A Simple 1D MODFLOW model for a part of a mine undergoing closure in Silesia, Poland

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Abstract

"Ruch II" is a part of "Janina" coal mine (Upper Silesian Coal Basin, Southern Poland). It is in fact an independent mine itself, accessed by two declines and the shaft named "Janina V". In the East and South "Ruch II" is bounded from "Ruch I" (the main part of "Janina" coal mine) by fault zones, permeable to some extent. In the West, Carboniferous sandstones with coal seams are in contact with highly permeable quaternary glaciofluvial deposits. Since the vertical recharge is limited due to Tertiary clays in the overburden, the quaternary aquifer seems to be the main source of inflow to the mine.

Simple 1D MODFLOW model has been built to simulate the shape of groundwater table across West – East cross-section. The area has a complicated history of groundwater drainage (pumping wells, mining activity, etc.); therefore several variants of the model have been simulated. Since "Ruch II" is now in closure process, one of model versions assumes entire flooding to quasi-natural conditions. In this case, the aspects of possible filtration through the fault zone into the still operating part of Janina coal mine ("Ruch I") are of major importance.

1 Introduction

MODFLOW models (McDonald and Harbaugh 1988), as well as the other models based on Darcy groundwater flow assumption are known to cause problems in mining areas, where major flow conditions are controlled by man-made excavations like: shafts, adits, declines, galleries, etc.; therefore flow conditions there are usually of non-Darcy turbulent character. However, while assessing the hydrogeological consequences of "Janina – Ruch II" coal mine closure, the need of constructing a simple groundwater model raised up (Frolik et al. 2004). The main task for was to assess the permeability of the Eastern as well as the Western border of "Janina – Ruch II" mining area in the aspect of possible increase in inflow to "Janina – Ruch I" coal mine. Since the time to build the model was rather short, it was decided to choose a simple 1D Modflow approach. In spite of methodological uncertainties mentioned above, the obtained results seemed to be reasonable. This paper describes the modelling approach, variants of the model as well as obtained results.

2 Conceptual model

"Janina – Ruch II" coal mine is located in the eastern part of Upper – Silesian Coal Basin (S Poland). The main river of this area is Przemsza, flowing from N to S near western border of "Janina – Ruch II" (fig. 1). Fractured Carboniferous sandstones form the main groundwater aquifer there. It is bounded from the top by impermeable Tertiary deposits of variable thickness, locally absent. Between Tertiary clays and Carboniferous sandstones, in some zones Triassic limestones can be found, with full hydraulic contact with Carboniferous aquifer. In the West, there is a post-glacial valley of Przemsza river, several tens of meters deep and filled with high permeable glaciofluvial Quaternary deposits. These deposits are in good hydraulic contact with Carboniferous aquifer. In the East and South "Ruch II" is bounded from "Ruch I" (the main part of "Janina" coal mine) by fault zones, permeable to some extent. Model area was 2700 m wide (from W to E) and 600 m long (from N to S) and covered the southern area of "Janina – Ruch II" coal mine next to former groundwater intake operated by leather industry plant "Chełmek". Carboniferous groundwater aquifer has been simulated by very simple, 1D model consisting of 27 cells, each of them 600 m long and 100 m wide. Top of simulated layer has been adjusted to the bottom of overlaying Tertiary deposits except the zones with absence of Tertiary. In the later case top of the layer has been adjusted to land surface. In zones where Triassic limestones overlay carboniferous sandstones, Triassic has been included into simulated groundwater aquifer. Since the aquifer does not have the sharp bottom (sandstones are gradually replaced with claystones and the fracture density decreases with depth), some simplifications had to be made and the bottom of the layer has been set arbitrally at 150 m below sea level.

3 Boundary conditions

Carboniferous groundwater aquifer has been simulated as one layer fully tranversible from confined to unconfined character. Since the model was 1D only, southern and northern boundary was simulated as non-flow. Westernmost as well as easternmost cells of the model were simulated as general head boundary. Hydraulic head at western boundary was equal to hydraulic head in river Przemsza valley quaternary aquifer (230 m above sea level); conductance of the boundary has been calibrated to value of 0.0002 m^2/s; as explained in McDonald and Harbaugh (1988), the in inflow of water to the model cell from general head boundary is equal to difference of hydraulic head in the model cell and at the boundary (ΔH, expressed in metres) conductance of the boundary (C, expressed in m^2/s). Hydraulic head of eastern boundary dividing “Janina – Ruch II” from “Janina – Ruch I” was set to 240 m a.s.l. (equal to groundwater level in “Janina – Ruch I” before its dewatering). Conductance of this boundary has been calibrated to value of 0.0001 m^2/s. In some variants of the model constant head boundary was used to model the mine dewatering impact. Former groundwater intake operated by leather industry plant “Chełmek” consisting of several wells has been simulated by constant flow boundary in six neighboring blocks of the model. Recharge constant in time but spatially variable has been applied; following McDonald and Harbaugh (1998) recharge flow rate expressed in m^3/s (defined as recharge flux times the given model cell area) has been applied to each model cell. The recognized zones of recharge were:

- Zones of Tertiary overburden absence (recharge flow rate = 7,5E-9 m^3/s)
- Zones of Tertiary overburden presence (recharge flow rate = 6,875E-10 m^3/s)

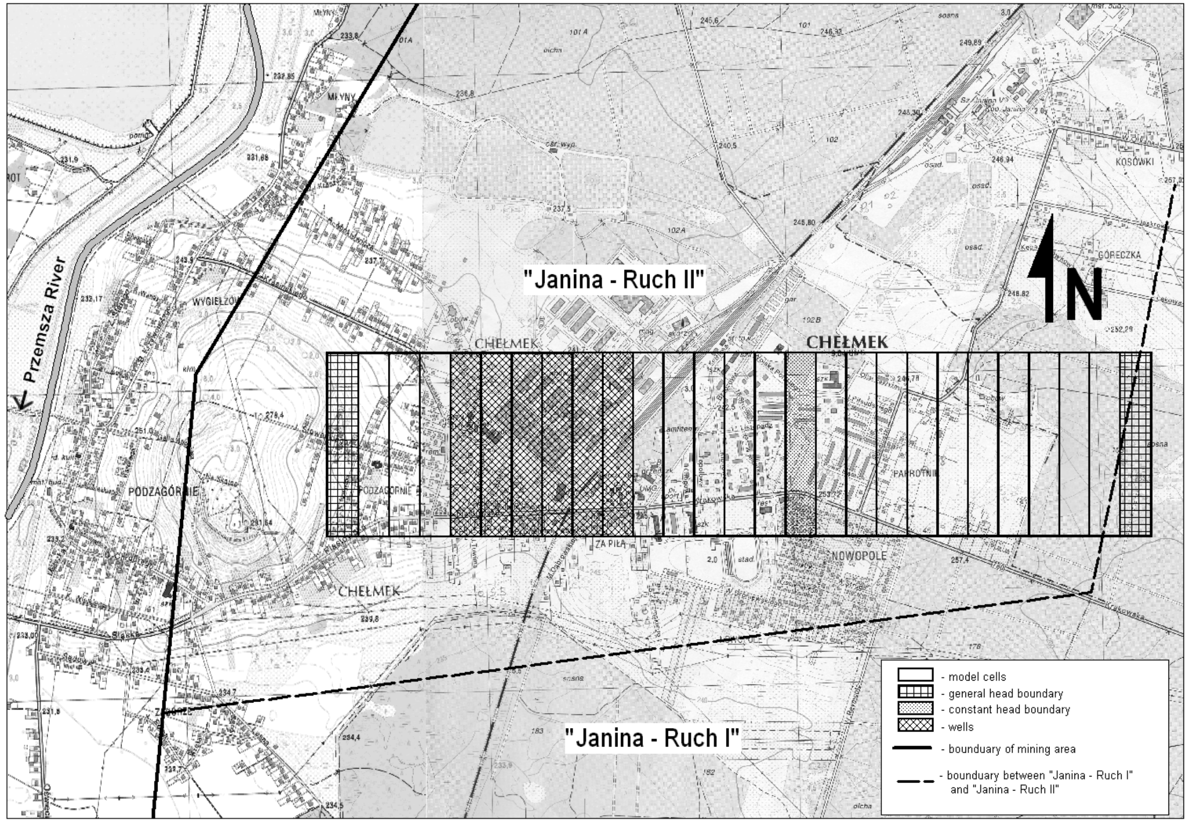

Fig.1. Investigated area

- Zones of Tertiary overburden presence, but neighboring with Triassic outcrops on the hill north of model area (recharge flow rate = 2,25E-9 m^3/s)

Hydraulic conductivity (*k*) of 7.5 E-6 m/s was set for entire Carboniferous aquifer. For variants after “Janina – Ruch II” exploitation *k* has been raised up in mined zones and calibrated to value of 1E 5 m/s.

4 Model variants and obtained results

4.1 Variant I

This was the base variant, for which conductance of eastern and western border as well as *k* has been calibrated (see: Chap. 3 Bounday conditions). This variant represented hydrogeological conditions during intensive dewatering of “Janina – Ruch II”, before dewatering of “Janina – Ruch I” behind eastern boundary of the model. Hand calibration of parameters mentioned above aimed at reaching the inflow of about 0.055 m^3/s to constant head boundary set at 30 m a.s.l. in single model cell representing mine dewatering. Hydraulic head modeled in variant I is shown at figure 2.

4.2 Variant II

This Variant represents hydrogeological conditions in time of accessing the deposit of “Janina – Ruch II”, still before intense dewatering of entire mine; it has been modeled in order to verify the parameters calibrated in variant I. Variant II is the only variant in which groundwater intake of chemical industry plant “Chełmek” still operated. The intake was simulated by 6 model cells with constant flow boundary; the total rate was set to 0.019 m^3/s.

Unlike the other variants, in variant II *k* was equal to 7,5 E-6 m/s in entire model domain (in these times there were still no significant impact of mining on conductivity of the Carboniferous aquifer). Constant head boundary remained in variant II in the same cell like in variant I, but this time it represented the dewatering impact of accession declines only, before “real” mine operation. Hydraulic head on this boundary has been calibrated to value of 112 m a.s.l., in order to reach the inflow to that boundary of about 0.017 m^3/s (equal to value measured during accession works). Hydraulic head modeled in variant II is shown at figure 2.

4.3 Variant III

This variant represented current situation in time of model creation. The only difference between variant I and variant III was the decrease in hydraulic head at eastern boundary of the model due to dewatering of “Janina – Ruch I” behind this boundary. It was assumed that this head dropped down to value of 200 m a.s.l. As it was expected, this resulted in only minor decrease of inflow to constant head boundary (from 0.055 to 0.051 m^3/s) comparing to variant I and also minor dropdown of hydraulic head in eastern part of model area (fig. 2).

4.4 Variant IV

This is a prognostic variant for assessing hydrogeological conditions after entire flooding of. The only difference between Variant II and IV was constant head boundary representing mine dewatering system – in variant IV the constant head boundary has been removed. Hydraulic head modeled in variant IV is shown at figure 2. It is expected, that after flooding of “Janina – Ruch II” coal mine the hydraulic head will recover to quasi-natural conditions in spite of close exploitation and dewatering of neighboring “Janina – Ruch” I coal mine.

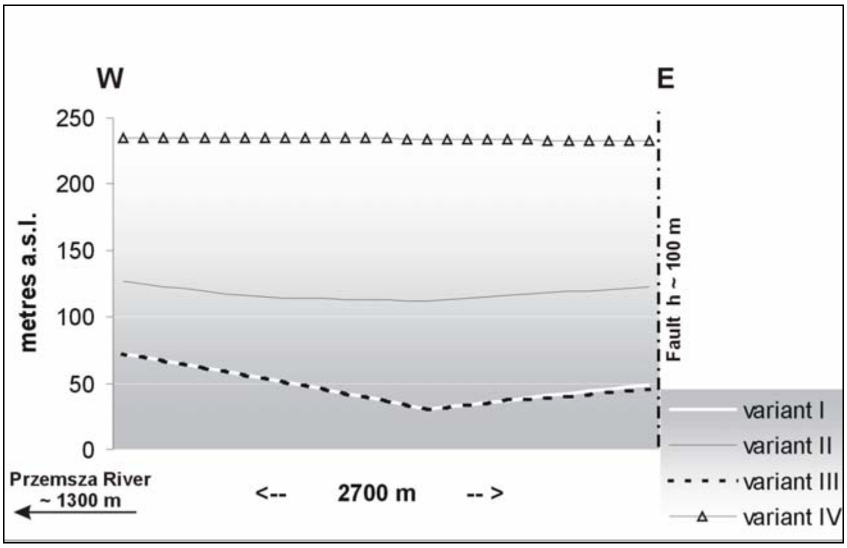

Fig. 2. Hydraulic head across the model area simulated in 4 variants of the model

5 Conclusions

- In spite of methodological constrains, simple 1D MODFLOW model of “Janina – Ruch II” has been successfully built, calibrated and verified.
- It is expected, that after flooding of “Janina – Ruch II” coal mine the hydraulic head will recover to quasi-natural conditions in spite of close exploitation and dewatering of neighboring “Janina – Ruch” I coal mine.
- Due to relatively low conductance of fault zone between coal mines “Janina – Ruch II” and “Janina – Ruch I”, possible increase in inflow to the later one should be limited.

6 References

Frolik A, Bukowski P, Staszewski B, Kubica J, Chećko J, Gzyl G, Kura K (2004) Dokumentacja określająca warunki hydrogeologiczne w związku z zaprzestaniem odwadniania KWK “Janina” Ruch II wg stanu na 01.03.2004 r. Central Mining Institute, Katowice, Poland (In Polish)

McDonald MG, Harbaugh AW (1988) A modular three-dimensional finite-difference ground-water flow model: *U.S. Geological Survey Techniques of Water-Resources Investigations*, book 6, chap. A1, 586 p.