EFFECTS OF LONGWALL MINING SUBSIDENCE ON GROUND WATER LEVELS WITHIN A WATERSHED HYDRAULICALLY ISOLATED FROM MINE DRAINAGE[1]

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Abstract: Surface and ground water resources are effectively preserved from depletion by underground mine drainage if impervious deposits of sufficient thickness and extent that underlie the aquifer avoid fracturing and undergo only plastic deformation resulted from the strata flexure. This does not mean, however, that these waters are not subjected to the effects of mining disturbance. Differential vertical settlement of the mine overburden and the ground surface can significantly affect flow pattern and water retention within a watershed area. This is evident, for example, in the areas of multiseam coal mining where the longwall method is used. The effects of this type of mining on water level were tested in a selected watershed where shallow water bearing deposits were entirely isolated from underground mine pumpage. Results of more than 7 years of field investigations were compared with data collected from other coal mining areas of various hydrogeological conditions. The study revealed a variety of water table responses on the postmining subsidence. Basically, changes of water table height in a given site above the point located at the top of aquifer base depend mainly on alteration of that point position against the local drainage base in the hierarchic structure of flow system. The relationship between the magnitude of ground subsidence and water level decline varies within the area of the subsidence trough, within the watershed, and among various watersheds of different hydrogeologic conditions. Except for the situation of hydrostatic flow conditions, lowering of water table elevation in response to the settlement of aquifer base was observed.

Additional Key Words: monitoring of watershed, induced ground water fluctuations, mining damages, inundations.

Introduction

Underground mining accompanied by deformations and fracturing of the overburden can cause partial or complete dewatering of the overlain water-bearing strata. The vertical range of the drainage influence can be restricted by a layer of waterproof sediments if it occurs above the zone of caving and does not undergo fracturing. Then all the overlying water-bearing layers will remain hydraulically isolated from mine drainage. This does not mean, however, that shallow ground water horizons are free from mining disturbance. Local inundations of land surface are the most characteristic effects of postmining subsidence in such a case. These effects become a major environmental problem in some coal mining areas where the longwall system with caving is carried out. Using this system for extracting the multiseam deposits results in lowering of the aquifer base by several or even tens of meters.

It is eften claimed that subsidence of the aquifer base does not involve change of the absolute (sae level) elevations of ground water level, which means that depth to ground water decreases of the value equal to the magnitude of subsidence. In that case, the aquifer is considered to be an underground reservoir and the assumption of hydrostatic law is valid. The question still exists as to the impact of subsidence on water level in dynamic flow conditions. It was tested in a selected watershed. Results of field investigations were compared with data collected from other coal mining areas of various hydrogeological conditions.

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Investigations in the Selected Watershed

Objective and Scope

The objective of the investigation was to record the behavior of ground water table as a response to subsidence resulting from longwall mining within dynamic water flow system free from the influence of mine drainage. It was aimed at better understanding the processes leading to the development of land inundation due to uneven subsidence in watershed scale.

The field investigations comprised baseline data collection, setting up an observation network for monitoring subsidence and water level fluctuations, observations of changes in flow pattern in the course of ground movement and after its stabilisation. Some results of these investigations within one of the selected watersheds in the Upper Silesian Coal Basin are presented below.

Description of the Project Site

The watershed, with an area of 3.5 sq km, is covered with Quaternary sediments composed of silts, sandy clays and sands. Their total thickness lies between 10 and 30 meters. The water bearing horizon is associated with the occurence of 1-2 layers of sands. The upper layer of continuos extent is covered on prevailing part of the watershed by semipermeable silts of 1-3 m in thickness and it forms an unconfined or semiconfined, leaky aquifer. The second layer occur locally at the bottom part of Quaternary deposits and is of confined flow conditions.

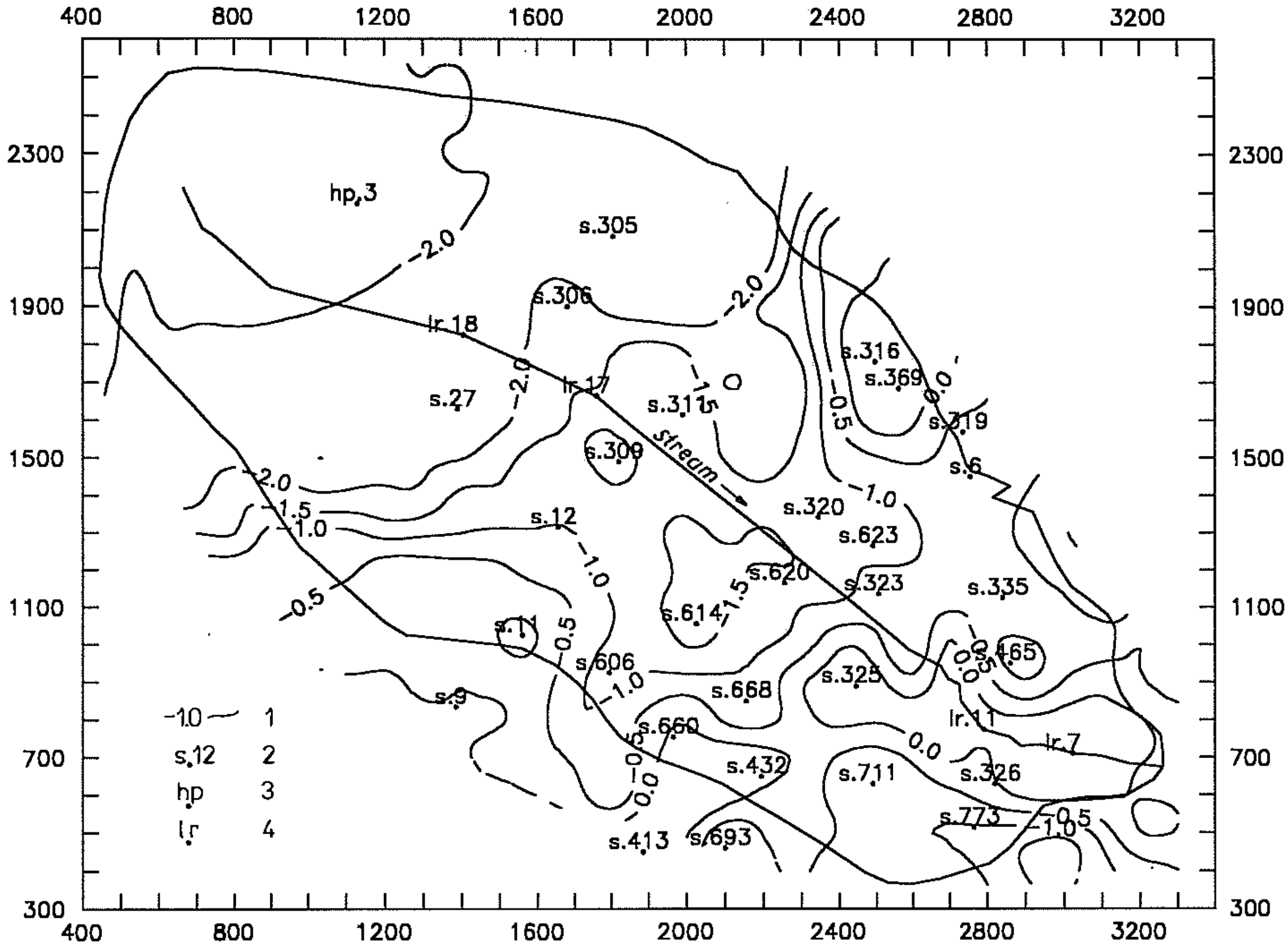
The Quaternary deposits are underlain by Tertiary formations of 140-300 m in thickness and build up with nonpermeable Miocene clays and claystones that separate shallow aquifers from the impact of coal mine drainage. Coal seams are mined under the watershed with the longwall system at depths 350-750 m, and about 80% of the watershed area is at present subjected to postmining subsidence.

Results of Monitoring Ground Water Level Fluctuations and Mining Subsidence

The effects of mining subsidence on the change of ground water level is superimposed on the response due to natural factors. To identify the induced modification to the elevation of water level, adequate long periods of observation are necessary and sometimes the reference to water level fluctuations in other points situated outside the range of mining influence is required.

The low ground water level stage recorded in October 1982 was chosen as the reference stage on the beginning of observation. Next, which proved to be the best comparable natural water level stage during the investigation period, was the stage of November 1986. Under the comparison of both stages, the change in ground water elevation within basinwide scale was approximately defined (fig.1). Over almost the entire drainage basin, decline of ground water elevation was observed. It ranges between 0.5 m to over 2 m. Relative to the corresponding ground surface subsidence that occurred during this period, changes of depth to ground water were found (fig.2).

The rise of water table relative to ground surface occurred in the central part of the subsidence trough and in areas where subsidence tilt is counter to the direction of ground water flow. Depth to ground water increased in the upper wing of the subsidence trough and in areas where subsidence tilt is the same way as the flow. Areas of positive and negative changes of water level with regard to ground surface are separated by zones where the magnitude of water level drop and subsidence are approximately equal to each other. It is illustrated by profiles of ground surface subsidence and water level fluctuations in well s. 19a (fig.3).



KEY

1 - isolines of ground water elevation decline,0.5 m interval
2 - observation well
3 - piezometer
4 - point of surface water measurement

Figure 1. Changes in elevation of ground water level, October 1982 - November 1986 within the research watershed

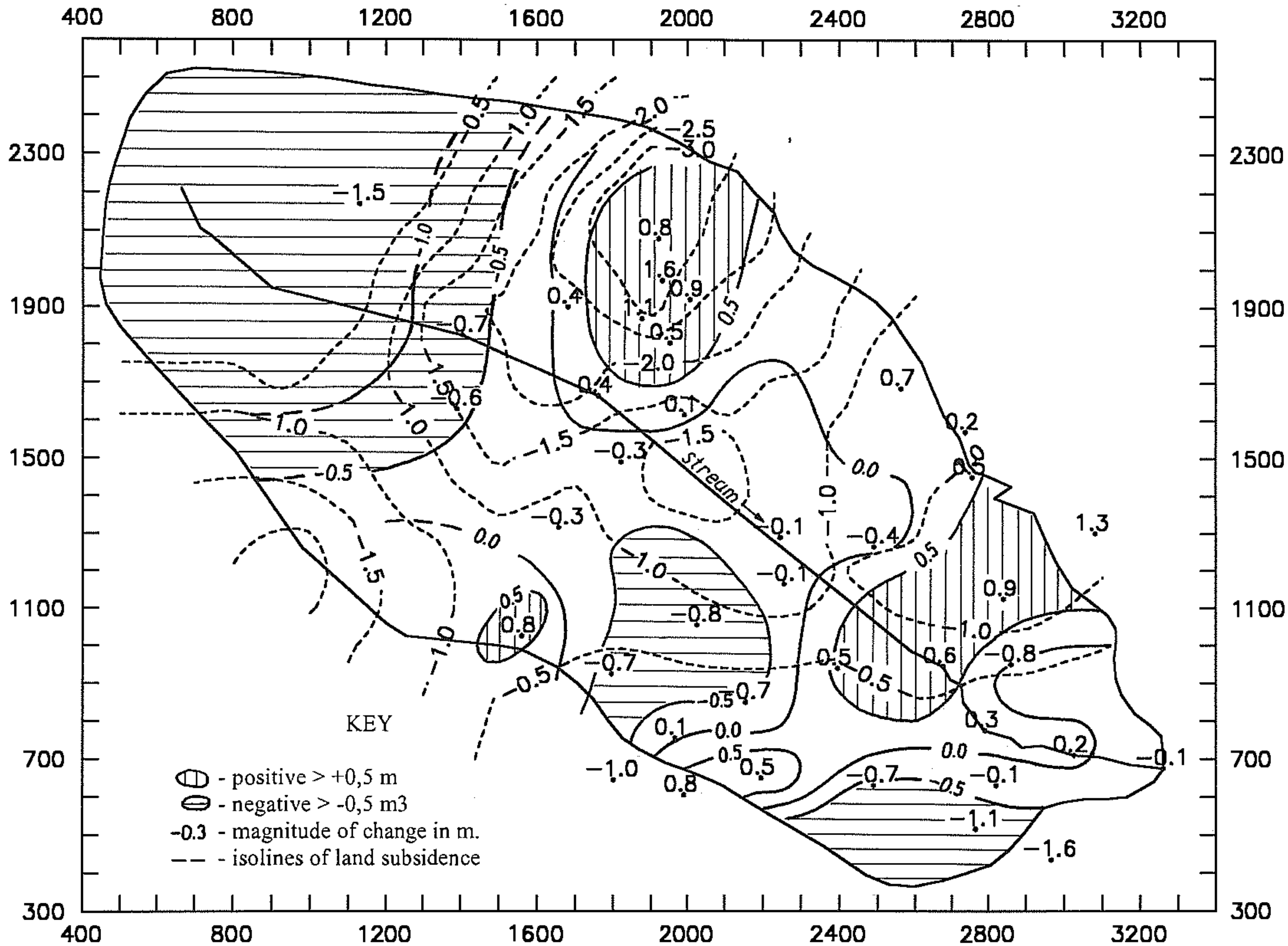


Figure 2. Changes in depth to ground water level, October 1982 - November 1986 within the research watershed.

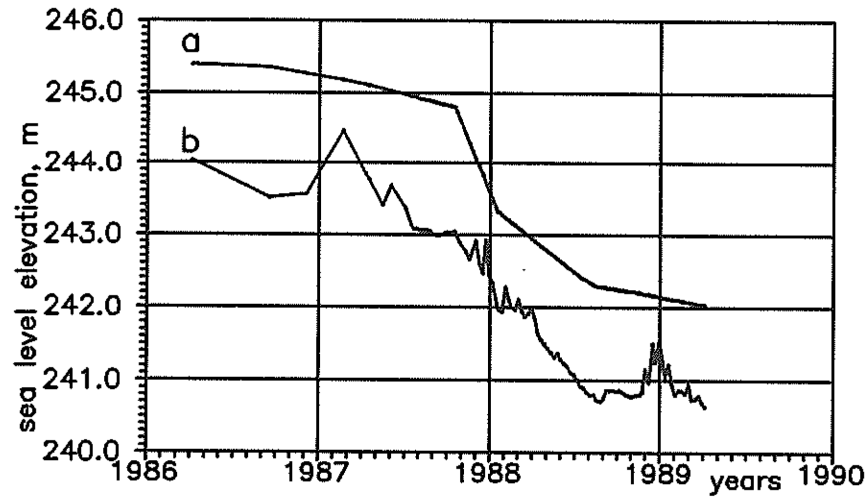


Figure 3. Profiles of surface subsidence (a) and fluctuation of water elevation (b) in well s. 19a.

Relationship between the magnitude of mining subsidence and decline of grouud water level

Results from other test watersheds and other drainage basins of different hydrogeological conditions have revealed a variety of water level responses to mining subsidence.

The magnitude and character of these changes depend on the depth, range, and geometry of a subsidence trough, as well as on natural conditions of a drainage basin in which this trough is being developed. The differentiation of individual features of a waterflow system causes the same subsidence in various drainage basins to create various effects. For example, the impact of mine subsidence on ground water level over the collieries in Da Tun Coal Mining Area, Jiangsu Province, China, was analysed. Subsidence troughs that have developed there in a vast drainage basin of infinite water resources within the alluvial plain of the Yellow River have not caused a change in ground water elevation. Depth to ground water has decreased by a value equal to subsidence (Staszewski, 1988).

Another example comes from small watershed bounded by the outcrops of water-bearing layer and entirely covered by the subsidence trough over supercritical extraction panels. Here, the ground water elevation has decreased by a value approximately equal to the magnitude of subsidence (Staszewski, 1992).

Essential to the problem discussed here is temporary position of a given point located at the top of aquifer base against the local drainage base. The local drainage base is understood to be the elevation of an aquifer base or streambed at the outlet of basin, subbasin, or catchment of the just developed subsidence trough, while the elevation of water table above the drainage base is called outflow level.

It is obvious that the relationship between subsidence and drop of water elevation at a given point is changing over the course of subsidence development. This is illustrated in figure 4, where curve H denotes a decline in ground water elevation and curve z- subsidence of the base of a flow path over time. Figure 4a presents the situation of a stable drainage base. In this case, after the base of flow path is lowered down to the level of the drainage base, water table reaches its lowest position (outflow level) and further settlement of the base of flow path has no impact on the water level elevation. The effect is an increase in saturated thickness of the aquifer h, and the flow path is transformed into a stagnant water body. Within small watersheds, drainage bases also undergo subsidence, as does the outflow level (fig. 4b). Even then, lowering of water elevation is limited by the elevation of a drainage base of the higher-order drainage basin (fig. 4c).

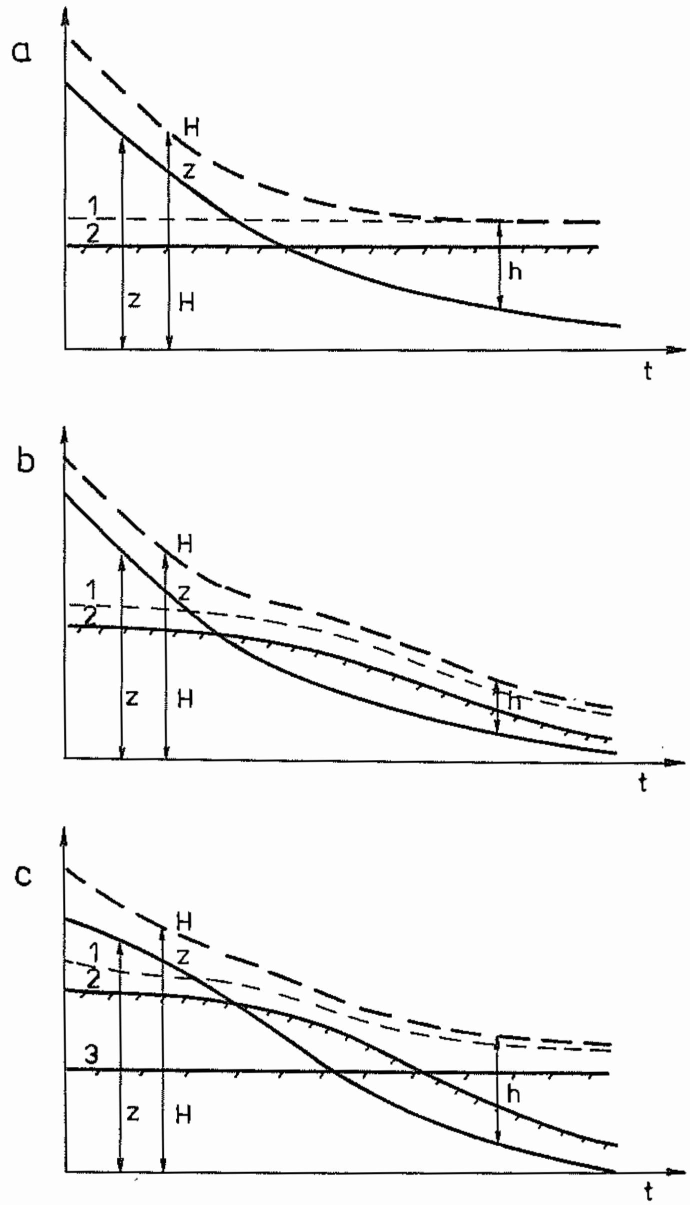


Figure 4. Diagrammatic representation of decline of ground water elevation (H) in course of subsidence of the aquifer-base (z) in a given point.

a - under stable drainage base, b - under lowering of the local drainage base, c - under lowering of the local drainage base and stable drainage base of the higher order flow system.
1 - outlow level, 2 - local drainage base, 3 - drainage base of the higher order flow system.

Conclusions

As a result of underground mining, settlement in the base of flow path causes, with few exceptions a drop in water level elevation. The magnitude of this drop in relation to subsidence varies within the subsidence trough, within the drainage basin, and among different drainage basins. It also varies with time depending on to what degree the deformations of the base surface of an aquifer modify the initial hydraulic gradient. The magnitude of the drop is controlled by the reduction of elevation head over the local drainage base. Lowering of the base of the flow path down to or below elevation of the drainage base leads to a situation in which hydraulic gradient reaches its critical value. Further settlement of the base has no impact on position of water level, and the flow path transforms into a stagnant water body.

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