Assessing of planed inflow and water quality for the closing down mines: example Niwka – Modrzejów Mine

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Abstract: The author refers to projects of closing down of a mine in the Upper Silesia Coal Basin and describes a method of the assessment of the planed inflow and quality of water which will be pumped after partial flooding of the underground workings. The forecast has been prepared basing on the many-year of analysis of the quality and quantity of water and, methods of mining operations applied in the said mine in consideration with the planned changes in the main drainage system. Hitherto the projects of closing down a coal mine have concentrated mainly on the assessment of the safety conditions in mines neighbouring this mine. However the more frequent idea of changing the existing water – drainage station with submersible pumps requires detail defining of the groundwater regime which occurs after the partial flooding of the underground workings. The forecast of the quality and quantity of water in the closing down mine described in the article may be useful not only to asses the scale of the danger in neighbouring mines but also for making the optimum selection of the submersible pumps along with their piping system. The forecast enables also to precise the additional scope of works which have to be done in order to obtain the permission for feeding the drainage waters from the closing down mine into the surface water system.

1 INTRODUCTION

One of the crucial factors which have an impact on the safety of the underground mining, environmental protection and costs connected with the extraction of hard coal in the Upper Silesia Coal Basin is the matter of correct drainage of the closing down coal mine. In the said region most of the coal mines have connections between the being current workings and old workings. Unfortunately as there is no access to the isolated goafs it is impossible to define clearly the hydrogeological parameters for possible groundwater flow. The approved conceptions of closing down of many coal mines assume the flooding of the parts of unnecessary underground workings together with changing of the existing system of main drainage. This assures the required safety for the other coal mines operating in the vicinity of the closing down mine. The change of the many-year existing drainage system requires from hydro-geologists not only to define the time schedule for flooding the excavations but also to estimate the quantity and quality of water which will be drained from the closing down coal mines after its total or partial flooding. The data gathered at coal mines since mid – 1960's which refer to quality and quantity of water inflow to underground workings may be useful to elaborate a forecast of water inflow and its quantity in hydrogeological reports. These reports are to be prepared in case of the change of a drainage system for a closing down coal mine. The trial of such forecast was prepared on the basis of the hydrogeological report which determined the groundwater resources captured by underground workings in the closing down „Niwka Modrzejów" coal mine.

2 THE CHARACTERISTICS OF THE CLOSING DOWN COAL MINE

Hard coal deposit of the closing down coal mine has been mined since 1810. At first only shallow coal beds near their outcrops were extracted. Up till 1945 numerous small mines have extracted coal in the northern parts of mine field, using with fall of roof. After 1945 the extraction has been continued in three areas: (that is) shallow coal mining in the northern region – Niwka and southern region – Modrzejów and, in the separate parts of the deposit belonging to the other mines and namely to„Jan Kanty" mine, in the dip – headings belonging to „Jęzor VI" mine and „Brzęczkowice" mine in the south mine, using partially the hydraulic filling technique (Figure 1). In course of time when deeper and deeper coal fields were extracted and the extraction of the shallow coal fields were abandoned. Together with deeper extraction new systems of main drainage were built. These new drainage systems were located at the level of 80+100 m (+170 and+150), 130 m (+120), 220 m (+30) in the „Niwka" region; 430 m (-180), 600 m (-350) and 910 m (-660) in Modrzejów region and 185 (+60 m) in hard coal mine incline „Jan Kanty" (Figure 2).
The 80+100 m and 130 m levels were closed down in the last decade and water from these levels was disposed to the deeper drainage levels. Between 1992 and 1999 the disposals from power plants such as dust, slag-dust and granulated slag were used to seal workings as well as to shut down shallow goafs or to make hydraulic filling.

In the programme of closing down of subject coal mine, prepared 1999, two alternatives of further drainage of the „Niwka Modrzejów" mine underground workings have been elaborated; both of them will allow to maintain the groundwater table on the depth of 390 m (-145 m). This depth has to be preserved in order to guarantee the safety of operating the neighbouring „Mysłowice" coal mine. Far more shallow are hydraulic connections of the mine with goafs of the „Kazimierz – Juliusz" mine (-101 m) and „Jan Kanty" mine (+60 m). The aforesaid alternative programme assumes:

– Further operating of the existing drainage pumping stations at the levels of 220 m and 430 m which will allow to de-water goafs down to - 192 m,
– Turning one of the shafts into a deep – well in which suspended pumps will be installed to keep the flooded working drainage goafs below the - 145 m level.

A method of drainage the incline of „Jęzor VI" mine whose underground workings are connected through the Eastern shaft with deeper lying goafs of the

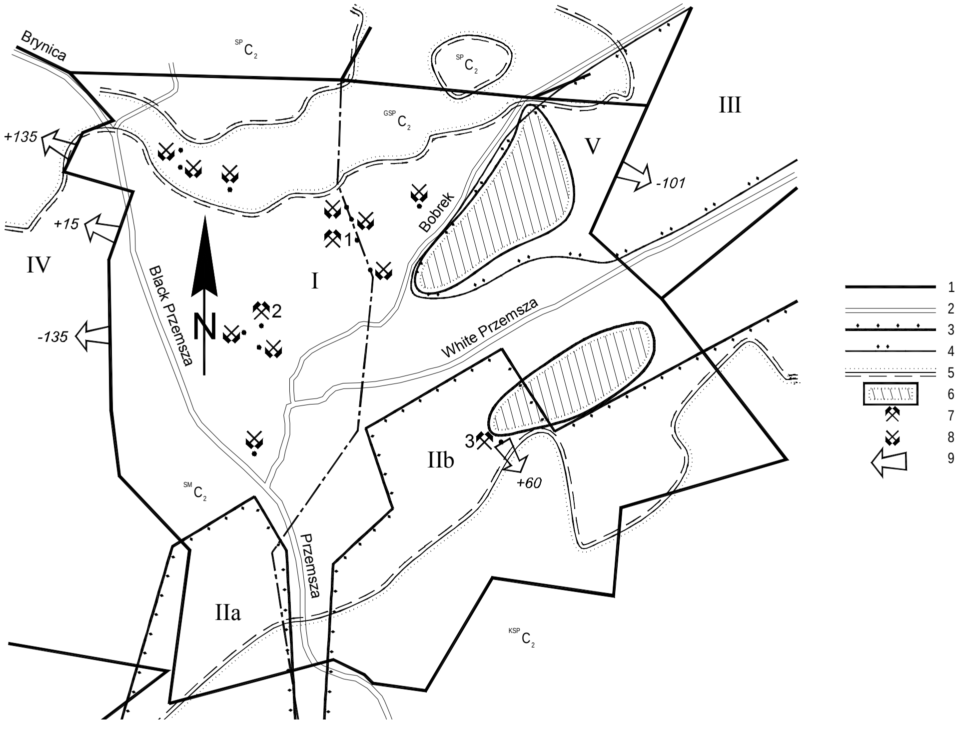

Figure 1 Map geological and developed mine
1 – border area coal mine (I – Niwka Modrzejów, III – Kazimierz Juliusz, IV – Mysłowice); 2 – rivers and streams; 3 – border area incline mine (IIa – Brzęczkowice, Iib – Jęzor VI); 4 – border area open mine (V – Maczki – Bór); 5 – boundaries and stratigrapfic symbols: $^{KSP}C_2$ – Cracow Sandstone Series, $^{SM}C_2$ – Mudstone Series, $^{GSP}C_2$ – Upper Carboniferous Sandstone Series, $^{SP}C_2$ – Paralic Series; 6 – barren rock waste sites; 7 – active shafts; 8 – liquidated shafts; 9 – hydraulic joint mines.

closing down mine has not been decided yet. At present the de-watering of the underground workings of the above mentioned incline are being performed by the „Jan Kanty" mine. Projects assume the building of either watertight dam or hydro-insulating plug of the appropriate toughness.

On the other side, the goafs of the incline „Brzęczkowice" have been flooded since 1985 and they have no connection with the existing goafs of the closing down mine. Water inflow from the active „Kazimierz – Juliusz" coal mine is not being anticipated either.

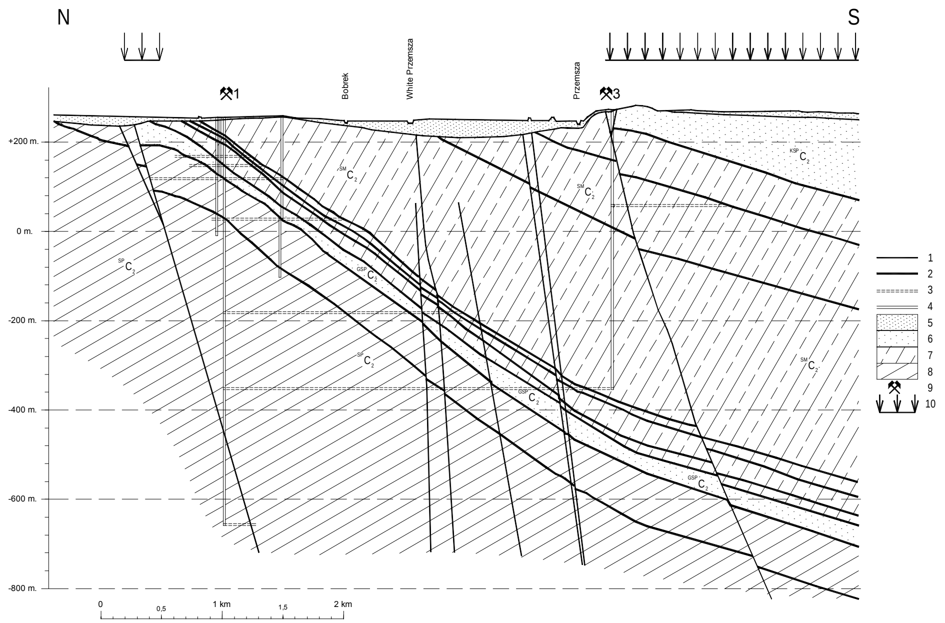

Figure 2 Hydrogeological cross-section
1 – faults; 2 – beds; 3 – dewatering levels; 4 – shafts; 5 – Quaternary; 6 – Upper Carboniferous Cracow Sandstone Series and Upper Carboniferous Sandstone Series; 7 – Mudstone Series; 8 – Paralic Series; 9 – active shaft; 10 – area of direct and indirect recharge to the usable aquifers.

3 LAND DEVELOPMENT AND HYDROGRAPHY

The closing mine is situated in the eastern part of the Upper Silesia Coal Basin, in Mysłowice Valley, for which typical are substantial antropogenetic changes caused by many-year extraction of hard coal and packing sand. Sand deposits were mined in many open casts. Having completed the extraction of some of them, they were covered up with barren rock from hard coal mines and were transformed into forests or industrial areas. At present barren rock is located in active underground workings of „Maczki Bór" sand mine. The described area is covered extensively with road and railway system along with plenty of individual or, older rental houses. The Przemsza river – left side inflow of the Wisła river is the main hydrographical element of this area. The river is composed of two inflows: White Przemsza and Black Przemsza as well as its in-flowing streams Bobrek and Brynica (Figure 1). Most of the surface watercourses have regulated and sealed beds thus resulting in very minor inflows to open cast sand mines. Most of the watercourses carries both urban and coal mine sewage. The water system of the White Przemsza is by far less contaminated than the Black

Przemsza hence the groundwater intakes of potable water are still open in the valley of the river.

4 AN OUTLINE OF GEOLOGICAL STRUCTURE

Carboniferous formations of the area are situated on the southern part of the main basin of the Upper Silesia Coal Basin. Their angle of inclination towards South ranges from 5° to 18° and they are cut by a number of faults which are the natural mining borders from the northwest and the east sides. Carboniferous formations consist of a complete profile of sediments from Namur A to Westfal B which is composed of claystones and sandstone and mudstones with layers of hard coal. These sediments are covered with formations of Quaternary formations of different seam thickness like fine and coarse sands, sand – gravel mixed interbedded with clay and loam. Quaternary sediments lie mainly on lower parts of the river valleys where their seam thickness reaches up to ~ 50 m.

5 GROUNDWATER REGIME

In hydrogeological cross-section of subject area there are water bearing horizons carrying water through Quaternary formations and Carboniferous formations (Figure 2). Quaternary is located mainly in the river valleys, where highly accumulated seam thickness of Quaternary formations exists. The groundwater regime is of the variable type and depends on the seam thickness and on the litological formation of the deposits. Water-bearing are fluvial deposits, glacial deposits and moraine sands. In one cross-section of the bed there are up to three water–bearing levels which are locally de-watered due to the draining activity of coal and sand mines. These levels are hydrogeologically partly opened and represent the porous character of the medium. Water of these levels is usable and their average mineralisation reaching up to 500 mg/dm^3. They contain low chlorides (~ 50 mg/dm^3) and are rich in sulphates (up to 136 mg/dm^3). Only in places where coal washings are being laid, the mineralisation of water is higher (up to 1200 mg/dm^3) and the water contains more chlorides (up to 200 mg/dm^3) and more sulphates (up to 300 mg/dm^3).

In the Carboniferous water – bearing horizon, four main complex of rocks with different percentage of water permeable rocks can be identified. They have their outcrops in subject area. The first water – bearing complex is the south-east located floor part of Crakow Sandstone Series (CSS) for which typical is the majority of thick bed sandstones (up to 80 %) with high permeability. These deposits lie under the Mudstone Series (MS) of substantial majority of the impermeable mudstone (up to 70 %) over the sandstone. Beneath this complex there is second water – bearing Carboniferous complex – the Upper Carboniferous Sandstone Series (UCSS) in which sandstone (~ 70 %) and pudding stone dominate. The UCSS formations lie on the Paralic Series (PS) built mainly of impermeable claystone.

The above mentioned rock complexes of the productive Carboniferous formations contain the separate groups of vertical fissure water-bearing levels which are connected with pudding stone and sandstone.These complexes are, at subject area, locally linked together, mainly due to the mining activity, but also due to the tectonic moves as well as the local pinching of strata of sediments. Carboniferous levels are fed with water mostly near their outcrops or through permeable overburden.

Extractions located in the northern coal mine at the 220 m depth and, in the southern coal mine on the depth of 910 m form the base for groundwater drainage. The physical and chemical properties of water from these levels are significantly diversified. At one side this results from the mineralisation which increase together with the depth and, at the other side, from the demineralisation of water as a result of drainage, being a part of mining works, as well as due to change of its chemical composition as it flows through old workings.

6 THE VARIABILITY OF WATER INFLOW AND WATER QUALITY DURING MINIG

Just like in other coal mines the quantity and quality of water which flows to mine extractions was determined in different groundwater measuring points. The location of these points changed as mining operations proceeded. The described coal mine operated with hydraulic filling and due to this reason and also as a result of pumping the water from deeper levels, the data on water quantity and quality bore a remarkable error. The hydrogeological report Kotlicka (1999), basing on the quantity-and-quality data from the spot water measuring at different mine underground workings, the sum-up of the gravity water inflow from upper levels to the main de-watering level has been determined.

To calculate the quantity of water inflow to the individual level, the inflow known from respective water measuring points was summed up, and to determine the quality of the inflow water, weighted averages for each water levels were calculated; the flow of water at each point was taken as the weight. Such made calculations allowed to assess the inflow of water to individual levels between 1970 and 1999. It can be seen out of the analysis of the changes of the water inflow to individual levels, in consideration with the underground workings works performed and the average annual rainfall, that in this period of time the total quantity of inflows varied between 10,7 m^3/min – 18,0 m^3/min and was dependent on rainfalls to the very low extent (the correlation coefficient equals

0,38). The variations of water quantity which flows to each level are illustrated on Table 1.

Table 1 Variability of water inflow to underground workings of the closing down mine in years 1970 – 1999

Region	Niwka area			Modrzejów area		
Level [m]	80+100	130	220	430	600	910
Q_{min} [m^3/min]	1,7	0,7	3,5	1,3	0,4	0,0
Q_{max} [m^3/min]	3,1	1,8	8,8	3,8	2,6	0,6

Three fourth of the total inflow to the mining extractions were captured at the three shallowest levels 80+100 m, 130 m, and 220 m in Niwka area and the balance water inflow came from deeper levels in Modrzejów region. It should be stressed that the correlation coefficient between rainfalls and water inflow in Niwka area and to 430 m level in Modrzejów area was higher and reached the value of 0,53. This result coincides with the fact that outcrops of UCSS are located in the northern part of the coal mine and there is intensive water infiltration from rainfalls in the area which is described by Różkowski (1996) as deprived of useful water degraded by active coal mines. Kotlicka (1999) however, recognised this area as the region of UCSS feeding, whose size is assessed to be 14,5 km^2. At 600 m and 900 m levels which are insulated from the watered Quaternary deposits with the impermeable MS formations the variation of water inflow evidenced in the Table 1 is the result of different intensity of mining operations in the new accessible parts of these levels and of fluctuant inflow connected with drainage the accessible parts of the deposit.

Throughout the a.m. years the changes of physical and chemical composition of the inflow were substantial. In order to demonstrate the degree of these changes the variation of mineralisation expressed by the dry residue of water at each level has been shown in the Table 2.

Table 2 Variability of dry residue of water inflow to the closing down mine in years 1970 – 1999

Region	Niwka area			Modrzejów area		
Level [m]	80+100	130	220	430	600	910
M_{min} [g/dm^3]	0,9	3,2	1,9	2,5	21,0	66,2
M_{max} [g/dm^3]	3,3	9,9	3,6	22,2	162,2	230,7

This juxtaposition evidences the growth of the water salinity along with the depth. On the other hand, when analysing the change of the quality of water in the pass of time, referring to individual levels one has to state that along with the intensification of mining works, gradual freshening of water was observed at individual levels. Water inflow to underground workings of the closing down mine may be divided into two hydro-chemical groups. Water from shallow levels (Niwka area) is mainly brackish water or sporadically salt water in which sulphate ions prevail hence it is acid water (pH ~ 4,2). Water from Modrzejów area is brackish water or strong brine water in which chloride ions prevail and the quantity of sulphate ions lowers along with the depth and therefore it has low acid reaction (pH ~ 6,0).

7 THE FORECAST OF INFLOW VARIATIONS AND WATER QUALITY AFTER THE MINE IS CLOSED DOWN

In order to prepare the forecast of water inflow to the mine the accepted conceptions of closing down have been considered and this is why the assumed water inflow has been estimated applying two different methods. As far as levels of 220 m and 430 m are concerned the forecast was prepared on the basis of the inflows in years 1970 – 1999 using the trend method of inflow expressed by exponential equation, recommended by Rogoż (1987).

$$Q = a \cdot t^b \qquad [1]$$

where:

Q – inflow to level [m^3/min],
a, b – coefficient of equation,
t – time [years].

The inflow determined using the method, for 10 years after the mine has been closed down shown minor variation equal to ~ 8,3 m^3/min for the level of 220 m and~ 2,9 m^3/min for the 430 m level. These calculations had very low confidence levels: 0,10 for the forecast of water inflow to 220 m level and 0,04 for the forecast of water inflow to 430 m level. This resulted from the existing correlation between water inflow to these levels and rainfalls. Due to this reason, taking into account that the aforesaid levels are fed mainly by means of the infiltration of rainfall to the shallow located goafs, the sum-up water inflow for the area was calculated basing on the data from the reported documentation of the area.

The calculations proved that for infiltration coefficient equal 0,40 and max. (1 023 mm) and min. (722 mm) the quantity of rainfall from years 1961 - 1987 reported at the rainfall measuring station at Niwka Kotlicka (1999) the sum-up inflow to both the levels changes and depending on the rainfall amounts to 11,3 – 8,0 m^3/min. The variability of inflow to both these levels in years 1970 – 1999 was 16,5 – 7,6 m^3/min. The inflow to both said levels exceeding the calculated values, coming from the infiltration, had taken place before 1984 and it that is when mining from deeper levels was marginal.

The inflow to deeper levels, which will be flooded no matter which alternative of closing down the mine will be applied, was determined by means of the method of analogy considering the difference in depression, by the following equation recommended for the groundwater of the tensed level (Rogoż, 1987):

$$Q = Q_1 \sqrt{\frac{S}{S_1}} \qquad [2]$$

where:

Q – inflow from deep level [m^3/min],
Q_1 – inflow before closing down the mine [m^3/min],
S – depression after mine flooding [m],
S_1 – depression before closing down the liquidation [m].

Calculations considering the sum-up water inflow to the levels of 600 m and 910 m which will both be flooded (2,1 m^3/min in 1998) evidenced that the inflow will decrease by 30 % to reach 1,4 m^3/min. This means that drainage of the closed down mine with minimal discharge of 12,7 m^3/min will be necessary when the underground workings down to the level of 430 m will be flooded. In case of drainage using submersible pumps which enables for damming the water by further 47 m, the dropout of inflow will be marginal and will not exceed 1 % of the predicted inflow quantity.

The forecast of the quantity of water which will be drained after the underground workings are flooded has been determined basing on the inflows from years 1970 – 1999 as well, applying the method of the trend of mineralisation changes expressed by the dry residue of inflow coming to the following de-watering levels: 220 m, 430 m and below 430 m. Again, like in case of inflow forecast, the calculations were done by means of exponential equation.

On the contrary to the inflow forecast, by analysing the fluctuation of the physicochemical composition of the inflow water coming to the a.m. levels, in the case of the 430 m level the approximation of the data on the changes of mineralisation from the period of 1990 – 1994 was abandoned because of the fact that at this level the infiltration water is mixed with the water coming from de-watering of the MS sandstone layers resulting in periodical high mineralisation of the total inflow. Confidence levels of calculations varied from 0,92 for water mineralisation at levels deeper than 430 m, down to 0,1 for water mineralisation at the 220 m level. The forecast was made assuming that after 10 years hydro-chemical equilibrium would prevail so that the quantity of drained water would not change.

As the calculations show, the mineralisation of water inflow to levels:

– 220 m will increase up to ~ 2 500 mg/dm^3,

– 430 m will decrease to ~ 4 100 mg/dm^3,
– below 430 m it will also decrease to 25 300 mg/dm^3.

As a result, the flooded mine will be supplying water with mineralisation of ~ 5 100 mg/dm^3 to the environment. The increased salinity of mine waters will coincident with the increase of chlorides in water together with the slight increase of sulphates, hence the mine water being discharged to the surface water system will have low acid reaction.

8 SUMMARY

The forecast the quality and quantity of water to be discharged from the partially flooded mine presented in this article, may leave many doubts if the statistical calculations done will be taken without criticism. Due to this reason, the comprehensive analysis of changes caused at water-bearing levels by mining activity is necessary. This analysis should be the basis for a schematic model of drainage the closing down mine. It will allow too, to verify the calculations done and, it is a simple instrument for the estimation of the quality and quantity of water after the mine has been closed down. On the account of this, to the new geological and mining law being currently discussed by the Polish parliament, new regulation has been proposed to elaborate a separate hydrogeological report in case of either changing the existing drainage system of the mine or when the mine is to be closed down.

The author expresses his thanks to the employees of the closing down coal mine and to the authors of the aforesaid reports for giving him the access to the literature to write this article.

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Określenie wielkości dopływu i jakości wód w kopalniach postawionych w stan likwidacji

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Streszczenie: Autor nawiązując do projektów likwidacji jednej z kopalń Górnośląskiego Zagłębia Węglowego omawia sposób określenia wielkości

projektowanego oraz jakości wód jakie będą pompowane po częściowym zatopieniu wyrobisk górniczych. Prognozę sporządzono w oparciu o wieloletnią analizę ilości i jakości wód oraz sposobu prowadzenia robót górniczych w omawianej kopalni w nawiązaniu do projektowanych zmian systemu głównego odwadniania. Dotychczasowe opracowania likwidacji kopalń koncentrowały się głównie na określeniu warunków bezpieczeństwa zakładów górniczych będących w ich sąsiedztwie. Natomiast powtarzające się koncepcje zastąpienia istniejących pompowni pompami głębinowymi wymagają szczegółowego określenia warunków hydrogeologicznych jakie będą po zatopieniu części wyrobisk górniczych. Przedstawiona w artykule prognoza ilości i jakości wód z likwidowanej kopalni może być wykorzystana nie tylko do określenia stanu zagrożenia sąsiadujących z kopalnią zakładów górniczych, ale także dla optymalnego doboru pomp głębinowych i ich armatury. Pozwoli również na sprecyzowanie dodatkowego zakresu prac jakie będą musiały być wykonane dla potrzeb uzyskania pozwolenia wodno-prawnego na zrzut wód z odwodnienia likwidowanej kopalni.