1		3										78						1						
55021				20	4	11	1	3	7						2		18	21			3	3		7						
55022				10		4		7	1								27	47			4			1						
55023			1	13	1	8		4	3						6		19	23			2	2		11		4			3	
55025				8		8		1	1						1		62				9			7		1			1	1
55026				1						1					23		35	1				5		10		20			4	
55028			1	18														80						1						
55029				21	2	5		4	2						3		1	55						3		1			1	
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55034															70		16					2				11			1	
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56001				24	11	5	1	3							12		23				3			2		10			2	
56002				32		2				2					12		17	2			8			8		16			1	
56003				2	2	7									8		57	2			8	2		8		6			1	
56004				6	13	8		2							15		33				5			3		12			2	1
56005				24	1	5		1		2					11		15	13			4			12		12			1	
56006					8	7		1							16		32				5			4		22			4	1
56007					19	8									15		17				4			12		22			3	
56008				62	3	10												3		2	6		2		10					
56010				24	12	5	1	3							12		23				3			2		10			2	
56011				33		2				2					10		16				8			8		19			1	
56012				66	2	1									16											7			7	
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56015			1	8	1	8		2	5								57	6			8			4						
57003				13	2	4	1	1		3					19		7				5			7		32			6	
57004				12	1	5				3					20		6				9			19		24				

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
57005				12	2	4	1	1		3					21		6				5			6		34			6	
57006				6						4					44		4				2			1		31			8	
57008				24	4	4	1	5		3					4		11	6			8			11		18				
57009		1		11	16	3	15	1		8					2		5	2			5			11		20				
57010				17	5	2	2			5					6		10				6			5		42				
58001		1		22		1		2		3					26		12				5		1	4	2	21				
58002				6		2		2		4					16		2				3			13		46			5	
58003		10		27	5	1	2	3		4					3		5			1	3		4	11	5	17				
58005				23				2		2					40		14				5					15				
58006				5		3		1		2					17						3			6		55			8	
58007				23				2		4					24		14				5					28				
58008				8		1		3		6					20		5				3			11		43				
58009		10		27	5	1	2	3		4					3		5			1	3		3	12	5	17				
58010					1										10											75			14	
58011		18		38	6		15	1	1	8										1			6		6					
59001				14		3		4		4					15		6				5			10		37			3	
59002				12	4	5		2		1					4		16	1			10			32		12				
60002					3			1		1					9		56					8		7		12			2	
60003				3		1		2	2						1		68	3			1	9		6		3				
60004				3				1	4						2		73	3				10		1		3				
60005								5	1	1					12		51					7		8		12			1	
60006								1	1						3		73					9		5		7				
60007					3										34		30					4		4		10			12	1
60009				6		3									19		32				5	1		15		16			2	
60012					2					2					14		34					5		14		25			5	
60013					4			1		1					10		53					7		7		14			3	
61001				12	3		1	2	4	1					2		49	2			1	7		5		10				
61002				5	4			2	4	1					4		51	4				8		5		12				1
61003				4				1	3	2					8		50		4			7				21				
61004				12	3		1	2	4	1					2		49	2			1	7		5		11				
62001				4	2			3	2	1					6		46	6				8		11		9			2	
62002				3	3			3	4	1					10		38	4				6		11		15			3	
63001				3				1	4	1					13		47	4				8		5		8			7	
63003				6						1					4		39	9				7		21		11			2	
64001								1	1						17		52	1				7		6		7	1		7	
64002				6	2			1	3						31		26					4				6	11		10	
64006				2											27		55	2				9				4			1	
65001				17				1	2	3		8			12		3		9			1		2		6	17		18	2
65004				1	4	2	1	1	3	4		10			21		15		2		3	2		6		6	6		10	2
65005				21		10	1			4					9						9			10		35				

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
65006				9	11	1	4	1	2						22		16		1		2	2		4		8	8		8	1
65007				3		1		1	2	1					41		16	1				2		3		14	2		12	
65801				47											16		5					1				2	16		14	
66001				8	9	8	3	2	4						4		37	5				6		11		2			1	
66002				1				2	1						7		52	2				7		12		8			6	
66004				21	15	29	5		1						1		19	3			1	4		1						
66005				8	2	9		4	2						2		33	8				5		22		4			1	
66006					1			2	1						8		52	2				7		11		10			7	
66011				2											19		20	1				3		4		14	8		28	
67001				2				1	1						19		11	1	1			1		17		9	6		26	3
67003															46											22			14	18
67005				1	1										17		44	3			3	6		8		7			10	
67006								1	1						21		29	2				4		18		12			9	3
67008				15	13	16	4	1	2						5		12	2			6	2		21					1	
67010															9				1					1		32	7		51	
67013															29		34					5		3		6			23	
67015				1	2		1	2	1						18		29	2			1	4		15		8	2		12	1
67018					1				1	1		2			27		3	2						15		4	12		33	
68001			3		17		3	1		12	2							10			1			50						
68003				4	11		1	1		15	1				6			8			1			44		2			4	
68004			1	1	21		4	1		14	3							11						43						
68005			1		13		4	1	1	12	3							16						48						
68006			2	9	3		1			4					16			5			2			40		6			11	1
68007					18		2			17	3							13						46						1
68010			10		1					9								19						61						
68014					3		2			16								14						65						
68015			7		18		1		1	19								11						43						
68020			12	1	15		2		4	7								13						46						
69008				23	13		5			7					1		1	7			5			32		3				1
69011				5	2		2			9					4			14			1			62		2				
69012				10	15		5		2	4	4				2		2	9			2	1		42		1			1	
69013					7		3			33	3	1						10						43						
69017				32						2					16		3	1			6			21		6			13	
69018			17		4					1								14						63						
69019											6	2												92						
69020				15							1				5						3			72		4				
69027				11				1	1	4					14			1			2			34		10			21	1
69031			2	2	5					14								15						60						
69034				8						3					36									3		21			29	
69802				1						1					6											6			85	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
70002				12	8					11	1							7			2			46		1			8	2
70004				8	7					2								36			2			42		1				
70006				12	19					43	5	1						3			2			15						
70803					10			2	1	14	2							25						46						
71001				8	1	2		1	1	3					7			2			3			42		16			11	
71003				2						4					8						1			7		35			43	
71004				16	1				2	3					7						3			44		16			7	
71005										2														50		19			28	
71006				4	3	4	1	1	1	3					7		1				5			39		20			11	
71008				4		2		1	1	3					11						2			37		18			21	
71009				8	2	2		1	1	3					8						3			41		18			12	
71010				17						5					6						3			38		20			10	
71011				6	4	3	1	1	3	3					11		2				4	1		12		26			23	
71802				6	5	3	1	1	3	3					11		2				4	1		12		25			23	
71804				6						1					24											4			66	
72001				6	4	4	1	2	1	3					12		8	1			3	2		17		17	2		17	
72002				2	1			6	1	8	2				8			7						35		20			9	
72004				6	3	4	1	2	1	3					12		9	1			3	2		17		17	2		17	
72005				11	1	5				2					18		17	2				3		12		8	3		16	
72006				7	4	3	1	1	1	3					13		14	2				3		11		16	3		18	
72007				3				1		8					14			1						17		47			9	
72008				4				7		5					13			1						24		31			17	
72009				4		7		1	2	2					12		2				10	1		27		14			16	
72011				4	2	2	1		1	4					8		6	1				1		14		29	1		26	
72811				3				3	2	13					12			1						17		41			8	
72814				5						3					23									21		28			20	
72817					5					1								23						69		1				
72818					3			1	1	5	2							21						66		1				
72820															16		44	4				6		28		2				
73001				10				1	1	1					2		17	2	20			4				10	12		15	7
73002				3											5		20	2	4			6				23	10		21	7
73003				6	3		1	1		2					3		34	4	6			6				13	5		16	
73005				10	5	2	2			1					4		37	5	4			7		3		7	3		12	
73007				6				1	1	2					3		17		16			2				13	16		24	
73008				15	3	2	1			1	3	1			5		29	9				6		19		6				
73009				6	1										2		35	2	10			6				7	5		25	
73010				10				1	1	1					2		18	2	19			4				10	11		15	7
73011				7	2		1								4		47	8				9		9		4	3		6	
73803				12											1		53	8				14				7			4	
73804				14	2			1	3	1									36							7	17		18	1

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
74001				7						4							2		16							22	22		27	
74002				8	5														15								37		29	6
74003				23	1					2					1		3	1						4			33		24	6
74005				15	12	2	2		1	3					2		4	5						27		1	13		9	2
74007				20	4				1	1									12							2	28		32	1
75002				3	4	4		1	1						5		21		6		5	3		22		2	9		11	3
75003				5	4	3			2						5		18		11		4	3		8		2	13		17	4
75004				1	1	1		2		1					7		49	1			2	7		3		1	12		8	3
75006					2	2			1						10		43				3	6		6			19		7	
75007				3		7			1	1					9		13		4		9	2		19		10	8		14	
75009				7		4				1					7		9		15		6	1		12		5	10		21	2
75010				6	16	7	1			1					6		23	2			3	3		27		2	1			
75017				6	13	4	3			2					4		9	4	1		1	1		50					1	
76002			4	9	12	6	2	1		4					3		2	6	4		1			22		4	3		14	1
76004				11	1	9				1					7			3	11		2			14		4	8		25	3
76005				11	8	9	3	1		5					4		2	7						31		6			13	
76007			3	6	13	4	2	2		6		2			3		2	8	2		1			25		5	2		12	1
76008					10		1			10		16						4						19		20			17	
76009				6	2	5		1	1	2					8		9	5			2	1		38			5		15	
76010			2	9	24		6	2		7								16						34						
76011										2		70														19			8	
76014			1	10	2	18	1			3					7			6						2		20			32	
76805				26		12									62															
77001							1			1		1		7	32		13	1						16		10			18	
77002							1			1		1	1	6	47		19							7		5			12	
77003						1				1				8	11		6							24		18			29	
77004						4						5		4	7		2							64		12			1	
77005					1			1		8		1						8						28		37			16	
78001					4	4	2	1	1	1		3	6	4	28	2	15	3	3			2		10		2			8	
78002					3	2	2	1		1		4	4	6	35	4	9	4						4		4			19	
78003					4	4	2	1	1	1		3	7	5	25	2	13	2	3			2		15		2			8	
78004							2	1		1		1	8	2	37	2	8	4	1			1		9		3			20	
78005					3	2	2	1	1	1		4	5	4	34	4	8	4						6		3			19	
79002					3	2	1	1		1		1		5	31	1	20	1	2			1		15		2			12	
79003					1	1	2	1	1	1		2	1	6	23		6							28		7			20	
79004					2									13	30		29		10			5		1					10	
79005					6	2	1			1		4		13	27	1	34	1	5			1		1					2	
79006					1	1	1					1		4	36		13	1	1					20		3			16	
80001					2							16			23		9		18			3		22		1			5	1
80004												5			74		5					1							13	1

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
80005												2			15		14					67							1	
81002					1		1					22		1	37		11		2			4				1	2		15	1
81003					1							14		1	16		7		5			1				4	1		49	
81004					1							58			11		16		4								4		4	1
82001					3	4	1					2		2	10	8	8		1					39		8			13	1
82003						6	1	1		1		13	4	5	15		14		3					11		2			24	
83002							2	1	1	1		2			19		11		3					44					14	1
83003					3	5						4			14			2						32					37	
83004					3	1						4		1	7		1	1						44		5			31	
83005					5		1	1		1		1			2		1							69					19	
83006					2	2						3			7			8						49		3			24	
83007					4		1					10					5							80						
83009					1		1	1		1		2			13		11		2					55		2			8	1
84002															16				9										73	1
84003					10	6	1	1		1		3		1	32		10	4						17		2			11	
84004					9	3	2	1		1		2		2	41		13	5						6		2			11	
84005					8	5	1	1		1		3		1	23		6	4						32		1			13	
84006					4	15	4	2	1	3		4			2			7	3					47					7	1
84008												3					5							79					12	
84009					2	24						1			13		2	2	2					23					28	
84011															1		51	2	9					17					19	
84012					4					8					8		21		2					47					8	2
84013					7	5	1	1		1		2		1	21		6	4						36		1			12	
84014					9	3	1	1				3			6		1	6						43					27	
84015					4	4	2	1	1	1		2			3		3	6	4					61					8	1
84016				3		1									7									82					7	
84018					9	5	2	1		1		2		1	36		11	4						12		2			12	
84020					7			1							8		13	7	13					28					22	
84022						1	1			1		4	1	3	45		9	2						7		7			19	
84023																		1						97						2
84025				1											3									92					3	1
84026															21		15		8					43					10	3
84029					2	2						1					1	33						61						
85002					6		2	1		1		2	7	1	11		11	5	8					25		1			18	
85003												18			48		17		10			2					1		4	
85004												16			51		29												3	
86002							1			1		12		1	44		14		6			1		2			8		6	3
87801												10			55				22								14			
89807												34			61		1												3	2
90002					2							13			38		16		22			1					6		1	

NWA_NO	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	LAKE
90003												13			31		30		16			6					4			
93001							1					15			39		18		18			2					1		2	1
94001												18			35		16		7			2					6		7	8
95001				6								15			26		22		2			1					9	1	11	7
96001					1							4			33													4	57	1
96002					2							17			51		2		2								1	4	18	3
97002				1		3						2			17									6				4	64	3
101001	11		37	2	8		1		3	1						9		13		3			1	8	5					
101005	9		36	3	4											13		13		4			1	11	5					

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
2001	Helmsdale	Kilphedir	A	551.4			.484
3001	Shin	Lairg	A	494.6			.55
3003	Oykel	Easter Turnaig	A	330.7			.239
3803	Tirry	Rhian Bridge	A	64.2			.275
4003	Alness	Alness	D	201			.451
5802	Farrar	Loch Beannachran	A	243.5			.334
6003	Moriston	Invermoriston	A	391			.291
6006	Allt Bhlaraidh	Invermoriston	A	27.5			.291
6008	Enrick	Mill of Tore	A	105.9			.367
7001	Findhorn	Shenachie	A	415.6			.369
7002	Findhorn	Forres	A	781.9			.408
7003	Lossie	Sheriffmills	D	216			.517
7004	Nairn	Firhall	A	313			.454
7005	Divie	Dunphail	D	165			.445
8001	Spey	Aberlour	A	2654.7			.581
8002	Spey	Kinrara	A	1011.7			.575
8004	Avon	Delnashaugh	A	542.8			.553
8005	Spey	Boat of Garten	D	1267.8			.618
8006	Spey	Boat o Brig	A	2861.2			.605
8009	Dulnain	Balnaan Bridge	A	272.2			.466
8010	Spey	Grantown	A	1748.8			.603
8011	Livet	Minmore	D	104			.632
9001	Deveron	Avochie	A	441.6			.588
9002	Deveron	Muiresk	A	954.9			.579
9003	Isla	Grange	A	176.1			.534
9004	Bogie	Redcraig	A	179			.676
10001	Ythan	Ardlethen	D	448.1			.718
10002	Ugie	Inverugie	D	325			.609
10003	Ythan	Ellon	D	523			.728
11001	Don	Parkhill	A	1273			.674
11002	Don	Haughton	A	787			.667
11003	Don	Bridge of Alford	A	499			.67
11801	Urie	Urieside	A	239			.72
12001	Dee	Woodend	A	1370			.533
12002	Dee	Park	A	1844			.535
12003	Dee	Polhollick	A	690			.508
12004	Girnock Burn	Littlemill	A	30.3			.407
12005	Muick	Invermuick	D	110			.521
12006	Gairn	Invergairn	A	150			.541
12007	Dee	Mar Lodge	A	289			.487

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
13001	Bervie	Inverbervie	A	123			.538
13002	Luther Water	Luther Bridge	A	138			.538
13005	Lunan Water	Kirkton Mill	D	124			.498
13007	North Esk	Logie Mill	A	730			.516
13008	South Esk	Brechin	A	490			.572
14001	Eden	Kemback	A	307.4			.6
14002	Dighty Water	Balmossie Mill	A	126.9			.572
15001	Isla	Forter	A	70.7			.565
15002	Newton Burn	Newton	A	15.4			.577
15004	Inzion	Loch of Lintrathen	A	24.7			.625
15005	Melgan	Loch of Lintrathen	A	40.9			.575
15010	Isla	Wester Cardean	D	366.5			.535
15013	Almond	Almondbank	A	174.8			.441
15017	Braan	Ballinloan	A	197			.386
15023	Braan	Hermitage	A	210			.466
15024	Dochart	Killin	A	239			.309
15809	Muckle Burn	Eastmill	D	16.5			.528
16001	Earn	Kinkell Bridge	D	590.5			.459
16003	Ruchill Water	Cultybraggan	A	99.5			.307
17004	Ore	Balfour Mains	A	162			.533
17005	Avon	Polmonthill	D	195.3			.398
18001	Allan Water	Kinbuck	A	161			.447
18003	Teith	Bridge of Teith	D	518			.439
18005	Allan Water	Bridge of Allan	A	210			.461
18008	Leny	Anie	A	190			.381
18011	Forth	Craigforth	D	1036			.422
18017	Monachyle Burn	Balquhidder	A	7.7			.195
18018	Kirkton Burn	Balquhidder	A	6.85			.394
19001	Almond	Craigiehall	Y	369	51.55	5	.384
19002	Almond	Almond Weir	A	43.8	62.63	11	.339
19003	Breich Water	Breich Weir	A	51.8			.33
19004	North Esk	Dalmore Weir	A	81.6			.538
19006	Water of Leith	Murrayfield	D	107			.459
19007	Esk	Musselburgh	D	330			.513
19010	Braid Burn	Liberton	D	16.2			.607
19011	North Esk	Dalkeith Palace	A	137			.53
19805	Spittle Burn	Ninemile Burn	A	.6			.68
20001	Tyne	East Linton	A	307	36.59	10	.519
20003	Tyne	Spilmersford	A	161			.491
20005	Birns Water	Saltoun Hall	A	93			.462

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
20006	Biel Water	Belton House	A	51.8			.608
20007	Gifford Water	Lennoxlove	A	64			.567
20804	Thornton Burn	Thornton Mill	B	14.2			.641
20806	Hedderwick Burn	North Belton	A	7.1			.243
20807	Woodhall Burn	Woodhall	A	10			.691
20808	Cogtail Burn	Athelstane Ford	D	3.9			.507
20809	Salters Burn	Crichton Dene	D	1.8			.32
21001	Fruid Water	Fruid	A	23.7			.307
21002	Whiteadder Water	Hungry Snout	A	45.6			.5
21005	Tweed	Lyne Ford	A	373			.559
21006	Tweed	Boleside	A	1500			.499
21007	Ettrick Water	Lindean	A	499			.397
21008	Teviot	Ormiston Mill	A	1110			.446
21009	Tweed	Norham	A	4390			.517
21010	Tweed	Dryburgh	A	2080			.514
21011	Yarrow Water	Philiphaugh	A	231			.441
21012	Teviot	Hawick	A	323			.426
21013	Gala Water	Galashiels	A	207			.509
21015	Leader Water	Earlston	D	239			.483
21016	Eye Water	Eyemouth Mill	A	119			.441
21017	Ettrick Water	Brockhoperig	A	37.5			.344
21018	Lyne Water	Lyne Station	D	175			.588
21019	Manor Water	Cademuir	A	61.6			.599
21020	Yarrow Water	Gordon Arms	A	155			.434
21021	Tweed	Sprouston	A	3330			.496
21022	Whiteadder Water	Hutton Castle	D	503			.511
21023	Leet Water	Coldstream	A	113			.341
21024	Jed Water	Jedburgh	A	139			.416
21025	Ale Water	Ancrum	A	174			.427
21026	Tima Water	Deephope	A	31			.269
21027	Blackadder Water	Mouth Bridge	A	159			.489
21028	Menzion Burn	Menzion Farm	A	5.7			.43
21030	Megget Water	Henderland	A	56.2	43.05	4	.382
21031	Till	Etal	D	648			.572
21032	Glen	Kirknewton	A	198.9			.481
21805	Whiteadder Water	Blanerne	A	277			.487
22001	Coquet	Morwick	A	569.8			.447
22002	Coquet	Bygate	A	59.5			.47
22003	Usway Burn	Shillmoor	A	21.4			.395
22004	Aln	Hawkhill	A	205			.46

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
22006	Blyth	Hartford Bridge	A	269.4			.342
22007	Wansbeck	Mitford	A	287.3			.353
22008	Alwin	Clennell	A	27.7			.45
22009	Coquet	Rothbury	A	346			.473
23001	Tyne	Bywell	D	2175.6			.349
23002	Derwent	Eddys Bridge	A	118	37.13	9	.426
23004	South Tyne	Haydon Bridge	A	751.1			.34
23005	North Tyne	Tarset	A	284.9	53.79	6	.269
23006	South Tyne	Featherstone	A	321.9	38.74	1	.329
23007	Derwent	Rowlands Gill	A	242.1			.495
23008	Rede	Rede Bridge	A	343.8			.328
23009	South Tyne	Alston	A	118.5			.299
23010	Tarset Burn	Greenhaugh	A	96	49.22	6	.267
23011	Kielder Burn	Kielder	A	58.8			.335
23012	East Allen	Wide Eals	D	88			.341
23013	West Allen	Hindley Wrae	A	75.1			.267
23014	North Tyne	Kielder temporary	A	27			.346
24001	Wear	Sunderland Bridge	D	657.8			.413
24002	Gaunless	Bishop Auckland	D	93			.513
24003	Wear	Stanhope	A	171.9	46.92	5	.343
24004	Bedburn Beck	Bedburn	A	74.9			.464
24005	Browney	Burn Hall	A	178.5	28.87	18	.516
24006	Rookhope Burn	Eastgate	A	36.5			.349
24007	Browney	Lanchester	Y	44.6	37.27	8	.449
24008	Wear	Witton Park	A	455			.444
24009	Wear	Chester le Street	D	1008.3			.457
25002	Tees	Dent Bank	A	217.3			.21
25003	Trout Beck	Moor House	A	11.4	64.76	5	.147
25004	Skerne	South Park	Y	250.1	24.58	5	.523
25005	Leven	Leven Bridge	A	196.3			.432
25006	Greta	Rutherford Bridge	A	86.1	46.49	2	.209
25007	Clow Beck	Croft	A	78.2			.536
25011	Langdon Beck	Langdon	A	13	47.02	1	.197
25012	Harwood Beck	Harwood	A	25.1	67.67	2	.224
25019	Leven	Easby	A	14.8			.579
25020	Skerne	Preston le Skerne	D	147			.368
25021	Skerne	Bradbury	D	70.1			.461
25810	Syke Weir	Moor House	M	.04	58.92	5	
26007	Catchwater	Withernwick	A	15.5			.353
27001	Nidd	Hunsingore Weir	Y	484.3	42.28	12	.496

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
27008	Swale	Leckby Grange	A	1345.6			.48
27009	Ouse	Skelton	D	3315			.427
27010	Hodge Beck	Bransdale Weir	Y	18.9	52.42	1	.483
27014	Rye	Little Habton	D	679			.623
27015	Derwent	Stamford Bridge	A	1634.3			.671
27024	Swale	Richmond	A	381			.354
27026	Rother	Whittington	D	165	34.13	8	.451
27027	Wharfe	Ilkley	D	443	50.73	24	.374
27031	Colne	Colne Bridge	Y	245	41.31	2	.391
27032	Hebden Beck	Hebden	D	22.17			.411
27034	Ure	Kilgram Bridge	A	510.2	59.9	10	.329
27035	Aire	Kildwick Bridge	A	282.3	40.99	11	.369
27040	Doe Lea	Staveley	A	67.9			.507
27041	Derwent	Buttercrambe	D	1586			.676
27042	Dove	Kirkby Mills	A	59.2			.595
27043	Wharfe	Addingham	A	427			.319
27044	Blackfoss Beck	Sandhills Bridge	A	47			.454
27047	Snaizeholme Beck	Low Houses	A	10.2			.192
27050	Esk	Sleights	A	308			.401
27051	Crimple	Burn Bridge	A	8.1	32.25	8	.307
27052	Whitting	Sheepbridge	A	50.2			.475
27054	Hodge Beck	Cherry Farm	A	37.1			.528
27055	Rye	Broadway Foot	A	131.7			.562
27056	Pickering Beck	Ings Bridge	A	68.6			.685
27057	Seven	Normanby	A	121.6			.366
27058	Riccal	Crook House Farm	A	57.6			.63
27059	Laver	Ripon	A	87.5			.407
27061	Colne	Longroyd Bridge	A	72.3			.375
27062	Nidd	Skip Bridge	D	516			.284
27064	Went	Walden Stubbs	D	83.7			.588
27065	Holme	Queens Mill	D	97.4			.47
27066	Blackburn Brook	Ashlowes	A	42.8			.271
27067	Sheaf	Highfield Road	A	49.1			.443
27069	Wiske	Kirby Wiske	A	215.5			.158
27071	Swale	Crakehill	A	1363			.439
27072	Worth	Keighley	B	71.7			.513
27074	Spen Beck	Northorpe	A	46.3			.561
28002	Blithe	Hamstall Ridware	A	163			.491
28008	Dove	Rocester Weir	A	399			.612
28016	Ryton	Serlby Park	Y	231	25.86	4	.695

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
28018	Dove	Marston on Dove	A	883.2			.603
28021	Derwent	Draycott	D	1175			.668
28023	Wye	Ashford	D	154	15.07	9	.742
28025	Sence	Ratcliffe Culey	A	169.4			.427
28026	Anker	Polesworth	Y	368	48.63	5	.474
28029	Kingston Brook	Kingston Hall	A	57			.383
28030	Black Brook	Onebarrow	A	8.4			.437
28031	Manifold	Ilam	A	148.5			.53
28033	Dove	Hollinsclough	A	8	24.38	8	.447
28037	Derwent	Mytham Bridge	D	203			.406
28038	Manifold	Hulme End	A	46			.31
28039	Rea	Calthorpe Park	A	74			.486
28041	Hamps	Waterhouses	A	35.13	44.23	5	.349
28046	Dove	Izaak Walton	A	83			.783
28048	Amber	Wingfield Park	D	139			.514
28049	Ryton	Worksop	A	77			.626
28055	Ecclesbourne	Duffield	A	50.4			.492
28058	Henmore Brook	Ashbourne	A	42			.457
28060	Dover Beck	Lowdham	A	69			.732
28066	Cole	Coleshill	A	130			.441
28070	Burbage Brook	Burbage	A	9.1	42.47	9	.447
28075	Derwent	Slippery Stones	A	17			.375
28079	Meece	Shallowford	D	86.3			.604
29001	Waithe Beck	Brigsley	A	108.3	7.49	9	.843
29002	Great Eau	Claythorpe Mill	A	77.4			.882
29003	Lud	Louth	D	55.2			.899
29004	Ancholme	Bishopbridge	Y	54.7	31.42	8	.455
29005	Rase	Bishopbridge	A	66.6			.541
29009	Ancholme	Toft Newton	A	27.2			.515
30001	Witham	Claypole Mill	A	297.9	27.5	11	.675
30002	Barlings Eau	Langworth Bridge	A	210.1			.454
30003	Bain	Fulsby Lock	A	197.1			.584
30004	Partney Lymn	Partney Mill	A	61.6	22.21	11	.654
30011	Bain	Goulceby Bridge	A	62.5			.722
30012	Stainfield Beck	Stainfield	A	37.4			.443
30013	Heighington Beck	Heighington	A	21.2			.746
30014	Pointon Lode	Pointon	A	11.9			.475
31005	Welland	Tixover	M	417	57.48	8	
31006	Gwash	Belmesthorpe	A	150			.69
31007	Welland	Barrowden	A	411.6			.444

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
31010	Chater	Fosters Bridge	A	68.9	41.41	7	.511
31011	West Glen	Burton Coggles	A	31.6			.355
31016	North Brook	Empingham	A	36.5			.939
31020	Morcott Brook	South Luffenham	A	19.6			.596
31021	Welland	Ashley	A	250.7	31.12	2	.412
31022	Jordan	Market Harborough	A	20.8			.411
31023	West Glen	Easton Wood	A	4.4	32.97	1	.142
31025	Gwash South Arm	Manton	A	24.5			.271
31026	Egleton Brook	Egleton	A	2.5			.342
31027	Bourne Eau	Mays Sluice Bourne	D	10.6			.71
32001	Nene	Orton	D	1634.3			.515
32002	Willow Brook	Fotheringhay	D	89.6			.687
32003	Harpers Brook	Old Mill Bridge	A	74.3			.465
32004	Ise Brook	Harrowden Old Mill	A	194			.551
32006	Nene/Kislingbury	Upton	D	223			.582
32007	Nene Brampton	St Andrews	D	232.8			.572
32008	Nene/Kislingbury	Dodford	D	107			.547
32020	Wittering Brook	Wansford	D	46.9			.859
32023	Grendon Brook	Ryeholmes Bridge	A	47.5			.602
32027	Billing Brook	Chesterton	A	24.3			.408
32031	Wootton Brook	Wootton Park	A	73.85			.506
32801	Flore Stream	Flore	M	6.81	39.84	8	
33001	Bedford Ouse	Brownshill Staunch	D	3030			.404
33002	Bedford Ouse	Bedford	A	1460			.515
33003	Cam	Bottisham	A	803			.653
33005	Bedford Ouse	Thornborough Mill	D	388.5			.504
33006	Wissey	Northwold	A	274.5			.815
33007	Nar	Marham	D	153.3			.905
33008	Little Ouse	Thetford No1 Staunch	D	699			.719
33011	Little Ouse	County Bridge Euston	A	128.7			.727
33012	Kym	Meagre Farm	A	137.5			.259
33013	Sapiston	Rectory Bridge	A	205.9			.633
33014	Lark	Temple	A	272	13.65	9	.775
33015	Ouzel	Willen	Y	277.1	36.03	10	.548
33018	Tove	Cappenham Bridge	A	138.1			.529
33019	Thet	Melford Bridge	D	316			.782
33020	Alconbury Brook	Brampton	A	201.5			.283
33022	Ivel	Blunham	D	541.3			.728
33024	Cam	Dernford	D	198			.77
33026	Bedford Ouse	Offord	A	2570			.493

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
33027	Rhee	Wimpole	A	119.1			.655
33029	Stringside	White Bridge	Y	98.8	11.72	7	.857
33030	Clipstone Brook	Clipstone	A	40.2			.377
33031	Broughton Brook	Broughton	A	66.6			.389
33033	Hiz	Arlesey	A	108			.851
33034	Little Ouse	Abbey Heath	A	699.3			.8
33035	Ely Ouse	Denver Complex	D	3430			.498
33037	Bedford Ouse	Newp't Pagnell Wr	A	800			.493
33039	Bedford Ouse	Roxton	A	1660			.543
33044	Thet	Bridgham	A	277.8			.745
33045	Wittle	Quidenham	A	28.3	21.93	7	.644
33046	Thet	Red Bridge	A	145.3			.633
33048	Larling Brook	Stonebridge	A	21.4			.829
33049	Stanford Water	Buckenham Tofts	A	43.5			.885
33062	Guilden Brook	Fowlmere two	D				.967
33063	Little Ouse	Knettishall	A	101			.691
33065	Hiz	Hitchin	A	6.8			.848
33066	Granta	Linton	A	59.8			.474
33067	New River	Burwell	D	19.6			.957
33809	Bury Brook	Bury Weir	A	65.3	55.53	9	.316
34001	Yare	Colney	A	231.8			.657
34002	Tas	Shotesham	D	146.5			.579
34003	Bure	ingworth	A	164.7	13.07	9	.831
34004	Wensum	Costessey Mill	A	536.1			.733
34005	Tud	Costessey Park	A	73.2	22.59	7	.652
34006	Waveney	Needham Mill	A	370			.48
34007	Dove	Oakley Park	A	133.9	42.95	5	.47
34008	Ant	Honing Lock	A	49.3			.864
34010	Waveney	Billingford Bridge	A	149.4			.428
34011	Wensum	Fakenham	A	127.1	11.23	5	.825
34012	Burn	Burnham Overy	A	80			.954
34014	Wensum	Swanton Morley Total	D	363			.749
34019	Bure	Horstead Mill	D	313			.795
35002	Deben	Naunton Hall	A	163.1			.357
35004	Ore	Beversham Bridge	A	54.9			.466
35008	Gipping	Stowmarket	A	128.9	44.29	10	.385
35013	Blyth	Holton	D	92.9			.342
36001	Stour	Stratford St Mary	D	844.3			.507
36002	Glem	Glemsford	A	87.3			.435
36003	Box	Polstead	A	53.9			.637

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
36004	Chad Brook	Long Melford	A	47.4			.425
36005	Brett	Hadleigh	A	156			.449
36006	Stour	Langham	D	578			.513
36007	Belchamp Brook	Bardfield Bridge	A	58.6			.416
36008	Stour	Westmill	A	224.5	46.19	12	.371
36009	Brett	Cockfield	A	25.7			.312
36010	Bumpstead Brook	Broad Green	A	28.3			.228
36011	Stour Brook	Sturmer	A	34.5			.357
36012	Stour	Kedington	A	76.2			.402
36015	Stour	Lamarsh	D	480.7			.525
37001	Roding	Redbridge	A	303.3	47.86	13	.395
37003	Ter	Crabbs Bridge	A	77.8	36.75	5	.492
37005	Colne	Lexden	D	238.2			.526
37006	Can	Beach's Mill	A	228.4			.419
37007	Wid	Writtle	A	136.3	38.9	7	.391
37008	Chelmer	Springfield	A	190.3	32.98	2	.548
37009	Brain	Guithavon Valley	A	60.7			.682
37010	Blackwater	Appleford Bridge	A	247.3			.531
37011	Chelmer	Churchend	A	72.6			.431
37012	Colne	Poolstreet	A	65.1			.267
37013	Sandon Brook	Sandon Bridge	A	60.6			.34
37016	Pant	Copford Hall	A	62.5			.274
37017	Blackwater	Stisted	A	139.2			.496
37019	Beam	Bretons Farm	A	49.7			.364
37020	Chelmer	Felsted	D	132.1			.517
37021	Roman	Bounstead Bridge	A	52.6			.613
37022	Holland Brook	Thorpe le Soken	A	54.9			.489
37024	Colne	Earls Colne	A	154.2			.471
37025	Bourne Brook	Perces Bridge	A	32.1			.49
37030	Holland Brook	Cradle Bridge	A	48.6			.494
37031	Crouch	Wickford	A	71.8	24.15	9	.305
38002	Ash	Mardock	D	78.7			.506
38003	Mimram	Panshanger Park	Y	133.9	11.85	6	.937
38007	Canons Brook	Elizabeth Way	A	21.4	37.2	18	.414
38014	Salmon Brook	Edmonton	A	20.5			.271
38018	Upper Lee	Water Hall	D	150			.813
38020	Cobbins Brook	Sewardstone Road	A	38.4			.239
38021	Turkey Brook	Albany Park	D	42.2			.216
38022	Pymmes Brook	Edmonton Silver Street	A	42.6			.438
38024	Small River Lee	Ordnance Road	A	41.5			.466

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
38026	Pincey Brook	Sheering Hall	A	54.6			.384
38029	Quin	Griggs Bridge	A	50.4			.437
38030	Beane	Hartham	A	175.1			.786
39002	Thames	Days Weir	A	3444.7			.643
39004	Wandle	Beddington Park	Y	122	5.81	22	.767
39005	Beverley Brook	Wimbledon Common	D	43.6	18.21	17	.606
39006	Windrush	Newbridge	A	362.6			.864
39007	Blackwater	Swallowfield	D	354.8	19.13	13	.684
39008	Thames	Eynsham	A	1616.2			.674
39011	Wey	Tilford	A	396.3			.742
39012	Hogsmill	Kingston upon Thames	Y	69.1	19.08	11	.728
39015	Whitewater	Lodge Farm	A	44.5			.936
39016	Kennet	Theale	A	1033.4			.873
39017	Ray	Grendon Underwood	A	18.6	57.38	25	.153
39019	Lambourn	Shaw	A	234.1			.964
39020	Coln	Bibury	A	106.7			.938
39022	Loddon	Sheepbridge	A	164.5	40.15	12	.753
39025	Enborne	Brimpton	Y	147.6	25.13	13	.536
39026	Cherwell	Banbury	D	199.4	34.83	10	.401
39027	Pang	Pangbourne	A	170.9			.869
39028	Dun	Hungerford	A	101.3			.95
39029	Tillingbourne	Shalford	A	59			.888
39031	Lambourn	Welford	A	176			.981
39032	Lambourn	East Shefford	D	154			.974
39033	Winterbourne St	Bagnor	A	49.2			.959
39034	Evenlode	Cassington Mill	A	430			.708
39036	Law Brook	Albury	Y	16	3.8	1	.933
39037	Kennet	Marlborough	A	142			.949
39038	Thame	Shabbington	D	443			.537
39040	Thames	West Mill Cricklade	D	185			.632
39042	Leach	Priory Mill Lechlade	A	76.9			.783
39044	Hart	Bramshill House	D	84			.626
39051	Sor Brook	Adderbury	A	106.4			.77
39052	The Cut	Binfield	Y	50.2	29.44	8	.422
39053	Mole	Horley	Y	89.9	51.05	7	.425
39054	Mole	Gatwick Airport	A	31.8			.245
39055	Yeading Bk West	Yeading West	A	17.6			.262
39061	Letcombe Brook	Letcombe Bassett	A	2.7			.959
39065	Ewelme Brook	Ewelme	A	13.4			.974
39068	Mole	Castle Mill	D	316			.414

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
39069	Mole	Kinnersley Manor	A	142			.368
39073	Churn	Cirencester	A	84			.87
39074	Ampney Brook	Sheepen Bridge	A	74.4			.76
39075	Marston Meysey Bk	Whetstone Bridge	A	25			.486
39076	Windrush	Worsham	A	296			.832
39077	Og	Marlborough Poulton Fm	D	59.2			.976
39078	Wey(north)	Farnham	D	191.12			.706
39081	Ock	Allott Gardens	A	234			.648
39091	Misbourne	Quarrendon Mill	D	66.29			.809
39092	Dollis Brook	Hendon Lane Bridge	M	25.1	46.86	8	
39097	Thames	Buscot	A	997			.728
39101	Aldbourne	Ramsbury	A	53.1			.972
39813	Mole	Ifield Weir	M	12.69	47.34	9	
39814	Crawters Brook	Hazelwick	M	4.5	43.78	13	
39830	Beck	Rectory Road	M	10	12.94	11	
39831	Chaffinch Brook	Beckenham	M	7	20.41	20	
40004	Rother	Udiam	Y	206	65.21	2	.39
40005	Beult	Stile Bridge	A	277.1			.239
40006	Bourne	Hadlow	A	50.3	22.98	16	.619
40007	Medway	Chafford Weir	Y	255.1	43.37	19	.501
40008	Great Stour	Wye	Y	230	35.11	10	.581
40009	Teise	Stone Bridge	A	136.2	43.46	11	.437
40010	Eden	Penshurst	A	224.3	48.64	27	.322
40011	Great Stour	Horton	D	345			.694
40017	Dudwell	Burwash	A	27.5			.439
40020	Eridge Stream	Hendal Bridge	A	53.7			.439
40021	Hexden Channel	Hopemill Br Sandhurst	A	32.4			.447
40024	Bartley Mill St	Bartley Mill	A	25.1			.421
41001	Nunningham Stream	Tilley Bridge	A	16.9			.356
41002	Ash Bourne	Hammer Wood Bridge	A	18.4			.51
41005	Ouse	Gold Bridge	D	180.9	45.22	23	.484
41006	Uck	Isfield	Y	87.8	60.44	15	.415
41007	Arun	Park Mound	M	403.3	77.49	11	
41010	Adur W Branch	Hatterell Bridge	A	109.1			.247
41011	Rother	Iping Mill	A	154			.624
41013	Huggletts Stream	Henley Bridge	A	14.2			.362
41014	Arun	Pallingham Quay	D	379			.321
41015	Ems	Westbourne	Y	58.3	4.68	10	.918
41018	Kird	Tanyards	D	66.8			.174
41020	Bevern Stream	Clappers Bridge	A	34.6			.272

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
41021	Clayhill Stream	Old Ship	D	7.1	53.52	5	.168
41022	Lod	Halfway Bridge	A	52	49.66	8	.348
41024	Shell Brook	Shell Brook P S	A	22.6			.523
41025	Loxwood Stream	Drungewick	A	91.6	57.88	6	.221
41026	Cockhaise Brook	Holywell	A	36.1			.523
41027	Rother	Princes Marsh	A	37.2			.62
41028	Chess Stream	Chess Bridge	A	24	48.03	18	.374
41801	Hollington St	Hollington	M	3.52	39.51	15	
41806	North End Stream	Allington	D	2.3			.422
42001	Wallington	North Fareham	A	111			.403
42003	Lymington	Brockenhurst Park	A	98.9			.363
42004	Test	Broadlands	D	1040			.944
42005	Wallop Brook	Broughton	A	53.6			.935
42007	Alre	Drove Lane Alresford	A	57			.98
42008	Cheriton Stream	Sewards Bridge	A	75.1			.969
42009	Candover Stream	Borough Bridge	A	71.2			.964
42010	Itchen	Highbridge+Allbrook	A	360			.961
42012	Anton	Fullerton	A	185			.965
42014	Blackwater	Ower	A	104.7			.45
42019	Tanners Brook	Millbrook	D	16			.7
43003	Avon	East Mills	A	1477.8			.91
43005	Avon	Amesbury	A	323.7			.909
43006	Nadder	Wilton Park	A	220.6			.813
43007	Stour	Throop Mill	A	1073			.661
43008	Wylye	South Newton	A	445.4			.913
43009	Stour	Hammoon	A	523.1			.319
43011	Ebble	Bodenham	A	109			.843
43012	Wylye	Norton Bavant	A	112.4			.873
43013	Mude	Somerford	A	12.4			.571
43014	East Avon	Upavon	A	86.2			.891
43021	Avon	Knapp Mill	A	1706			.89
44001	Frome	East Stoke total	A	414.4			.841
44003	Asker	Bridport	A	49.1			.644
44004	Frome	Dorchester total	A	206			.812
44006	Sydling Water	Sydling St Nicholas	A	12.4			.861
44008	Sth Winterbourne	W'bourne Steepleton	A	19.9			.886
44009	Wey	Broadwey	A	7			.945
45001	Exe	Thorverton	A	600.9			.513
45002	Exe	Stoodleigh	A	421.7	33.07	21	.518
45003	Culm	Wood Mill	A	226.1	43.38	15	.524

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
45004	Axe	Whitford	Y	288.5	42.53	15	.495
45005	Otter	Dotton	A	202.5			.538
45008	Otter	Fenny Bridges	A	104.2			.488
45009	Exe	Pixton	Y	147.59	19.65	18	.501
45010	Haddeo	Hartford	D	50			.547
45011	Barle	Brushford	D	128	35.99	14	.565
45012	Creedy	Cowley	D	261.6			.45
45013	Tale	Fairmile	D	34.4			.535
46002	Teign	Preston	A	380			.549
46003	Dart	Austins Bridge	A	247.6	30.1	23	.524
46005	East Dart	Bellever	A	21.5	58.32	11	.424
46007	West Dart	Dunnabridge	D	47.9			.416
46008	Avon	Loddiswell	A	102.3			.509
46802	Swincombe	Swincombe intake	Y	14.2	63.11	13	.368
46805	Bala Brook	Bala intake	M	5.9	44.43	8	
46812	Hems	Tally Ho]	D	39.2			.542
46818	Hems	Woodlands	D	3.3			.389
47001	Tamar	Gunnislake	A	916.9			.462
47004	Lynher	Pillaton Mill	A	135.5			.569
47005	Ottery	Werrington Park	A	120.7			.39
47006	Lyd	Lifton Park	A	218.1			.476
47007	Yealm	Puslinch	A	54.9	28.74	13	.54
47008	Thrushel	Tinhay	A	112.7	31.14	7	.385
47009	Tiddy	Tideford	A	37.2			.598
47011	Plym	Carn Wood	Y	79.2	28.93	13	.482
47014	Walkham	Horrabridge	A	43.2			.585
47015	Tavy	Denham / Ludbrook	D	197.3			.477
47016	Lumburn	Lumburn Bridge	D	20.5			.636
47017	Wolf	Combe Park Farm	D	31.1			.383
48002	Fowey	Restormel one	D	171.2			.641
48003	Fal	Tregony	A	87			.694
48004	Warleggan	Trengoffe	A	25.3	33.49	11	.72
48005	Kenwyn	Truro	A	19.1	12.69	10	.668
48006	Cober	Helston	D	40.1			.735
48009	St Neot	Craigshill Wood	A	22.7	37.19	7	.628
48010	Seaton	Trebrownbridge	A	38.1			.726
49001	Camel	Denby	A	208.8			.614
49002	Hayle	St Erth	A	48.9			.836
49003	De Lank	De Lank	Y	21.7	47.59	18	.582
49004	Gannel	Gwills	D	41			.683

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
50001	Taw	Umberleigh	A	826.2			.424
50002	Torridge	Torrington	A	663			.393
50006	Mole	Woodleigh	D	327.5			.467
50007	Taw	Taw Bridge	D	71.4			.453
50012	Yeo	Veraby	D	53.7			.392
51001	Doniford Stream	Swill Bridge	A	75.8			.626
51002	Horner Water	West Luccombe	D	20.8	20.09	8	.624
51003	Washford	Beggearn Huish	D	36.3			.641
52003	Halse Water	Bishops Hull	A	87.8			.739
52004	Isle	Ashford Mill	A	90.1	43.38	10	.476
52005	Tone	Bishops Hull	D	202	35.94	10	.579
52006	Yeo	Pen Mill	Y	213.1	33.87	13	.407
52007	Parrett	Chiselborough	D	74.8			.448
52009	Sheppey	Fenny Castle	D	59.6			.676
52010	Brue	Lovington	D	135.2	47.37	9	.473
52011	Cary	Somerton	A	82.4			.373
52014	Tone	Greenham	D	57.2			.577
52016	Currypool Stream	Currypool Farm	A	15.7	13.91	7	.709
52020	Gallica Stream	Gallica Bridge	A	16.4	66.05	3	.262
53002	Semington Brook	Semington	D	157.7			.566
53003	Avon	Bath St James	D	1595			.627
53005	Midford Brook	Midford	A	147.4	18.59	12	.616
53006	Frome(Bristol)	Frenchay	A	148.9			.393
53007	Frome(Somerset)	Tellisford	Y	261.6	28.87	14	.522
53008	Avon	Great Somerford	Y	303	28.83	10	.584
53009	Wellow Brook	Wellow	Y	72.6	14.92	9	.621
53013	Marden	Stanley	A	99.2			.638
53016	Spring Flow	Dunkerton	A				.756
53017	Boyd	Bitton	A	48			.459
53018	Avon	Bathford	D	1552			.608
53022	Avon	Bath ultrasonic	A	1605			.584
53023	Sherston Avon	Fosseway	D	89.7			.659
53024	Tetbury Avon	Brokenborough	D	73.6			.659
53025	Mells	Vallis	D	119			.588
53026	Frome(Bristol)	Frampton Cotterell	D	78.5			.417
53029	Biss	Trowbridge	D				.519
54001	Severn	Bewdley	A	4325			.524
54004	Sowe	Stoneleigh	Y	262	41.15	13	.599
54006	Stour	Kidderminster	Y	324	21.66	5	.717
54008	Teme	Tenbury	A	1134.4			.567

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
54010	Stour	Alscot Park	A	319	40.21	6	.503
54011	Salwarpe	Harford Mill	Y	184	34.85	16	.646
54012	Tern	Walcot	A	852			.691
54013	Clywedog	Cribynau	A	57			.4
54014	Severn	Abermule	D	580			.42
54015	Bow Brook	Besford Bridge	A	156			.397
54016	Roden	Rodington	A	259	27.05	7	.609
54018	Rea Brook	Hookagate	A	178			.506
54019	Avon	Stareton	Y	347	40.68	15	.477
54020	Perry	Yeaton	Y	180.8	24.6	5	.652
54022	Severn	Plynlimon flume	A	8.7	36.69	21	.317
54025	Dulas	Rhos-y-pentref	A	52.7			.375
54027	Frome	Ebley Mill	A	198			.862
54029	Teme	Knightsford Bridge	D	1480			.567
54032	Severn	Saxons Lode	D	6850			.564
54034	Dowles Brook	Dowles	A	40.8	34.66	3	.416
54038	Tanat	Llanyblodwel	A	229			.47
54041	Tern	Eaton On Tern	A	192			.713
54043	Severn	Upton On Severn	D	6850			.547
54044	Tern	Ternhill	A	92.6			.759
54048	Dene	Wellesbourne	D	102			.446
54049	Leam	Princes Drive Weir	D	362			.366
54052	Bailey Brook	Ternhill	A	34.4			.652
54053	Corve	Ludlow	D	164			.568
54054	Onny	Onibury	A	235			.475
54055	Rea	Nean Sollars	D	129			.608
54057	Severn	Haw Bridge	A	9895			.574
54059	Allford Brook	Allford	A	10.2			.691
54060	Potford Brook	Potford	A	25			.761
54062	Stoke Brook	Stoke	A	13.7			.749
54065	Roden	Stanton	D	210			.664
54066	Platt Brook	Platt	A	15.7			.744
54083	Crow Brook	Horton	A	16.7			.727
54084	Cannop Brook	Parkend	A	31.5			.585
54085	Cannop Brook	Cannop Cross	A	10.4			.606
54087	Allford Brook	Childs Ercall	A	4.7			.663
54088	Little Avon	Berkeley Kennels	A	134			.596
54090	Tanllwyth	Tanllwyth Flume	A	.9	57.65	16	.295
54091	Severn	Hafren Flume	A	3.6			.39
54092	Hore	Hore Flume	A	3.2			.318

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
54818	Roden	Northwood	A	20.9			.573
55002	Wye	Belmont	A	1895.9			.463
55004	Irfon	Abernant	A	72.8			.381
55005	Wye	Rhayader	A	166.8			.373
55008	Wye	Cefn Brwyn	A	10.55	43.74	12	.324
55009	Monnow	Kentchurch	A	357.4			.501
55010	Wye	Pant Mawr	A	27.2			.303
55011	Ithon	Llandewi	A	111.4			.385
55012	Irfon	Cilmery	A	244.2	50.7	5	.385
55013	Arrow	Titley Mill	A	126.4			.562
55014	Lugg	Byton	A	203.3			.668
55015	Honddu	Tafolog	A	25.1			.512
55016	Ithon	Disserth	A	358			.382
55017	Chwefru	Carreg-y-wen	A	29			.34
55018	Frome	Yarkhill	D	144			.496
55021	Lugg	Butts Bridge	A	371	32.56	7	.652
55022	Trothy	Mitchel Troy	A	142	47.55	8	.507
55023	Wye	Redbrook	A	4010			.559
55025	Llynfi	Three Cocks	A	132	29.3	7	.577
55026	Wye	Ddol Farm	A	174	46.63	5	.381
55028	Frome	Bishops Frome	A	77.7			.472
55029	Monnow	Grosmont	A	354			.516
55033	Wye	Gwy flume	A	3.9			.537
55034	Cyff	Cyff flume	A	3.1	54.41	14	.296
55035	Iago	Iago flume	A	1.1			.285
56001	Usk	Chain Bridge	A	911.7			.509
56002	Ebbw	Rhiwderyn	Y	216.5	20.32	4	.58
56003	Honddu	The Forge Brecon	D	62.1	29.79	7	.516
56004	Usk	Llandetty	A	543.9	46.17	8	.474
56005	Lwyd	Ponthir	A	98.1	30.69	12	.552
56006	Usk	Trallong	Y	183.8	46.55	13	.446
56007	Senni	Pont Hen Hafod	A	19.9			.37
56008	Monks Ditch	Llanwern	A	15.4			.595
56010	Usk	Trostrey Weir	A	927.2			.572
56011	Sirhowy	Wattsville	Y	76.1	29.73	4	.503
56012	Grwyne	Millbrook	A	82.2			.593
56013	Yscir	Pontaryscir	A	62.8			.471
56015	Olway Brook	Olway Inn	A	105.1			.497
57003	Taff	Tongwynlais	D	486.9			.438
57004	Cynon	Abercynon	D	106	35.69	17	.417

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
57005	Taff	Pontypridd	D	454.8	39.4	10	.473
57006	Rhondda	Trehafod	D	100.5	35.27	25	.421
57008	Rhymney	Llanedeyrn	D	178.7			.506
57009	Ely	St Fagans	D	145			.489
57010	Ely	Lanelay	A	39.4			.44
58001	Ogmore	Bridgend	A	158	29.74	14	.494
58002	Neath	Resolven	Y	190.9	30.45	6	.335
58003	Ewenny	Ewenny Priory	Y	62.9	33.88	11	.591
58005	Ogmore	Brynmenyn	A	74.3			.493
58006	Mellte	Pontneddfechan	A	65.8	44.47	6	.354
58007	Llynfi	Coytrahen	A	50.2			.491
58008	Dulais	Cilfrew	A	43	55.26	7	.386
58009	Ewenny	Keepers Lodge	A	62.5	25.36	6	.579
58010	Hepste	Esgair Carnau	A	11			.244
58011	Thaw	Gigman Bridge	A	49.2			.699
59001	Tawe	Yynstanglws	D	227.7			.341
59002	Loughor	Tir-y-dail	D	46.4			.423
60002	Cothi	Felin Mynachdy	A	297.8	46.22	9	.434
60003	Taf	Clog-y-Fran	A	217.3	42.25	1	.546
60004	Dewi Fawr	Glasfryn Ford	A	40.1			.531
60005	Bran	Llandovery	A	66.8			.354
60006	Gwili	Glangwili	A	129.5	27.8	1	.456
60007	Tywi	Dolau Hirion	A	231.8	49.86	2	.331
60009	Sawdde	Felin-y-cwm	A	81.1			.336
60012	Twrch	Ddol Las	D	20.7			.34
60013	Cothi	Pont Ynys Brechfa	A	261.6			.439
61001	Western Cleddau	Prendergast Mill	D	197.6	25.22	20	.65
61002	Eastern Cleddau	Canaston Bridge	D	183.1			.543
61003	Gwaun	Cilrhedyn Bridge	A	31.3	40.52	8	.568
61004	Western Cleddau	Redhill	A	197.6			.644
62001	Teifi	Glan Teifi	A	893.6			.532
62002	Teifi	Llanfair	A	510	55.17	3	.486
63001	Ystwyth	Pont Llolwyn	A	169.6			.407
63003	Wyre	Llanrhystyd	A	40.6			.403
64001	Dyfi	Dyfi Bridge	A	471.3	48.34	6	.363
64002	Dysynni	Pont-y-Garth	D	75.1			.49
64006	Leri	Dolybont	A	47.2			.445
65001	Glaslyn	Beddgelert	D	68.6	30.74	14	.313
65004	Gwyrfai	Bontnewydd	A	47.9			.427
65005	Erch	Pencaenewydd	A	18.1			.529

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
65006	Seiont	Peblig Mill	A	74.4			.395
65007	Dwyfawr	Garndolbenmaen	D	52.4			.372
65801	Nant Peris	Tan-Yr-Alt	M	11.4	61.96	3	
66001	Clwyd	Pont-y-cambwll	A	404			.599
66002	Elwy	Pant yr Onen	Y	220	21.59	4	.451
66004	Wheeler	Bodfari	A	62.9	19.78	5	.828
66005	Clwyd	Ruthin Weir	A	95.3			.582
66006	Elwy	Pont-y-Gwyddel	Y	194	43.52	4	.455
66011	Conwy	Cwm Llanerch	A	344.5	57.69	11	.284
67001	Dee	Bala	A	261.6			.529
67003	Brenig	Llyn Brenig outflow	X	20.2	74.26	6	.498
67005	Ceiriog	Brynkinalt Weir	A	113.7	24.92	4	.54
67006	Alwen	Druid	A	184.7			.464
67008	Alyn	Pont-y-Capel	Y	227.1	18.3	7	.564
67010	Gelyn	Cynefail	A	13.1	46.73	12	.259
67013	Hirnant	Plas Rhiwedog	A	33.9			.4
67015	Dee	Manley Hall	D	1019.3			.519
67018	Dee	New Inn	D	53.9			.273
68001	Weaver	Ashbrook	A	622			.538
68003	Dane	Rudheath	A	407.1			.516
68004	Wistaston Brook	Marshfield Bridge	A	92.7			.644
68005	Weaver	Audlem	A	207			.5
68006	Dane	Hulme Walfield	A	150	43.21	6	.547
68007	Wincham Brook	Lostock Gralam	B	148			.54
68010	Fender	Ford	M	18.4	49.59	1	
68014	Sandersons Brook	Sandbach	M	5.4	41.58	8	
68015	Gowy	Huxley	A	49			.511
68020	Gowy	Bridge Trafford	A	156			.47
69008	Dean	Stanneylands	M	51.8	36.57	5	
69011	Micker Brook	Cheadle	M	67.3	27.22	2	
69012	Bollin	Wilmslow	D	72.5	51.71	3	.643
69013	Sinderland Brook	Partington	A	44.8	21.26	8	.586
69017	Goyt	Marple Bridge	A	183			.498
69018	Newton Brook	Newton Le Willows	M	32.8	59.4	3	
69019	Worsley Brook	Eccles	M	24.87	29.55	6	
69020	Medlock	London Road	D	57.5			.536
69027	Tame	Portwood	Y	150	40.21	7	.562
69031	Ditton Brook	Greens Bridge	Y	47.9	48.44	8	.562
69034	Musbury Brook	Helmshore	M	3.1	37.24	9	
69802	Etherow	Woodhead	M	13	55.71	2	

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
70002	Douglas	Wanes Blades Bridge	A	198			.554
70004	Yarrow	Croston Mill	D	74.4			.417
70006	Tawd	Newburgh	M	28.9	35.32	8	
70803	Newreed Brook	Slate Farm	A	5.4			.26
71001	Ribble	Samlesbury	A	1145			.321
71003	Croasdale	Croasdale flume	D	10.4	54.05	24	.35
71004	Calder	Whalley Weir	A	316	39.74	10	.434
71005	Bottoms Beck	Bottoms Beck flume	D	10.6			.211
71006	Ribble	Henthorn	A	456			.287
71008	Hodder	Hodder Place	Y	261	38.52	8	.304
71009	Ribble	Jumbles Rock	A	1053			.3
71010	Pendle Water	Barden Lane	D	108			.426
71011	Ribble	Arnford	A	204			.253
71802	Ribble	Halton West	M	207	64.3	6	
71804	Dunsop	Footholme	M	24.9	32.88	6	
72001	Lune	Halton	D	994.6			.323
72002	Wyre	St Michaels	A	275	59.16	14	.324
72004	Lune	Caton	A	983			.321
72005	Lune	Killington New Bridge	A	219			.343
72006	Lune	Kirkby Lonsdale	M	507.1	59.95	8	
72007	Brock	U/S A6	D	32			.352
72008	Wyre	Garstang	A	114			.305
72009	Wenning	Wennington Road Bridge	A	142			.305
72011	Rawthey	Brigg Flatts	A	200			.285
72811	Brock	Roe Bridge	A	37.3			.316
72814	Calder	Sandholme Bridge	A	18.5			.241
72817	Barton Brook	Hollowforth Hall	A	31.9			.176
72818	New Mill Brook	Carvers Bridge	A	64.5	25.47	9	.161
72820	Burnes Gill	Tebay(M6)	A	.71	36.51	9	.29
73001	Leven	Newby Bridge	A	241			.476
73002	Crake	Low Nibthwaite	A	73			.573
73003	Kent	Burneside	A	73.6			.332
73005	Kent	Sedgwick	A	209	34.97	11	.453
73007	Troutbeck	Troutbeck Bridge	M	23.6	43.67	5	
73008	Bela	Beetham	A	131	28.92	8	.504
73009	Sprint	Sprint Mill	A	34.6			.372
73010	Leven	Newby Bridge	A	247			.504
73011	Mint	Mint Bridge	A	65.8			.386
73803	Winster	Lobby Bridge	M	20.7	60.48	4	
73804	Brathay	Brathay Hall	M	57.5	61.31	13	

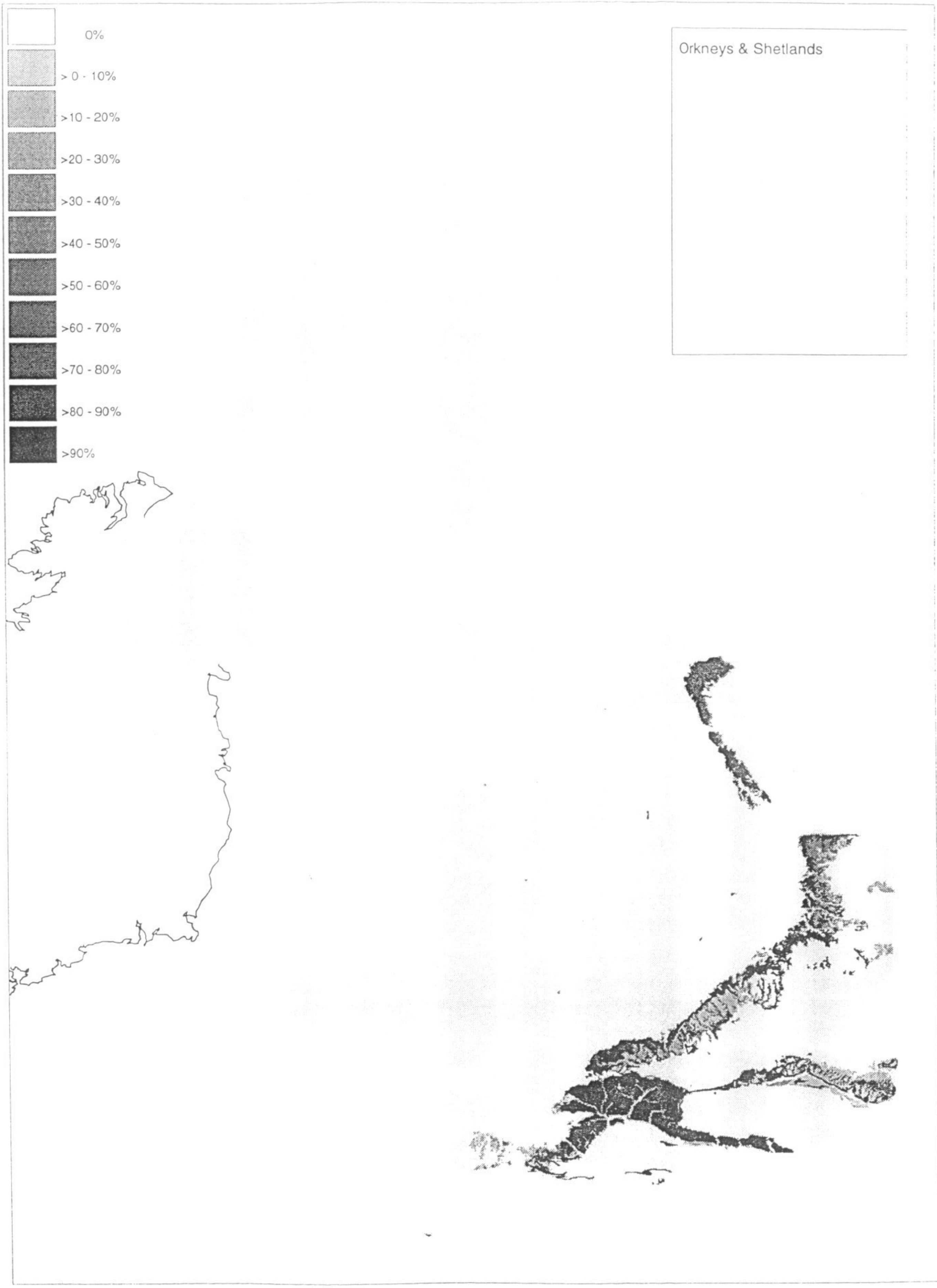
NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
74001	Duddon	Duddon Hall	D	85.66	61.22	7	.278
74002	Irt	Galesyke	D	44.2			.458
74003	Ehen	Ennerdale Weir	D	44.2			.321
74005	Ehen	Braystones	D	125.5			.39
74007	Esk	Cropple How	A	70.2			.279
75002	Derwent	Camerton	A	663			.474
75003	Derwent	Ouse Bridge	A	363			.493
75004	Cocker	Southwaite Bridge	D	116.6			.422
75006	Newlands Beck	Braithwaite	A	33.9	66.88	7	.317
75007	Glenderamackin	Threlkeld	A	64.5	48.58	8	.295
75009	Greta	Low Briery	A	145.6			.347
75010	Marron	Ullock	A	27.7			.484
75017	Ellen	Bullgill	D	96			.481
76002	Eden	Warwick Bridge	D	1366.7			.483
76004	Lowther	Eamont Bridge	D	158.5			.413
76005	Eden	Temple Sowerby	A	616.4	64.97	1	.368
76007	Eden	Sheepmount	A	2286.5			.5
76008	Irthing	Greenholme	A	334.6	54.47	2	.318
76009	Caldew	Holm Hill	A	147.2			.487
76010	Petteril	Harraby Green	A	160			.463
76011	Coal Burn	Coalburn	A	1.5	69.05	26	.175
76014	Eden	Kirkby Stephen	A	69.4	66.82	16	.236
76805	Force Beck	M6 Shop	A	4.1	52.11	11	.27
77001	Esk	Netherby	A	841.7			.366
77002	Esk	Canonbie	A	495	51.07	7	.383
77003	Liddel Water	Rowanburnfoot	A	319			.325
77004	Kirtle Water	Mossknowe	A	72			.287
77005	Lyne	Cliff Bridge	A	191			.266
78001	Annan	St Mungos Manse	D	730.3			.411
78002	Ae	Elshieshields	D	143.2			.353
78003	Annan	Brydekirk	A	925			.43
78004	Kinnel Water	Redhall	A	76.1			.275
78005	Kinnel Water	Bridgemuir	A	229			.354
79002	Nith	Friars Carse	A	799			.383
79003	Nith	Hall Bridge	D	155			.269
79004	Scar Water	Capenoch	A	142			.313
79005	Cluden Water	Fiddlers Ford	A	238			.375
79006	Nith	Drumlanrig	A	471			.343
80001	Urr	Dalbeattie	A	199			.351
80004	Greenburn	Loch Dee	A	2.6			.451

NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
80005	Dargall Lane	Loch Dee	A	2.1			.279
81002	Cree	Newton Stewart	A	368			.275
81003	Luce	Airyhemming	A	171			.232
81004	Bladnoch	Low Malzie	A	334			.329
82001	Girvan	Robstone	A	245.5			.333
82003	Stinchar	Balnowlart	A	341			.299
83002	Garnock	Dalry	Y	88.8	50.1	1	.211
83003	Ayr	Catrine	A	166.3			.294
83004	Lugar	Langholm	A	181			.244
83005	Irvine	Shewalton	A	380.7			.269
83006	Ayr	Mainholm	A	574			.302
83007	Lugton Water	Eglinton	A	54.6			.247
83009	Garnock	Kilwinning	A	183.8			.234
84002	Calder	Muirshiel	Y	12.4	60.48	4	.15
84003	Clyde	Hazelbank	D	1092.9			.496
84004	Clyde	Sills	D	741.8			.519
84005	Clyde	Blairston	D	1704.2			.444
84006	Kelvin	Bridgend	A	63.7			.437
84008	Rotten Calder Wtr	Redlees	D	51.3	57.76	7	.32
84009	Nethan	Kirkmuirhill	A	66			.339
84011	Gryfe	Craigend	A	71			.304
84012	White Cart Water	Hawkhead	A	227.2	56.72	6	.357
84013	Clyde	Daldowie	D	1903.1			.45
84014	Avon Water	Fairholm	A	265.5			.261
84015	Kelvin	Dryfield	A	235.4			.434
84016	Luggie Water	Condorrat	A	33.9			.397
84018	Clyde	Tulliford Mill	A	932.6			.524
84020	Glazert Water	Milton of Campsie	A	51.9			.311
84022	Duneaton	Maidencots	A	110.3	31.18	7	.446
84023	Bothlin Burn	Auchengeich	A	35.7			.507
84025	Luggie Water	Oxgang	D	87.7			.408
84026	Allander Water	Milngavie	D	32.8			.333
84029	Cander Water	Candermill	A	24.5			.272
85002	Endrick Water	Gaidrew	A	219.9	56.17	4	.311
85003	Falloch	Glen Falloch	A	80.3			.174
85004	Luss Water	Luss	A	35.3			.277
86002	Eachaig	Eckford	A	139.9			.356
87801	Allt Uaine	intake	A	3.1			.145
89807	Abhainn A Bhealaich	Braevallich	A	24.1			.232
90002	Creran	Taraphocain	D	66.1			.212

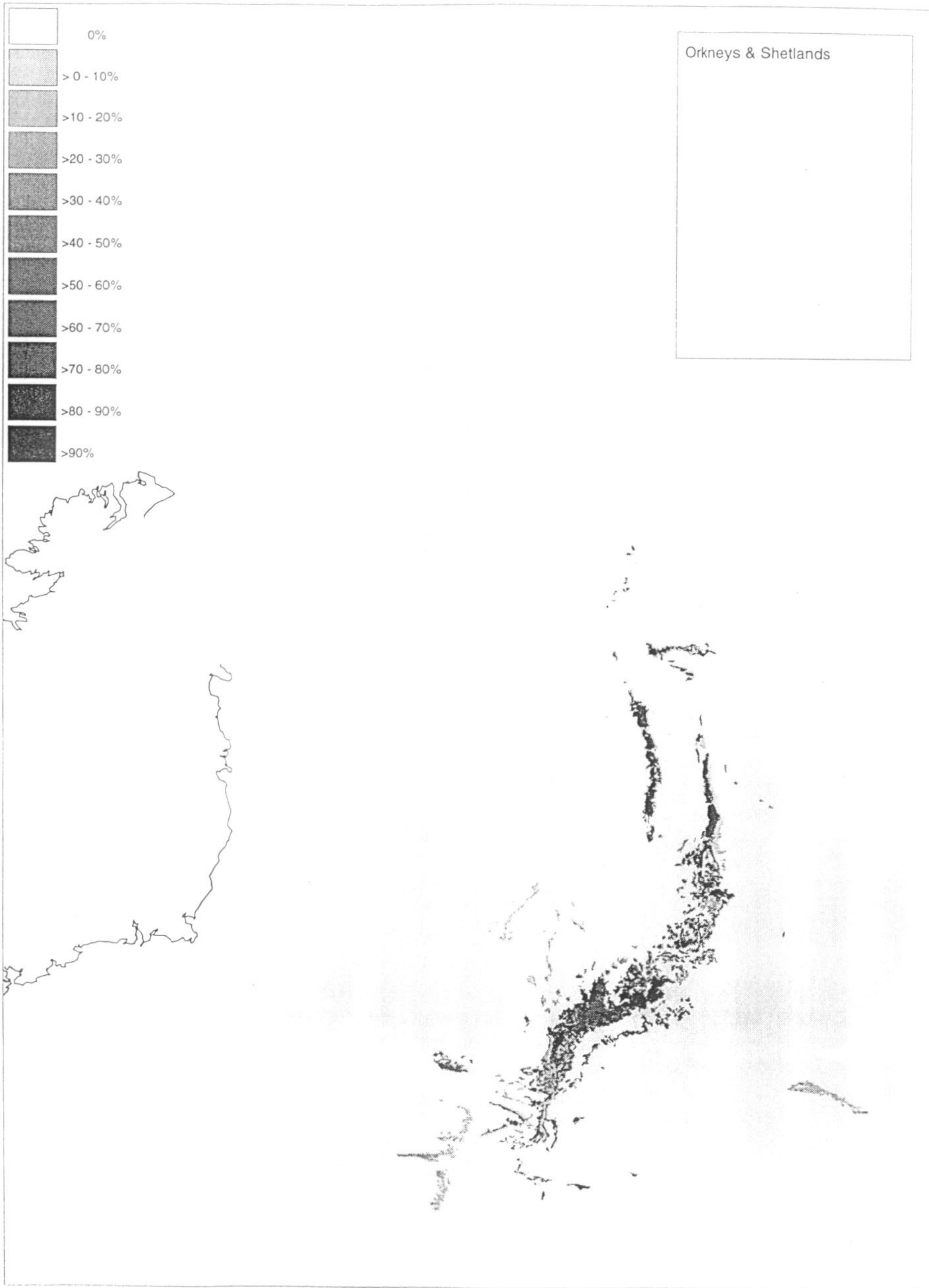
NWA_NO	RIVER	LOCATION	Q	AREA	SPR	EVENTS	BFI
90003	Nevis	Claggan	D	76.8			.263
93001	Carron	New Kelso	A	137.8			.27
94001	Ewe	Poolewe	A	441.1			.67
95001	Inver	Little Assynt	A	137.5			.625
96001	Halladale	Halladale	A	204.6			.26
96002	Naver	Apigill	A	477			.416
97002	Thurso	Halkirk	D	412.8			.457
101001	Eastern Yar	Alverstone Mill	D	57.5			.594
101005	Eastern Yar	Budbridge	D	22.5			.632

Appendix D Maps showing the distribution of the 29 HOST classes

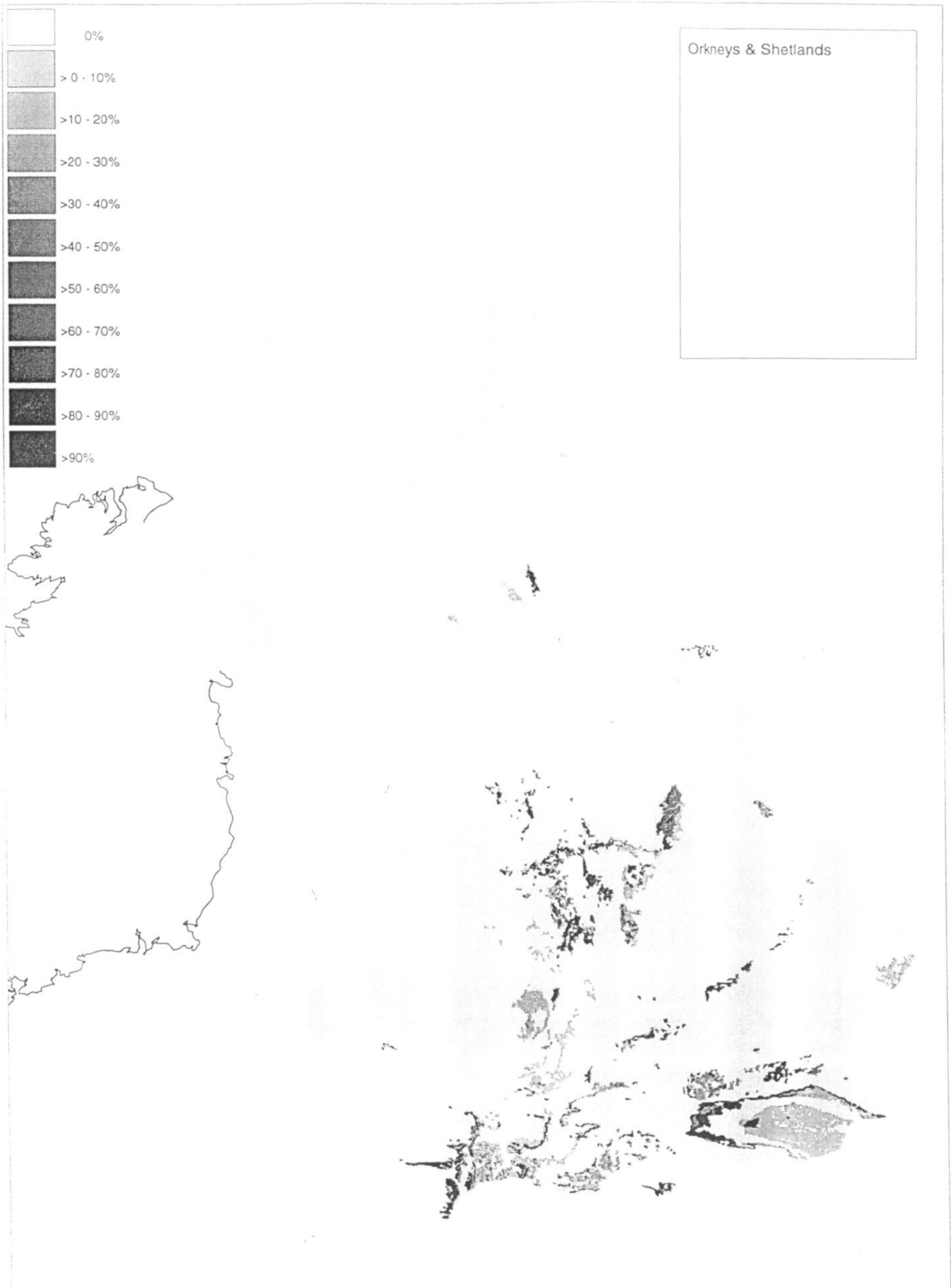
Distribution of HOST Class 1



Distribution of HOST Class 2



Distribution of HOST Class 3



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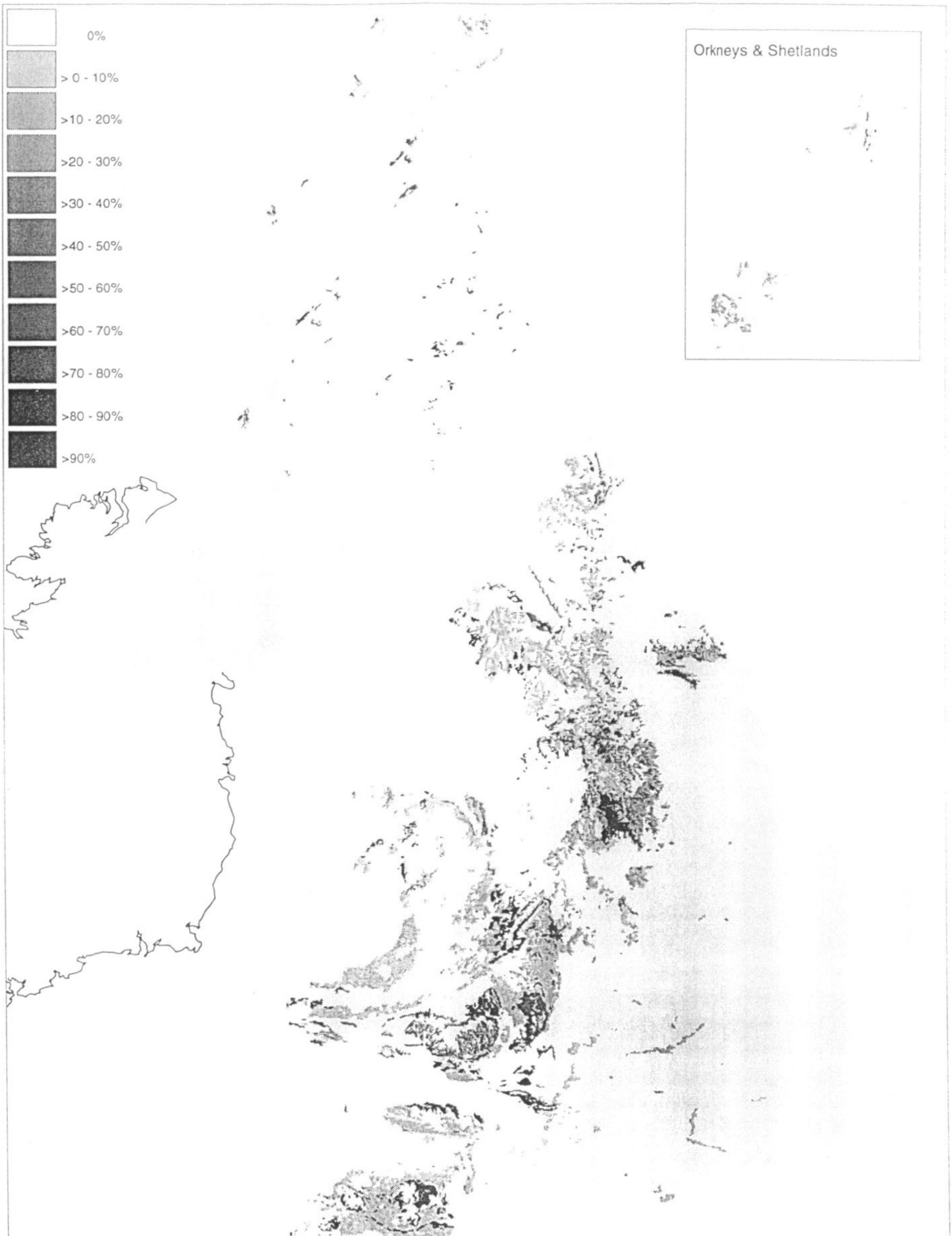
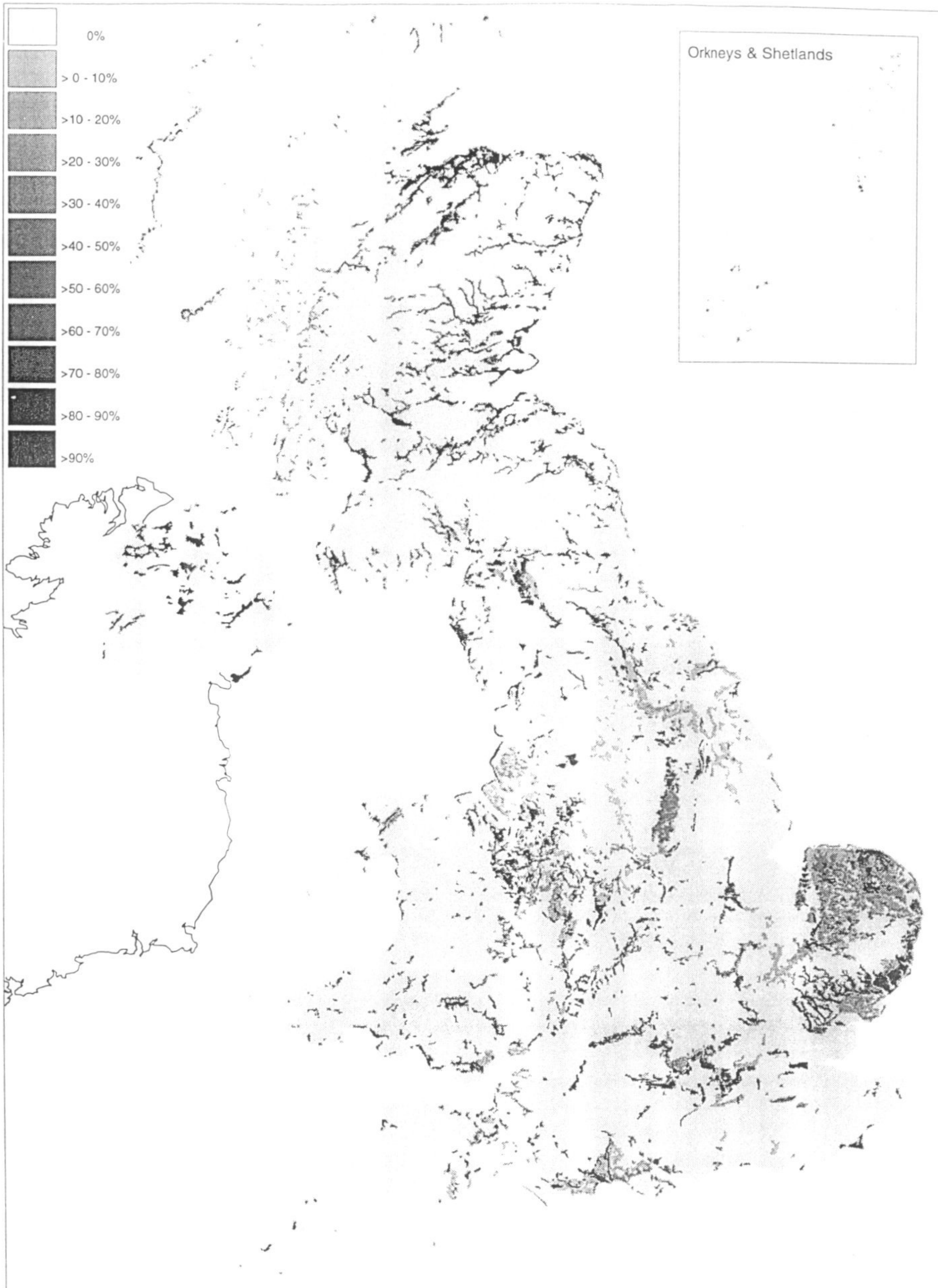
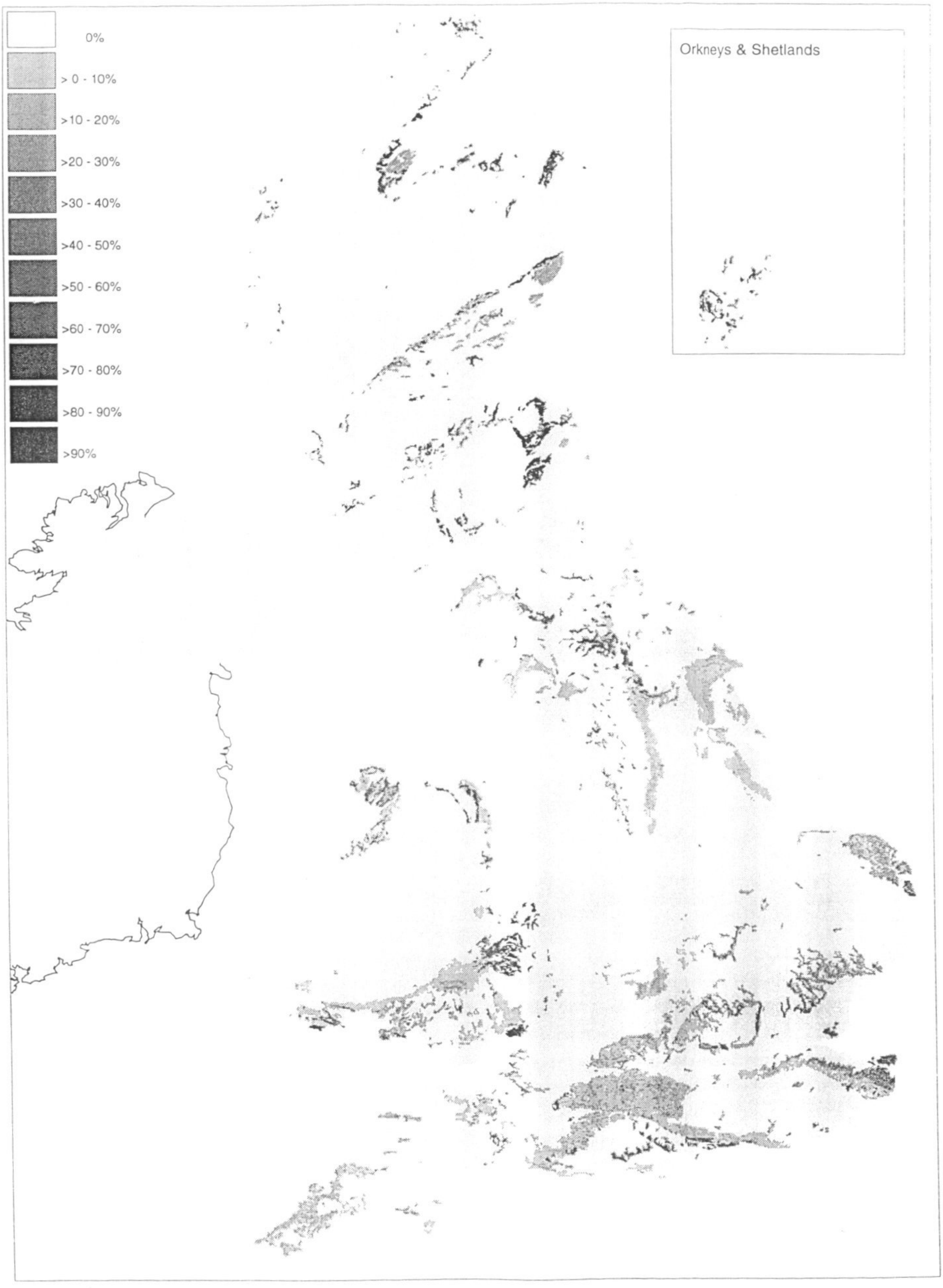


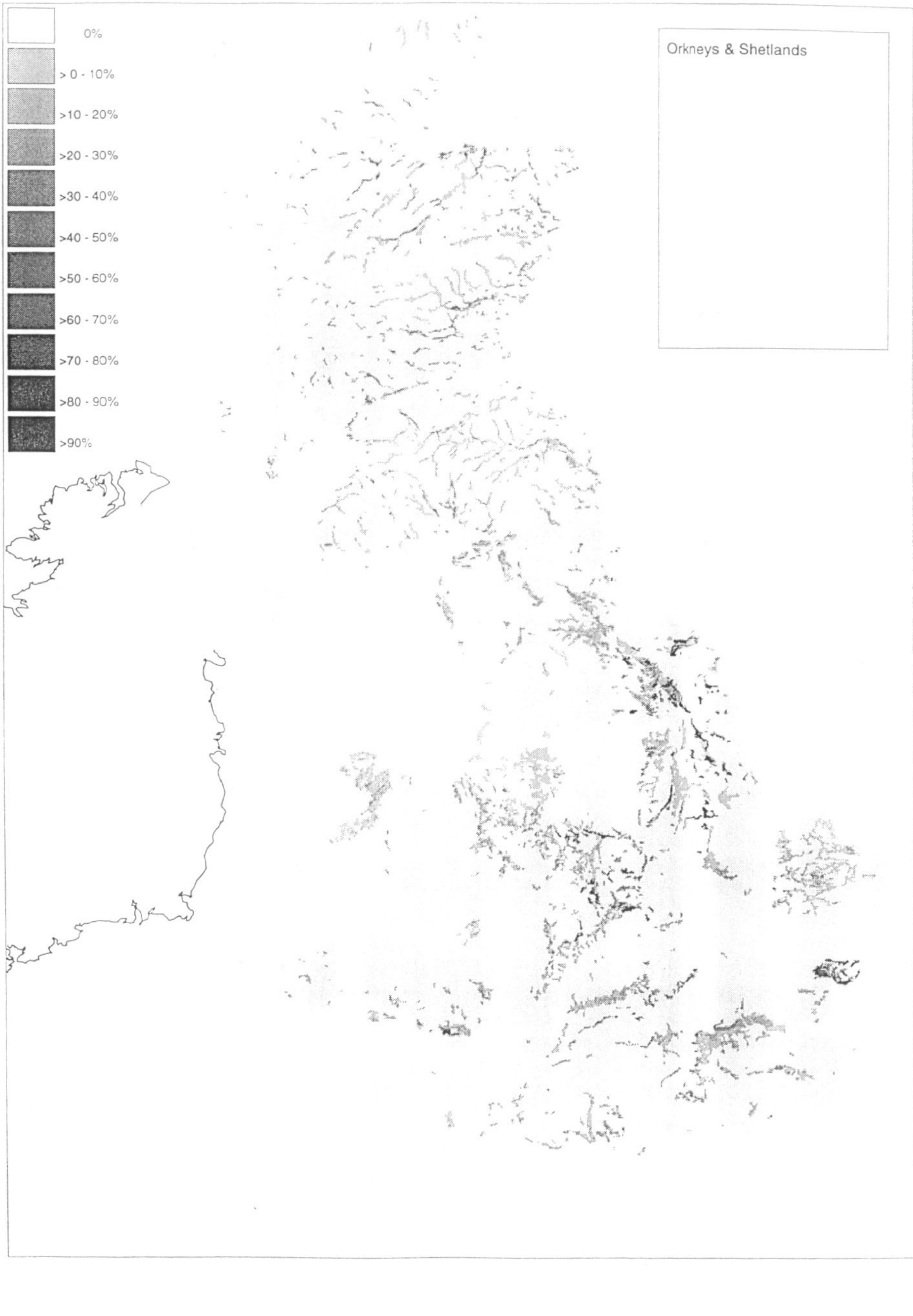
Distribution of HOST Class 5



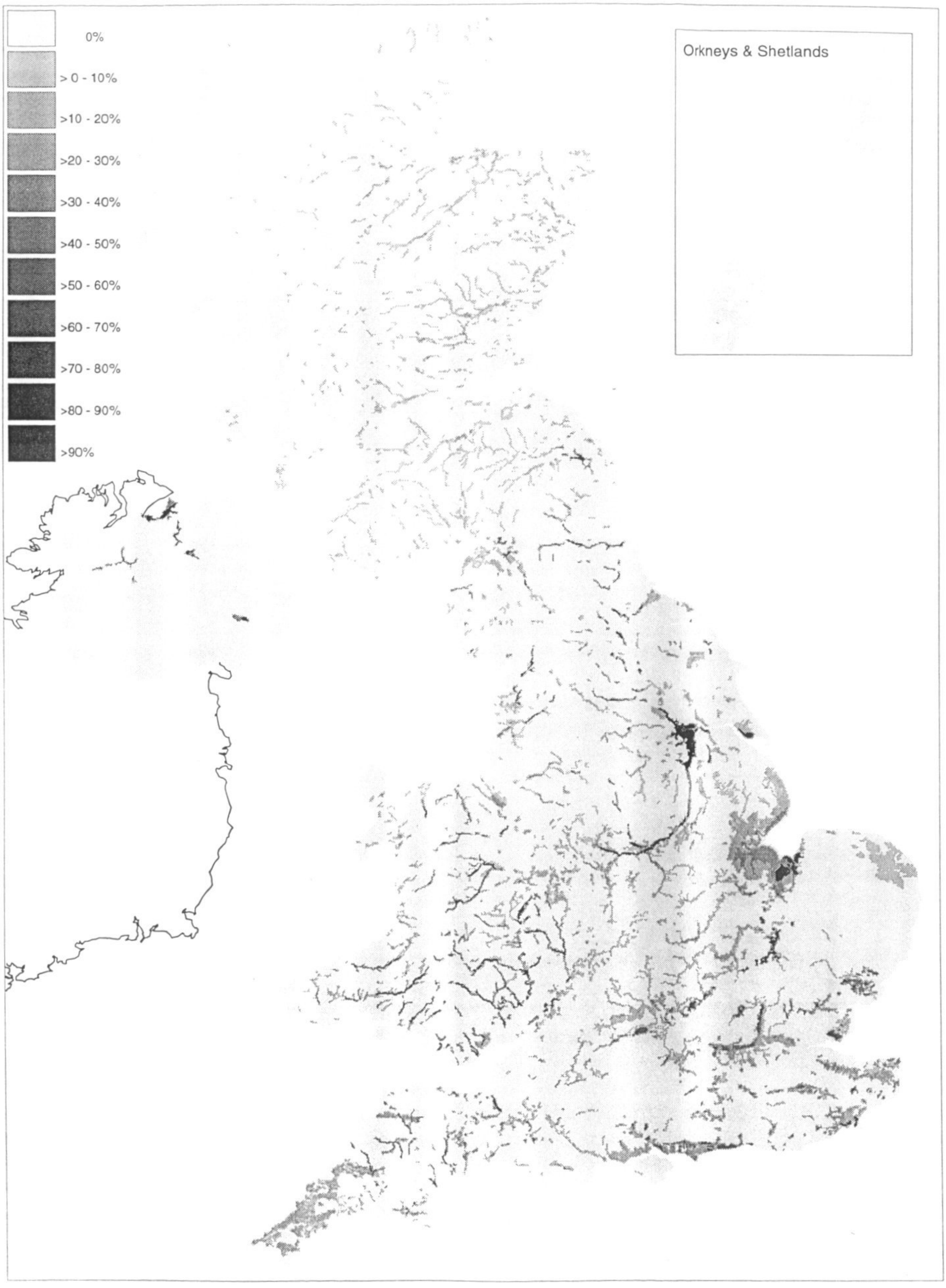
Distribution of HOST Class 6



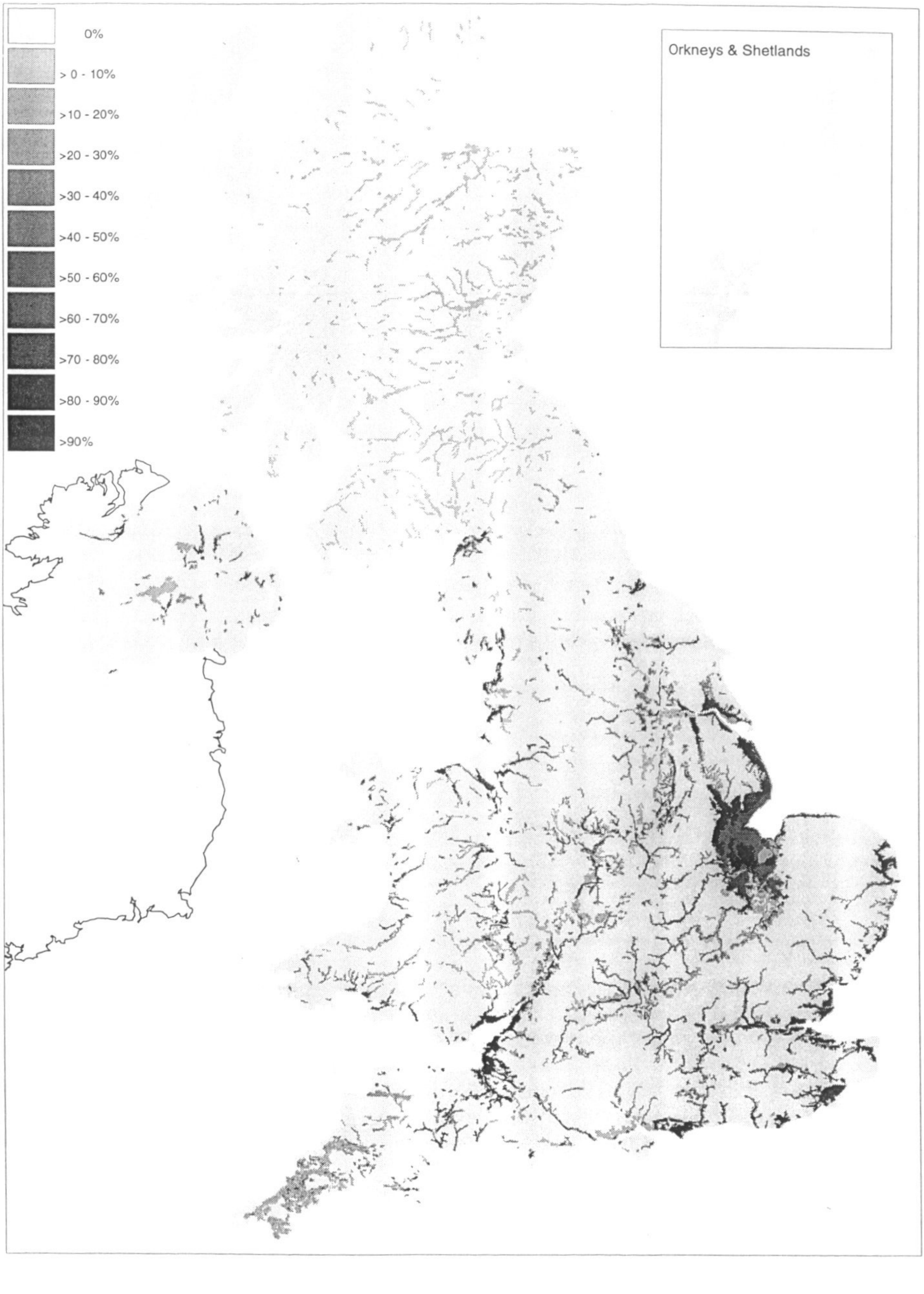
Distribution of HOST Class 7



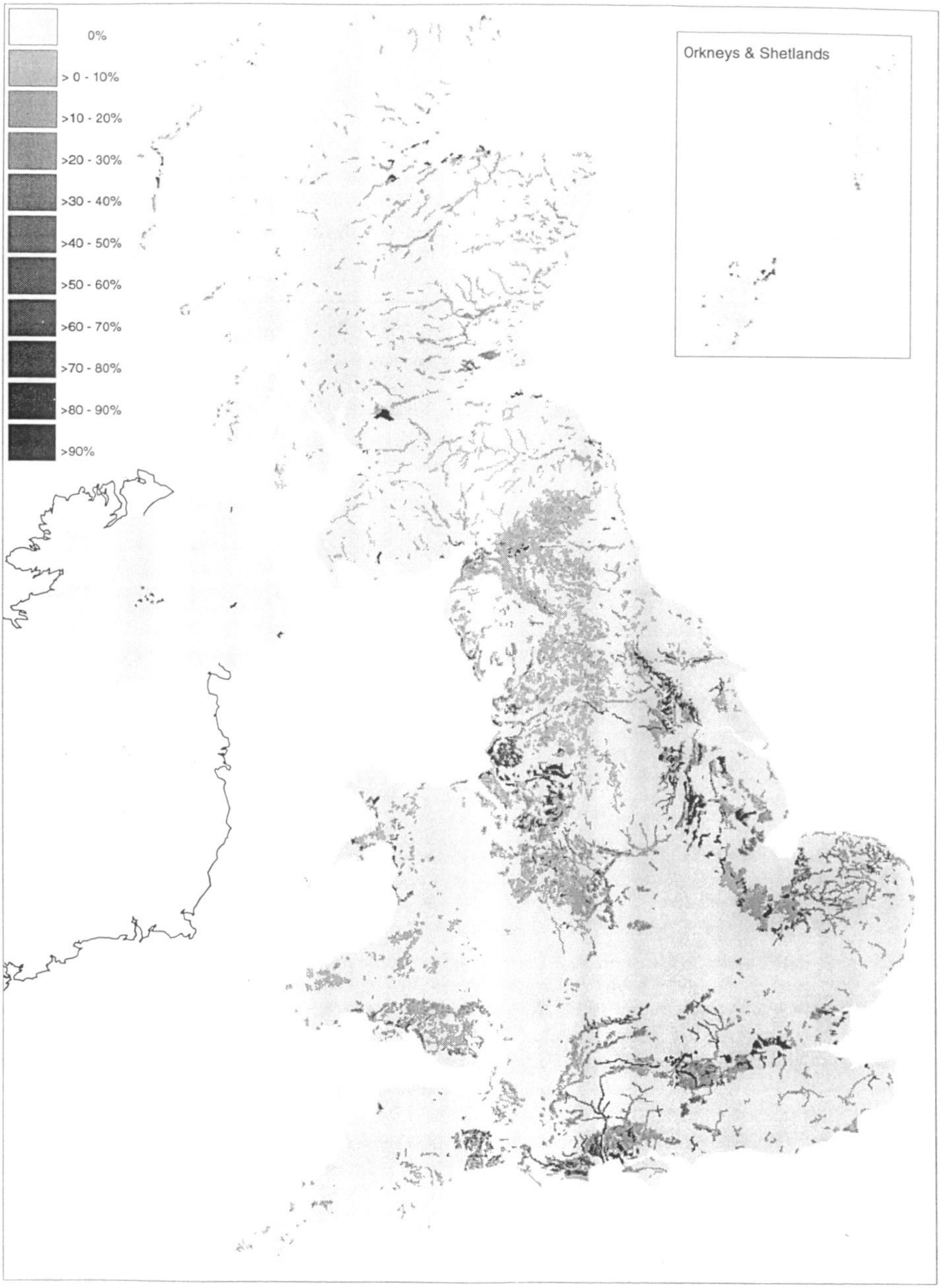
Distribution of HOST Class 8



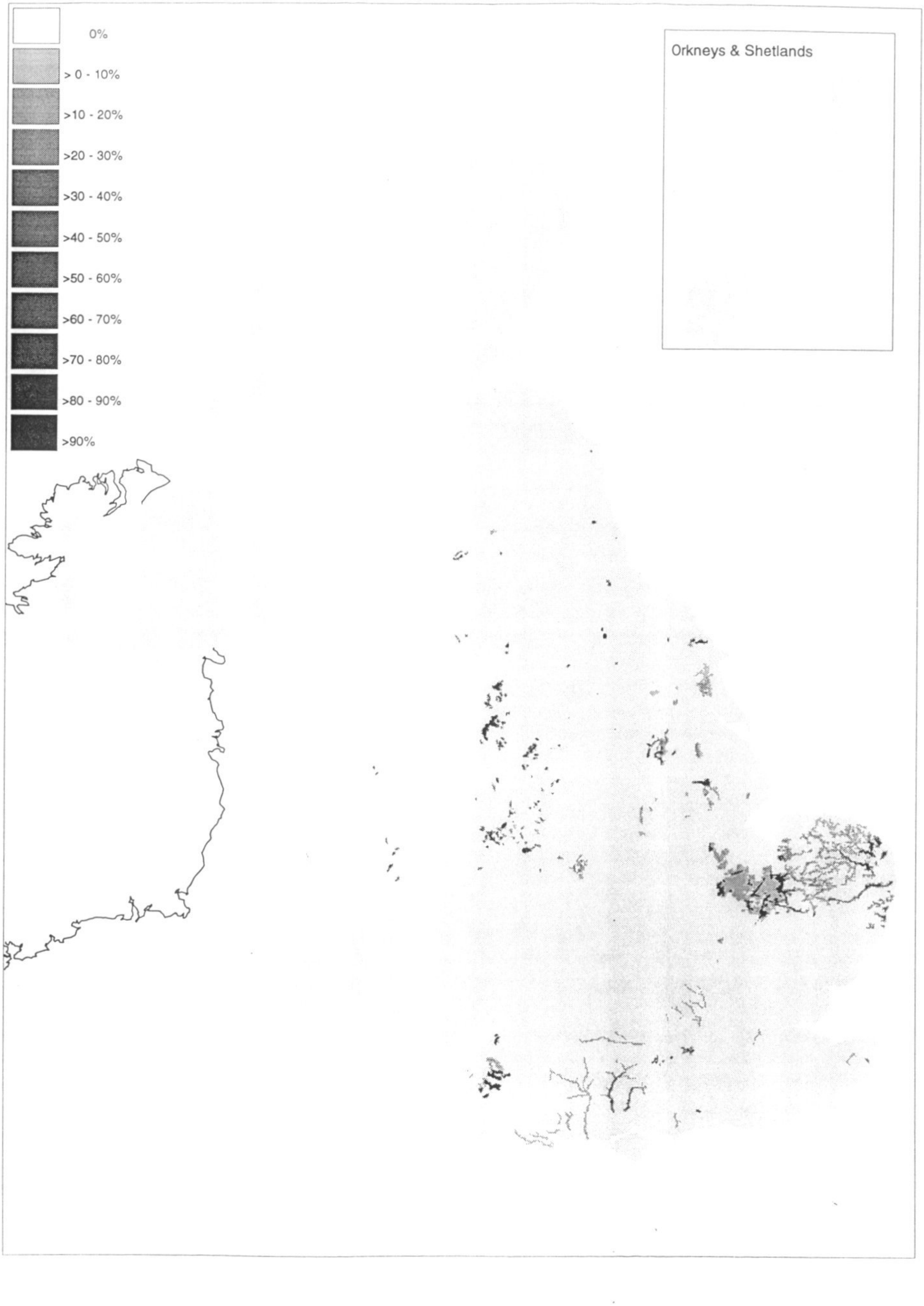
Distribution of HOST Class 9



Distribution of HOST Class 10



Distribution of HOST Class 11



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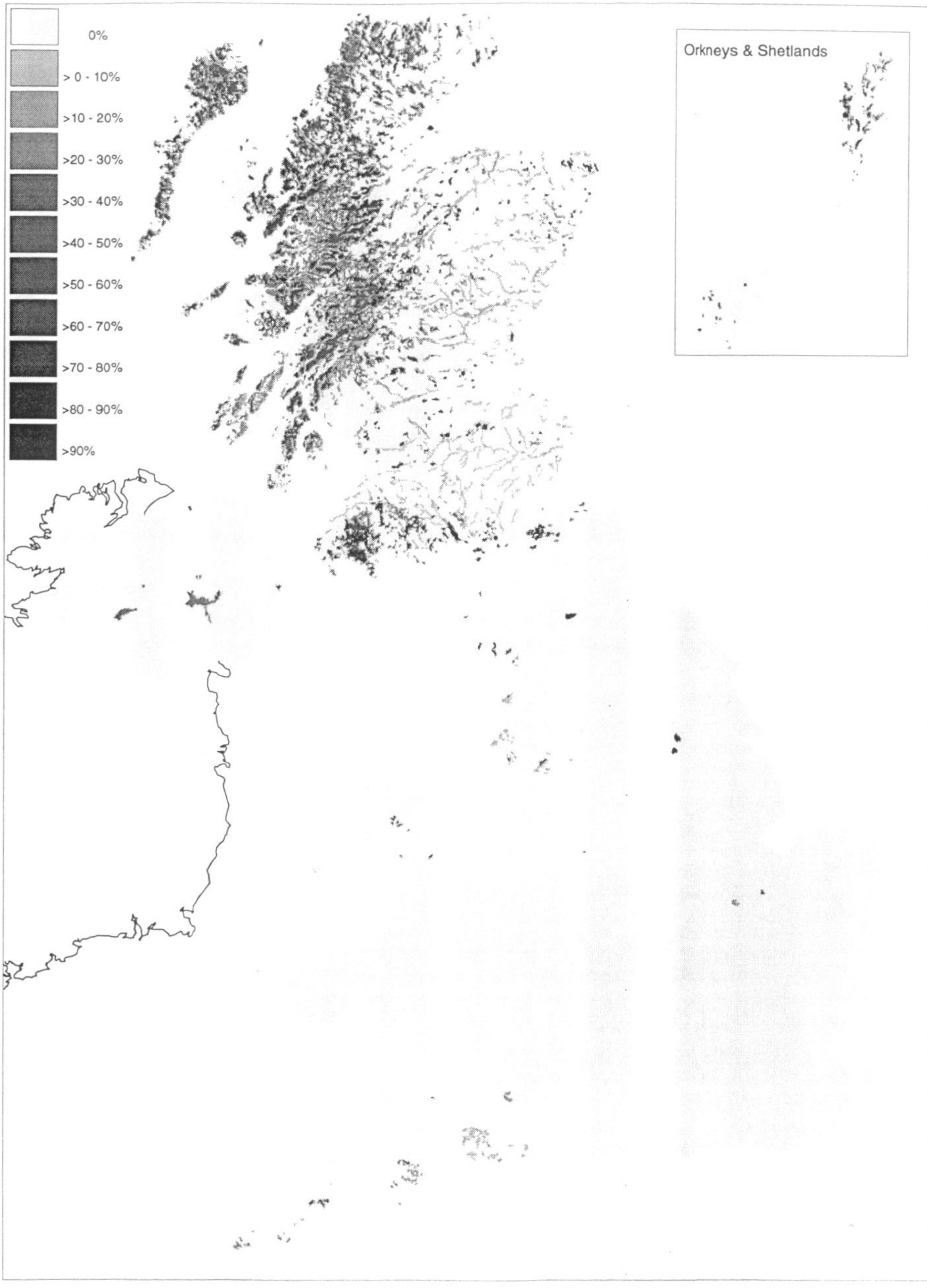
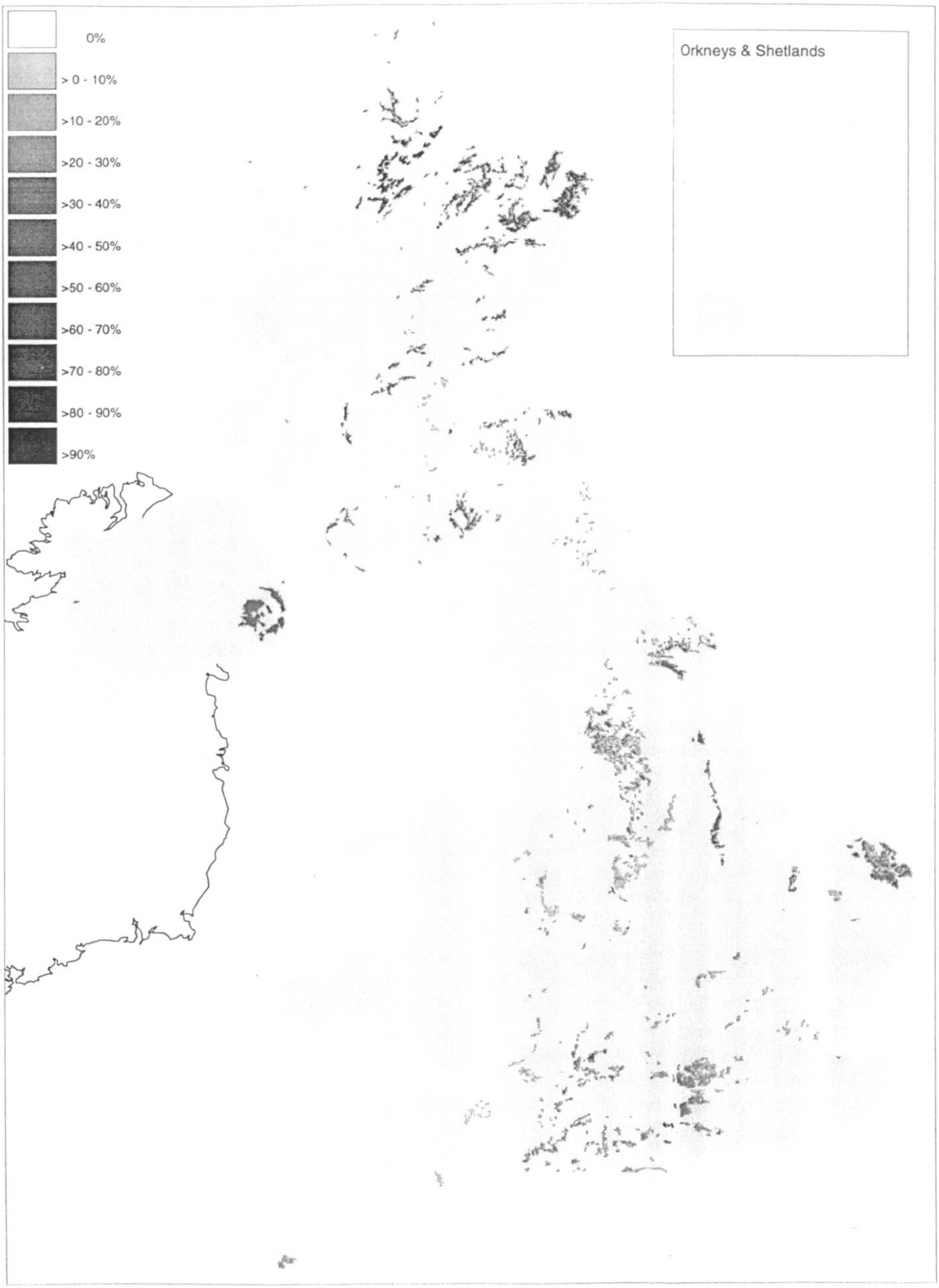
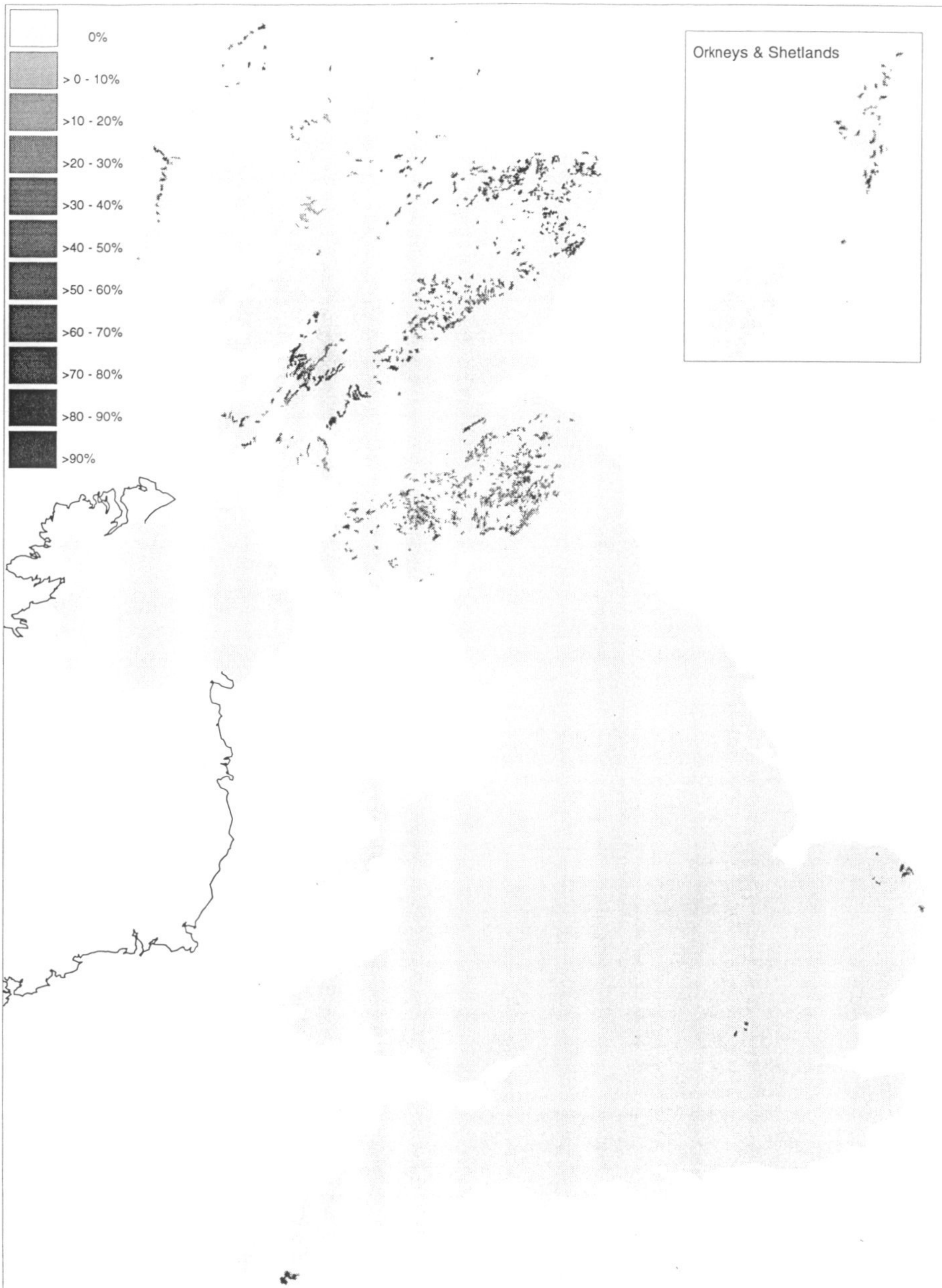


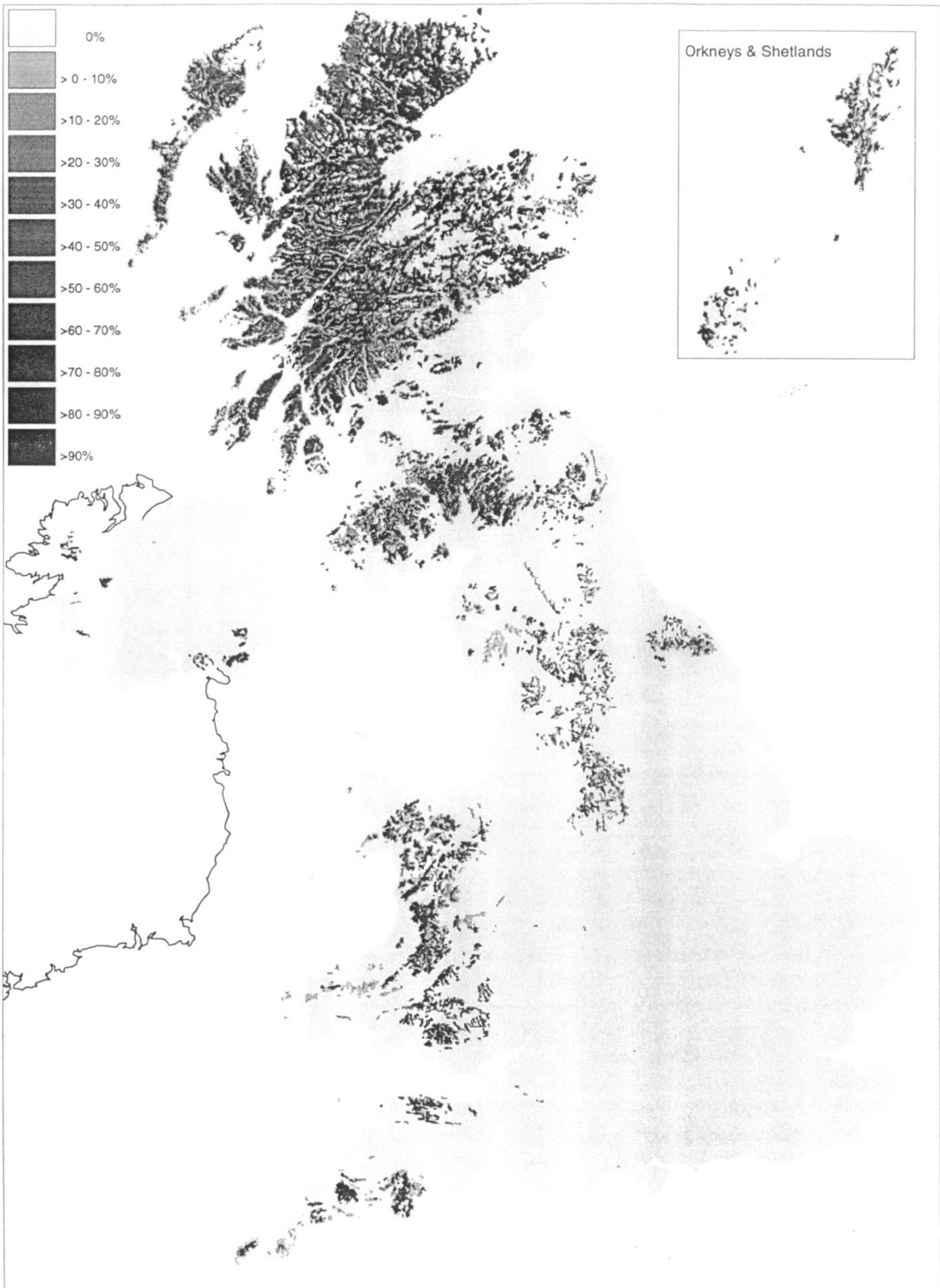
Distribution of HOST Class 13



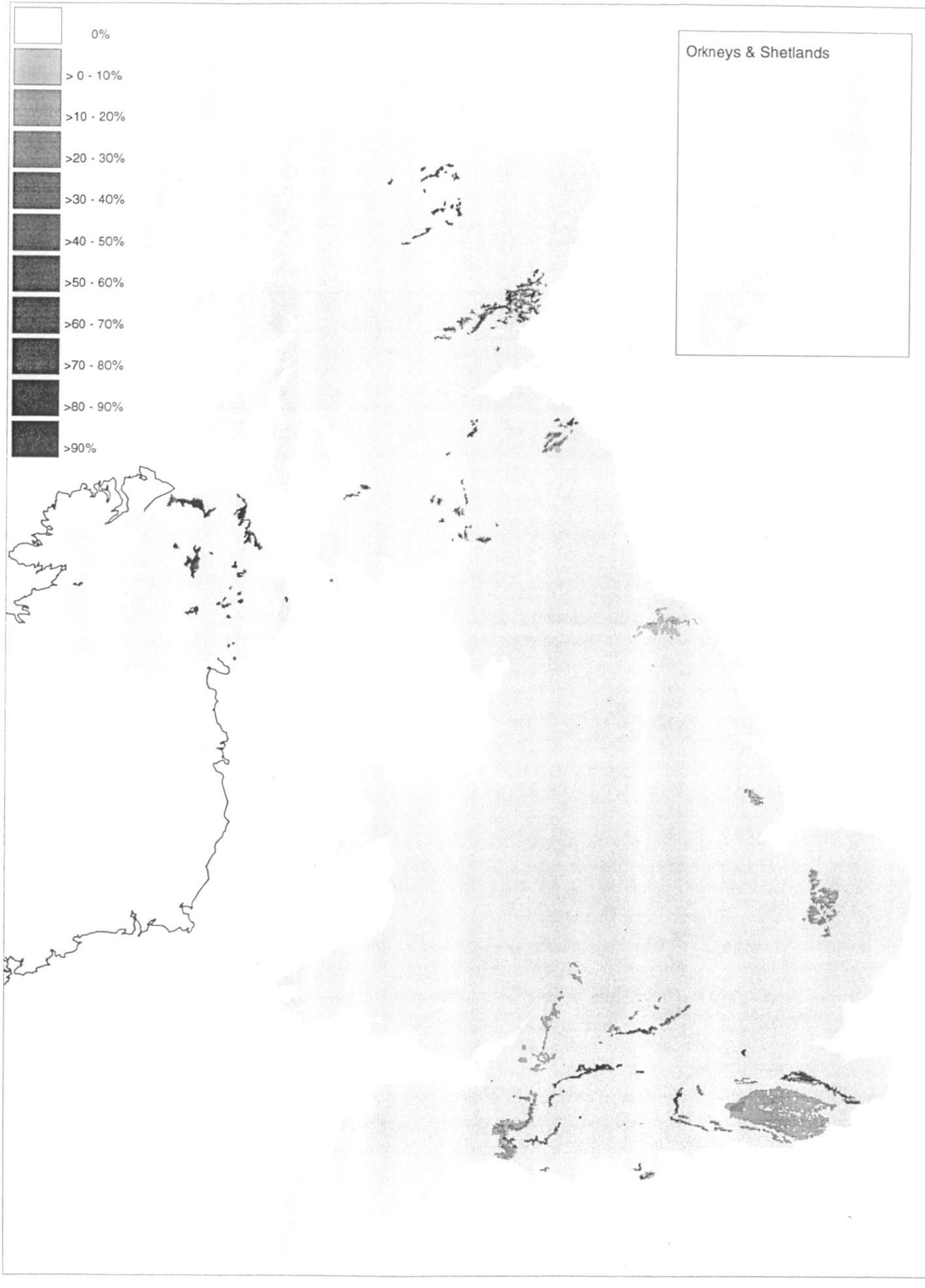
Distribution of HOST Class 14



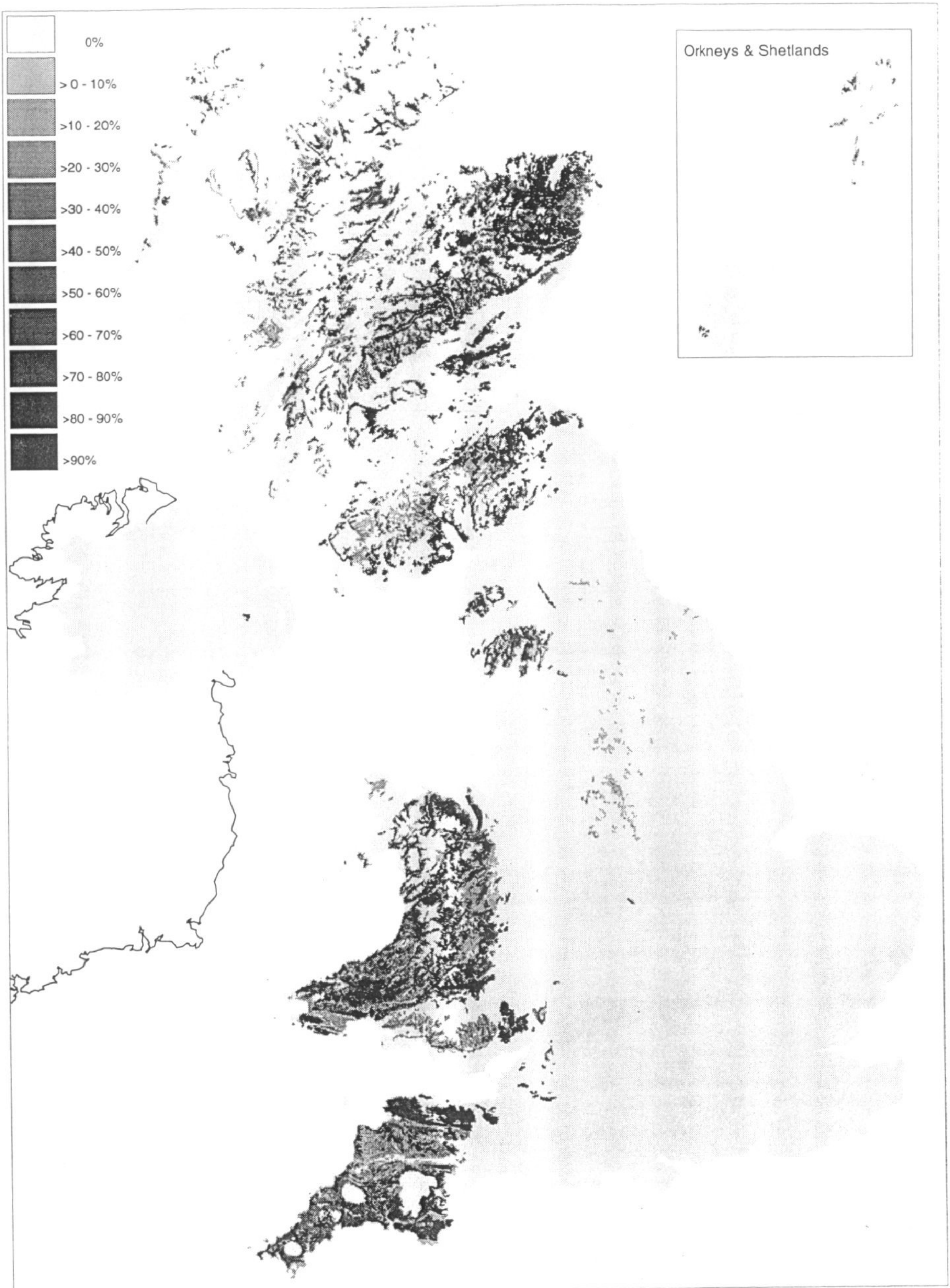
Distribution of HOST Class 15



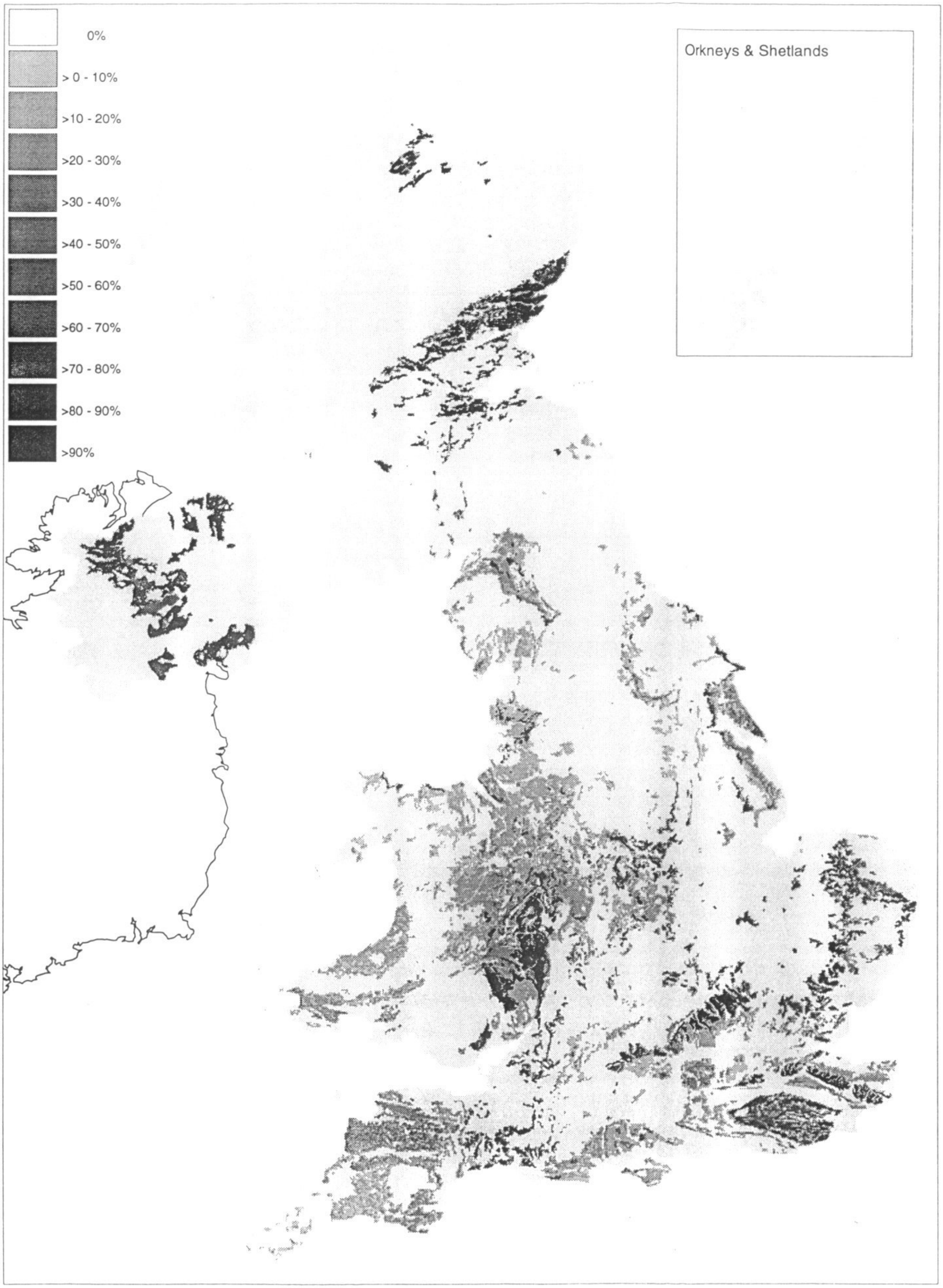
Distribution of HOST Class 16



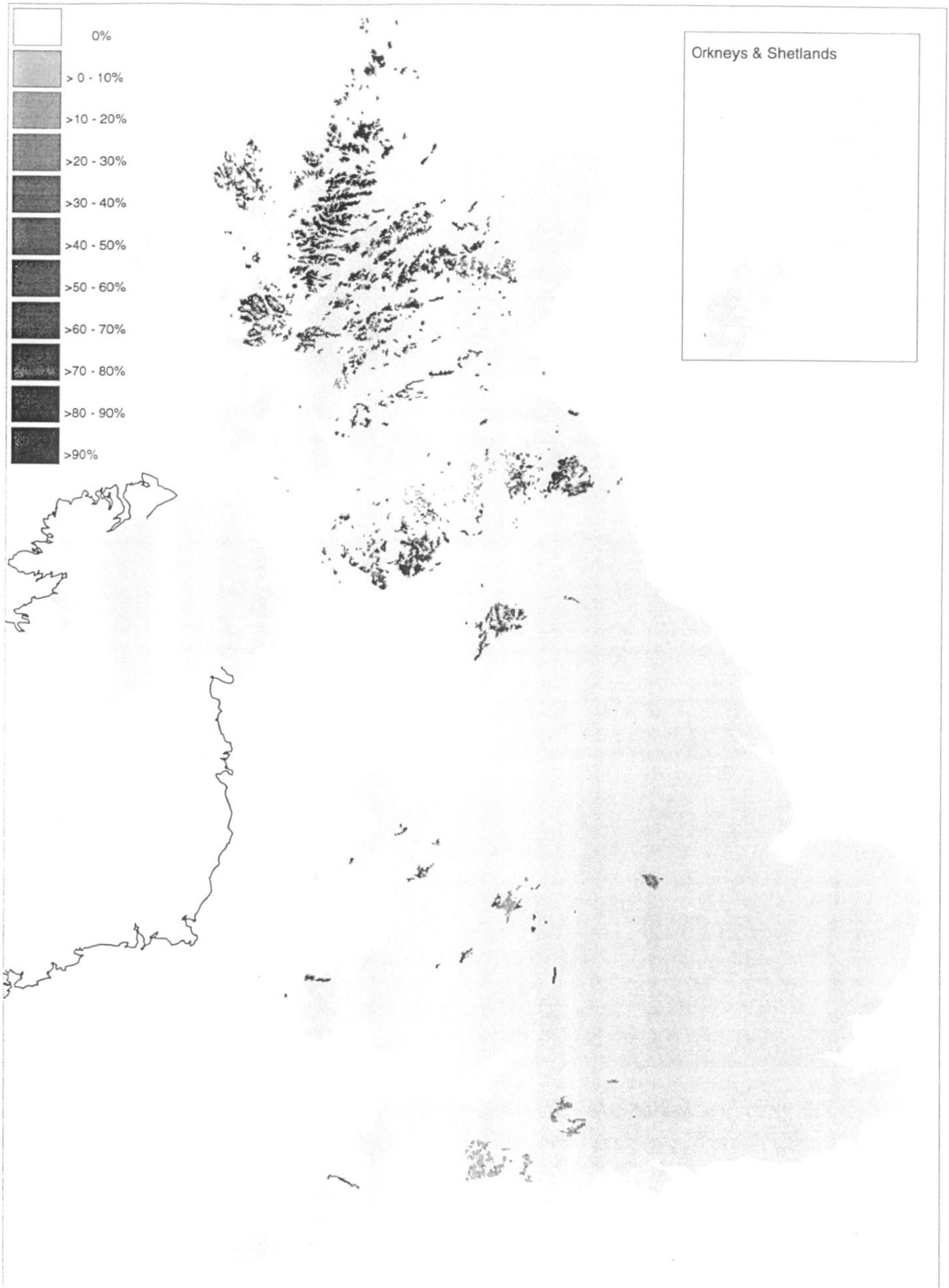
Distribution of HOST Class 17



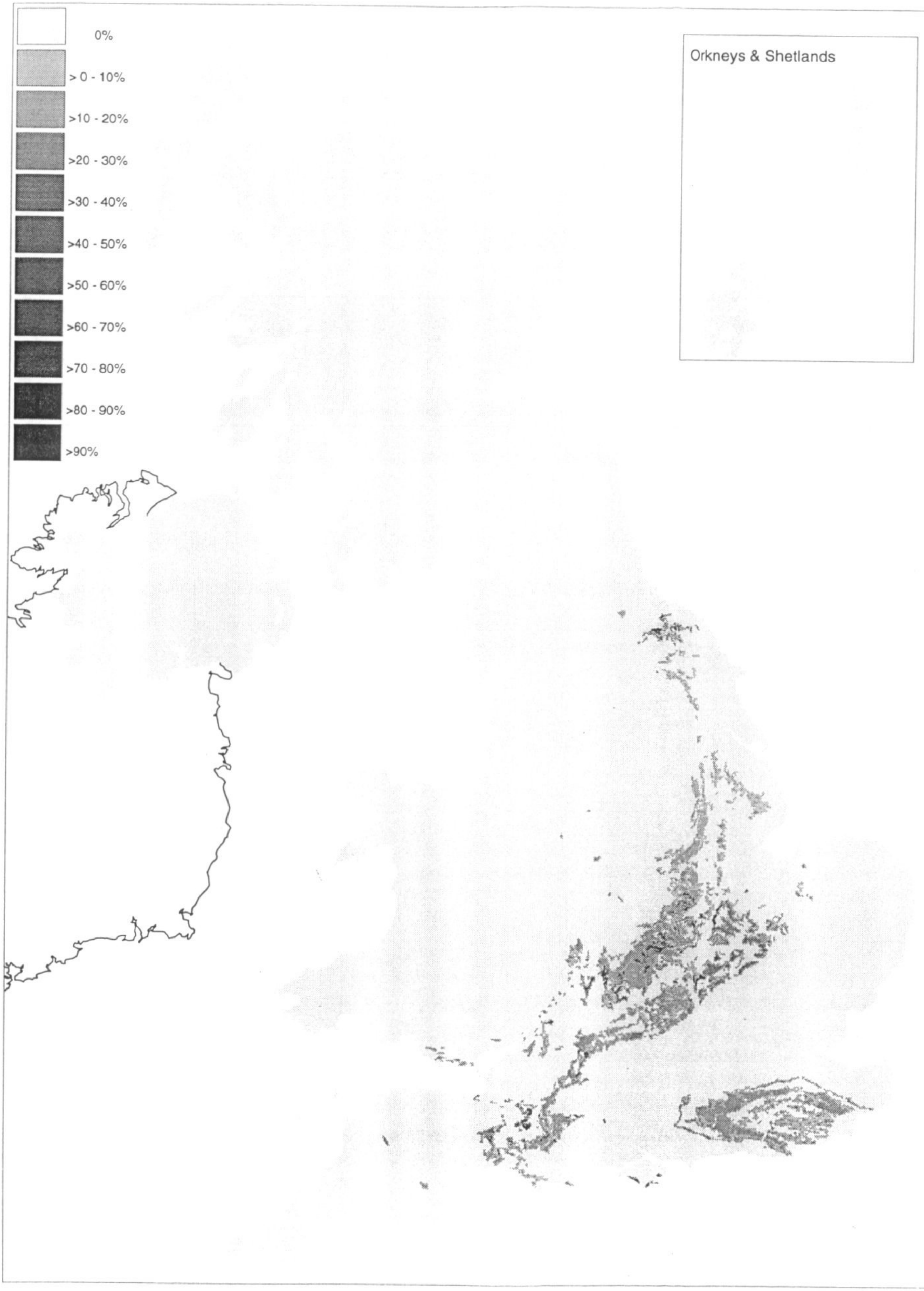
Distribution of HOST Class 18



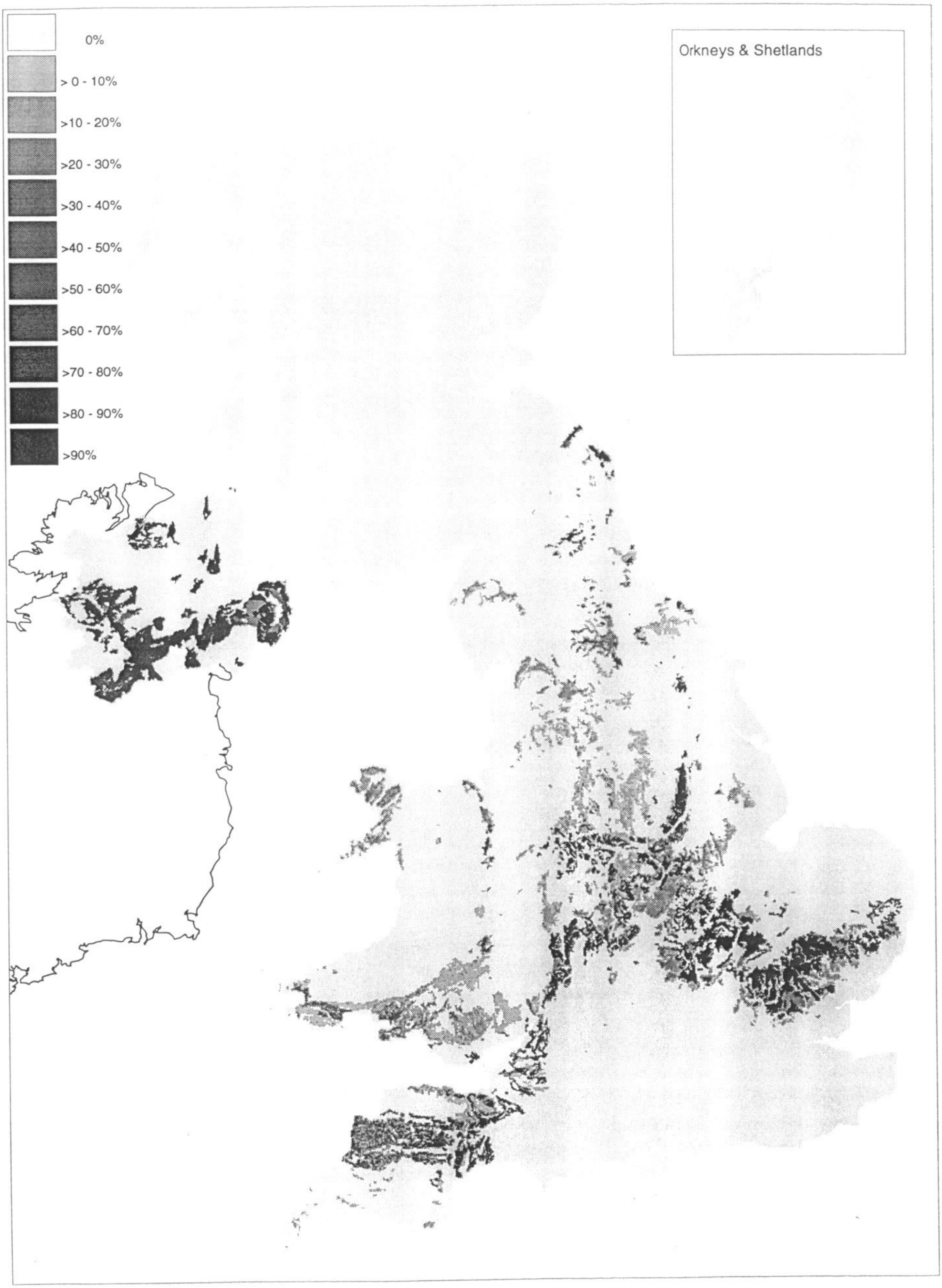
Distribution of HOST Class 19



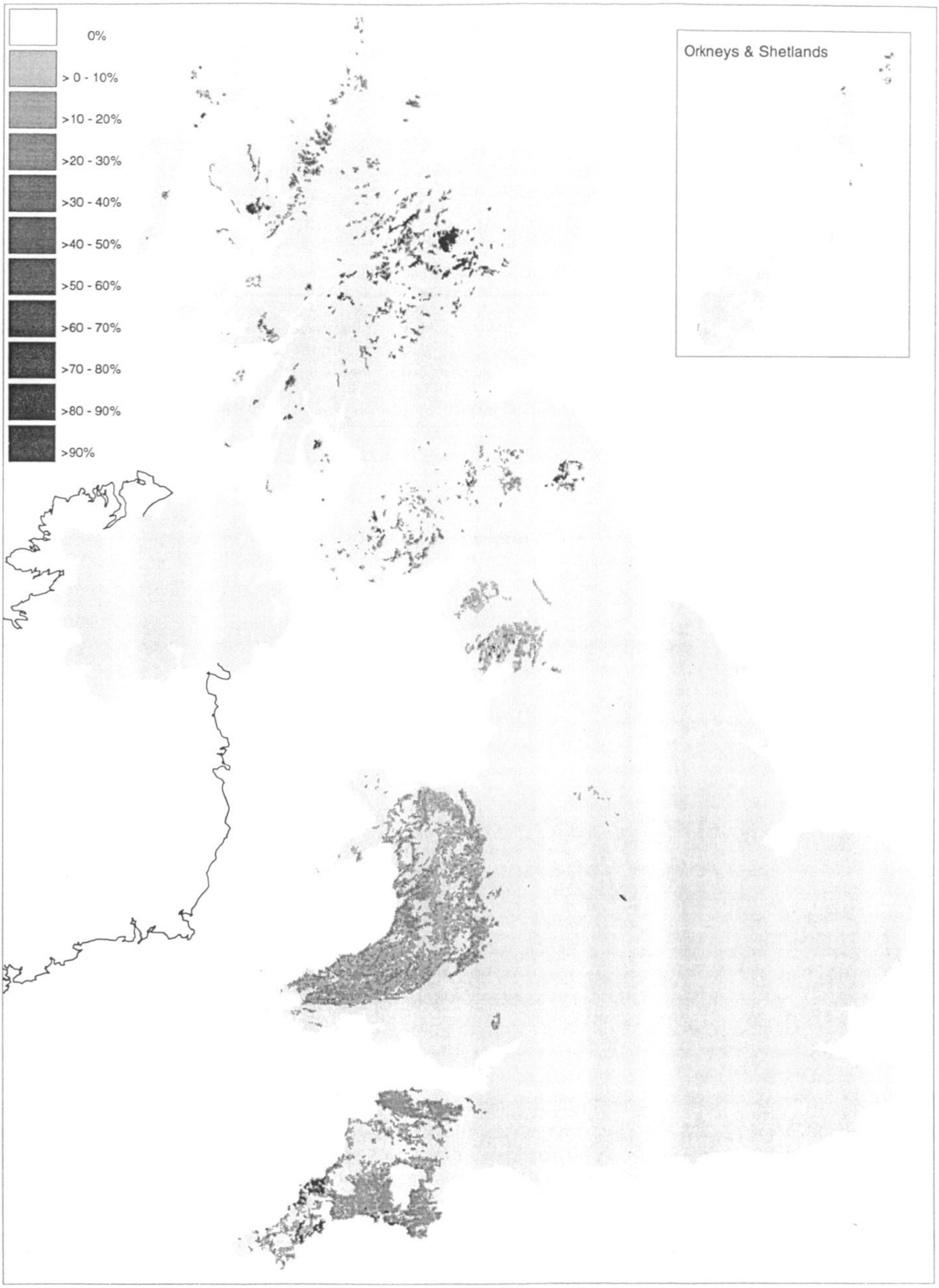
Distribution of HOST Class 20



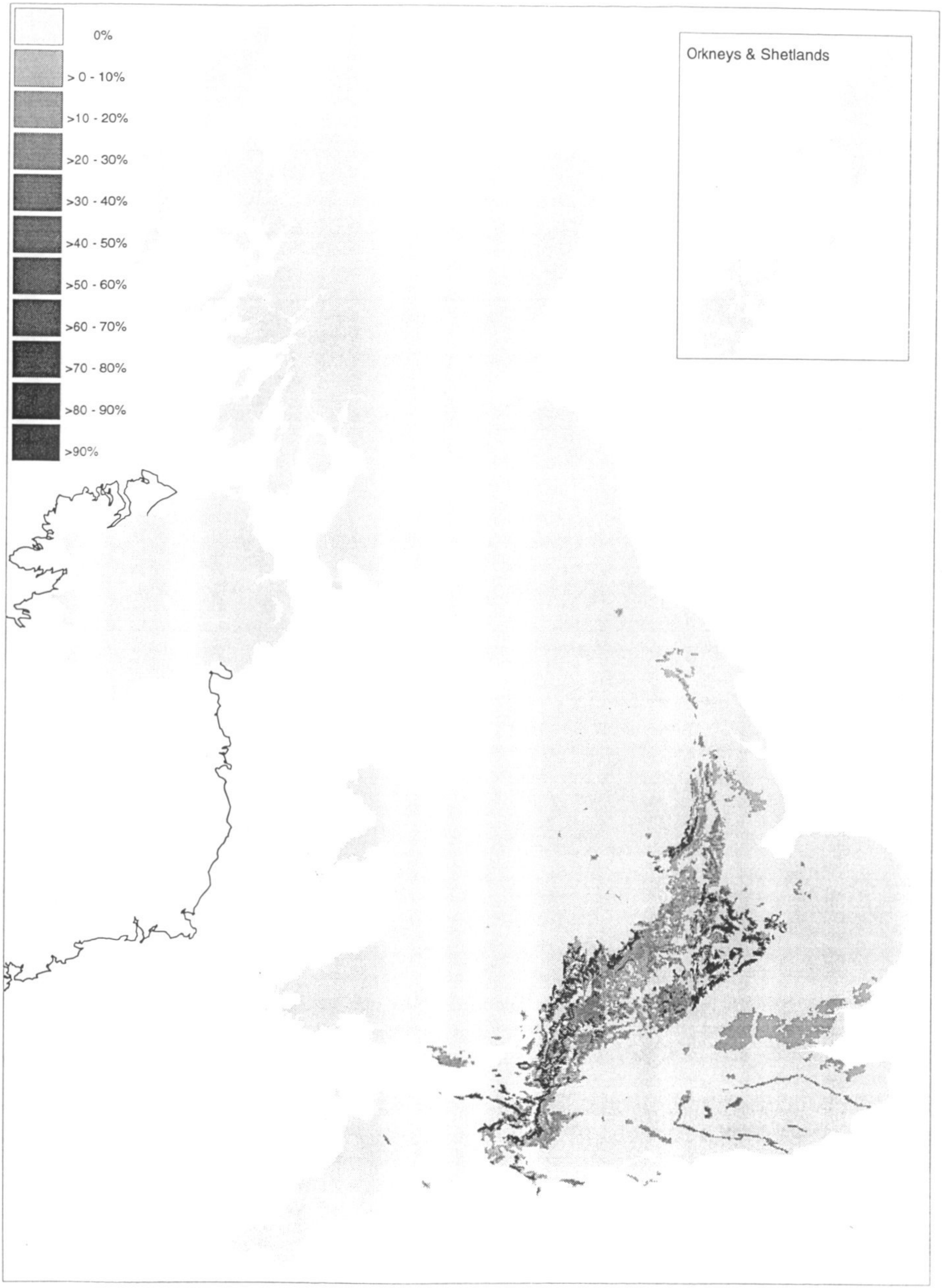
Distribution of HOST Class 21



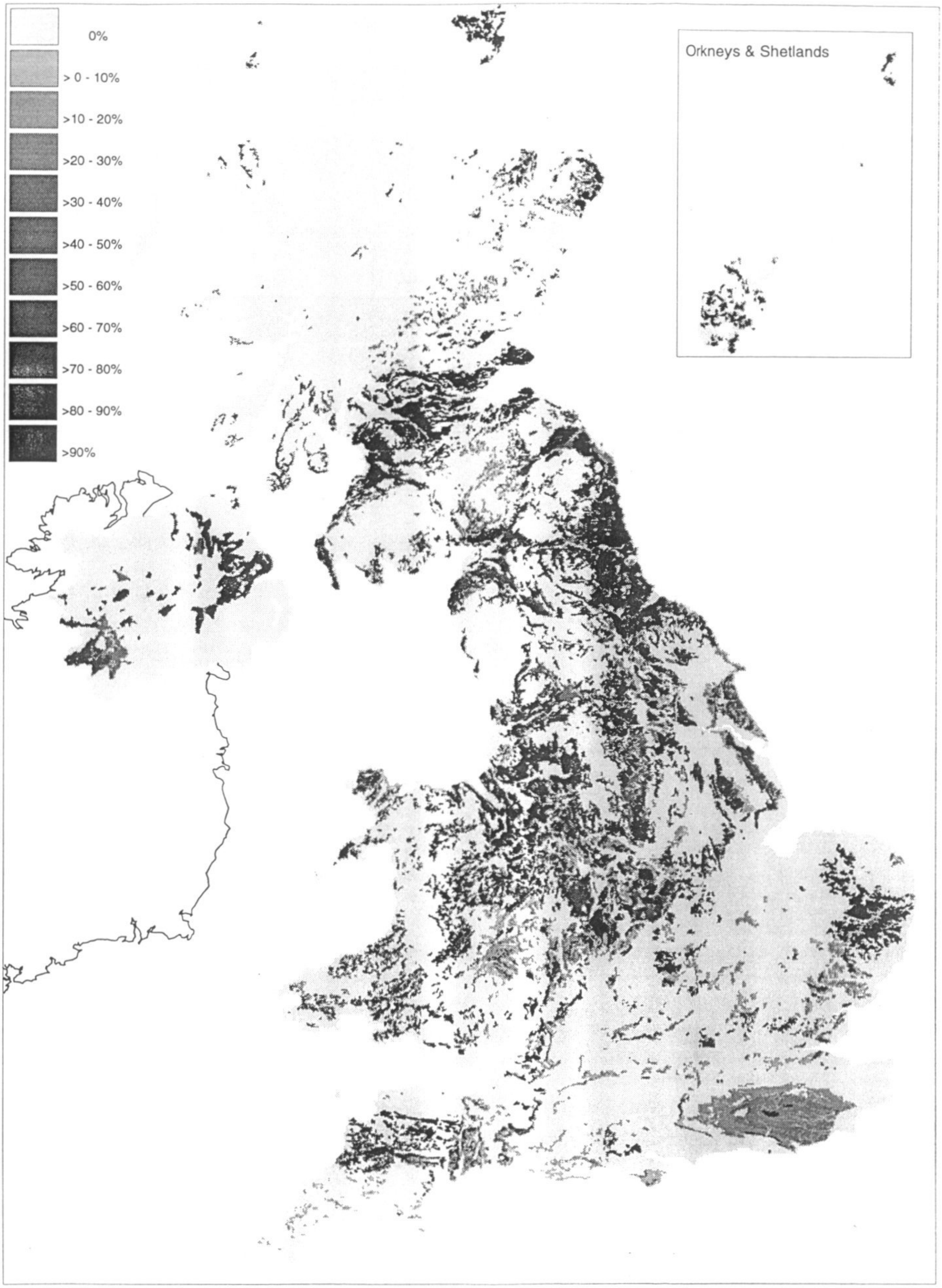
Distribution of HOST Class 22



Distribution of HOST Class 23



Distribution of HOST Class 24



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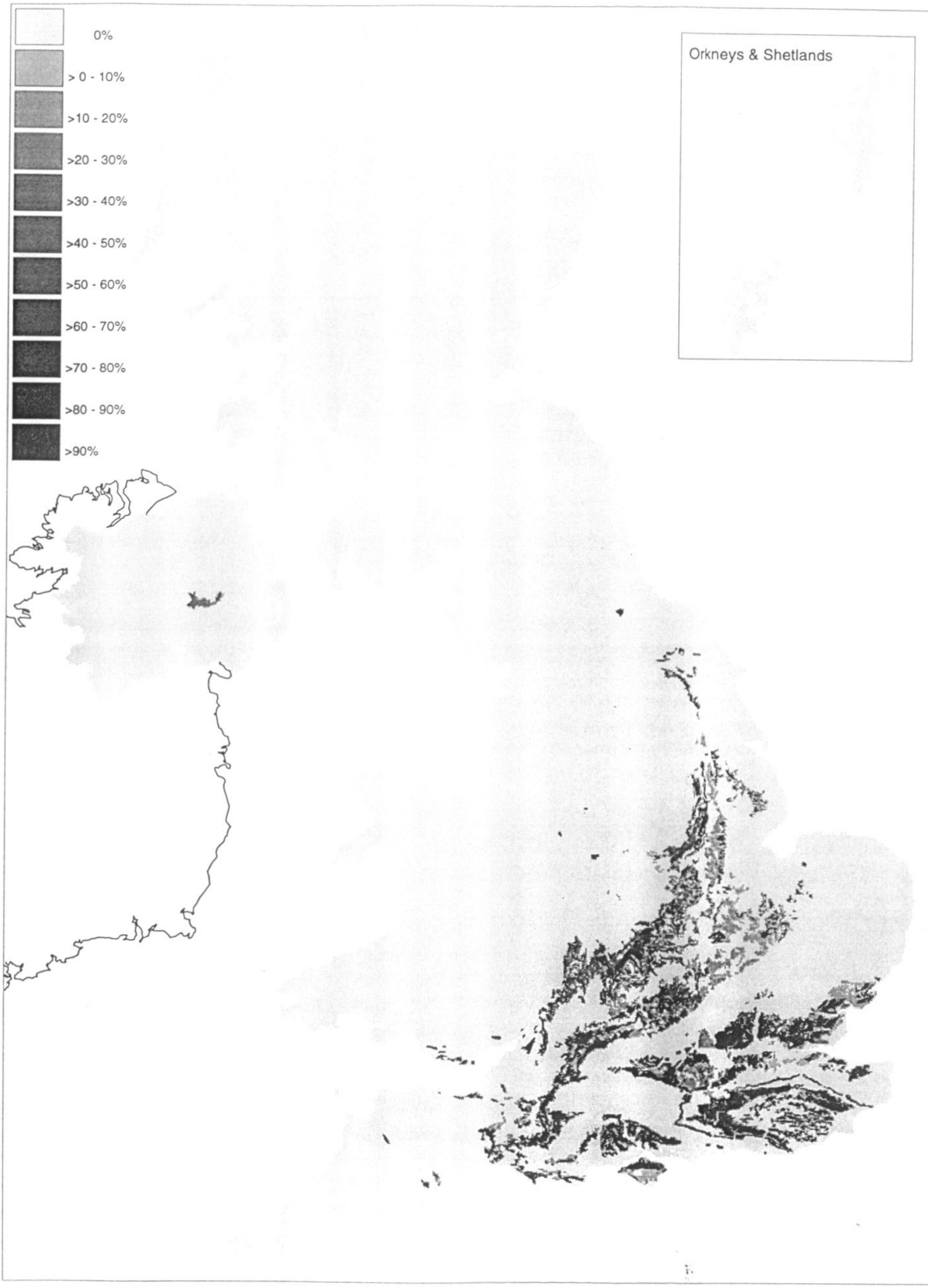
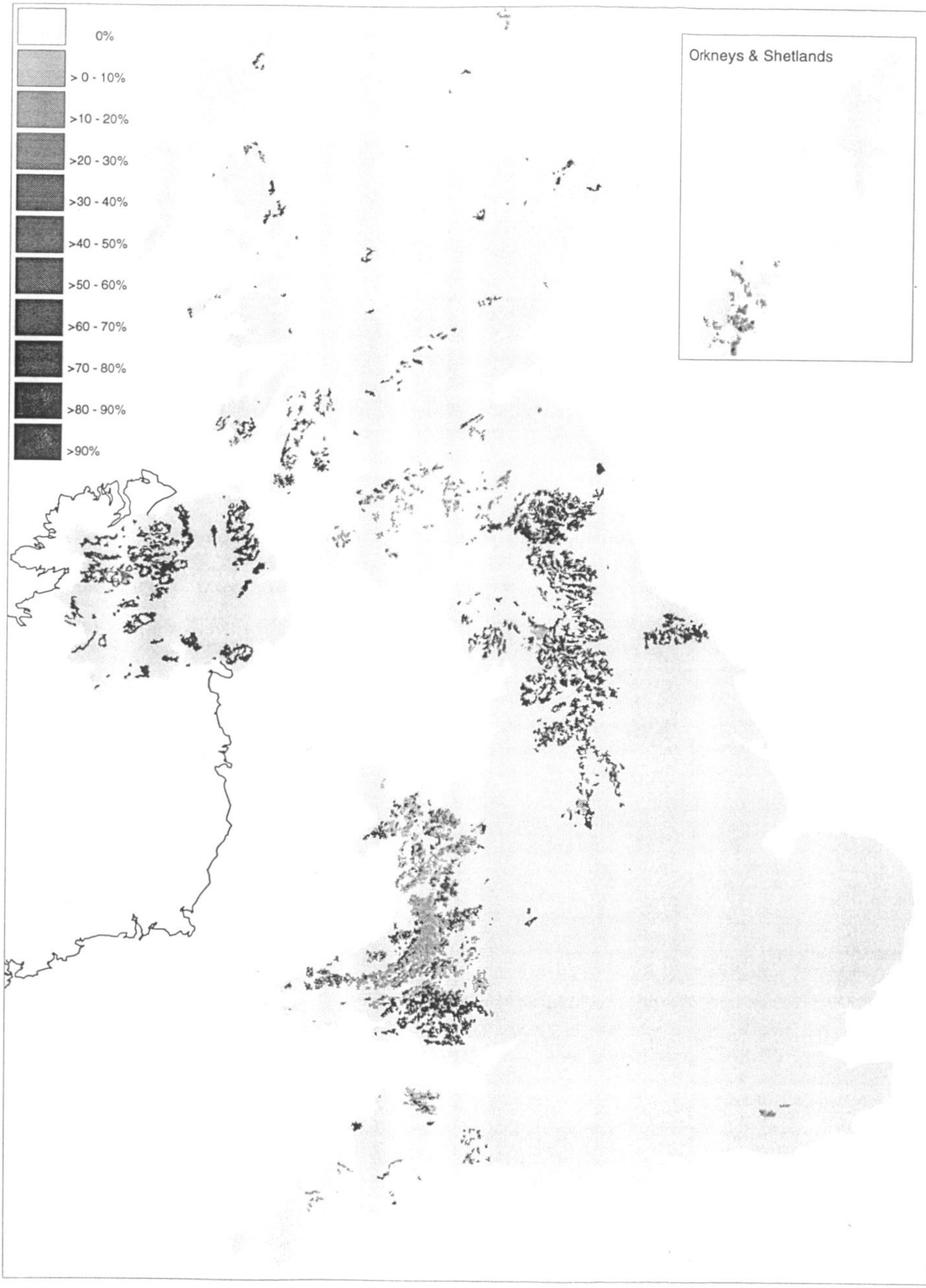
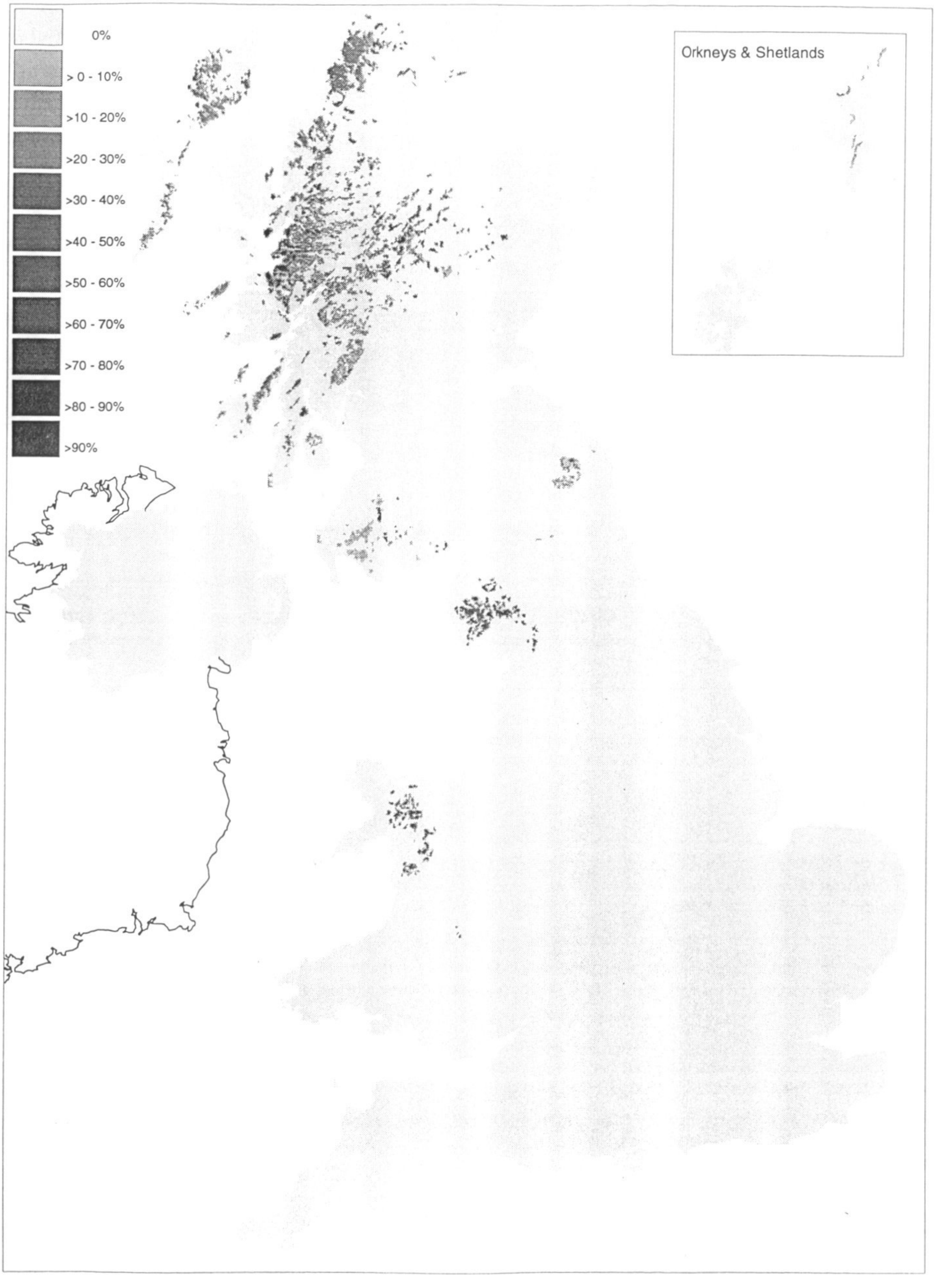


Distribution of HOST Class 26



Distribution of HOST Class 27



Distribution of HOST Class 28