Plate 6.1 Water Balance of River Basins

Introduction

The water balance of a catchment is composed of the elements precipitation (P), runoff (R), evaporation (E), and storage changes (δS). Whereas all other variables are based on measurements, evaporation must be determined by means of the following equation: $E = P - R \pm \delta S$. As neither quantities of storage changes in soil and groundwater nor the snow cover are available, reliable calculations of evaporation can only be made for periods of several years.

For the larger catchments (river basins) of Switzerland, all components of the water balance were calculated on a monthly basis for the period 1901–1984 [1]. To permit comparisons with other maps, all the average values refer to the period 1961–1980. By means of the time-series, these average values can be assigned to the fluctuations occurring within the first eighty years of the 20th century.

Basin water balance

The maps depicting areal precipitation and runoff as well as evaporation give an overview of the regional distribution of the individual values compared to the Swiss average value. The climatic differences between the river basins can easily be distinguished.

The map on storage changes represents absolute values. The cause of the increase in storage is mainly due to the years with a positive glacier mass balance between 1965 and 1980, and also, to a small extent, to the filling of newly-constructed reservoirs. The time-series in figures 10 to 12, however, reveal that the average storage change in the years 1961–1980 of +7.5 mm/a is not representative for the 80-year period of 1901–1980 (–6 mm/a).

Table 1 includes all the basins depicted on the maps. The yearly mean values of the water balance components are indicated in millimeters per year (mm/a). The numeration facilitates identification of the basins on all the maps and illustrations.

The water balance of Switzerland (fig. 13) shows the average water circulation, indicated in millimeters of water depth per year. One millimeter of water per year over the area of Switzerland is equivalent to 41.3 million m^3 per year, or 1.31 m^3/s.

The amount of 415 m^3/s of water flows into Switzerland through various surface waters, flowing out again via the larger rivers. In 1980, the available water supply held back in the natural and artificial lakes, and in the snow and ice, corresponds to approximately 3.5 times the annual precipitation.

Temporal variability

Figures 1 to 9 present time-series of yearly values from 1905 to 1980 for a selection of basins. The curves represent 9-year moving averages calculated by means of a Gauss low-pass filter. To show the variability of the individual years, the deviations between the observed yearly values and the smoothed curve are illustrated in columns.

In the course of time, large differences are revealed in the precipitation series and, parallel to them, in the discharge series. Extremely dry years can follow immediately extremely wet ones (1920/21). Fluctuations recurring every 6 to 11 years, (on average 9), can be seen for the entire observation period. In the south of Switzerland, where the greatest depths of precipitation and discharge are observed, the fluctuations are particularly pronounced. Besides these periodic fluctuations, the dry period of the 1940s is most evident: due to a shortage of precipitation, the discharge values were very low all over Switzerland. In mountainous basins (Rhône, Inn), however, the precipitation deficit in the discharge was compensated by increased melt water.

On the whole, the amounts of precipitation have hardly changed. A tendency toward lower discharge values, however, is apparent. The cause of the general decrease in discharge is an increase in evaporation. In years not marked by extremely dry conditions, evaporation is directly dependent on air temperature. The tendency observed in evaporation can be explained by the general increase in temperature.

For the Ticino, the lower level of discharge in the second part of the observation period is particularly significant. Here, the smaller amount of precipitation is the cause.

The yearly fluctuations of evaporation appear to be very important. This is, however, due merely to methodical errors, which cancel out over several years. The cause can be found in the varying amounts of water stored in the soil, the groundwater and the snow cover at the beginning of each hydrological year. At the beginning of the century, more evident errors made in discharge measurement and in the estimation of changes in water storage were converted into more evident errors in the determination of evaporation.

Storages of different kinds are filled up and emptied again in the course of a year: natural and artifical lakes, groundwater, soil water, snow cover. These storage changes mostly even out in the course of several years. Glaciers, on the other hand, just as important in storing water, only change very slowly over many years. Thus it is essential to give these changes due consideration when determining long-term water balances. As the water level of artificial reservoirs is at the peak at the beginning of the hydrological year, only slight storage changes occur from one year to the next. With the first damming up of the lakes, however, the retained water has to be considered as a storage change.

Figures 10 to 12 contain cumulative curves of storage changes for three selected basins for the period 1901–1980. The total storage change between two points of time can be determined from them accordingly.

These representations emphasise the great importance of the glaciers as a storage unit. Interrupted by only short periods, the glaciers have melted considerably with a loss of about 25 % of their initial volume between 1901 and 1980 for the whole of Switzerland. The increase in the number of reservoirs in the Canton of Valais in the 1950s becomes equally apparent.

The calculation of the water balance in [1] which depicts the seasonal fluctuations of the water balance components, was based on the period of one month. While measurements of precipitation, runoff and storage changes in the natural and artificial lakes are available, the distribution of the annual evaporation had to be derived from empirical values of literature. This allowed the estimation of monthly values of both the storage and the loss of snow, ice, soil- and groundwater.

For four basins, the average monthly fluctuations (regimes) are shown in figures 14 to 17. On the left, the input and negative storage changes (losses) of water in the basin are represented by bars. Similarly, on the right, the corresponding output values and positive storage changes are shown, thus portraying the water balance in a given basin.

Precipitation is the only source of input in a catchment. Losses, on the other hand, include the outflow of water from the reservoirs in winter, the melting of snow and ice in summer, the depletion of soil- and groundwater during the vegetation period, and the lowering of the water level in natural lakes.

Runoff and evaporation are the basin output quantities. The positive storage includes the increase of water in the form of snow and ice, of soil- and groundwater in winter, as well as the damming up of water in artificial and natural lakes.

The differences in the seasonal distribution of storage changes and discharge between alpine basins and the lower catchment of the Birs are evident. The significance of artificial lakes in the region of the Rhône retaining water from summer into winter can be seen as well (fig. 16). This transfer is only possible due to snow melt in summer. The runoff decreases in summer and increases in winter by these amounts.

References

[1] **Schädler, B. (1985):** Der Wasserhaushalt der Schweiz. Mitteilung der Landeshydrologie und -geologie, Nr. 6, Bern.