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GROUNDWATER PROBLEMS AND DEWATERING SYSTEMS FOR THE ELBISTAN OPEN PIT LIGNITE MINE, ELBISTAN, TURKEY

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ABSTRACT

The groundwater conditions in the Elbistan Basin cause many of the difficulties which the mine has to face. It is mainly the unfavorable hydrologic parameters of the thick limnic overburden series - low hydraulic conductivity, low specific yield, high water content - which must be met by a suitable dewatering technique. The major fraction of water in storage in this formation is being withdrawn by large diameter gravel packed wells which are intermittently operated. The remaining water will be removed in the course of the mining operations.

The recharge of karstic groundwater from the limestone massif of the Kızıldag to the east of the mine will be intercepted by means of deep large-diameter wells. They will be equipped with heavy duty submersible motor pumps. Geologic and hydrologic patterns indicate that there is a barrier developed that prevents the unrestrained flow of water towards these wells.

1. INTRODUCTION

The town of Elbistan with about 45 000 inhabitants is located in an intermontane basin between the Taurus and the Antitaurus Mountains in southeastern Turkey. During the late sixties, an exploration program for lignite in Turkey was conducted by the Turkish and W. German Geological Surveys. In the Elbistan basin the existence of a huge deposit, containing 3 x 10^9 tons lignite was proven [4].

In the seventies, construction of a thermal power plant with a capacity of 1 360 MW was begun by the Turkish State Electricity Authority (TEK). To supply the coal requirements of this plant, Turkish Coal Enterprises (TKI) operates an open pit in a part of the deposit which contains mineable reserves of approximately 580 x 10^6 tons. Consultants to TKI are RHEINBRAUN-Consulting GmbH (RC). Excavation and handling of both overburden and lignite are done

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by the bucketwheel excavator - belt conveyor - stacker system. Upon achieving the production target, the mine will eventually produce 20 x 10^6 tons of lignite per year. 18.5 x 10^6 tons will go to the power plant; the remainder shall serve as feedstock for domestic fuel. The average calorific value of the coal is 4 400 kjoules/kg, and the average overburden to coal ratio amounts to 2.7 cubicmeters to 1 ton.

The first bucketwheel excavator out of eventually six broke ground in October 1981. Along with it went the start of operation of the first of five stackers. According to the production schedule, the first ton of lignite shall be delivered in May 1983.

Large scale open pit mining operations like Elbistan require complete dewatering of the overburden within the bounds of the mine and interception of the groundwater recharge along its perimeter. Due to the occurrence of confining strata in the footwall, no depressurization is necessary here.

2. HYDROGEOLOGY OF THE AREA

2.1 INTRODUCTORY REMARKS

The lithological features of the strata and the structure of the basin determine the hydrogeologic patterns. Geology and hydrogeology of the basin and of the surrounding mountains are described in publications [6] and [5].

The principal water bearing units within the mining field are fluviatile Quarternary deposits and the Piocene limnic strata above the coal series. Both units have to be completely dewatered.

Of major importance to the safety of the open pit is the existence of the karstified terrane of the Kizildag Mountains immediately to the east of the mine.

The principal problems which evolve from the peculiar hydrogeologic characteristics of these different units are discussed in the following chapters.

2.2 HYDROGEOLOGY OF THE MINING FIELD

Figure 1 shows a characteristic lithologic profile of the sequence above and below the lignite. Above the Paleozoic basement, which is made up to phyllitic slates or slightly crystallized limestone, the limnic series begins with loamy

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gravels which are overlain by impermeable marly clay. Locally, as shown here, gravels also occur within the clay stratum. This clay is topped by the lignite formation, consisting generally of two major and several minor seams.

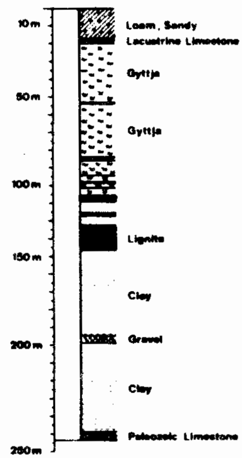

Fig. 1 Characteristic Profile of the limnic and fluviatile basin sediments, Elbistan Basin, after [5]

Intercalations between the seam are made up of clay in the lower part of the formation and gyttja in its upper part. The latter also forms the hydrologically significant part of the overburden.

Gyttja is a sapropelic black or brown mud with determinable organic matter. In its upper part it contains significant amounts of calcareous silt and is referred to as white gyttja. The gyttja formation is highly inhomogeneous and anisotropic. Its thickness varies between about 3 meters in the northern opening up area and approximately 45 meters in the south of the mining field. Its water content ranges between 50 and 70 per cent. An average value of its transmissity was found to be $T = 10^{-5}$ m^2/s. The

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storage coefficient was $S \approx 10^{-4}$. But hydraulic conductivity, specific yield, and, hence, the dewatering characteristics have proved to be hardly determinable. The latter is estimated to be in the range of 1 - 2 %. Both field and laboratory investigations have shown that most of the gyttja is - for practical purposes - impermeable or kind of leaky. Groundwater mainly flows in thin layers of broken shells of gastropods which are embedded in the impermeable beds. The hydraulic conductivity of such layers is comparable to that of coarse gravels.

The top of the limnic sequence is formed either by a blue, marly clay or a dense lacustrine limestone which acts as confining layer (fig. 1).

The Quaternary detrital deposits are products of the denudation of the older, mostly calcareous hard rocks in the mountains surrounding the basin. In the foothills of the mountains, they consist of ever alternating layers of coarse gravels and pebbles and sandy loam. Towards the center of the basin, the coarser, better permeable materials give way to generally loamy sediments of low hydraulic conductivity. This series is traversed by a branching system of buried sandy stream deposits which carry groundwater from the karstic massif and the foothills into the lower parts of the basin and the gaining streams. Here again, hydraulic conductivities are very high ($K \geq 10^{-3}$ m/s) at generally low transmissivities.

The thickness of the whole series varies between 20 meters along the axis of the basin and more than 100 meters in the foothills. There are many tectonical faults which, in the basin, have no impact on the dewatering charcteristics of the overburden. In the foothill area between the mine and the karst, however, faults do heavily dissect both limnic and fluviable sediments so that a correlation of well logs, even at close distances, is not possible (fig. 2).

2.3 HYDROGEOLOGY OF THE KARSTIC TERRANE OF THE KIZILDAG

To the northeast and east of the mine, the Mesozoic limestone terrane of the Kızıldag rises to elevations of more than 1 700 meters a.s.l., that is, more than 500 meters above the axis of the basin along the western perimeter of the mine.

Because of the proximity of the karstic terrane to the mine - the upper benches will directly face the solid rock - withdrawal of groundwater from the karstified limestone is a must to prevent a flooding of the mine.

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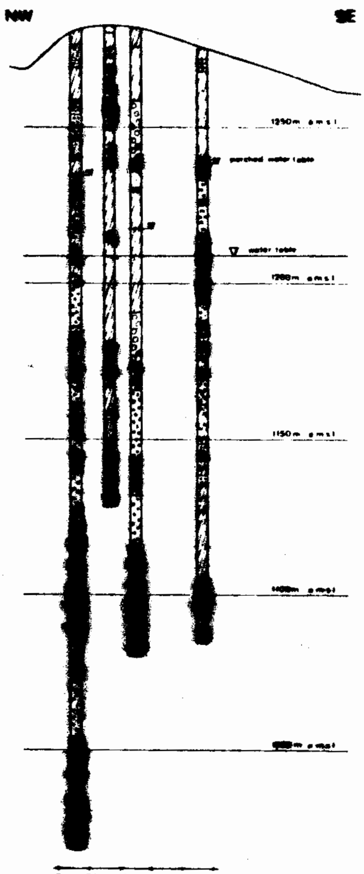

Fig. 2 Profiles of perimeter wells and piezometers in the foothill area between open pit mine and karstic terrane. Signs are as in fig. 1.

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Investigations directed to establish a hydrogeological model of the Kizildag were started in 1974 [2]. This author developed a formula which allows to semiquantitatively describe the intensity of karstifiction. A karstifiction index is computed by utilizing some surficial features of the karstified rock

$$\text{Index} = \frac{\begin{array}{c}\text{number of fractures}\\ \text{per running meter}\end{array} \times \begin{array}{c}\text{total width of frac-}\\ \text{tures per running meter}\end{array}}{\begin{array}{c}\text{number of fractures}\\ \text{infilled by calcite}\end{array} \times \text{degree of loam cover}}$$

Application of this simple formula to describe the degree or index of karstification of the limestone outcrops of the Kızıldag rendered it possible to distinguish six units with indexes < 0.1, 01. - 0.5, 0.5 - 1, 1 - 5, 5 - 10, 10 - 50, which cover the range between "no karstic features" (< 0.1) and highly karstified (10 - 50). As can be seen in fig. 3, the intensity of karstification is generally low along the western slope, but medium to high in the central and eastern parts of the Kızıldag.

On assigning to each index a relative value of hydraulic conductivity such as "impermeable", "permeable", etc., a map could be drawn which reflects the fact that hydraulic conductivity is low in this part of the Kizildag which borders the mine. In other words, it is assumed that a kind of barrier exists which separates the highly permeable part of the karstic terrane from the mine area.

The following observations give evidence to this conculsion:

- The Quaternary fan and talus deposits occur mainly along the western slope. That means that a substantial part of the precipitation does not percolate down to the water table(s) but runs off surficially. In the better permeable ares, infiltration occurs.

- The major springs of the Kızıdag issue only from the western and southwestern slopes. They are always connected with outcrops of the colored complex, a rock series of radiolarites, conglomerates etc., which are impermeable.

- There is an upwarp of the permo-carboniferous basement which forms a real barrier between basin and karstic terrane in the central-southwestern flank of the Kızıldag.

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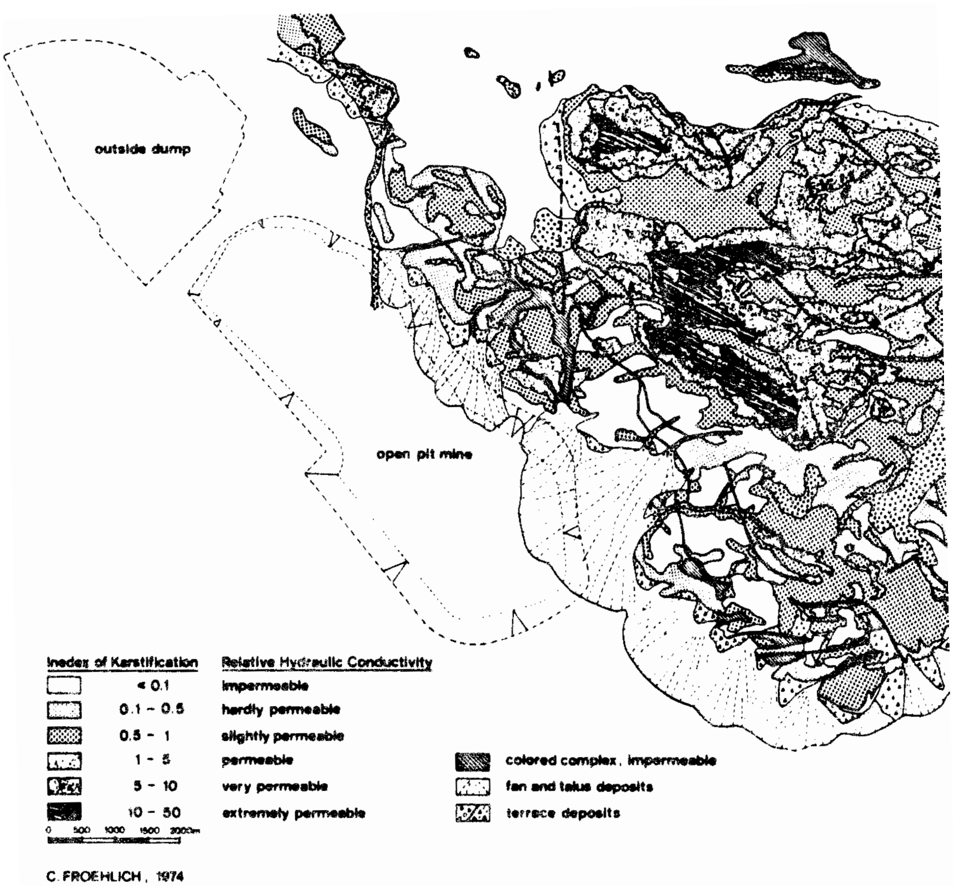

Fig. 3 Intensity of Karstification in the Limestone Terrane of the Kızıldag. After [2]

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- Drill holes proved the existence of a 30 to 40 meter thick claystone bed within the limestone series that dips to the east respectively northeast. It separates an upper and a lower karstic aquifer.

- Major faults appear to separate different aquifer compartments thus forming sub-barriers between them (fig. 3).

It appears that all these different features combine not to form a continuous, solid barrier, rather a system of flow-constraining obstacles.

3. DEWATERING MEASURES

3.1 INTRODUCTORY REMARKS

There are several methods to dewater water bearing strata above seams which are to be exposed in open pits. The traditional dewatering methods in Germany's lignite open pits have been drain drifts or adits which were driven into the seams. From the surface, wells were drilled into these adits and screened in the aquifers. Groundwater discharged by gravity into the adits from where it was pumped [3, 7].

This procedure requires skilled labor, and its economical applicability is limited by depth. The Elbistan Mine will have 5 benches and a depth of 80 meters in the development stage and 6 benches and a depth of 150 meters in the closing stages of operations. At such depths, only gravity flow dewatering by means of vertical tube wells can yield substantial rates of groundwater at reasonable costs.

3.2 DEWATERING OF THE OVERBURDEN

Due to the hydraulic pecularities of the limnic and fluviatile overburden series, it was not possible to run a numerical dewatering model to design wells, their spacing, and their modes of operation. Rather a trial and error approach was pursued, which is based on personal and corporate experience. It is outlined below.

The very low transmissivity and hydraulic conductivity of the gyttja aquifer prevent the continuous discharge of groundwater from the well. The low yield of the aquifer seldom matches the capacity of even a small submersible motor pump. So wells have been drilled with 1 meter diameters, using the reverse circulation air injection methods. To this end, Wirth B3A rigs have been successfully employed.

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The wells were equipped with DN 250 (ID 250) asbestos-cement casings and screens. The screen slots were prepared on site and protected by 1 mm nylon mesh which was wrapped around the screened portions.

After installation of the screens and casings into the wells, the screened portions were gravel packed with sand of 1 - 2 mm and 2 - 4 mm gradations. The annulus facing impermeable beds were backfilled with gravel of the gradation 6 - 10 mm. There, where the wells faced permeable beds in the fluviatile overburden, they were gravel packed with usually the gradiation 4 - 6 mm (fig. 4).

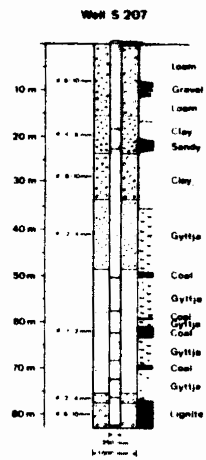

Fig. 4 Typical Design of a Dewatering Well in the Overburden.

The selection of the gradations 1 - 2 mm and 2 - 4 mm was a somewhat arbitrary approach. None of the known rules for proper selection of the gravel pack refers to a biogenic sediment like gyttja. One year of operation has been shown that both gradations do well, however.

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The large diameter wells have been and will be equipped with small Grundfos submersible motor pumps of different capacities which automatically switch off as soon as the dynamic water tables falls short of their non return valves. (Today, rates of discharge range from around 0,03 to 0,15 m^3/min). During recovery, the wells with their large screens facing the saturated strata, act as reservoirs replenished with storage water from the aquifer. In the course of recovery, any particular cone of despression flattens but keeps growing in radius. After a partial recovery, the pump is automatically switched on and the cycle begins again. In time, accompanied by a decrease in the rate of discharge and an increase in pumping head of any pump, the cone of depression will grow and deepen steadily and eventually interfere with the cones of the adjacent wells. It will not be possible to completely dewater the aquifer utilizing this approach. The lower part of the aquifer will remain saturated and must be dealt with in the course of mining. This may well involve horizontal drain holes, maintenance of drain ditches and sumps.

Spacing of wells was arbitrarily set at 125 meters. More wells are necessary to be placed in between. Most of these will be sunk as bench wells within the mine.

Groundwater withdrawal began as late as December 1980, some years behind schedule. The delay was caused by the lack of electrical power on site. Right now, 55 wells are pumping. In the first year of operation, they have discharged about 800 000 m^3 groundwater. As a result of the above-mentioned delay, the next years will not be without problems for the mining operations. The excavators will face still saturated strata.

3.3 KARSTIC DEWATERING

To prevent the water from the Kızıldag entering the mine, a line of perimeter wells is being completed along the northeastern and eastern perimeter of the mine. Most of the wells are being drilled and screened in the unconsolidated Quaternary fan and talus cone deposits because these are hydraulically connected to the karstified terrane. Only locally is hard rock drilling unavoidable. Drilling diameters are 1 000 mm. Steel casings and screens have an internal diameter of 18 in (450 mm). The depths of the wells vary between 200 and 250 meters. Hydraulic conductivity is as high as $K = 10^{-3}$ m/s.

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As to be seen in Fig. 2, correlation between lithologic units as logged in wells and piezometers along the north-eastern perimeter has so far not been possible. It has been most difficult, quite often even impossible, to distinguish lateral facies changes from those caused by tectonical faults.

To allow for sequential changes of submersible motor pumps in the course of drawdown, several types of pumps have been ordered. The maximum discharge per well will be Q = 6 m³/min in the initial stages of operation and will gradually decline to less than Q = 1 m³/min. The maximum required drawdown in the center of the perimeter gallery is 150 meters.

Up to date it has not been possible to accurately assess the total rate of discharge from all karstic wells pumping at particular point of time. In addition, the rate of the decline of the water table in the water bearing strata along the perimeter of the mine cannot yet be established. The main reason for this uncertainly remains the insufficient knowledge about the true nature of the barrier in the Kızıldag as discussed in chapter 2.3. Because the power plant alone will consume approximately Q = 90 m³/min (during the winter months slightly less), which is to be provided from the karstic wells, higher pumping rates than so far estimated will not adversely affect the economics of the mining operation. Surplus water will be discharged into a perimeter channel. This water will than available for irrigation farther downstream. The start of pumping from the karstic wells is scheduled for fall 1982.

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