Rehabilitation of the Lusatian Water Balance, in Consideration of Climate Change and the End of Lignite Mining

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Abstract

The restoration of Lusatia's water balance by LMBV mainly consists of the refilling of groundwater deficits, the creation of secure post-mining lakes, their connection to the public water system and the enhancement of water quality.

Up to now, the coexistence of active mining and rehabilitation work has largely allowed for the maintenance of a demand-based discharge situation into receiving waters, by offsetting water deficits in rehabilitation areas with the surplus water generated by the dewatering of active mines.

In the future, the flow of the Spree River, which is currently dominated by a high amount of mine water drainage, will gradually be reduced as coal-based power generation comes to an end. Simultaneously, there will be an increased demand for water caused by the flooding of newly abandoned mines and the replenishing of groundwater deficits.

The restoration work of LMBV will also require the long-term supply of water to maintain geotechnically necessary lake water levels and to ensure required water qualities.

Furthermore, the long-term effects of climate change on the water balance in Lusatia cannot yet be reliably assessed. However, recent dry years have given a first impression of possible future conditions.

In order to cover the needs of all water users, including LMBV and currently active mining operations, it is urgently necessary to develop additional water resources and increase existing storage capacities. In this context, additional reservoirs, water transfers from other rivers as well as water retention in the area are all under discussion as potential options. A working group with members from the German states of Saxony, Brandenburg and Berlin as well as the publicly financed LMBV and private mining companies are all working together to find solutions to the upcoming water shortage.

Keywords: LMBV, Climate Change, Water Balance Restoration, Lignite Mining

Introduction

The Lusatian lignite mining area is located in eastern Germany, south of the capital Berlin and south of the Spreewald biosphere reserve.

With the start of industrial lignite mining in the region, considerable quantities of drainage water were discharged into the receiving waters of the Schwarze Elster and Spree rivers. In addition, dams were built on the Spree to secure the service water supply for coal-fired power plants. This led to an increase and equalization of the flow of the Spree (ARGE WaFL 2022) and thereby benefited the water supply of the Spreewald and the metropolitan region of Berlin.

As a result of reunification, some opencast mines in Lusatia were privatized (known as LEAG today). The majority of opencast mines in the former GDR that could not be privatized were taken over by the federal government and the lignite-producing states (LMBV today), with the aim of rehabilitating them.

In 1992, the water deficit in Lusatia was 13 billion m^3 and consisted of a 9 billion m^3 deficit in the aquifer and 4 billion m^3 in the hollow opencast mining pits.

With the decline in lignite mining in the 1990s, the drainage water discharge into receiving waters also decreased (ARGE WaFL 2022).

Cross-state committees and LMBV's flooding control center were established to coordinate and control the water management rehabilitation and to ensure minimum water levels. The prioritization of water transfer and use was made binding in the management principles. With the construction and commissioning of the water transfer line from the river Lausitzer Neisse, additional water resources could be used.

The water deficit in rehabilitation areas could be reduced from 7 to 0.9 billion m^3 by 2020, thanks to these measures. The deficit of approx. 6 billion m^3 in active mining areas remained as a result of the operational pumping of water and its discharge into the Spree. This largely made it possible to maintain the discharge situation in the Spree, particularly to secure the drinking water supply for the capital Berlin and to protect the Spreewald biosphere reserve.

The advanced state of water balance restoration by LMBV will be significantly affected by two important changes. The first one is the politically decided phase-out of coal-based power generation, which will also end lignite mining in Germany. This will cause the phasing out of groundwater pumping and its discharge into surface waters. The second one is the increasing influence of climate change, especially the more frequent and intensifying dry periods and extreme rainfall leading to flood events.

Consequences of the end of lignite mining

The flow of the Spree is currently still benefiting greatly from the discharge of mine water from active lignite mining. For example, in 2021, 41% of the Spree's flow at Spremberg, averaging 9.7 m^3/s, was generated from mine water discharges. In dry years, this proportion increases accordingly, as observed, for example, at 57% in 2020 (see fig. 1).

The sulphate concentration of the Spree is of particular importance for the production of drinking water by means of bank filtration systems in the Spree's floodplain. Without the mine water discharge, a relevant reduction in

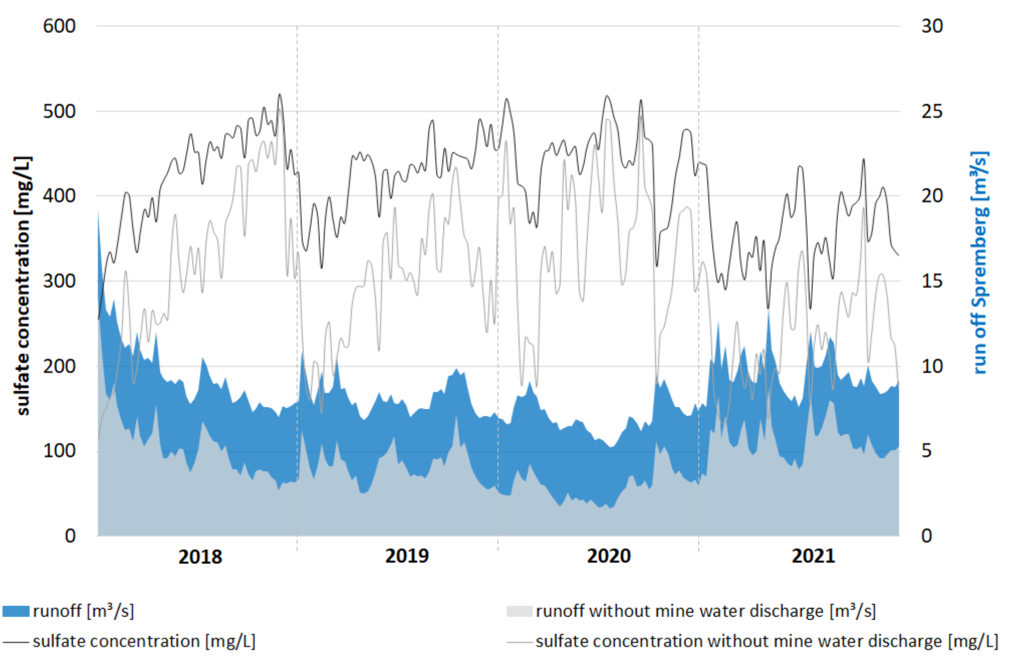

Figure 1 Percentage of discharge water and sulfate concentration in the flow of the Spree at Spremberg, from 2018 to 2021

Table 1 Percentage of discharge water and sulfate concentration in the flow of the Spree at Spremberg, from 2018 to 2021

year	runoff	runoff without mine water discharge	mine water quantity	sulfate concentration	sulfate concentration without mine water discharge
	[m³/s]	[m³/s]	[%]	[mg/L]	[mg/L]
2018	9,6	5,4	44	426	321
2019	8,2	4,2	49	422	295
2020	7,0	3,0	57	445	347
2021	9,7	5,7	41	358	236
average	8,6	4,5	48	413	300

sulphate loads by 63%, in conjunction with a reduction in the mean sulphate concentration of 27%, can be demonstrated for the years 2018 to 2021, on the basis of the measured values collected at Spremberg's Wilhelmsthal gauge. This shows that the sulphate problem in the Spree should ease considerably with the reduction in the discharge of mine water. Whether, when and to what extent the sulphate concentration in the Spree will increase again due to the infiltration of groundwater, as the groundwater once again rises, still needs to be investigated.

As a result of the end of lignite mining and the associated gradual ending of water drainage and discharge into the rivers, their flow will be reduced to the naturally available supply. At the same time, the increased water demand for the flooding of residual mining pits must be covered, since for geotechnical and hydrochemical considerations, the aim is to flood the lakes with water from the receiving waters (ARGE WaFL 2022). In addition, rehabilitation will also require water over the long-term for water management aftercare, particularly for maintaining lake water levels and ensuring water quality conditions.

In the long run, the groundwater deficit will be partially compensated by the gradual cessation of groundwater pumping. After the replenishment of the groundwater, this part of the Spree catchment area will again contribute to the generation of runoff to the Spree River.

Climate change

Existing climate forecasts vary in terms of the speed, scope and sometimes also the nature of change, depending on the chosen scenario. The resulting uncertainty is due, on the one hand, to a lack of understanding of these extremely complex processes. On the other hand, the extent of the changes also depends heavily on the future emission of greenhouse gases and thus on humans themselves.

Due to these uncertainties, predictions must be made with a range of probable climate scenarios. The climate scenarios generally show a trend toward increasing temperatures. In terms of precipitation forecasts, the climate models for the area currently show rather constant annual precipitation levels, on average. However, the intra-annual distribution of precipitation is expected to shift, and extreme events such as heavy precipitation leading to flooding or long periods of drought will increase.

For lakes and rivers, the climatic water balance, which is the difference between precipitation and evaporation, is decisive, while groundwater recharge is decisive for the groundwater.

In (Rumpf 2021), the climatic water balance, the difference between precipitation and potential evaporation, was evaluated and compared for various previous time series. A clear decline in the climatic water balance was observed in the last decade, compared to the 1961 – 1990 time series, from 142 to 57 mm, which is a decrease of 60%.

Next, the influence of the recent dry years (2018 – 2020, first half of 2022) on surface waters will be considered, since such periods of drought will presumably become more likely as climate change progresses.

In the dry years from 2018 to 2020 as well as in the first half of 2022, sections of the Schwarze Elster were repeatedly observed to

Figure 2 Dry riverbed of the Schwarze Elster near Buchwalde in summer 2019 (Photo: Oliver Totsche)

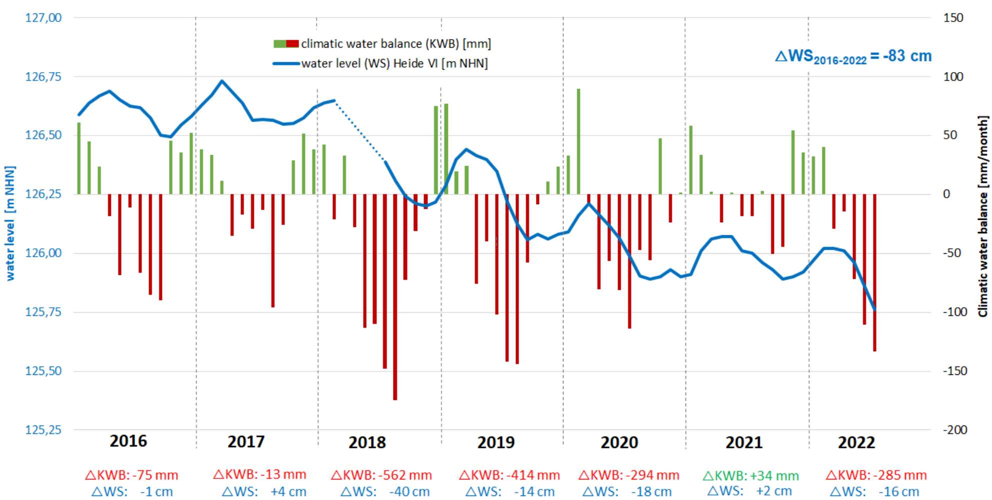

Figure 3 Water level development and climatic water balance of the Heide VI post-mining lake

completely dry up due to low precipitation and high evaporation rates (see fig. 2).

Furthermore, there has been a trend towards falling lake water levels in Lusatia since 2018. In the post-mining lake known as Heide VI, for example (see fig. 3), a water level of +126.2 to +126.8 m NHN had been established in the lake by 2017, and excess water was being discharged. The restoration of groundwater in the catchment area of the Heide VI post-mining lake has been completed for years.

The post-mining lake shows a typical intra-annual water level development, with rising water levels in the hydrological winter half-year and falling water levels in the hydrological summer half-year, as a result of the climatic water balance. In the years 2018 to 2020, these intra-annual fluctuations were marked by a trend of falling water levels, by a total of almost one meter. The year 2021, which had average levels of precipitation, saw the lake water stagnate at a low level. The subsequent first half of 2022, which in turn had below-average precipitation, caused a further drop in the water level. Under balanced meteorological conditions, the evaporation losses from the lake surface are mainly compensated by groundwater inflow to the body of water. This balance is disturbed in dry years, when groundwater recharge is greatly reduced.

By retaining water in the winter months using existing dams and the reservoirs previously created in opencast mining, it has been possible to largely maintain the water flow into receiving waters during the dry years. However, the first restrictions on water use, for example irrigation, are already becoming necessary today.

For the considerations of LMBV, the use of the seven climate realizations of the Central German Core Ensemble for the RCP 8.5 ("continue as before scenario") was coordinated across states. These climate realizations generally show a tendency towards an increase in temperatures, but also a shift and increase in annual precipitation from the summer to the winter half-year (Struve *et al*. 2020).

The effect of the climate realizations on the water balance variables of evaporation and groundwater recharge was calculated using a soil water balance model. The result of the RCP 8.5 realizations of the Central German Core Ensemble showed, under the given boundary conditions, a higher annual groundwater recharge in six of the seven realizations, compared to the reference period.

The shift and increase in annual precipitation from the summer to the winter half-year contained in the climate realizations used is being discussed as the cause. Furthermore, the low precipitation levels observed in 2018, for example, are not represented by the climate realizations used (Hattermann 2021).

In (Struve *et al*. 2020) it is pointed out that the climate projections are not regarded as reliable forecasts, as there are uncertainties in connection with climate change. Rather, they reflect a possible future development of the complex climate system based on the current state of knowledge.

Research into climate change and its consequences on the water balance is a process that is constantly subject to new findings and updates. Climate realizations and their integration into soil water balance models can serve as a good supporting tool. The interpretation of the data and the derivation of recommendations for action must continue to be carried out by technical experts.

Evaluation of observations vs forecasts

It is currently not foreseeable for Lusatia whether there will be a trend towards drier conditions, as shown by the measurement results from 2018 to 2020 and the first half of 2022, or whether (extremely) dry and (extremely) wet conditions will alternate and may even out, or an increase in groundwater recharge will be recorded.

With regard to LMBV's tasks in the creation of post-mining lakes, in particular the stabilization and design of slopes as well as the dimensioning and construction of inlet and outlet structures for connecting to receiving waters and stable post-mining areas, reliable approaches to planning are required, which must be based on reliable forecasts and a comprehensive knowledge of the system.

Consequences for LMBV post-mining rehabilitation work

If the observed hydrological conditions of recent dry years continue in the future, further declines in groundwater levels as well as falling lake water levels and a reduction in the lakes' own water supply can be expected.

This can lead to different consequences for LMBV's rehabilitation tasks:

- Falling lake water levels can affect the stability of slopes by changing the balance of forces in those slopes.
- Falling groundwater levels can also cause initial movement in mining areas that are still at risk of liquefaction, because they alter the unstable states of equilibrium of stresses in the subsurface.
- Drawdown of the groundwater can also cause subsidence damage to buildings or pipelines if the subsoil contains water-sensitive layers such as peat.
- Falling lake water levels can intensify bank erosion by lowering the water exchange zone and can lead to the formation of cliffs.

- Low water levels can lead to the death of vegetation and thus to increased slope erosion.

Flood safety considerations are already being carried out as part of the creation of post-mining lakes and appropriate measures are being implemented, so that the expected increase in flood situations is being taken into account accordingly.

New strategies for overcoming the water management challenges

With regard to the upcoming challenges, new strategies and options for action in water management will be necessary to be able to meet the demands of water users along the Spree up to Berlin, also taking into account ecological concerns.

The water balance in Lusatia is already being managed based on regulations agreed between the German states of Saxony and Brandenburg. The LMBV flooding control center already plays a key role by coordinating and carrying out most of the river basin management tasks. On the one hand, the opencast lignite mines pose a problem for the necessary adjustment of the water balance due to the high demand for flooding water and evaporation losses. On the other hand, they can also contribute to solving water management challenges by using them as reservoirs for flood retention and for raising low water levels in dry seasons. It may be necessary to make structural adjustments to the LMBV post-mining lakes to accommodate lower water levels or larger water level spreads.

To be able to meet the needs of all water users including LMBV and currently active mining operations, despite the lack of support from mine dewatering, it is urgently necessary to develop additional water resources and increase existing storage capacities.

In this context, an additional head reservoir in the Schwarze Elster catchment area, water transfers from other rivers as well as water retention in the area (LfU 2021) are all being discussed as major potential courses of action. Otherwise, demands would have to be reduced and/or the compensation of the water deficit would have to be stretched over a very long period time.

Conclusion

The rehabilitation of the water balance in the Lusatian lignite mining area is a long-term task.

Up to now, the coexistence of active mining and rehabilitation work has largely allowed for the maintenance of a demand-based discharge situation into receiving waters, by offsetting water deficits in rehabilitation areas with the surplus water generated by the dewatering of active mines. This will change in the coming years.

The long-term effects of climate change cannot yet be reliably assessed. However, recent dry years have given a first impression of possible future conditions.

River basin management must therefore be as robust and flexible as possible to be able to cover existing usage requirements in the long term. This includes the development of further water resources and additional storage areas in the upper reaches of the river basins, in close cooperation with all those responsible and affected.

The further development of former opencast mining pits into water reservoirs for flood retention and for raising low water levels in dry periods can also contribute to solving the water management challenges.

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