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ANALYSIS OF WATER LEVEL AND LAND SUBSIDENCE DATA FROM THOREZ OPEN-PIT MINE, HUNGARY

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SUMMARY

The most important occurrence of land subsidence in Hungary caused by underground water withdrawal can be found in the NE of Hungary, in an area of open-pit mining at the foot of the Matra mountains. This paper presents the monitoring system of the underground water withdrawal, the processing method of achieving the underground water depletion and of the land subsidence as its indirect effect, as well as conclusions which can be drawn from the analysis of the observed data. The back analysis is illustrated by examples.

INTRODUCTION

The most important occurrence of land subsidence in Hungary caused by underground water withdrawal can be found in the area of the brown-coal open-pit mines of Matraalja (see Figure 1).



Figure 1 Site location map

The first exploratory wells were drilled in 1920 and by 1961, the total number of geological exploratory wells was 646. These were supplemented by exploration for production purposes, hydrogeological, engineering geological and soil mechanical exploration, geophysical measurements, the information from geological logs of local and regional water level observation wells, as well as the geological, hydrogeological and water quality data from the water-wells. The data made it possible to make a basic geometrical model, which was the basis of an integrated seepage-hydraulic -mechanical model used to describe the complex processes of water decrease and the resultant land subsidence. In the coal sequences 12 coal seams can be found, dipping at 2-3 degrees in S-SE direction. The dewatering affects 13 water bearing layers in the multi-layered aquifer system. The dewatering of the Upper-Pannonian brown-coal area of the open-pit mines at Thorez was begun in 1961 by using a dewatering gallery method. Since 1967, this method of dewatering was changed to the filter wells method used in the intermediate layers.

The opening of the first mining sector (East-I) began in 1964, its exploitation lasted from 1969 to 1984. The extension of that mining sector is planned in an area of about 5 km². The dewatering of the second mining sector (West) began in 1970, with actual production beginning in 1975. The dewatering of the third open-pit mine (East-II) began in 1980, and it has been mined since 1982. During the drainage of the Matraalja sector which has been progressing since 1961, about 460 million m³ of underground water has been pumped by the Matraalja Coal Company from an area of 900 km² from a maximum depth of 200 m.

MONITORING SYSTEM OF THE MATRAALJA OPEN-PIT MINES

The process of mine drainage meant a slow decrease in water level over several years in a given vertical cross-section at first and afterwards, maintenance of the water level was necessary for the purposes of the mining activity. The mine drainage was performed by using the method of intermediate layers and a system based on the transverse range of the wells. Because of this method and drainage system the process of the water management and recharging has to be taken into account in certain areas, the effect of the drainage on new mining areas is superimposed on the former water levels. Because of the complicated hydraulic connections of the multi-layered aquifer system, the direct and indirect effects including decrease of water level and land subsidence of the transverse drainage systems can not be separated, the resultant is recorded by monitoring time-logs.

The regional water level was recorded every three months by using groups of observation wells of the Panpipe system, suitable for separate observation of each water-bearing layer. The drilling of observation wells was continuous and progressed as the cone of depression extended, so the time intervals between the observations are different. Because of the limited utilization possibilities of the depressed area the distance between the observation wells are also not uniform (see Figure 2). The local water level decrease and the efficiency of the drainage has been controlled by using a system of local observation wells located inside the mining zone and in its immediate surroundings.

Mining began after obtaining the planned degree of advanced drainage. A geodetic measuring system was used for the measurement of land subsidence caused by the drainage of aquifers. This geodetical net work has been continuously expanded, the measurement of its net-points was performed every six months. The surveying net work is correlated to lineal surface facilities such as roads and railways, and can be found at various distances from the observation wells. The distance between the surveying net work and the nearest observation well varies from some hundred to some thousands of metres. Levelling of some basic points was carried out in 1955. The basic surveying net work was laid between 1970 and 1973, 9-12 years after the

beginning of advanced dewatering, since that time it has been continuously expanded.

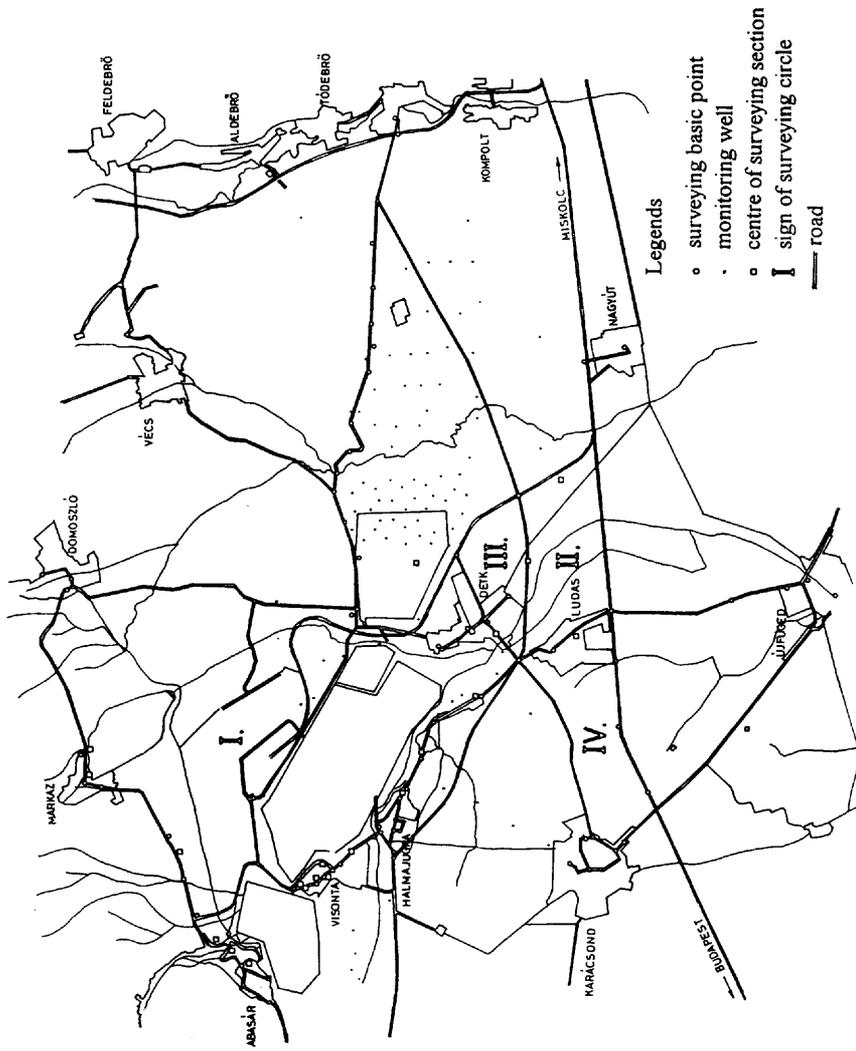


Figure 2 Water pressure of II/0 water bearing layer in 1975 [m.a.s]

PROCESSING THE WATER LEVEL DATA

The data of water yield and regional water tables depletion can be found in the tables, hydrographical maps and reports for the most important aquifers prepared by the Matraalja Mining Company.

These data were complemented by the production data of the relevant water authority for static and dynamic water tables; characteristics of the inter connections between the standing or moving surface water and underground water; results of area of influence investigations and analysis made for different purposes; hydrological and hydrometeorological time-logs of the observed area. The data analysis was assisted by a series of papers presented by research workers of the Central Mining Development Institute, especially regarding the knowledge concerning the underground water recharges in the Matra Mountain region (Schmieder, 1965).

The above data were used as input parameters to a hydraulic seepage model used for the simulation of the water level of the aquifers. The accuracy of the data provided the basis for assessing the reliability of the model. The model was calibrated by using hydrographical maps constructed every six months. The computer data processing was carried out every five years since 1965 for 13 aquifer layers. In Figure 3 an example can be seen of the results of the computer aided data processing concerning 15 years of advanced dewatering.

PROCESSING THE LAND SUBSIDENCE DATA

The surveying network used for monitoring the progress of land subsidence with time has continuously expanded, and its length is more than 80 km today (see Figure 2). The monitoring points of the net work located at a distance of 20 m are very sensitive, so the number of the monitoring points and the lengths of the time-lags of land subsidence in individual points are prone to change. Because of these facts the evaluation of the observation results was made after dividing the net into sections by using the average values of the monitoring points and relating the values to the centre of each section. The number of the individual sections was 24, their distribution in the areas of various villages is as follows: Visonta 6; Halmajugra 4; Detk-Kapolna 3; Nagyut-Detk 4; Ludas 1; Abasar 3; Markaz 3.

The distribution of the surveying data can be seen in Table 1.

Table 1. Distribution of the surveying points by sections

Village	Observation Point (Section)	Basic Point (Section)	Total time-lag* (Section)
Visonta	64	5	38
Halmajugra	101	5	47
Detk-Kapolna	130	3	39
Nagyut-Detk	90	-	***(21)
Ludas	32	3	18
Abasar	126	5	24
Markaz	78	5	37
Sum total	621	26	203(21)

* surveying points established at the beginning of the drainage;

** surveying points established from 1970 to 1973.

*** observation began in 1981, the number of observation points have continuously expanded.

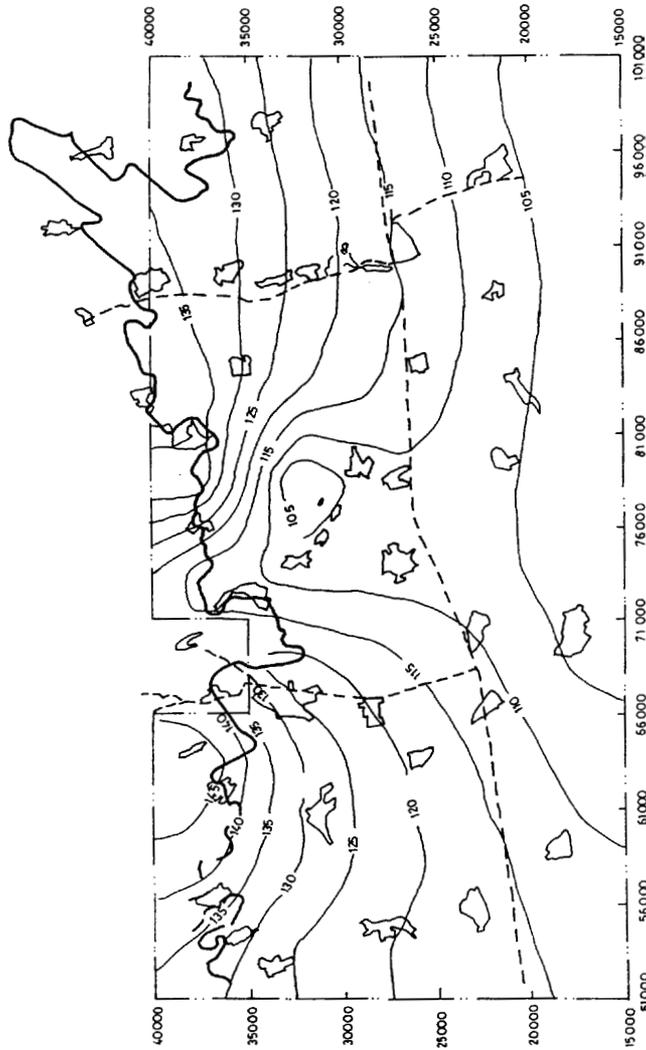
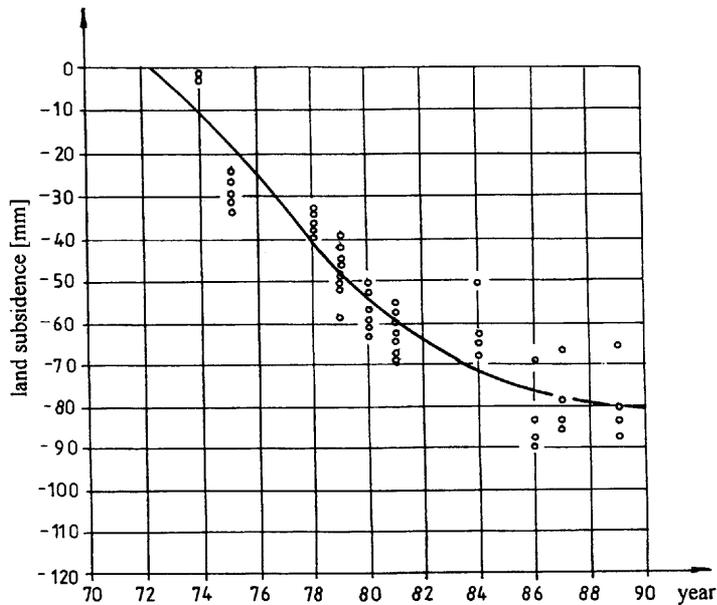


Figure 3 Water pressure of III/0 water bearing layer in 1975 [m.a.s.]

The evaluation of the observed data was performed in 3 steps:

- (i) The regressional function of all observed data for 20 years was determined for each observation section by taking into account the installation date as a basic condition (see Figure 4.)



$a = 104,329$ $b = - 79,564$ $c = -0,292639$ $d = - 22,3683$

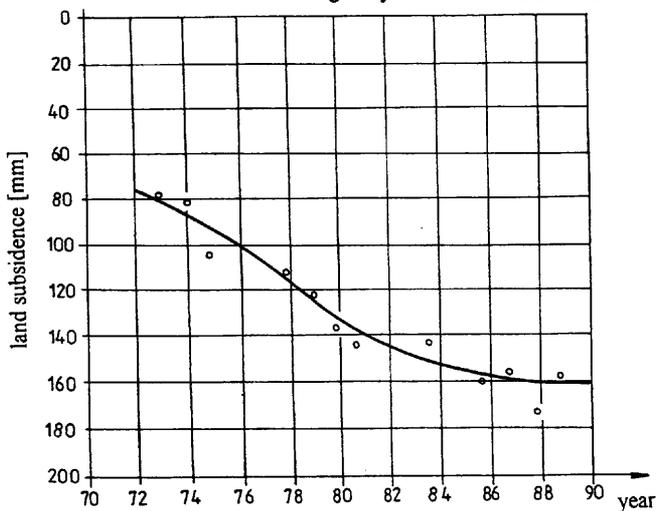
$$y = \frac{1}{1 + e^{-cx+d}} + b$$

$Dy = 7,890226$ $Dy\% = -16,68$ $r = 0,9458$

Figure 4 Chronological data of land subsidence (Visonta 2. monitoring section)

- (ii) As water withdrawal began in 1961, the normalized data of the surveying net (obtainable from the regression curves) were corrected by the original level of the surveying points established before the drainage began in 1955. The corrections were made by sections and were related to the centre of the sections. After the corrections were made, a regression function was determined at every central point by computer (see Figure 5.).
- (iii) For the period prior to establishing the basic surveying network, the surveying points were accepted as reference value (seen as dashed line in the figures) and the corrected surveying data of the integrated sections were plotted together with the normalized values of the water level decrease data measured in the

observation wells closest to the centre of gravity of the observation line.



a = 95,0207 b = 155,240 c = -0,338524 d = -25,1544

$$y = \frac{1}{1 + e^{-cx+d}} + d$$

Dy = 7,855589 Dy% = -6,27 r = 0,9729

Figure 5 Corrected chronological data on land subsidence (Visonta 1-3, section)

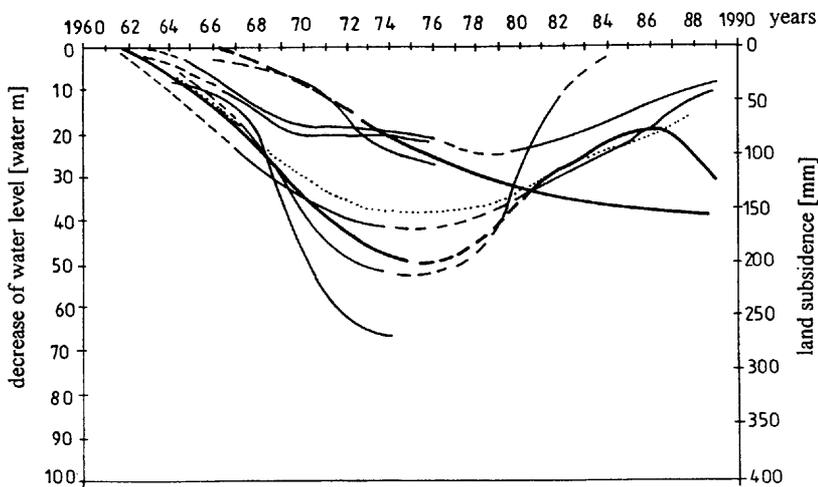


Figure 6 Chronological water table and land subsidence (Visonta 1-3, section)

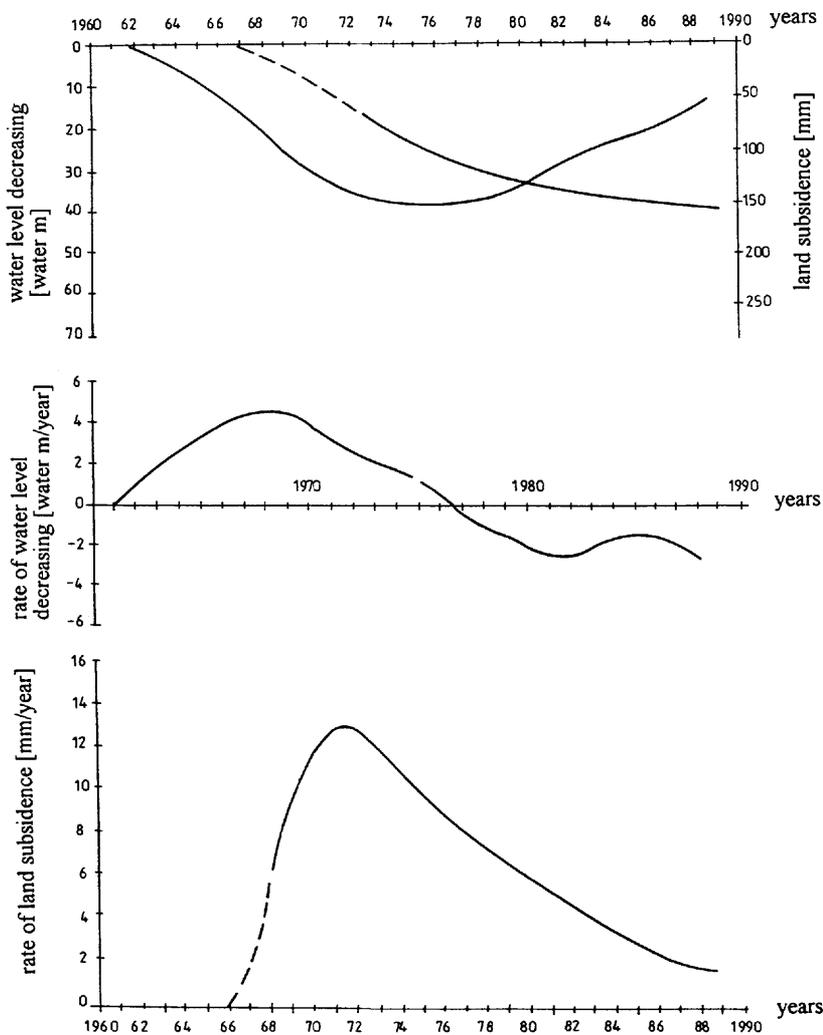


Figure 7 Chronological data of water level lowering and land subsidence

As the regular monitoring of the basic surveying points was established prior to the beginning of advanced drainage between 1970-1973, and their observation had taken place a few times on an experimental basis beforehand, the initial section of the subsidence curves is rather uncertain. Therefore, it needs correction based on the mass of the subsequent data of the later period for statistical analysis and on the physical basis of the process. An example of time depended water level and subsidence curves is given in Figure 6 showing the Visonta area possessing the longest observation time-logs and the highest number of observation points.

The figures pay special emphasis to the time-logs of layer III/0 acting as an intermediate layer between the aquifer as well as the time-log of the average water table value of aquifers on different sites. Figure 7 shows the time-logs of the average water level decrease, land subsidence together with the rates of water level decrease and land subsidence.

CONCLUSIONS

From the large number of water level and land subsidence observations, in above examples, the following conclusions can be reached:

- The land subsidence occurring as the resultant effect of the water withdrawal from the aquifers system is delayed and appears to commence at a certain critical value of water level decrease.
- The rate of land subsidence increases rapidly after the beginning of the subsidence, reaching a maximum value at the inflexion point and then becomes smaller and smaller. The maximum rate of land subsidence is 13-21 mm/year in the observation area.
- The inflexion point of the subsidence curve appears 5-7 years after the beginning of the subsidence and 3-5 years after reaching the maximum rate of water level decrease.
- The land subsidence also continues during the recharging period, although with a continuously decreasing intensity. The decreasing tendency of the land subsidence rate can be considered linear from the beginning of the recharging period (see Figure 7).
- While the effect of the water drainage of the East-II. open-pit mine makes the recharging process slow, but it does not halt it in the area of Visonta and Abasar, while the recharging process comes to a halt in the area of Halmajugra. In addition, a repeated subsidence begins in certain layers, as a result, the slowed down land subsidence process becomes rapid again.
- While the maximum average depression facilitating effective water drainage is 35-40 m along the surveying net of Visonta, the average depression is 65-70 m along the surveying net work of Halmajugra. Naturally, the depression of the deepest layers of the water-bearing sequence of 180-200 m is greater than that.
- The maximum subsidence of the depressed water-bearing sequence of Visonta is 200-220 mm, while subsidences of more than 300 mm were measured in the Halmajugra area.

The results of the abovementioned study enabled the author to determine the consolidation parameters for the site, which were used as the input data for a land

subsidence prediction model. This study predicted the expected values of land subsidence as an indirect effect of dewatering the aquifer. The method of analysis and results of the consolidation studies is a topic for a separate paper.

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