A Impact of Climate Change on Flood Protection in Switzerland

A Position Paper of the Commission for Flood Protection of the Swiss Water Resources Society (KOHS)

KOHS

Summary

To date the effect of climate change on future flood events in Switzerland can only be defined in terms of trends. Experts anticipate that more floods will occur and that extreme values will increase. Current flood control principles appear to be far-sighted with regard to the expected impacts of climate change. Therefore they remain valid and have to be implemented consistently.
The protection effect of existing measures has to be periodically checked. The potential for damage has to be evaluated and improvements are to be made if necessary.
For the evaluation of existing and for the planning of new protection measures, their performance with regard to overloading has to be established. If not already done, new projects need to be tested for overloading.
The design parameters (discharge, flotsam, bed load) must be defined with foresight in the upper spectrum.
Decision makers and other involved parties have to be informed on any need for action.
The necessary funds must be made available.

1. Introduction

KOHS is an expert commission of the Swiss Water Resources Society on matters of flood control. The members comprise experts of the Federation, the cantons, the universities, and consulting practice.

With this policy document, KOHS defines its position on the current problem «Climate Change and Flood Control».

It defines how, in the opinion of KOHS, climate change has to be taken into account for flood protection and which measures have to be taken for future flood protection projects.

This document summarizes what is known today on climate change and its impact on the rainfall-runoff behavior and it suggests approaches for use in practice. It is the result of a KOHS-workshop held on November 13 and 14, 2006, where some 15 specialists in various fields of meteorology, hydrology, hydraulic engineering, and flood control participated.

The past three decades have been characterized by many flood events leading to considerable damage. During the same period, population density and infrastructure investment alongside water bodies increased significantly.

Flood damage is a result of water inundation, erosion, sedimentation, debris flow, and the blockage of narrow passages (e.g. bridges and closed conduits) with flotsam.

To provide effective flood protection, it is important to know how such processes are influenced by climate change. The question arises, whether existing flood control principles are sufficient with regard to climate change or whether they require adjustment.

2. Principles of Flood Control

Flood control should be sustainable. The objective is the protection of human lives and valuable investments, as well as the conservation of natural resources at an economically justifiable expense. Dealing with floods relies on answering the following questions:

- What could happen?
- What is allowed to happen?
- How can we protect ourselves?
- How can residual risks be minimized?

2.1 What could happen?

The basis for the assessment of hazards is, amongst other indicators, the documentation and evaluation of past events. The hazard map indicates areas that are susceptible to natural hazards and the extent of the threat. It serves as the foundation for further risk analyses.

2.2 What is allowed to happen?

This question is answered with the aid of risk assessments taking into consideration socio-political, ecological and economical aspects.

2.3 How can we protect ourselves?

Dealing with natural hazards necessitates an integrative risk management. A wide range of measures is available. These involve urban and rural planning measures to avoid areas at risk, appropriate maintenance of water bodies, physical protection measures, alerting and evacuation as well as insurance.

The objective of protection measures is to cater for an event of a certain magnitude, the design event, without damage.

Hence, protection design is based on design parameters such as flood discharge, for example. These parameters can be determined by statistical evaluation of past observations. One of the main problems is that most record lengths are too short. Consequently, the reliability of predictions for extreme events is limited. Floods are always accompanied by erosion, sediment transport, and flotsam. These processes occur in numerous and sometimes arbitrary combinations. The precedent conditions of an event also have a relevant impact. For example, the saturation of soil due to antecedent precipitation has a significant influence on flood generation. The planning of flood control measures can only account for this variability of natural processes to a limited extent. Thus, only a representative selection of process combinations – so called scenarios – is used.

2.4 How can residual risks be minimized?

Full protection against floods is not possible. Extreme events can lead to the overloading of measures that were designed for a specific protection level. The associated residual risk has to be recognized and minimized with adequate provisions. Alerting and evacuation, individual object protection as well as insurance coverage are the main elements available to handle residual risk.

Physical flood protection measures have to be robust and resistant to overloading. Thereby it is ensured that they do not suddenly fail and that a sudden increase in damage does not occur. Their behavior with regard to overloading is evaluated during the design phase. Additionally, the delineation of areas that are affected in the event of overloading serves as the basis for the assessment of the residual risks.

3. Fundamentals and Facts about Climate Change and Extreme Flood Events

The predictions on the possible hydrologic consequences of climate change in Switzerland within the next 50 years, in particular concerning the development of floods, are based on the assessment of experts who rely on the current understanding of this phenomenon. A detailed description of these assessments can be found in the appendix to this document.

Figure 1. The river Töss in flood.

3.1 Discharge Regime

The annual precipitation volumes will decrease by approximately 7%. In summer a decrease is expected, while in the winter months an increase of precipitation is expected. Since evaporation will also increase, the average annual runoff volumes may decrease by about 10%. Snow melt will start earlier and it will be less in low lying areas due to the expected rise in snow line elevation. Low flows in summer and autumn will be more pronounced.

3.2 Floods

Regions below 1500 m a.m.s.l. Due to saturated soils (increase in precipitation) and higher rainfall intensities, greater flood peaks are anticipated in winter. Despite warming, occasional snow covering can be expected for the low-lying midlands of Switzerland resulting in some combined melting/rainfall events. The impact of snowmelt increases with increasing catchment elevations. These events can be expected to extend into spring. At these elevations, the annual floods already occur in winter or spring. An increase in peak flow can therefore be expected.

In summer, reduced floods will occur at lower altitudes because here discharge formation is significantly reduced due to less precipitation and more evaporation. However, the occurrence of thunderstorms (convective precipitation cells) can always lead to regional floods mostly in small catchment areas.

Regions in the northern Alps above 1500 m a.m.s.l. Discharge increases in winter because of occasional rainfall. In spring there are occasional snowmelt flood events. The peak flows are higher than today. As in the present, the annual maximum floods will occur in summer and will probably not be greater in magnitude. No significant changes are expected in autumn. The central alpine regions (Wallis, Engadin) that are subject to rainfall spilling over from the south, behave in a similar fashion to the regions south of the Alps.

Regions south of the Alps. South of the Alps the regions are not subdivided by elevation due to a lack of differentiation possibilities. In winter and spring floods will increase as a result of increased precipitation volumes and intensities. In summer lower peak flows are expected, due to a decrease in precipitation amounts. Autumn will remain decisive for the annual flood peaks with a tendency to increase.

3.3 Sediment Transport

The volumes of sediments susceptible to erosion will increase considerably at high altitudes in the Alps. The main reasons are glacier melting and the thawing of permafrost at altitudes between ca. 2300 and 2800 m a.m.s.l. Since more precipitation will fall in form of rain instead of snow, and due to greater precipitation intensities sediment transport will increase.

3.4 Landslides

In the pre-Alpine regions the amount and the intensity of rainfall will increase in winter, whereas snow coverage will decrease. The soils in these regions will be saturated over longer periods of time during winter and spring. With intensified rainfall the hazard of landslides and debris flow rises. As a result, the sediment load of the watercourses will increase.

Figure 2. The fire brigade of Wetzikon in action.

Figure 3. Flood of Zurich at the Seefeldstrasse in 1878.

4. Evaluation of the Current Flood Protection Strategy with Regard to the Consequences of Climate Change

Based on the foregoing assessments, it can be assumed that the frequency and magnitude of flood events in Switzerland will change. Greater regional and seasonal differences are expected. In general, an increase of the flood volumes and peaks is expected in the winter period. Overall there will be an increase in sediment transport. Seasonal increased flood discharge and larger total sediment loads require adequate cross-section and deposition zone areas. This leads to the conclusion watercourses will need more space than they do at present.

Currently, Switzerland lacks a reliable basis to quantitatively take climate change into account for the determination of design parameters for flood protection measures. Flood control principles that are valid today display considerable flexibility even though they are not geared towards climate change. They allow response to change by considering appropriate scenarios. As a result of this qualitative approach, great importance is attached to the consideration of overload scenarios that significantly exceed the design levels.

The principles outlined by the federation and the cantons are future oriented, but have as yet been implemented in only a few cases. The flood event in August 2005 demonstrated that where projects were realized in accordance to modern flood control principles, greater damage could be prevented.

There is a great need for action, because many of the existing protection measures do not satisfy the increased requirements. They do not cater for overload conditions and adapting them to the increased flood hazard and other changing requirements means large costs in time and effort. Further shortfalls will become apparent when the as yet outstanding hazard maps are completed.

Flood protection is a continuous task because the implementation of the current flood protection strategy requires appropriate time and resources.

5. KOHS Recommendations

Sustainable flood protection requires the consistent implementation of an integral risk management approach.

- For the planning of measures, the consequences of climate change have to be factored in by means of appropriate scenarios.
- The worst case scenarios have to be considered in order to determine the space requirements for a watercourse, this space must be made available.
- Physical protection measures have to be planned in a way that they can be adapted with a justifiable effort. They have to be robust and cater for overload.
- The overload case has greater significance in relation to climate change.
- Residual risks cannot be avoided completely but they can be minimized by adopting secondary measures (individual flood protection) and with organizational planning (emergency plan and emergency concept).

It is of the utmost significance to acquire more knowledge and reduce the unknowns – a comprehensive understanding of the fundamentals is an important prerequisite to adequately dealing with natural hazards.

- To quantify the hydrological consequences of current climate scenarios, models with a high time and space discretisation of water balance and discharge formation are needed. Consequently, a denser network of hydrometric stations is required.
- Scenario based design requires a profound knowledge of the processes involved and of the behavior of the measures proposed. A thorough analysis of past events is a prerequisite to furthering our understanding and to reducing uncertainties.

The general public has to be sensitized to flood hazards in order to be able to recognize their personal responsibilities.

- Simple adaptations to buildings and infrastructure can reduce damage in an extreme event. The appropriate knowledge has to be communicated to owners, architects, and planners through public channels and education.
- Insurance institutions should play a role and promote individual responsibility through information programs and adoption of premium policies.

The funds available for flood protection are limited. The protection measures that are already necessary today cannot be implemented simultaneously. Where flood control projects cannot be realized immediately, risks can often be significantly reduced with other inexpensive measures from the other domains of integrative risk management, such as urban and rural planning, individual object protection, or emergency planning.

6. Closing Remark

The immediate and enduring reduction of the causes of climate change is a major task and obligation of society. Flood control measures only mitigate the individual symptoms of climate change.

Climate Fundamentals

Bruno Schädler, Christoph Frei, Dietmar Grebner, Hans Peter Willi

1. Climate and Extreme Precipitation

1.1 Basics

The scenarios that are described here are based on extensive simulations with global and regional climate models of the European climate research projects (PRUDENCE: Christensen et al., 2007; STARDEX: Goodess, 2003), and their specific assessment for the alpine region (Frei, 2006, Frei et al., 2006, Schmidli et al., 2007). The scenarios reflect current understanding (as per beginning of 2007). The consideration of various assessments on future greenhouse gas emissions enables the quantitative description of the uncertainties involved. The scenarios depict changes up to the middle of the 21st century (2050) in comparison to the end of the 20th century (1990).

1.2 Mean Climate Change

Temperature: Currently the temperature in Switzerland is expected to increase by 1 to 3,5°C. There is little seasonal difference in this change and regional warming differences are smaller than the assessable magnitude of uncertainty *(Figure 1)*.

Snow Line and Permafrost Boundary: As a result of warming, there is a shift in the vertical temperature structure in the atmosphere. Consequently, the snow line and the permafrost boundary are expected to rise by 150 to 600 m.

Precipitation: In contrast to temperature, the average yearly precipitation distribution changes considerably. In winter (Decembe–February), precipitation increases by 0–20% and in summer (June–August) it decreases by 5–30%. The changes in spring and autumn lie in between these values. The shift to drier summers dominates the change in yearly precipitation, for which a decrease of 5–10% is estimated *(Figure 1)*.

1.3 Change in Extreme Precipitation

The evaluation of climate simulations enables the precipitation extremes for return periods of between 5 and 50 years to be quantified. Only small differences for the extremes with a duration of between 1 and 5 days are discernable. Seasonal and regional changes are as follows:

Autumn, Winter, Spring: In Autumn extreme values are expected to increase by 10% in the northern alpine regions and by 20% in the southern alpine regions. In winter and spring an increase between 0 and 20% is expected for both regions. Under the most unfavourable conditions, a 100-year event of today could in the future become a 20-year event (Frei et al. 2006). In winter and spring the precipitation volumes are expected to increase as a result of greater extremes and longer durations.

Summer: Because of highly variable results and the uncertainty of the model simulations, no predictions can be made for summer. At most, a tendency towards an increase in the northern Alps and a decrease in the southern Alps is indicated.

1.4 Comparison with Observed Changes

The future scenarios display qualitative consistency with the observed climate changes in the alpine region during the 20th century, i.e. an increase of the average temperature, of winter precipitation, and of the frequency of intense precipitation.

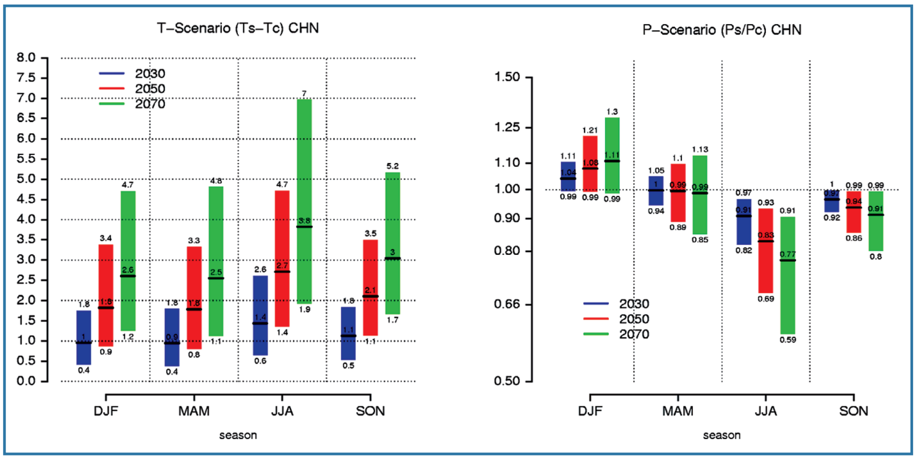

Fig. 1. Changes of the average temperature (left, in degrees Celsius) and of the mean precipitation (right, relationship future/present) for the four seasons in northern Switzerland. The bars illustrate the uncertainties and the lines show the best estimate of the changes. The changes are shown for the periods 2020–2040 (blue), 2040–2060 (red), 2060–2080 (green) compared to 1980–2000. (according to Frei, 2006).

2. Hydrology

2.1 Fundamentals

The statements on the hydrological consequences, in particular with regard to the development of floods, are based on qualitative evaluations of the current know-how. They require quantification in the future.

The average development is indicated in the following assessment. The extreme individual case cannot be estimated as yet, due to the absence of fundamental information. This includes the future precipitation distribution in events and episodes, and the development of antecedent precipitation, the soil water content, of the groundwater levels, and the behaviour of the snow cover (build-up and melting) as well as combinations of these effects (BWG, 2000; and Figure 2). Increased precipitation intensities alone do not automatically imply increased peak flow (BWG, 2000). Furthermore, complex processes in the drainage basins, e.g. the effect of lakes and their regulation, are difficult to assess.

2.2 Mean Change in Discharge

Discharge regime: The regimes change by 1–2 classes towards nival and pluvial. Model calculations by Horton et al. (2006) support this prediction. Snow melt begins earlier and is of lesser importance in the middle and lower altitudes. Low water flows in summer and autumn will be more pronounced.

Discharge Volume: The annual precipitation volumes decrease by about 5 to 10%. Since evaporation increases however, the average annual discharge volumes will probably decrease by 7 to 12%. The contribution of melt water from the glaciers, amounting to less than 1% of the total discharge in large river catchments, is comparatively small and cannot even temporarily compensate this decrease.

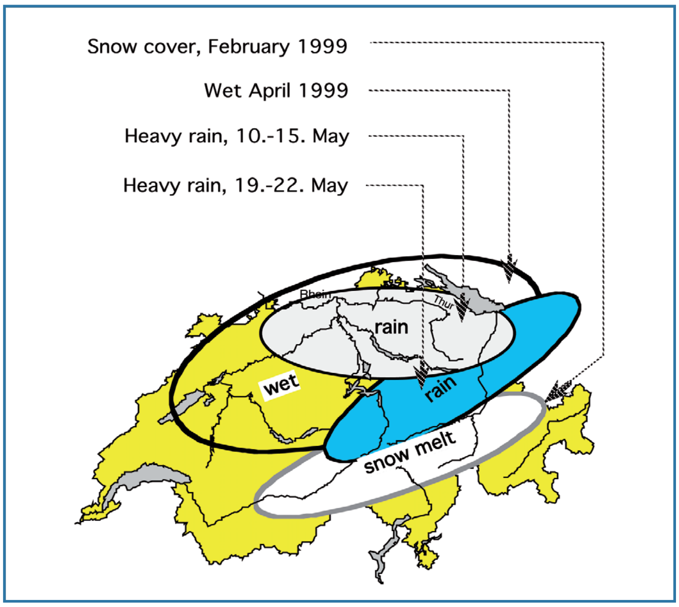

Fig. 2. Scheme of the chronological sequence and spatial distribution of the discharge contributions during the flood period in May and June 1999. Large ellipse: flood area. (Grebner and Gurtz, 2003).

2.3 Flood Changes

Predictions on flood changes need to be differentiated by season, by region and also in relation to the size of the catchment.

Floods in northern alpine regions below 1500 m a.m.s.l.: In winter increased flood peaks are expected due to higher soil water contents and to increased precipitation. Despite warming, snow cover and consequently combined melting/rain events will remain possible in the midland regions of Switzerland (BWG 2000). The influence of snow melt events increases with the elevation of the drainage basins in the altitude levels considered as hitherto. In these regions, the maximum yearly floods currently occur in winter and spring. In the future, they will still occur in spring, but in higher altitudes in accordance to the changed climate.

Flood flows will be reduced in summer, especially in the lower regions, due to decreased discharge formation potential of the soils resulting from less precipitation and increased evaporation. However, it has to be considered that in summer extreme convective precipitation (thunderstorms) can always occur leading to floods mainly in small drainage basins.

Floods in the northern and central alpine regions above 1500 m a.m.s.l.: The regimes in the Alps change from glacial to nival character. Winter discharge increases slightly due to occasional rainfall. This does not, however, lead to actual floods. In spring small snow melt flood events are possible, with greater peak flows than toady. The maximum yearly flood will occur in summer as hitherto and will presumably not increase. In autumn hardly any changes are anticipated.

Note: The central alpine regions that are subject to precipitation spilling over from weather formations from the south behave similar to the southern alpine region.

Southern alpine region: Here no altitude ranges are distinguished due to the lack of differentiation characteristics. In winter and spring an increase in floods is expected as a result of an increase in precipitation. Decreasing precipitation suggests smaller discharge peaks in summer. The hydrometeorological conditions in autumn remain decisive for the maximum yearly floods. An increase of floods is expected here because of greater precipitation.

Sediment transport: As a result of the retraction of the glaciers and the thawing of permafrost, the sediment potential will increase considerably in the regions between ca. 2300 and 2800 m a.m.s.l. More intense rainfall further enhances the potential for sediment transport.

Landslides: In the pre-alpine region, the future hydrometeorological conditions mentioned above (precipitation, snow cover, evaporation) over long periods in winter and spring suggest increased soil saturation. This implies an increased danger of landslides and sediment transport.

Kommissionsmitglieder und Klima-Experten, die am Workshop vom 12.–14. November 2006 teilgenommen respektive an diesem Dokument mitgearbeitet haben:

Membres de la commission et experts en climat qui ont participé à l'atelier du 12 au 14 novembre 2006 ou qui ont collaboré à ce document:

Membri della commissione e esperti per fenomeni climatici, che hanno partecipato al workshop del 12–14 novembre 2006, rispettivamente che hanno collaborato alla redazione di questo documento:

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