Extension of Measuring Points Network for the Upper Aquifers of RAG Aktiengesellschaft Through the Drilling Pferdekamp

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Abstract

Before the planned rise of mine water, the existing measurement profiles "*Tiefe Pegel Mitte*" and "*Tiefe Pegel Ost*" of RAG Aktiengesellschaft needs to be expanded. Measuring points to monitor the hydrogeological status and the hydrochemistry in different groundwater levels, were created with which the water level before, during and after a rise in the mine water is monitored. For this purpose, the drillings Pferdekamp 1, 2 and 3 with depths of 780 m, 355 m and 90 m respectively were created in Marl, Germany at the former location of the Auguste Victoria mine shaft 8.

Keywords: Groundwater, Hydrochemistry, Hydrogeology, Mine Water

Introduction

The RAG AG mine water concept was design to reduce the locations of the central water management in the Ruhr area with a very high priority to human and environmental protection. The remaining locations are to be converted into well water retention systems. A rise of the mine water level is necessary to enable underground mine waterflow from the individual fields that have been dropped into the central water management system.

The state report on the subject "*Gutachten zur Prüfung möglicher Umweltauswirkungen des Einsatzes von Abfall- und Reststoffen zur Bruch-Hohlraumverfüllung in Steinkohlenbergwerken in Nordrhein-Westfalen, Teil 1*", also supports the evaluation of the RAG experts, that an increase in mine water significantly reduces the PCB emissions. The report deals with the storage of waste in mines under defined conditions. It concludes that waste contact with the increasing water-level, does not cause any detectable increase in substance flow and that a higher mine water level also helps in reducing the substance flow.

The plan is primarily to combine mine water provinces with underground mine water flow with a goal to relieve drainage water, especially the Emscher. The target mine water levels are selected primarily under the premise of maintaining a sufficient safety distance to the usable aquifers. Furthermore, by reducing the number of locations and their new pump levels, energy consumption will be minimized.

To carry out this task, the existing measurement profiles "*Tiefe Pegel Mitte*" and "*Tiefe Pegel Ost*" needs to be expanded. The measuring points are expected to record the hydrogeological situation in the various groundwater aquifers, preferably before, during and after the mine water rises.

Particularly, attention is paid to areas of drinkable water production in the northern part of the Ruhr. *Figure 1* shows the current mine water forecast with increasing water level below the distribution area of the Haltern-Formation. The construction of the new measuring points is planned to be completed in 2025. At that point in time, the mine water level is below the access area of drinkable water production within the Haltern-Formation at about *-800m NN* and in the An der Haard area at *-690 m NN*. Both the planned and existing measuring points should help clarify the question of whether there will be changes in the hydrogeological situation of the various groundwater aquifers during the rise in mine-water level. To do this, the groundwater levels in the respective aquifers must be observed and their chemistry analyzed.

The Pferdekamp boreholes supplements the existing "*Messprofil-Mitte*", which runs in the south-north direction from the

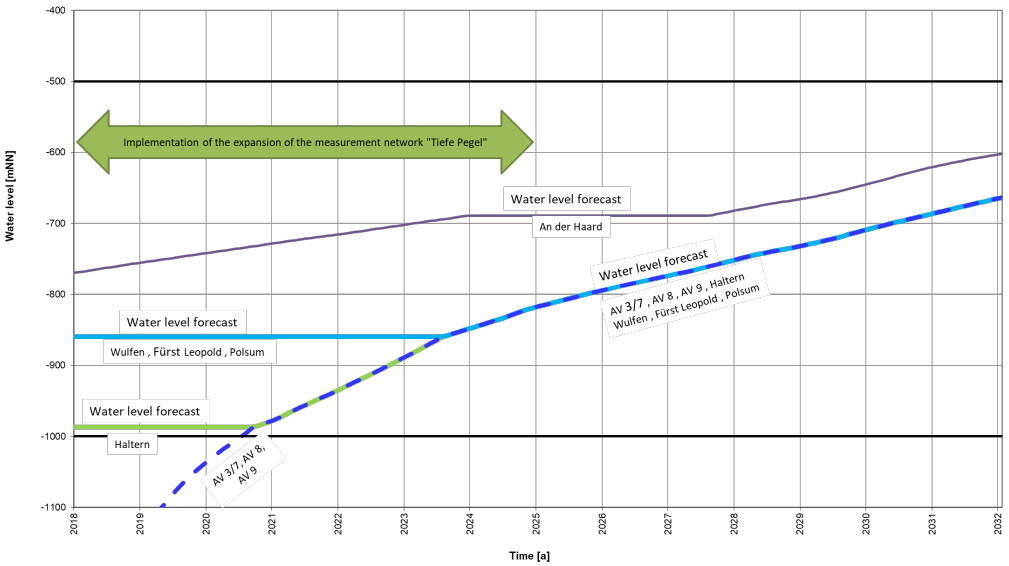

Figure 1 Mine-water level forecast below the distribution area of the Haltern-Formation.

Highway junction BAB A42 and A43 near Herne down to the Herten exit of the A43 Highway near Recklinghausen around the Marl location, in Germany.

Borehole

The boreholes for the groundwater measuring points were made in (Cretaceous-*Marl*) overburden with different depths. The underlying coal-bearing carbon of the hard coal deposit was not drilled as planned. The borehole of ***the groundwater measuring point Pferdekamp 1*** has a depth of 780 m and reaches the layers of the Cenomanium and Turonium of the Upper-Cretaceous (lower groundwater level of the overburden, *Figure 2*).

The borehole of ***the groundwater measuring point Pferdekamp 2*** has a depth of 355 m. The section 170 m to 270 m reaches the lower, fissured area of the aquifer close to the surface within the Recklinghausen-Formation. The groundwater measuring point was deepened to enable hydraulic tests to reach the level of the *Emscher-Marl*, with a non-conductive groundwater characteristic.

The borehole of ***the groundwater measuring point Pferdekamp 3*** has a depth of 90 m and reaches the upper part of the aquifer close to the surface.

To regenerate as much information as possible about the overburden, especially about the Emscher-Formation, while drilling, the *Pferdkamp 1* borehole was cored at a depth of 300 m (start of the Emscher-Formation). The cores are to be examined by the Georg Agricola University of Applied Sciences (THGA) to acquire more information's about the rock properties and permeability. Furthermore, a hydraulic test for horizontal permeability study was carried out in the drilling section of the Emscher-Formation, as well as some geophysical measurements (dual laterolog, electrical resistance, gamma ray, neutron neutron). The results of these measurements shall be linked to the results of the scientific investigations done by Georg Agricola University of Applied Sciences to gain further knowledge about the Emscher-Formation.

Geophysical measurements

The *Pferdkamp 2* bohrhole was drilled to a depth of 355 m. The first section of the drill ended at a depth of 170 m. Since the borehole was not proven stable enough up till this depth, a highly viscous mud with an appropriate density was used throughout the entire drilling operation, which only allows a limited

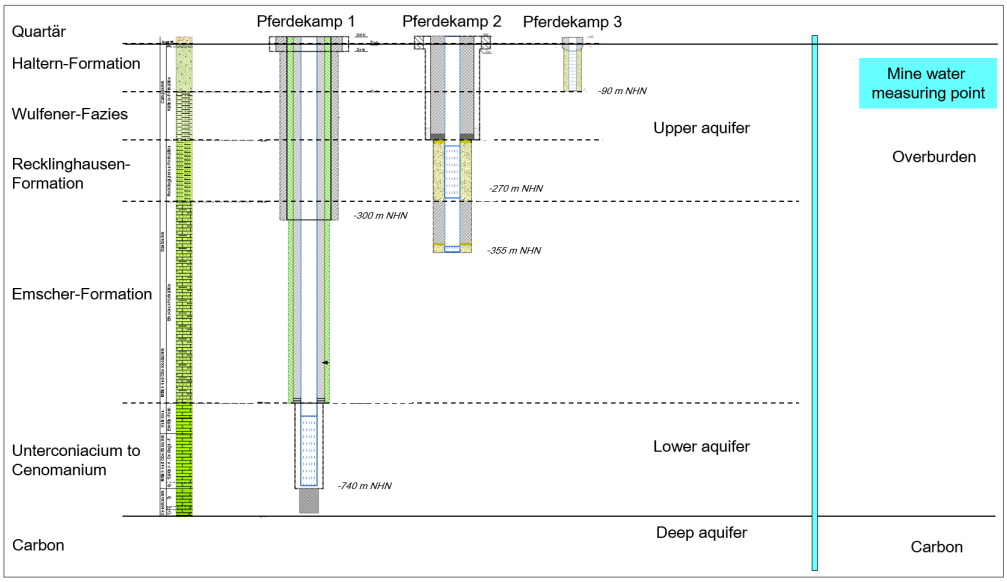

Figure 2 Expansion scheme and depth profile of the boreholes.

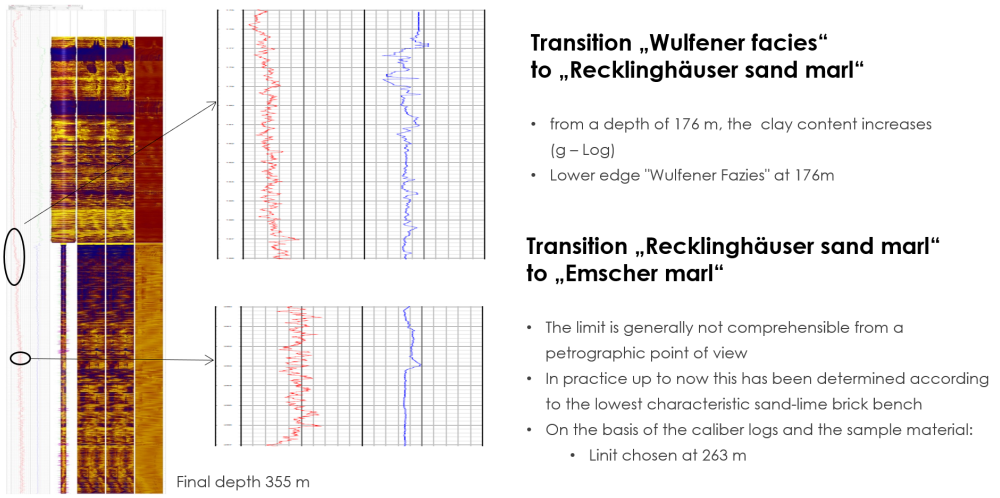

Figure 3 Geophsical result log (GR and ABI) (original LOG DMT, December 2019).

selection of geophysical measurements. To be able to verify the transitions of the different rock packages, the following geophysical measurements were carried out:

- Gamma - Ray - Log (GR)
- Acoustic Televiewer (ABI) with calculated caliber - log (CAL)

After completion of the measuring point, the integrity of the seal in the section 270 m to 340 m (Emscher-Marl section) had to be verified. For this purpose, a Cement Bond - LOG (CBL) was used for the verification in that depth range (270 m – 340 m).

The measurements result shows the following transitions within the rock layers (*see Figure 3*):

- Lower edge “Bottrop marl” at 28.5 m
- Lower edge “Haltern sand” at 98 m
- Lower edge “Wulfener facies” at 176 m
- Lower edge “Recklinghäuser sand marl” selected at 263 m.

The Pferdkamp 1 borehole was cored from *-300 m NHN* to the "*Essener greensand*" at *-780 m NHN* to get a complete overview of the geology at this point and information about the seals of the Emscher-Formation and its barrier effect. The cores were examined lithologically and petrographically and then made available to the Geological Service of North Rhine-Westphalia and THGA for further investigations.

THGA examines the cores with regards to their lithology / sedimentology and petrology. For that purpose, the following geological approaches had to be taken:

- Classical lithological approach
- Sedimentological recording
- Sedigraph / Laser particle sizer (Siliziklastika)
- Petrographic approach

In the petrophysical approach the mineral content, dry density, porosity, and permeability were determined though the results are currently pending.

During the drilling of the *Pferdekamp 1*, the following geophysical measurements were carried out around the Emscher-Formation:

- Dual Laterolog (DLL)
- Electrical resistance (EL-KN / EL-GN)
- Gamma Ray (GR)
- Neutron-Neutron (NN)

The electrical resistance measurements (EL-KN / EL-GN) and the inductive resistances (LLS / LLD) consistently show relatively low resistances of around 6 Ohm/m. The monotonous course of the curve indicates a bit differentiated but homogeneous mountain range. Same phenomenon was observed in the neutron-neutron measurements, which also indicate a homogeneous and monotonous layer sequence. Changes in level in the gamma ray measurements were used to characterize the existing *marl* sequence in detail. Sections were endured, which can be described as much clayey and chalky (*BLM 2020*).

Hydraulic tests

After the geophysical measurements, a single packer test was carried out and evaluated by *Solexperts GmbH* in depth area of about 548 m to 590 m to better describe the hydraulic parameters of the Emscher-Formation in its lower area.

The hydraulic parameters were determined using a multi-phase test procedure. After closing the interval by tensioning the packer, two pulse injection tests were performed. The experimental setup of the test is shown in *Figure 4*.

Cause the results of the evaluated curves vary by two to three orders in magnitude (*Table 1*), an inverse modeling of the measurement data was carried out with a programming tool called n-Sights. The modeling confirms the very low permeability rate of about .

According to *DIN 18130 (1989)*, the layers of the Emscher Marl, between 548 m and 590 m in depth, are classified as very low to almost impermeable. This confirms

Table 1 *Hydraulic test result (from Solexperts, 30.06.2020).*

Test- interval	Depth	Length	Test	T-Value	K-Value	Note
	m bgl	(m)	phase	(m^2/s)	(m/s)	
			PI1	1.1E-08	2.7E-10	A
				8.3E-12	2.0E-13	B
i1	548-590	42	PI2	2.1E-09	5.0E-11	A
				8.3E-12	2.0E-13	B
			n-Sights	**3.1E-11**	**7.4E-13**	-

PK1

Interval i1 => (548.00 -590.10m)

K = 7.4 ⋆10^{-13} ***m/s***

PSR: After installing the test system and including the interval, the pressure rises continuously. An approach to a static pressure level cannot be seen for 3.7 hours.

PI1: After reaching a pseudo-static pressure level after 73 minutes, the interval pressure rises again.

PI2: After approx. 4.3 hours an apparently steady pressure level can be seen again. The interval pressure then rises again continuously overnight, however, without reaching static conditions.

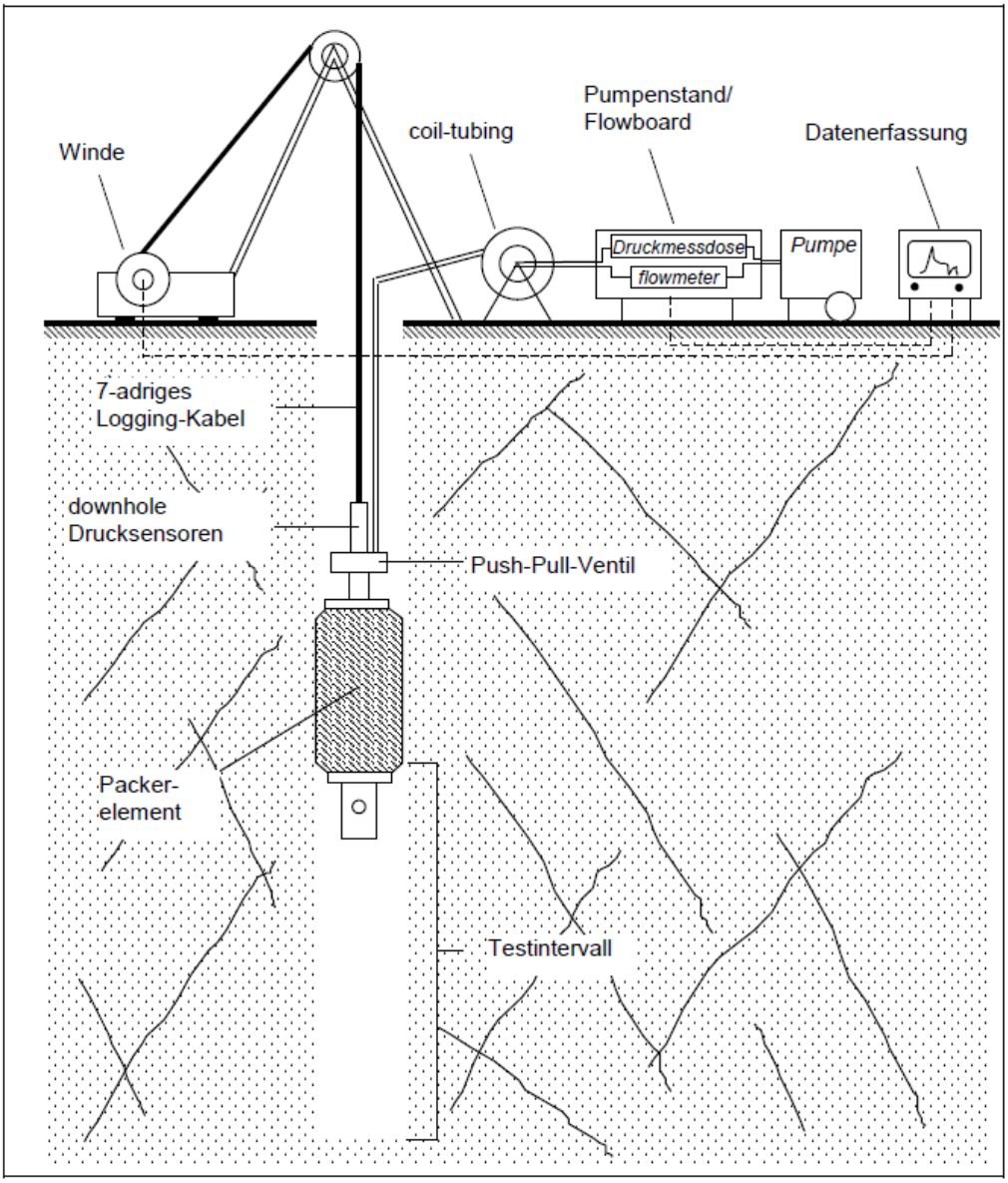

Figure 4 *Experimental setup of the hydraulic test with test equipments (from Solexperts, 06/03/2020).*

the information given in the literature of the Emscher-Formation as a low / non-conductive area.

In the future, a packer test to assess the vertical permeability of the upper section of the *Emscher Marl* is to be carried out at the Pferdekamp 2 measuring point (possibly be done by *Solexperts*, Bochum). For this purpose, in addition to the filter section within 170 m to 270 m depth, the measuring point has been equipped with a further filter section at 340 m to 355 m depth and a circumferential seal between 270 m and 340 m in depth. By placing a single packer at the level of the sealed area, a downward hydraulic gradient can be generated by pumping below the packer.

Based on observation of subsequent time-dependent increase in pressure, taking into consideration the water levels above the packer, a conclusion could be drawn on the vertical water- permeability of *Emscher Marl* in this section.

Conclusion

The Pferdekamp boreholes in Marl, Germany at the former Auguste Victoria Shaft 8 supplements the measuring system of RAG Aktiengesellschaft for observing various aquifers in the overburden, before, during and after the mine water rises. Not only the water level in the respective groundwater aquifers is observed, but also the hydrochemistry.

Furthermore, additional geophysical measurements and a hydraulic test showed that the Emscher formation is a very homogeneous and low to almost non-conductive rock layer.

This result shall be substantiated with a further hydraulic test for the vertical permeability in the upper section of Emscher-Formation and the scientific investigations done by Georg Agricola University of Technology.

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