LARGE OPEN-PIT DRAINAGE SYSTEM AND ITS EFECT ON ENVIRONMENT

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INTRODUCTION

The area occupied by the Bełchatów lignite deposit belongs to the province of Piotrków Trybunalski.

The deposit, or a prolate shape, is running evenly with a parallel of latitude. Its total length is about 38 km and width 1.5 - 2 km. The deposit is divided naturally into three fields (fig. 1):

- the field Szczerców, ca 10 km long, the western part of the deposit by the Dębina salt diapir,
- the field Bełchatów, ca 13 km long, separated from the West by the salt diapir and from the East by the Widawka river,
- the field Kamieńsk, ca 15 km long, East of the Widawka River.

The subject of the paper is the "Bełchatów" field on which final preparatory works prior to lignite seam exploitation are being carried out.

GENERAL CONDITIONS OF WATER DRAINING

The "Bełchatów" deposit, located within the North-East border of the Świętokrzyskie Mountains forms the South-East wind of Łódzka syncline.

The deposit region lies within the Łódzka climatic district. Atmospheric precipitation are from 350-800 mm per year, average - 560 mm. The most intensive precipitations are observed in June, July and August.

The discussed area is situated in the Widawka River basin - the right bank tributary of the Warta river. Total area of the basin is 2440 km^2, the river length being ca 98 km. Average natural flow in the vicinity of Bełchatów mine was 2.1 m^3/sec.

The Widawka river takes a number of little tributaries of a smaller importance for the mine. Those are: Żłobnicka - Stream and Aleksandrowska - Stream, Jeziorka stream and Krasówka stream.

Lignite deposit is located in the tectonic tranch Kleszczow, the depth of which is ca 400 m, and width ca 2 km.

In the deposit region the following geological formations can be distinguished: Permian, Jurassic, Cretaceous, Tertiary and Quaternary.

Permian in a form of a salt diapir was found on the West side of the Bełchatów field. The salt dome had been squeezed up by Mesozoic formations and caused upheval of Tertiary series which became then partly eroded (1). The diapir stucture naturally divides the deposit into two fields: Szczerców and Bełchatów. Gypsum - of clay in the form of cover[1] occurs above rock-salt and has been found at the depth 47 m any rock - salt at the depth 169 m. Salt formation is sealing which most probably protected against mineralization of underground waters in the lignite deposit region (1).

Mesozoic deposits, represented by Jurassic systems and Cretaceous, form a continuous base for younger Tetiary and Quaternary formations which are found on smaller depths. Deposition depth of Mesozoic formations is increasing from the South to the North and varies from ca 80 m below ground level on the South side of deposit to ca 200 m on the North side. The picture is complicated by tectonics - the most important element of which is in this region tectonic tranch Kleszczowa. Mesozoic formation roof is lowered within the tectonic tranch.

Jurassic deposits found in the Bełchatów field region, mainly on the southern side of Kleszczowa tectonic tranch, are most frequently represented by limestones and marls which are characterized by intensive crackings and developed Karst.

Among Cretaceous formations - more common in the Bełchatów field region than in Jurassic formations, upper Cretaceous formations are more frequently observed. In litholody dominate: marls, limestones, gaizes and sandstones having various degree of cracking.

Various Tertiary series occur only within the tectonic tranch. On the lowered Mesozoic base are represented three characteristic series. The lowest consists mainly of sands, above is lignite seam (average thickness ca 60 m) and then silt - sand series (1). The depth of lignite floor on seam axis varies from ca 170 to more than 300 m. Tertiary formations beyong the limits of the tectonic tranch occur only in fragments and only in its immediate vicinity.

Quaternary deposits are found on Tertiary formations within the Kleszczowa tectonic tranch and beyond that area usually directly on Mesozoic base. Average thickness of Quaternary formations within the seam limits is ca 100 m. Sands and gravels dominate over clays and silts (1).

Important elements of water drainage conditions for the Bełchatów field are tectonics of Mesozoic bed with Karst phenomena within upper Jurassic formations and erosion gullies filled mostly with sands and gravels. Particulary important for the preliminary draining period is the gully running in parallel to tectonic trench axis, on its North side, where Quaternary sands and gravels occuring directly on limestones and Cretaceous marls have average thickness ca 200 m and the maximum more than 300 m. Analysis of Karst phenomena indicates that they occur on the whole area where Oxford and Kimmeridgian limestones are found. Karst is more intensive in the immediate vicinity of the deposit and gradually with the distance. The following Karst phenomena were observed: caves, interseam Karst, widened tectonic crackings and Karst craters. While drilling wells Karst was observed in a few zones down to the final well depth, i.e. to ca 350 m.

Underground waters occur in all stratigrapic complexes and forms one water - bearing system as a result of hydraulic contacts.

Characteristic values of filtration coefficient for the discussed complexes were determined in investigations on (1):

- more than 20 m/d in Quaternary
- ca 2 - 3 m/d in Tertiary formations above lignite and below lignite
- ca 3 - 8 m/d in Cretaceous and Jurassic formations.

From - the viewpoint of water inflow to mine the most important stratigraphic links are Quaternary and Jurassic formations. Tertiary formations having slight influence on influent qantity are an important element for water drainage because of the predicted difficulties in their drying (poor bleeding ability).

These hydrogeological properties and spatial arrangement of water-bearing complexes determine localization of drainage system . Regardless the adopted method best conditions of water intake must be taken into account particulary within Quaternary gully and in Jurassic formations, beyond lignite seam.

Water from all stratigrapic complexes are similar in their physico-chemical composition. They are poorly mineralized, mostly up to 300 mg/l, and have a relatively high content of total iron (a few milligrams per liter). The content of chlorides and sulphates is low, to 30 mg/l, althong salt diapir is found in the region. Slight anomalies were noticed in salt diapir components in underground water , for example: chlorides up to 260 mg/l at total dissolved solids up to 800 mg/l.

EXPLOITATION

The openpit has been designed on the deposit eastern side in the region of Piaski village. Lignite will be mined in parallel system towards the West with annual advance from 300 to 500 m.

Overburden and lignite is planned to be mined with wheel excavators on track chain running gears. They include:

- four overburden excavators SchRs 4600, effective output 6600 m^3/h, with booms 70, 45 and 30 m long (produced in West Germany)

- four lignite excavators SRs 2000, effective output 3350 m^3/h, produced in East Germany

- two lignite excavators ERs 710, effective output 1300 m^3/h, produced in East Germany.

Overburden and lignite is going to be transported with belt conveyors localized within the open-pit on main floores of the northern slope.

Approach output is planned to be ca 39 mill. ton/year (after 1985).

OPEN-PIT DRAINAGE SYSTEM

Method of water drainage

Considerable depth of the deposit, complicated geological conditions as well as high degree of water content are hard problems for the designers and builders of the mine. Such difficult problems have not been experienced in open-pit mining up to the present days.

One of the fundamental problem is to choose such water drainage means which would provide lowering ground water level as quickly as possible.

Water drainage problem become more and more important in the present times of higher technology which makes possible quick removal of overburden and lignite mining. Highly effective excavators enable to achieve great increments in working depth, of the order 50 and more meters per year. Because of that water drainage method took into account the shortest possible cycle of mine construction. Other fundamental criteria which decided about the method selected for water drainage are following:

- hydrogeological conditions of deposit,

- method of mining,

- industrial safety conditions,

- environmental protection,

- degree of structure difficulty and system exploitation,

- present state of technology,

- economical factors.

Two water drainage methods: mining - deep well drainage system and separate well drainage system have been studied from the viepoint of their applicability. Analyses considered conventional technologies of drainage systems and new technologies which have not been used in Poland yet. The possibility to use vertical screens to limit water inflow to the open-pit hase been also analysed.

It has been decided that under hydrogeological and mining conditions existing in Bełchatów, conventional drainage method for mining can not be applied. Beside the heading system there must be also a well system for water draining. Methods of well construction (used before 1973) such as: manual, percussion, rotary using direct circulation, can not provide efficient drainage of water from the Bełchatów mine. This is due to small diameters of drilling and insufficient depths.

It has been stated that effects of flow screening began at the screen depth more than 150-200 m. As it is not technologically possible to produce such screens in a short term (1974-75) inflow screening can not be a fundamental element of water draining.

In the light of all these criteria the well drainage method was adopted in Bełchatów mine. A basic element of the method are large-diameter wells. In order to drain residual water from the open-pit area auxiliary draining devices will be used.

A system of observational holes, hydrogeological drillings and investigations wereanticipated for current control of water drainage effects, depression cone and to investigate some unexplained hydrogeological problems.

Water draining wells

Basing on draining results for various arrangement schemes and depth arangement of drainage system the wells have been localized evenly in a form of parallel barriers. The adopted well depth was from 120 to 350, the maximum being 400 m, depending on the open-pit depth, hydrogeological conditions and their purposes. The deepest wells have been localized where water permeability is the highest, i.e. within the erosion gully (fig. 1) or in Mesozoic formations usually beyond the lignite seam in external barriers N, E, S and in internal constant bariers A and G (fig. 2). The deepest barriers (A and G) are used to take inflow in periods of maximum lowering water table, when all barriers having smaller depths are beyond dynamic water table. It is anticipated to make well completions in Jurassic and Cretaceous, permeable cracked and Karst formations. That would enable decompression of poorly permeable Tertiary formations under the deposit.
Within the lignite seam were designed wells with smallest depths (barriers C, D, F, H and K - fig. 2), average depth being 130 m, which drain water only from overburden. Draining of Tertiary under-deposit formations, after preliminary decompression by A and G barriers, is planned to be realized with notches from lignite mine floor in exploitation front.

Well drilling was planned to be executed with drilling rigs L4, L3A, B4A, B3A, B2A and B1A produced by Wirth.

Submersible pumps, Polish and imported, (for $H > 160$ m at $Q > 2.5$ m ^{3}/m) were planned to operate the wells. Characteristic parameters, anticipated and realized, for inflow and depression values are presented in the fig. 4. Drilling 240 wells with total length 47 000 running metres are planned till 1980. Taking into account reserve wells, some wells removed in internal barriers and work diversity factor (0.8), the number of wells in continuous operation should be from 76 in 1975 to 145 in 1980. Later, the number should increase to about 250 wells continuously active in 1985.

The anticipated average well outputs were determined as 1.8 - 3.0 m^3/min., maximum values for individual wells being to 7 m^3/min.

Well have been drilled since the second term of 1973 and operated since 1st October 1975. Till 30.06.1981 380 wells have been drilled and 320 of them is being operated. From the total well output planned for 1981 (430 m^3/m) only 390 m^3/min. is being pumped. The anticipated quantity of pumped out water was 1060 mill. m^3, 924 mill. m^3, i.e. 15 percent less, has been obtained. Due to that the real depression of underground water table within the open-pit is also lower by ca 15 percent than the anticipated in November 1981.

The average real well output were from 1.8 to 4 m^3/min., maximum outputs in individual wells, limited by deep-well pumps capacity, were 6 - 8.5 m^3/min.

The real work diversity factor for the wells is about 0.88, total efficiency of the system ca 0.7, and the degree of inflow screening (without taking into account lower depression than the anticipated) was 99-100 percent.

Incomplete, as compared to the anticipated, water drainage results and greater number of drilled wells were mainly due to the delays in the initial phase of construction and to worse quality of some wells, as well as to lack of devices and materials required to operate drainage system.

Auxiliary devices

The degree of inflow screening by the basic system - drainage wells - was determined as 80 to 90 percent. This means that 10 to 20 percent of total water inflow will not be drained by wells. To drain these residual water various auxiliary drainage means are planned within the open-pit. The most important of them are:

- horizontal drainage holes
- normal drainage holes
- shallow wells and wellpoints batteries
- notches from lignite levels decompressing lignite floor
- drainage ditches and cuts
- headings in lignite seam drifted from the exploted slope with notches and run-off holes.

Using the discussed drainage systems depend on the degree of drainage by basic wells.

Till the mid of 1981 residual waters outflows have been a little part (0.8 percent) of total inflow. Only sometimes they increased to maximum value of ca 7 m^3/min., which was 2 percent of total inflow. Because of that number of drainage auxiliary devices was also small.

Mine water discharges (1)

Water is drained from the wells with individual, short (about 30 m) pressure pipelines directly to ditches and gravitational channels. Only some of the internal barrier wells have pressure cumulative pipelines - those where building gravitational drainage pipelines is not favourable.

Drainage channels are situated along external barriers and also play a role of ditches protecting the open-pit against waters from ground surface. Water from the channels is then discharged to the Widawka river and the channels are filled with water from ditches localized on the open-pit foreland within the area to be exploited.

Ditches and channels are sealed with insulating foil covered by 10 cm thich concrete layer.

Water drained from the wells are of high quality - 1-st class of water purity.

Drainage of the Bełchatów mine determined changes in the existing hydrographical network. River-beds had to be relocated, sealed and protected.

The Widawka river-bed must be relocated, regulated and sealed to reduce water infiltration into the open-pit drainage system (fig. 1). The upper part of the river (on the southern side of the open-pit) is going to be sealed to the border of the depression cone to maintain minimum flow and prevent against dissolving municipal wastes.

Mine waters from the open-pit, polluted in contact with soil and lignite, will be clarified of suspended solids. The waters after pumping them onto the ground surface will be drained through a dirty water ditch into a settling tank. Water will be clarified with combined methods: conventional sedimentation, grass-filter and flowing through a peat-sand filter to the horizontal drains' system. After purifying to the second purity class the water is discharged to the Widawka river.

EFECT OF OPEN-PIT DRAINAGE ON GROUND WATERS IN THE ENVIRONMENT

The depression cone

A negative effect of drainage is a depression cone. In prognostic studies its radius is determined as maximum 20 km, and within the depression S = 1 m - up to 17 km. Because of various hydrogeological conditions its shape may be irregular.

The present (June 1981) range of the depression cone, within the depression S = 1 m, is on the average 8 km. It is much less than the predicted value.

An monitoring system has been designed to control the depression cone. The system consists of piezometers localized on 16 radii (fig. 1) running about 22 km from the open-pit (beyong the limits of forecasted limity of the depression cone).
Shallow wells in 33 villages are also observed.

At the present moment are carried measurements in 263 specially made piezometers, localized beyond the open-pit.

Water supply

The depression cone will cause disappearance of water in farm wells which supply water for local population. Therefore on the area 1300 km^3 were designed deep wells below the maximum depth of the depression cone. Water intakes fro 30 water supply systems will be built on the area of the predicted depression cone.

It has been assumed that water intake and water supply system have to be built 2 years before water is expected to disappear from shallow form wells. The predicted time of such situation is based on measurements carried out in piezometers holes.

Till June 1981 39 wells have been built. This was 19 of group water intakes and 20 water supply systems on the area of about 700 km^2.

Effect of drainage on forests and agriculture

The decrease o f water content in surface soil layers (the result of drainage) will cause losses in forests and crops cultivated on the area. These losses will be tempered by impermeable formations. 31 percent of the depression cone area are grounds covering either impermeable formations or formations which permeability is considerably limited. Due to them negative effect of the lowered water table is reduced. Also there where natural ground water table is at the depth more then 5 m (16 percent of the area) further lowering has no practical effect on agriculture.

It is anticipated that the decrease of humidity of soils within the depression cone will cause following losses in crops (9):

- 80 to 50 percent of the original state on the area 90 km^2, which is 7 percent of the depression cone area,
- 50 to 30 percent of the original state on the area 160 km^2 (12 percent of the area),
- 30 to 10 percent of the original state on the area 270 km^2 (21 percent of the area),
- less than 10 percent of the original state on the area 780 km^2 (60 percent of the area).

REFERENCES

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FIGURES

Figure 1. A sketch map of the Bełchatów deposit region

1 - borders of the deposit fields
2 - Bełchatów open-pit
3 - Dębina salt diapir
4 - range of a deep erosion gully filled with Quaternary(sandy deposits
5 - regions of recognized Karst
6 - lines of observational holes
7 - maximum range of the depression cone in the Bełchatów open-pit
8 - present range of the depression cone (S = 1 m, state on 30 June 1981).

Figure 2. Conceptional cross-section of the Bełchatów open-pit mine drainage

1 - sands and gravels
2 - fissures Karst formations
3 - impermeable and poorly permeable formations
4 - lignite
5 - faults
6 - dynamic ground water table
7 - wells in external barriers
8 - wells in constant internal barriers
9 - wells in overburden internal barriers
10 - shallow wells
11 - normal drainage holes
12 - notches.

Figure 3. Diagrams of drainage wells and observational holes numbers

1 - designed number of wells
2 - actual number of wells
3 - designed number of continuously active wells (coefficient 0.8)
4 - actual number of continuously active wells
5 - designed number of observational holes
6 - actual number of observational holes (in internal and in external system).

Figure 4. Diagrams of the Bełchatów open-pit drainage systems.

1 - designed depths of the open-pit
2 - actual depths of the open-pit
3 - designed depression
4 - actual depression in the central part
5 - actual depression in the southern part
6 - actual depression in the northern part
7 - anticipated water inflow
8 - actual water inflow.

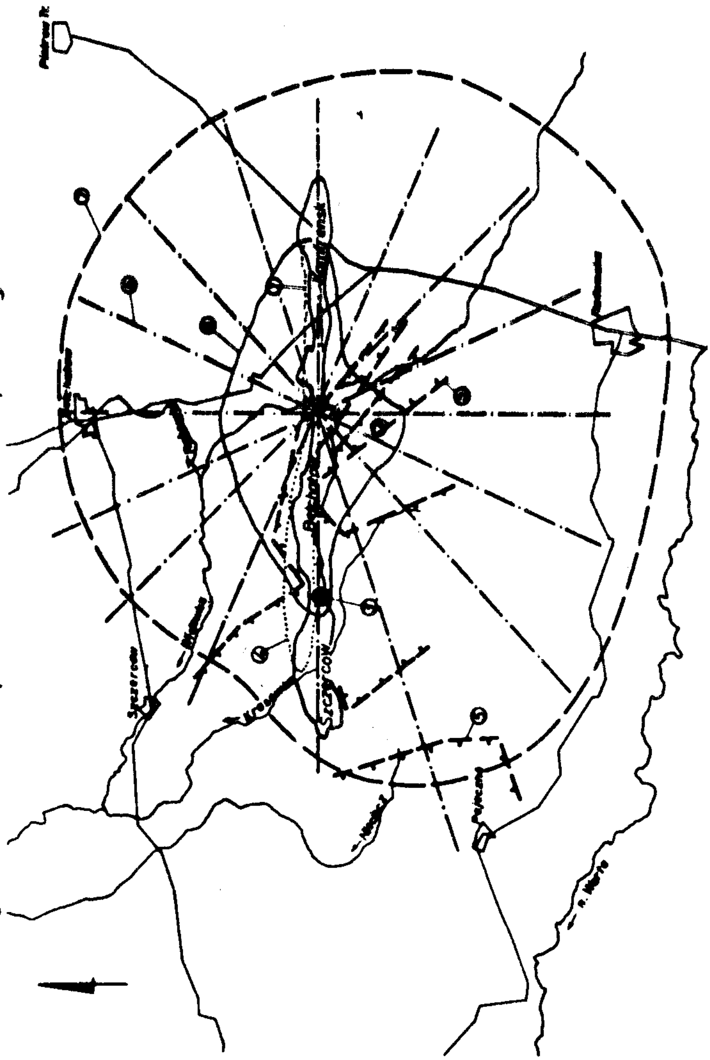

Fig. 1 A sketch map of the Belchatow deposit region

Fig. 2 Conceptional cross-section of the Betchatow open-pit mine drainage

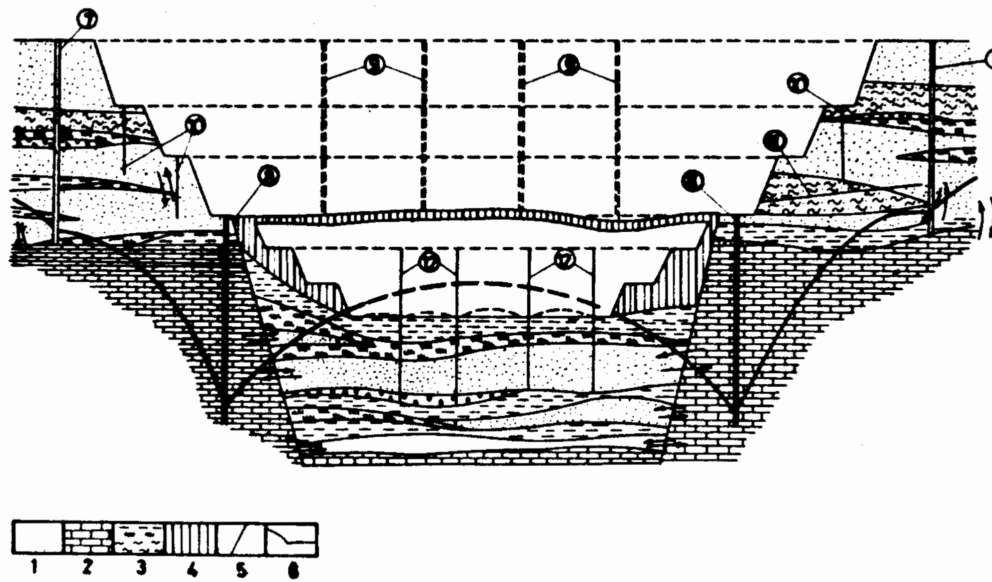

Fig. 3 Diagrams of drainage wells and observational holes numbers

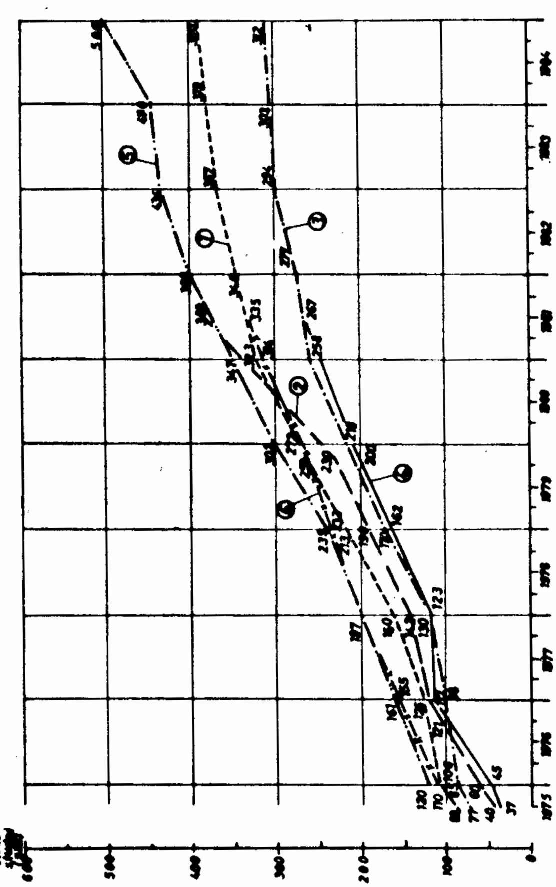

Fig. 4 Diagrams of the Belchatow open-pit drainage systems