Computer Simulation of the Process of Flooding up a Group of Mines

By Marek Rogoz

Central Mining Institute, Katowice - Poland

ABSTRACT

The closing of a mine and stoppage of its drainage causes the flooding of mine workings with underground waters. If the closed mine is connected with an adjacent mine, the water will rise until it reaches the connection level and then will flow over to the adjacent mine. If the drainage system of the adjacent mine is not sufficient, this mine also has to be inundated.

In the area of the Upper Silesian Coal Basin there are a lot of mines connected on various levels, forming complicated hydraulic systems. Among them are mines being planned for closure. In an effort to predict the course of flooding in a group of connected mines very often complicated calculations have to be made. To assist in such calculations, a computer program for IBM-PC has been compiled. The program enables simulation of the flooding processes of several connected mines, taking into consideration the distribution of void capacities in particular mines as a function of depth, as well as the distribution of water inflows to mine workings and their variation during the process.

INTRODUCTION

The closure of a mine and stoppage of its pumps causes the flooding of mine workings with underground waters. The level to which water may rise in the workings of the closed mine depends on the existence or lack of the connections between this mine and adjacent mines. The coal mines in the Upper Silesian Coal Basin are in the majority connected at various levels producing a group of mines with complicated hydraulic systems. The closure of any mine in such a group will induce a rise in the water level up to the level of the lowest connection before flowing over to the lower workings of the adjacent mine. Mines that are separated with no connections to other mines are very few.

Before the closure of a mine is undertaken, the consequences of terminating the mine drainage system should be analysed. One of the substantial elements of such an analysis is the forecast of the course of the rate of flooding of the workings. The prediction should be made based on the calculated water capacities of goafs, the dewatered rock mass as well as the inflow rate to the mine workings. It is very important to also forecast the rate of water outflow from the closed mine into the adjacent mines in relation to the efficiency of their pumping facilities.

CONNECTIONS BETWEEN MINES

To properly determine the course of mine flooding one has to define a separate mine and joint mines.

Separate mines are ones that have only one drainage system and are not connected to adjacent mines with controlled or uncontrolled flow ways. Joint mines can be composed of parts that are independently drained and connected to each other through mine workings at various levels or mines that have controlled or uncontrolled connections with other mines.

To produce the forecast of the course of a joint mine flooding, all connections of the closed mine with adjacent mines have to be examined and the level of the lowest connection should be determined. Uncontrolled flow ways between mines should be taken into consideration, such as exploitation slots, zones of tectonic dislocations and places where boundary pillars are weakened by mining induced stresses.

After the stoppage of a drainage system in a separate mine, the mine gradually floods with underground water and the water table in workings and goafs will rise until a hydrodynamic equilibrium with the water-bearing strata in the surrounding rock massive is achieved. Theoretically the water table in the mine workings should stabilize at the level of the static water table of the carboniferous rocks.

The stopping of the drainage system in a joint mine induces flooding of the mine workings up to the level of the lowest connection between the closed mine and an adjacent mine. Having achieved the connection level, the water that previously flowed into the closed mine will now flow over into the adjacent mine to finally reach its pumping station. If the drainage system of the adjacent mine has sufficient capacity to pump out the water from the additional inflow, then the process of mine flooding will finish and the water table in the closed mine will stay at the level of the connection. However, in an alternative case where the drainage system of the adjacent mine is also switched off then this mine will also be flooded until the water table reaches the level of water in the first mine. Later both mines will undergo further flooding simultaneously. In this case, the water will rise in the workings of both mines until the water table achieves the level of lowest connection with some other adjacent mine, after that the process may repeat itself.

A schematic diagram of connections between mines has been presented in Figure 1.

WATER CAPACITY OF GOAF AND THE ROCK MASS

To estimate the time of flooding of particular mine levels, the capacities of goafs have to be determined. The capacity of a goaf is defined as the volume of all voids in the goaf and mine workings that may be filled with water. The capacity of goaf is always less than the volume of the worked out seam and is calculated as a product of this volume and of the coefficient of water capacity of goaf [1].

During mine pumping the rock mass around a mine is dewatered. Drainage can take place via the part space of a rock, via fissures and via a fracture system induced by caving. The estimation of water capacity of rock massive is in general difficult. It is made, based on a reconnaissance of the hydrogeological conditions of the region under consideration. For a rock massive consisting mainly of sandstones, the capacity of rocks may be much greater than the goafs.

The capacities of goaf and of rocks are calculated to a depth interval that is usually determined by mine levels and connection levels with adjacent mines. Constant depth intervals may be also accepted, for instance every 50 or 100 m.

WATER INFLOWS TO MINE WORKINGS

In order to determine the dynamics of the mine flooding process in a closed mine and eventually in connected adjacent mines, it is necessary to assess the characteristics of the mine water inflows. The characteristics should comprise of information concerning the distribution of water inflows to the mine workings, the localization of concentrated inflows and their intensities, as well as determination of the total inflows to particular levels or parts of the mine.

The coal mine from a hydrodynamic point of view with its complicated system of mine workings distributed at various levels, in various seams, in the heterogeneous and anisotropic rock masses is composed of a very complicated and vast system of drains. The source of mine water inflows can be from confined aquifers with very little recharge or from unconfined aquifers in which the water table is controlled by the dynamic processes associated with surface recharge and precipitation. In such conditions the construction of a reliable numerical model that can predict the variation in inflow rates as the flooding of the mine progresses, would be very time-consuming and not feasible. In practice, to estimate these changes it is necessary to undertake a series of simple calculations based on the following assumptions:

- as the flooding of mine progresses, the water table in mine workings rises;
- in any stage of the flooding, the water inflows to workings situated above the water table stay unchanged, whereas for mine workings below a confined aquifer the inflows to flooded workings will decrease as the cone of depression induced by the mine gradually reduces;
- water inflows to the mine originate from the carboniferous confined water bearing strata, whose static water table (piezometric level) is at the same altitude, H.

The rate of water inflow to the mine during its flooding, when the water table in workings is at the altitude H, is the sum of particular inflow intensities.

$$Q_H = \Sigma Q_{hi} \qquad (I = 1 \dots n) \qquad (1)$$

where each of inflows is determined with formula

$$Q_{Hi} = \frac{H_s - H}{H_s - H_{oi}} Q_{oi} \qquad \text{while } H > H_{oi} \qquad (2)$$

and

$$Q_{hi} = Q_{oi} \quad \text{while } H \leq H_{oi} \tag{3}$$

The symbols used in the formulas are:

H	-	current altitude of the water table in mine workings,
H_o , Q_o	-	head and flowrate of a single water inflow before the starting of flooding,
H_s	-	head of the static water table (piezometric level in the carboniferous water-bearing strata,
Q_H	-	flowrate when the water table in mine workings is at the altitude H,
I	-	subscript of the number of inflow; lack of subscript refers to the total inflow to the mine.

Practical units used in the calculations are: heads in metres in relation to sea level and flowrates in cubic metres per day.

Heads and flowrates of particular inflows H_{oi} and Q_{oi} are contained in the hydrogeological documentation of the mine. Some difficulty may arise in the determination of H. In many cases it can be determined based on the archived data. Usually in the areas not affected by mining, the static piezometric level of the carboniferous water-bearing strata occurs at the depth of tens of metres below the surface. Taking into consideration the numerous potential inaccuracies of the input data and the simplicity of the hydraulic model, in which one value of H_s for all carboniferous water-bearing strata is accepted, the error of determination of H_s will have a small influence on the accuracy and credibility of the results.

The model expressed by formulas (2) and (3) will also consider water inflows from a shallow dynamic source. These inflows therefore controlled by rainfall or surface recharge usually occur in the highest of mine levels. Their flowrates can be estimated based on a knowledge of the local dynamic head conditions.

THE DURATION OF THE FLOODING PROCESS

The estimation of the duration of the flooding process is derived from dividing the water capacity of the system by the inflow rate. As the geometry of mine workings is very complicated, the workings are irregularly distributed in the vertical plane and the prediction of flooding time is usually burdened with considerable error. To reduce this error, the capacities of workings and their flooding time are calculated at specific depth intervals for which the mean inflow flowrates are calculated.

As the calculation for several connected mines can be very time-consuming, a special computer program has been compiled in the Central Mining Institute. The program that enables the variant simulation of the course of the flooding of the groups of connected mines, assuming that the start of flooding is from an optimal mine.

The program is written in the computer language "C". It has a data base that allows data input, correction and saving data on to disc. The basic data that is inputed into the program is:

- the mine names and maximal yields of their dewatering systems;
- for every mine separately: depths of levels and capacities of working between the levels;
- for every mine separately: heads and flowrates of water inflows to mine workings;

- depths of the lower connections between particular mines.

A filename to accept the input and output is defined along with a decision as to which mine is to be flooded first.

The yields of dewatering and the flowrate should be given in m^3/day, the capacities of goafs in m^3 and the depth in metres in relation to sea level.

The division of rock mass into levels is in principle unrestricted and may be different in every mine. There is however a recommendation to take into consideration the existing mine levels, which may be supplemented with additional calculated levels. The head for the first (top) level in every mine is the depth of the static water table in the carboniferous formation (H_s). Goaf capacities between levels are calculated by means of linear interpolation.

The results of simulation are:

- scheme of connections between mines (Figure 1);
- table of workings capacities and duration of the flooding period for a particular mine (Table 1);
- diagram of the flooding process in time (Figures 2a and 2b).

The table is shown on the screen as the text file and may be printed. The scheme of connection between mines and the diagram of flooding process are displayed in graphic mode, the printing for this file requires some auxiliary programming to print the graphic screen.

The calculation process sums the total inflow from all sources on a level by level basis. Inflows are not calculated independently for each mine.

REFERENCE

1. Rogoz, M. Water capacity of abandoned workings in underground coal mines. Proc. Int. Conf. "Water in Mining and Underground Works". SIAMOS, Granada (Spain) 1978.

Table 1

TABLE OF WORKINGS CAPACITY AND TIMES OF FLOODING

Level	Mine 1		Mine 2		Mine 3		Mine 4	
+350.0	110000	743	82500	743	90000	743	130000	743
+300.0	110000	435	82500	435	90000	435	115000	435
+250.0	100000	374	82500	374	90000	374	115000	374
+200.0	100000	171	82500	171	100000	171--	113333	318
+150.0	100000	141	140000	141	100000	141	113333	291
+100.0	125000	47--	121429	111	100000	111	113333	257
+50.0	50000	23	48571	95	40000	95	49333	195-
+30.0	75000	14	125000	71--	96667	89	74000	192
+0.0	---------	0	125000	59	96667	83	74000	187
-30.0			---------	47	96667	77	74000	182
-60.0					---------	71	98667	177
-100.0							---------	171

Level	Mine 5	
+350.0	125000	743
+300.0	125000	435
+250.0	360000	374
+200.0	360000	318
+150.0	600000	291
+100.0	600000	257
+50.0-	167273	228
+30.0	250909	222
+0.0	250909	213
-30.0	250909	204
-60.0	---------	195
-100.0		

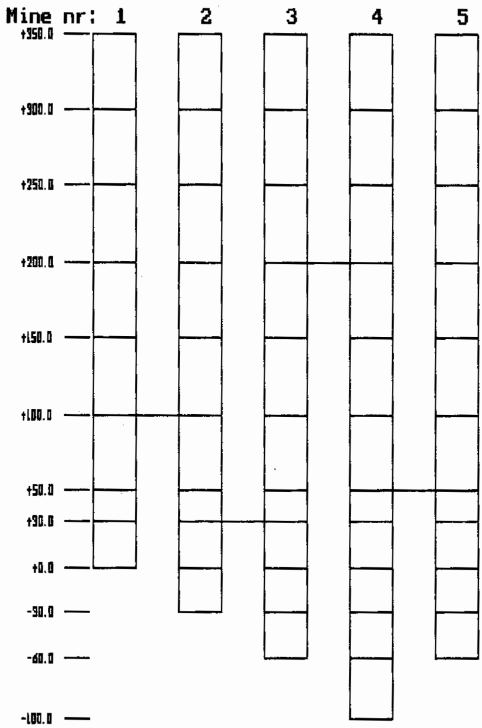

Fig. 1. SCHEME OF CONNECTIONS BETWEEN MINES

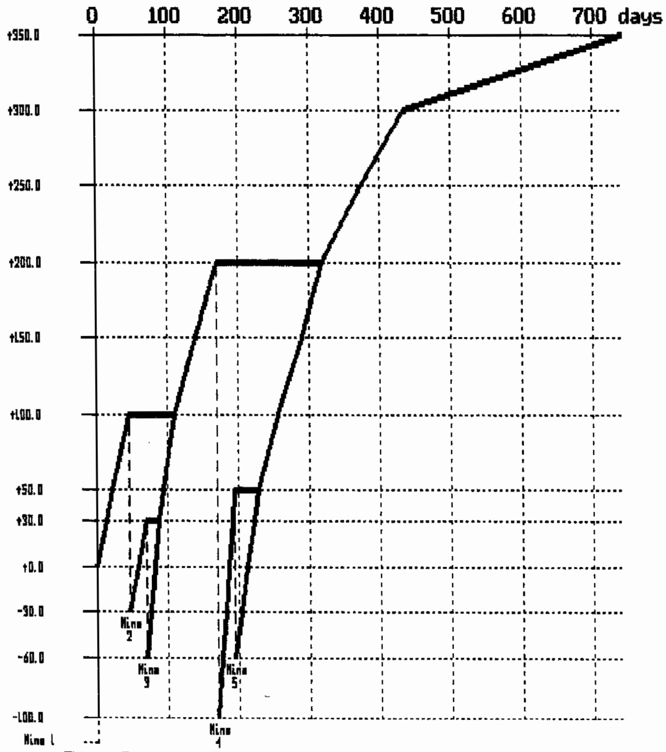

Fig. 2a. DIAGRAM OF THE FLOODING PROCESS IN TIME

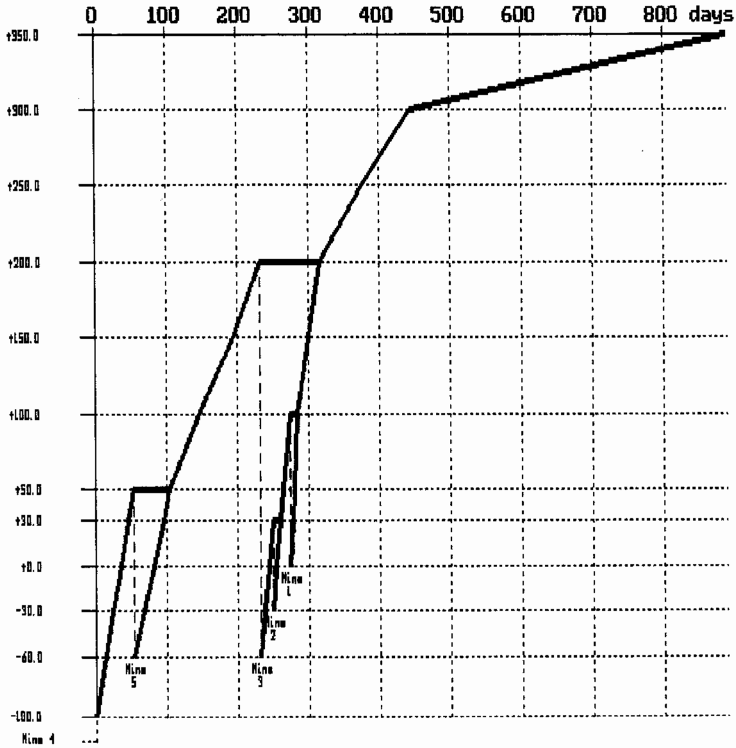

Fig. 2b. DIAGRAM OF THE FLOODING PROCESS IN TIME