THE METHODOLOGY OF FORECASTING THE KARSTIC WATER INBRUSHES FROM THE ROOF UNDER SPECIAL CONDITIONS

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ABSTRACT

Coal and bauxite deposits are exploited under heavy karstic water danger. The karstified bedrock is covered a conglomerate of dolomite, clay and bauxite. Before exploitation this conglomerate was identified as a protective barrier of decreased protective effect.

The paper discusses the methodology of forecasting the mine water inflow under these conditions. The results of forecasting are compared with the experiences of the exploitation in order to fit the forecasting models to the experiences.

INTRODUCTION

Because of environmental and economical limits the conventional mine drainage methods are not allowed. For this reason the passive way of control and its combination with the method of the instantaneous drainage are used in Hungary. For sizing the pumping station and for predicting the environmental impacts the forecasting of the spontaneous mine water yield has an increased importance.

Analitical, analogous numerical simulation methods are applied for forecasting the spontaneous yield of mine waters simultaneously. For the purpose of sizing the protection systems and for determining the preventive life protection measures not only the reported yield of the mine and its reliability, but the maximum yield of an individual inrush should also be predicted.

The forecasting methods meeting these requirements and the results of their practical applications are presented hereinafter.

THE CONDITIONS OF THE MINES ENDANGERED BY INRUSHES FROM THE KARSTIFIED BEDROCK

Most of the mines endangered by karstwater inrushes are situated in the Transdanubian Mountains. The exploitable mineral resources (coal, bauxite, manganese) are located either on the reservoir bedrock directly,or on the so-called protective layer which is interbedded between the seems and the reservoir. The thickness and the protective effect of the interbedded protective layers are different. The reservoir extends over 11.000 km^2 regionally. The thickness of the middle and upper Triasic limestone and dolomite strata ranges from 100 to 1000 m. The water head is 200 - 300 m on its surface (Figure 1/a).

If the protective barriers are impermeable, e.g. marls or clays, these layers limit the munber of in rushes or prevent against inrushes depending on their thickness and on the water head. Layers of modest permeability can limit the yield of inflows only. About 1500 cases of water inrushes were detected from this reservoir during the past mining activity. The maximum value of water yield had reached 140-150 m^3/min.

Over 50 mine floodings happened during the past 100 years (partly or fully). In the most of the cases the undersizing of the pumping capacity was concluded.
In addition to undersizing the chance of flooding increased because of the use of centrifugal pumps of horizontal axis. These pumps did not operate under submersible conditions and were not protected against sediments transported by the water.

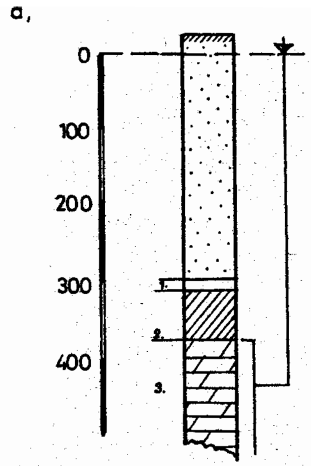
Forecasting the water yield and the transported sediment volume are the basis of protection of mines in operation or under construction. The forecast should be based on the direct experiences and hydrodynamical investigations. The safety of the new mines is increased by applying submersible pumps and setting system designed in accordance with the expected water yield.

The principle of planning is that the effective pumping capacity (without standby units) must be equal or greater than the probability maximum of the water yield of an inrush (q/t/max). (The chance of two or more simultaneous water inrushes with high yield can be neglected.)

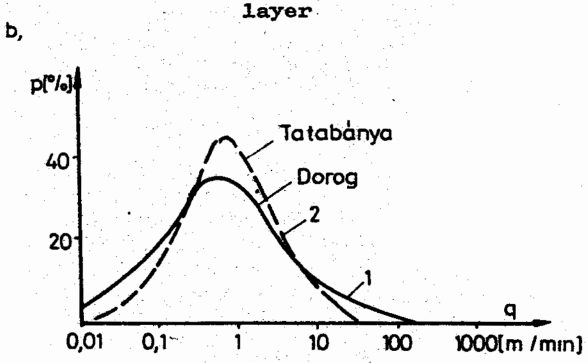
$$Q(t)_{sz} - Q(t) \geq q(t)_{max}$$

The terms of the formula are: $Q(t)_{sz}$ is the "free" pumping capacity and Q (t) is the actual water yield at time t.

To fulfil the requirements of sizin g pumping stations and of planning safety measures



1. telep seam
2. védőréteg protective layer
3. karsztviztároló karstified aquifer



1 mészkőkarszt limestone

2 dolomit dolomite

1. ábra

Fig. 1.

- the average value of the simultaneous water yield
- the confidence interval of the forecast
- the probability peak yield of an individual inrush should be forecasted.

Forecast of water yield from bedrock

The total yield of mine water inflows depends on (Figure 2/a)

- the kinetic and dynamic character of the seepage
- the protective effect of the interbedded layers
- the geometrical localisation of the openings and
- an the efficiency of "a posteriory" sealing activity.

The whole interval of the possible case is given as follows:

$$0 \lesssim Q(\nu) \lesssim Q(kM)$$

Q = 0 represents those cases, when the protective layer excludes any inflow.

The maximum yield refers to the linear seepage conditions without any protective layer under the conditions of confined radial seepage. The maximum yield can be approached by the Dupnit-Thiem formula

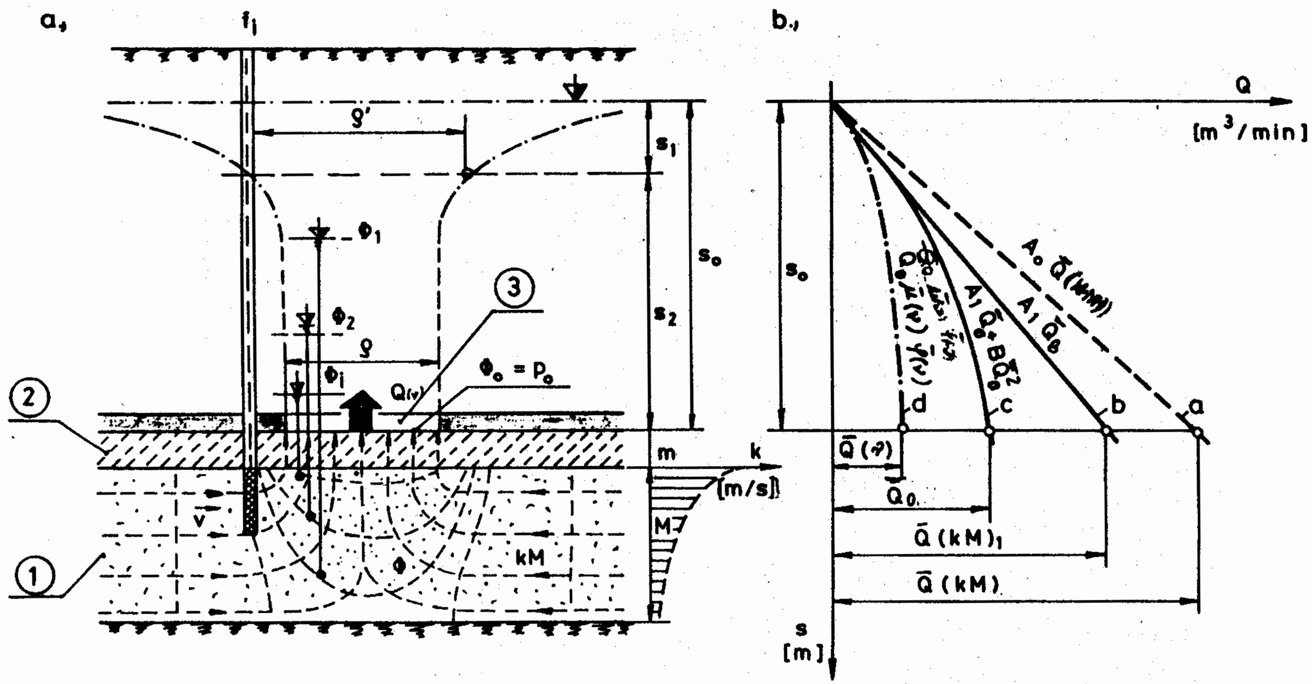
$$s_o = \frac{Q\ (kM)}{2\pi\, kM} \ln \frac{R}{\varsigma}$$

The function and the A_o $\overline{Q}$ (kM) line is shown in Figure 2/b. The medium relative dispersion is ± 15 - 20 % depending on the calculation of the transmissibility.

It can be calculated by using either the data of hydrogeological testing wells or the measured data of water head in function of the water yield.
In most of the practical cases the actual yield of the water inflow should be less than the maximum yield for two reasons:

- the deviation of seepage conditions from the laminar radial flow,
- the effect of protective layers.

The seepage, which is supposed to be horizontal out of the opening's boundary, turns to vertical position continuously in case of the boundary conditions drafted in Fig. 2/a. The change of the dynamic character of seepage is also verified by measurements of inrushes, Schmieder (1978, 82).
In accordance with these geometric and dynamic conditions an analytic function (Schmieder, 1978) expressing the total hyd-



Bányamüveletekkel csapolt viztároló-védőrétegrendszer elvi vázlata
és vizhozamának alakulása

Scheme of seepage through protective layer from aquifer drained
by openings and change of water yield

2. ábra   Fig. 2.

raulic energy in the reservoir can be applied for those conditions where no protective layers exist.
The obtained formula, which is verified in practice, runs as follows:

$$s_o = \frac{\bar{Q}_o}{2\pi kM} \ln \frac{R}{\varrho} + \frac{\bar{Q}_o}{\pi k \cdot L} \ln \frac{\varrho}{r_o} + \frac{\bar{Q}_o^2}{(kL)^{3/2} \cdot r_o}$$

where

- Q_o - the mean value of the surface water yield without hydraulic resistance at a definite time
- ϱ - the inner radius of the parallel seepage zone
- k - the average hydraulis conductivity of the reservoir
- L - the summarized length of the tectonic zones detected in openings
- r_o - average radius of drifts.

This formula expresses also the theoretical upper limit of the confidence interval of the water inflow under conditions of existing protective layers ($\bar{Q}_o$)

The results obtained are shown as a

$$s_o = A_1 \bar{Q}_o + B\bar{Q}_o^2$$

parabola in Fig.2/b. The relative standard deviation of $\bar{Q}_o$ is about twice as much as that of $\bar{Q}$ (kM).

The next step is the estimation of the mean value of $\bar{Q}(\nu)$, which means the water yield of spontaneous inrushes or systematic draining (Fig. 2/b).

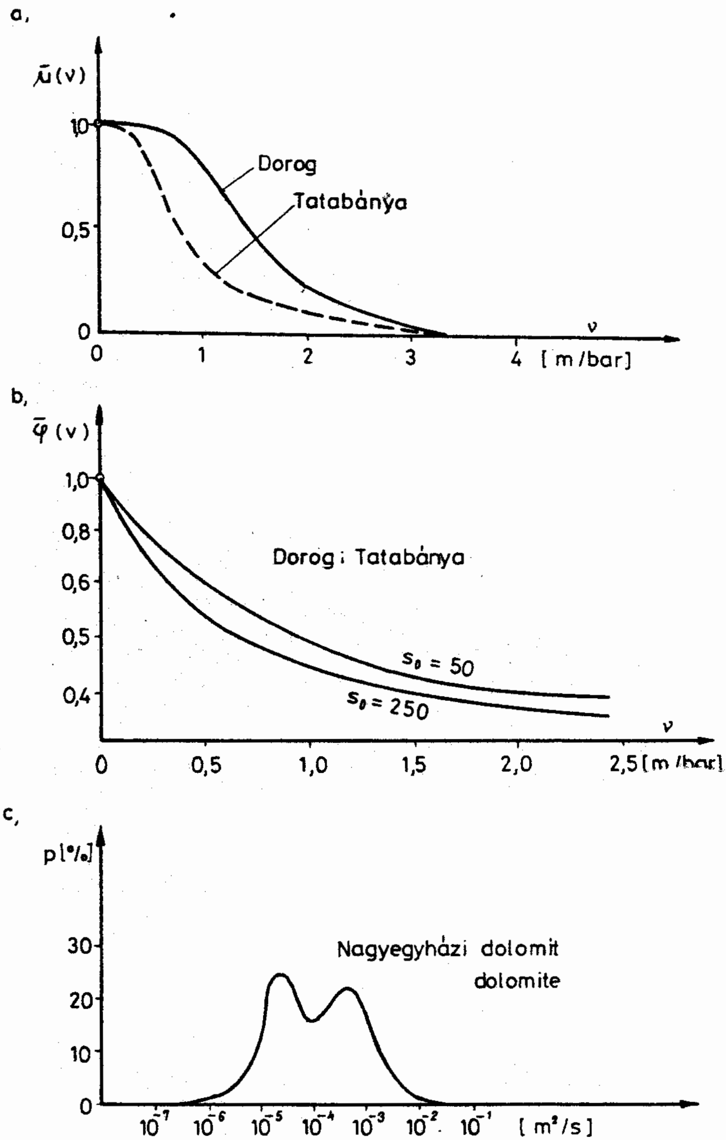
The mathematical model of its estimation is (Schmieder 1972, 1978)

$$\bar{Q}(\nu) = \bar{Q}_o \, \bar{u}(\nu) \, \bar{\varphi}(\nu)$$

where

- $\bar{u}(\nu)$ - the average sealing coefficient:
- $\bar{\varphi}(\nu)$ - the average hydraulic resistivity coefficient

The sealing coefficient is shown in Fig.3/a, representing the probability occurrence in the $0 \lesssim \bar{u}(\nu) \lesssim 1$ interval.


a,
μ̄(v)
1,0
0,5
0
Dorog
Tatabánya
v
0
1
2
3
4 [m/bar]
b,
φ̄ (v)
1,0
0,8
0,6
0,5
0,4
Dorog ; Tatabánya
s₀ = 50
s₀ = 250
v
0
0,5
1,0
1,5
2,0
2,5 [m/bar]
c,
p [%]
30
20
10
0
Nagyegyházi dolomit
dolomite
10⁻⁷
10⁻⁶
10⁻⁵
10⁻⁴
10⁻³
10⁻²
10⁻¹
[m²/s]

3. ábra

Fig. 3.

The function presented in the figure of

$$\bar{u}(\nu) = \frac{\bar{n}(\nu)}{n_o}$$

where

$$\bar{n}_o = \frac{k\Gamma}{k\bar{m}}$$

is the set of occurrences without protective effect.

The hydraulic resistance coefficient (see Fig.3/b) shows the $0 \leq \bar{\varphi}(\nu) \leq 1$ relative decrease of the water yield, which comes from the additional flow resistance of the protective layer.

Both of the coefficients are determined in empirical way. They are considered as analogous terms in planning of new mines, but in case of openings they are taken into account as looal coefficients for the purpose of finer estimation.

The confidence interval of the mean value $\bar{Q}(\nu)$ is also estimated by using statistical methods in addition to the hydraulical methods. The results obtained from both methods are compared to each other. Moreover, economical and safety analysis had to be carried out to determine the pumping capacity necessary for lifting the simultaneous water yield.

This pumping capacity must be increased by the probability maximum value of was water yield of an in rush, q t max. The result is the necessary free pumping capacity without standby. Analytic, analogous and statistical methods are used for its estimation. (Bogárdi et. al. 1978).

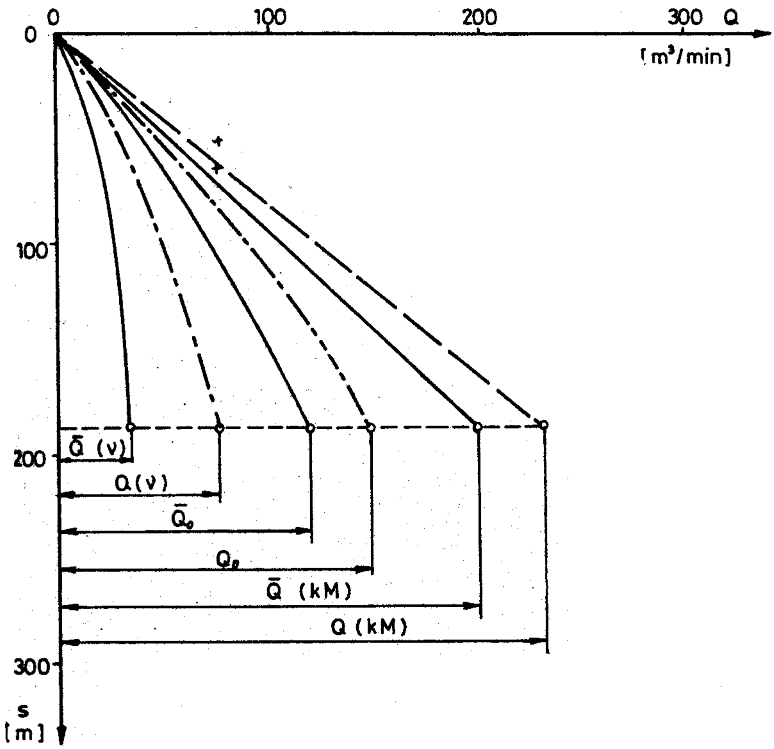
Since the empirical density function of the local value of transmissibility (km) is known (Fig.3/c), the maximum of the single mean value and its distribution can be estimated analytically by the expressions (Schmieder 1978):

$$s_o = \frac{\bar{q}_o}{\pi \, km} \ln \frac{\varrho}{r_o} + \frac{\bar{q}^2{}_o}{(\bar{k}m)^{3/2} \cdot r_o}$$

and

$$\bar{q}(\nu) = \bar{q}_o \, \varrho \,)(\nu)$$

The presented methods were used for the estimation of the water yield in the new but already operating coal mines (Schmieder, Kesserü, Szilágyi 1975). By now fairly enough experiences exist to compare the estimated and real water yields.



számitott jellemző — calculated

tény — actual

$l_{o\ max}$= 3om³/min mért maximum 27m³/min

measured maximum

4. ábra.

Fig. 4.

Experiences for forecasting

The determination of the water yield and pumping capacity of the Nagyegyháza coal mines was based on the method presented before. The calculated and measured values are compared to each other in Figure 4.

The continuous line curves are calculated and the dash-line curves are based on the measured values. It can be proved, that the minimal difference is in forecasting $\bar{Q}(kM)$ but the maximal difference can be shown in they $\bar{Q}(\nu)$ term. The deposits are characterized by a protective layer which covers the reservoir and consists of an inhomogeneous dolomite conglomerate with clay and bauxite. Local information on the protective effect of the strata was not available previously and analogous mine sites were un known for determining the protective effects of the dolomite conglomerate. The calculation is based on the knowledge collected about the protective layer of clay and marl from the surrounding mines. (Schmieder, Kesserü et.al.1975). Additional information was obtained from exploration by drilling.

According to the drilling samples and tests of the sealing effect of the partly compact and loosened dolomite conglomerate was supposed to be negligible. Consequently, the so-called sealing coefficient of the protective layer was supposed to be equal to the unit. The hydraulic resistance coefficient of the dolomite conglomerate was estimated as a half of that of the strongly tectonized clay and marl rocks. The calculated water yield concerning the actual depth and are of the openings was

$$\bar{Q}(\nu) = 30 - 40 \ m^3/min$$

and

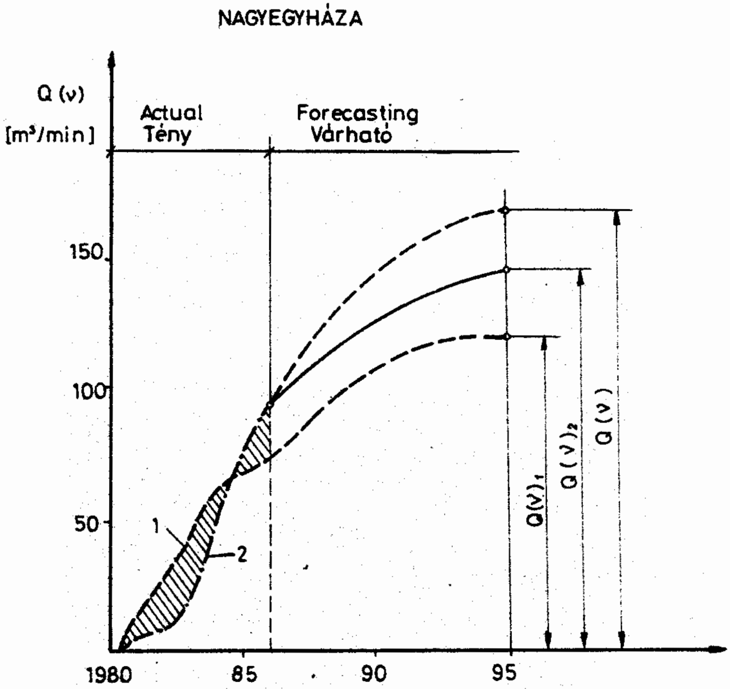
$$\bar{q}_{o\ max} \leq 30 \ m^3/min$$

The present day actual water yield $\bar{Q}(\nu)$ is over the estimated value and the maximum yield of the biggest inrush ranged 12 - 15 m^3/min. The water lifted permanently is shown in Fig.4.

Comparing the forms of analytical and empirical curves and their parameters, the main consequences are as follows:

- The model of forecasting used before fits to the experiences (see the form of curves).

- No important differences were detected between the reservoir parameters given by the exploration and by the mining experiences.



számitott érték 2 tény
Calculated volume actual

5. ábra
Fig. 5.

- Although the dolomite conglomerate interbedded with clay and bauxite lenses really serves as a protective barrier of limited hydraulic resistance (=l; 1) but its hydraulic resistance was overvalued. This is the main reason of the deviation between the forecasted and the actual mine water inflow.

Some possible causes of the deviation between the forecasted and actual parameters of the dolomite conglomerate can be studied in Fig.5, where the conductivity of the hard reservoir rocks and that of the dolomite conglomerate are presented in form of density curves. Curves marked a represent the data measured in the exploration holes, curves b are given by the data of drainage holes bored from the mine (or given by mine water inflow data).

The deviation between the a and b density curves is greater in case of the dolomite conglomerate, although the boring and testing methods and treatments were the same for all kinds of rocks, consequently this deviation is the special feature of the dolomite conglomerate.

In accordance with these results of the com parison the main reasons for the deviation may be as follows:

- The suffosion and erosion of the con glomerate around the mining openings and holes bored from these openings surely increase its water conductivity. (The solid content of drained water also indicates this phenomenon.)

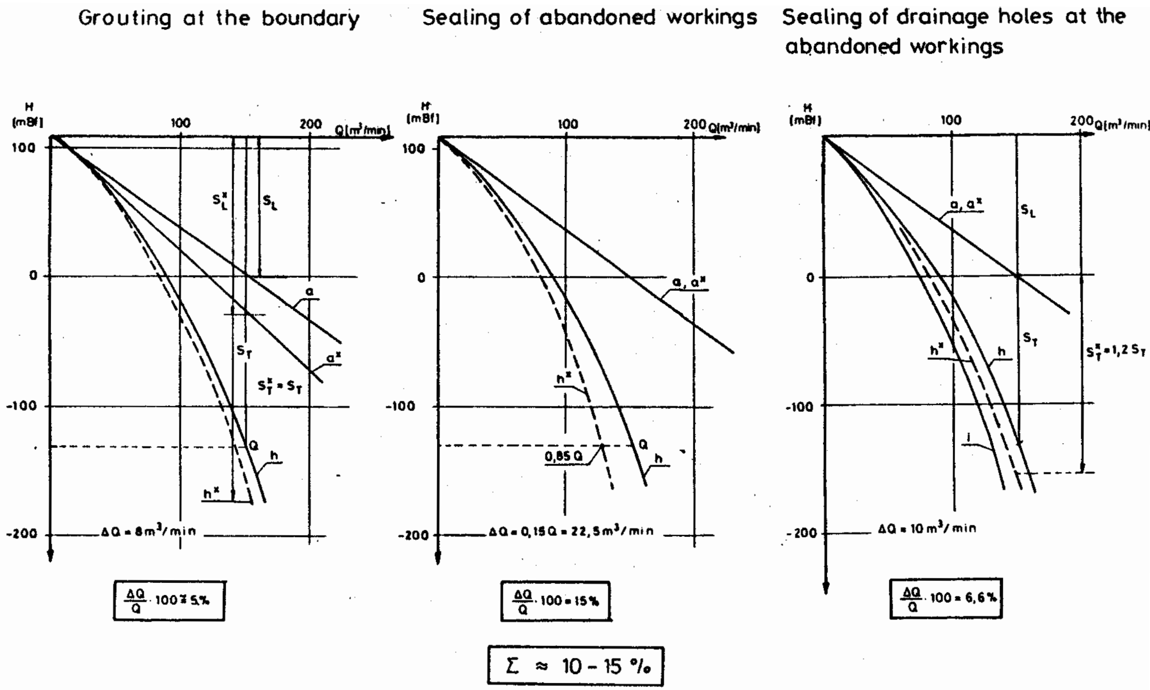
- Although in all exploration test holes the same measures were carried out to clear the skin caused by the boring slurry from the wall of the holes, these measures were surely more effective in hard rocks than in the conglomerate.

As a result of the comparison discussed above new forecast was prepared using the same model, but with new parameters supplied by the mining experiences. Because of the decreased parameter uncertainty, the uncertainty of the forecast was also decreased.

As a result of this new forecast the increased importance of the further limiting the water yield for economic reasons and to meet the environmental requirements appeared.
The same forecasting model was used to select the proper methods in order to limit the water yield.
Under the given conditions the "theoretical" possibilities of limitation were as follows:

a.) sealing-off at the boundary of mines or at sets of workings for reducing the water recharge;

b.) blocking the abandoned areas;



Estimation on the efficiency of the limitation of drained water yield using different measures

Fig. 6

c.) local injection for strengthening the conductive zones of the protective layer;

d.) subsequent blocking of the dewatering holes and water drifts in the abandoned area.

The efficiency of each method can be estimated by this model as presented in Fig.6:

a.) Sealing-off at the boundary can be estimated as transmissibility parameter decreasing kM_s kM_o (see Fig.6/a) in a given area of the laminar radial flow.

b.) Blocking the abandoned area can be estimated as a given decreasing of the surface of the mining operations (see Fig.6/b).

c.) and d.) Preventive injection of the conductive zones of the protective layers and "a posteriory" blocking of the former drainage openings at the abandoned area are all measures for decreasing locally the conductivity in the zone of turbulent flow (see Fig.6/c).

Under the conditions where the turbulent losses of water head are dominant, sealing at the boundary is the less effective method.

Some conclusions

The model for forecasting the mine water inflow was justified by mining experiences. The model can also be used to select the proper methods for limiting the water inflow.

Comparing the forecasted and actual mine water inflows the result of each parameter uncertainties appeared.
The most uncertain parameter has been the protective effect (the hydraulic resistance) of a dolomite conglomerate, which was never tested before by mining experiences.

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