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TECHNICAL COMMUNICATION

Drainage of the 12th Mining Field in the Handlová Mine (Slovakia)

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Abstract

Most of the Handlová coal deposit is located beneath the central part of the Vtáčnik mountain range. Mining under this mountain range is deteriorating hydrogeological conditions in this area. We evaluated drainage of the coal deposit in the last (southernmost) mining field in the Handlová Mine, where the volcanic strata of the Vtáčnik mountain range are significantly fractured due to their geological genesis and nearby mining. At the same time, there is a significant reduction in the protective overburden clay layer in the 12th mining field, which hydrologically isolates the Handlová coal deposit and the overburden aquifers of the Vtáčnik mountain range.

Keywords Handlová coal deposit · Work safety · Drainage of coal deposits · Vtáčnik mountain range · Inrush prevention

Introduction

Mining first began in the eastern part of the first mining field of the Handlová coal deposit in 1751, but did not expand until 1854. According to data from the Statistical Office, mining represents 1% of total industrial production in Slovaka. Coal and lignite are also produced, but such mining is decreasing in Slovaka. The largest coal producer in Slovakia is "Hornonitrianske bane Prievidza, a. s," which in 2018 produced more than 1.5 million metric tons of brown coal from three underground mining areas (Handlová, Nováky, and Čáry), for energy purposes (Manová et al. 2019).

Construction of the existing Handlová Mine only began in 1909. The actual coal deposit is delimited by the villages of Veľká Lehôtka, Cigeľ, Podhradie, Nová Lehota, Handlová, and Morovno (Fig. 1). The Handlová coal deposit currently has two designated mining areas (Handlová and Cigeľ).

The original Handlová mining area was designated in 1959 by the Ministry of Local Fuels and Oil Industry for Slovakia. The current mining area (≈48.7 km^2) was determined by the Federal Ministry of Fuels and Energy in Prague in 1981 (Vondráček et al. 1982). The 12th mining field is located in the southernmost part (Fig. 1) of the Handlová Mine (Beck et al. 2009).

Geological Conditions

The strata underlying the coal deposit is represented by alternating positions of epiclastic volcanic conglomerates and sandstones with irregular to lenticular bedding (Kamenec Formation). These are the redeposited products of the underlying volcanism of tuffite development and can be observed all around the perimeter of the Handlová coal deposit. The material's composition points to the Badenian stratovolcanoes of the Štiavnica and Kremnica hills as its source (Beck et al. 1994). The Kamenec Formation transitions gradually into the Handlová Formation (Fig. 2), which in this area is represented by a 5–7 m thick continuous coal seam, which decreases in thickness to the south. The calorific value of the seam reaches 15–18 MJ•kg^{-1}. The maximum carbonization of the seam is connected to tectonically mobile zones (Beck et al. 1994).

A 30–110 m grey clay layer (the Koš Formation) directly overlies the coal seam. It consists of pelitic sediments with a layered structure (Kolarovič 1972). The thickness of these overburden clays in the 12th mining field increases from west to east, and is also affected by erosion. The

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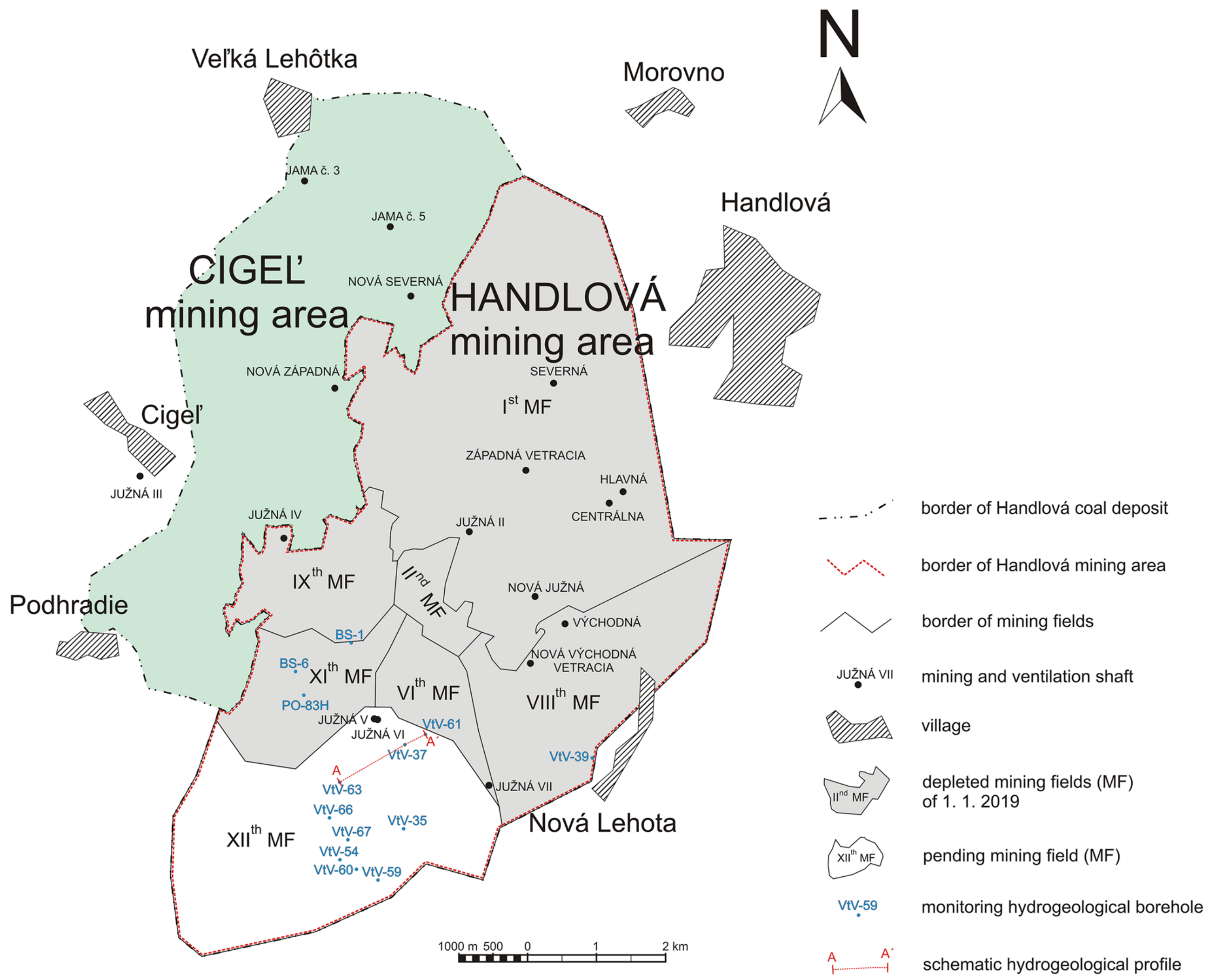

Fig. 1 Geological position of the Handlová coal deposit, with adjacent villages

physico-mechanical properties of these clays were determined in the Handlová Mine using approved methodologies (Beck et al. 1994). The results show that these clays are susceptible to disintegration; this was confirmed using overburden samples collected during drilling of hydrogeological wells.

Tectonic disturbance associated with volcanic activity followed deposition of the Koš Formation (Šimon et al. 1991). This tectonic disturbance resulted in the breakup of already deposited sedimentary and volcanic formations, which is verified in the Handlová coal deposit (Šimeček 1980). The tectonic disturbance caused uneven erosion of individual blocks and the Lehota Formation discordantly preserved on Upper Badenian to Lower Sarmatian strata. The Lehota Formation evolved in a river environment, in paleo-valleys with a N–S direction (Hók et al. 1995) and has a very diverse lithological and granular composition, with frequently alternating clay, sandstone, and plum-pudding stone.

Above the Lehota Formation are volcanic strata (the Vtáčnik Formation): andesite breccia and andesites (Kolarovič et al. 1974). These strata have a wide range of hydrogeological properties, associated mainly with fractures in the rock massif, generally caused by regional tectonics (Škvarka 1975). The Vtáčnik Formation results from explosive-effusive, and ultimately only effusive, volcanic activity. The northern and western part of this formation is built by andesite gravels and conglomerate towards the south of the 12th mining field, reaching up to 500 m thick. A drilling survey (from a mine working) in the area of the 12th mining field to a depth of 100 m found no volcanic strata, minimizing the risk of a water inrush. However, an underground well drilled for drinking water verified the presence of the Vtáčnik Formation strata in the 12th mining field. The overall thickness of the overburden reaches 500–670 m in the 12th mining field (Fig. 3).

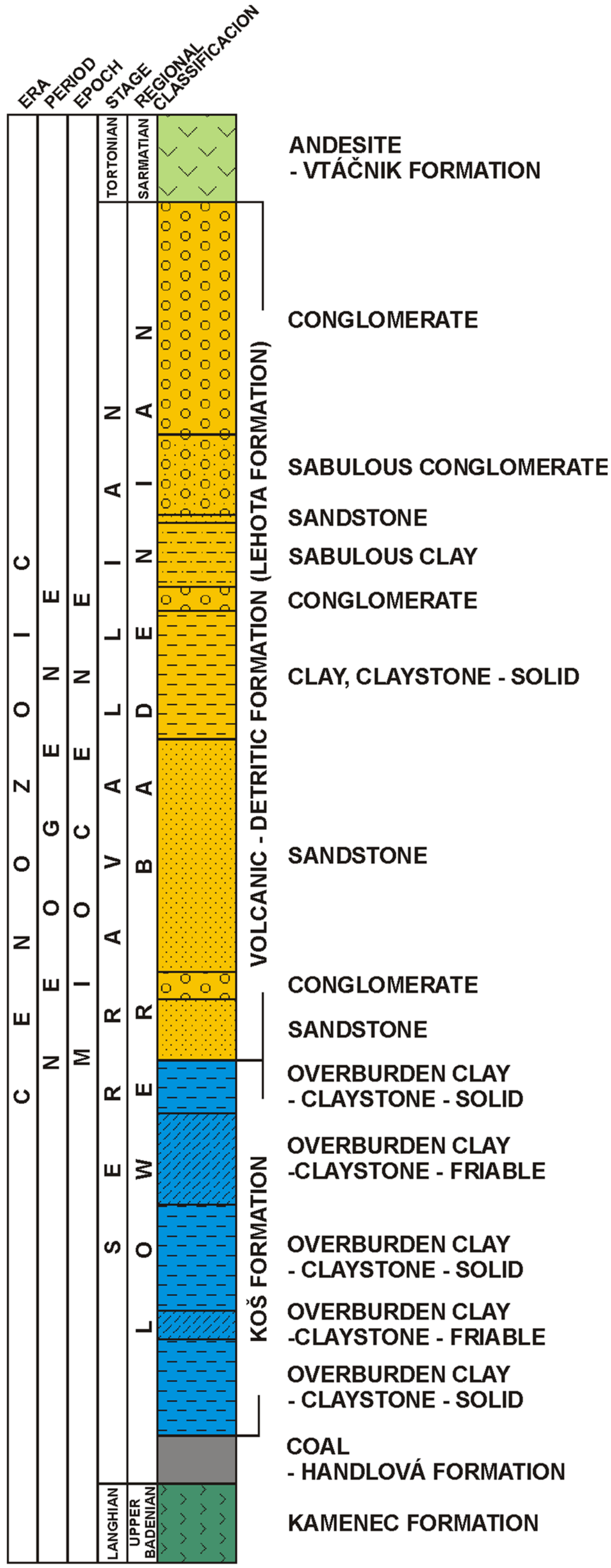

Fig. 2 Segmentation of the overburden formations

Hydrogeological Conditions

Two hydrogeological units are designated in the 12th mining field (Beck et al. 1994), one above and one below the coal seam. The underlying hydrogeological unit is formed by strata of the Kamenec Formation, which is only slightly permeable and contain little water. Possible water leaks are mainly related to tectonic zones. The entire underlying aquifer system is characterized by a static water level. The hydraulic conductivity, determined at tests performed at surface and underground boreholes, spans 10^{-6}–10^{-8} m·s^{-1} (Beck et al. 1994).

The overburden hydrogeological unit is represented by two aquifers. The first aquifer horizon is represented by strata of the Lehota Formation with fracture, interspan, or combined permeability. Volcanic-detritic strata rise to the surface in the area of Nová Lehota and the northern part of the Cigeľ mining area (Fig. 1), where there is direct infiltration of atmospheric precipitation.

The volcanic Vtáčnik Formation is the second aquifer system, with very good fracture permeability, mostly in the vertical direction. Strongly cracked andesites form the top parts of the Vtáčnik mountain range, which are highly water-saturated, with a hydraulic conductivity from 10^{-5} to 10^{-6} m·s^{-1}. Andesites (continuous lava flow) create a semipermeable environment between the pyroxenic andesites and the Lehota Formation, which has a hydraulic conductivity of 10^{-8} m·s^{-1} (Beck et al. 1994).

Both horizons are hydraulically interconnected. Experience shows that their hydraulic interconnection increases directly in proportion to the amount of mining in the area. This was also detected in the northern part of the 12th mining field (Fig. 4) (Mečiar et al. 2017).

The catchment area for infiltration of atmospheric precipitation into the overburden is the entire surface area of the Vtáčnik mountain range. The inclination of the collector rock base is from north to south, which also represents the main direction of groundwater flow.

There is more groundwater in the overburden than below the coal seam. The water in the sandstones and limestones of the Lehota Formation is more alkaline and are characterized as sodium-calcium bicarbonate type, with mineralization of 336–656 mg·L^{-1} and a pH of 7.3–8.8 (Beck et al. 2009).

Influence of Regional Tectonics on the Hydrogeological Conditions

Deep tectonic fracture zones are the most important groundwater collector in the Vtáčnik mountain range. In addition to draining their surroundings, they also enable

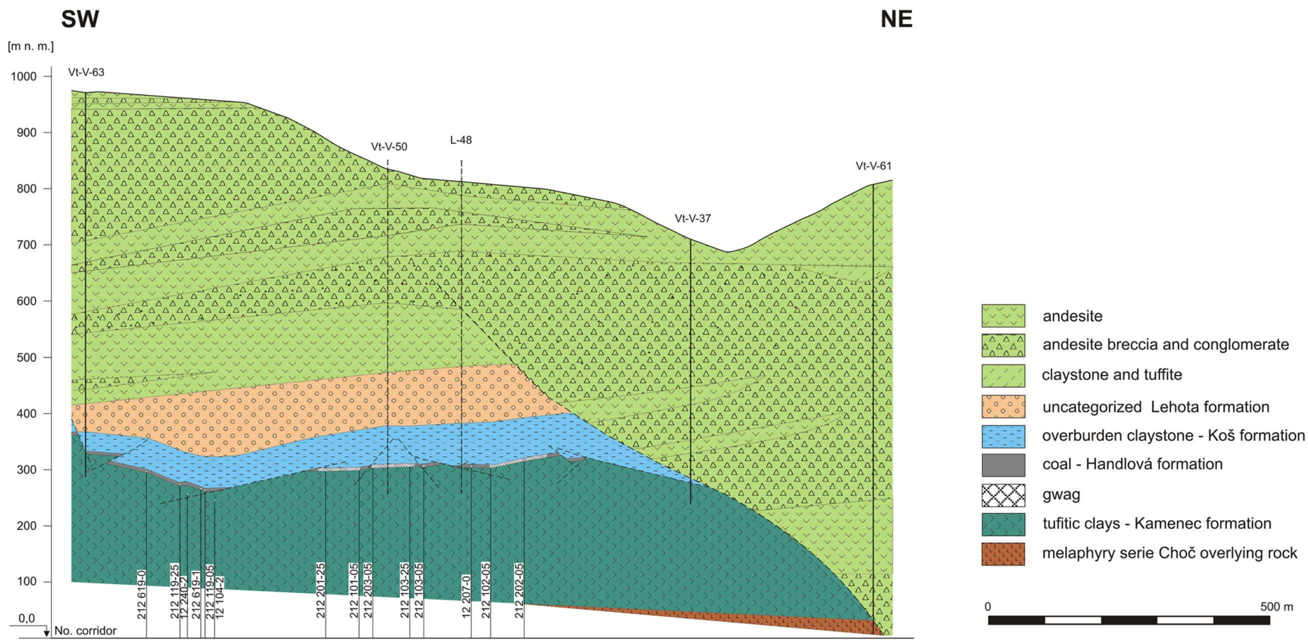

Fig. 3 A schematic geological profile across the northern part of the 12th mining field of the Handlová Mine

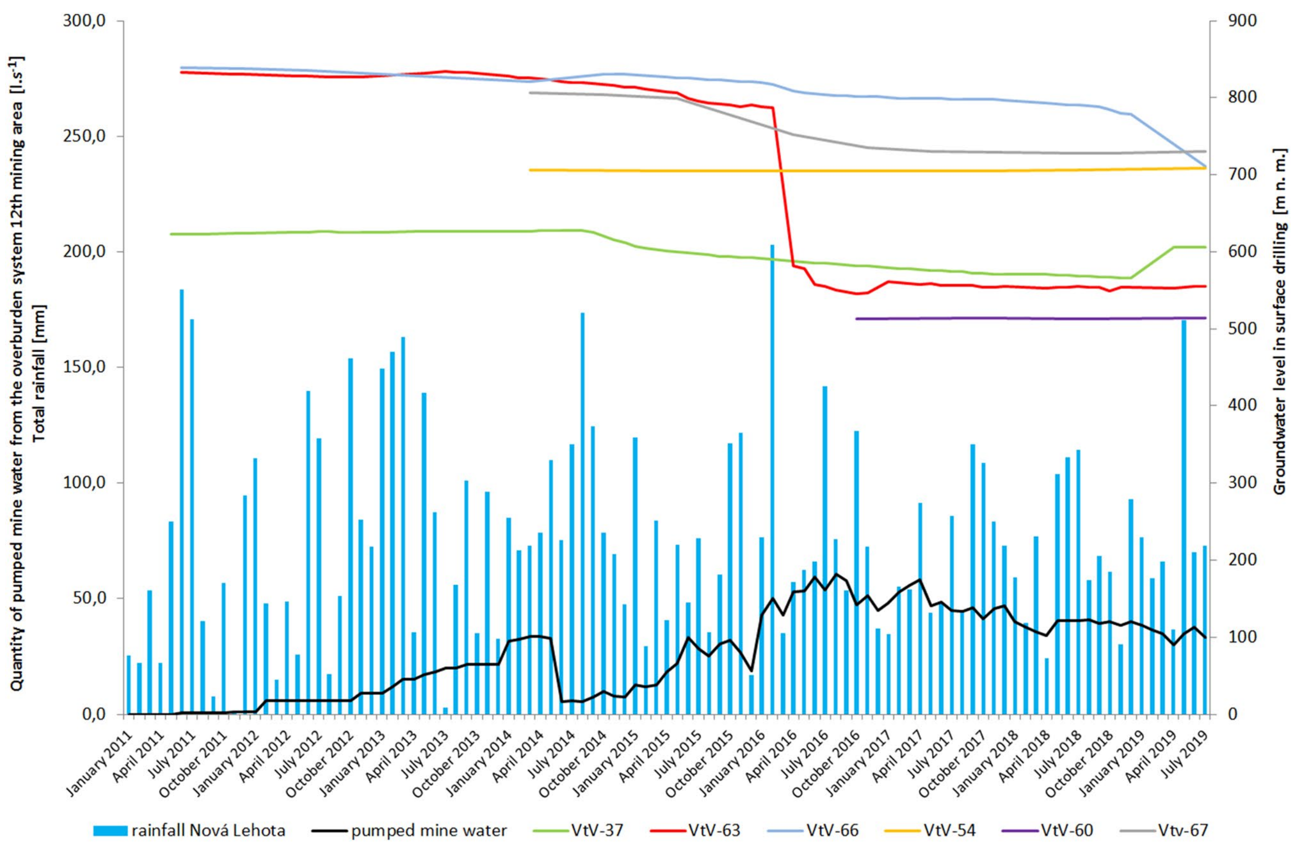

Fig. 4 Effect of monthly pumping of overburden water and total precipitation on groundwater levels in surface boreholes drilled in the 12th mining field of the Handlová Mine, for the period January 2011 to July 2019 (Modified from Mečiar et al. 2017)

groundwater communication over long distances. The predominant direction of regional tectonic fractures is in the NE–SW direction. These fractures also permit the interconnection of several aquifers (Franko et al. 1997). Wells drilled through these fractured zones in the valleys of the Vtáčnik mountain range are often very productive. Examples of such a phenomenon are surface drillings VtV-35, VtV-39, and VtV-54 (Table 1), where the inflow is still recorded. The position of these boreholes is apparent from Fig. 1.

Dewatering of Overburden in the 12th Mining Field

The Handlová coal deposit is very complicated hydrogeologically, and is potentially susceptible to water inrush. Hydrogeological exploration and dewatering of the deposit are important for mine safety. In compliance with the provisions of the Decree of the Slovak Mining Office in Bratislava no. 21/1989 Coll (Slovak Mining Office 1989) and of the Arrangement of the District Mining Office in Prievidza no. 2000/1989 (District Mining Office in Prievidza 1989), as well as other legislation, the Prievidza District Mining Office decided that the impermeable clay layer in the overburden of the Handlová coal deposit provided sufficient safety when it was at least five times as thick as the coal seam and at least 30 m thick. This was determined based on a relationship (Eq. 1) of the magnitude of chaotic collapse (Kubica and Kroul 2013):

$$h_z = \frac{m}{k_0 - 1} = \frac{m}{1.2 - 1} = 5m \tag{1}$$

where h_z = height of the overburden (m), m = seam thickness (m), and k_0 = loosening factor. Given the balance power of the seam, the leavening factor in the denominator is reduced by one. In the past, a 6 m seam thickness was considered to be the maximum amount possible to be mined at one time, and the tilting coefficient of 1.2, which was considered general, would give exactly five times the balance power (i.e. 30 m) for the caving height.

Since the thickness of the overburden strata in the 12th mining field of the Handlová mining area (500–670 m) does not allow pumping of water through surface boreholes, hydrogeological exploration and dewatering of the deposit is concentrated exclusively underground (in the mining environment). Water flowing from individual hydrogeological wells and other drainage objects are concentrated in sump pools and pumping stations (auxiliary and main), where they are subsequently pumped to the surface. This dewatering method has been functioning well since mining of the coal deposit began (Fides et al. 1987).

Table 1 Measured inflow rate on surface boreholes situated in tectonic lines from 2015 to 2019

Borehole marking	Inflow rate (L·s^{-1})				
	2015	2016	2017	2018	2019
VtV-35	1.29	1.86	1.7	1.43	1.5
Vtv-39	0.035	0.04	0.035	0.003	0.02
Vtv-59	drip	0.003	drip	drip	drip

Monitoring of water levels in surface boreholes since May 2011 has demonstrated the mutual relationship of the overburden aquifer system with precipitation and drainage in the 12th mining field of the Handlová Mine. These measurements are carried out at least once a month by the hydrogeological service of the Hornonitrianske bane Prievidza mining company.

Overburden dewatering usually has only a local effect on the groundwater level. The groundwater level in surface boreholes is significantly affected by mine dewatering, especially when a working face in the 12th mining field is carried out near a surface borehole. Such a condition is particularly noticeable in surface boreholes VtV-63 (February 2016) and VtV-66 (January 2019). Boreholes VtV-54 and VtV-64 were drilled in the SE part of the 12th mining field of the Handlová mining area (Fig. 1). As is evident, their distance from mining was sufficient to prevent any significant effect.

The VtV-63 borehole in February 2016 (Fig. 4) documented the hydraulic interconnection of the two aquifer horizons of the overlying hydrogeological unit. This occurred during extraction of working face no. 212 002-95, which was highly mechanized. The “Schramming” method, which is used in the Handlová coal deposit, allows interconnection of overburden aquifers. There is no other part of the Handlová coal deposit overhead aquifer system drained so intensely, because the Kos Formation clays provide sufficient passive protection against floods and aquiferous rocks.

Mines always have a drainage effect on their wider surroundings, and can create significant local changes in groundwater flow directions. Due to the intensive drainage of the coalface area to prevent water inrushes, the overburden is depressed and the direction of groundwater flow changes. The service life of drainage corridors and boreholes, which are located close to individual coalfaces, is limited. Occasionally, these drainage ways are adequately replaced by the drainage provided by already mined areas. After consolidation of the overburden strata has been achieved, the groundwater regime gradually returns to normal (Fig. 5).

Conclusion

Active and already extracted mine workings significantly influence groundwater flow. The overburden of the coal seam in the Handlová mining area represents a well-collapsing

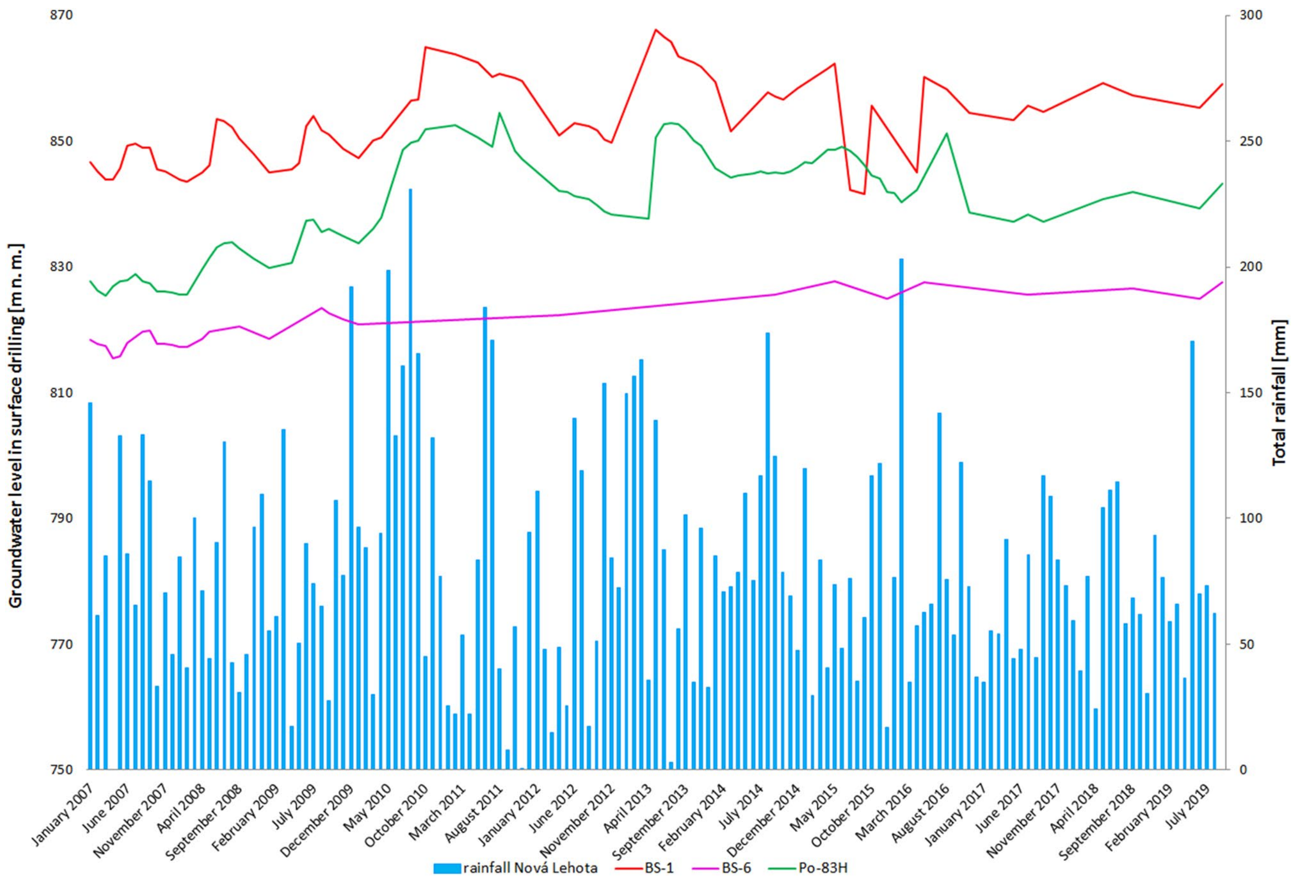

Fig. 5 Graph of groundwater recharge dependence on total precipitation (Modified from Mečiar et al. 2019)

type of overburden with continuous bending in space and time. In the area of the 12th mining field of the Handlová coal deposit, there was a significant reduction of overlying clays (the Koš Formation), which act as an insulator between the productive coal formation and the overlying aquifer system. Therefore, the overburden system intensely drained by boreholes from the tunnels excavated in the stone formation or coal seam and through the shaft of pits J.V and J.VI (Fig. 1). The mining works lie directly in the coal seam or in the upper third of the thickness of the underlying aquifer system. There are drainage boreholes that drain the overburden aquifer system and thus create a highly efficient gravity drainage system without the use of pumping equipment in wells.

The overburden aquifer system is most intensely drained by boreholes during active extraction. Some of these drainage boreholes remain intact and continue to function after mining. Regular regime measurements measure groundwater level changes in surface boreholes. Based on these measurements, it is possible to present the relationship of the overburden system to drainage efforts in the Handlová coal deposit during (Fig. 4) and after mining (Fig. 5). The intensive drainage of the overhead aquifers has caused a causes a change in the direction of groundwater flow. The main direction of groundwater flow affected by rock base inclination in the Handlová coal deposit is in the N–S direction.

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