

Landslide25_21**On the results of repeated studies of the mechanism of discharging excessive surface water (using the example of a quarry in Kryvbas)**

P. Pigulevskiy (*S.I. Subbotin Institute of Geophysics of NAS of Ukraine, Kyiv, Ukraine*), **V. Svistun** (*Dnipropetrovsk Geophysical Expedition "Dniprogeofizika", Dnipro, Ukraine*), **S. Yaremii** (*Dnipro University of Technology, Dnipro, Ukraine*), **L. Anisimova** (*M.S. Poliakov Institute of Geotechnical Mechanics of the NAS of Ukraine, Dnipro, Ukraine*)

SUMMARY

Repeated geophysical observations studied the mechanism of discharging excessive surface water in the geological environment (using the example of quarry research carried out in the south of Kryvbas). The results obtained in 2021 and repeated in 2024 showed how the hydrogeodynamic process in groundwater proceeds with significant flooding of the sedimentary cover with surface waters.

Studies using the natural field method confirmed the possibility of its use to study the mechanism of rapid water saturation of the geological section and the path of groundwater discharge.

The behavior of the potential and gradient of the natural field shows their dependence on the process of infiltration of excessive surface water into the geological environment. The sign and amplitude of the soil potential in the area of the studied profiles shows the prospects for applying the method in areas with open and closed fault systems.

The obtained results can be used at the initial stage of monitoring areas with active landslide development to build an optimal observation grid and select places of possible primary collapse with the subsequent use of expensive monitoring methods. The NF method is inexpensive and very fast. It can be used to study the processes of saturation and dehydration of landslide areas in different regions of Ukraine and beyond.

Introduction

Sharp changes in groundwater levels and flooding of territories (Pigulevskiy et al. 2017; 2023) are also influenced by the discharge of huge volumes of water for flushing river waters in cities of active ore mining in Southern Kryvbas. They cause rapid hydrodynamic processes that affect the development of landslides not only on river banks, but also on the sides of quarries, dumps and sludge storages (Dovgyi et al. 2021; Rudko et al. 2017), causing significant damage to both the enterprises themselves and agricultural lands and the population.

In 2021, in March, April and June (Pigulevskiy et al. 2023), monitoring field observations were carried out to assess the impact of mining operations in the quarry on the Ingulets River (right tributary of the Dnipro River) using electrical prospecting (various modifications), natural field and gravity prospecting methods. As a result of processing field geophysical observations and previously obtained data from hydrogeological and geophysical studies, space imaging in the quarry area and around it (Ivanik et al. 2020; Pigulevskiy et al. 2017), modern hydrogeodynamic processes in the geological environment were established.

During the research in 2021, the impact of the discharge of huge volumes of water from the Karachuniv Reservoir into the Ingulets River was first studied, which caused a significant and rapid increase in the water level in the river and the overwetting of the quarry slopes and river banks by groundwater (Pigulevskiy et al. 2023). In July 2024, repeated observations carried out at the same points and using the same methodology.

Geophysical research methodology

In July 2024, geophysical work was repeated with a step of 10 m on the profiles of 2021 - B2L1 and Z1 (Fig. 1): profile observations using the vertical electrical sounding (VES) method; profile observations using the electrotomography (ET) method; profile observations of the natural field (NF); profile observations using the gravity survey method; repeated high-precision topo-geodetic observations. To accurately reference the points observed in 2021, topographic and geodetic work was performed using modern high-precision GPS satellite equipment, namely: GPS receiver Trimble R3; GPS receiver Topcon GRS-1. Field observations using the NF method were performed using the gradient method along a closed contour, which was tied to points with a known potential of the reference polygon. The starting and ending points of each profile were tied to the ending points of the previous profile. The course of observations on the profiles was performed in the forward and reverse directions. With this order of observations, their polarization will be included in the measurements either with one sign or with the opposite sign, and when summing measurements along the contour when calculating potentials, the error due to polarization will not accumulate. For each profile, quantitative parameters of potentials and gradients of the natural field (in millivolts) were calculated, which are shown in Figures 2 and 3.

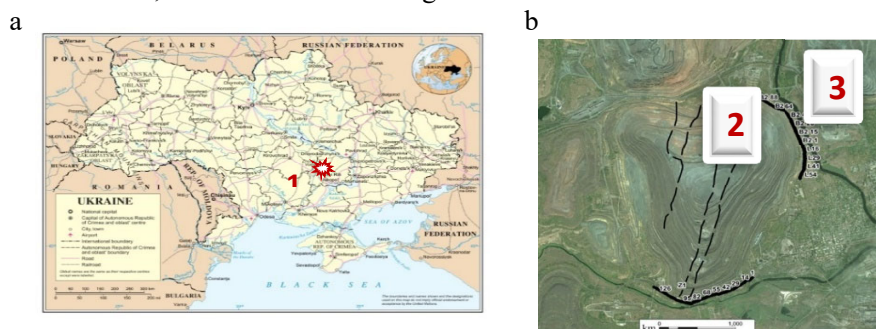


Figure 1. (a) Map of Ukraine, (b) location scheme of geophysical profiles B2L1 and Z1 on the territory of the quarry. Legend: 1 – location of the research territory on the map of Ukraine; 2 – Tarapakiv system of faults; 3 – Ingulets River

Hydrogeological conditions of the territory. According to the results of hydrogeological studies of previous years, three aquifers have been established within the territory, which are confined to Quaternary loams, sandy deposits of the Neogene and fractured waters of crystalline rocks. Groundwater of crystalline rocks is confined to the zones of fracturing of ferruginous quartzites, shales, metasandstones and other rocks

of the Kryvyi Rih series, hydraulically connected into a single zone of fractured-layer waters of the pressure-free type. The quarry has now become the main area of discharge for all aquifers and the complex. The direction of groundwater flow in the quarry area has acquired a radial character from the periphery to the center of the depression (quarry). In the east and south, the boundaries of the depression funnel mainly coincide with the contour of the Ingulets River.

Examples

To improve the Ingulets River bed and flush it of highly mineralized water that enters it from the mine water storage pond, large volumes of fresh water are being discharged from the Karachuniv Reservoir. About 160 million m³ of water were discharged from March to October 2021. To analyze the behavior of groundwater as a result of the rapid increase in surface water, the results of hydrogeological changes in the geological environment in the quarry were studied during the discharge of water from the Karachuniv Reservoir in 2021 and repeated in July 2024.

Research results

Processing of electrotomographic observations, natural field and gravity exploration along the B2L1 profile (Fig. 1) showed a very complex geological structure of the upper part of the quarry side. Low-mineralized waters do not reach the daylight surface, but are mainly located in weakened tectonic zones and in the interlayer space. Their upper edge is mostly located at depths of -3 ÷ -5 m from the surface.

Waterlogging in the northeastern part of the profile is associated with the fracturing of rocks, which are located near the tectonic zone formed by the Tarapakiv-Skelevatskaya fault system (Pihulevskiy et al. 2023). Comparing the results of field observations in 2021 and 2024 it should be noted that the geoelectric section has become more highly resistive, which is probably due to an increase in the geoelectric resistance of the geological section during the dry and hot weather that lasted during June-July 2024. The NF graphs (Fig. 2) show a high potential of the upper part of the geological section for water enrichment in the profile interval between PC 96 - 145.

Figure 2 shows that up to PC 30 there is no filtration of river water in crystalline rocks, and further south, along with an increase in the thickness of the sedimentary cover, its absorption by rocks also increases. Over time, the geological section is saturated with water and the absorption process turns into equilibrium mode. However, within the profile there remain two areas between PC 65 - 80 and 125 - 145, where water absorption continues (Fig. 2).

As shown in Fig. 2 The general trend of the natural field level for three years from 2021 to 2024 has not changed, with the exception of 2 areas between PCs 32 - 33 and 53 -54, where modern water absorption is noted.

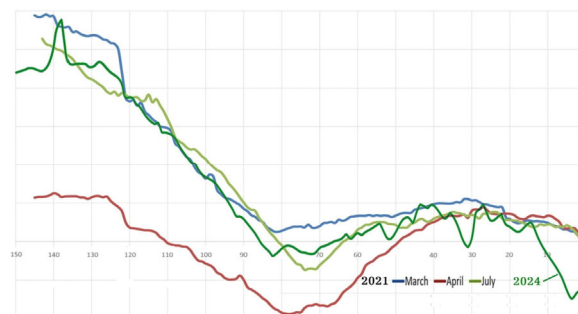


Figure 2. Graphs of changes in the natural field on the northeastern profile in 2021 and 2024 (profile B2 L1, obtained on March 21, April 14, and June 25 (Pigulevskiy et al. 2023))

Research of the southern side of the quarry. The results of the complex processing of electrotomography observations and natural field monitoring along the Z1 profile in the south of the quarry are shown in Fig.

3. The profile has a lower-ohmic geoelectrical resistance, which is associated with a greater thickness of the sedimentary layer overlying the crystalline basement rocks, which causes increased waterlogging of the geological section compared to the B2L1 profile. Sharp changes in the resistivity show the predominance of subvertical and steeply dipping faults in the geological section. The most waterlogged rocks lie mainly at depths from 5 to 20 m. In the west of the Z1 PR between PK 100 - 140 (Fig. 3), water enrichment of the upper part of the section is noted. It is traced by fragmentary cells located at different levels, which indicates the presence of blockiness in the tectonic zone with vertical shifts of small blocks in it. A powerful zone of the Tarapakiv fault system passes here (Fig. 1) annual water from Ingulets enters the quarry from the south along this fault system.

Along the profile Z1 PK 43, PK 21 - 23, PK 9 - 10, intervals of different water absorption intensity are traced in the lower part of the section, where various quartz sands (with pebble inclusions) lie. Under them, at depths of more than 15 - 20 m, rocks that are more resistant to waterlogging stand out. Repeated observations showed that during this time the sedimentary cover was saturated, which led to an increase in the level of the NF potential in the eastern part of the PR between PK1 - 43 (Fig. 3). The graphs show a local area where the absorption of excess annual water continued in July 2021. This fact indicates the presence of an open fault that feeds this layer from the west. The results of monitoring observations on July 2 (Fig. 3) show that the water enrichment of the sedimentary layer has been completed and the water balance regime in groundwater has begun.

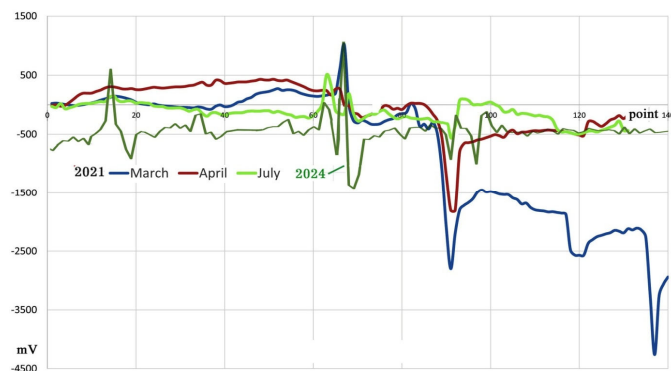


Figure 3. PP graphs on the Z1 profile obtained on March 21, April 14, and July 2 in 2021 (Pigulevskiy et al. 2023) and July 2024

Repeated observations in 2024 showed that during this time the sedimentary cover was saturated, with an increase in the level of natural field potential in the eastern part of the Southern Profile and in the western part from its beginning PK 1 to PK 43 (Fig. 3). Geological sections in wells 2128 and 2129 show that from a depth of 2.2 m to the bottom of the wells 5.1 m, a layer of quartz sand with fine-grained pebble inclusions up to 10 cm in size lies. In addition, the graphs show a local area where the absorption of excess annual water continues. This fact indicates the presence of an “open” fault, which feeds this layer from the west. The results of monitoring observations show that the water enrichment of the sedimentary layer is complete and the water balance regime in groundwater has come.

Conclusions

The discharge of water from the Karachuniv Reservoir to flush the Inhulets River affects the hydrogeodynamic state of the surrounding rock massifs. A sharp rise in the water level in the river affects geofiltration processes in the sedimentary cover and in open cracks of powerful tectonic zones, but their insignificant volumes are not reflected in the river-quarry interaction system that has developed over many years. There is a mutual interaction between river and quarry, which have formed along the lines of many rocks.

The mechanism of discharging excessive surface water in the geological environment can proceed according to the following scheme: with an open system of faults – excess water flows down through them to deeper layers (water-resistant horizons); with a closed fault system – spread over the area (horizontally) in the interlayer space, where groundwater inflow occurs, above water-resistant rocks.

The results of repeated observations in 2024 showed that groundwater in the sedimentary layer is in a state of water balance.

The results obtained can be used at the initial stage of monitoring areas with active landslide development to build an optimal observation grid and select locations for possible primary collapse with the subsequent use of expensive monitoring methods. The NF method is not expensive and very fast. Using this method, it is possible to study the processes of saturation and dewatering of landslide areas in different regions of Ukraine (Ivanik et al. 2020; 2023) and beyond (Ivanik et al. 2025).

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