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Hydrological Aspects of the Low-water Period of 2022 on the Lowland Section of the Tisza River

Climate change poses more and more challenges to the water management. Future predictions show that the possibility of extreme drought events are increasing, especially the rolling drought phenomena have become critical when consecutive years of drought multiply the adverse effects of previous years. These new extreme hydrological situations need to be properly handled in water management, thus an additional task of the water management can be the fulfilment of the increasing water demands. The article provides a comprehensive picture of factors influencing the formation of water scarcity period. The water supply of the Hungarian Great Plain is ensured by the water supply systems established in the last century. Coordinated water management is important in similar situations. The author describes the hydrological characteristics of last year's water shortage period and how its harmful effects could be reduced.

Keywords: *water scarcity, drought, water management, water supply, irrigation*

Introduction

The watershed of the Tisza River can be regarded as special with European standards. Under certain hydrometeorological conditions, there is a high risk of flood waves. It was especially true to the River Tisza (on its Hungarian course), at the beginning of the year 2000, when flood waves came one after another, reaching record water levels.[2] At the same time, last decades' water shortages also bring more and more challenges for those who work in the water sector. Dry spells are especially common at the flatlands of the Tisza watershed. These extreme hydrometeorological phenomena can also be caused by climate change.[3]

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2 Szlávik 2006.

3 Lehner et al. 2006: 273–299.

If we examine droughts in time and location, we can say that here in Europe, all severe droughts affected our country in previous times. About 90% of Hungary's territory is expected to be affected by droughts, especially in the area of lowlands.[4] Damaging impacts of droughts can be moderated by efficient water management and irrigation methods. It is very important to develop these methods, because in the forthcoming years, the frequency of occurrence of dry spells show prolonged periods.[5] In a period of 10 years, 3–4 years can be considered droughty. The effect of droughts can be amplified if the previous years were also droughty.[6] For instance, 2022 was very droughty, despite the fact that the previous years also had a lack of precipitation. The average annual water shortage according to the water-balance is about 200–250 mm. Because of these water deficits, there will be higher demand for irrigation.[7] Water Directorates are responsible for providing water at the place and time required. To be protected from extreme hydrometeorological phenomena here in Hungary, the National Water Strategy orders short-, and long-term measures.[8] To reach this aim, and to be able to provide enough water on the flatlands, even in years like 2022, there is a need for preparedness. Providing water for the plains in Hungary, the so-called Tisza-Körös Valley Cooperative Water Management System (TIKEVIR) gives the basis for engineering grounds.[9] The main purpose of the foundation of TIKEVIR was to ensure water resources, provide controlled water governance and prevent the Great Hungarian Plain from hydrometeorological extremities. Last year's droughty period brought highlighted attention for the appropriate operation of this water supply system. This publication gives a comprehensive explanation of processes from the perspective of environment security and flood damage protection that had been taken in the low water period of 2022. We can declare that water management regarding resources on the surface – especially during the summer period – sets new challenges for stakeholders, so it was necessary to introduce new measures and methods.

Hydrometeorological progresses causing water shortages

Professionals of the Middle Tisza district Water Directorate (KÖTIVIZIG) calculated the quantity of precipitation in Hungary and the bigger river watersheds, regarding the last 7 months. The conclusion said that, in the first 7 months of 2022, there was about 45% less precipitation, which was almost half of the average amount. The smallest amount of precipitation – regarding the 7 months period – was localised in Szolnok-Szandaszőlős, in total of 98 mm. The regional average precipitation for Hungary was 188 mm, which was 154 mm less, than it should have been in the same period. According to the data of the Hungarian Meteorological Service, that 7 months period was the driest since 1901 in Hungary.

4 Tamás 2016: 13–20.
5 Szalai 2009: 501–504.
6 Pálfai 1992: 33–40.
7 Somlyódy 2011.
8 OVF 2017.
9 KÖTIVIZIG 2022.

Reviewing the period, starting from the beginning of January and lasting to the end of July, we can say that the watershed of the River Danube and Tisza got far less precipitation. The watershed of the Danube – comparing it to the climate average – got 25% less, while the watershed of the River Tisza got 31% less precipitation. In both cases, March was the driest period, lacking 79–89% of precipitation. From the perspective of watersheds, last year was drier than the average ones, but that year's first 7 months just brought an even bigger deficit. This exceptionally dry period was also preceded by years long period of dry weather. According to the Water Directorate's data, the last time when the years long regional average exceeded 525.6 mm was in 2020. 15 months in the following 2 years – especially under the vegetative period – had a lack of precipitation (comparing it to the long-term average). In case of 10 months, the difference could be even more than 20 mm (Figure 1). In total, to the operational area of KÖTIVIZIG, the deficit was 241.6 mm regarding 2021 and 2022.

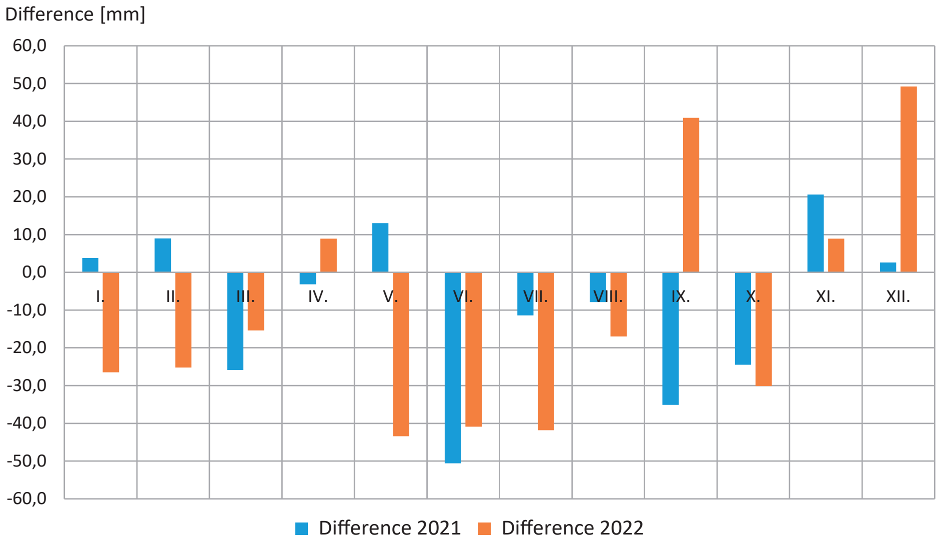

Figure 1: The deviation from the long-term average monthly precipitation during the years 2021–2022 based on KÖTIVIZIG measurement data
Source: Compiled by the author.

Only March – observing the normal annual average temperature – was exactly the same as the average, which is 5.7°C. Except March, in 2022 every month exceeded the normal annual average temperature. The difference was about 1.2–4.0°C. During the summer months, when the air temperature was higher than the average, evaporation was also bigger, than as it should have been. Hydrometeorological phenomena like the above-mentioned ones, cause less water in the open surface waters. Maintaining the efficient storage capacity is becoming harder in such a state. New challenges are made by these phenomena for those who work in the water sector.

The effect of bed level degradation to low-water level

The river's life and processes were highly affected by meander cut-offs. Some parts of the river got shorter, causing river bed deepening and growing inclination. The impact of these measures substantiated significant changes, both in our life and in our environment. In the last 127 years, the River Tisza's section between Szolnok and Kisköre (which is about 63.5 km long) has been measured and documented 6 times (between 1890 and 2017). Certain cross-sections of the river have been designated for monitoring the river bed and the floodplain. Thanks to these measured reference (VO) cross-sections, we can monitor changes in the river bed. Observing mean average water level (according to Figure 2), we can say that in most cases the river deepened its river bed. The most significant change can be seen on reference cross-section No. 144. The deepening of the river bed between 1929 and 2017 was 4.2 m.

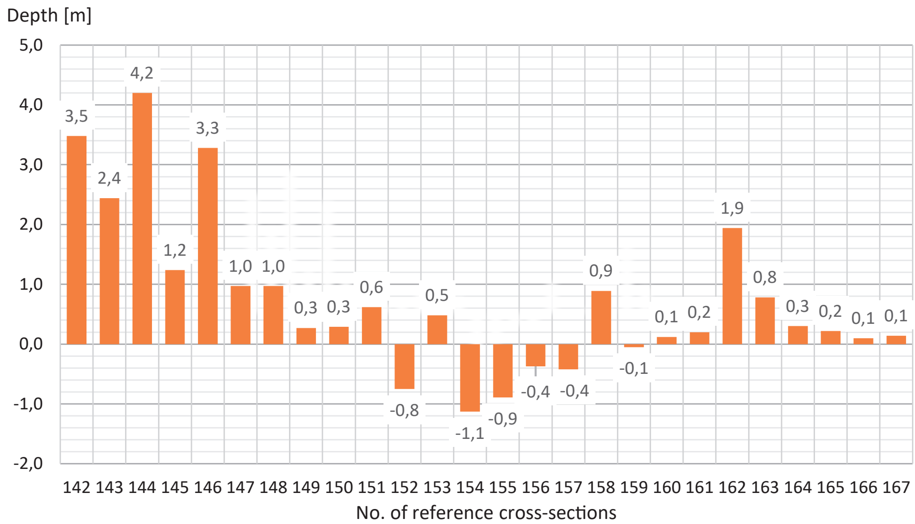

Figure 2: Change in the water depth between 1929 and 2017
Source: Compiled by the author.

The alignment of the river and development of the curves are constantly changing to reach a dynamic balance. River regulations cause river bed deepening, especially in river bed slopes and bank protection areas. Due to river regulation interventions, the speed of the river got higher. The river bank's energy of degradation moved to the lower parts of the river. At the cross-section of the river, we can show that in most cases the convex side of the river bank is constantly building up, so we can face channel contraction. I illustrated the survey data of reference cross-section No. 178 (Figure 3). There is a significant decrease in area in the middle water range, while it remains almost unchanged in the small water range.

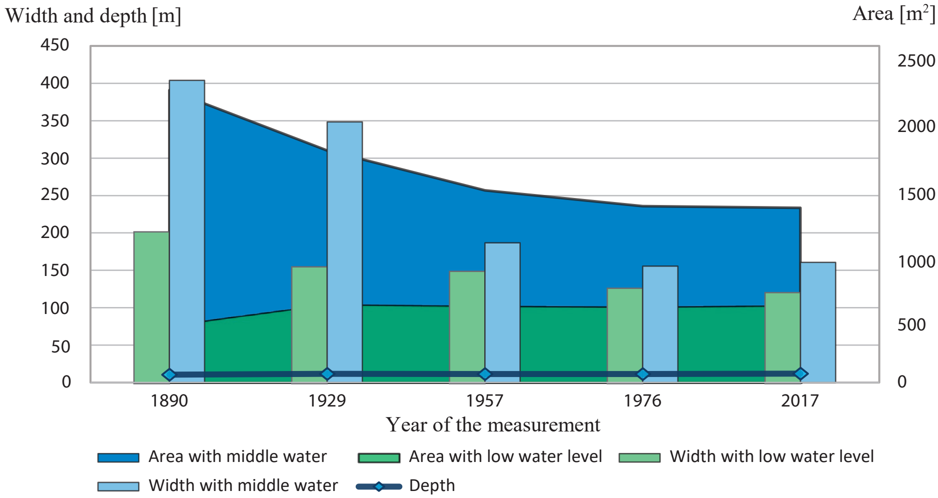

Figure 3: Change in the width, depth and area at reference cross-section No. 178
Source: Compiled by the author.

Navigation is also affected, so shipping low-water levels should be revised. Currently, this revision is ongoing here in the Hungarian part of the River Tisza. Taking weather extremes into consideration, for instance dry spells, maintaining the intake of water is getting harder and harder mainly in low-water periods too.

Water shortage, the biggest challenge for the water sector

During the summer months in 2022, Lake Tisza's water budget turned to constant negative, so it means that the streamflow coming from the upper stream is less than the outlet of the reservoir. The replacement of the water quantity in Lake Tisza is supported by Eger and Laskó creeks, but local precipitation also contributes to it. There are loads of diversion canals coming from the Lake Tisza and these are irrigation canals (Nagykunsági, Jászsági, Tiszafüredi irrigation canals), during the summer months the transported water can exceed 40 m^3/s streamflow. The barrage in Kisköre also requires the minimum of 60 m^3/s streamflow, to maintain the tailwater level. On summer days, evaporation can reach 10–15 m^3/s. All in all, we can say that if we want to maintain a stable water budget in the region, at least 100 m^3/s streamflow is required. This amount of water got less than 100 m^3/s in 2022, so it was necessary to introduce extraordinary measures. As part of these measures, water governing rules have been altered at the barrage in Kisköre. Under conditions like that, water governance is driven by the idea of providing enough water to the tailwater's minimally needed water levels. This procedure requisites 60 m^3/s streamflow. Measures that have been undertaken, caused even lower water levels than the lowest low water levels (LLW) on the tailwater's staff gauges. According to water restriction plans, the quantity of water, which went to the TIKEVIR system, was lowered in different steps.[10] Due to unfavourable hydrometeorological conditions, at the end of June, extremely low water levels occurred on the downstream of Tisza at Kisköre. At the end of June, the average water level in Kisköre-alsó was –230 cm, which was 300 cm lower than the annual mean average (130 cm). In Szolnok the average water level was –188 cm, meanwhile the annual mean average is 150 cm, so the difference was 338 cm. Maximum streamflow in Kisköre was 298 m^3/s (recorded on 3 June), in Szolnok it was 250 m^3/s (recorded on 5 June). The average streamflow in Kisköre-alsó was 135 m^3/s, while in Szolnok it was 153 m^3/s. The smallest streamflow in Kisköre was 73.6 m^3/s (recorded on 30 June), meanwhile in Szolnok it was 81.6 m^3/s (recorded on 28 June). Long-term average precipitation in the watershed of the River Tisza remained the same like in previous months, so in July only the long-term average precipitation's 46–82% fell, resulting low water levels. In Kisköre-alsó it was needed to maintain the River Tisza's tailwater level on –320 cm (this method is called "string" mode). These actions provided the possibility to be able to intake drinking water in Szolnok. Sustaining the intake, requires a minimum of 60 m^3/s streamflow. In August, the maximum streamflow was 64.8 m^3/s in Kisköre, while in Szolnok this number was 70.9 m^3/s. Average streamflow in Kisköre-alsó was 64.0 m^3/s, whilst in Szolnok it was 67.0 m^3/s. In Kisköre the smallest streamflow was 62.4 m^3/s, in Szolnok it was 65.6 m^3/s. During low-water period in Kisköre, the barrage's tailwater level was ordered to be maintained, in order to be able to sustain minimum streamflow. These measures caused the reduction of the remaining water resources' surplus. It would be important to revise the minimum tailwater level, because in case of an early low-water period, it would be possible to keep more water in reservoirs, for further use (Figure 4).

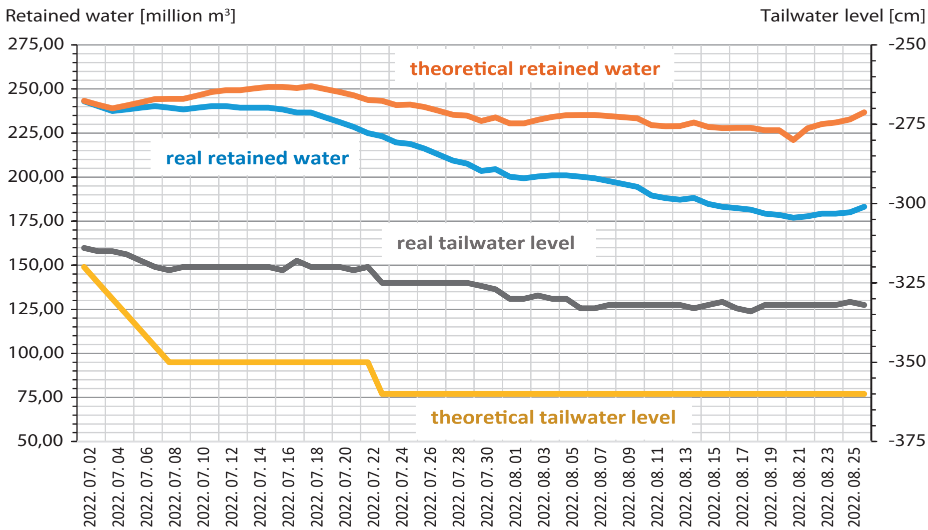

Figure 4: The possible impact of the extraordinary operation of the Kisköre barrage on the stored water resources
Source: Compiled by the author.

10 Vizi et al. 2019: 55–64.

From this perspective, I studied how much more water could have been retained, if the barrage had used lower minimum tailwater level. I compared the water levels and water volumes that actually developed with a theoretical operating schedule. The possible water flow could be calculated from the theoretical tailwater level using a water flow curve. From this, it can be estimated how the retained water would have changed in such an operating order.

If in previous phases the water level had been kept –350 cm and –360 cm on the downstream side – while still providing the minimally required streamflow – than the upstream water level in Kisköre would have been 50 cm higher (holding 54 million m^3 more water back).

Because of extreme hydrometeorological conditions, discharges were measured at multiple occasions. These measures were taken at the same time, but in different places along the river stretch (between Kisköre and Tiszaug) (Figure 5).[11] The sections of the water inlets and outlets were also marked. Generally, we can say that the measured data were within the ±5% margin of error. These results were produced by ADCP instruments.

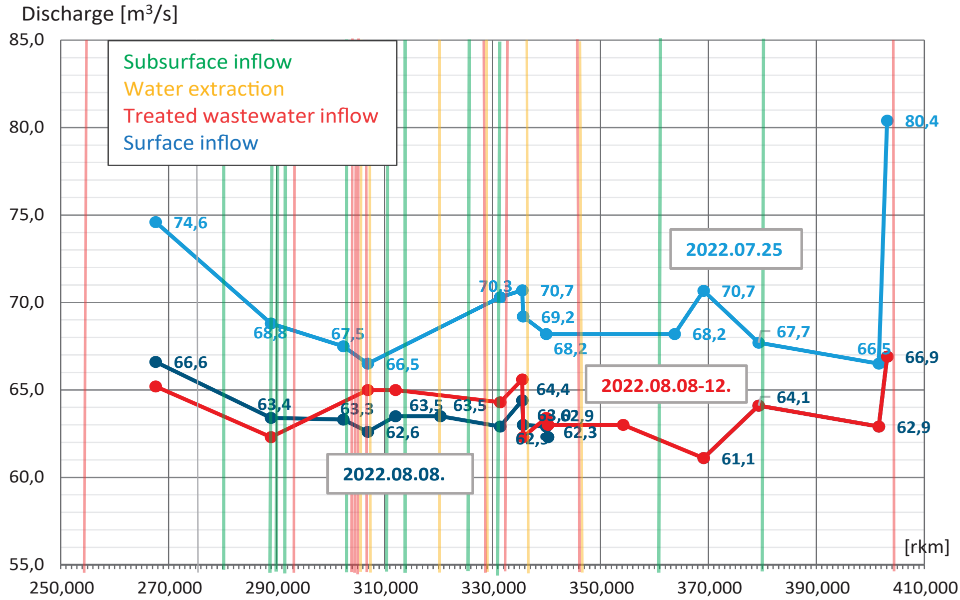

Figure 5: Discharge longitudinal section between 267 + 600 and 403 + 100 river km
Source: Compiled by the author.

From the results, we can say that the discharge of the river is constantly growing towards the endpoint. Only a few results were different from the above-mentioned tendency. This difference may came from local cross-section changes along the river. Measurements are also subject to uncertainty for example at 60 m^3/s 6% error takes 3.6 m^3/s. Therefore, the longitudinal profile fluctuation can also be a fact of uncertainty. It is very important to point

[11] Rózsa 2023.

out that there were no further inflows along the Middle Tisza. Measured water inflows and outputs (in August) resulted no significant changes in the quantity of the streamflow. In all cases, measured data showed that in the town centre of Szolnok, the streamflow quantity was higher than on the upstream part of the river. Underground water inflows could have resulted this phenomenon. Between Martfű and Tiszaug streamflow increment was experienced. Former surveys show that underground water inflows may have resulted water quantity growth on this river stretch.

The results of the streamflow surveys show that the quantity of the water intake is within the instrument's margin of error, so it would be necessary to do these surveys again, under the same conditions by using multiple instruments at the same time. By doing this, it would be possible to minimise the number of false measures in the results.

Control of the water shortage damage

Last decades' hydrometeorological trends prove that the Water Sector must be able to control damages caused by excess water or even water shortage. Ecological water supply and irrigation are both very important in our country. Maintaining the TIKEVIR system in the lowlands is inevitable from a water supply point of view.

Meteorological data show that the natural summer water resource of the Körös Valley is very exiguous, so in order to be able to maintain the river's ecosystem and irrigation needs, it is necessary to supply it with water from the River Tisza. Thanks to the TIKEVIR system – in cases like this – the River Tisza's water flow in the river bed of Hármas-Körös.

The operation area of the system covers 15 thousand square kilometres, stretching on four counties: Szabolcs-Szatmár-Bereg, Hajdú-Bihar, Jász-Nagykun-Szolnok, Békés. The River Tisza and Lake Tisza provide water from their water resources, to the two main artificial canals Keleti and Nagykunsági main canals, but also for Hortobágy-Berettyó. During the summer months, it can also happen that insufficient amount of water comes from abroad to the Körös Valley, so it is necessary to supply it from multiple points via the TIKEVIR system.

Supply comes from the barrage in Tiszalök through the Keleti main canal and Berettyó to the Hármas-Körös with a streamflow of 10.5 m^3/s, and also from the reservoir of Kisköre through the Nagykunsági main canal to the Hármas-Körös with a streamflow of 16.0 m^3/s. The River Hármas-Körös's morning streamflow (27 July 2022), was 10.7 m^3/s at Gyoma, and 25.5 m^3/s at Kunszentmárton. Without water supply through TIKEVIR, these values would have been between 0 and 5 m^3/s.

Due to persistently dry weather conditions and unfavourable hydrometeorological forecasts, KÖTIVIZIG reacts to the unfavourable hydrological situation with series of measures to alleviate water shortage damage. The last time it happened in the Summer of 2013. It was necessary to limit the ecological water replenishment of the Körös Valley, when instead of the prescribed 16 m^3/s only 11 m^3/s flowed from the Tisza – through the eastern branch of the Nagykunsági main canal – into the Hármas-Körös.

Water retaining is one of the best measures that can be taken to grow water resources, keep the groundwater on a higher level (in case of backwater) and prevent situations like the above-mentioned ones.

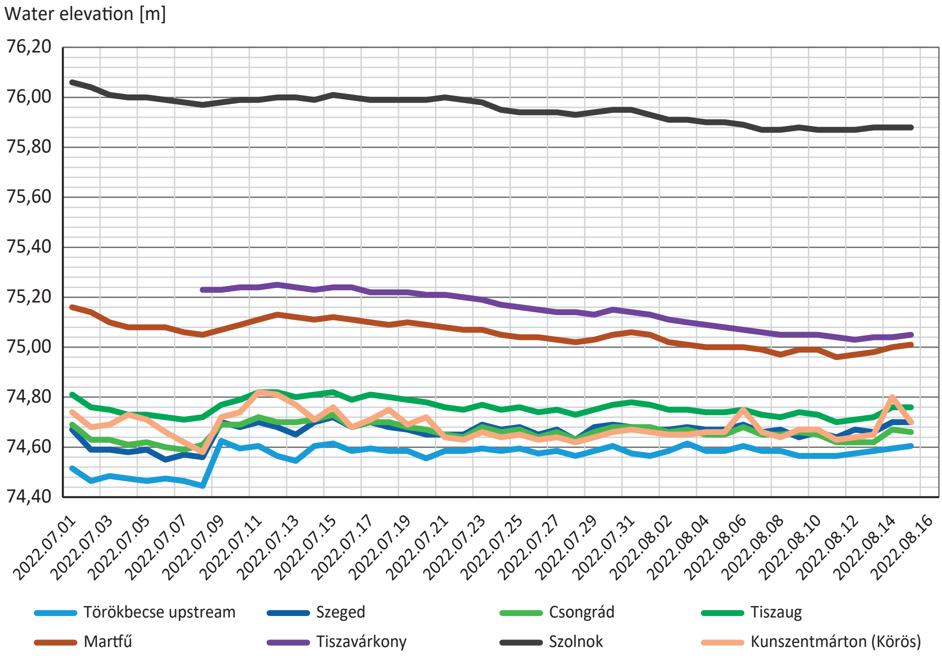

Figure 6: Water elevation between Törökbecse (blue) and Szolnok (grey)
Source: Compiled by the author.

During low water period, the extent of impoundage can be felt along a 257 km river stretch (Figure 6), raising the water level about 0.1–2.5 m comparing to the lowest low (LLW), which was registered on the summer of 2022.

Besides the excessive surface water resources, it would be recommended to examine the impact of backwater between the river stretch of Kisköre and Csongrád. After the examination, we would be able to see the changes to the quantity of ground water resources.

Consequences

In Hungary, the past decades' low water periods show that not only excessive water damages are going to challenge the water sector, but also water shortages, too. Generally, the most important thing is to use integrated water management methods, based on cooperation. Nowadays, we can choose from a wide range of systems working along those principles (for instance TIKEVIR). Growing the capacity of reservoirs can be just one solution from the opportunities, but the mentioned one is a highly accepted technical solution. Keeping back the melted snow and excessive precipitation via coordinated plant management can solve issues like water shortages, and it can also result in growth of underground water level (for further use, during the rest of the year).

The subsidence of the Tisza riverbed further increases the probability of extreme periods of low water. During the last century, the deepening in certain sections exceeded 4 meters.

Because of the dam in Tiszabecs, the extent of impoundage can be felt even in Tiszavárkony, during dry periods. It would be very important to examine the extent of impoundage (regarding the water resources of the Middle Tisza), if a dam were to be built at Csongrád. In Szolnok, and around its area, from the perspective of drinking water security, it would be very important to realise some sort of technical solution like that.

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