The effect of climate change on the flood risk – example of a section of the river Neckar

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1 Abstract

The question of a possible climatic change and the associated effects on human society is presently a major topic of public discussion. The observed weather phenomena of recent years, in particular precipitation events, make clear that also water management must adapt to changes occurring in the runoff behaviour. In order to investigate these implications, the states of Baden-Wuerttemberg and Bavaria as well as the German weather service initiated the joint project KLIWA (climatic change and consequences for water management) in 1999, which was to examine the influence of climatic scenarios. In this joint project so-called climatic factors were determined with which regionally dependent peak discharge quantities for different occurrence probabilities needed to be increased, in order to be able to consider the climatic changes. This contribution points out how climatic change affects, in view of further discharge processes of flood events, flood security as well as potential flood damages.

2 KLIWA Project

The design of flood protection installations and the evaluation and examination of the degree of flood protection is based on flood events with a certain probability of occurrence or exceedance. Within built-up areas the degree of protection is laid out for floods which statistically occur once in 100 or 200 years (HQ100 or HQ200, respectively). The return periods of corresponding peak discharges are derived from flood frequency analyses, which are based on time series of observed water levels recorded by gauges. The extreme weather events of recent years (2002 flooding of the Elbe and Danube and their tributaries, drought in the summer/autumn of 2003) raised the question as to whether these events are to due to changes in climatic conditions.

The fourth report of the joint project KLIWA has been published and includes the influence of the climatic scenarios for the catchment area of the Neckar River on the behaviour of mean annual peak discharges (derived from daily mean discharges). Using flood frequency analysis the effects on the discharge characteristics were determined. Based on the climate model the computations show clearly that an increase in the peak discharges is to be expected, especially for the discharge range corresponding to small to middle floods. For events with a lower probability of occurrence (large floods) the influence is less.

The introduction of a climate-change factor f is recommended, in which the return period T of a particular event K is selected. For design purposes the peak discharge HQ becomes:

$$HQ_{T,K} = f_{T,K} \cdot HQ_T \qquad \text{(Equation 1)}$$

The computed climate-change factors for the Neckar catchment area are given in Table 1. The largest increases in peak discharges due to climate change occur for the more frequent flood events. For

longer return periods the factor continuously diminishes and amounts to only 1.15 for a flood with a return period of 100 years. For events which statistically occur more than every 1000 years no effect on peak discharges due to climate change is expected.

Table 1: Climate-change factors $f_{T,K}$ for flood events of different return periods for the Neckar catchment area (from IHRINGER, 2004).

Return period [a]	2	5	10	20	50	100	200	500	>1000
climate-change factor $f_{T,K}$	1.5	1.45	1.4	1.33	1.23	1.15	1.08	1.03	1.0

3 Effect of climate change on flood security and damage potential

Within the context of a pilot study at the Institute for Water and Water Resources Management (IWG), the effects of the modified discharge characteristics were examined more closely for the barrage of Gundelsheim at the river Neckar. The section extends from the lock at Gundelsheim (Neckar km 93.8) to the weir at Neckarsulm (Neckar km 107.15).

The water levels were computed with a 1D computer model of the Neckar which was developed at IWG within the framework of the IKoNE-project (Integrierende Konzeption Neckar-Einzugsgebiet), a contracted given by the state of Baden-Württemberg.

Table 2 shows the changes in the peak discharges for the investigated return periods; Figure 1 shows the effects on the water levels and the potential damages.

Table 2: Influence of the climate-change factors $f_{T,K}$ on the peak discharges river section at the community of Offenau (Neckar-km 98.0) situated downstream from the confluences of the tributaries Jagst and Kocher.

Return period [a]	**Climate-change factor $f_{T,K}$**	**Peak discharge currently [m³/s]**	**Peak discharge with climate change [m³/s]**	**ΔQ [m³/s]**
10	1.4	1680	2350	670
20	1.33	1960	2600	640
50	1.23	2330	2870	540
100	1.15	2610	3000	390
200	1.08	2885	3120	235
500	1.03	3200	3300	100
> 1000	1.0	3400	3400	0

Determining the potential flood damages was carried out exemplarily for the municipality of Offenau/Neckar using GIS-aided tools for flood damages analyses (also developed at the IWG within the context of the project *Risk Map Germany* contracted out by CEDIM – Center for Disaster

Management and Risk Reduction Technology). The calculations were carried out for the small-scale based on the fine-resolution land-use map ALK. The calculations of monetary flood damages are based on the HOWAS damages database from which a square-root function of damages dependent on flood depth was derived. Since the study site is predominantly a residential area only damages to residential buildings were considered. In the pilot study the potential flood damages were determined, i.e. existing preventative measures were not considered.

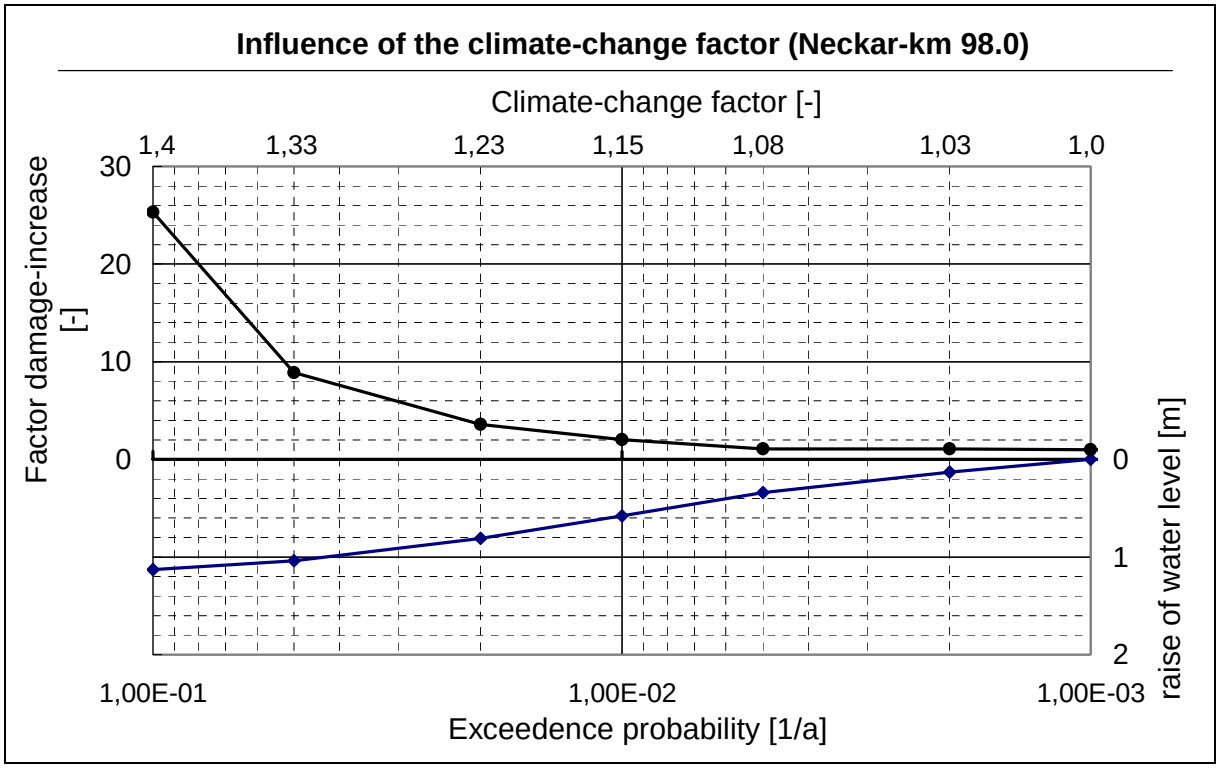

Figure 1: Influence of the climate-change factor on water depths and potential flood damages in the municipality of Offenau (Neckar km 98.0).

The increase of the peak discharges leads, in particular for frequent flood events, to a significant increase in the water levels and thus to a substantial increase in potential flood damages. For an event with a return period of 20 years the climate-change factor increases water levels by more than 1 m, which leads to a 9-fold increase in flood damages. Even with a 100-year flood event with only a relatively small proportional change in the discharge volumes of 15%, an increase of 60 cm in flood depths is expected which can potentially cause a doubling in flood damages.

The consequences of a possible change in climate conditions on the design of flood defence installations or the "re-valuation" of the degree of flood protection becomes significant when the changes in the peak discharges are calculated back to the associated return periods. In Figure 2 the HQ_T values of both the current state and the state due to climate change are plotted with respect to return periods. It can be seen that the defences for a 100-year flood for the current condition will only be adequate to protect against a 20-year flood in the future. If the influence of climate change is incorporated into the planning of flood-protection measures, the design flood of the future return period of 100 years requires a degree of protection which corresponds to a 300-year event based on present climatic condition.

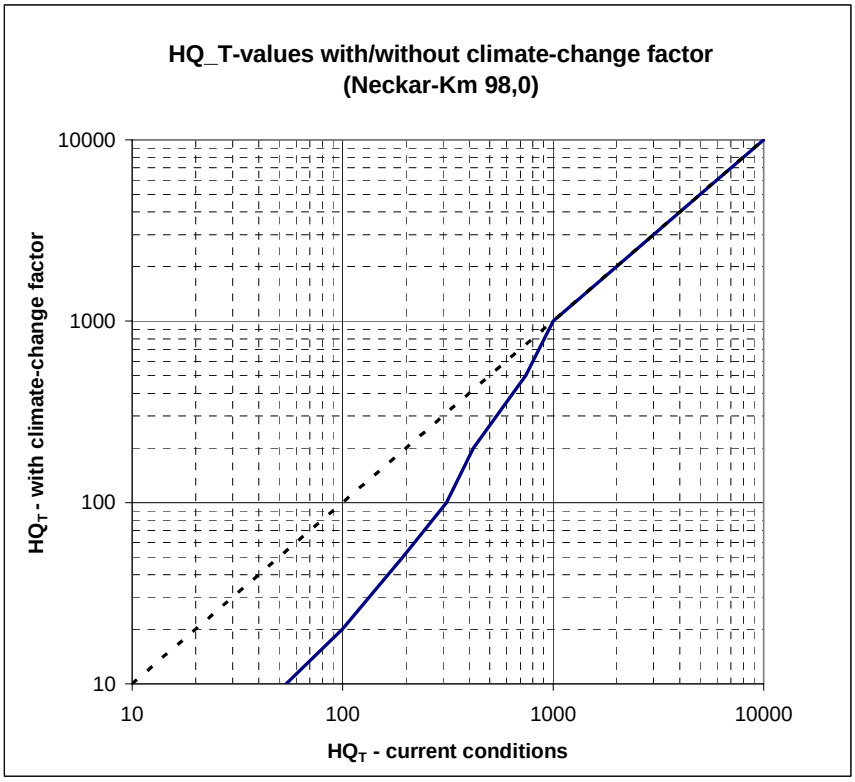

Figure 2: Comparison of HQ_T values at Neckar-km 98 between the current and future climatic conditions.

The investigations show that the climatic scenarios carried out in the KLIWA project can have substantial effects on flood security. In the investigated study area, a significant rise in water levels leading to an increase in potential flood damages, in particular for flood events of lower to medium extremity, can be expected. This means a reduction of flood security for existing protection facilities. These aspects are already being considered for new and planned installations in Baden-Wuerttemberg. In 2006, a reference guideline was published in which climatic change factors for additional design load factors are provided.

References

IHRINGER, J. (2004) Ergebnisse von Klimaszenarien und Hochwasser-Statistik, in KLIWA - Berichte Heft 4, S. 153-168, Arbeitskreis KLIWA 2004

IKoNE (1999) Integrierende Konzeption Neckar-Einzugsgebiet, Arbeitgruppe Öffentlichkeitsarbeit Herausgeber: Ministerium für Umwelt und Verkehr, April 1999

KRON, A., EVDAKOV, O., NESTMANN, F. (2005) From Hazard to Risk – A GIS-based Tool for Risk Analysis in Flood Management. 3. International Symposium on Flood Defence, 25.-27. Mai 2005, Nijmegen, Niederlande

LFU (2005) Festlegung des Bemessungshochwassers für Anlagen des technischen Hochwasserschutzes, Leitfaden Bd. 92, 2005

OBERLE, P. (2004) Integrales Hochwasserinformationssystem Neckar – Verfahren, Werkzeuge, Anwendungen und Übertragung, Dissertation, Institut für Wasser und Gewässerentwicklung, Universität Karlsruhe, Heft 226