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## **HYDROGEOLOGICAL ASPECTS OF THE SHALLOWING OF LAKE SYNE IN KYIV**

Syne Lake is located in the northwestern part of Kyiv, on the western outskirts of the Vynohradar residential area. The ancient origin of the lake is evidenced by old maps, in particular the map of 1746, which shows the lake without a name [6]. The lake is shown and captioned on later maps of the XIX and XX centuries, and the reservoir is partially visible on an aerial photograph taken in September 1943.

The lake is located on the watershed plateau of the Dnipro and Irpin rivers within the upper part of the Gorenka River basin, the right tributary of the Irpin River, and is considered the largest watershed lake in Kyiv (Fig. 1).

The lake consists of two parts: the northern and southern reaches, although according to Vyshnevskiy (2021), in the past the lake consisted of one reach, the southern one. In the second half of the 1970s, during the active development of the adjacent Vynohradar residential area, the lake was artificially enlarged. The lake acquired its current configuration in the 1980s. The lake area reached 4.4 hectares, with an average depth of 0.85 m, a maximum depth of 1.85 m, and a volume of 37.6 thousand meters [3]. The absolute water level at the end of the last century was 152.5 m.



Fig. 1. Lake Syne (satellite image [4])

The watershed nature of Lake Syne's location has largely determined its vulnerability to external influences caused by natural and man-made changes in its water balance, which has led to the current problem of shallowing.

The lake has been shallowing since at least the early 2010s. According to the Pleso utility company, which manages Kyiv's water bodies, including Lake Syne, the problem became acute in the spring of 2019, when the lake began to rapidly shrink. By the fall of the same year, the water level had dropped by 1.5 meters, and the water had moved away from the cutoff by 10 meters, which led to the transformation of the lake into two separate shallow water bodies. An analysis of Google Earth satellite images shows that over the past 10 years, the lake has been losing its water surface, which eventually resulted in a complete loss of water in the lake in the summer of 2023. As of March 2024, a water mirror was observed in the lake, but in a limited area, critically small on the northern paddle.

Maintaining the water balance of the lake was partially ensured by the flow of technological water discharges from the Vynohradar-1 water supply station, where, according to the regulations, twice a year, drinking water tanks with a total volume of 14 thousand m were cleaned. After the introduction of the latest water treatment technologies (without the use of liquid chlorine), technological discharges stopped, which also negatively affected the lake's level regime [3]. According to local residents, the last filling of the lake with

water from the Vynohradar-1 water supply station took place at the beginning of the full-scale Russian invasion in 2022, based on the need to create a reserve water supply.

Experience has shown that artificially filling the lake with water does not solve the problem of its shallowing, which is caused by a change in the water balance, namely a decrease in water inflow (underground and surface) and water losses due to increased evaporation.

The development of the adjacent territory and the regulation of surface runoff have significantly limited the surface water inflow to the lake, and also negatively affected the infiltration of groundwater.

The current morphology of the territory's relief surface shows the presence of depressions to which Lake Syne is confined, as well as Blue Lake, located to the east (Fig. 2). The analysis of the catchment area of Lake Syne (Fig. 3), conducted using the Surfer software based on the digital surface of Kyiv, shows that in the absence of development, it could have been 635 hectares, which is quite close to the estimates obtained by other researchers based on the analysis of topographic maps from the first half of the last century [3]. This was the surface watershed of the lake before the regulation of surface runoff in the second half of the 1970s, which has intensified in the last 10 years with the resumption of development of the adjacent territory. As a result of the development, which was accompanied by the regulation and diversion of surface runoff, the current area of the lake's surface catchment is probably about 20 hectares, actually limited to the hollow in which the lake was formed.

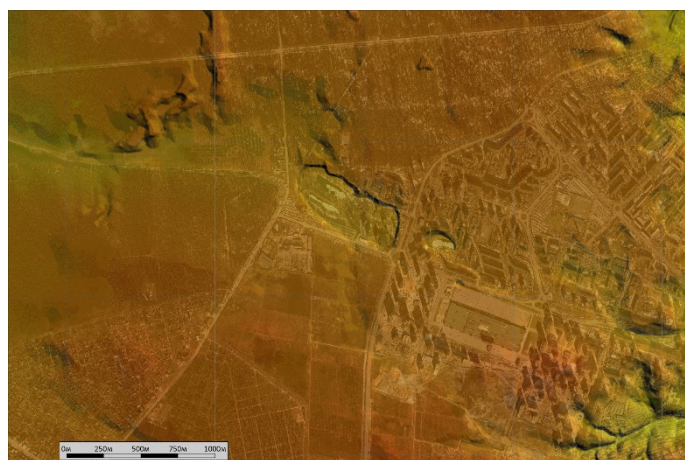


Fig. 2. Relief in the area of Lake Syne (based on a digital elevation map of Kyiv at a scale of 1:10,000) [5]

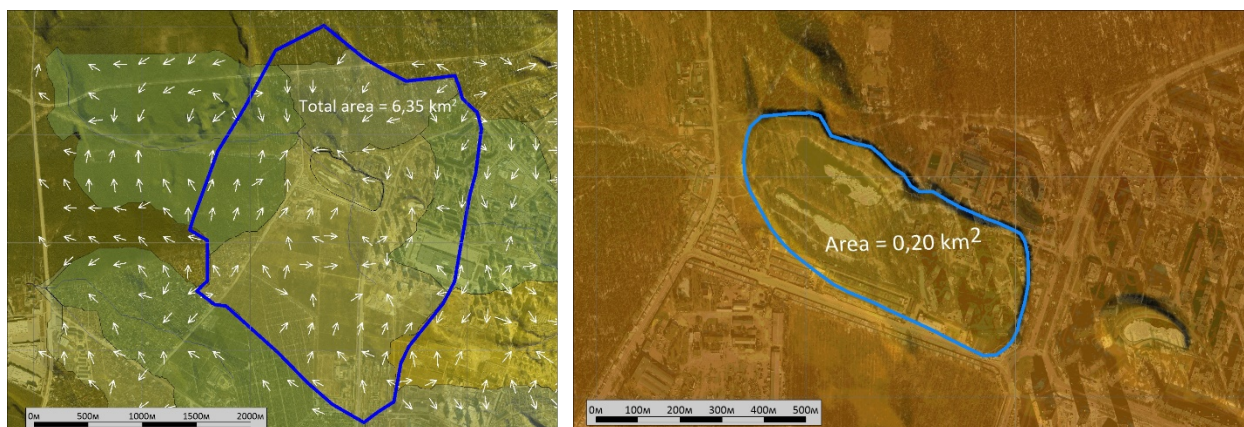


Fig. 3. Catchment area of Lake Syne: a) in natural conditions, b) in conditions of modern development

Another positive item in the lake's water balance, which is the main one, is groundwater recharge. The lake is believed to be of glacial origin [3]. Its formation is determined by the presence of a depression formed in Quaternary fluvio-glacial and glacial sediments. The first aquifer from the surface was formed in this rock layer, which lies on Miocene-Pliocene water-resistant clays and provides underground water supply to the lake.

According to the surveys [2], the lake is a drainage for the groundwater aquifer, and the surface water level in it reflects the level of the groundwater aquifer. The absolute surface elevation of the lake bed is about +150 m. As of summer 2020, the water surface elevation of the lake was +150.5 m, and groundwater elevations in wells drilled in the lake area were close to this value. This means that the lake's water supply and water level are primarily determined by the groundwater aquifer and its level.

The catchment area of the groundwater feeding the lake is complex and disturbed. Its boundary in the upper part of the groundwater flow from the Dnipro-Irpin watershed probably coincides to some extent with

the contour of the surface water catchment area under natural conditions. To the west of the lake, the groundwater catchment area may be significantly smaller than the natural surface runoff catchment area and is determined by the ratio of water levels in the reservoir to groundwater. In order to establish the exact catchment area within which Lake Syne is groundwater fed, it is recommended to conduct additional hydrogeological surveys to build a hydrogeological map of the area.

The main factors affecting groundwater are climate change and anthropogenic factors related to the development of the territory. The downward trend in groundwater levels observed in the lake area is typical for Ukraine in recent decades. The decrease in water content in the Polissia region, which includes the study area, is mainly caused by climate change [1]. In the case of Lake Syne, the situation is further aggravated by the development of a large part of the territory where the underground runoff that feeds the lake is formed. As noted above, this significantly reduces groundwater infiltration, in particular due to the evaporation of precipitation from asphalt and other hard surfaces, as well as their collection and disposal. Thus, on the one hand, the development of the territory becomes an obstacle to surface runoff to the lake, and on the other hand, it reduces groundwater recharge, which leads to a decrease in its level. Development can also change the nature of the filtration flow, in particular, lead to a redistribution of flow directions due to the impact of foundations that become an obstacle in its path, and as a result of water reduction works during the construction and operation of buildings. Thus, a part of the groundwater flow may be directed towards the Dnipro River valley and not enter the lake's underground recharge zone.

With limited surface runoff to the lake, groundwater is becoming the dominant source of its recharge. At the same time, the development of the territory, as well as climate change, negatively affect groundwater recharge, resulting in a decrease in its level, which has led to the shallowing of Lake Syne.

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