5.7 Major Floods – Differing Reactions of Catchments

Introduction

Catchments react very differently to intense rainfall. This is mainly due to the specific storage capacity of different parts of the catchments. Runoff following intense rainfall will be generated more quickly for surfaces with a low storage capacity than for those with a high storage capacity. A catchment can be divided into areas of varying reaction (rapid, slightly delayed, delayed, much delayed) on the basis of geological and soil maps as well as the results of investigations in the field. The way in which a catchment reacts to intense rainfall of different types can be deduced from the relative size and spatial distribution of these areas. Experience gained from sprinkling tests [1,4] is an important basis for assessing the transformation of rainfall into runoff from catchments (cf. fig. 1). With this knowledge it is possible to provide a better explanation for the formation and extent of floods.

The present map focuses on six catchments with areas of between 0.9 km^2 and 195 km^2 which illustrate the different reaction patterns. Representative precipitation and discharge measurement series are available for these catchments. For each case study there are two features provided: firstly, a map showing the catchment and its division into areas with different reactions, and secondly a diagram indicating the most important flood observed in that catchment. The precipitation data were obtained from a local or adjacent ANETZ station (cf. map 2.1), while the discharge figures were provided by stations run by the Swiss National Hydrological and Geological Survey and the canton of Aargau (cf. map 5.1). The additional illustrations show a particular feature of the catchment in question.

The Hinterrhein

Major floods occur in the Alpine catchment of the Hinterrhein only after at least 60 mm of rainfall. Hydrographs for major occurrences are characterised by a slow build up of runoff followed by short, intense peak flows once the soil becomes wetter, these peaks reflecting the rainfall pattern.

The catchment is made up of gneiss and granites, with Triassic sedimentary rocks and Jurassic calcschists in the east. These rocks are partly overlain by moraines, debris and boulders at the foot of rock faces and alluvial deposits on the valley floor (Quaternary). The thickness of the soils is mostly limited, lithosols and podzols being dominant. Runoff is rapid or only slightly delayed in the areas of gneiss and granite, which have very little soil cover or none at all. The areas of debris and alluvial deposits, as well as those with a thicker soil cover, demonstrate delayed or even much delayed runoff, these areas being of little importance vis-à-vis floods.

As can be seen from the small-scale map, there is a significant difference in the greatest specific discharge rates in various subcatchments of the Alpine Rhine; that of the Hinterrhein is quite distinctive from those of most of the other subcatchments.

The Aach

The Aach catchment is mainly made up of areas with a delayed contribution to the runoff. Major floods therefore occur only after longer periods of rainfall and the corresponding hydrographs show a pattern of gradual increase, low peak discharge rates and moderate volumes.

In most of this catchment, Würmian moraines overlie the Upper Freshwater Molasse marls and sandstones. The thickness of the moraine cover (ground moraine and in a few cases push moraines) varies from 60 m in the southern part of the catchment to only a few meters in the north. These moraines are on the whole almost impermeable, and pseudogleyed brown soils and luvisols with a thickness of between 30 and 50 cm are consequently most common. There are alluvial deposits in the floor of the Aach valley, with some moorland or very wet areas in the west. Large-scale drainage systems with underground drainage pipes have been laid to improve agricultural productivity (cf. sketch map). Rain penetrates the soil and gradually seeps through it into the drainage system. Overland flow occurs only in built-up areas.

The Saltina

In the Saltina catchment, the areas which react rapidly to intense rainfall are to be found throughout the area. Short, localised rainstorms are therefore not sufficiently uniform or strong enough to result in flooding. Long periods of heavy rainfall are necessary for the Saltina to flood, in which case the areas that react slowly also contribute to runoff. A decisive factor in this connection is that the 0 °C isotherm lies at a very high altitude and precipitation consequently falls everywhere in the form of rain.

From a geological point of view, a distinction can be made in this catchment between the zone of sedimentary rocks and that of crystalline rocks which are both partly overlain by Quaternary deposits. The sedimentary rocks include calcareous micaschist, argillaceous slate and dolomite and calcite marble, while the crystalline areas are made up of mica-containing gneiss and micaschist. The physical weathering of the rocks results in sandy detritus that is porous and has a high storage capacity. The Quaternary geology of the catchment is dominated by massive moraines of various ages, as well as by boulders and debris at the foot of the rock-faces. Springs are a feature of the movement of the underground water. The thickness of the soil cover decreases the steeper the gradient; the flatter, south-facing zones have as much as 1 m while the steep slopes have no more than 50 cm of soil.

The difference in discharge reaction can be illustrated by the ratio of discharge to total precipitation (cf. figure). In the Saltina catchment, following intense rainfall of for example 200 mm, the discharge represents around 90 % of the total precipitation in rapidly reacting areas but only approximately 5 % in the slowly reacting areas.

The Suze

In the Suze catchment major floods are caused by the combined effects of longer rainfall with snow-melt and a frozen surface [2]. The flood hydrograph is characterised by a very slow increase in discharge, a small peak and a large volume.

This catchment is located in a syncline in the Folded Jura. The youngest strata – Tertiary marl and sandstones – are to be found in the valley floor and are partly covered by argillaceous ground moraines. Karstic limestone makes up the northern and southern flanks of the valley. The valley floor contains brown soils and gley, while the slopes include brown soils and calcareous lithosols (rendzina). The latter are particularly permeable, allowing the water to penetrate into the karstic sub-soil (cf. figure) and generally causing a long delay in discharge. The zones with a rapid or only slightly delayed reaction include built-up areas and the argillaceous ground moraines in the valley floor, where overland flow is dominant. Since by far the larger part of the soils in this catchment are highly permeable, major floods occur only when frost restricts this permeability.

The Allenbach

Major floods occur in the Allenbach catchment following summer rainstorms, the floods being of short duration and with extreme peak levels. After longer periods of rain the discharge peaks are less marked.

The sub-soil of this catchment is made up of argillaceous flysch, limestone and post-glacial local moraine. In the flysch series of the very steep southern flanks there is only lithosol, if any at all. Thick gleyed detritus can be found on the northern flanks, which lie parallel to the incline of the flysch strata. These slopes are often unstable and liable to landslides. Owing to its low storage capacity, the steep rocky and lithosol areas (cf. photo) reacts immediately to short bursts of intense rainfall. These areas are usually adjacent and connected to the channel network and can be affected by a localised rainstorm, resulting in a rapid runoff response. The partly argillaceous moraine deposits and the gleyed detritus play a far smaller role in generating floods, while the areas with thick detritus and debris deposits hardly react at all.

The Brunngraben

The short measurement series (1981–1990) provided by the cantonal measuring station at the Brunngraben near Zofingen shows that major floods occur in this area after brief rainstorms. As with the Allenbach, this catchment reacts immediately to summer storms which result in short discharge build-up. The peak discharge rates, however, are not very marked; floods are normally of short duration. Flooding may also occur in winter following precipitation combined with snow-melt or after longer periods of precipitation. Peak discharge rates are not comparable with summer occurrences, however.

In this small (0.86 km^2) forested catchment the substrata are made up of Upper Marine Molasse sandstones which are fine to rough-grained, fissured, porous and act as good water retainers. The sandstone is overlain mostly by a sandy weathered layer up to 50 cm deep (cf. map 8.4, Lenzburg example), above which are sandy, slightly silty brown soils and luvisols. The steep slopes on either side of the channel have an unstable, thin soil cover (cf. photo). It is only these small steep areas which contribute to floods after short, intense rainfall. The decisive discharge processes are overland flow as well as subsurface flow through highly porous layers of soil above the rock. The infiltration capacity of the remaining areas with a thick, sandy soil cover is not exhausted even with intense rainfall.

Sprinkling tests

The extent of flood discharge in catchments is mainly the result of the combined effects of areas with differing runoff processes and a varying water retention capacity. In this connection, intensive artificial rainfall of between 50 and 110 mm/h, which corresponds to an extreme event rarely experienced in reality, was created by a sprinkler system over a surface of 60 m^2. The runoff process (infiltration, overland and subsurface flow) was studied in 18 hillside locations in Switzerland (cf. overview map) [1,3,4]. Overland and subsurface flow was measured, and in addition gauges were used to determine the wetting and drainage processes in the soil. The map includes four hillside locations which show important differences in the processes observed and water retention capacity.

References

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