

Establishment of a monitoring system for measuring the water conditions in the Buda Castle Cave

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ABSTRACT

The importance of water regime studies of the cave system under the Buda Castle Hill has been highlighted by previous hydrogeology research, as it can serve to inform the maintenance and hazard mitigation of the Buda Castle District. After more than ten years since the latest measurements, an opportunity has risen to study the hydrology of the cave, with a much higher temporal resolution than before. Thus, a monitoring system was developed: the water levels in the cave wells and the amount of drip water are measured. This enables a detailed evaluation of the measured data using statistical methods and the identification of short- and long-term trends. An important objective of the research is to carry out comparative analyses with the results of previous studies and to identify how the infiltrating water increases. It was observed that the water levels in the wells decreased, although the drip water intensity increased.

Keywords: Buda Castle Cave; well water level; drip water; monitoring system; water regime.

1 INTRODUCTION

The Buda Castle Cave, consisting of natural limestone formations and artificial corridor systems, is located in Budapest, Hungary, underneath the Buda Castle Hill, which landscape is part of the UNESCO World Heritage Sites. The area above the Castle Cave has a series of monuments and medieval buildings, which makes it even more important to study the underground areas, that are of particular importance for the preservation of the surface. The hydrology of the Castle Cave was first researched in the 1970s by Kessler (1971). The investigations continued in the 1990s, and a comprehensive study of the hydrogeology of Castle Hill was accomplished by Hajnal (2003). In his work, he advised establishing a monitoring system for the caves, including continuous detection of water levels in the wells, to provide long-term data for planning and damage prevention work in the area. However, data on the cave system's water conditions are currently limited. The latest measurements were carried out between 2008 and 2010 (Hajnal & Farkas, 2011).

2 AIMS

Water infiltrating to the cave and the resulting wetness is a current problem, which is also reflected in weathering and rock fall from the roof of the cave. In the long term, this could have a negative effect on the stability of the cave system, which could cause structural failures underground or at the surface. Therefore, the installation of a monitoring system is essential. This research aims to build, develop, and operate a modern monitoring network to determine the water regime of the cave. This includes water level measurements in wells and measurements of drip water with a tipping bucket gauge. This study also aims to quantify the current water conditions and to evaluate the water levels and drip water intensities compared to historical data and previous studies.

3 METHODS

The water levels in three wells are measured and stored by DATAQUA sensors (from Dataqua Electronics Ltd.). These measure the hydrostatic pressure above them, which is converted to fluid level by using the fluid density. Drip water is measured by tipping bucket gauges at two different points of the cave. The tips are detected and recorded by a special device, consisting of an Arduino microcontroller, a micro-SD card module and a clock module. The best temporal resolution these measuring devices can produce is 10 minutes. To investigate the spatial variability of the drip water, ad-hoc measurements were done at 12 locations.

4 RESULTS

The data series recorded for one of the wells is shown in Figure 1 with historical data (Hajnal, 2003; Hajnal & Farkas, 2011; Kessler, 1971). The average water level has been decreasing since the 1970s. The shape of the recovery curve after the pumping test is similar to the measurements in 2009-2010. The new monitoring device

collects significantly more data than the previous investigations. Therefore, the higher resolution has allowed us to evaluate the recovery curve with much greater accuracy, which also improves further calculations for hydraulic conductivity or another parameter of the fractured rock aquifer. The short-term fluctuation of the water level was also detectable for the first time. The result of the ad-hoc drip water measurements (Nr. 1-12th) can be found in Table 1, compared with past measurements in the same area (Kessler, 1971).

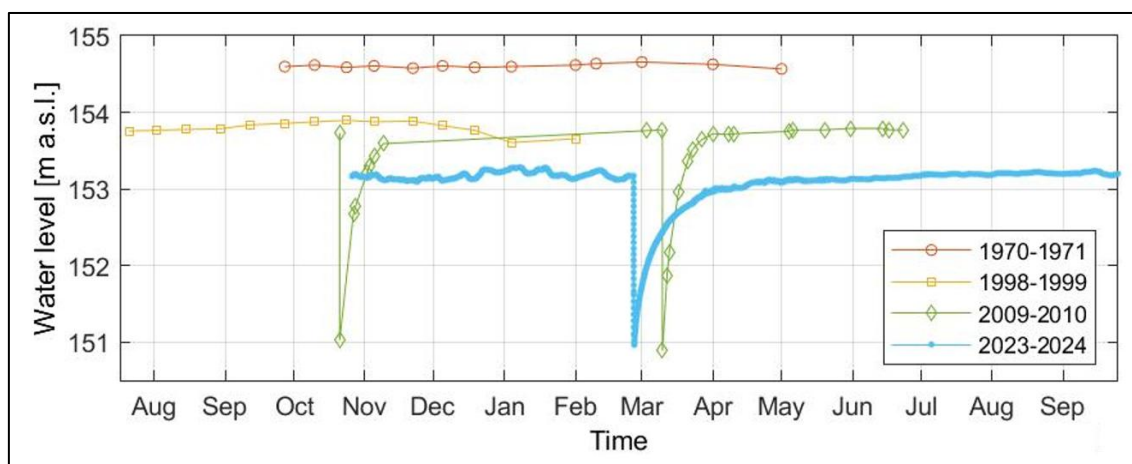


Figure 1. Water levels from current measurements and previous studies for the Mamutfogas well.

Table 1. Drip water intensity values (1-12: new measurements; K-II, K-VI: based on Kessler, 1971)

Location	1	2	3	4	5	6	7	8	9	10	11	12	K-II	K-VI
I [ML/H·M ²]	6310	1246	840	629	755	1371	413	716	1444	637	182	32.6	58.3	200

5 CONCLUSIONS

At the Hadik and Mamutfogas wells, the water levels have decreased by approximately 0.6 m in the last decade. In both wells, the water level took more time to recover after the pumping test than in the past. The water level in the Barlangos well did not change significantly. However, the water level in the Barlangos and Mamutfogas wells seems sensitive to precipitation, which will be investigated in the future. The ad-hoc measurements imply that the drip water intensities around the cave system are very diverse, ranging from 30 to 6300 ml/h m². The intensity has increased since the 1970s. Presumably, infiltrated precipitation and utility loss are the source of the drip water. For example, the first measurement point is under a water fountain, and it has an extremely high intensity compared to the other points. Recently, constructions have been in progress on the Castle Hill surface, which have a major influence on the infiltration rate: larger areas are affected by drip water in the cave, and the intensity of the spots is notably varying.

In the future, we are planning to build a numerical model that can quantify the changes in the water level of the wells based on pumping test results. A further study should assess the effect of precipitation on wells and drip waters. Another essential next step would be to calculate and quantify the total infiltrating water volume from drip water based on similar areas in the cave.

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