Groundwater level monitoring in the East Chuya groundwater basin

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The East Chuya groundwater basin (ECGWB), which is part of the larger Chu-Sarysu groundwater basin, is located in the north of Kyrgyzstan within the Chuya depression and includes the northern slope of the Kyrgyz and southern slope of the Kendyktas ridges. The slopes of these ridges correspond to parts of the hydrogeological massifs of the same name, forming the rocky foundation of the East Chuya groundwater basin, within which fissure and fissure-fault groundwater are developed in the rocks. Directly in the Chuya depression, on a rocky foundation, there is a bedded, partly artesian, East Chuya basin [1], composed of sedimentary clastic rocks. The thickness of the sedimentary cover of the bedded basin reaches 4-5 km along the southern side of the basin and up to the first tens of meters along the northern side, along the bed of the Chu River, which is the regional base for the drainage of groundwater in the East Chuya basin (Fig. 1, 2). The sedimentary cover of the East Chuya basin is composed from top to bottom of the Quaternary aquifer complex (Q^{2-4}), represented by clastic pebble deposits with sand and gravel filler, up to 300-400 m thickness within the southern part of the basin, located along the low foothills of the Kyrgyz Range, with a gradual replacement of these deposits in the northern direction by gravel, sand and clayey ones, having a thickness of the first tens of meters in the northern part of the basin, in the Chu River valley [1,2]. This change in the size of the clastic material occurred in accordance with its differentiation in the process of transport and deposition by permanent river and temporary water flows, which have the greatest gravitational energy potential on the northern slope of the Kyrgyz Range, which is higher than the Kendyktas Range. The permeability of these Quaternary deposits also changes from south to north from maximum values, on the order of several tens of meters per day, in the southern zone of groundwater recharge and subsequent transit, to a few meters per day or less - to the north, approximately from the latitude of the Bolshoi Chuisky channel, where after the zone of groundwater transit in the northern direction, a mixed zone of transit and wedging out onto the earth's surface of the regional groundwater table of the upper aquifers of the Quaternary aquifer complex begins [2,4]. At a greater depth, below the Quaternary aquifer complex, as can be seen in Figure 2, lies the Sharpyldak aquifer complex (N^2-Q^1) with a thickness of up to 1000 m, represented by large-clastic pebble deposits, which, unlike the Quaternary complex, are unevenly cemented, mainly by carbonate cement and for this reason have a permeability an order of magnitude less than that of the Quaternary aquifer complex. Even deeper, there are Chuisky (N^{1-2}) and Kyrgyzsky (Pg-N^1) aquifers complex with a thickness of up to 3000 m and 500-1000 m, respectively, represented by fine-grained sandstones, siltstones cemented by carbonate and partially silicate cement, with a permeability of less than 1 m / day. These aquifers contain thermal mineral pore and fissure, less often fault, underground waters, with a temperature at a depth of 2000 m of about 50 ° C and mineralization from several to tens of grams per liter. Within the ECGWB, in these aquifers, there is practically no renewal of groundwater resources due to water filtration from overlying aquifers, that is, they are characterized by a passive water exchange regime and are represented by the volume of ancient pore and fissure waters. The reason for this is most likely the presence of a regional epigenetic cementation aquicludes in the Sharpyldak complex, which prevents vertical filtration of groundwater from the upper to deeper aquifers [5].

In the eastern part of the East Chuya basin, the zoning discussed above is observed in the direction from east to west, with a reduced capacity of the Paleogene-Neogene aquifer complex due to the shallow occurrence of the rocky basement. The main zone of groundwater recharge of the Quaternary aquifer complex here is associated with the alluvial fan of the Chu River, which enters the Chuya depression, and the wedging zone is located in the area of c.Tokmak. The northwestern part of the East Chuya groundwater basin is located on the territory of Kazakhstan, for this reason, here the regional groundwater flow in the Quaternary aquifer complex has a transboundary character, crossing the state border of Kyrgyzstan in the northwest direction and continuing to move on the territory of Kazakhstan. Also, the northern part of the East Chuya basin, limited by the bed of the Chu River, is located on the territory of Kazakhstan, the groundwater flow from which, mainly from Quaternary deposits, is discharged into the Chu River.

The main resources of fresh, with mineralization up to 1 g/l, cold, with a temperature of about 13-17 ° C underground waters of the East Chuya basin are concentrated in the Quaternary aquifer complex, within its boundaries the main deposits of underground waters, which are used for water supply, have been explored. The city Bishkek is located on one of these deposits - Ala-Archa [1,2,3,4], for which its underground waters are the main source of drinking water supply.

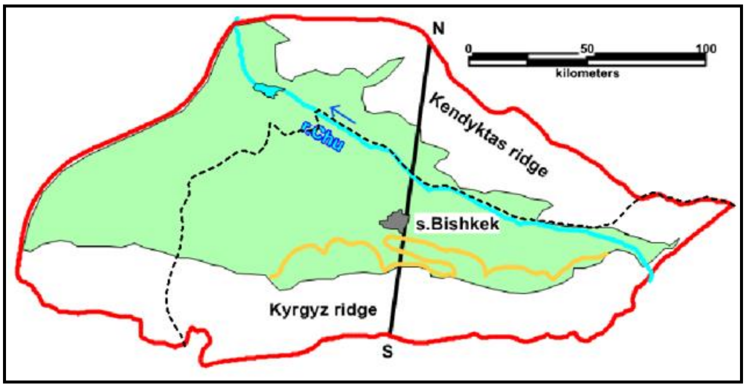

Fig. 1 East Chuya groundwater basin (ECGWB). The position of the profile (NS) is shown in Figure 2. Green color - sedimentary cover of the basin. White color - hydrogeological massifs represented by rock formations of mountain ranges and the basement of the sedimentary cover. Red line - watershed of surface and groundwater. Yellow line - boundary of the outcrop of sedimentary deposits of the Sharpyldak and Chuya aquifer complexes on the surface in the form of low foothills (adyrs). Dotted line - state border.

Groundwater of the Ala-Archa groundwater deposit, concentrated in the Quaternary aquifer complex, is estimated as approved operational reserves in categories A+B in the amount of 7.4 m^3/sec [1,2,3], they, like the reserves of other deposits of the East Chuya sedimentary groundwater basin, are renewable due to the constant filtration of water underground from rivers and other surface watercourses and reservoirs of the basin, from the Chu River in the east to the Aspara and Kuragaty rivers in the west. In general, natural renewable groundwater resources in the amount of 68 m^3/sec [1] are formed from rivers, canals, reservoirs and other surface water sources in the East Chuya sedimentary basin, they represent a constant regional flow of groundwater in the Quaternary aquifer complex, distributed throughout the area of the basin, on the territory of Kyrgyzstan. Here, within the Quaternary aquifer complex, in the pore space of water-bearing rocks, there is a constant volume of groundwater, which for the East Chuya basin was estimated at 300 km^3 [1] (excluding the northwestern and northern parts of the basin, located on the territory of Kazakhstan). This volume of groundwater, filling the space between the fragments of sedimentary rocks (pebbles, gravel, sand) and contained in the pores of clay rocks, is not constant and changes depending on climatic conditions that determine the amount of groundwater recharge by surface runoff, as well as on the operating mode - the amount of groundwater pumping out. Control over changes in the volume of these groundwaters is carried out by regularly measuring the position of the groundwater level in special regime wells under the jurisdiction of the Kyrgyz Hydrogeological Expedition.

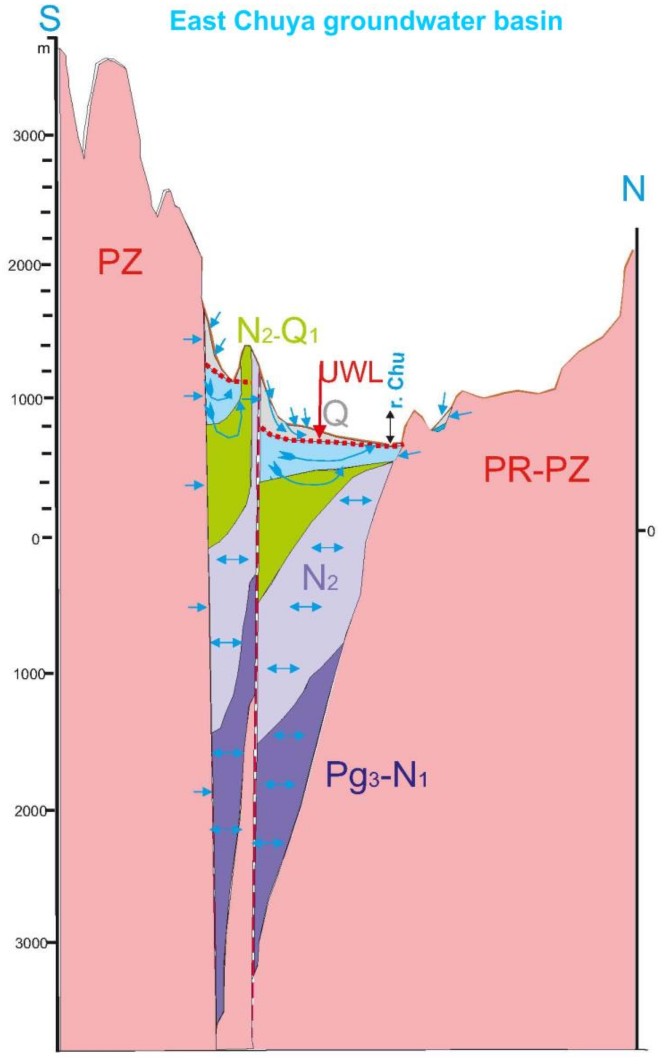

Fig. 2 Profile through the East Chuya groundwater basin (see Fig. 1), constructed according to the data of the Kyrgyz Integrated Hydrogeological Expedition. Blue arrows show the areas of groundwater recharge by surface runoff and the direction of groundwater movement. In deep horizons, there is no unidirectional movement of groundwater. The ratio of vertical and horizontal scales is 1:42

For two of these wells: No. 1089 and No. 1301-4, shown on Google Maps: (https://www.google.com/maps/d/edit?mid=1-TtyqVZpy6We3QerLb1bMeF_ePyD19A&usp=sharing), (http://maps.google.com/maps/ms?ie=UTF&msa=0&msid=203965682782791499971.0004b53779c0491758c3a), within the framework of cooperation between the Central-Asian Institute for Applied Geosciences (CAIAG) and the Kyrgyz Hydrogeological Expedition (KHE), long-term observations of changes in the groundwater level of the Quaternary aquifer complex of the Ala-Archa groundwater deposit were carried out. The wells under consideration are located in the transit area of the regional groundwater flow moving in the northern and northwestern direction from the southern feeding area starting from the southern edge of the basin, along the foothills of the Kyrgyz ridge, to the regional drainage zone of the southern and northern edges of the basin – the Chu River valley. CAIAG began measuring the groundwater level in these wells, the location of which is also shown in Figure 3, in 2012 in well No. 1301-4, located at an absolute elevation of 740 m, and since 2018 in well No. 1089, located at an absolute elevation of 776 m, using the OTT_ecoLog_500 and Ott Orpheus Mini sensors with an accuracy of ± 0.05% FS and, more recently, the HOBO U20 Water Level Logger sensor with a typical water level measurement accuracy of ± 0.05% FS, 0.5 cm and a maximum error of ± 0.1% FS, 1.0 cm.

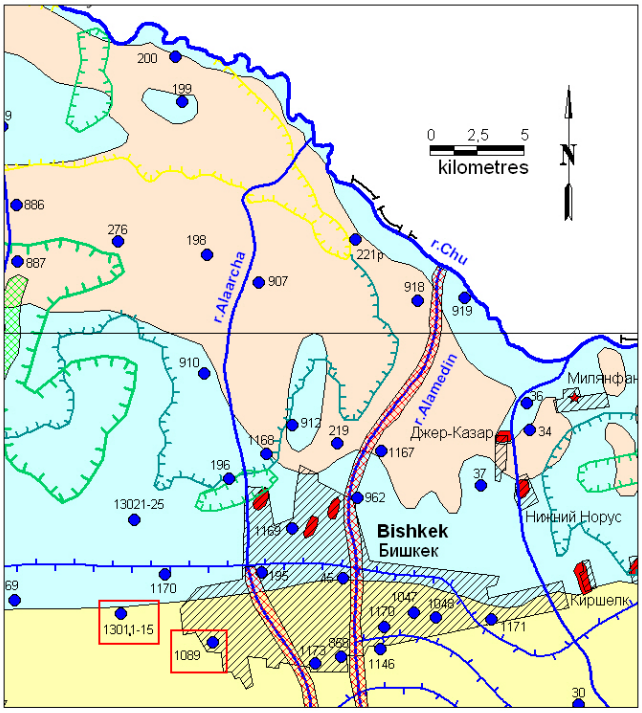

Fig. 3 Location of wells No. 1089 and No. 1301-4 (red rectangles) in the East Chuya sedimentary groundwater basin.

The results of measuring the groundwater level of the Quaternary aquifer complex obtained by the Kyrgyz Hydrogeological Expedition before 2012 (No. 1301-4) and 2018 (No. 1089) and by CAIAG after 2012 and 2018 are shown in Figures 4 and 5. As can be seen from these figures, from 2003-2004 to 2023, wells No. 1089 and No. 1301-4 have shown a long-term trend of decreasing the groundwater level of the Quaternary aquifer complex by about 5.1 m (No. 1301-4) and 6 m (No. 1089). Moreover, the maximum rate of decrease in the groundwater level was observed in well No. 1301-4 from 2004 to 2015, with a decrease in the level by 4.7 m, starting from a depth of 7.5 m and amounted to 0.4 m/year, followed by relative stabilization from 2015 to 2023 at an average depth of 12.4 m. Similarly, the maximum rate of level decline in well No.1089 was observed from 2003 to 2012, with a level decrease of 5.8 m, starting from a depth of 45.4 m and amounted to 0.6 m/year, followed by relative stabilization from 2012 to 2023 at an average depth of 51.3 m. Relative stabilization of groundwater levels in both wells is manifested in the multidirectionality of low-amplitude fluctuations and a decrease in the rate of level decline starting in 2012. Thus, in well No.1089, in the period from 2012 to 2023, even an insignificant increase in the level is observed with an average rate of 0.02 m/year, and in well No.1301-4, for the period 2015-2023, the average rate of level decline was 0.09 m/year. In this case, the synchronicity of the level change in two wells and the similar nature of the decrease in the groundwater level in the wells under consideration are noteworthy, with a distance between the wells of about 4.6 km, this indicates that the process of lowering the groundwater level has a significant areal distribution within the Ala-Archa groundwater deposit. One of the main reasons for the decrease in the groundwater level is a decrease in the recharge of the Quaternary aquifer complex associated with the long-term cyclicity of climate humidification, supplemented by the factor of global warming, which can be traced in Figure 5, where it is possible to determine the period of maximum humidification in the territory under consideration of about 30 years, with a possible maximum of the next humidification in the 30s of the current century. In addition to the natural factor of decreasing the groundwater level, it is also necessary to take into account the anthropogenic impact, in the form of redistribution of surface runoff in the territory of the groundwater deposit and the scale and trend of their exploitation. The combination of these factors, as can be seen in Figures 4, 5, has lost in the last decade from 2012-2015. to 2023, the previous activity and the degree of negative impact on the balance of groundwater of the Ala-Archa deposit, which is

expressed in the relative stabilization of the groundwater level with multidirectional level fluctuations. This may indicate, as noted above, the beginning of the next phase of the cycle of naturally conditioned rise in the groundwater level.
A more detailed long-term change in the groundwater level, including in the seasonal aspect, is shown in Figure 6 for well No. 1301-4 from 2009 to 2023, demonstrating a consistent annual decrease in the level, and Figure 7 shows the process of annual decrease in the groundwater level in the period from 2018 to 2023 for well No. 1089. In general, the results of observations of the groundwater level in the Quaternary aquifer complex, for wells No. 1089, No. 1301-4 indicate a decrease in the capacitive static reserves of groundwater from 2003 to 2023 within the considered area of the Ala-Archa groundwater deposit with a clear slowdown in this process in the last decade. This process may be caused by both a decrease in the amount of groundwater recharge in accordance with the natural cyclicity of dry years and the impact of global warming, and by the growing anthropogenic load caused by an increase in groundwater withdrawal, and a slowdown in the reduction of storage reserves may be caused by an increase in recharge in the groundwater balance or stabilization, and possibly a decrease in the amount of their withdrawal. These factors must be taken into account when planning the operation mode of c. Bishkek water intakes in order to avoid problems in the city's water supply due to critical depletion of groundwater reserves.

In addition to the results of observations of the long-term course of the groundwater level, observations of the groundwater level were carried out with a measurement frequency of 1 hour or less, which made it possible, in particular for well No. 1301-4, to detect the influence of lunar-solar tidal movements of the earth's crust with a daily periodicity on groundwater level fluctuations [6]. In this case, daily level maximums are observed at about 05-00 h. and minimums occur at about 23-00 h., with a level fluctuation amplitude of 0.3-0.8 m (Fig. 8). These level fluctuations must be taken into account in high-precision monitoring of the groundwater level. Similar fluctuations in the groundwater level are also observed in well No. 1089, however, in this case, the amplitude of daily level fluctuations is about 0.05 - 0.13 m and they are non-uniform in amplitude and configuration (Fig. 9). The difference in the magnitude of the amplitudes of the levels in the two wells is due to the difference in the lithological composition of the aquifer, which is represented in the area of well No. 1089, mainly by pebble rocks with gravel and sand filler, and in the area of well No. 1301-4 - by interbedding of gravel, sand and clay rocks. In the first case, the aquifers are less compressible under the influence of tidal stresses than in the second. In addition, in this case, the nature and amplitude of fluctuations in the groundwater level are affected by the operation of the nearby municipal well groundwater intake.

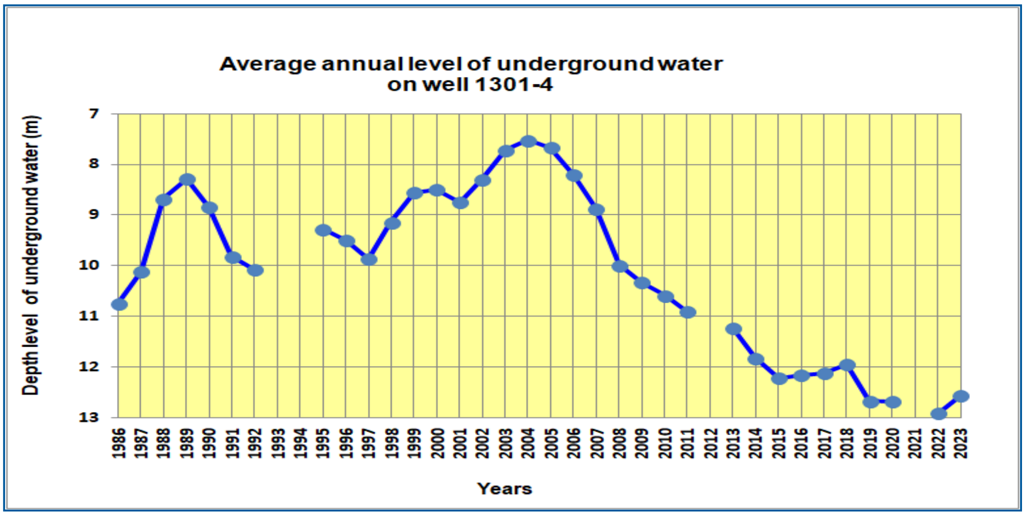

Fig.4 Measurement of the groundwater level of the Quaternary aquifer complex in well No. 1301-4

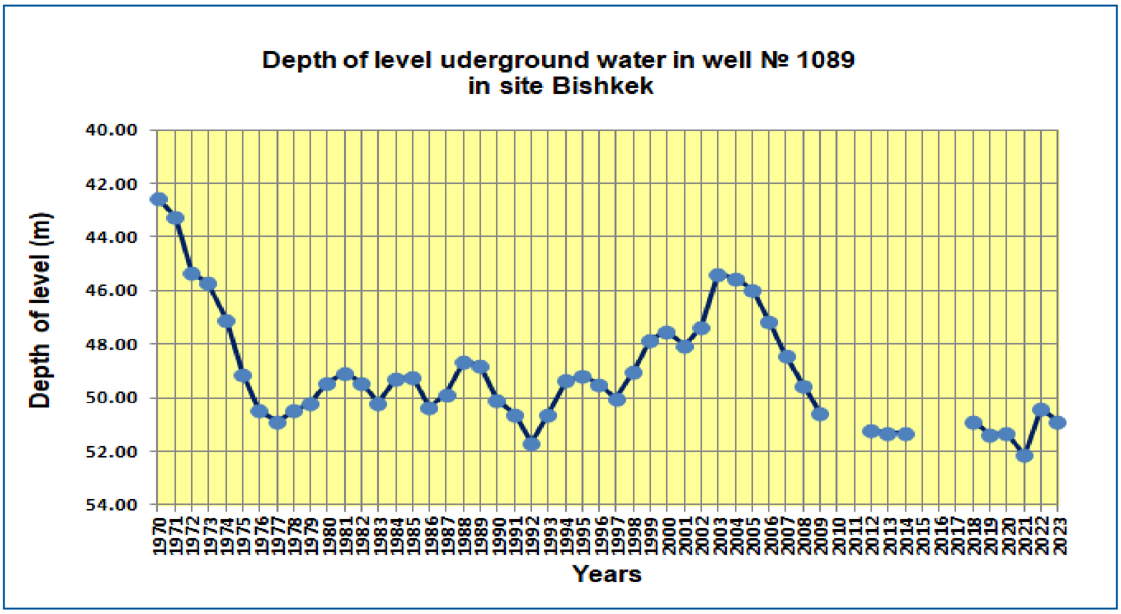

Fig. 5 Measurement of the groundwater level of the Quaternary aquifer complex in well No. 1089

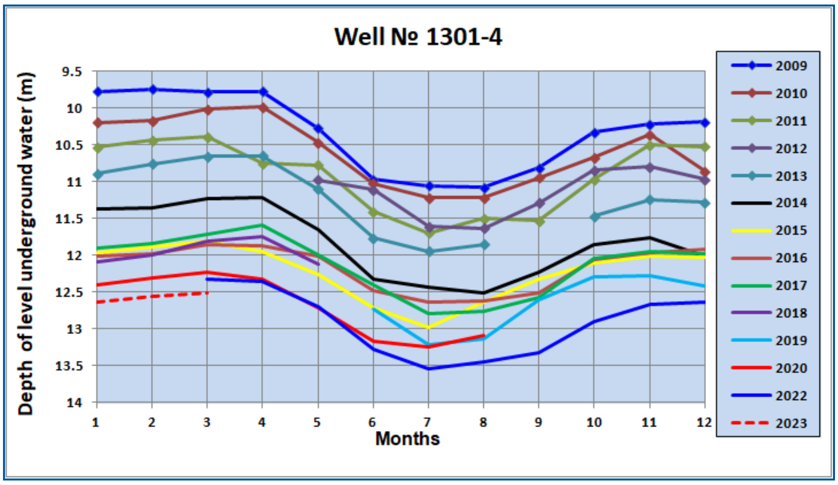

Fig. 6 Seasonal long-term change in groundwater level in well No. 1301-4

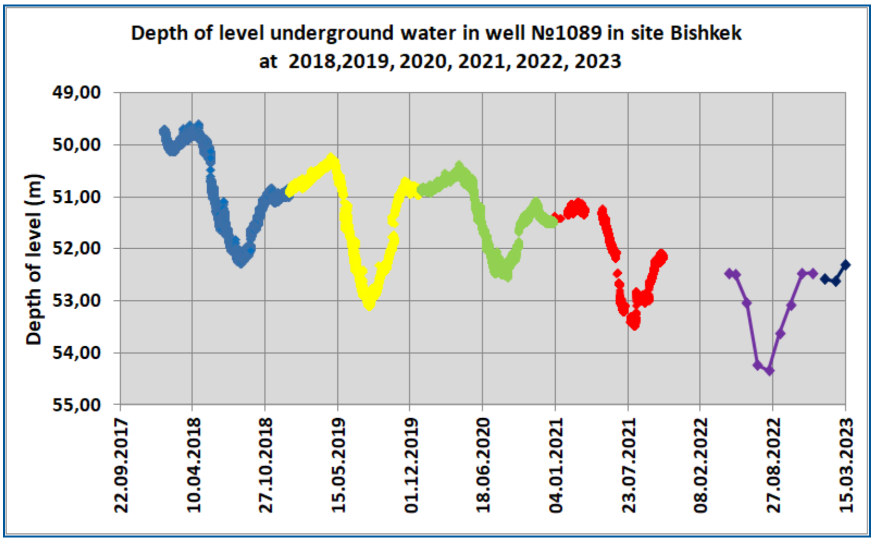

Fig. 7 Long-term decrease in groundwater level in well No. 1089

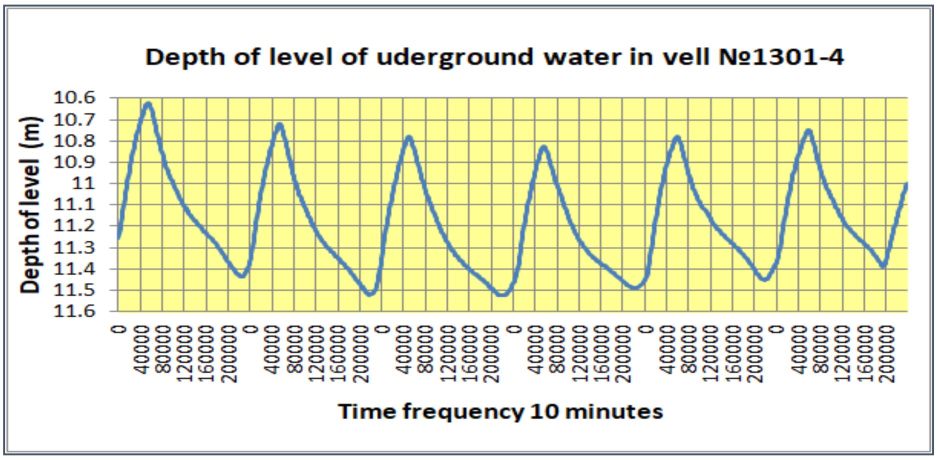

Fig. 8. Daily fluctuations in the groundwater level in well No. 1301-4 for the period 05-06/2012, under the influence of lunar-solar tidal movements of the earth's crust

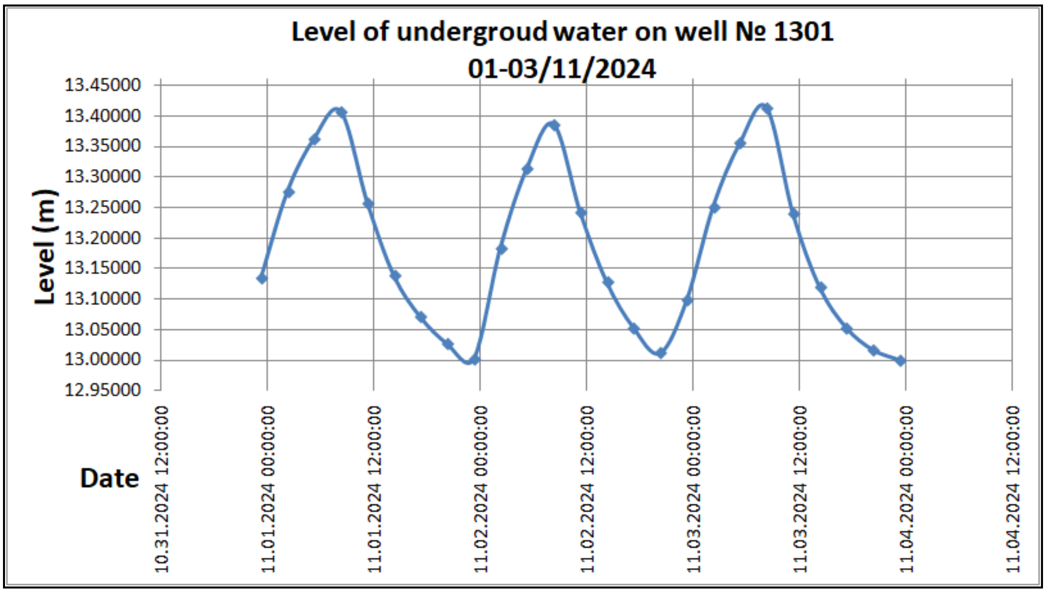

Fig. 9 Daily fluctuations in the groundwater level in well No. 1301-4 for the period 01-03/11/2024, under the influence of lunar-solar tidal movements of the earth's crust

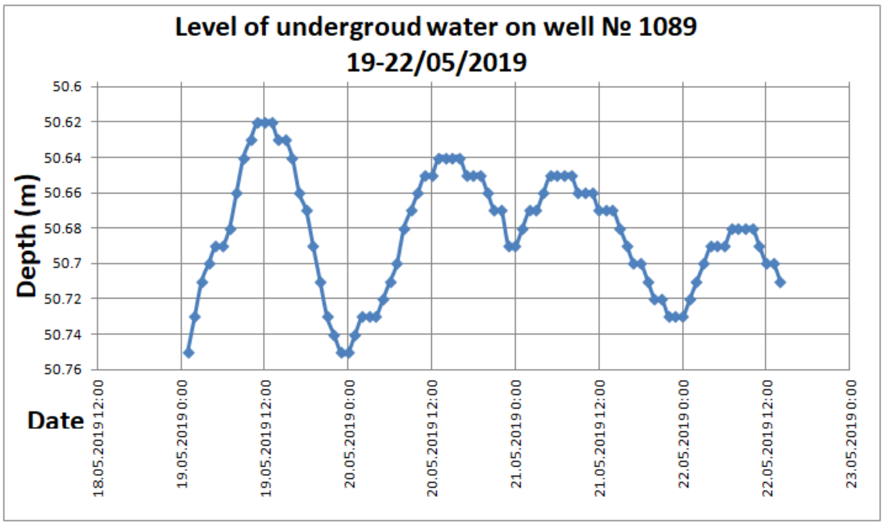

Fig. 10. Daily fluctuations in the groundwater level in well No. 1089 for the period 19-22/05/2019, under the influence of lunar-solar tidal movements of the earth's crust

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