Evaluation of the Reliability of Hydrogeological Information

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Abstract: Ground-water is of great importance for both natural processes and economic activities. However, because of a number of causes the hydrogeological information is not clear-cut. The consideration of this ambiguity is obligatory when making scientific and economic decisions. A method to evaluate the uncertainty of hydrogeological information when making decisions is suggested. It is elaborated for the Bayesian principle of decisions with the use of statistical analysis of experimental data. The suggested approach is useful for the economic justification of additional investigations.

Introduction

The purpose of this article is to draw specialists' attention to the importance of ground-water studies and to the necessity of hydrogeological information when forecasting both economic development and environmental changes. The article also aims to discuss both the reliability of hydrogeological estimations and an approach to the estimation, taking into account uncertainty of hydrogeological information and probable economic losses. This approach is not traditional for hydrogeology. We discuss ground-water resource evaluation using Moldavia as an example. Moldavia is one of the Soviet republics (located in the very SW of the Union) having a developed industrial-agrarian complex and a great population density.

Ground-water and Changes of the Environment

Changes of the environment by human activities are inevitable and have also negative consequences. Disturbances of natural conditions as a result of man-made influences have become rather substantial and the changes of natural conditions can result in serious and irretrievable consequences in a short period of time. Therefore, scientific justification of actions for both complex water resource utilization and protection of optimal ecological situations is one of the most urgent world problems. To substantiate it, the prediction of probable environmental changes under various alternatives of socioeconomic decisions must be made. For this a complete analysis of the whole regional complex of natural and technical data is necessary. This analysis requires efforts of many disciplines and various specialists (in climatology, hydrology, hydrogeology, soil science, biology, technology, economics, and so on). The realization of corresponding programs and the elaboration of valid decisions having economic and social consequences are impossible without the knowledge of the hydrogeological situation and the regularities of its change because the ground-water role in economic activities and natural processes is very important. This can be shown on the example of Moldavia, where ground-water is the primary water supply source and the cause of many unfavourable phenomena.

Ground-water provides over 80% of the entire drinking water supply of the Moldavian Republic. The intensity of ground-water use for the past 15 to 20 years has increased 5 to 6 times (in some parts of the region 8 to 10 times). At the same time the drawdown of ground-water levels in some areas has increased to 90 m. The existing ground-water withdrawal is near the limit fixed by nature. The intensive ground-water pumping may induce the migration of water of inferior quality from the adjacent aquifers. Besides that there is a threat of the contamination of productive shallow aquifers. All this can in short time disturb the existing water supply system and change its development prospects.

The ground-water role is not limited to the water supply problems. Ground-water has to be considered in much broader aspect as the main regulating part of the water balance. The investigations conducted (Zelenin 1972) showed that from the normal annual precipitation
of about 500 mm, 90 to 95% of water is lost by evapotranspiration (which in overwhelming majority takes place after an underground transformation), 2 to 5% penetrates into deep aquifers (not drained by rivers), and the rest forms the streamflow (an essential part of which is a ground-water contribution).

Human activities can substantially influence the given balance correlations, which are close to the natural ones. Thus the changes of water and thermal balances in the industrial and urbanized areas cause ground-water level to rise at the rate of 2 to 3 m per year. This in turn causes an unfavourable change of soil properties, and also deformation and damage of buildings, and rise in the cost of construction and ground-water exploitation. Due to irrigation the rise in ground-water level can increase evapotranspiration very strongly. When the depth of ground-water level is 4 to 5 m, its average discharge by evapotranspiration is 20 to 50 mm/yr, but when the depth is about 1 m, other conditions being equal, the discharge is 300 to 500 mm/yr (Bayer et al. 1979). The higher the water level, the higher the air humidity and the lower the solar radiation. This influences the erosion and landslide processes, composition and structure of the soil, and plant development conditions.

Other examples of undesirable consequences of human activities include thermal and mineral waters, artificial recharge of aquifers, disposal of toxic wastes and so on. From the above it follows that the ground-water study in addition to other studies is one of the basic tasks, the solution of which is very important for the evaluation of the ecological consequences caused by human activities. Hydrogeological problems of water supply, in spite of their paramount significance, are only one part of the general problem.

The Reliability of Hydrogeological Estimation and its Consideration in Economic Decisions

The arrangement of the alternatives of economic development and the choice of the optimal one must be carried out with both the consideration of socioeconomic consequences and the assessment of risk connected with the reliability of predictions. Considering the hydrogeological predictions (ground-water resource evaluation, salt-water regime determination in connection with land reclamation, migration predictions of contaminated water and so on) from this point of view, the following has to be noted. As a rule, the forecast of the aquifer conditions are made on the basis of mathematical equations, with the use of rather rough ideas about the properties of the systems and processes taking place in aquifers. In doing this it is traditional to use the determination approach. This approach implies simplification of both calculation indexes and calculated final results (without the consideration of possible estimation errors). Such an approach is unsatisfactory as hydrogeological systems are very complicated diffusion systems (Nalimov 1977), the behaviour of which is determined by many complicately interacting factors. Theoretical models used for the description of these systems have a sketchy character. They do not take into account all the factors and interactions in the system. At the same time, in practice, the solution strongly depends on an uncompleteness of initial actual data, an imperfection of investigation methods, and a diversity of insufficiently controlled influences. All this causes an ambiguity of the hydrogeological evaluation, the errors of which can run up to hundreds of percent (Bayer et al. 1979, Gorokhovskiy 1977, Zelenin 1976, Zelenin and Pertzovskiy 1977).

For the above reasons it is more realistic to speak about probable distribution of the evaluation, but not to confine oneself only to one determined value. Moreover, it is necessary to distinguish two types of uncertainty and the corresponding evaluation of statistical and nonstatistical character. For example, the evaluation of hydraulic parameters and the estimate of ground-water level fluctuations (under a statistical stability premise) belong to the first type, but boundary-condition type determination and so on — to the second one. In the first case, the probability is evaluated by the statistical processing of experimental data. In the second one, it is made by expert conclusions (Raiffa 1969). Both evaluation types must be based on a special hydrogeological analysis.

The general methodological approach to the evaluation of the reliability of hydrogeological information can be shown on the example of the prediction of a ground-water withdrawal. Usually such a prediction is based on the "effective values" of the hydraulic parameters, which are based on averaging the values calculated from pumping-test data, as well as on the most realistic (in the opinion of an investigator) type of boundary conditions (Bochever et al. 1969). The result of the prediction is shown as having only one value. In addition (taking into account the existing differences in the results obtained from different calculation schemes), the decrease of the possible production rate is considered more preferable than its increase, and the possible difference is attributed to an "engineering reserve" (without its numerical estimation). The "reserve" is not taken into consideration when choosing economic decisions.

In general, the described traditional approach is not believed to be the best one, because it considers neither the probable character of the ground-water resource information nor the gains (or losses) connected with the economic decision (in particular the damage caused by the underestimation of the safe ground-water yield). Besides that it is not constructive for the economic justification of the worth of a detailed ground-water prospection. The degree of the detail of the prospection must depend on the possible losses caused by the shortage of the hydrogeological information. There is no sense of making investigations if their expenditures exceed the cost of the prediction error.