Forcasting of groundwater table recovery after closure of the Bełchatów lignite open cast mine

Jacek Szczepiński

POLTEGOR - engineering Ltd., Powstańców Śląskich 95, 53-332 Wrocław, Poland.
e-mail: water@poltegor-eng.com.pl

Abstract: The U.S. Geological Survey's program MODFLOW was used to simulate the process of groundwater table recovery after closure of the Bełchatów lignite open cast mine. The cumulative volume of the Bełchatów and Szczerców postmining reservoirs, which will be filled with water, will reach 2.4 billion m^3. The results obtained during simulation performed in the regional groundwater flow model has shown that the process of groundwater table recovery in a natural way will last 60 years after the operation of dewatering system is ceased. In the case of additional recharge of both reservoirs with water from outside the cone of depression at a rate of 4 m^3/sec this process will last 45 years. In this case the hydraulic gradient in the region of reservoirs will be reversed and the reservoirs will become an additional element recharging the aquifers.

1 INTRODUCTION

Many opencast mines developed in the 60-ties and 70-ties come all over the world to the end of operations. The management of open pits and then reclamation becomes to be a big problem especially when the operation were conducted deep below the original ground water table. In case of large operations those issues have to be predicted even many years before the closure and adequate measures have to be undertaken earlier. The good example of this way of thinking is the Bełchatów lignite open pit in Poland.

2 MINING

The lignite open pit Bełchatów is the second largest open pit all over the world and has production capacity 38 mill T/y, overburden stripping is 110 mill m^3 yearly, the depth of operation will reach about 280 m of depth and the area of the open pit at the time of its closure will be 33.6 km^2. The average lowering of the original groundwater table within area of mining operation will be 280 m. Area of the cone of depressions is about 460 km^2 and it will be increased maximum to about 800 km^2 after starting Szczerców open pit dewatering system. The mine water inflow ranged from 180 m^3/min to 450 m^3/min.

In 09.2000 dewatering system at the adjacent Szczerców Field was started. The mine water inflow is 330 m^3/min. In 2002 overburden stripping and in 2007 lignite production will start. The designed area of Szczerców open pit will be about 21 km^2, while the depth of the open pit will reach maximum also 280 meters. In 2019 it is planned to complete lignite production at the Bełchatów open pit. Adjacent Szczerców open pit will finish lignite exploitation in 2038.

3 POSTMINING

A general concept of the closure of both abandoned pits is to shallow them with overburden to the final depth of about +100 m asl. This will be done to create two huge water reservoirs, which area will reach 17.5 km^2 and 15.0 km^2 and volume of 1.41 billion m^3 and 1.0 billion m^3 respectively. The preparation of both excavations for filling with water will be completed in 2049. Since 2050 the process of filling the post-mining excavations with water will start.

As the slopes of Bełchatów open pit final excavation are being shaped just now and also, for reason of protection of a salt diapir situated between Bełchatów Field and Szczerców Field as well as for improvement of lignite mine management at adjacent Szczerców open pit, the problems of final reclamation in both reservoirs require thorough analyses to be made as early as now.

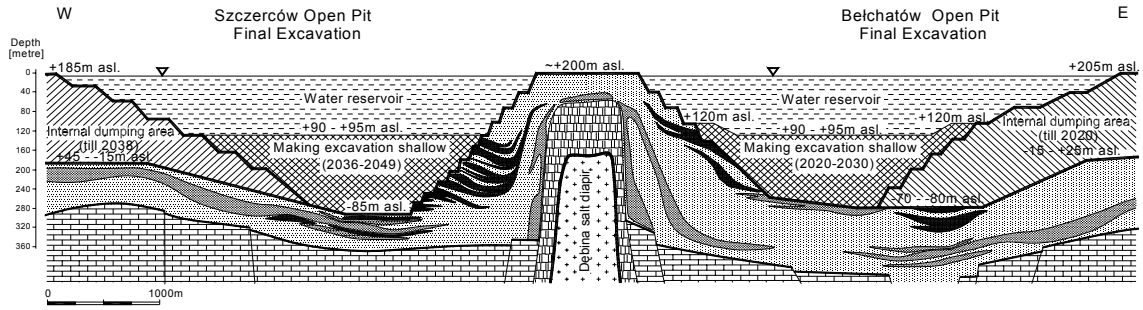

Figure 1. Final excavation at Bełchatów/Szczerców open pits (Szczepiński, 2000)

The U.S. Geological Survey's program MODFLOW (McDonald & Harbaugh, 1988) was used to simulate the process of groundwater table recovery after Bełchatów lignite open cast mine closure.

The existing calibrated numerical model, which successfully operates for the determination of the water inflow to mine dewatering system, was used in forecasting the dynamics and duration of the reservoirs water filling and in forecasting of groundwater table recovery after the operation of dewatering system is ceased.

The water reservoirs were placed over areas represented by nodes where the layer I and impermeable lignite seam had previously been simulated. Some additional modifications were made to the mining input data to reflect the changes caused by mine reclamation. In stage of filling conditions the water reservoirs space were simulated by constant hydraulic conductivity of 10000 m/d and specific yield of 1. The leakage parameter was changed to 1 d^{-1} simulating direct hydraulic contact between layers (Szczepiński, 2000).

Assuming that in the Bełchatów area the precipitation is equalised by potential evapotranspiration (Stachy, 1987), lack of recharge from precipitation was assigned in the reservoirs area. Furthermore, in the cone of depression the elements of natural water balance have been changed. As shown in modelling study the amount of effective infiltration from precipitation increases, even twice with the lowering of groundwater table (Szczepiński & Libicki, 1999). At the

stage of water table reconstruction it will return again to its natural values. The dried water courses will be recreated.

4 RESULTS FOR RESERVOIRS FILLING WITH WATER

Calculation for final reservoirs filling with water were made for two alternatives. For first one the assumption was that the water inflow will proceed in a natural way, i.e. through the slopes and bottom of reservoirs. For second the assumption was that the reservoirs will be filled with water in a natural way, but aided by additional recharge with water from outside the cone of depression at a rate of 4 m^3/s. For this purpose, within area of reservoirs, recharge boundary Q = const was added, thus simulating constant water inflow independent of hydrogeodynamic conditions in the region. The simulation was carried out in transient condition.

The results obtained during simulation performed in the groundwater flow model has shown that the process of filling the reservoirs with water in a natural way will last for about 60 years, but the steady-state conditions will be reached after 120 years. In the case of additional recharge of both reservoirs with water from outside the cone of depression at a rate of 4 m^3/s this process will last 18 years (Szczepiński, 2000).

5 RESULTS FOR GROUNDWATER TABLE RECOVERY IN THE AREA OF THE BEŁCHATÓW MINE CONE OF DEPRESSION

As the reservoirs get filled with water a process of groundwater table recovery in the area of the Bełchatów Mine cone of depression will proceed. A rule was used that in polish conditions, the range of the cone of depression has been assumed to be such a distance at which the groundwater table level has been lowered by one metre relative to the average many year's level (Kleczkowski & Różkowski, 1997).

In the years 2020-2049 when the works related to shallowing the final excavations will be taken place, the mine dewatering system will still have to be in operation. It will allow to safe storage of overburden inside the excavations. At that time, the boundary of the cone of depression delimited by isoline s=1m will change to an inconsiderable extent. Their area will start to grow less when postmining reservoirs will begin to fill with water.

The rate of groundwater table recovery will be highest in the central part of cone of depression and will proceed as quick as the reservoirs get filled with water. The farther away the reservoirs the slower increase of water table.

In conditions of filling the reservoirs with water in natural way the water level in the reservoirs will always be below the water table in the slopes of reservoir and the total duration of depression cone recovery will be 60 years (fig.2).

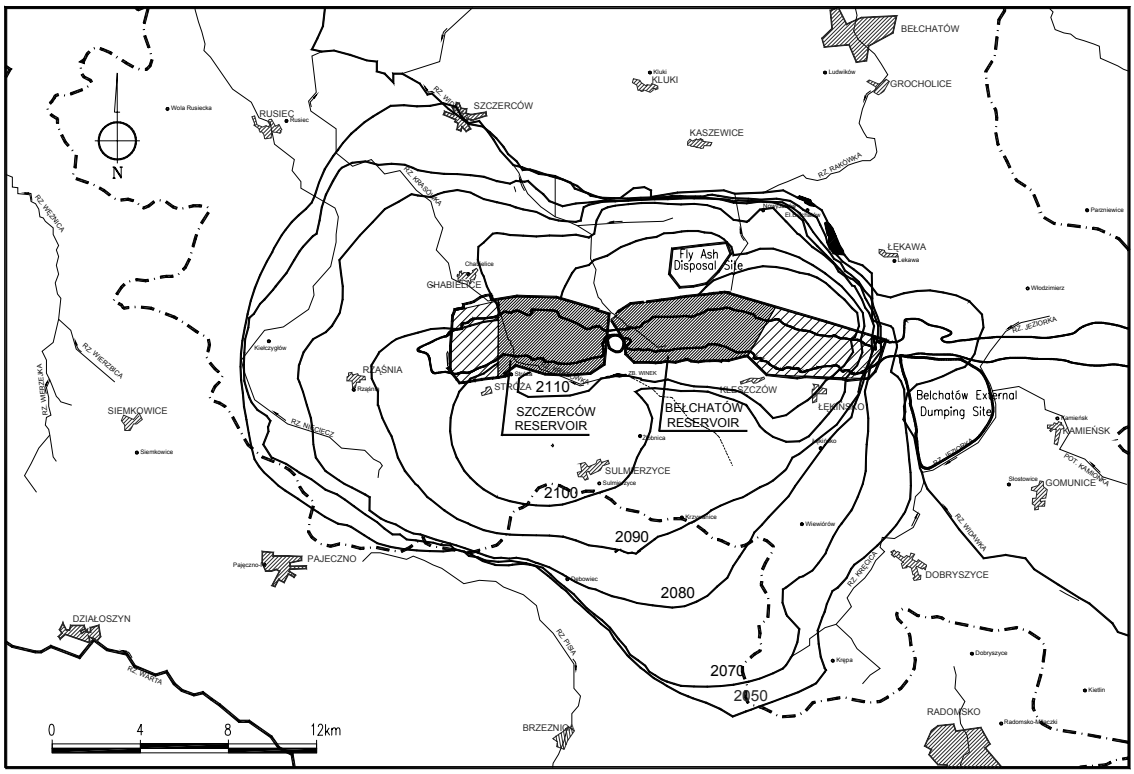

Figure 2. Reduction of the Bełchatów mine cone of depression for filling the reservoirs with water in natural way

According to the second alternative, owing to the recharge of reservoirs with water from outside of the cone of depression the reservoirs will become an additional element recharging the aquifers. The amount of water inflowing to the reservoirs from beyond the cone of depression will be 109.2 m^3/min and 131.6 m^3/min for Szczerców and Bełchatów reservoirs, respectively. The water inflow resulting from the natural drainage of groundwater will take place in the first years of filling only. After 2055, the hydraulic gradient in the region of reservoirs will be reversed and the process of aquifer recharge with water from reservoirs will start (table 1).

Table 1. Values of final reservoirs recharge for the second alternative; [m^3/min]

	Szczerców reservoir			**Bełchatów reservoir**		
Year	**Recharge outside of the cone of depression**	**Inflow from/to aquifer**	**Total inflow**	**Recharge outside of the cone of depression**	**Inflow from/to aquifer**	**Total inflow**
2050	109.2	104	213.2	131.6	105	236.6
2055	109.2	3.2	112.4	131.6	18.7	150.3
2060	109.2	-25	84.2	131.6	-4.5	127.1
2065	109.2	-27.9	81.3	131.6	-29.6	102.0
2068	109.2	-48	61.2	131.6	-54.3	77.3

The duration of both reservoirs filling with water will be about 18 years. The time of groundwater table recovery in the area of the cone will also become as short as 45 years and thus the time of detrimental effect of mine dewatering operations on groundwater will be shorter to the same extent.

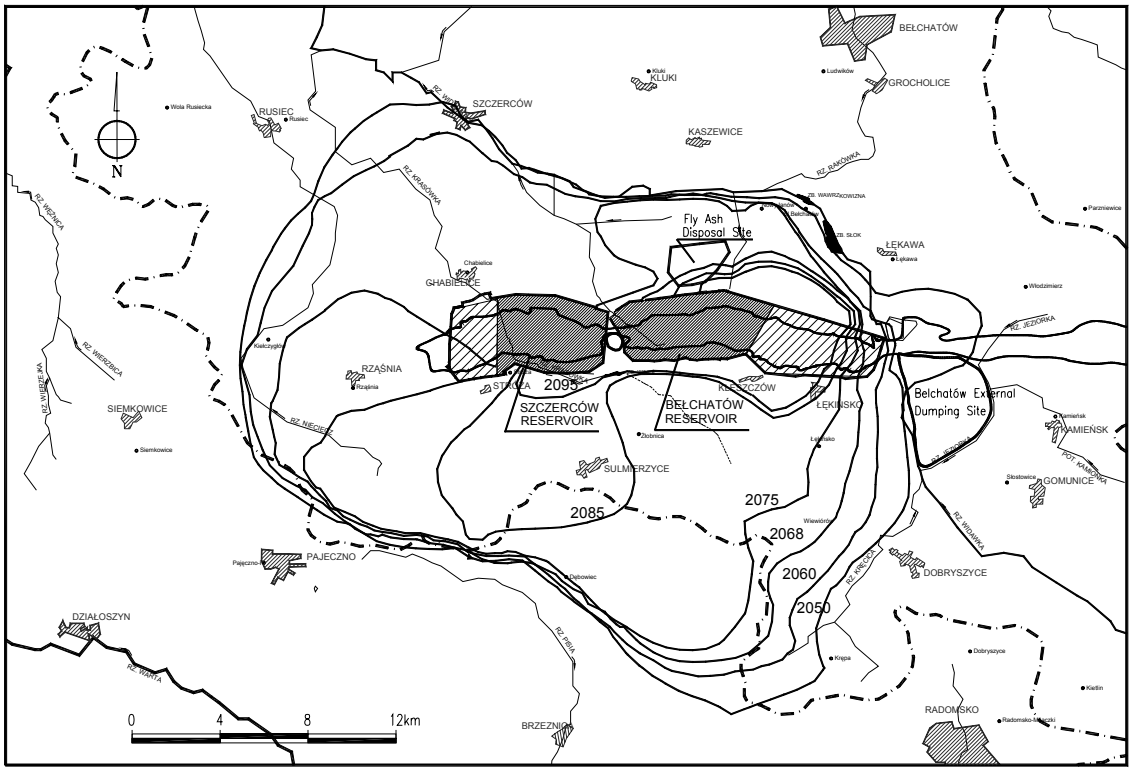

Figure 3. Reduction of the Bełchatów mine cone of depression for filling the reservoirs with water with enhancement of recharge from outside of the cone of depression

6 SUMMARY

The process of filling the postmining excavations with water and the process of groundwater table recovery in the area of Bełchatów mine cone of depression will bring about problems associated with the change of quantitative and qualitative regional water conditions. During this time flow rates in water courses, evaporation and effective infiltration in the area of the cone of depression will tend to their natural limits. Moreover the water table recovery process will lead to the resaturation of aeration zone produced during the dewatering period. It will bring about that a new hydrogeochemical field in the area of the cone of depression will emerge, and some earlier oxidized chemical compounds will penetrate into water.

The modelling study indicate that groundwater table recovery, which in natural conditions will take 60 years, will be possible to make shorter to 45 years making use of additional recharge of the reservoirs with water from outside of the cone of depression at a rate of 4 m^3/sec. In this case, the reservoirs will become the additional element recharging the aquifer.

REFERENCES

Kleczkowski,A.S, & Różkowski A., 1997. *Hydrogeological Dictionary*. Warszawa, pp. 327.

McDonald, M.G.& Harbaugh A.W., 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Techniques of Water-Resources Investigations of the United States Geological Survey*. Book 6, Chapter A1, US Government Printing Office, Washington, D.C.

Stachy J., 1987. Hydrological Map of Poland. IMGW. Wyd. Geol. Warszawa.

Szczepiński J.& Libicki J., 1999. Modelling of the Bełchatów open pit impact on the groundwater environment. In: Rubio F. R. (ed) *Proc. of the IMWA Congress on Mine, Water & Environment*, Sevilla, T.1, 69-77.

Szczepiński J, 2000. Predictive modelling of filling with water the Bełchatówlignite mine final excavation. In: *Proc. of the IMWA Congress on Mine, Water & Environment*, Ustroń, 331-341.