Plate 5.12 Flood Discharge – Statistics for 1971–2007

Introduction

Awareness of the characteristics of flood discharge is extremely important for many aspects of hydro-engineering, water use or the protection of rivers and lakes. This plate re-addresses the topic dealt with in plate 5.6 (Flood discharge – Analysis of long-standing measurement series) in greater depth. On the one hand, it has been possible to use much longer measurement series and on the other, additional statistics have been analysed apart from mean annual flood discharge peaks and coefficients of variation. The text to plate 5.6 provides a general introduction to the subject of flood discharge. The authors of the present plate have decided not to include a similar table to that shown in plate 5.6, since annually updated flood data from each measuring station are available on the internet [3].

The choice of the period 1971 to 2007 offers various advantages: comparisons can be made with plate 5.6, the major flooding that occurred in 1999, 2005 and 2007 is included, a large number of measurement series is available for this period, and since it covers 37 years the period is sufficiently long for a statistical analysis. Moreover, since the same perod is being taken into account for all measuring stations, it is also possible to compare the data from selected stations.

Stations were chosen on the basis of the availability of data and the degree of influence of man-made factors on flood discharge. Stations where such factors influence flood discharge to a medium or greater degree were included only in the map of mean annual flood discharge peaks. The classification used in plate 5.6 was also employed here.

Mean annual flood discharge peaks

The first map shows the mean annual flood discharge peaks for the period 1971 to 2007. The catchments for stations where there is little or no human influence on flood discharge are indicated, the total catchment for a given station being made up of all the catchments upstream of that station. In each case, the classified values for specific discharge indicated by colour apply to the whole catchment. Apart from the specific discharge, the flow rate [m^3/s] of the mean annual flood peaks is also given. This figure is also shown for stations where there is a medium to greater influence on flood discharge. The numbers allotted to the measuring stations refer to plate 5.1[2], which includes some general information on measuring stations.

Overall, it is difficult to distinguish larger areas where specific flood discharge is similar. An exception is the catchments in north-west Switzerland and the Grisons where mostly only small specific discharge can be observed. It should be noted, however, that caution should be applied when comparing specific discharge from an extremely small basin with that from considerably larger basins, even if discharge has been standardised on the basis of the area of the basin. Much greater specific discharge is possible in small catchments than in large basins.

Variation in annual flood discharge peaks

The second map shows the variation in annual flood discharge peaks (for the period 1971 to 2007) for selected measuring stations in the form of box plots. The box plots show the mean, the 25 % quantile, the 75 % quantile and maximum and minimum for the annual flood discharge peaks. Standardised values have been used instead of absolute values, the mean corresponding to 1, so that the plots for the various stations can be compared. The box plots reveal the marked variability between the stations. The difference between the mean and the maximum annual flood discharge in particular varies considerably: at some measuring stations, the maximum annual flood discharge value is only around 1.5 times more than the mean annual flood discharge value, while in other cases it is 3 to 4 times greater.

As an additional indicator of variability, the colour of the box plot shows the order of magnitude of the coefficient of variation (quotient obtained from the standard deviation and the mean). The coefficient of variation is in fact particularly suitable for interpreting symmetrical distribution but less useful in the case of asymmetrical distribution [1]. The individual box plots show whether annual flood discharge values are symmetrically distributed. It must be said, however, that there are only a few measuring stations where the distribution is really skew. The map shows that the coefficient of variation differs from one station to another. No spatial pattern is apparent; even stations that are relatively close to each other can have totally different coefficients of variation.

Seasonal distribution of annual flood discharge peaks

The third map shows the seasonal distribution of annual flood discharge peaks. Three different aspects are addressed: the colour of the segment of the circle indicates the season when flood discharge peaks occur on average (for calculations see [7]); the radial lines indicate the number of annual flood discharge peaks per half-month and the red triangle on the circumference of the circle indicates the date of occurrence of the greatest annual flood discharge peak for the entire period; in exceptional cases there is more than one equally great flood discharge peak.

If we analyse only in which season the mean date of occurrence lies, the picture is quite clear: apart from the Jura Mountains and a few other stations in western Switzerland, this theoretical date is almost always in the summer. For a more precise interpretation of the data the number of flood events per half-month also needs to be taken into consideration, since the average season of occurrence is not always representative. This applies in particular to stations where flooding can occur at any time of the year (e.g. Töss–Neftenbach, station no. 549).

The date of occurrence of annual flooding is linked to the processes that trigger the event [4,5]. It has been shown, for example, that most of the flooding in the Jura Mountains occurs during the winter half-year owing to the type of processes that lead to flooding in this area [8]. In contrast, at stations where data are strongly influenced by the meltwater from glaciers or snow, maximum discharge is normally seen in the summer half-year. The highest annual flood discharge peaks may be the result of extreme rainfall, however, and may therefore occur at other times of the year (e.g. the River Rhone in Brig, station no. 866).

Trends in annual and seasonal flood discharge peaks

The fourth map shows the trends in annual and seasonal flood discharge peaks for the period 1971 to 2007. The inner area of the code-signs indicates the trends that were calculated on the basis of annual flood discharge peaks, while the four outer segments show the trends in the four seasons; the latter were calculated from the seasonal maxima. The character of the trend is defined by its linear value and its significance. The linear trend value was calculated from a regression equation using the method of least-squares [1]. No trend is apparent if the increase per year compared to the mean annual flood discharge is less than 0.25 %. The significance of the trend was calculated using the Mann-Kendall trend test [6] for a probability of error of 5 %.

At a few stations flood discharge is extremely low in certain seasons. In order to show this the radius of the individual outer segment varies. For this purpose, the four average seasonal flood discharge values were compared with each other for each station. The highest value was defined as 100 %: the percentage for the other three seasons is in relation to this highest value. Percentages over 66 % correspond to a higher radius in the outer segment, while percentages equal to or below 33 % are indicated by a small radius in the outer segment. For example, for station no. 1143, Engelberger Aa–Buochs, it can be seen that although the flood discharge during the winter season increased significantly, the mean is in fact low in relation to the seasonal high flood discharge levels in spring, summer and autumn (mHQ_{winter}: 20.8 m^3/s; mHQ_{spring}: 44.3 m^3/s; mHQ_{summer}: 81.5 m^3/s; mHQ_{autumn}: 44.0 m^3/s).

In comparing individual stations, it is noticeable that the trend in annual flood discharge peaks can often be deduced from the trends in the principal flood seasons (with a larger radius in the outer segment). This is not always the case, however, since the measurement series of annual maxima may comprise maxima from different seasons. Although overall trends are positive, a comparison of certain stations with others clearly shows that there is a marked spatial variability. This is especially apparent, for example, in the case of the stations within the Thur catchment.

Trends in flood discharge peaks in various periods

Figures 1 and 2 show the trends in annual flood discharge peaks and flood discharge peaks in the summer half-year (April–September) for various periods. The character categories correspond to those used in the map of annual and seasonal trends. The trends were analysed for four periods of different length, all ending in 2007: 1926–2007, 1941–2007, 1956–2007 and 1971–2007. The shortest period thus corresponds to the period taken into consideration for the page of maps. Only those stations are included for which data for at least the period 1956–2007 are available. Figure 3 shows measurement series for summer and winter flood discharge peaks from selected stations. The measurement series shown on the left-hand side are from stations on large rivers that were used in plate 5.6 but which the authors have now been able to update by including data for 17 additional years. Some of these stations show a medium to marked influence. The measurement series shown on the right-hand side were selected on the basis of their interest in relation to trends in annual flood discharge peaks or flood discharge peaks during the summer half-year (cf. figs. 1 and 2).

Figures 1 and 2 show that the results of analysing the trends varied according to the period taken into consideration. Depending on the station, the stability of the trend in particular varied. For example, there was no change in the character of the trend for station no. 284, Muota–Ingenbohl, regardless of whether annual flood discharge peaks or flood discharge peaks for the summer half-year were considered, which can also be deduced from the corresponding measurement series shown in figure 3. At many other stations, an analysis of the four different periods showed that the character of the trend varied at least once. If the trend during only one period is analysed, the results should be interpreted with caution, especially if only a very short measurement series is analysed. Moreover, trend analyses are not suitable for identifying a possible cyclical pattern in the frequency of flooding [2].

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