Reconstruction and quantification of “extreme” and detection of “normal” pre-instrumental flood events of major Swiss Rivers

Presentation of the goals and first results of the Swiss National Science Foundation research project

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Goals of the project

The reconstruction of extreme hydrological events of the period before the onset of national hydrological gauge measurements (pre-instrumental period) is one of the main goals of this research project. This will include an emphasis on the long-term series of reconstructed peak discharges of pre-instrumental flood events of main Swiss rivers (Aare, Limmat, Reuss, Rhine, Sihl and Thur Rivers). The occurrence of so called “normal” floods of the Aare and Rhine Rivers will be reconstructed, from which a better understanding about long-term normal flood seasonality and frequency should be obtained. A longer term goal is to the set up a historical hydrological database, specially designed for the needs of research and (federal or private) institutions being interested in flood risk assessment and/or flood protection measures. The aim is on the one hand to facilitate the access to raw data which generally is needed for further historical hydrological reconstruction and quantification, so that future research will be achieved in significantly shorter time. On the other hand, new historical hydrological research results shall be continuously included in order to establish this database as a useful tool for the assessment of flood risk by including the long-term experience of reconstructed pre-instrumental floods.

Methodology

The methodology developed by *Wetter et al.* (2011) combines different documentary and instrumental sources, retaining relevant information for the reconstruction of extreme pre-instrumental flood events. These include hydrological measurements (gauges), historic river profiles (cross and longitudinal profiles), flood marks, historic city maps, documentary flood evidence (reports in chronicles and newspapers) as well as paintings and drawings. It has been shown that extreme Rhine River flood events of the pre-instrumental period can be reconstructed in terms of peak discharges for the last 750 years by applying this methodology to the site of Basel. *Pfister & Wetter* (2011) furthermore demonstrated that this methodology is also principally transferable to other locations (Bern and Solothurn) and rivers (Aare River). Preliminary investigation concerning the potential of further archival sources showed that conditions for completing similar historic hydraulic and hydrological extreme flood reconstructions to those in Basel are most appropriate for the Swiss cities of Aarau, Bern, Brugg, Lucerne, Schaffhausen, Solothurn and Zurich, and for the nearby German cities of Constance and Lindau. The main steps of this methodology are described below.

M1 Qualitative calibration

The principle of the comparative “qualitative calibration” approach is shown in figure A. Qualitative calibration basically works with overlapping periods of different “flood information systems” like daily water gauge readings, flood marks and narrative flood reports, which allows to calibrate the pre-instrumetal flood infromation systems (flood marks, reports etc.) with instrumental measurements.

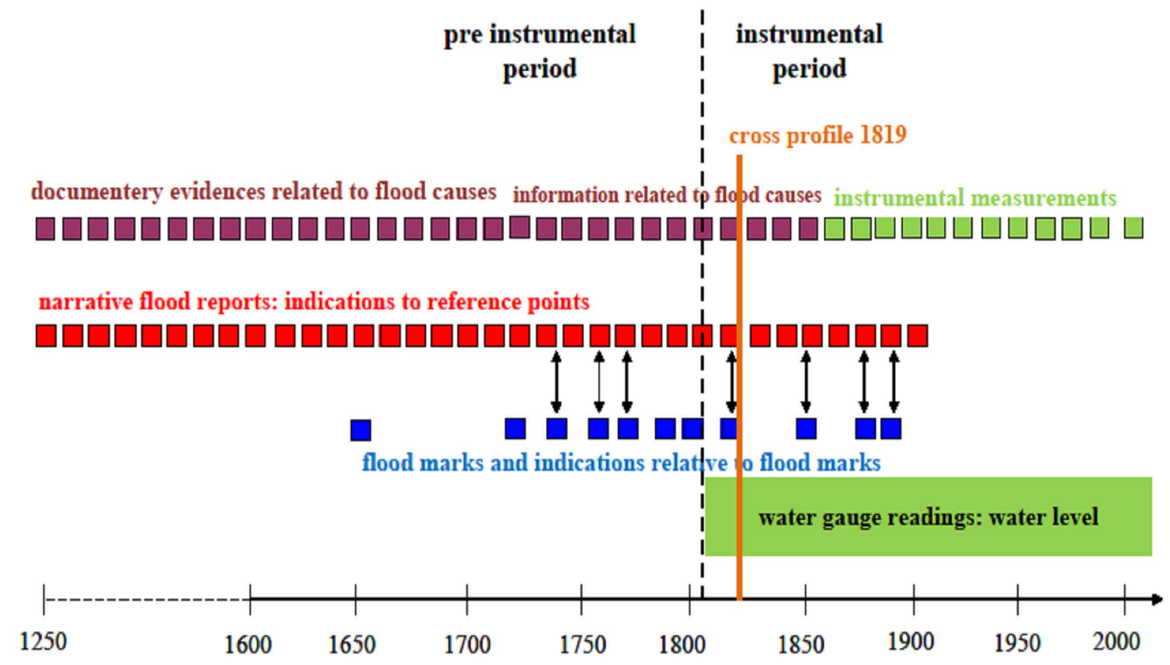

Fig. A: Qualitative calibration scheme of pre instrumental flood events using overlapping periods of different flood information systems

M2 Reconstruction of flood reference points and peak water levels

Flood reference points (FRP) are included in chronicler - and/or newspaper flood reports. A FRP may be e.g. the level of a bridge or the level of a window. The levels of these FRP need to be reconstructed in meters above sea levels (asl) and need to be distinguished from peak water levels (PWL). Once FRP are reconstructed it sometimes may be necessary to assess the water depth at the site (figure B).

The River Rhine was so high that the bridge was partly destroyed and one could wash the hands in it (while one was standing on the bridge). Boats could be boarded through the windows of the guild house of the boatmen. (…) The bridge looked like a float on the river.

(Basler Chroniken 4. Band 1890. IV. Anonyme Zusätze und Fortsetzungen zu Königshofen, nach der Abschrift Erhards von Appenwiler 1120-1454.)

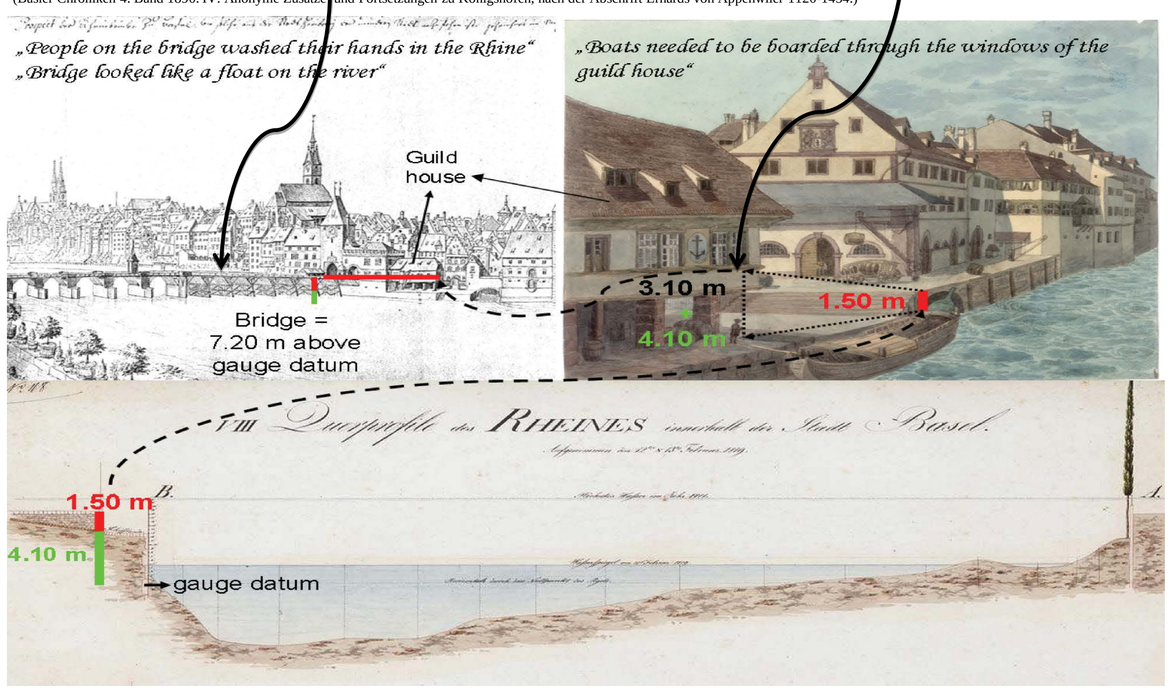

Fig. B: Reconstruction of flood reference points and peak water levels based on narrative flood information and documentary sources

M3 Stability check of FRP levels over time

As we are dealing with long-term study periods, it is necessary to check whether the FRP were stable over time. If there is no stability of the levels, it is necessary to reconstruct the alteration of the FRP levels.

M4 Reconstruction of changes of run-off conditions due to river engineering measures over time

In a next step the changes of run-off conditions of the river under investigation need to be reconstructed. This is necessary to build homogenous groups of flood events and the attribution of representative river profiles to those flood groups to calculate the peak discharges (based on the reconstructed PWL) with hydraulic models. It furthermore helps to understand the changes of PWL over time and thus may help to quantify the difference in peak discharge of actual and pre-instrumental flood events (figure C).

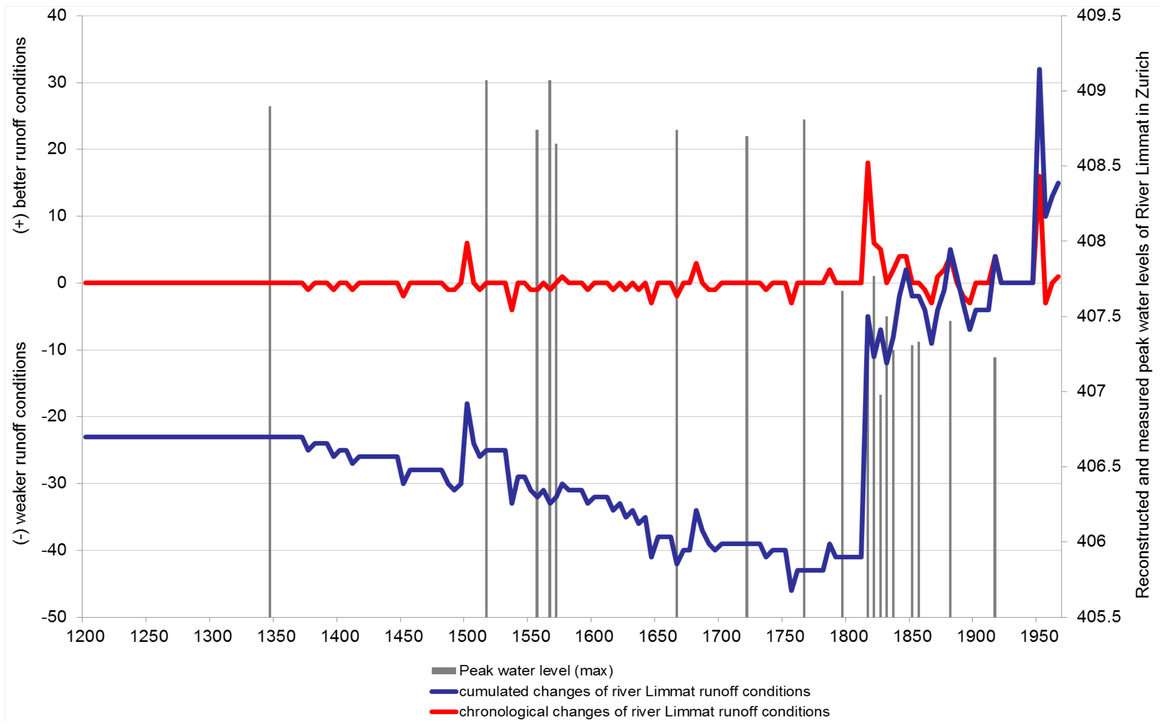

Fig. C: Changes of river Limmat runoff conditions in Zurich over time. Qualitative assessment of river engineering measures influences to runoff conditions:

+/- 1	none up to almost none better (+) / weaker (-) runoff conditions
+/- 2	almost none up to little better (+) / weaker (-) runoff conditions
+/- 3	little upt to mid -level better (+) / weaker (-) runoff conditions
+/- 4	mid-level up to a great degree better (+) / weaker (-) runoff conditions
+/- 5	great degree up to most intensively better (+) / weaker (-) runoff conditions
+/- 6	most intensively better (+) / weaker (-) runoff conditions

M5 Calculation of peak discharges of pre-instrumental flood events

At this point of the project peak discharges of pre-instrumental flood events have only been calculated for Rhine River at Basel. Quantification of the runoff obtained from the evidence available for the pre-instrumental and instrumental periods was done by applying the one-dimensional (1D) hydraulic model FLUX/FLORIS2000, which is a flood routing software that calculates the transient 1D flow in river systems based on the de-Saint Venant equations (Ven Te Chow, 1973), these being the Navier-Stokes equations for flow, integrated over the cross-sections of the river. The 1D flow equations are solved with a finite volume method. Measured cross-sections are used to discretize the river branches. The program package includes options for automatic calibration and flow regulation. The model can be used with a prescribed inflow and the results are the water levels for every cross-section. To quantify the peak flow for each historical flood mark, the inflow in the model of the river is increased until the historical water level is reached. Thus, for every observed water level, a corresponding flow can be calculated. The calculated peak discharges for Rhine River in Basel are displayed in figure D (figure D).

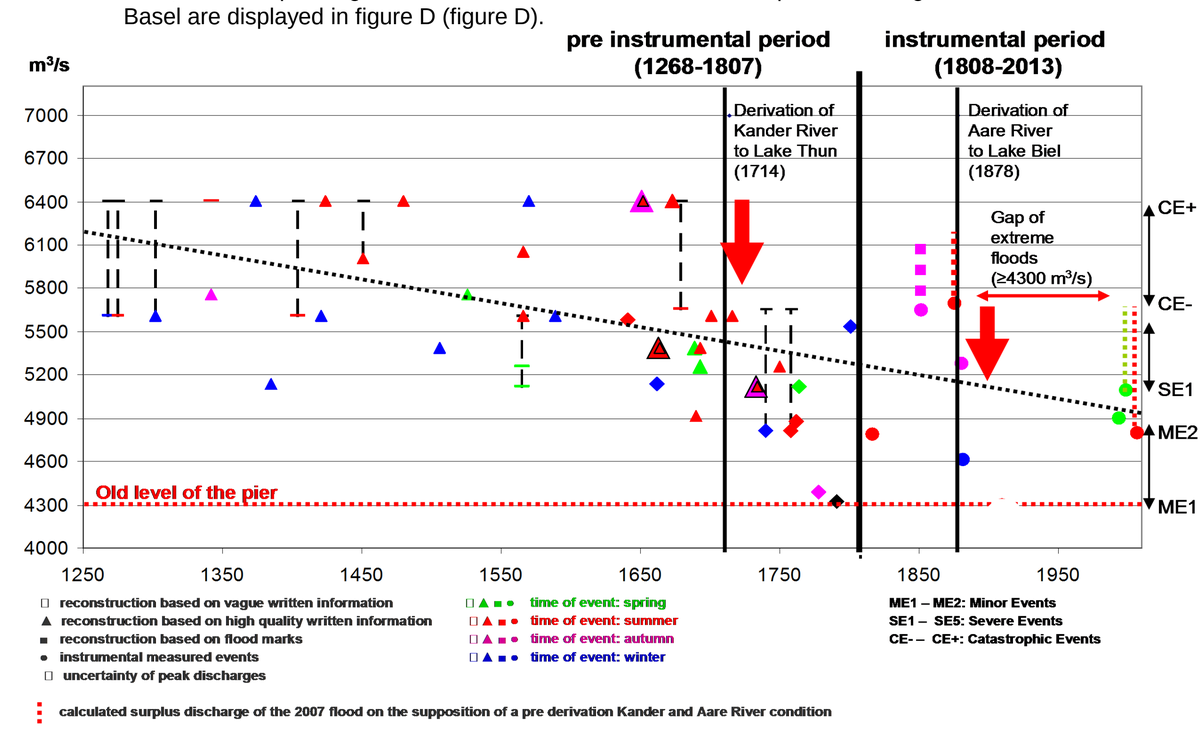

Fig. D: Reconstructed discharge series of extreme Rhine River flood events at the site of Basel based upon Flux/Floris2000 software

In the long run (starting with this research project) it is the aim to set-up a new tool for the Euro-Climhist database which will be specially designed for the needs and desires of historical hydrological research and public or private institutions that have a common interest in flood risk and flood protection topics. The integration of this tool in the Euro-Climhist database will offer the advantage that the historical flood events may be interpreted in climatological and (extreme) weather conditions terms, through the provision of access not only to flood related but also to climatological and (historical) meteorological data (Fig. E).

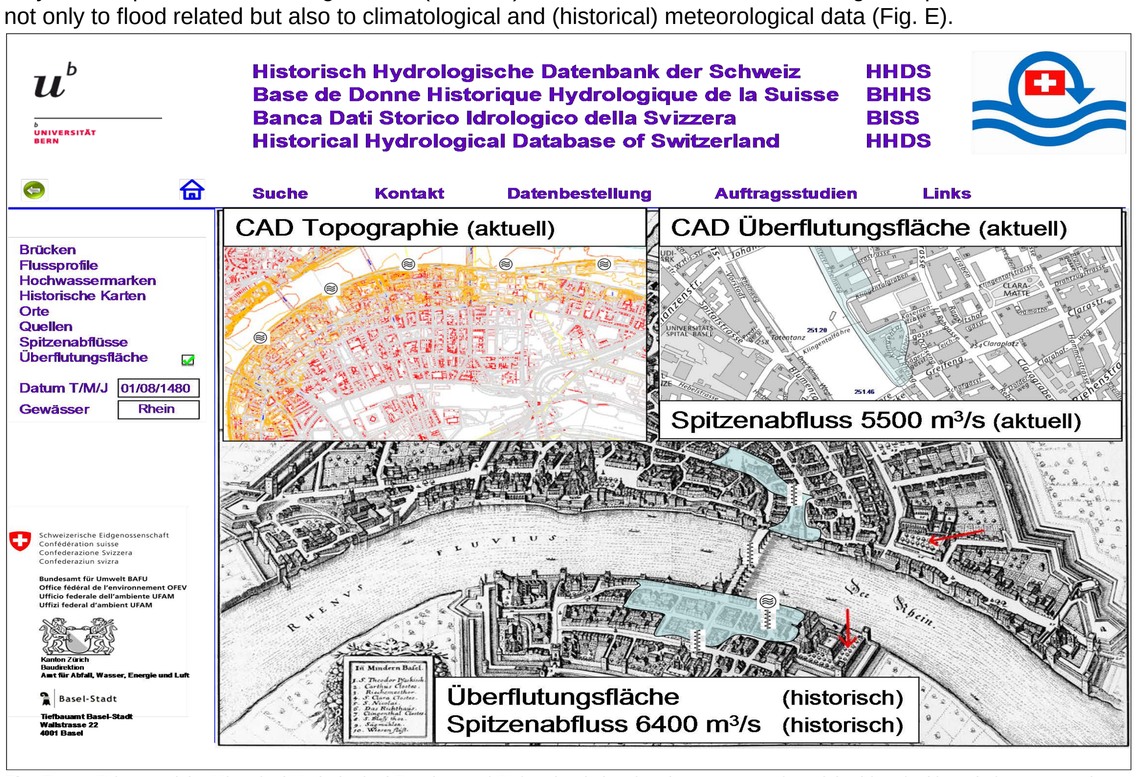

Fig. E: Printout of the Historical Hydrological Database of Switzerland showing the reconstruction of the historical inundation area and the peak discharge of the pre-instrumental flood event of 1480 (on the bottom) homogenised to the actual hydrological regime and present day topographical conditions in Basel.

References:

Wetter, O.; Pfister, C., Weingartner, R.; Luterbacher,J.Reist, T.; Trösch, J. (2011) The largest floods in the High Rhine basin since 1268 assessed from documentary and instrumental evidence. Hydrological Sciences Journal, 56:5, 733-758

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Ven Te Chow (1973) Open Channel Hydraulics. New York: McGraw-Hill.