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1. INTRODUCTION

The Flood Estimation Handbook published in 2000 together with the new software released with the FEH handbook have provided invaluable tools for the Drainage Engineer. Whilst the main research was aimed at estimation of flood flows and flood return periods in rivers it is every bit as applicable to urban sewerage systems.

The FEH software provides a far more advanced means of producing design storms for any given return period and duration and is far more sophisticated than the old Flood Studies Report (FSR) approach used in the Wallingford Procedure. The FEH software utilises digital terrain modelling and has data for over 4 million catchments in the UK from 0.5km² upwards (ie almost everywhere). The FEH software uses a far larger and more precise data set than was used for the FSR approach and also much of the rainfall data is more recent.

The results of assessments using the FEH software and comparing this with the traditional design storms from FSR shows that in some parts of the country the FEH storms are more severe whilst in other areas they are less severe.

2. Flood Studies Report (FSR)

The Flood Studies Report was published in 1975 and was initially, primarily intended for use with major river catchments rather than small urban catchments. Between 1977 and 1988 a total of 18 Supplementary Reports (FSSR's) were produced. The methods included in the Flood Studies Report were adapted for other purposes, in 1978 for Reservoir safety, in 1979 for urbanised catchments and it was not until 1981 when it was adapted for use in storm sewer design.

The FSR methods for determining design storms was incorporated into the Wallingford Procedure and was then built into the simulation programs WASSP, WALLRUS and HydroWorks. The design rainfall produced within these programs is widely known and readily used by Modellers.

There has always been some criticism of the Flood Studies Report that it was too over-generalised, that it did not take sufficient account of local features and that important local or regional variations were masked. In spite of this the methods used and embodied within the mainstream simulation programs were (and still are) widely used for storms with return periods of less than 1 year to over 100 years. The main data used in the development of the FSR methods comprised 96,000 station years of daily data and 2,300 station years of hourly data. From this the annual, monthly and summer maximum rainfall was established. The 1 in 5 year (M5) rainfall was used as the index.

Synthetic design storms are generated using the FSR methods with just 3 variables:- the M5-60 rainfall, the ratio of the M5-60 rainfall to the M5-2day rainfall (r), and the catchment area (the latter applies the Areal Reduction Factor). The only other variable being the location which is accounted for by the use of plans with the above data for the whole of the UK plotted on individual maps. At best the above factors can be interpolated on these plans to one significant place.

3. Flood Estimation Handbook (FEH)

The Flood Estimation Handbook was published in January 2000. The 5 volume book is complimented by a suite of software programs. The most important software in contained on the FEH CD-ROM with which the catchment descriptors can be identified and in turn the rainfall depth-duration-frequency (DDF) graphs can be generated. The basis of the FEH CD-ROM is a digital terrain model in which the drainage routes within each 50m by 50m grid square are determined irrespective of whether there is actually a watercourse along that route (ie 'dry' valleys are also considered as drainage routes). All catchments in England, Wales and Scotland which are greater than 0.5km² are included within the digital terrain model. The number of catchments included is in excess of 4 million.



The preparation of the Flood Estimation Handbook was undertaken between 1992 and 1999 by the Centre for Ecology and Hydrology (formerly the Institute of Hydrology). The work was based on a far greater amount of rainfall data from 6,106 daily raingauges and 375 hourly raingauges. The amount of hourly data available at 7,389 station years was over 3 times the amount of hourly data available for the Flood Studies Report.

The Flood Studies Report used the 1 in 5 year rainfall (M5) as the index and it is this which is the cause of some criticism that the FSR over-generalised rainfall in several areas of the UK. The FEH approach is different as the index used is the Annual Maximum Rainfall interpreted as the median annual maximum rainfall (RMED). The growth curves are generated using the FORGEX method.

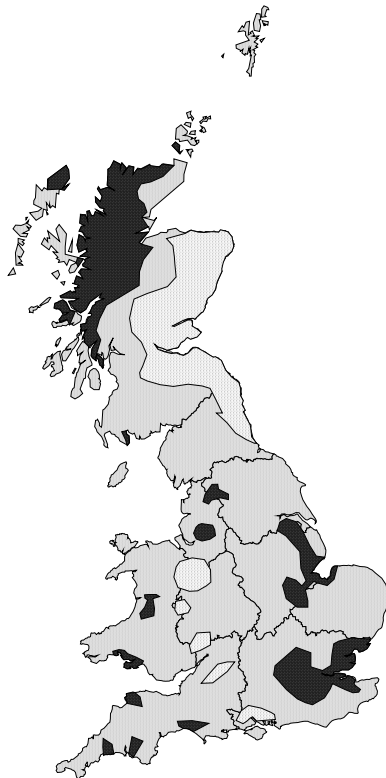
The number of variables used in the FEH approach is far greater and is currently set at 30 variables though this could be expanded to over 50. This number of variables can be used because the FEH CD-ROM enables a digital approach to be taken which is far quicker and avoids the need for any manual calculations. With this greater number of variables it has been possible to taken far greater account of local conditions, local topography, prevailing winds, water sources (seas and oceans), land cover, soil types, urban and suburban areas.

The FEH handbook explains in great detail the approaches taken in the different aspects of flood estimation. These are beyond the scope of this paper but interested readers are advised to consult the FEH handbook for more detail.

In a more simplified manner it can simply be concluded that the FEH approach uses far more data than the FSR approach and uses a far more sophisticated analytical procedure which takes better account of local conditions.

One aspect worth noting however is in relation to return periods of less than 1 year. The DDF (Depth-Duration-Frequency) Model is designed to provide rainfall estimates for return periods longer than 1 year. For shorter return periods, frequently required in analysing urban pollution events, the annual maximum scale is inappropriate, as it only allows for one extreme rainfall event per year, and the peak-over-threshold (POT) scale must be used instead

4. Differences between FSR and FEH Storms



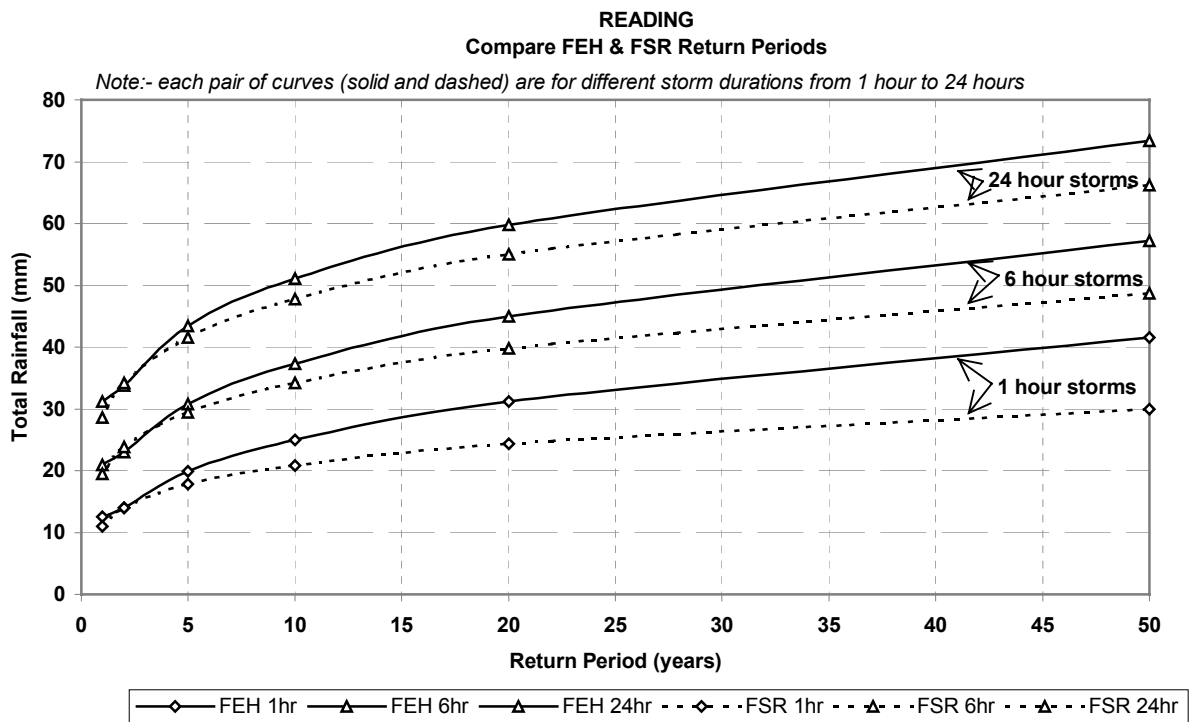
Volume 2 of the FEH handbook has some used plans which illustrate some of the differences between FSR and FEH Storms in terms of depth of rainfall. The plan to the left is reproduced to illustrate the differences in total rainfall for storms with return periods of 100 years and 1 hour duration. The dark areas which are principally on the western side of Scotland, in the Thames valley and between the Wash and the Humber have greater rainfall in FEH storms than in FSR storms. The differences can be up to 40% difference.

The light areas, principally on the eastern side of Scotland and northern England but also in other pockets have less rainfall with FEH storms than FSR storms. These differences can be as much as 30% but are generally less than 20%.

This plan cannot be relied upon with any degree of accuracy and a more sophisticated approach is suggested to assess the differences in specific catchments which are being investigated.

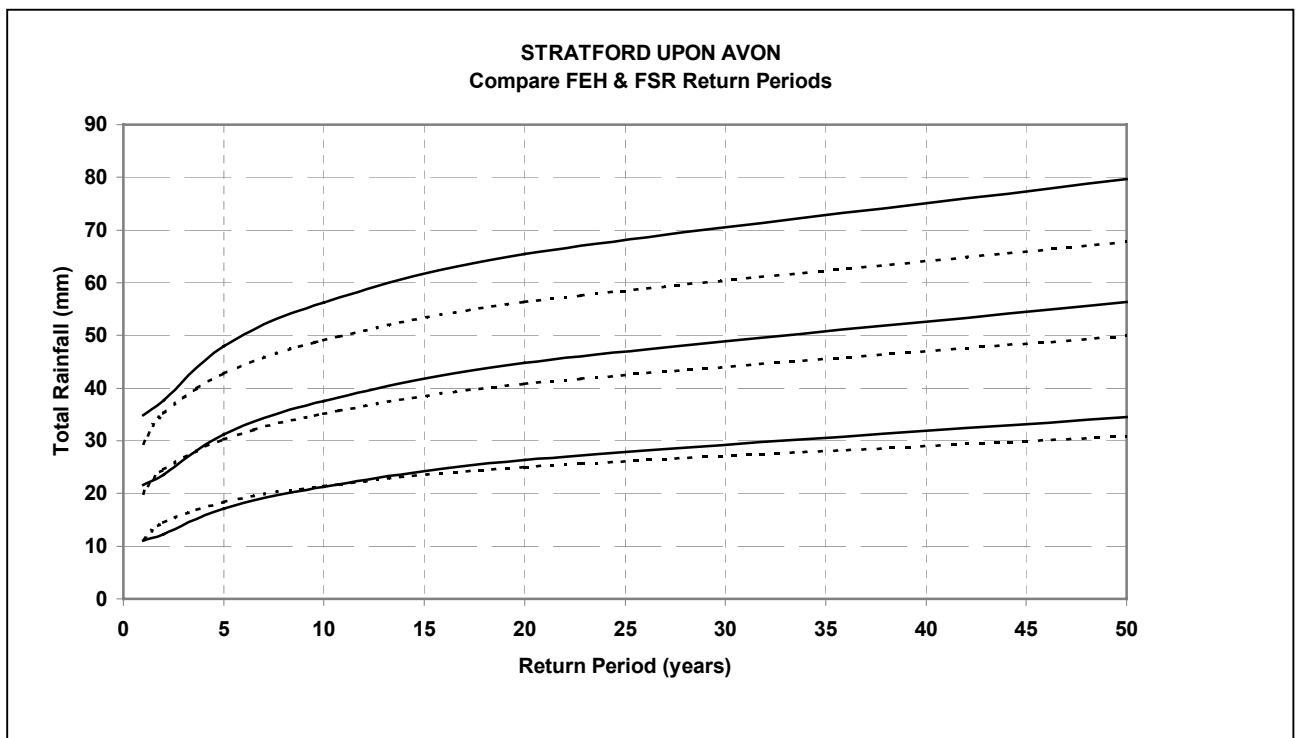
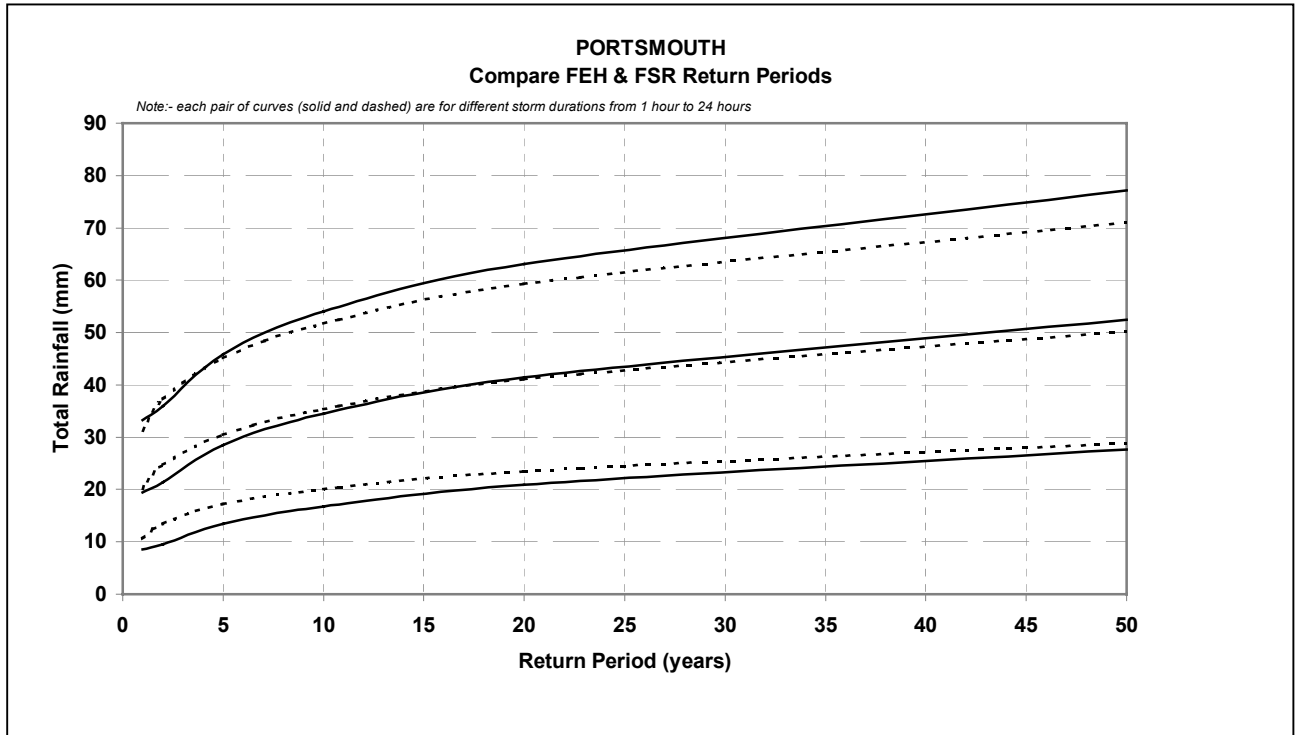
For this paper a number of catchments were studied for comparison purposes. The graph below shows an example of the analysis undertaken (in this graph for Reading).

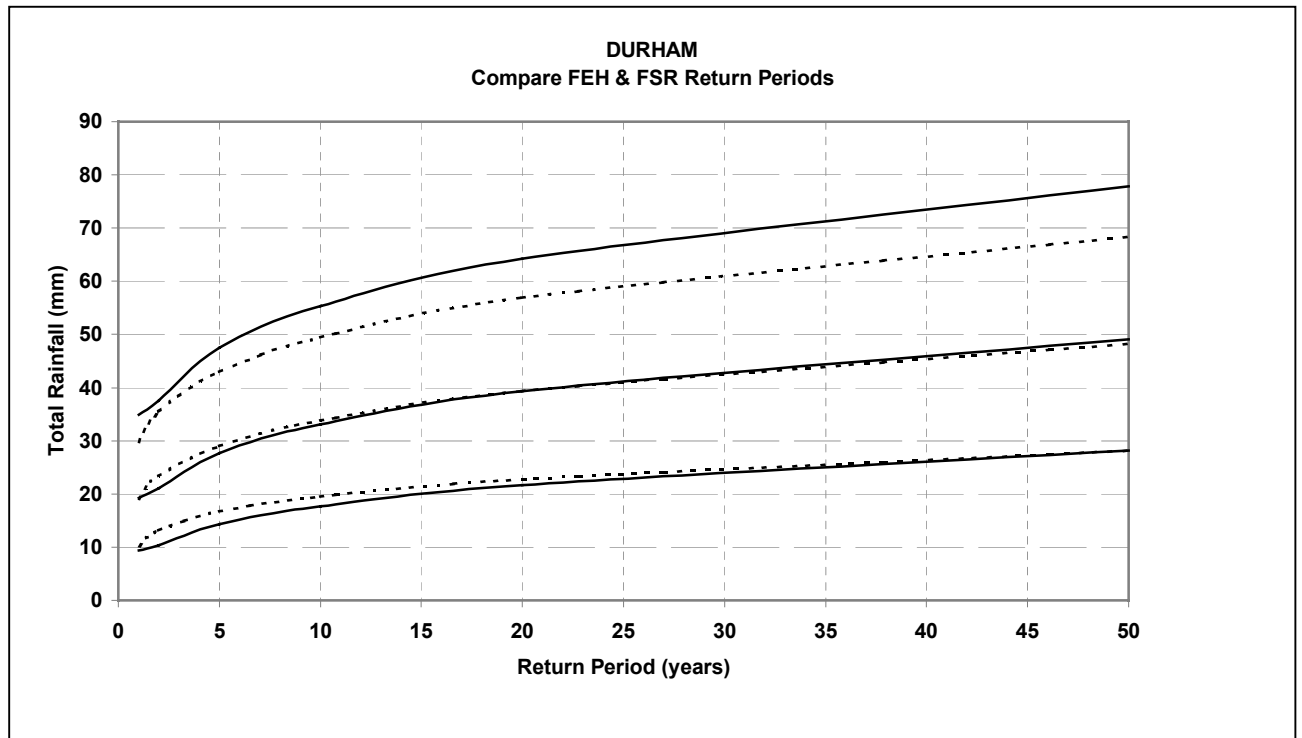
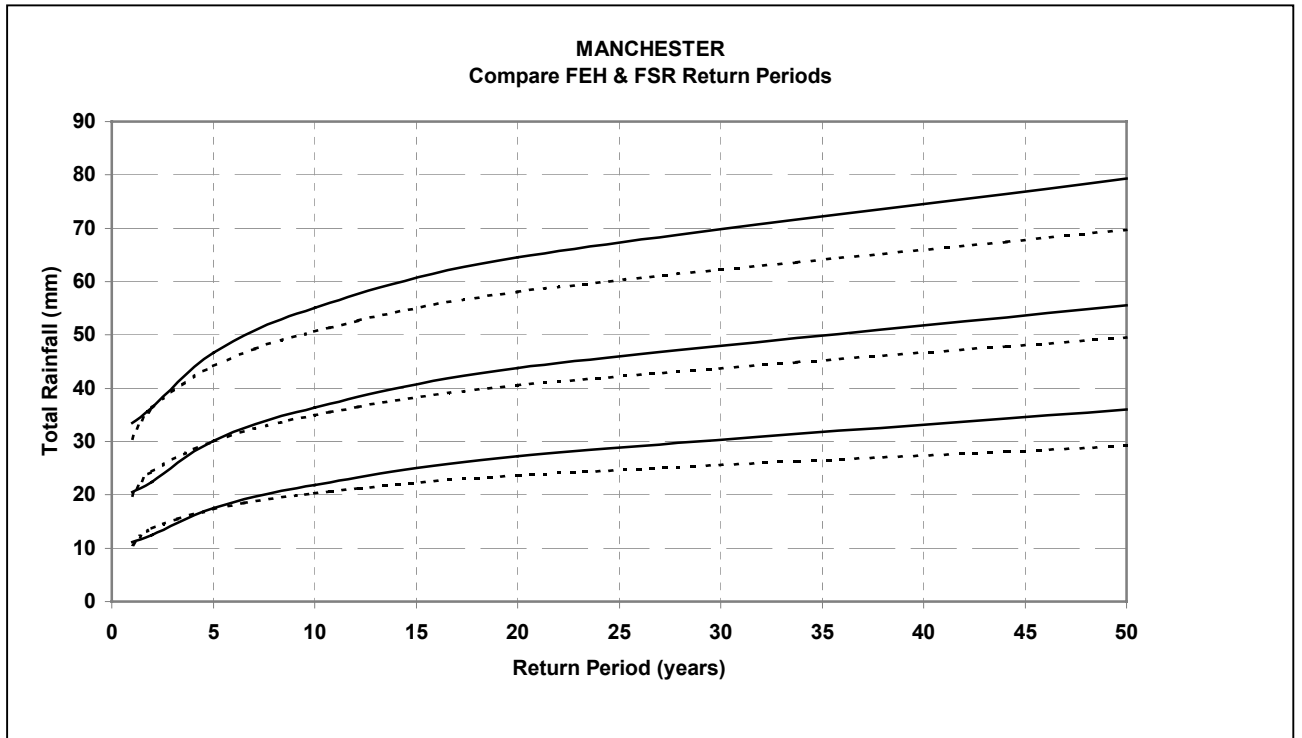
The graph shows storm return period along the X-axis, total rainfall along the Y-axis and has a number of curves for different duration storms and also for FSR and FEH storms. The dashed lines are FSR storms and the solid lines are FEH storms. The lines are not actual storms but join together points at which the total rainfall was calculated for specific return periods. The FSR data was calculated using the Rainfall Generator in Hydroworks in the normal manner. The FEH data was determined for the same catchment using the FEH CD-ROM software.

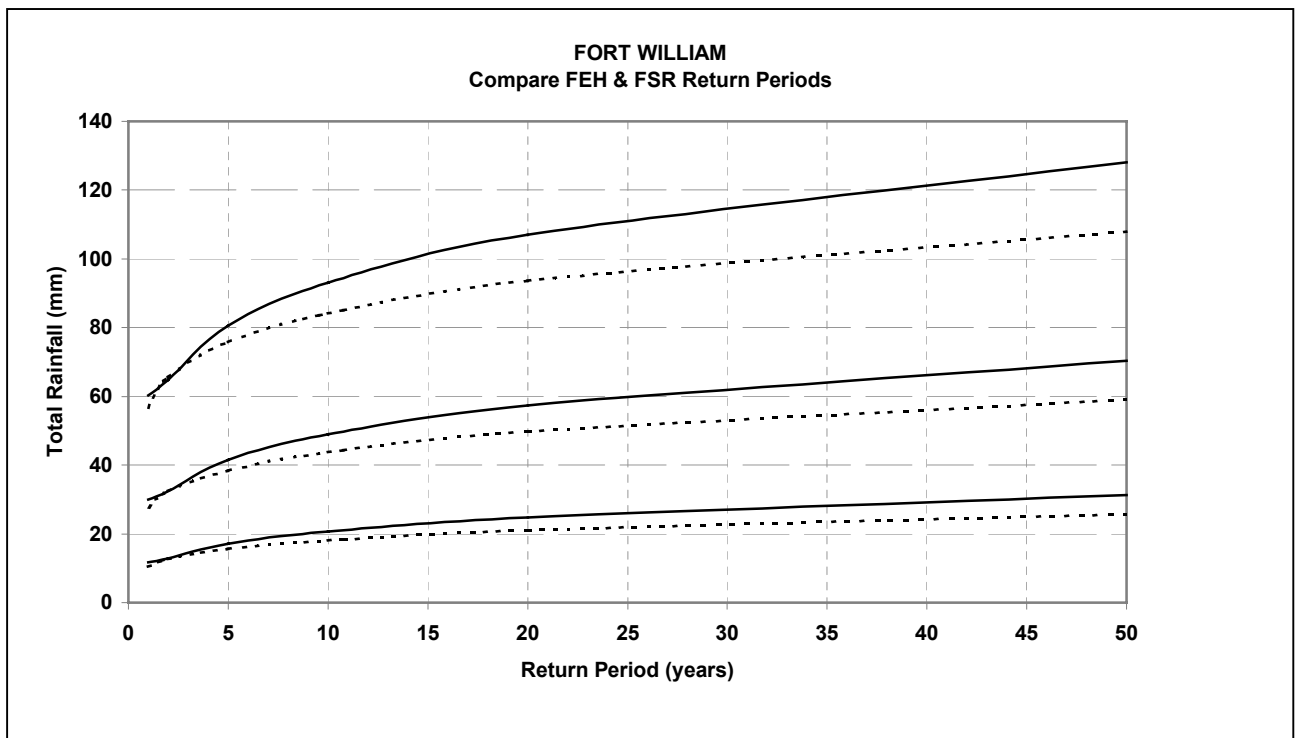
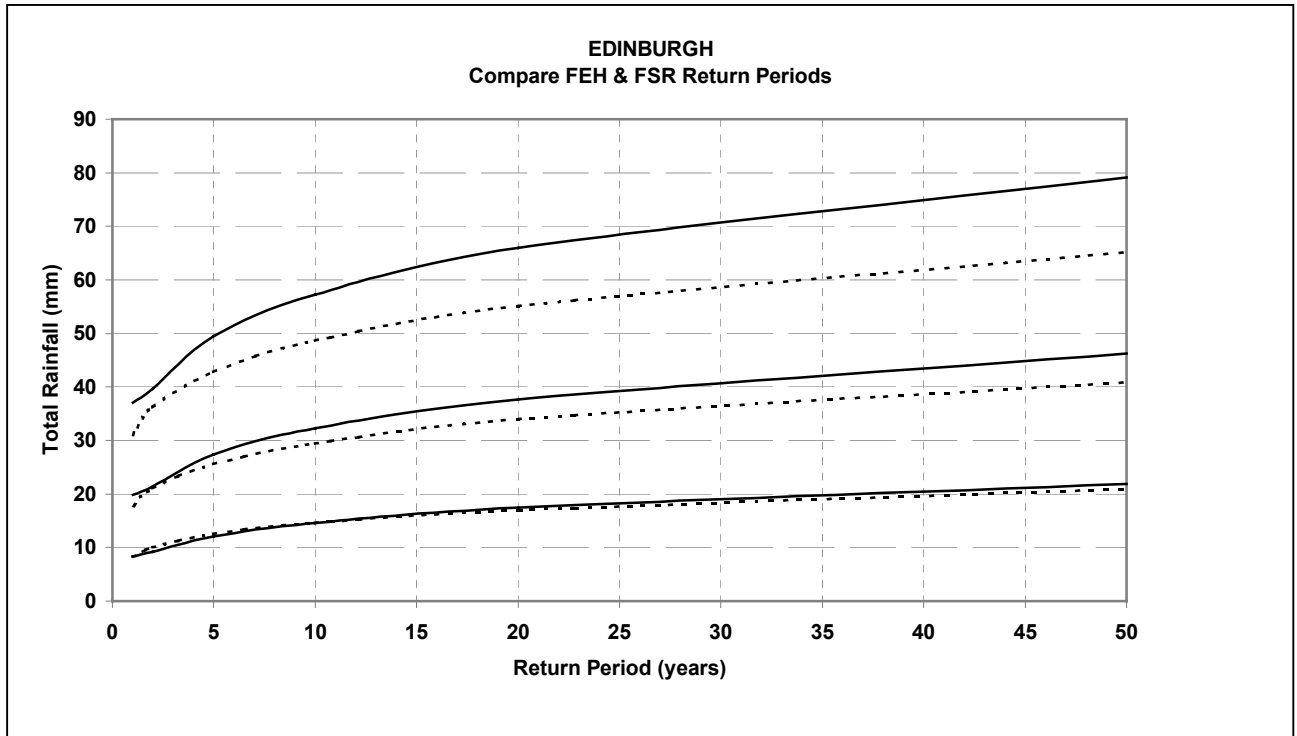


In this case it can be seen that for all durations plotted (1 hour, 6 hour and 24 hour) the rainfall from FEH storms is significantly greater than for the FSR storms. By plotting the graphs in this manner it is possible to compare return periods for storms generated using FSR to those which would be generated nowadays with FEH. As an example for the FSR storm with return period of 30 years there is 27mm of rain but for a 1 hour storm generated by FEH the same rainfall occurs with a storm with a return period of only 12 years. With greater return periods the differences get bigger. With 6 hour storms the picture is similar but this time the equivalent return period is 17 years and with 24 hour storms is 19 years.

Not all parts of the country show a similar pattern and indeed many areas are completely different.



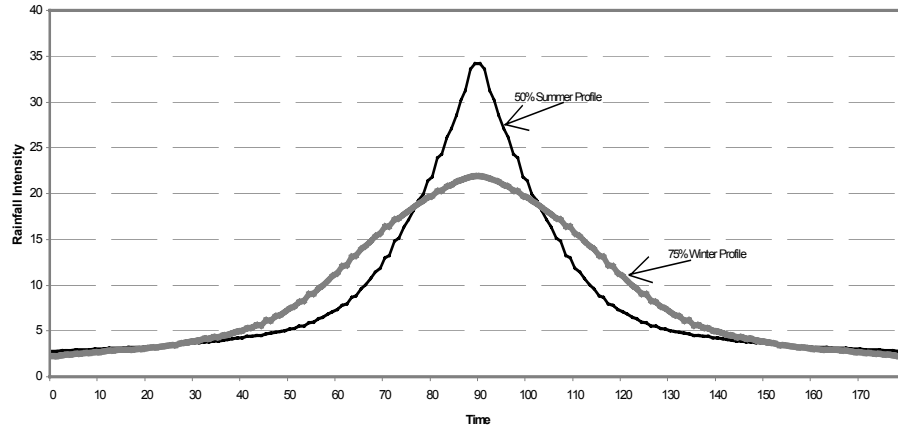




It can be seen from these graphs that there is a wide variation between catchments but also there is variation within each catchment with different storm durations and with different storm return periods.

5. Rainfall Profile Shapes

The synthetic rainfall profile shapes developed as part of the Flood Studies Report namely the 50percentile storm for summer storms and the 75percentile storm for the winter storms have been retained in the Flood Estimation Handbook. There has been no evidence to suggest that these shapes are inappropriate for synthetic design storms. The FEH CD-ROM provides data on the Depth-Duration-Frequency (DDF) graphs for the chosen catchment



(ie it provides the total rainfall) but it does not provide a rainfall profile nor does it state whether the worst case is summer or winter.

As the rainfall depth is based on the Annual Maximum it is inappropriate to state whether a summer or a winter profile should be

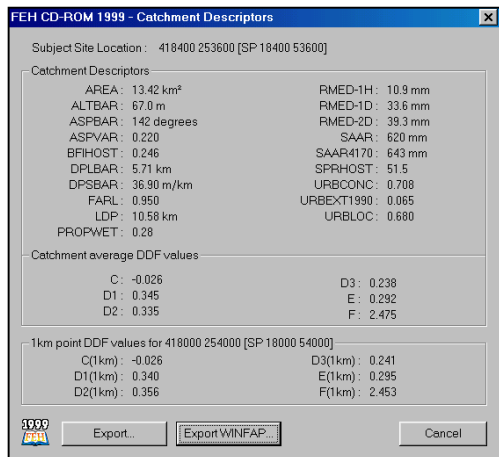
applied. It is recommended that the general procedures which have been used by Modellers; namely to use summer storms for flooding and flood alleviation studies and to use winter storms where storage or overall flow volumes are important.

6. FEH CD-ROM

The FEH CD-ROM can be purchased separately from the FEH handbook though for users who will make extensive use of the CD-ROM it is recommended that the handbook is also purchased so that the user can gain an understanding of the FEH approach.

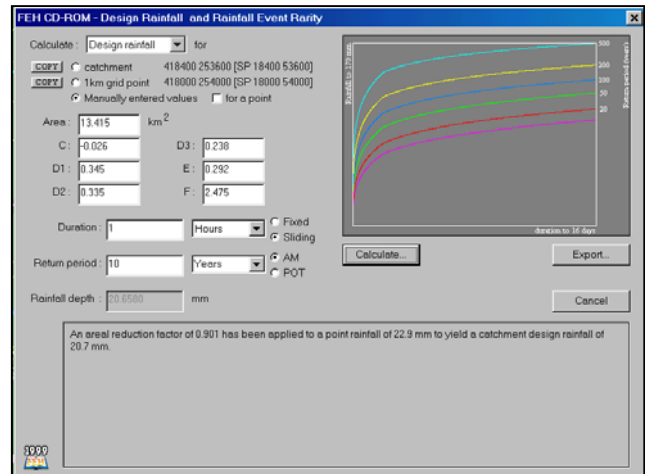
The FEH CD-ROM includes 1 km grids over the UK of the six parameters of the DDF model. Catchment average, 1 km values or point values for the parameters can be determined for every drainage catchment in the UK which has a catchment area greater than 0.5km² (this is over 4 million catchments).

The FEH CD-ROM is a user friendly means of quickly zooming in on the catchment being considered and then identifying the catchment. Once the catchment has been highlighted by pressing the Query button the characteristics of the catchment are displayed and can be exported as a CSV file which can then be imported into Infoworks or MicroDrainage. The diagram below left is a typical display of the characteristics for a catchment. The upper portion shows all the data for the catchment and provides the catchment average DDF values so that rainfall over the whole catchment can be generated. The lower box provides the DDF values for a 1 km square point at the quoted grid reference (the downstream end of the selected catchment).



It will be seen that the DDF values are subtly different – this is because of the averaging which has taken place. When importing into Infoworks the catchment average DDF values are used whilst in MicroDrainage the point DDF values are used.

For the selected catchment the DDF values and the rainfall for any given return period and duration can also be displayed. A typical screen is shown to the right. The choices of catchment area, 1km grid, manually entered values or point values are straightforward. When the desired return period and storm duration are entered the rainfall is calculated. When the catchment average values are used the software applies an Areal Reduction Factor to the point rainfall.



7. Creating Rainfall Files

Infoworks and MicroDrainage now have inbuilt facilities to generate FEH storms. In both of these the six DDF parameters can either be manually input or alternatively the CSV file generated with the FEH CD-ROM can be imported.

Infoworks imports the catchment average DDF values and it is therefore important that the correct catchment area is selected. Because the FEH routines are principally aimed at flood estimation from watercourses etc the catchments as defined in FEH CD-ROM always start at the head of the catchment but can be extended as far downstream as required by the user. However for a relatively small urban catchment it maybe inappropriate to also have a large rural upstream catchment which does not contribute to the sewer system. In these cases it maybe better to use the 1-km data or alternatively to average a number of 1-km values to get a more representative average for the catchment.

MicroDrainage (WinDap and WinDes) import the 1-km DDF values either from the CSV file or by manual inputting. The reason why MicroDrainage uses the 1-km values lies in the fact that the programs stem from a design background rather than a simulation background. Generally in sewer design Areal Reduction Factors are not applied and are in reality only applicable to the last pipe in the system. There is a facility within WinDap to change the Areal Reduction Factor which has a default setting of 1.

There are no facilities in Hydroworks for generating any FEH storms. However, suitable RED files can be prepared by creating them in the normal way for the required catchment. The values in the RED file are then factored up (or down) to give the same overall rainfall depth as given by FEH. It is important that all values are factored so that the correct shape of the storm profile is maintained.

8. Areal Reduction Factors

Areal Reduction Factors are the factors which are used to reduce the point rainfall values to catchment wide rainfall values. The Areal Reduction Factors are a function of the size of the catchment and also the storm duration.

Areal Reduction Factors are applied to the rainfall file in Infoworks (and Hydroworks) so that the values included in the rainfall file have already been reduced from the point values. In MicroDrainage the rainfall files have the point rainfall values and any Areal Reduction Factor required (the default being 1.0) is applied at the stage when the rainfall data is read by the program and converted to runoff.

In checking rainfall depths generated in FEH CD-ROM, Infoworks and MicroDrainage it was found that a reasonable agreement was reached with point rainfall. However, for catchment wide rainfall in Infoworks the final values did not agree with FEH – the reasons for this are not fully understood at present and are being investigated by Wallingford Software – it is however thought possible that the differences could be due to the Areal Reduction Factors used.

9. Further Research

The Flood Estimation Handbook has given Engineers and Modellers a far more appropriate tool for estimation of flood flows and for the generation of appropriate rainfall data. However, the FEH approach like all the preceding methods relied upon historical records.

In times of climatic change it may no longer be entirely appropriate to rely solely on historical records but maybe some forward predictions of likely rainfall at scheme design horizons would be more appropriate. A UKWIR research project is due to commence shortly which will address all these issues and will advise the most appropriate techniques to use for sewerage design.