Pit Lake Baerwalde Revisited: Comparing Predictions to Reality

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Abstract
Pit Lake Baerwalde is an acidified lake forming in a pit from lignite mining in the German Lausitz district. It is flooded with surface water from three different rivers and receives ground water inflow. The water balance of the lake was calculated from measured data and compared with results from a ground water - surface water model. Ground water discharge from the lake was underestimated in earlier predictions as well as the amount of surface water that could be utilized for flooding. Predicted acidity fluxes from soil leaching were compared with acidity fluxes calculated from balancing the measured water quality data and water fluxes. Acidity fluxes were underestimated for times of lake level stagnation with shallow water covering the mining dump.

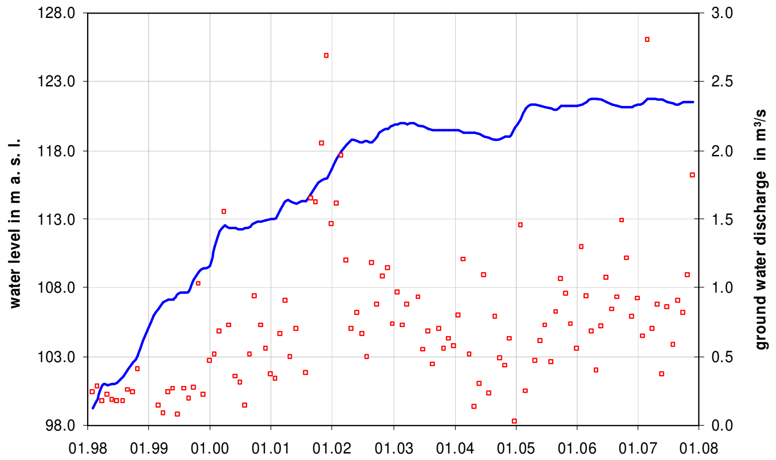
Key words: pit lakes, lignite mining, mine flooding, prediction, Germany, Lausitz

Introduction
Flooding of Pit Lake Baerwalde started in 1998 and continues until today. Its volume is approximately 130 $*10^6$ m^3 with a maximum depth of about 50 m. From 2000 to 2003 a research project has been conducted in which course a coupled model was developed (see conjunctive paper from Mueller et al.). The coupled model MODGLUE was tested and applied to Lake Baerwalde. Predictions were made for the future development of water quality. Predictive modelling is an important aspect of pit lake modelling as water management strategies often have to be evaluated for times of changing boundary conditions. The earlier made predictions for Lake Baerwalde are compared to the monitoring data available in the meantime. A new model run using updated input for the water management data is presented.

Methods
The measured data for Lake Baerwalde consists of the surface water fluxes and the surface water quality that is used to fill the lake. Ground water quality in the recharge area is monitored as well as lake level and lake water quality. From lake level change the changes in lake volume were calculated based on the bathymetry of the lake. No surface water discharge occurs so far as the lake level has not yet risen to the necessary height. The water budget of the lake was calculated from this measured data and estimates for ground water inflow and atmospheric losses as described by Werner et al (2001).
A mass balance for sulphate and acidity was performed on the basis of the water balance by assigning mass fluxes to the water fluxes. In addition to the water fluxes that make up the water balance of the lake for the mass balance leaching of soils has to be considered as a source of acidity and sulphate.
The input data for the lake model were updated with respect to surface water fluxes used for flooding. Water quality of the river spree and the small creeks remained unchanged. The mass fluxes due to leaching are calculated by the model based on the geometry of the lake, the lake water rise and by parameters describing the soil material and its ability to release acidity into the water. The area of land that is covered by the flooded lake during a unit of time for the first time is multiplied with a specific mass flux. This flux is reduced over time.

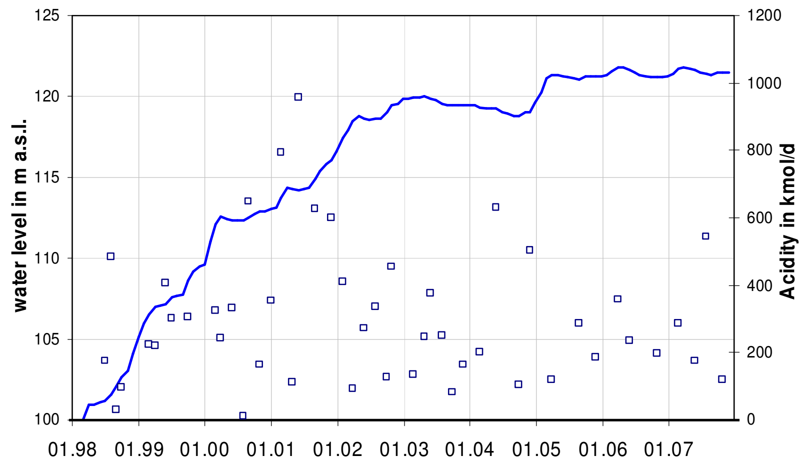
Results and Discussion
Ground water discharge was calculated from the water balance of the lake (Figure 1). Mean annual surface water input ranged between 7 and 60 $*10^6$ m^3 per year. Ground water discharge exceeds ground water recharge. Active pit mines in the vicinity create steep gradients in ground water levels. It is increased in times of rapid lake level rise due to the rewetting of the aquifer. The fact that it does not significantly decrease in the years 2006 and 2007 hints to the fact that ground water discharge occurs at these levels in highly permeable layers of the aquifer. This is supported by the geological model. The high discharge is favourable for the water quality development as it enables an effective flushing of the lake.

Figure 1 Calculated ground water discharge from Lake Baerwalde



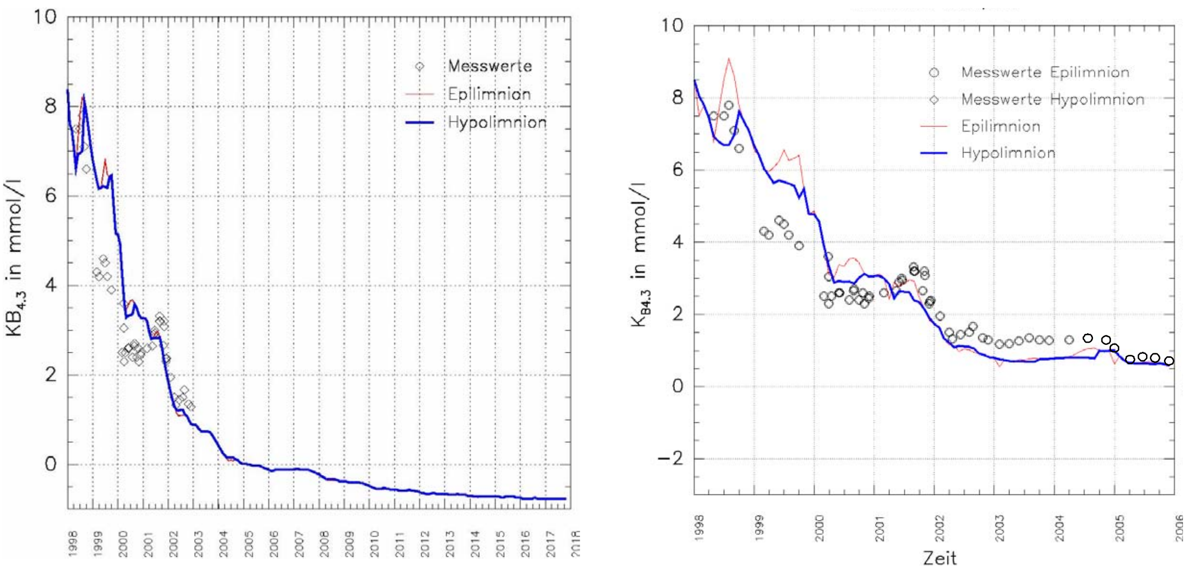
The calculated acidity input into lake Baerwalde (Figure 2) is mainly driven by leaching of soils from the banks and bottom of the lake. The lake bottom consists of a mining dump. Up to recent lake levels large parts of the surface of the dump are covered with water less then 2 m deep. The calculated acidity input reaches a peak during the lake level rise between 112 and 118 m a. s. l.. It remains on a high level for the past years. A decrease of these high fluxes is expected for lake levels higher then 123 m a.s.l. when the shallow water dump areas have disappeared.

Figure 2 Calculated acidity input into Lake Baerwalde



Model based predictions of the water level rise were overestimating the surface water input. The capacity of the surface water inlet building is around 5 m^3/s. These high fluxes were not achieved in reality due to a lack of water in the river and technical problems. Predictions made in 2003 (DGFZ 2003 and Mueller 2004) were using the fluxes that could be obtained in the previous year (about 2 m^3/s) what appeared to be too optimistic. Real fluxes were less than 1 m^3/s. The amount of surface water that is used in the flooding of the lake dominated its water balance as illustrated above. In 2003 a neutralization was predicted for 2006 assuming high surface water input. The reason for the non occurrence of this prediction was a wrong assumption concerning human action expressed in water management. A later simulation performed in 2005 could benefit from the measured data available for the flooding period 2003 to 2005. The simulated acidity shown in Figure 3 is compared to the measured values (KB4.3 stands for base titration with end point 4.3)

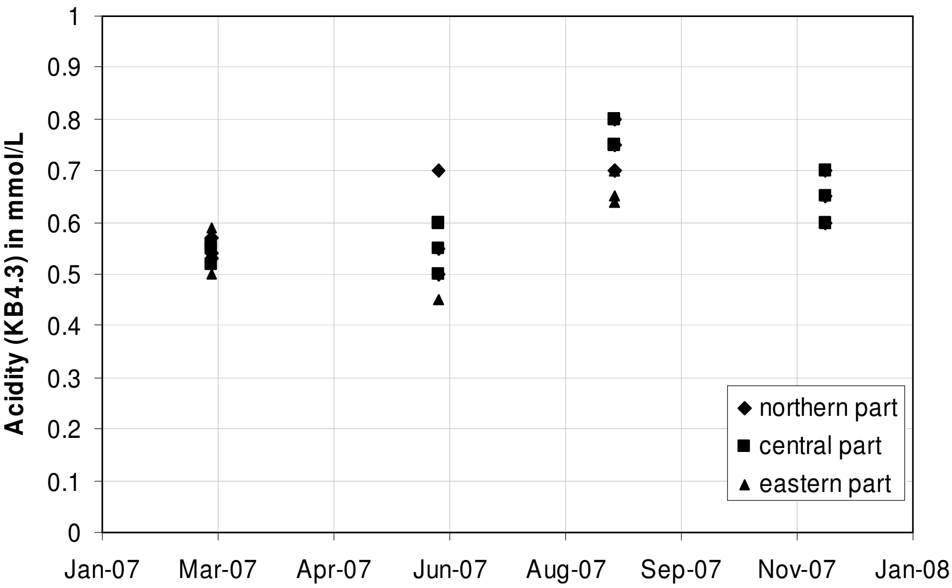
***Figure 3** Predictions for acidity*



Acidity vs. time. Predicted and measured concentrations (2003)

Acidity vs. time. Predicted and measured concentrations (2005)

***Figure 3** Measured acidity in Lake Baerwalde*



Conclusions

Water management in the east saxon post mining area is a complex task of distributing the available river water among all users. The filling of mining lakes with surface water is a key strategy to minimize ecological impact and economical effort. In the planning of future actions predictive modeling is an important tool for the management tasks. The value of this tool is determined by the precision of its predictions. In the presented case, the prediction of the water quality of Lake Bärwalde is strongly depended on the predicted water management decisions as well as the discharge this lake will produce into the groundwater.

For the modeling of groundwater rise in long time dewatered areas like the Lausitz mining area only sparse data is available that can be used to calibrate groundwater flow within the uppermost parts of

the aquifers. This creates the need for a high vertical resolution of the hydrogeologic model and a consequtive transfer of this information into the numeric model.
By using a model to simulate the water quality changes in Lake Bärwalde insight could be gained concerning the magnitude of acidity fluxes occurring during the flooding of this pit lake. Nevertheless these findings can not be transferred to other pit lakes without close investigation.

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