A WATER MANAGEMENT SOLUTION OF THE WATER RESERVOIR OF NÝRSKO

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Abstract

This article focuses on a water management solution of the storage function of the Nýrsko reservoir for compensatory runoff control for the Homolka water treatment plant in Pilsen.

The aim is to develop a water management solution for the Nýrsko reservoir that simulates the compensatory runoff management and estimates the inflow from the interbasin using a hydrological model for current climate data and for the climate change scenario data in the periods between 2041 to 2060 and 2061 to 2080.

Keywords

Water reservoir Nýrsko, storage function, water management solutions, GR4J, CemaNeige

1 INTRODUCTION

The impacts of climate change on water resources and rainfall-runoff processes in river basins are becoming increasingly significant. Studies have shown that in the future there will be a reduction in river flows and a reduction in reservoir outflows [1].

The effects of climate change on the reliability of water resources under hydrological drought were studied by Sýs et al. [2]. An interesting approach to assessing the uncertainty of climate change is offered by the possibility theory [3]. A methodological approach to integrating uncertainty in flood control management of reservoirs is presented in Fošumpaur et al. [4]. Compensatory reservoir management can have a positive effect on water levels in a navigable river, which can make navigation more profitable at low flows [5], [6], [7].

This study aims to develop a model for the storage function of a reservoir for compensatory runoff management on a river. The model is further applied to the Nýrsko reservoir on the Úhlava river and uses the compensatory runoff management for the Homolka water treatment plant in Pilsen for the current hydrological data and for data affected by future climate change in the periods 2041 to 2060 and 2061 to 2080, developed by Vizina et al. [8].

The reason is to verify the reservoir's storage function in future years under the climate change. To evaluate the water storage capacity, a balance model was developed in the software Matlab, which deals with the storage function of the reservoir while managing the compensatory runoff for withdrawal to the water treatment plant Homolka on a daily basis.

There are two important questions to address for the purpose of the study.

1. Will the reservoir be able to provide maximum long-term withdrawals for the Milence and Homolka water treatment plants?
2. Is it possible to increase withdrawals for the Homolka Water Treatment Plant in Pilsen and by how much?

2 DESCRIPTION OF THE WATER RESERVOIR AND ITS/THE CATCHMENT AREA

According to the National Geoportal INSPIRE, the Nýrsko reservoir is located on the northwestern edge of the Šumava Mountains on the Úhlava river, south of the village of Nýrsko. The reservoir is located in the Natura 2000 area Šumava, it is also part of the UNESCO World Heritage Site Šumava and is situated in the Šumava Protected Landscape Area [9]. The location of the reservoir and the location of the catchment area are shown below (Fig. 1).

According to the Digital Database of Water Management Data (DIBAVOD), the reservoir is located at the river station km 89.4, while the water treatment plant Homolka in Pilsen is located at the station km 0.4. This distance (89 km downstream) between the point of withdrawal in the Pilsen reservoir and the point of inflow below the Nýrsko reservoir results in the withdrawal to the Homolka water treatment plant being supplied by a significant

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inflow from the interbasin, and the inflow time from the Nýrsko reservoir is around 1 day at lower flows which are essential for compensatory flow control [10].

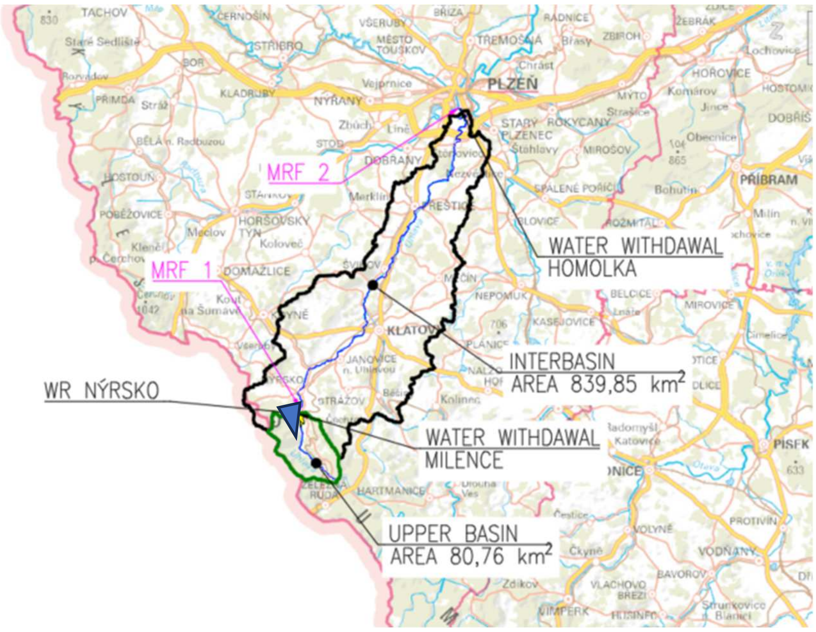


Fig. 1 Location of water reservoir and catchment.

3 INPUT DATA

The input data for the balance model were the maximum withdrawals to the Milence water treatment plant directly from the reservoir with the maximum permitted long-term withdrawal of 142.7 l. s^{-1} [11], the minimum residual flow under the reservoir dam of 360 l. s^{-1} [12], and the minimum residual flow after the withdrawal to the Homolka water treatment plant of 630 l. s^{-1} [13] and the maximum long-term withdrawal to the water treatment plant Homolka of 580 l. s^{-1} [13]. Basic hydrological and climatological data are freely available on the website of the Czech Hydrological Institute (CHMI) according to Act No. 123/1998 Coll. about the right to environmental information [14], which were input to the hydrological model GR4J described by Perrin [15] and linked to the CemaNeige snow module described by Veléry [16] to simulate flow series, flooded area lines and reservoir volumes (Fig. 2) [17]. Flow lines of tributaries to the reservoir and inflows from the interbasin were calculated from flow lines of the CHMI limnigraphic monitoring stations [14].

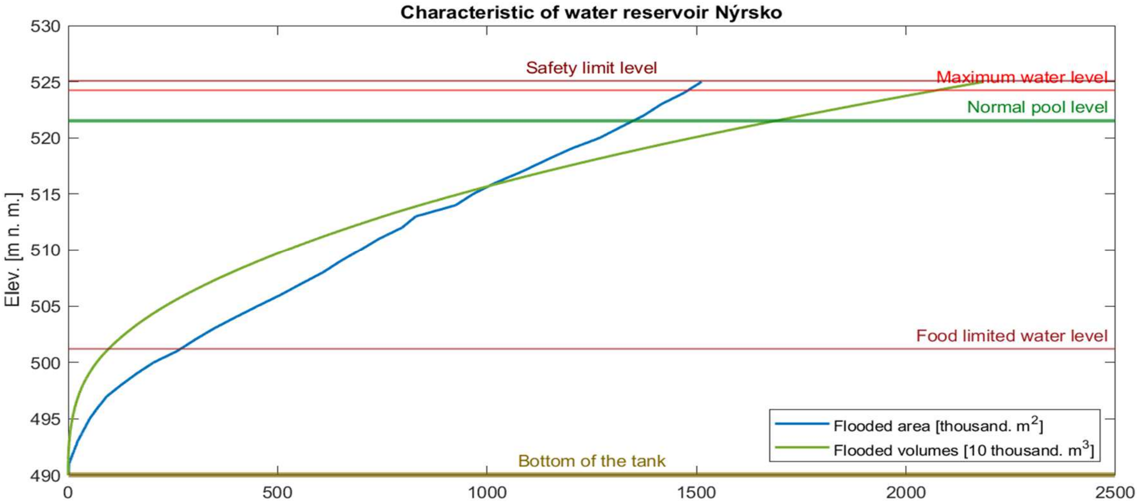


Fig. 2 Characteristics of water reservoir Nýrsko.

Precipitation data for each watershed were obtained by weighted average rainfall in each watershed according to the areas of the Thiessen polygons shown in the figures below (Fig. 3).

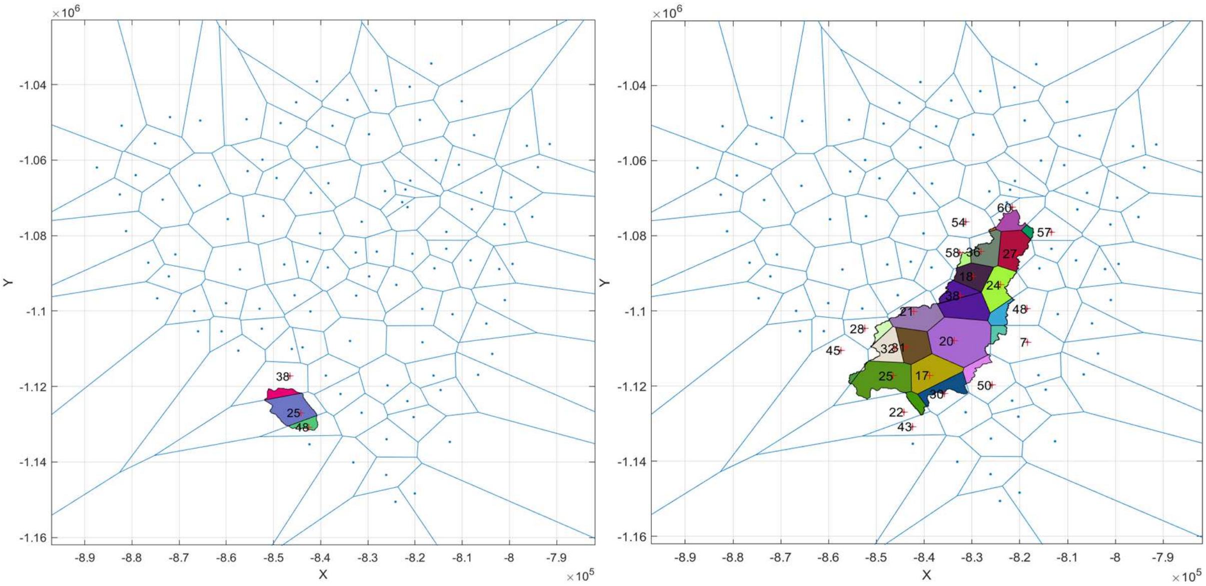


Fig. 3 Maps of Thiessen polygons.

To further deal with the problem, coefficients of the climate change for the medium climate change scenarios 2041-2060 and 2061-2080 were applied to these data according to the study for the medium climate change scenario for the Vltava River basin conducted by the T. G. M. Water Research Institute [8].

The calculation was made for the hydrological data collected between 1981 and 2020 for the existing condition. To determine the reservoir's storage capacity utilization under future climate development, the climatological data were adjusted to climate change scenarios for the period 2041-2060 and 2061-2080 and applied in the calibrated GR4J model coupled with CemaNeige to generate flow series.

4 METHODOLOGY

The model is used to solve the reservoir's balance in the framework of the compensatory outflow control for the Homolka water treatment plant in Pilsen.Its scheme is shown in the diagram below (Fig. 4). The inflow to the reservoir and the inflow from the interbasin were specified according to the data generated from a hydrological model which was calibrated according to the Nash-Sutcliffe efficiency criterion described by Nash in 1970 [18]. The evaporation from the reservoir was solved according to the ČSN 75 2405 standard Water Management Solutions of Reservoirs [19]. The water treatment withdrawals were set for the maximum long-term permitted withdrawal over the entire solution. Ass boundary conditions of the model, the values of the minimum residual flow below the dam and the minimum residual flow downstream of the withdrawal point to the Homolka water treatment plant were chosen.

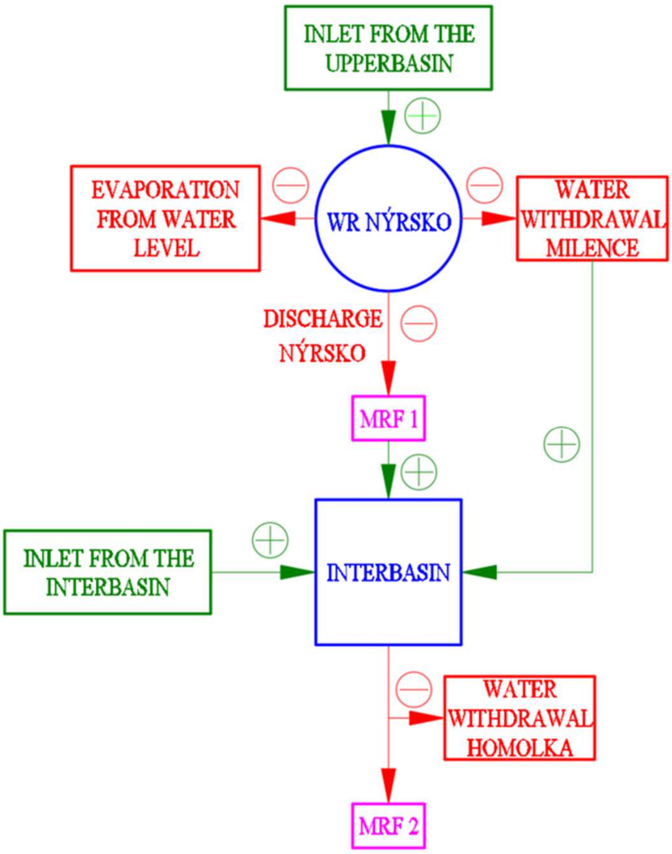


Fig.4 Scheme of the computational model.

The water supply reliability was calculated for the whole period under consideration according to the following equation:

$$Pt = \frac{m - 0{,}3}{n + 0{,}4} \cdot 100 \ [\%] \tag{1}$$

where n is the total number of months and m is the number of months without failure. A failure month is defined as a month in which at least one failure occurred. The water supply reservoir is classified as class A according to standard 75 2405 because it supplies more than 50 000 inhabitants. The standard requires a water supply reliability of Pt = 99,5% (1) for Class A reservoirs.

5 RESULTS

The result of the water management balance is the water level profile in the reservoir for the flow series from the hydrological model for the current climatic situation at the maximum long-term withdrawals to the water treatment plants Homolka in Pilsen and Milence and providing the minimum residual flows below the reservoir and after the withdrawal to the water treatment plant Homolka. These level paths are further compared with the level paths on the data affected by the mean climate change scenario for the periods 2041-2060 and 2061-2080, as shown in the graphs below (Fig. 5).

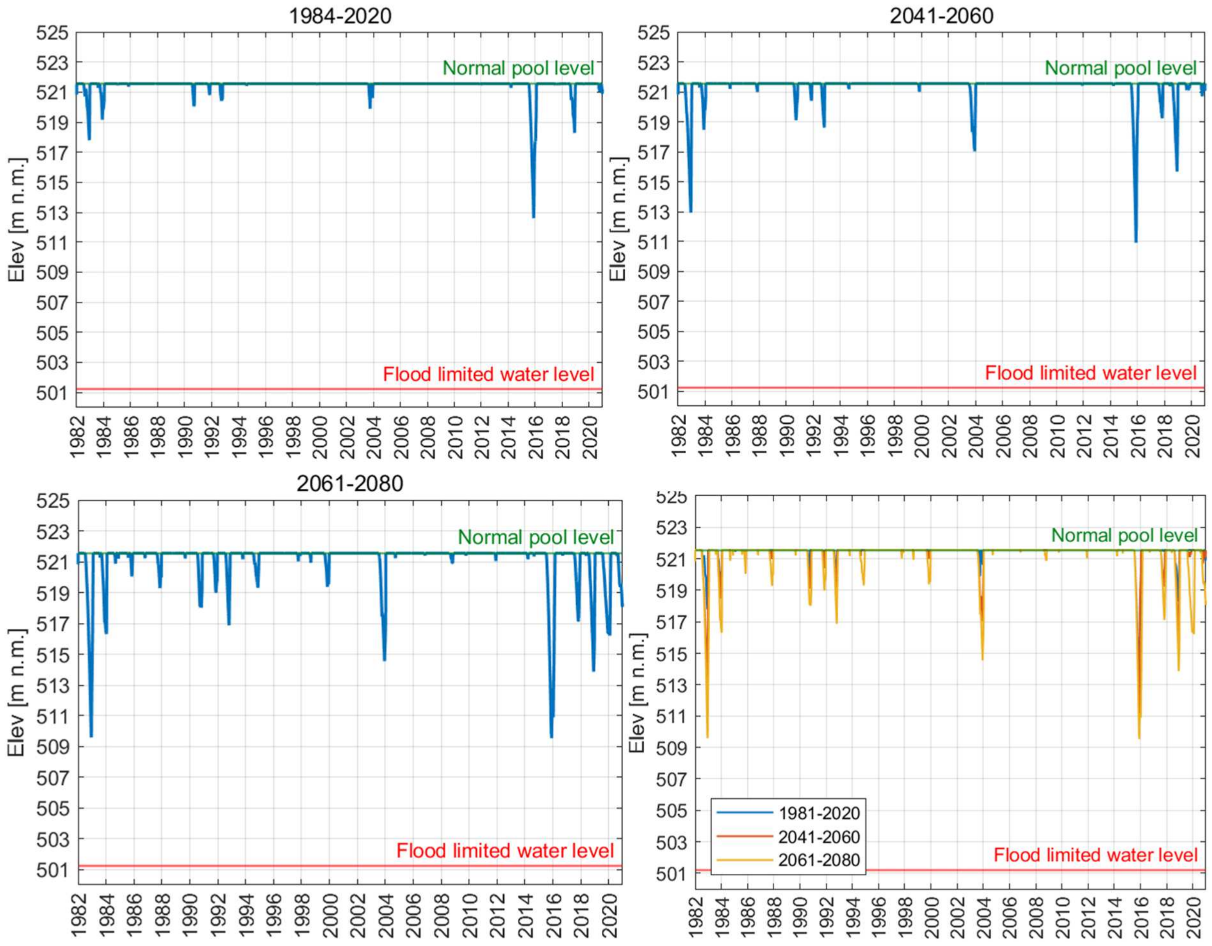
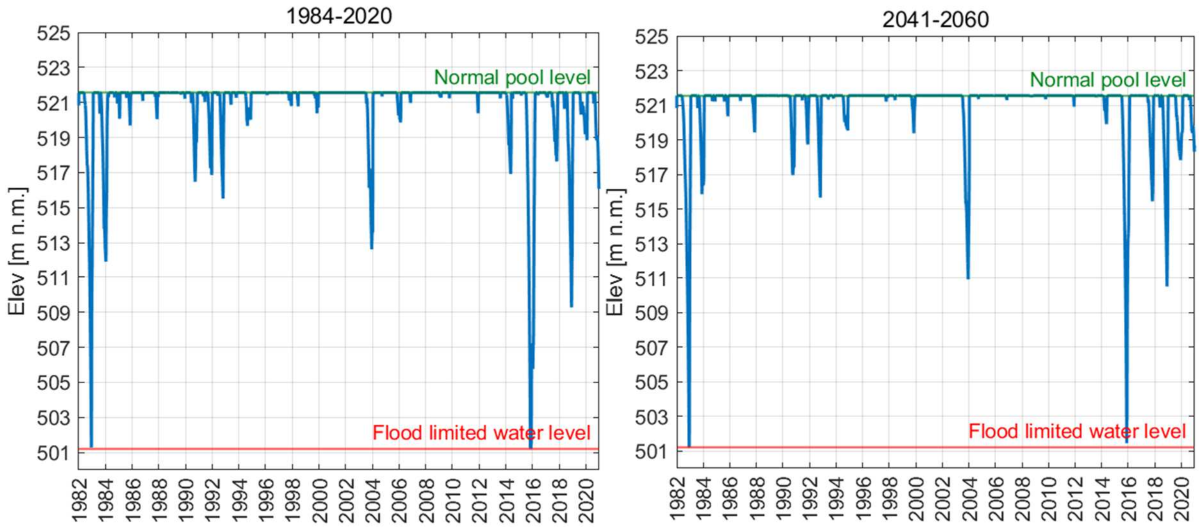


Fig. 5 Water level fluctuations in the reservoir for current withdrawals.

The results of the maximum possible sustainable withdrawal at the Homolka Water Treatment Plant are presented in the following graphs (Fig. 6). The graphs show water levels when maintaining the minimum residual flow below the reservoir, the minimum residual flow behind the withdrawal at the water treatment plant and the security of the water supply to the Milence Water Treatment Plant. The abstraction to the Homolka Water Treatment Plant was maximum while maintaining water supply reliability by a duration of at least 99.5%.



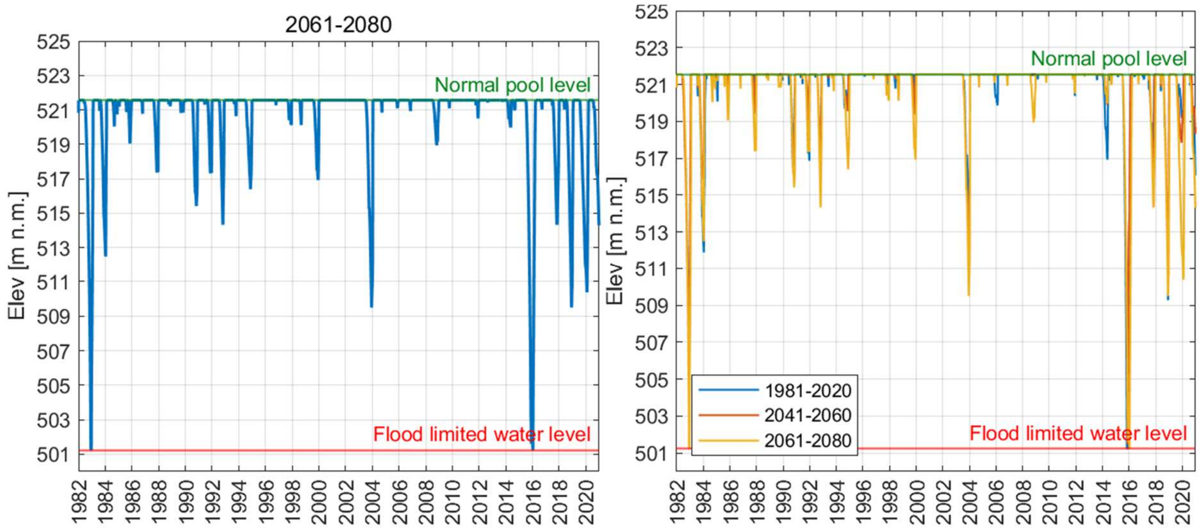


Fig. 6 Water level fluctuations in the reservoir for maximum withdrawals.

Tabulated values of minimum residual flows and withdrawal rates for each climate change scenario are shown below (Tab. 1).

Tab. 1 Results of water supply security by withdrawals.

Variant	**MRF$_{Nýrsko}$**	**MRF$_{Homolka}$**	**Withdrawal Milence**	**Withdrawal Homolka**	**Pt**
	[m^3 · s^{-1}]	[m^3 · s^{-1}]	[m^3 · s^{-1}]	[m^3 · s^{-1}]	[%]
Climate scenario			1981–2020		
Current withdrawal	*0.360*	*0.630*	*0.1427*	*0.580*	*99.85*
Maximum withdrawal	*0.360*	*0.630*	*0.1427*	*1.331*	*99.65*
Climate scenario			2041–2060		
Current withdrawal	*0.360*	*0.630*	*0.1427*	*0.580*	*99.85*
Maximum withdrawal	*0.360*	*0.630*	*0.1427*	*0.990*	*99.65*
Climate scenario			2061–2080		
Current withdrawal	*0.360*	*0.630*	*0.1427*	*0.580*	*99.85*
Maximum withdrawal	*0.360*	*0.630*	*0.1427*	*0.885*	*99.65*

6 DISCUSSION

Water management design showed that the reservoir is capable of supplying sufficient amount of water at a given level of water supply reliability based on the duration of the day step. Furthermore, the reservoir proved to be able to supply the required amount of water under future climate change under the medium climate change scenario for the periods 2041–2060 and 2061–2080.

Furthermore, the reservoir proved to be able to supplya greater amount of water for water supply purposes using both current and climate change influenced data. In the case of current hydrological and climatological data, the long-term maximum possible abstraction at the Homolka water treatment plant is 1.331 m^3.s^{-1}, 0.99 m^3.s^{-1} in the climate change period 2041–2060 and 0.885 m^3.s^{-1} in the period 2061–2080.

For the current maximum permitted long-term withdrawals, the climate change is causing more frequent use of the reservoir's storage water and fluctuations in the reservoir level. This effect is most pronounced in the data for the period 2061–2080. At the maximum possible long-term withdrawal, the reservoir experiences significant level fluctuations that can affect water quality for water supply purposes.

The study was prepared for a calibrated hydrological model that contains some uncertainties. The compensatory outflow control solution for the Homolka water treatment plant has an inflow time of around 1 day due to the distance of the reservoir. For this reason, it is necessary to predict the inflow at least 1 day in advance.

In case the model overestimates the flows, there may be an error in the prediction and a consequent deficit of water for the water treatment plant.The hydrological model may also overestimate the inflow values which could result in emptying the storage space of the Nýrsko reservoir.

7 CONCLUSION

The study on the water management of the Nýrsko reservoir is an important contribution to the study of the sustainable use of water resources in the Pilsen region and its capacity to respond to the future climate change. The main results of this study and the answers to the basic questions mentioned above can be summarized as follows:

1. Will the reservoir be able to provide maximum long-term withdrawals for the Milence and Homolka water treatment plants?

The study has confirmed that the Nýrsko reservoir is capable of supplying sufficient amount of water to the Homolka water treatment plant in Pilsen, following the requirements for securing water supply in daily time steps. The analysis of the medium climate change scenario for the periods 2041–2060 and 2061–2080 showed that the reservoir will still be able to perform its function despite the expected changes in hydrological conditions.

2. Is it possible to increase withdrawals for the Homolka Water Treatment Plant in Pilsen and by how much?

The study shows that it is possible to increase withdrawals for the Homolka water treatment plant in Pilsen above the current permitted long-term withdrawals. However, it should be pointed out that the maximum long-term abstraction causes significant fluctuations in the reservoir water level, which could lead to a decrease in the water quality for water supply purposes.

This study provides important insights for water resources planning and management in the region. The results show that the Nýrsko reservoir is capable of responding to future challenges related to the climate change.

The next steps of the research should include another detailed analysis of the impacts of the climate change on the reservoir's water regime and a sensitivity analysis to different scenarios should be performed. Further research should investigate a solution to the problem in terms of operational management of the reservoir in terms of compensatory outflow management, as the inflow time from the reservoir to the Homolka water treatment plant is around one day. This research could be used as a basis for further water management planning and adaptation to the climate change in the Pilsen region.

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