Plate 5.11 Low Flow – Minimum Mean Discharge over Several Days

Introduction

Low flow is defined as follows: water level or discharge that is clearly below the long-term mean [4]. This is not a quantitative definition, and threshold levels are consequently dependent on the issue at hand and other water parameters such as temperature. A given low water level can, for example, create problems for shipping but at the same time be negligible in relation to sewage discharge. Similarly, low discharge is more serious for the survival of fish during a heat-wave than when temperatures are lower.

Low-flow conditions can be described using various characteristics [9]. In Switzerland the Q_{347} flow rate has legal implications for water management (see plate 5.8). Depending on the issue at hand, the lowest discharge value, the length of time that discharge remains below a threshold level or the deficit in relation to a discharge threshold level can be significant [5]. Moreover, the time of year at which low water occurs (seasonality) is also often of interest.

When using low-flow data, one must be aware of the fact that the relative measurement error is greater for low discharge than for mean discharge. Minor changes in the water level can have a considerable percentage effect on the discharge figures obtained, in particular in the case of wide, shallow channels. At some discharge measuring stations attempts are being made to minimise the measurement error by creating low-water channels [8].

The NMxQ low-flow index

The NMxQ low-flow index denotes the lowest discharge measured over x consecutive days within a low-water year (lowest x-day mean). The use of so-called low-water years is necessary for the following reasons. In Alpine rivers and streams low water often occurs in winter. If calendar years are used, yearly low-flow indices would not be independent from a statistical point of view, for example if a dry period extends beyond the chosen annual limit and statistics for low flow thus cover two consecutive years, although referring to one single dry period. Such dependence is not acceptable in statistics. For the present analysis, a 12-month period from 1 May to 30 April (low-water year) has therefore been used with regard to low-flow indices, since in April and May minimum discharge is rarely seen by reason of the snow-melt.

This plate focuses on the NM7Q low-flow index, i.e. the lowest 7-day mean discharge within a low-water year (see fig. 2). Discharge means may be chosen for other time periods, however, such as 1, 14 or 30 days (see table 1) [2,3]. The advantage of using the NM7Q index is that it is similar in scale to the lowest daily mean but is less liable to measurement error or short-term human influence since such problems are balanced out. On the other hand, discharge means over longer periods of time (NM14Q or NM30Q) present the disadvantage that they often include temporarily higher discharge values especially in rivers and streams in the Central Lowlands and the Jura Mountains (cf. fig. 2).

The three maps for this plate show various aspects of the NM7Q low-flow index. The maps are based on data obtained from federal discharge measuring stations. In order to ensure comparability, discharge data for the period 1984 to 2003 have been used throughout. This period was chosen because the data are both recent and abundant.

Mean discharge and mean specific discharge

The corresponding map indicates the mean expected low flow in various catchments. It is preferable to use the NM7q (NM7Q divided by the catchment area) specific discharge index as this eliminates the influence of catchment size, thereby ensuring better spatial comparability of the data. Insofar as the data is reasonably reliable and the catchments are not outside Switzerland, this value is shown in colour for all catchments where human influence is non-existent or negligible; hatching has been used where a value refers to a partial catchment with no upstream measuring station. Despite the evident variability, certain spatial patterns can be seen on the map.

In general, the lowest NM7q values are to be found in the Jura and in the western part of the Central Lowlands and the highest in the Alps. No conclusive explanation can be given for this, nor for the local variability in certain areas. Low flow from any area is the result of an extremely complex combination of a wide range of factors such as volume and distribution of precipitation, air temperature, evapotranspiration, water retention capacity of soils and sub-soil. The mean NM7Q discharge value is indicated for all the discharge-measuring stations that were in operation during the period 1984 to 2003, including those subject to moderate or marked influence.

Only a relatively small number of Swiss rivers and streams display a natural discharge pattern today; many are affected to a greater or lesser extent by reservoirs, hydro-electric plants, lake-level control (cf. plate 5.3), emissions from sewage treatment plants or diversion of water for drinking supplies and irrigation (cf. plate 5.10). As far as concerns low water, the following three degrees of influence can be identified:

1) no or only negligible influence: the catchment is subject to no known influence of any importance;
2) medium level of influence: known influences within the catchment although they cannot be demonstrated through low-water data and are therefore of only minor importance (e.g. diversion to supply drinking water);
3) marked level of influence: the catchment is subject to influences that can be corroborated through low-water data (cf. fig. 1). Such influences are mainly related to reservoirs and water diversion.

Ratio of NM7Q to mean discharge

The map showing the ratio of NM7Q to mean discharge (Anteil an der mittleren Abflussmenge) compares low flow with mean discharge in order to relate it to the overall discharge pattern in a given catchment. In addition, it shows the range of minimum 7-day means. The map indicates the ratio of the low-flow index (NM7Q) to mean discharge (MQ) for the period 1984 to 2003 (NM7Q to MQ). The blue columns represent a more equable discharge pattern while the green and yellow columns indicate a more marked deviation of low flow from MQ values. The greater the precipitation stored temporarily in the form of snow, the less equable the discharge pattern, which explains why the ratio of NM7Q discharge to mean discharge is smaller in catchments at higher altitudes.

Seasonality

The third map shows seasonality, i.e. the pattern of distribution of NM7Q discharge over the year. The direction of the red line indicates the average date of occurrence, the colour of the segment it is in the season. The length of the line relates to the degree of seasonality: if the NM7Q occurs on exactly the same date each year the line has a length of 1 on the unit circle and if the NM7Q occurs totally at random its length is 0. Directional statistics were used to calculate these two factors [6].

The map reveals, among other things, the connection between type of regime and seasonality with regard to low water. In Alpine catchments the lowest discharge levels normally occur in the winter half-year, when precipitation is stored in the form of snow. In the Central Lowlands and the Jura Mountains low water often occurs in summer and autumn, although the time of its occurrence varies more markedly than in the Alps.

Time series from selected measuring stations

The time series graphs show the NM7Q low-flow index pattern for six stations where measurements have been taken over a long period. Three stations that have different types of regimes (see plate 5.2) and are largely free of influence are indicated on the left. The moving 20-year mean shows that the data hardly vary over a longer period and in particular show no trend. This means that the period chosen for the maps (1984–2003) can be considered as representative of a longer period. The low-pass filtered 9-year mean emphasises more clearly the short-term fluctuations in annual low-flow values [7]. The time series from three stations that have been affected to a considerable extent by reservoirs are shown on the right. In the case of the Rivers Vispa and Rhone the production of hydro-electricity has led to increased discharge in the winter half-year and thus to higher NM7Q values. As far as the Drance de Bagnes is concerned, the NM7Q has fallen as a result of water being deviated to other catchments (see plates 5.3 and 5.10).

NMxQ return periods: a comparison of two drought years (1947, 2003)

Return periods are based on the statistical calculation of probability and indicate the average frequency of a given event. The maps that make up figure 3 compare the extremely dry years of 1947 and 2003 using NM7Q, NM14Q and NM30Q indices. A dark blue segment for example signifies that the corresponding NMxQ occurs on average less frequently than every 100 years. All stations that were operating at the time and can provide a measurement series for at least 30 years are included for each of the years; data is available for both years from some stations. The meteorological conditions were similar in 1947 and 2003: in both years precipitation from January until the autumn was considerably lower than the long-term mean and the summer months were much warmer than normal. As a result of very little precipitation combined with a high level of evaporation, the runoff in the rivers and streams in the Central Lowlands and the Jura Mountains was extremely low, in particular in summer and autumn. A comparison of these two drought years reveals that the low-water situation in 1947 was more marked than in 2003 [1,5].

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