Modelling the management of water quantities in the Federal waterways between the rivers Rhine and Oder with BEWASYS

Background

Navigation on inland and coastal waterways and on the seas is of vital importance for the German economy. In the trans-European transportation network, the German Federal waterways constitute the infrastructural centerpiece.
Regarding the west-east canal system, the Federal Institute of Hydrology (BfG) in cooperation with the Karlsruhe University (KIT) and supported by the working party on Inter-regional Water Management of the Federal Waterways and Shipping Administration (WSV) have upgraded, parameterized, and applied a daily time-step model for the quantitative simulation of the management of the water in a network of navigable waterways.

Methods

BEWASYS is a modular daily time-step model that allows to combine various model modules arbitrarily:

- **linear modules** (e.g. impounded reaches of rivers or canals, free-flowing watercourses)
- **nodes** (e.g. ship locks, lateral inflows, water withdrawals, pumping stations)

The aim of the modelling effort is to operate the pumping stations and spillway facilities on each impoundment in such a way that in cases of water deficits (or excess of water) the target water level in the impoundment can be retained.

Study area & data basis

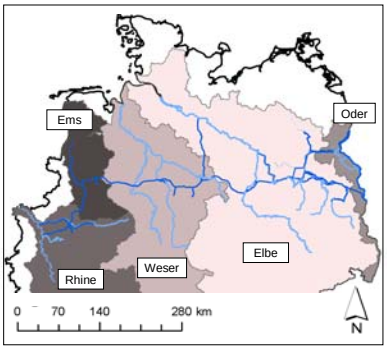


Figure 1: Waterway network and main river basins in the study area

Table 1: BEWASYS input data

Canal impoundment / River impoundment	Free-flowing watercourse	Nodes
• length of impoundment • mean area of water surface of impoundment • target water level	• parameters of the parallel storage cascade	• daily number of lockages • lock chamber area • number of water saving basins • permanent water loss by lock gates
• potential evaporation • precipitation	• lateral inflows • boundary inputs	• maximum capacity of pumping stations
• stage-discharge relation		
• percolation to groundwater • inflow from groundwater		• maximum capacity of spillways
• translation time • slope-discharge relation		• water withdrawals • return flows • diversions of water

The network of Federal waterways between the rivers Rhine and Oder (Figure 1) sums up to a total length of some 1,300 km, with two ship lifts and 84 locks. Figure 2 shows a scheme of the waterway network in the study area. Locks, pumping stations, and spillway facilities connect the impoundments with the rivers Rhine, Lippe, Weser, Elbe, and Oder. Table 1 lists the data that are required to parameterize the respective model modules.

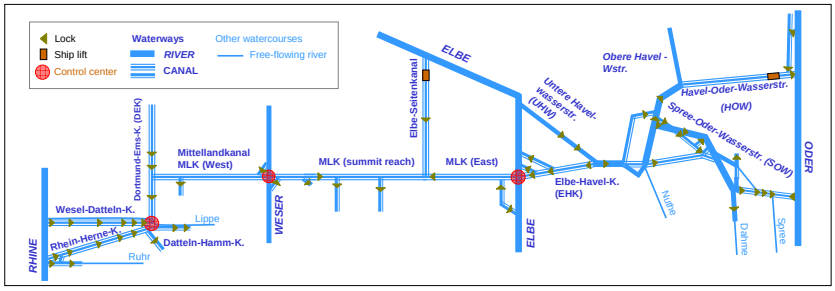


Figure 2: Scheme of the waterway network in the study area

Plausibilization of model outputs

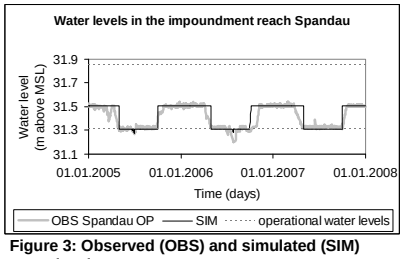
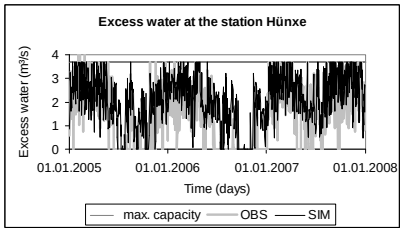


Figure 3: Observed (OBS) and simulated (SIM) water levels

The model outputs are subjected to a plausibilization by a comparison of selected simulated data with observation over the period 2005-2007. This allows to judge the quality of the model. By investigating Figure 3-5 one can summarize that the simulated model outputs fit well with the observations.



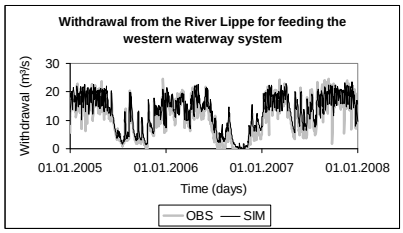


Figure 4 and 5: Observed (OBS) and simulated (SIM) excess water at Hünxe (top) and water withdrawal from the River Lippe (bottom)

Regional variant – intensified ship traffic

This variant examines the consequences of **higher traffic density** on the Datteln-Hamm-Kanal (DHK), the Rhein-Herne-Kanal (RHK), and the Wesel-Datteln-Kanal (WDK). The underlying assumption of this variant says that due to the construction of coal-fuelled power stations on the DHK, the demand for coal and thus the number of ship movements will rise from 6 lock passages as daily average by additional 12 passages in the DHK. Table 2 is an overview of the expected average changes of water-management parameters at all DHK and WDK lock sites considered in this study. Figure 6 illustrates the changes for the excess water at station Hünxe.

Table 2: Expected changes due to intensified ship traffic (Increase: values > 0, Decrease: values < 0)

Station	Change in lockage water		Change in excess water		Change in pumped water	
	(m³/s)	(%)	(m³/s)	(%)	(m³/s)	(%)
Hamm / DHK	0.19	119	1.06	8	0.01	-
Datteln / WDK	1.21	22	-0.05	-3	0.42	47
Ahsen / WDK	1.16	22	-0.02	-1	0.40	43
Flaesheim / WDK	0.64	20	0.28	8	0.19	44
Dorsten / WDK	1.43	18	-0.01	-25	0.68	30
Hünxe / WDK	0.89	18	0.28	13	0.44	28
Friedrichsfeld / WDK	1.26	19	0.06	7	0.59	32

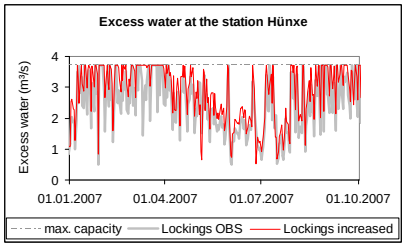


Figure 6: Simulated excess water at Hünxe with the observed and an increased number of lockages

Inter-regional variant – changed pumping strategy

With the model BEWASYS **different pumping strategies** to meet the water demand in the summit reach of the Mittellandkanal (MLK) were examined. Figure 7 shows the electric power consumption of each pumping station for the baseline variant, which was defined by means of comparisons with observed pumped water volumes, and for an alternative variant with changed boundary conditions. Although there are hardly any differences in the total electricity consumption between the two variants, differences in costs may exist because of special contracts between single Waterways and Shipping Offices and power suppliers.

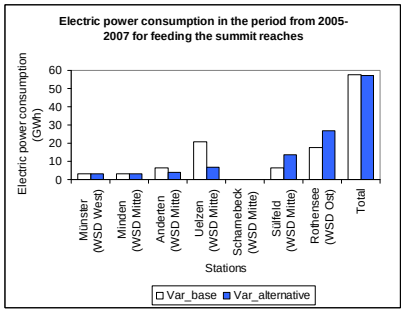


Figure 7: Electric power consumption in the period 2005-2007 for feeding the summit reaches.

Conclusions

The model system BEWASYS is suitable for computing variants in the examination of the consequences for the water budget of changed boundary conditions in water-resources management and for analysing them under economic aspects.

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