Modeling of the riverside groundwater intakes exploitation taking into account of the stream flow changes

*S. V. Telyma (Institute of hydromechanics, NAS of Ukraine), O. S. Voloshkina (Kyiv national university of construction and architecture), YU. O. Bereznytska (Kyiv national university of construction and architecture), V. M. Efimenko (National Taras Shevchenko University of Kyiv)

SUMMARY

Purpose. As known the main part of the groundwater intakes are situated in river valleys where the close interconnection of the surface and groundwaters have a place. At this the part of the exploit resources is providing for account of the river flow reduction. Purpose of the research consists of the systematic and complex analysis of the riverside groundwater intakes work taking into account of the geological and hydrogeological conditions forming of the water resources on the territory Volyno-Podol artesian basin. Methodology. The research methodology consists of the using the methods of numerical modeling for evaluation of the prognosis resources of the groundwater intakes for water supply of Lviv region(Ukraine). Results. A permanently working mathematical model of the geofiltration of the investigated groundwater field has been created for evaluation of the operational groundwater resources for a long-term period which allows to carry out the imitative modeling of project water intakes exploitation in different operating regimes, solving problems of regulating and optimizing water withdrawal under different conditions of water intakes work, the expansion the productivity depending on the economic needs in the region and to solve the problems of the maintenance the quality of the drinking water by predicting the possible pollution and depletion of major aquifers during their operation. The created model of the ground water deposit of the Gorodok area(Lviv region,Ukraine) can be used as a intake-analog when selecting promising sites for the placement of new water intakes that will reduce material resources during their substantiation and construction. Originality. A permanently working mathematical model geofiltration has been created for the assessment of groundwater resources on the basis of a comprehensive analysis of geostructural features and hydrogeological conditions at a given territory. The model allows to consider of the different variants of water intakes operation depending on the technical and economic conditions and the possible increase in water supply needs taking into account of the environmental measures and the impact of water intakes on the environment. Practical significance. As a result of the research the exploit groundwater resources in the water intakes area were wellgrounded determined which allows to increase the available water supply of the population on this territory for a long-term period and to reduce the load on the operation of existing water intakes thereby regulating the groundwater resources of the given artesian basin.
Introduction. As known the mathematical modeling of the geofiltration problems is widely instilled into the practice of the hydrogeological investigations. At that modeling is used on the different stages of the search and research works including search, epignose, prognose, imitation and optimization ones. In the article the results of the evaluation of the prognose exploitre resources of the groundwater’s on the Gorodok area (Lviv region) by the methods of the mathematical modeling taking into account the interconnection of the ground and surface water are presented.

Methodology. Methodology consists of in using the methods of the numerical modeling for solution of the direct and inverse problems of the geofiltration at the evaluation of the prognose exploitre groundwater resources on the investigated territory.

Geohydrogeological conditions. The investigat area in geosctructural relation is located in the south-western part of the Volyno-Podilsky subregion of the East European Platform and is presented the platform region, foundation and sedimentary rocks which are hollowly immersed in the western and southwestern directions (Gurskiy and Kruglov, 2007). From the point of view for the fresh groundwater use in these sediments the deposits of the Cretaceous system which are widespread within the platform are represented of the interest. Analysis of the geostuctural conditions of this region allowed to choose out the three types of groundwaters deposits that differ in terms of the formation of operational groundwater resources (Shestopalov at al., 1991, 2010): 1 - deposits of groundwater’s in river valleys; 2 – in limited area structures; 3 - in artesian basins. The water supply system of the Lviv city (Ukraine) includes more than 40 water intakes which are grouped into four ones, namely: North, Western, Eastern and Southen (Shestopalov at al., 2010; Ljuta and Ljutyi,2016). They are located in areas of general distribution and using of groundwater’s of the Upper Devonian, Upper Cretaceous and Neogene deposits. Investigated territory Gorodok belongs to the Western group which also includes the water intakes Rudno, Malchytsia, Kernytsia, Kamenebrid and Budzen. The researches carried out at the sites of these water intakes showed that there is a direct hydraulic connection between the aquifer deposits of the Lower Baden and the Upper Cretaceous aquifer. The recharge of the aquifer is ensured by the infiltration of atmospheric precipitation in areas where the Middle and Lower Baden deposits lie directly under the water-permeable Quaternary ones and the discharge takes place in the river and streams in the form of numerous sources. The main aquifer in this area belongs to Miocene sediments. Aquifer are conditionally well protected and connected by a fissure type collector with varying thickness and the different filtration properties. The formation of the operational resources of the aquifer is due to infiltration and river flow.

Results. As mentioned above the studied area is characterized by the complexity of hydrogeological conditions and there is a necessity in a detailed account here the main factors of the formation of the existing operational resources. With a purpose of the groundwater resources evaluation at the Gorodok area the geofiltration model of the groundwater’s was created with using mathematical modeling methods (Edvards and Penny,2008; Telyma, 2003, 2014).The geofiltration model of the deposit covers an area of 165 sq. km (11 x 15 km) (Figure 1). The discrete mesh consists of the uneven blocks with a maximum step of 500m and a minimum of 250 m. The total number of nodes of the discrete model is 1870 (34x55). The form of this discrete domain have an irregular contour taking into account of the spreading area of the investigated aquifer in given site. On this model the groundwater filtration in Miocene sediments was modeled. At this the interaction of the ground and surface waters and the infiltration of the precipitation were taking into account of. The main input data were obtained at the analysis of the experimental field ones on the investigate area. So that to obtain the input data for determination of the main filtration parameters (transmissivity and storage) the results of the pumping tests in operation wells and the observations in observation ones were analyzed. Interpretation of the obtained data allows to get the values of the parameters in the separate points of the considered filtration domain. The regime observations were analysed with a purpose to investigate the hydrogeological conditions of groundwaters forming and the evaluation of the intercommunication of the surface and groundwaters’ and its influence on surrounding media. The plane dimensions of the model and the boundary conditions were choose taking into account the conditions of spreading of the aquifer and results of preliminary analytical calculations of predictive depression cone on forecast period water intakes operation. As a whole the model boundaries were
choose on the watersheds of the river net where the boundary conditions of second type were set (contours with zero lateral inflow). At the first stage of the research the schematization of the filtration area was carried out both in the plane and in the section. In the plane the external boundaries of the model were selected taking into account the distribution of aquifer in the area, their filtration heterogeneity and also taking into account the possible influence of the existing groundwater’s intakes Kamenebrid, Kernytsa and Budzen. The inner boundaries of the model are the Vereshchytsia and Stara rivers and their tributaries located within the selected model which take into account the additional concentrated aquifer accretion. The mathematical description of transient filtration for this model which taking into account the adopted schematization is given in the work (Telyma, 2003). In order to simplify the simulation of the given problem it was solved relatively to the function of drawdowns of the levels and heads. With a purpose to account of the infiltration accretion on the model it was realized as the difference between the mean value of rainfall and evaporation for given region with using of the hydrometeorological data and equals 0.00036 m/day. To increase the probability of solving of the predictive problem a calibration of the model was performed which consisted in refining and determining of its main parameters. At first the group pumping’s from a network of exploring and operational wells was modeled which allowed to carry out the precision of the hydrogeological parameters of transmissivity and conductivity. At the next stage the redistribution of the heads of groundwater’s of the Miocene aquifer in undisturbed conditions was restored on the model. As the basis of the solution of this inverse problem was a map of water table isolines created in the process of the analysis of the field data of the levels and heads in the given area. In addition, the field data of previous works (hydrogeological surveys and other search works) were used. When processing the mentioned above data the method of kriging was used (Gogu et al., 2001). With the help of this method a schematic map of groundwaters levels in an undisturbed condition was created. The analysis of the obtained cartographic material showed that the map created in this way trustworthy reflects the hydrodynamics of groundwaters in undisturbed conditions within the research area taking into account the existing river network. Created head map in undisturbed conditions allowed to create a map of the coefficients of transmissivity in this area. The peculiarity of the solution of this inverse problem consists in that when determining the values of transmissivity in discrete points on the model as additional information the data about the heads at the same points were used for the conditions of the undisturbed filtration regime. Thus the multi-parameter problem was solved in relation to the transmissivity parameter which allowed to significantly increase the degree of probability of the obtained transmissivity map. To determine the values of the permeability of underchannel sediments in the valleys of the Vereshchytsia and Stara rivers and their tributaries as well as the permeability of the separation layer in the Quaternary deposits the inverse non-stationary filtration problem was solved. At this the nonstationary regime was reproduced at the expense of the modeling of the work of the Kamenebrid, Kernytsa and Budzen water intakes with a total water withdrawal of 64200 cubic meters/day. The maximum values of the drawdowns for the period of 25 years from the beginning of the water intakes work were obtained on the results of the simulation as 10.0-15.0 m in the center Budzen and Kernytsa water intakes. The obtained value of drawdowns are greater than regime ones as on the model no account the part of the resources of river flow Vereshchytsia which are accumulated during the autumn-winter season in river alluvial sediments. In whole the model and natural data coincide in quite enough. As a result of the solution of the inverse nonstationary problem the values of the coefficients of permeability of the underchannel sediments were corrected and constituted 0.00068 days⁻¹. The calibration all created geofiltration model of the Gorodok site allowed to identify the main hydrogeological parameters and get over to the solutions of various variants of the forecast problems for the estimation of the productivity of the designed water intakes in the given area. The forecast of water intakes productivity on the territory Gorodok site was performed on the more accurate with a help of the solutions of the series of inverse problems filtration model for the period up to 2025 at condition of taking into account the productivity of the projected water intakes on sites Artyschiv and Mavkovychy with a summary water withdrawal accordingly of 9000 and 7800 cubic meters/day. The predicted problem was solved in two stages. At first the nonstationary problem for the period of 25 years with the reproduction of the work of the Kamenebrid, Kernytsa and Budzen water intakes was solved and then the withdrawal of the designed wells was included and the problem was solved further on the year 2025. At the same time the time step varied from 0.1 days to 5 days as the rate reduction of the heads drop on model during modeling. To prevent
the additional modeling errors when setting of the debits of the design wells the time step was again to set to the minimum (0.1 day) and then was increased in the process of solving the predictive problem. As a result of simulation the maximum drawdowns in the calculative period in the center of the depression cone of the designed water intake Artyschiv was obtained 16.65m, in Mavkovychy intake – 12.19m and in the center of the existing water intake Kernytsa 14.37 m with a permissible drawdown of the heads in the center of the Gorodok water intakes of 28.0 m that is the existing and designed withdrawal within the defined area is secured at the accepted value the projected drawdowns of groundwater heads. The forecast depression cone covers the areas of the projected and working water intakes with a general contour of head drawdown almost of 7.0 m and is distributed mainly along Vereschytsa river valley (Fig.1). The operational resources at this site are formed by the resources of the aquifer, infiltration (98000 cub.m/day) and the amount of water recharge at the expense of the river network (21000 cub.m/day) that is the operational resources of groundwater of the all working and projected water intakes are fully provided by the natural resources.

**Figure 1.** Schematic map of the isodrawdowns of the groundwaters on the territory Gorodok site obtained in the result of the numerical modeling the pronounce problem of geofiltration on the 2025 year taking into account of the exploitation of existing water intakes Kamenebrid, Budzen, Kernytsa and projected ones Artyschiv and Mavkovychi.

- ○ 5 - exploitative wells;
- ● 6 - projected wells.

The calculative prognosis resources of the Kamenebrid, Kernytsa and Budzen water intakes are providing owing to Vereschitsa river flow and infiltration and Artyschiv and Mavkovychi owing to the infiltration. Reliability of the received data concerning the quantities of groundwaters resources is ensured due to the accepted validated calculation scheme and modeling with using the trustworthy values of the main hydrogeological parameters which were improved at the solutions of the inverse identification problems. A permanently working mathematical model has been created for the
assessment of groundwaters resources on the basis of a comprehensive analysis of geostructural features and hydrogeological conditions of the territory of the projected water intakes. The model allows to consider different options for the regimes of operation of water intakes depending on the technical and economic conditions and the possible increase in water supply needs taking into account environmental measures and the impact of the water intakes on the environment. As a result of the research the groundwaters resources in the Gorodok area were provided which allows to increase the water availability of the population of this territory for a long-term period and reducing the load on the operation of existing water intakes thereby regulating in such way the groundwaters resources of the Carpathian region.

**Conclusions.** The carried out studies on the assessment of groundwaters resources of the designed and existing water intakes in the given area for the perspective have shown that the main resources of fresh groundwaters are found in fissured rocks of the Miocene sediments. The numerical model of the geofiltration for evaluation of the exploite water resources on the Gorodok area is created. During the modeling the series of direct and inverse tasks were solved that allows to carried out the quality calibration of the model and to improve its trustworthiness. The results of modeling showed that in forming the exploit resources on the investigated area take part the natural resources that satisfy the possibility to increase the total exploit resources almost in two times without the damage on the environment taking into account of that the underground feeding of the river on the given site is more than 0.42 cub.metres/s and every year the seasonal accumulation of the water in the Quaternary sediments occurred. The creative permanent model of the geofiltration of the investigated area may be used for examination of the different variants of the watersupply on the perspective. Taking into account of the fact that there is the limitation on the water resources in the given region in whole due to the existing geohydrodynamic conditions we assume that the obtained modeling results help us to use of the groundwaters for watersupply of the population in the region in an optimization regime and to prevent the depletion and reduction of groundwaters resources of the main aquifers.

**References**


