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Extreme discharges in the Meuse basin

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Introduction

Over the last years the frequency and magnitude of floods of the river Meuse have been relatively large. These floods have caused a lot of trouble and triggered the design of national and international flood action plans. The recent floods have also generated many valuable observations of extremes. This presentation consists of i) a description of the river Meuse basin, ii) an impression of observed extremes, iii) an overview of ongoing research to derive the design discharge and scenarios for future extreme discharges of the river Meuse, and iv) a brief overview of the ongoing measures in the Meuse basin that aim at a reduction of flood risk.

The Meuse basin

The Meuse basin (Figure 1) covers an area of approximately 33,000 km^2, including parts of France, Luxembourg, Belgium, Germany, and the Netherlands. The Meuse basin has a temperate climate, with rivers that are dominated by a rainfall-evaporation regime, which produces low flows during summer and high flows during winter. The Meuse basin can be subdivided into three major geological zones: i) the Lotharingian Meuse (upstream of Charleville-Mézières). This part of the Meuse basin mainly consists of consolidated sedimentary Mesozoic rocks, ii) the Ardennes Meuse (between Charleville-Mézières and Liège). Here the river transects the Paleozoic rock of the Ardennes Massif, and iii) the lower reaches of the Meuse (downstream of Liège). The Dutch and Flemish lowlands are formed by Cenozoic unconsolidated sedimentary rocks. The average annual precipitation amounts 800 to 900 mm·year^{-1} in the southern part of the basin, around 700 to 800 mm·year^{-1} in the northern part of the basin and up to 1500 mm·year^{-1} in the central part of the basin. The annual average discharge of the Meuse at the outlet is approximately 350 m^3·s^{-1}.

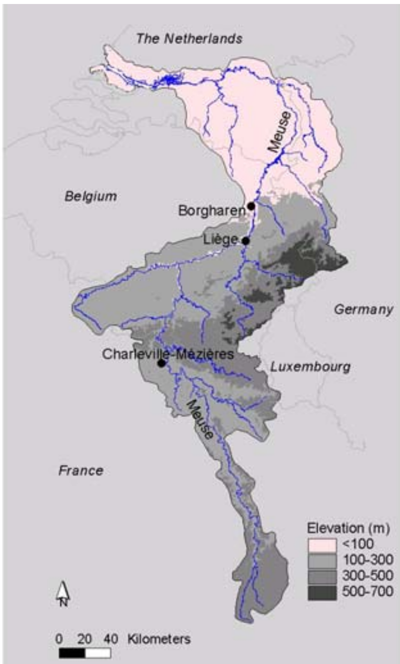

Fig. 1 Location of the Meuse basin

Observations

The longest discharge record available for the Meuse is that of Borgharen (upstream area 21,000 km^2). From Figure 2 it can be observed that even the average annual discharge of the

Meuse shows strong fluctuations. The average discharge in 1966 is about 6 times larger than the average discharge in 1976. The Borgharen record also shows that five out of the seven largest floods in the Meuse have occurred during the last decade. Tu et al. (2004) detected long term changes in precipitation and discharge in the Meuse basin. They showed that both the annual maximum daily discharge and the k-day extreme precipitation depths (e.g. over 5 days and 10 days) have significantly increased since the early 1980s. Floods in the Meuse are typically preceded by a wet period with basin average 10-day precipitation depths of around 100 mm. The January 1995 flood was even accompanied by a basin average (upstream of Borgharen) 10-day precipitation depth of 164 mm (Leander & Buishand, 2004). During the recent flood events large differences have been observed in area specific runoff. Observed area specific runoff ranges from almost 30 $l \cdot s^{-1} \cdot km^{-2}$ for tributaries in the northern part of the basin to almost 600 $l \cdot s^{-1} \cdot km^{-2}$ in some tributaries in the central and southern part of the basin.

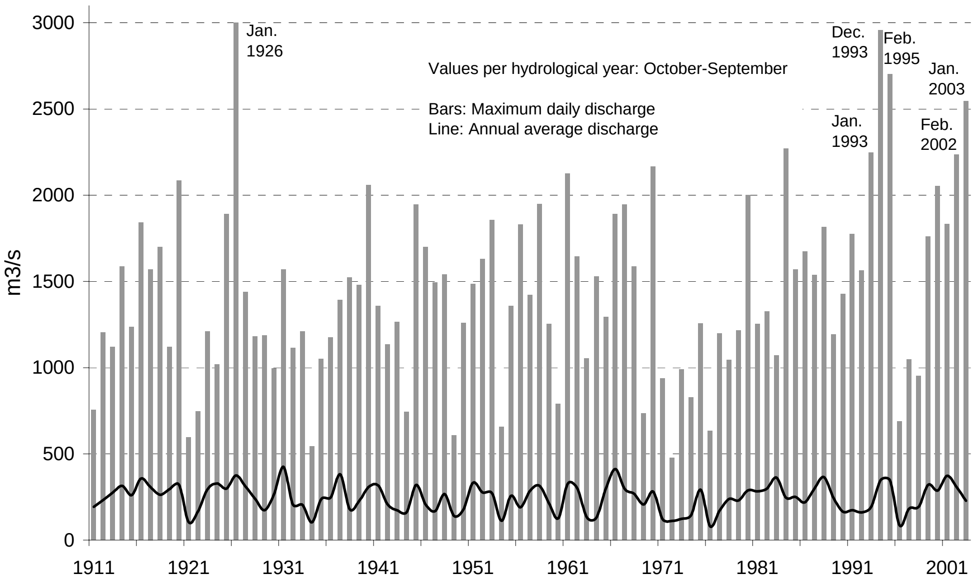

Fig. 2 Discharge record Meuse at Borgharen Source: Rijkswaterstaat

Moreover, it appears that maximum discharges in the different tributaries are often observed during different flooding events. The ratio between 10-day precipitation volume and the discharge volume at Borgharen strongly depends on initial moisture conditions. For example: a relatively low 10-day precipitation depth, but very wet initial conditions accompanied the floods of February 2002, whereas the floods of 1993 and 1995 were characterized by less wet initial conditions but much larger 10-day precipitation depths. Almost all floods in the Meuse basin have been observed during the winter season. One exception is the flood of July 1980 during which a peak discharge of about 2,000 $m^3 \cdot s^{-1}$ was measured at Borgharen. The 30-day precipitation value (244 mm) that preceded this flood was very exceptional for the Meuse basin (Leander & Buishand, 2004).

Design discharges and extreme scenarios

Along the embanked part of the river Meuse in the Netherlands, an average annual exceedance frequency of 1/1250 holds for the design discharge and the corresponding design water levels. This design discharge is obtained by analysing annual maximum discharges and peak over threshold data. For the Meuse the Borgharen record is used for this analysis. Several theoretical distributions have been fitted and used to make an extrapolation to the required exceedance frequency. The average value from the fitted distributions has been taken as the final estimate of the design discharge (at present 3800 $m^3 \cdot s^{-1}$). A detailed description of the procedure is given in Parmet et al. (2002). Recently a new methodology is being developed by KNMI and RIZA to provide a better physical basis for the design discharge of the Meuse. The first component of this new methodology is a stochastic multivariate weather generator, which generates long simultaneous records of daily rainfall and temperature over the basin. The second component is a hydrological model (HBV) for the Meuse basin, which transforms the generated rainfall into a discharge series at Borgharen. The first results obtained with this new methodology are described in Aalders et al. (2004) and Leander et al. (2005). The weather generator reproduces the distribution of the extreme 10-day rainfall quite well. Also the distributions of the maximum 1 day and 10 days discharges simulated with the generated meteorological data resemble those from the HBV simulations with observed meteorological data. Possible improvements of the methodology include the coupling with a hydraulic model for flood routing. The methodologies described above do not account for the possible impact of climate change. Several authors (e.g. Gellens & Roulin, 1998; Booij, 2005) have addressed the impact of climate change on the occurrence of floods in the Meuse basin. The general picture that evolves from these studies is that human-induced climate change will increase the risk of flooding in Northwest Europe. At present KNMI and RIZA are analysing the possibilities to apply the rainfall generator for the Meuse to the output of Regional Climate Model (RCM) simulations from the EU funded project PRUDENCE.

Policy

Over the last decade many measures have been taken or are being prepared to reduce the flood hazard and vulnerability to flooding in the Meuse basin (WHM/GTIM, 2002). The discharge levels that have been used to design those measures differ in the different regions of the Meuse basin. Like for most rivers, the flood protection level and the corresponding design discharge generally increase in downstream direction, where the effects of floods are potentially most devastating. This difference in design discharges complicates a supra regional tuning of measures.

Conclusion

The analysis of observed flood events as well as the first results of the rainfall generator for the Meuse reveal that there is no reason to assume that the observed floods in the Meuse are the most extremes that can occur. This motivates the need for a supra regional analysis of extreme conditions for the Meuse basin. The recently published and ongoing activities presented in this paper can support such an analysis.

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