Plate 6.3 Components of the Natural Water Balance 1961–1990

Introduction

The water balance describes the hydrological character of the catchments and provides an overview of available water resources. Its components are areal precipitation (P), areal runoff (R), areal evaporation (E) and change in water storage (δS). Under particular hydrogeological conditions, in particular in karst areas, natural underground inflow and outflow (I) must also be taken into account. The equation for the water balance is therefore:

$$P = R + E + \delta S - I$$

The water balance is directly linked to climatic conditions. For example, there is a close correlation between evaporation and decrease in temperature or net radiation with increasing altitude (cf. plate 4.2).

A spatially differentiated approach to the water balance, which is the aim of this plate, makes it possible to carry out a detailed analysis of water resources in Switzerland. In earlier studies on the water balance of selected catchments [e.g. 1,3] major inaccuracies were observed in drawing up the balance, with the result that it did not appear to be possible to carry out a detailed, small-scale analysis of the water balance for the whole of Switzerland. For the present study, large river basins whose water balance is examined in detail in plate 6.1 were divided into medium-scale catchments and initial analyses of runoff were carried out (plate 5.4). These analyses served as a starting point for determining the water balance for the 287 medium-scale catchments. The period covered by the study was the standard 1961–1990 period used by the World Meteorological Organisation (WMO), and the corresponding mean values for this period were used.

In Switzerland precipitation and runoff are recorded in relatively dense networks, such networks being in general less dense in the Alps. This results in marked differences in the accuracy of figures for the water balance components, especially in catchments in the Alps. As far as evaporation is concerned, for which no information was available so far for the whole of Switzerland, excellent data has now been provided by [4] (plate 4.1). On the basis of individual, representative glaciers for which annual figures for changes in mass are available [5] assertions can be made concerning change in water storage in glaciated basins. Overall, therefore, information can be obtained on water balance components for all the medium-scale catchments, although of varying quality, which is very important for the explanations given below. In many areas the collation of this information on water balance gives results which are not plausible. For example, in Alpine catchments the difference between precipitation and runoff, taking into account change in water storage, often gives a figure for evaporation which cannot be explained physically. As the analyses showed, in most cases these problems are caused by imprecision with regard to areal precipitation which can be explained by difficulties in measuring, as well as spatial interpolation and extrapolation. In view of these uncertainties, [2] recommended as early as 1985 that precipitation in mountain areas should be seen as the remaining element in the water balance, i.e. in concrete terms, that precipitation should be calculated on the basis of runoff, evaporation and change in water storage, instead of using explicit precipitation measurements. This method was used for the present plate and additional steps were incorporated that allow precipitation values obtained in this way to be checked in the context of regional water balances, and corrected if necessary.

Methods

The precipitation of the medium-scale catchments is calculated from runoff, evaporation and change in water storage by glaciers on the basis of the conditions indicated above. For the sake of precision, inaccuracies in runoff data must be given careful consideration, since in most parts of Switzerland runoff represents the larger part of the precipitation calculated (cf. runoff coefficient map). Evaporation figures are much lower than those for precipitation and runoff; this means that inaccurate evaporation figures have only a minor effect on errors in calculating precipitation. Although the relative errors in estimating changes in mass balance of glaciers are comparatively large, in absolute terms they have little influence on the accuracy of areal precipitation figures.

In view of these errors, data for the medium-scale catchments must fulfil certain requirements. In particular the plausibility tests for runoff data shown in plate 5.4 are used in this connection. In catchments where the runoff data is reliable the water balance is calculated directly and used as it stands for further analyses. In other catchments the water balance can only be determined approximately, owing to the unreliability of runoff data. For this reason a regional adjustment is made wherever possible, which necessitates larger basins which encompass several medium-scale catchments and for which reliable runoff data is available. In all, 17 such larger basins can be used. In a number of regions along the national borders there are no larger basins, so that it is not possbile to make regional adjustments. There are thus two methods for calculating the water balance:

1) Water balance calculations with a regional adjustment: In the medium-scale catchments with plausible runoff data all water balance components, i.e. including areal precipitation, are incorporated as they stand (plausibility level of the water balance = 1; see map of precipitation in the medium-scale catchments). Elsewhere areal precipitation is estimated on the basis of regional hydrological considerations or models (plausibility level 2 or 3, depending on available data). The sum of the areal precipitation figures for all medium-scale catchments must correspond to the areal precipitation figure for the larger basin. Any difference is compensated for only with respect to areal precipitation in catchments with a plausibility level of 2 or 3. Runoff must subsequently be calculated using the water balance in these catchments.

2) Water balance calculations with no regional adjustment: The procedure here is the same as for 1); in this case, however, a regional adjustment is not possible. In other words, estimated water balance figures must be used as they stand, since they cannot be verified on a regional level. For this reason the plausibility of the water balance cannot be estimated (plausibility level 4).

A plausibility level of 1 can be attributed to 57 % of all medium-scale catchments while 16 % have a level of 2 and 9 % a level of 3. The plausibility level of 18 % of the medium-scale catchments is unknown (level 4). All in all, we have a closed system as it were for deducing water balances which is based on plausible data and produces regionally coordinated water balances.

Results

The four maps show the components of the water balance and the runoff coefficient for all the medium-scale catchments. Those on the northern slopes of the Alps between the Grimsel Pass area and the Säntis, as well as in the western Tessin, have the greatest precipitation. This spatial distribution pattern is even more marked in relation to runoff, since loss through evaporation is relatively low in these high areas. The runoff data provided here represents natural flow. Corrections have been made to allow for the influence of hydroelectric power stations (see plate 5.3).

Apart from this basic information on water balances, the individual maps provide further information: the precipitation map also contains indications of the plausibility of the water balance (cf. Methods). The runoff map also shows the degree of change in mass balance in glaciated catchments. With the exception of the Aletsch Glacier (catchment 50-050), which is very slow to react to changes in climatic conditions owing to its size (cf. plate 3.7), the mass balance of all glaciers for the period 1961–1990 is negative. Furthermore, it can be seen from the runoff map that there are underground drainage systems which are vast in the areas around the Walensee and Lake Thun.

The runoff coefficient shown on the fourth map indicates the long-term mean proportion of precipitation which is included in runoff. In the eastern part of the Bernese Oberland and in the upper reaches of the Reuss catchment, as well as in other scattered parts of the Alps, as much as 90 % of precipitation becomes runoff. This confirms very clearly that these areas make a major contribution towards Switzerland's role as the «water tower» of Europe. Runoff coefficients are lower in the medium-scale catchments of the eastern and western parts of the Central Lowlands and north-western Switzerland, where evaporation is high while precipitation is low.

The water balances for the medium-scale catchments have been aggregated to form new spatial units in that water balances for selected larger catchments and for cantons as well as for the whole of Switzerland are presented and compared. This makes it possible, for example, to quantify the contribution of one canton towards Switzerland's role as a «water tower». Some concrete examples are given below by way of explanation.

The long-term mean volume of water flowing from the upper reaches of the River Rhone into Lake Geneva is 5645 million m^3 per year (map, point 50-5). This corresponds to a mean runoff of 179 m^3/s (table 1). The upper reaches of the Rhone therefore contribute 52.6 % of the 10 732 million m^3 of water which the Rhone transports across the border into France each year (point 50-6, map, table 1). If one considers only those parts of the catchment in the upper Rhone valley which are within Swiss territory, it can be seen that they have an annual runoff volume of 5575 million m^3 (table 1). This corresponds to a mean of 13.6 % of the total runoff originating in Switzerland.

Similar statements can be made concerning the cantons. For example the canton of St. Gallen contributes 1519 million m^3 of water to the River Rhine each year above the confluence of the River Aare while a further 823 million m^3 of water flows into the River Limmat (see map). Table 2 gives more details on these figures. Overall, the canton of St. Gallen produces 2342 million m^3 of water per year, which represents 8.8 % of the total discharge of the River Rhine at Basle and 5.7 % of the total discharge of all rivers flowing out of Switzerland. As figure 1 shows, precipitation, runoff and, interestingly, evaporation are slightly higher than one would expect in view of the area of the canton of St. Gallen in relation to Switzerland as a whole.

Table 1 also shows the water balances for certain river basins as well as Switzerland as a whole. Despite the different methods used, with a figure of 1458 mm for precipitation, 991 mm for runoff and 469 mm for evaporation there are only slight deviations in comparison with plate 6.1, which describes the water balance for Switzerland for the period 1961–1980 (P: 1481 mm; R: 961 mm; E: 513 mm).

References

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