**Modelling and Simulation of Internal Pollution of Shallow Lakes**

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To evaluate changing water quality levels caused by improvements of the waterway between Hannover and Berlin within the Traffic Projects German Unity No. 17 the water quality of a shallow lake area of the River Havel was investigated. Special focus was given to develop a set of water quality models which simulate changing water quality levels on different time scales, and for river basin management options (Fig. 1). For system identification and parameter estimation samples are taken from different measuring points along the course of the river.

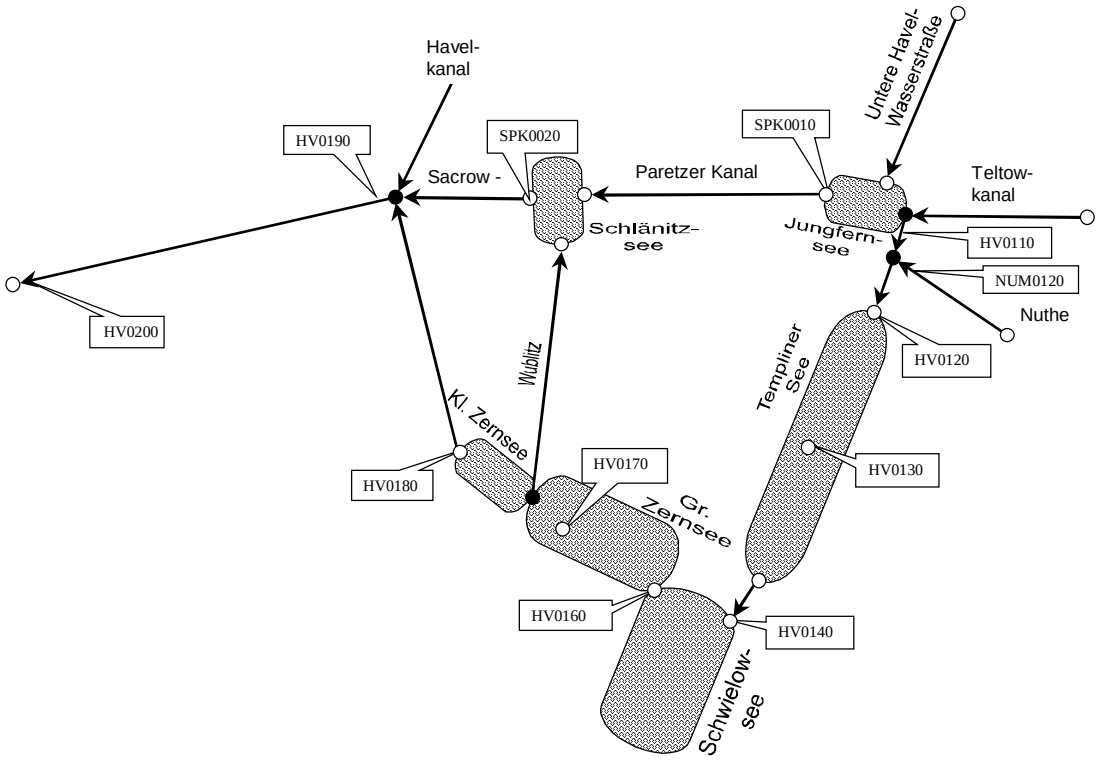


*Figure 1. Generalised graph of the experimental area*

The *HavelMod* modelling framework consists on a set of different types of models for water quality management purposes:

1. Process models describing interrelations between single processes (wavelet models, regression type models),
2. A water quality model for riverine lakes (nutrient and biomass balances),
3. Selfpurification model for river stretches (extended Streeter-Phelps type models),
4. Multicriteria optimisation model (including management options).

In this paper the simulation results of an water quality (eutrophication) model are presented. Firstly, the interrelations between variables of freshwater quality were investigated by time series analysis methods. From wavelet analysis results that the control of phosphate storage into sediment and phosphate remobilisation depends on the value, direction and the speed of change of the water temperature. The processes included in these submodels are diffusion of dissolved oxygen, nitrate and SRP-flux into and out of the sediment, the consumption of DO, nitrate and iron by mineralisation processes and the release of SRP from iron hydroxides due to mineralisation processes. On the basis of time series analysis a phosphorus release model was developed showing the dependency of phosphorus release from water temperature due to enhanced microorganisms activity. It confirmed the results obtained by wavelet analysis. These results were presented at UI 2001 conference. To predict water quality states of shallow riverine lakes due to internal pollution the eutrophication model *HavelMod* was developed. The amount of remobilised phosphate from sediment gives a strong nutrient basis for the eutrophication process. The model concept is given in (fig. 2).

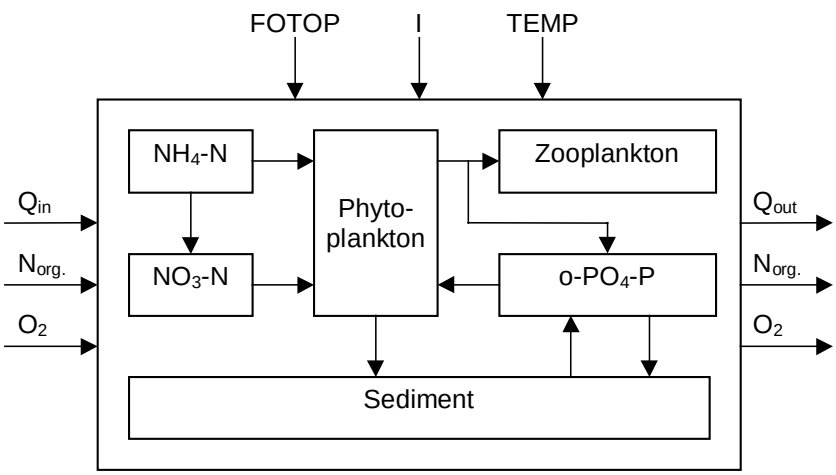


*Figure 2. Conceptual model of HavelMod*

This model serves as an informatic tool for prediction of changing water quality states caused by internal and external loadings. The time behaviour of physical water quality variables was modeled by sinusoidal functions. The model itself consists of six differential equations describing the time behaviour of phytoplankton-biomass, orthophosphate-phosphorus, ammonia-nitrogen, nitrate-nitrogen, filtrating zooplankton and phosphorus remobilisation. For water quality simulations the watershed was divided into two parts. Comparisons of system input (25002) and system outputs (25014, SPK0010) are shown in fig. 3. As can be seen, in both cases the phosphorus content increases in late summer and autumn caused by phosphorus remobilisation.

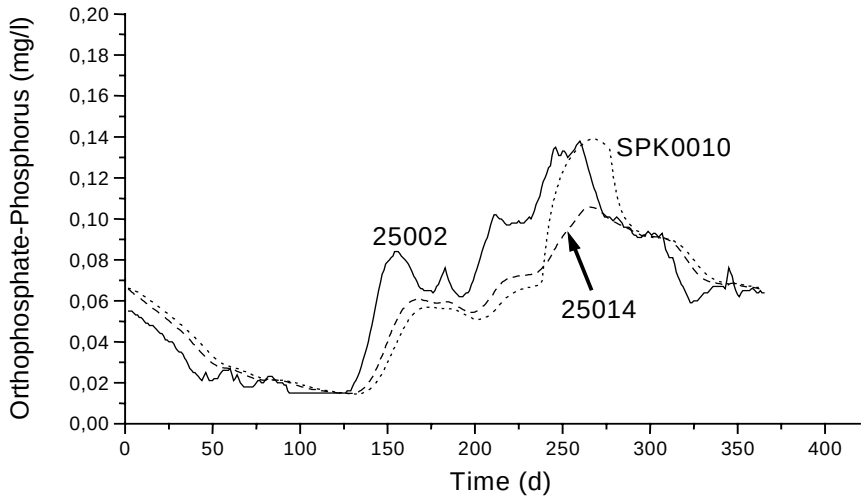


*Figure 3. Simulation results for orthophosphate-phosphorus*

In the paper the simulation results for changing management influences from the watershed will be discussed. As a result of this part of the modelling framework the following statements can be made:

1. Phenomenological descriptions of phosphate remobilisation processes indicating internal pollution of shallow riverine lakes are confirmed by time series analysis methods and by simulation results.
2. Phosphate remobilisation from sediment must be included into water quality models.
3. Because of the dependence from other environmental and man-made influences the process of internal pollution must be analysed intensively and have to be considered for sanitation programs and regional developments in the catchment area.