Plate 5.8 Elements Used for Determining Q_{347} Flow Rate

Introduction

For a long time low flow was not a topic of interest among hydrological researchers in Switzerland owing to the mountainous character of the country and the resulting abundance of water. Today this situation has changed, however: on the one hand, the expanding population and their needs and demands have led to an increase in the use of water, while on the other hand, there are increasing calls to use our water resources only to an extent that is environmentally acceptable. Fears associated with the threat of climatic change and the risk of more frequent extreme hydrological situations have roused serious interest in low flow and various scenarios concerning its management and protection. Furthermore, the use of the expression «Q_{347} flow rate» in the Federal Law on the Protection of Waters of 24th January 1991 has instigated a whole series of investigations of the topic at universities and in federal and cantonal offices. Q_{347} flow rate forms one of the bases for determining the appropriate residual water flow below water diversions or dams (Arts. 31–33 of the Water Protection Law).

Definition of Q_{347} flow rate

In contrast to floods, low flow can be described in terms of many characteristics. The legislative body decided to use the expression «Q_{347} flow rate», a statistically determined value which is normally published in hydrological yearbooks. Article 4 of the Water Protection Law defines Q_{347} flow rate as «the rate of flow which, averaged over ten years, is reached or exceeded on an average of 347 days per year and which is not substantially affected by damming, withdrawal or supply of water». This means that Q_{347} flow rate has to be calculated from measurements using the duration curve, which represents observations of equal statistical weight, in order of value [1] (cf. fig. 1). Q_{347} flow rate corresponds to the quantity of water which is reached or exceeded in 95 % of cases and thus not reached in only 5 % of cases. In English-speaking areas Q_{347} is known as Q95.

Temporal and spatial variability

Discharge processes are governed by the climatic and physiographical conditions of the catchment. Owing to the variations in these factors within Switzerland, the duration and degree of low flow varies from region to region. Figures 1 to 5 show these regional differences which are illustrated through the examples of the Lütschine and the Simme rivers (Alps), the River Töss (central lowlands) and the River Birs (Jura). In the Alps low flow is limited to the period between October and March. In the central lowlands and the Jura mountains it typically occurs in the summer and autumn, although it can occur in any month. Figure 2 shows this phenomenon in the long-term mean, while figure 3 gives values for one single year. The reason for this difference lies in the varying discharge processes. In the Alpine regions winter precipitation remains at the surface in the form of snow and ice, and this is when discharge is at its lowest. The degree and duration of the low flow period is governed by climatic factors such as radiation and air temperature, and physiographical factors such as gradient, aspect and altitude. Underground storage is typical of the low flow process in the central lowlands and the Jura. These reserves build up mainly in winter and spring, depending on inflow (precipitation and snow-melt). Low flow occurs when these reserves are approaching their minimum level, subject to periodic interruption by rainfall. The differences between the pattern in the central lowlands and the Jura mountains can be found in the complexity of the respective hydrogeological conditions.

The Q_{347} flow rate is subject to natural variations caused by dry and wet periods and phases of cold weather (fig. 4). These variations can be seen in annual as well as 10-year mean Q_{347} flow rates. In an Alpine catchment the maximum annual Q_{347} flow rate over a longer period of observation is at most 4 times higher than the minimum rate. In the case of 10-year mean values this factor is between 1.3 and 1.5. The averaging process thus has a considerable dampening effect. The corresponding factors for the central lowlands are significantly higher: as much as 10 for individual years and 2.5 for the 10-year means [1].

According to the definition of Q_{347} flow rate not all years carry the same weight in relation to the mean. Figure 5 shows this very clearly; again the differences between the Alps and the central lowlands and Jura in particular are very marked.

Regionalisation of the Q_{347} flow rate

Despite the dense measurement network, experience repeatedly shows that for locations where hydraulic measures are planned or for a certain river section where the residual water flow needs to be determined, precise discharge conditions are usually not known and can only be estimated. Preliminary work carried out by the Swiss National Hydrological and Geological Survey has shown that it is easier to make such estimations for the Alps, with their simple, single-peak discharge pattern with marked and annually recurring low flow periods, than for the central lowlands, the Jura and the lower areas south of the Alps, where the geological structure and climatic conditions are more complex. The results of this study for the Alpine regions were published in 1992 as a recommendation [1] and the method of estimation used is available as a software programme [2]. In 1995 the question of estimating Q_{347} flow rate for the whole of Switzerland was reviewed owing to some shortcomings and in particular because there was no procedure applicable for the central lowlands and the Jura. Not only were more data made available by the federal and cantonal measurement networks in the meantime, but the data concerning catchment characteristics had considerably improved, thanks to the introduction of Geographical Information Systems. These investigations resulted in different estimation methods depending on the region, with which it is possible to calculate the Q_{347} flow rate from climatic and physiographical characteristics [3].

Information given in the map

The map is based on a combination of information obtained from measurement sites and from points within the hydrographic network for which the Q_{347} flow rate was estimated by means of the acquired procedures. These estimation points are obtained where the network intercepts the limits of the so-called small catchments in map 1.2. The map shows both the Q_{347} flow rate at the measurement sites and the calculated values for the estimation points. The Q_{347} flow rates calculated for these points were rounded up or down according to established rules and adjusted to the available measurement stations in order to take into account the precision of the estimations and to obtain a consistent cartographic representation [3]. The measurement stations form the basis for the map. All stations for which a Q_{347} flow rate value can be calculated on the basis of values for at least three years, and where the discharge is not significantly influenced, are represented by a symbol on the map. Cantonal measurement stations are an exception and have been included for purposes of information even if their current measurement series do not cover three years but measurements will definitely be continued in the future. The main focus is on those stations for which a value can be indicated for the standard period of 1984–1993, but it was decided on the basis of various criteria [3] to include values from other stations whose series do not fall within the standard period. 1984–1993 is an ideal standard period in view of the fact that the information is up-to-date and the number of available measurement stations is high. All the measurement sites and estimation points can be related to the table using the number key. According to Article 31, paragraph 1 of the Water Protection Law, the minimum residual water flow is fixed at a constant value where Q_{347} flow rate exceeds 60 000 l/s. For this reason the larger rivers are specially depicted downstream from the point at which this condition is met.

Information given in the table

The map is accompanied by a table which is based on the elements of the map and complements them insofar as is necessary for purposes of comprehension and for more intricate estimations. The table follows the hydrographical order and, for subdivision, the water balance basins (cf. map). Within these basins easy reference can be made to the map using the consecutive numbering system. For measurement stations, the Q_{347} flow rate for the standard period 1984–1993 and/or the operational period of the station is shown, depending on data availability. It is thus possible to compare the standard period with a longer operational period. For the estimation points a flow rate is given which has been calculated using the described procedures and harmonised with the measurement stations. Data on the catchment surface can be used for spatial interpolation but is lacking where it was not possible to determine the surface owing to the geological or hydrogeological conditions. The remarks refer to important or complementary information concerning the measurement station or the catchment.

Use

The map can be used for determining residual water flow, among other things:

- The Q_{347} flow rates shown for the measurement sites can be used to determine the minimum residual water flow defined according to Art. 31, paragraph 1 of the Water Protection Law.
- The flow rates at the estimation points obtained using the procedures or interpolated values in between provide only an approximate estimation, as required for a preliminary investigation. This estimation can be refined using more intricate methods than those used to produce the map, for example involving data from measurement stations further downstream or data from measurement surveys, etc. The method which best suits each individual situation must be chosen on the basis of scientific, hydrological considerations.
- The status of other Q_{347} flow rates obtained through interpolation depends on the initial data (measured or estimated values) used.

Under certain circumstances it may be necessary to corroborate the estimated value with a short-term (at least 3 years) measurement series. The paper published by the Swiss Agency for the Environment, Forests and Landscape [4] gives details of the method used to determine Q_{347} flow rate as a basis for calculating residual water flow according to Articles 31–33 of the Water Protection Law.

References

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