



# Development of a technical concept of spatial and temporal coordinated mine water recycling exemplified by a mining area with urban influence

Antje Ulbricht<sup>1</sup>, Felix Bilek<sup>1</sup>, Katrin Brömme<sup>2</sup>

<sup>1</sup>Groundwater Research Centre Dresden, Meraner Str. 10, 01217 Dresden, Germany, aulbricht@dgfz.de

<sup>2</sup>Ruhr University Bochum, EE+E Environmental Engineering and Ecology, Universitätsstraße 150, 44780 Bochum, Germany, katrin.broemme@rub.de

## Abstract

A technical concept for an integrated mine water management regarding the spatial and temporal change and the strong seasonal weather variations was developed. The aim of the concept is the modification of the water infrastructure within the project area Hon Gai peninsula, Ha Long, Vietnam, to balance temporal water deficits. The adaption of the water treatment to the individual requirements of various users is also included in the concept. The methods and tools to identify the need for action and assess possible solutions are described.

**Keywords:** integrated water management, technical concept, mine water use, post-mining land use planning, Vietnam

## Introduction

One of the hardcoal mining areas in Quang Ninh, Vietnam, is located on the Hon Gai peninsula next to Ha Long City. The mine water affects the surface water on the peninsula and the coastal water of Ha Long Bay, which was recognized as World Natural Heritage Site by UNESCO in 1994. For this region a concept for an integrated mine water management will be developed by the WaterMiner project, which is sponsored by the German Federal Ministry of Education and Research (BMBF). Due to spatial changes and the predictable change of the water demand caused by closure of mining and the socio-economic development, the concept includes the current stage as well as future stages of development of the region. The project combines the analysis from a material flow perspective (Brömme et al. 2018) and from an economic perspective (Do et al. 2018) with the technical perspective which is presented here. The final product is a spatial and temporal coordinated mine water management.

On the Hon Gai peninsula the mine water origins from the draining of the mines (pit water) and the surface runoff within the mining area. The pit water is characterised by moderate concentrations of iron and high

manganese concentrations. Currently, this water is treated partly and reused for purposes like coal screening, truck wash, domestic use and watering plants. Due to the closing of open pit mines the process water volume will decrease in the future. Consequently the amount of water which can be reused for these purposes will decrease. The surface runoff contains high loads of sediment and coal dust. After heavy rain events the water and the sediments are transported by rivers to the urban area where the sediment and coal dust deposit. The amount of this water and the containing substances are currently not treated or reused.

Due to socio-economic changes of the region the water demand for domestic purposes will increase. Thus one of the major future challenges of this region is to cover the increasing water demand. The temporal fluctuating water quantity with water scarcity in dry season and flooding events in the rainy season is a major difficulty for the water management.

A technical concept is established which includes solutions to support the water infrastructure and balance water deficits and excess supply to guarantee a constant and long-term water supply for the whole region. The



aim is to store, treat and supply surplus water to various users in the area according to their individual quality and quantity requirements.

### Data acquisition

From 2005 to 2015 morphologic data, climatic data and data about the water quality of the project area were collected with in RAME project (EE+E Environmental Engineering+Ecology 2016). These data were expanded and revised by the integration of new data which was collected during fieldtrips. Interviews with staff and managers of the mining companies and VINACOMIN (Vietnam National Coal – Mineral Industries Holding Corporation Limited) resulted in new information regarding the future territory planning. On the basis of this information the existing digital elevation models were updated (fig. 1) to get information about future morphology, catchment area borders and possible water storage volumes.

The geometry of the rivers (cross sections, slopes) was surveyed and water qualities were determined by taking water samples. The sediment samples were taken within the mining area and along the riverbanks to obtain knowledge of the sediment composition (grain sizes, share of coal dust).

Data about hydrological conditions of the rivers are currently not available. Due to this fact a monitoring concept was created to observe the river water levels and to measure the quality parameters pH, electrical conductivity, temperature and turbidity. For the monitoring multiparameter probes and cameras, which observe the water levels at

water gauges, will be used. The water levels at various cross sections are required to calculate the water discharges. The knowledge of the discharge amount is the basis of the determination of the surface runoff within the mining area and the calibration of the precipitation-runoff model.

### Methods

Due to the declining mining activities, the corresponding landscape transformation and the change of the water demand and water sources, the technical concept includes three stages of the project area. Stage 1 is the current stage with both open pit and underground mining. Stage 2 represents the near future when the opencast operations and partly underground operations will be stopped. Stage 3 describes the final situation of the area when the recultivation and landscaping is finished. For these stages the data was collected to identify the main difficulties of the water and sediment management and find solution approaches (tab. 1). Possible measures to improve the water quality and water management will be examined with the help of modeling tools (fig. 2).

The major uncertainty of the currently available data is the quantity of surface runoff and the sediment which is transported from the mining area into the rivers. The discharge data is necessary for planning technical measures to improve the water treatment and the water distribution system. It is also needed to estimate the effectiveness of future water storages. Information about the eroded sediment and coal dust will be used to plan the recov-

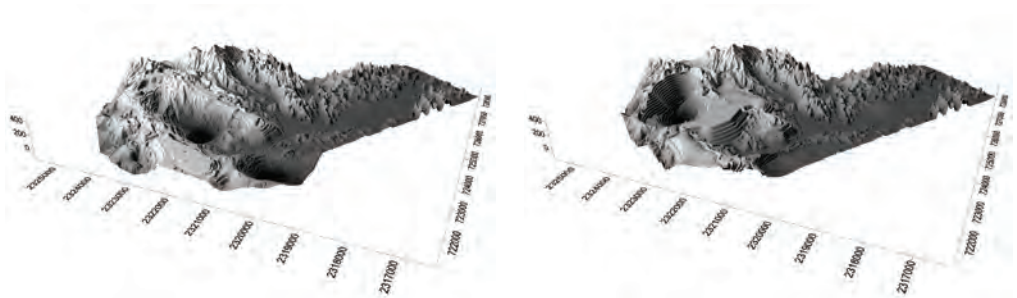


Figure 1 spatial change of the Ha Tu mining area (left: current stage, right: final stage)



ery and separation of this material. To obtain these information the surface water runoff and the sediment transport will be calculated with the precipitation-runoff model HEC-RAS. The developed monitoring system will provide data to calibrate the model.

To determine the quantity of usable water in storages like lakes or aquifers the knowledge of water levels and the interactions be-

tween water and the geological structures is indispensable. The model ModelMuse (MODFLOW) will be used to simulate groundwater and lake water levels depending on the climatic conditions and different mining stages to identify the quantity of these storages. The influence of withdrawal rates will be analysed. Possible positions of wells and treatment plants will be planned.

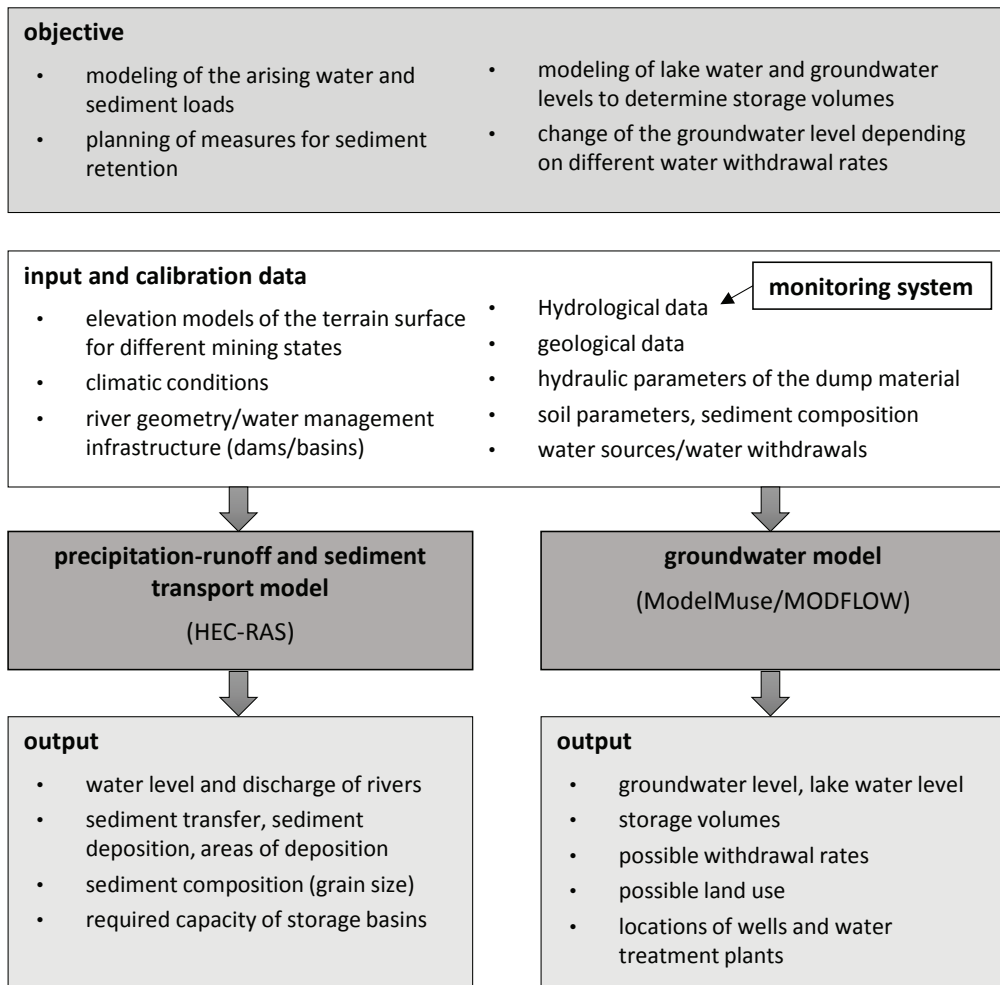


Figure 2 modeling tools and data requirements for system analysis and the assessment of technical measures



## Results and Discussion

Several difficulties for the water management occur due to the high climatic seasonality, the socio-economic development of the region and the change of landscapes caused by the closing and restructuring of the mining areas (tab. 1). Currently, the greatest difficulty is the poor water quality in rainy season caused by the high sediment loads. To prevent the sediment deposition in the urban area and to retain the sediment within the mining area the technical concept includes the restructuring of the rivers and the installation of settling basins. Within the WaterMiner project those measures will be planned exemplary for a section of the Lo Phong River in the Ha Tu mining area. Depending on the needs of the Vietnamese partners the coal sludge and the clastic sediment can be either recovered and separated for later reuse or simply dumped together.

In the future the greatest difficulty will be the water deficit in dry season (tab. 1). On the annual average there is enough water to cover the increasing water demand. Consequently, storage possibilities are identified to guarantee the water supply in dry season.

When the coal dust and sediment loads will decrease due to the restructuring or the closing of open pit mines the settling basins will not be necessary anymore. Then the basins can be used as storage basins for water. Furthermore, a concept for the final stage was developed which includes the re-utilisation of the already existing pits and dumps as water storages (fig. 3). The water of the pit lakes and the groundwater which is accumulated in the porous material of the dumps can be used for several purposes. Depending on the quality requirements of the future water users the treatment process and the distribution system have to be adapted.

*Table 1. Difficulties and solution approaches depending on different mining stages*

	stage 1 – current stage	stage 2 – near future	stage 3 – final situation
difficulties	high water discharges with high sediment loads, sediment deposition along the river (rainy season)	increasing water deficit in the urban area (dry season) retention of floods is necessary (rainy season)	large water deficit in the urban area (dry season) retention of floods is necessary (rainy season)
solutions	installation of settling basins to retain sediment load, restructuring of the river	former settling basins can be used as retention basins, use of closed open pits as reservoir	use of the water of pit lakes, use of dumps as groundwater storage, adaptation of the water infrastructure and the water treatment
water sources	water from open pit and underground mining, precipitation	water from underground mining, precipitation	precipitation
treated water	base flow, water from open pit and underground mining	base flow, water from underground mining, water which is stored in open pits and basins	lake water, ground water
water use	truck wash, coal screening, watering plants, domestic use (mine internal)	agriculture, industry, domestic use (mining companies)	domestic use (city), agriculture, industry
possibilities to store water		settling basins, open pits	Lake, settling basins, aquifer
sediment retention		Settling basins, separation of coal sludge	(vegetation of dump sites)



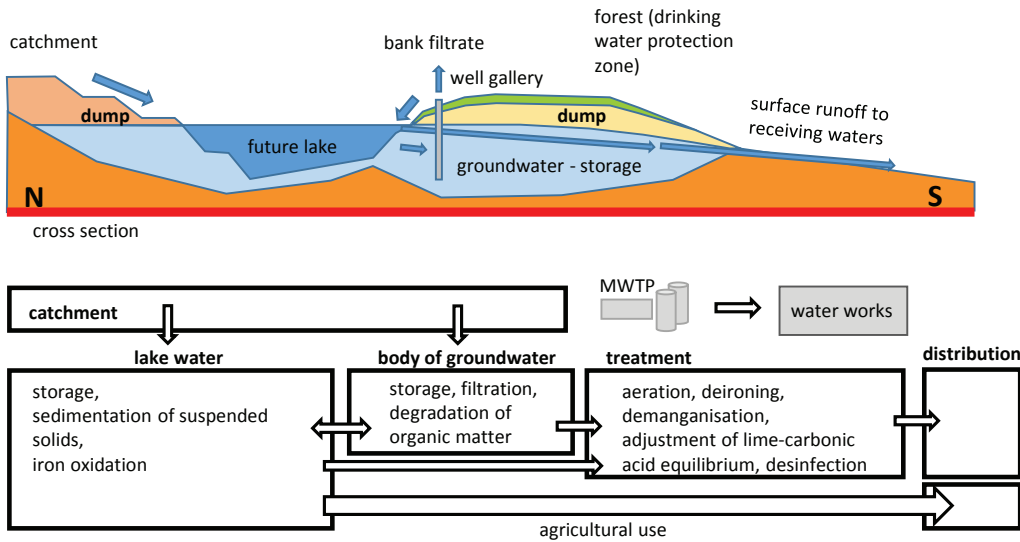


Figure 3 concept for the use of pit lakes and adjoining aquifers as water sources and storages and necessary treatment steps for several purposes

The developed technical concept is suitable for the water management of regions with open pit mining in areas characterised by strong seasonality of precipitation. In mining areas with underground mining problems like the salinization of groundwater occur, thus the water can not be used or has to be treated by cost-intensive technologies. In such cases a well-connected regional water distribution system and appropriate artificial water reservoirs are the basis for the prevention of local water deficits.

### Conclusions

A general technical concept of spatial and temporal coordinated mine water recycling was developed. It will be used to identify suitable measures in a pilot area to improve the water management of the entire Hon Gai peninsula in its current and future stage. Precipitation-runoff, transport process, sediment and groundwater models will be used to quantify the volume of water and sediment resources which can be recovered. The concept will support the adaption of the water infrastructure to the future development and the increasing demands of residents, tourists and the industry.

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