Hydraulic Simulation and Flood Protection in the River Basins of Kocher and Jagst, Germany

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1 Situation

Kocher and Jagst are two of the most important tributaries of the river Neckar. Both rivers originate in the gently hilled region of the Swabian Alb, which is located in south-west Germany. They flow in nearly parallel and deep cut meandering valleys through the north-eastern part of Baden-Württemberg and meet the Neckar near the town of Bad Friedrichshall.

table 1: river data

	Kocher	Jagst
catchment area	2000 km²	1900 km²
river length	180 km	210 km
slope	1-5 ‰	1-5 ‰
MNQ	4.7 m^3/s	3.5 m^3/s
MQ	22.4 m³/s	15.9 m³/s
$HQ_{Dec.\ 1993}$	620 m³/s	593 m³/s

table 2: existing flood protection

	Kocher	Jagst
retention basins	17 Mio. m³	20 Mio. m³
river regulation	16.1 km	15.9 km
dams and levees	9.2 km	3.2 km

Because of the geological and meteorological situation, flood events in the Kocher and Jagst valleys mean large inundated areas. Since the 50th many technical measures for flood protection have been realized in the Kocher-Jagst-basin with a financial volume until 1996 approximate 390 million Euro (table 2).
The retention basins entailed marked improvements of the flood protection down to the central parts of Kocher and Jagst. The natural flood retention of the riverplains is secured by valid classification by the administration. Dams, levees and water development measures like river regulations were limited to locations within riparian communities which they efficiently protect against damages by smaller or medium floods.
Continuous and heavy rainfall during December 1993 and April 1994 caused an extraordinary flood event in the river basins of Kocher and Jagst. Particularly in the medium and lower parts of the rivers the flood caused enormous monetary damages (approx. 30 million Euro).
This was the release for the foundation of planning communities comprising riverain municipalities, the districts and the state Baden-Württemberg. The Institute of Hydraulic Engineering of the University of Stuttgart in co-operation with a Stuttgart engineer's office was commissioned to work out unsteady hydraulic models for river Kocher (1998) and river Jagst (1999). On the basis of these models regional and cumulative supraregional effects of additionally required flood protection measures should be examined.

2 Model Description

2.1 Type of Model

Using an 1D-unsteady flow simulation model (Saint-Venant-equations) for floodplain rivers designed at the institute, main characters are:

- four-point implicit finite difference scheme (Preissmann),
- double-sweep solution method with Newton-Raphson-solver,
- explicit consideration of flooded areas behind overtopped levees,
- internal boundary conditions at bridges and weirs.

In order to guarantee the numerical stability of the solution under mixed flow conditions in steeper river parts, it was necessary to neglect the local acceleration term for some subreaches (diffusion wave). For an appropriate representation of the floodplain water retention, a program module introducing sinuosity into the continuity equation was implemented.

2.2 Data Basis

Cross-sections (in distances from 50 to 500 m) representing geometrical-hydraulic boundary conditions relevant at the time of the flood event were used to build the model of the Dec. 1993-situation.
Plausible parameters (roughness-coefficient according to Manning-Strickler) could be obtained along the entire river courses. With the unsteady flow model the observed water surface elevation and the flood wave propagations, which are characterized by wave translation and wave superpositions, could be well reproduced.

2.3 Calculation Scenarios

2.3.1 Effects of Additional Flood Protection Measures

Calculated and measured maximum water surface elevations built the basis for the planning of supplementing flood protection measures. The appropriate design was integrated into a planning model by modification of the geometrical and hydraulic boundary conditions and then studied in its individual and summarised effects. In addition, the influences of further planned flood control storage basins in the catchment area (water associations Seckach, Kirnau and Brettach) were considered in the planning model.

figure 1: flood elevation marks and computed water surface elevation

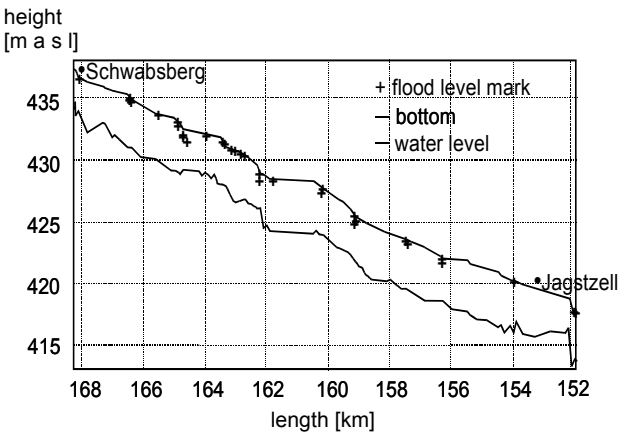
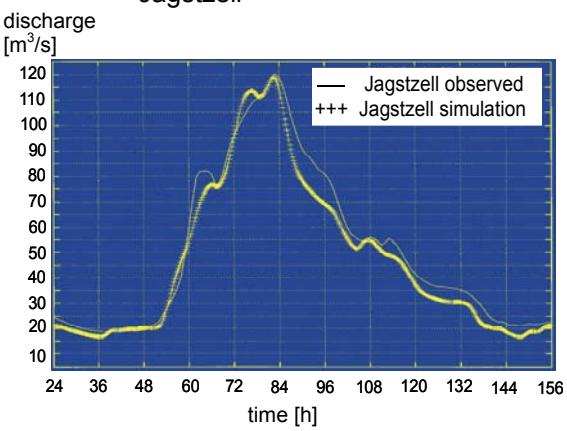


figure 2: discharge hydrograph at gage Jagstzell



2.3.2 Effects of the Flood-Control Storage Basins on River Neckar

In the framework of IKoNE (Integrierende Konzeption Neckar-Einzugsgebiet) and IRMA (Interreg-Rhine-Meuse-Activities) the influence of the flood control storage basins in the catchment areas of Kocher and Jagst on the flood situation in the Neckar was examined by the simulation models.
For Kocher and Jagst in each case an assumed zero-version, without effect of the existing and the planned basins, was calculated. The results were compared with the existing and the planned status. Again, the flood event of December 93 was the basis for the calculations.
The simulation results in combination with a statistical analysis of historical floods reveal that the basins have a weak positive effect on floods of the river Neckar.
Fears expressed by the riverains in the lower Neckar that flood retention basins in the catchment areas of rivers Kocher and Jagst could have lead to a more negative superposition of the flood waves from Kocher, Jagst and Neckar, could be cleared thereby.

figure 3: system of existing and designed retention basins (example)

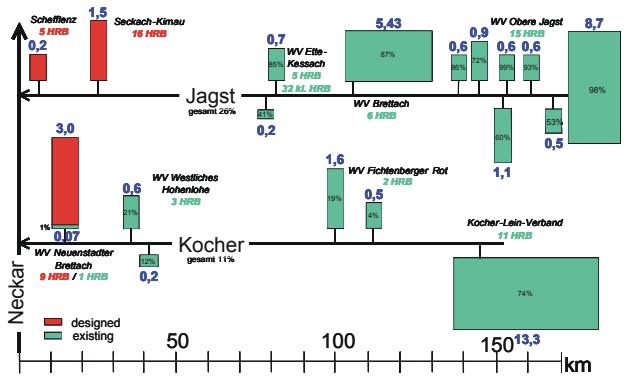
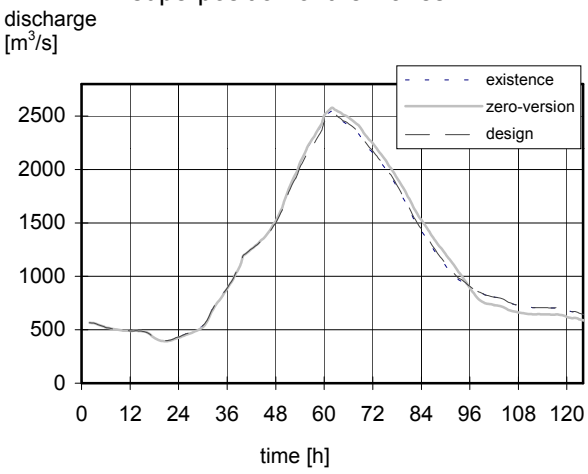


figure 4: comparison of the three versions after superposition of the waves



3 Conclusions

By unsteady flood modelling the technical basis for necessary supplements of the flood protection in the Kocher and Jagst valley was created. It could be proven that the cumulated individual measures do not produce negative effects for the downstream riverains. The suggested individual measures have been co-ordinated with all owners and a great majority of them has already be realised on river Kocher. The measures for river Jagst are in the state of execution planning.
The hydraulic-hydrologic model tools can also render valuable services for future functions of flood protection in the Kocher-Jagst catchment area provided the model is appropriately maintained. In the framework of scientific investigations it is to be checked, how the model and database developed for a particular project can be merged into future functions of ecological water management.