Project MIKAS (Most Important Karst Aquifers' Springs): Progress and request for information

John Gunn, School of Geography, Earth and Environmental Science, University of Birmingham, United Kingdom*
Zoran Stevanović, Centre for Karst Hydrogeology, University of Belgrade-Faculty of Mining & Geology, Serbia
Augusto Auler, Instituto do Carste / Carste Ciência e Meio Ambiente, Belo Horizonte, MG, Brazil
Avihu Burg, Geological Survey of Israel, Jerusalem, Israel
Seifu Kebede, School of Agricutural Earth and Environmental Sciences, University of KwaZulu-Natal, South Africa
Neven Kresic, Independent Consultant and Director, Karst Waters Institute, Warrenton, VA, USA
Peter Malik, Geological Survey of Slovakia, Bratislava, Slovakia
Junbing Pu, School of Geography and Tourism, Chongqing Normal University, P.R.China
Benjamin Tobin, Kentucky Geological Survey, University of Kentucky, Lexington, KY, USA
*Corresponding author j.gunn.1@bham.ac.uk

Abstract

The MIKAS (Most Important Karst Aquifer's Springs) project was launched by the Karst Commission of the International Association of Hydrogeologists in 2022 and is intended to be concluded by the end of 2025. The first aim is to identify, and to provide a list of, the most important karst springs at the global, but also at the national level. Subsequently, it is intended that a Code of Practice for their utilisation and protection will be drawn up and the springs will be promoted by labelling them in-situ and publicising them on the Internet. The project has an advisory board whose members recruited National Experts who agreed to compile information on karst springs in their country. As of January 2025, over 100 national experts had been recruited and 175 springs in 40 countries had been evaluated. This paper provides background to the project, a summary of the results to date with examples from the four UK MIKAS and an appeal for assistance from speleologists carrying out exploration in remote areas where springs may be poorly documented.

Introduction

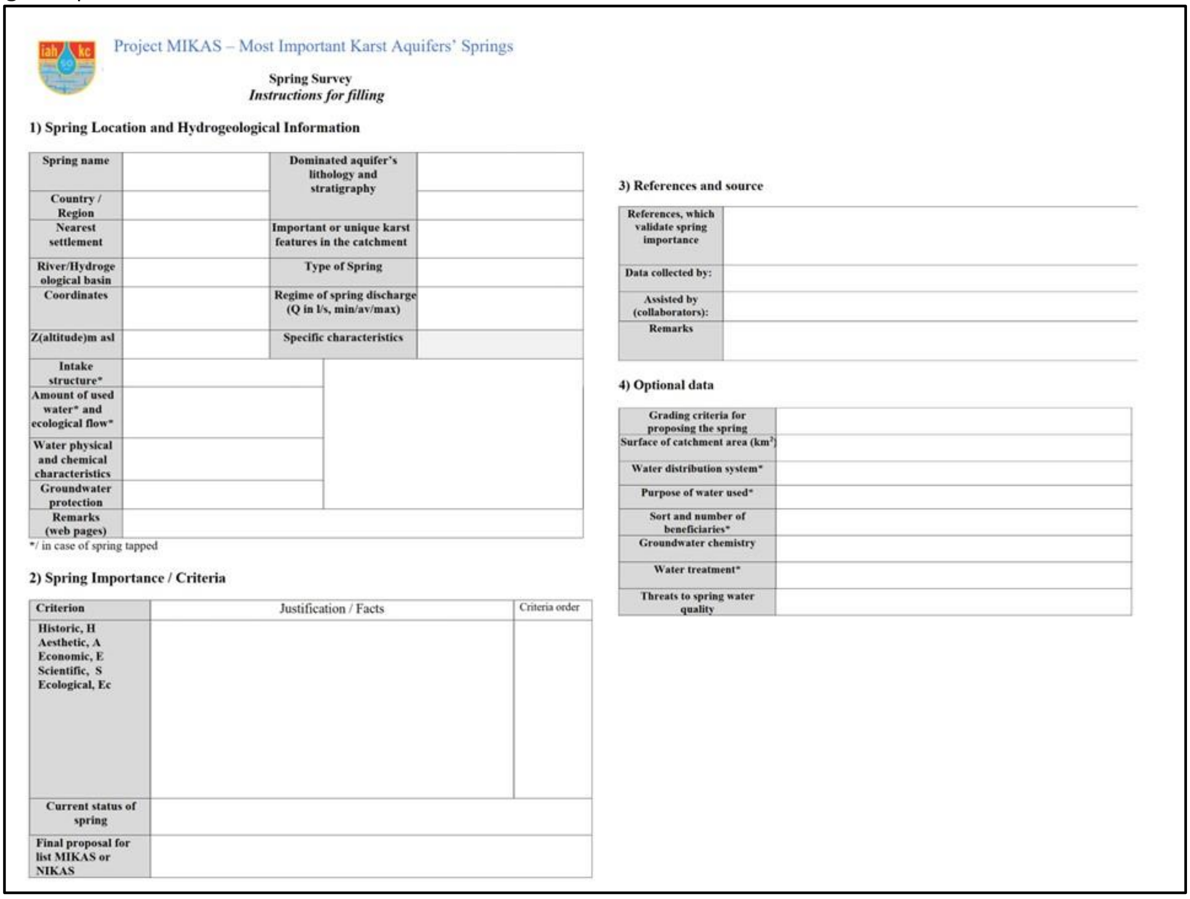
Globally, the majority of large springs discharge from karst groundwater systems and karst springs provide the base flow to many rivers and form important sources of potable supply, including to some large cities. Springs with lower discharges may also be important because of their aesthetic, cultural, ecological, economic, historic or scientific values. Some lists have been published showing the largest springs (for example, Ford & William 1989, Table 5.6 and 2007, Table 5.9) but there is no consensus on which springs are the most important. Hence, the aim of the MIKAS (Most Important Karst Aquifer's Springs) project is to identify, and to provide a list of, the most important karst springs at the global, but also at the national level. Subsequently, it is intended that a Code of Practice for the utilisation and protection of these springs will be drawn up and the springs will be promoted by labelling them in-situ and publicising them on the Internet. The project was launched in June 2022 at the annual meeting of the International Association of Hydrogeologists (IAH) Karst Commission (KC). The MIKAS project team leader is Zoran Stevanović and the Project Advisory Board (PAB) consists of the team leader, five regional representatives, and the three rotating chairs of the KC. These individuals are co-authors of this paper.

During preliminary discussions the PAB decided that the project would best be accomplished by appointing national experts who would be responsible for identifying the most important karst springs in the countries for which they were responsible. It was also decided that national experts should have the option of producing a list of Nationally Important Karst Springs (NIKAS) although only the MIKAS are reviewed by the Advisory Board. A set of Guidelines has been agreed that include selection criteria for MIKAS and NIKAS together with a template for the Spring Survey Form (discussed below). The PAB also agreed that spring selection would be on the basis of five criteria: the cultural, ecological, economic, historic or scientific value of the spring. However, it was recognised that all five criteria will not be present at all springs. This approach provides built-in flexibility allowing MIKAS and NIKAS lists to be created based on a set of common criteria, but adapted to local conditions, recognising that something that is important in one country does not have to be important in others.

The Survey Form

Initially it was planned to have as much information about the proposed springs as possible. However, the PAB recognised that the amount of information available varies widely from country to country and decided to simplify the Survey Form to facilitate the work of national experts. The form requests certain mandatory basic information for each of the proposed springs together with other optional information. One of the parameters that was initially thought of as being mandatory is the spring regime. However, it has become apparent that surprisingly few of the springs that meet other MIKAS and NIKAS criteria have their flow measured on a continuous basis and for some the flow has only ever been estimated as opposed to being measured using recognised hydrometric techniques. A case in point is Tobio in Papua New Guinea which was listed in Ford & Williams (1989, Table 5.6 and 2007, Table 5.9) as being the world's largest karst spring with a mean discharge of 85 – 115m^3s^{-1}. The main reference given (Maire, 1981) states that "the huge Tobio emergence has been reckoned by Beck to [sic] 85 – 115 cubic metres per second". No reference is given but the actual source is thought to be Beck (1975) who states that "*at Tobiu something like 3000 – 4000 cusecs (85 – 113 cumecs) was thundering from an entrance 55m high by at least 24m in width*". The lead author of the present paper was able to contact Beck (pers. comm., 8 January 2025) who provided the following information: "*On route to Pulupare the Iaro River which emerges from Tobio is crossed on a bridge about 16km upstream… our estimate of water flow at the cave had no scientific basis, other than attempting to gauge volume from the banking at this crossing. I would think this would be the only safe place where a proper measurement might be attempted, but it was beyond our remit and abilities at the time. The river could well of course have picked up other unknown tributaries between bridge and resurgence*". This is entirely reasonable and Beck is to be commended from at least making an estimate but it illustrates the problems of assembling data on world karst spring regime.

The template (Figure 1) can be downloaded from the project website (https://mikasproject.org/) which also has more information about the project, including the Guidelines, Instructions for completion of the Survey Form and the list of engaged experts.



Project MIKAS – Most Important Karst Aquifers' Springs

Spring Survey
Instructions for filling

1) Spring Location and Hydrogeological Information

Spring name		Dominated aquifer's lithology and stratigraphy	
Country / Region			
Nearest settlement		Important or unique karst features in the catchment	
River/Hydrogeological basin		Type of Spring	
Coordinates		Regime of spring discharge (Q in l/s, min/av/max)	
Z(altitude)m asl		Specific characteristics	
Intake structure*			
Amount of used water* and ecological flow*			
Water physical and chemical characteristics			
Groundwater protection			
Remarks (web pages)			

*/ in case of spring tapped

2) Spring Importance / Criteria

Criterion	Justification / Facts	Criteria order
Historic, H Aesthetic, A Economic, E Scientific, S Ecological, Ec		
Current status of spring		
Final proposal for list MIKAS or NIKAS		

3) References and source

References, which validate spring importance	
Data collected by:	
Assisted by (collaborators):	
Remarks	

4) Optional data

Grading criteria for proposing the spring	
Surface of catchment area (km^2)	
Water distribution system*	
Purpose of water used*	
Sort and number of beneficiaries*	
Groundwater chemistry	
Water treatment*	
Threats to spring water quality	

Figure 1: Project MIKAS Spring Survey Form

Results to date and a request for assistance from speleologists

As of January 2025 over110 national experts had been recruited and 175 springs in 40 countries had been evaluated. Countries and their MIKAS springs are presented in alphabetical order on the project website (https://mikasproject.org/). The list is preliminary and has been created based on evaluations by the Advisory Board. A final list, possibly containing only 200 springs, will be announced at the end of the project and it is intended to publish a monograph with assembled information. The United States of America has by far the largest number of MIKAS (26) with France second (14). In part this is due to the excellent historical documentation of karst springs in both countries and this is reflected in a free to download book by Kresic (2024). In contrast, there are countries that are known to contain spectacular karsts with large caves and springs but for which very little information is available. As discussed above, Tobio in Papua New Guinea is listed as the world's largest spring on the basis of a single estimate made on a caving expedition in 1975. The site is very remote and it is possible that since then it has not been visited other than by indigenous peoples. There have been a greater number of caving expeditions to the Nakanai Mountains, an area of spectacular karst on the Papua New Guinea Island of New Britain (Gabriel et al., 2018) and information from cavers (Jean-Paul Sounier, pers. comm. 2024) has been used to compile survey forms for candidate MIKAS sites. Similar information is sought from speleologists visiting remote areas containing important karst springs that are not already listed on the MIKAS website. Information can be sent to the corresponding author of this paper or via the website (https://mikasproject.org/contact-us/).

Examples of MIKAS in the United Kingdom.

The United Kingdom comprises Great Britain (England, Scotland and Wales) and Northern Ireland and within Great Britain there is a greater temporal range of carbonate rock outcrops per unit area than anywhere else on earth: Quaternary freshwater carbonates (tufa); limestones and dolostones of Cretaceous, Jurassic, Permian, Carboniferous, Devonian, Silurian, Ordovician and Cambrian ages and Cambrian to Neoproterozoic metacarbonates (marbles). Groundwater is present in all of these carbonate rocks and there are many hundreds of springs most of which have a relatively small average annual flow (<1 m^3s^{-1}) as a consequence of limited catchment area. Information on springs in the different lithologies was reviewed by three National Experts (Farrant, Gunn and Maurice) and whilst many were thought to qualify as NIKAS only four were prosed as MIKAS: Bath Hot Springs, Bedhampton & Havant springs, the Castleton spring group, and Wookey Hole spring.

The Bath Hot Springs were selected on the basis of their Historic, Economic and Scientific values. The springs were developed as a spa in Roman times and the baths gave their name to the city of Bath which is a UNESCO World Heritage Site, designated for its cultural values. They were of economic value to the Romans and this continued from mediaeval times to the present when they are a key tourist attraction to this day, bringing more than 1 million visitors each year to the city. Scientifically, the Bath springs discharge from Carboniferous limestone and are an unusual example of hot springs (44-47°C; the highest in the UK) in a karst aquifer because the water is thought to be of Holocene age (at least 1,000 years) with a small modern component. The springs have been the subject of many studies, most recently summarised in an Environment Agency (2020) report which discusses the hydrogeological settings of deep springs (fed by groundwater from >400m), and the Bath Springs in particular, with the aim of illustrating how best to assess their provenance.

The Bedhampton and Havant spring complex was also selected on the basis of Historic, Economic and Scientific values. The springs discharge from the Cretaceous Chalk and there are multiple (at least 28) outlets with an average combined discharge of 1110 Ls^{-1} and a range of 610-1960 Ls^{-1}. Based on average flow, they are amongst the largest karst springs in the UK but there are many springs discharging from the Carboniferous limestones that have higher peak flows. The springs are an important source of potable water and currently supply approximately 250,000 people, the largest Chalk spring supply in Western Europe. There are very few caves in the English Chalk and this contributed to an erroneous assumption that the rock, and aquifer, are not karstic. This has remained to the present when much hydrogeological work and groundwater management and protection still fails to consider karst. However, early work on karst at the Bedhampton and Havant springs, including water tracing experiments from sinks, contributed to the recognition and development of conceptual ideas about chalk karst (Atkinson et al., 1974). The springs continue to be an important site for improving understanding of chalk karst and its importance for groundwater protection (e.g. Farrant et al., 2023; Maurice et al., 2023).

The Castleton spring group were proposed as MIKAS primarily because of their scientific value but also have historic, aesthetic and ecological value. There are three springs that emerge from Carboniferous limestone within a 100m radius: Peak Cavern Rising (PCR), Slop Moll Rising (SMR) and Russet Well (RW). They drain an extensive (>16km) vadose - phreatic cave system of Quaternary age that has intersected large hypogenic voids of putative Carboniferous age. Over 50 sumps (water-filled conduits) have been explored by cave divers, the deepest descending over 70m with a complex profile. Under low to average flows RW and SMR, the 2 lower elevation springs discharge mixed-allogenic/autogenic recharge and PCR discharges only autogenic recharge. As flow increases the capacity of the conduits feeding RW and SMR is exceeded and PCR becomes dominant. RW and SMR display complex periodicities related to siphons and flow switching between conduits but PCR only displays such complex behaviour at times of high flow. The rhythmic and episodic changes in discharge at RW and SM (and at PCR during high flow) are more complex than in any other spring globally. They are largely due to variations in flow from two phreatic conduits (Main Rising (MR) and Whirlpool Rising (WR)) that pass through Speedwell Cavern en route to the springs. The short-term temporal variability in water depths at both MR and WR is greater than any documented in previous studies. This is attributed to conduit bedrock geometry and changes in conduit permeability due to sediment accumulation in phreatic loops, which together influence the response to recharge (Gunn & Bradley, 2023). Within the catchment and at the springs there has also been research into bacterial water quality, clastic sediment dynamics and geochemistry.

Peveril Castle was established directly above PCR soon after the Norman Conquest of 1066, the Domesday Book (1086) mentions 'William Peveril's castle of Pechesers' ('Peak's Arse') and by medieval times the cave was known as "The Devil's Arse" because the gurgling sound made by a siphon inside the cave was likened to the Devil breaking wind. It is the largest cave entrance in the British Isles, 100m long, 20m high and 35m wide and contains the remains of a village used from 1642 to 1880 by rope makers, making rope for the lead mining industry around Castleton. The cave has been visited by tourists for over 400 years and was described by Martel following a visit in 1897. The aesthetic value lies in PCR emerging at the foot of an impressive gorge (Figure 2) and the ecological value relates to observations of depigmented fish in the springs by cave divers and by this being one of only a few springs systems in UK in which there have been detailed studies of the aquatic invertebrate community

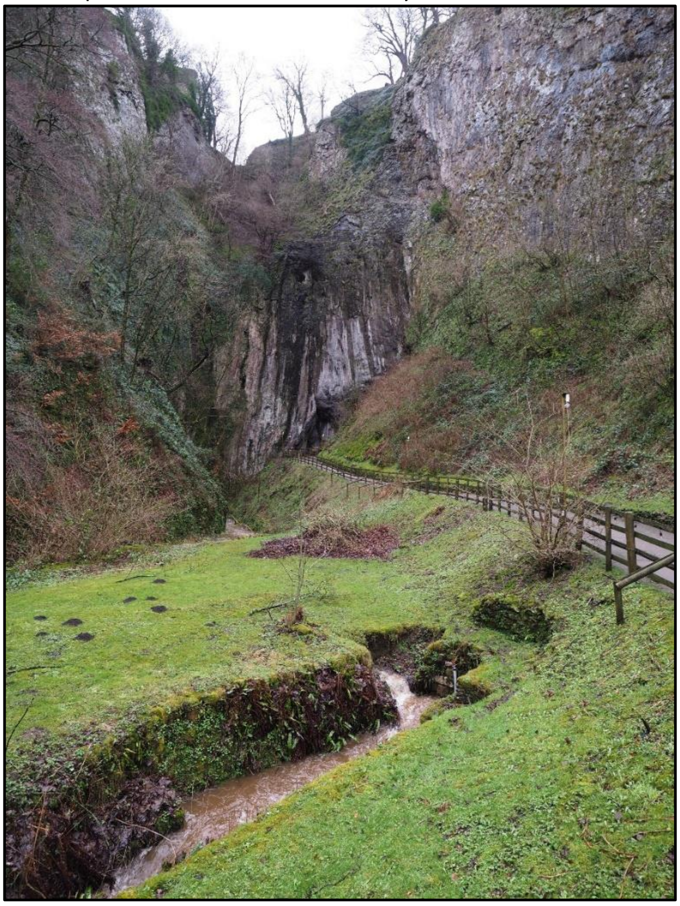


Figure 2. Peak Cavern Gorge. Slop Moll Rising is at bottom right. Path on right leads to entrance of tourist cave "The Devil's Arse". Peak Cavern Rising is mid-left. Photo by John Gunn

<u>Wookey Hole spring</u>, the final UK MIKAS was nominated for its Aesthetic (Figure 3), Historic Economic and Scientific values. Unlike the other three sites there is a single spring and although this discharges from Carboniferous limestone the cave behind the spring has also formed developed in Carboniferous aged limestones in Triassic conglomerate with a neptunean dyke. The cave has been developed for tourism and contains material with prehistoric archaeological significance. Water from the spring was used by a mill that dates from the 1600s and the spring itself is of historical significance for cave diving It was the site of the first cave dive in the UK (1935) and was instrumental in the development

of deep cave diving, with the deepest explored sump in the UK. Globally important studies of karst hydrogeology have been conducted at the spring, most notably the widely cited work of Atkinson (1977).

Figure 3:Wookey Hole Resurgence in context (photo by Andrew Farrant)

Acknowledgements

Thanks are due to all those who have contributed to the MIKAS project as National Experts and particularly to Dr Andrew Farrant and Dr Lou Maurice for their work on the UK MIKAS

References

Atkinson, T.C. 1977. Diffuse flow and conduit flow in limestone terrain in the Mendip Hills, Somerset (Great Britain). *Journal of Hydrology*, 35(1-2), 93-110.

Atkinson, T.C. & Smith, D.I. 1974. Rapid groundwater flow in fissures in the Chalk: An example from South Hampshire. *Quarterly Journal of Engineering Geology and Hydrogeology*, 7(2), 197-205.

Beck, H.M. 1975. Iaro River Cave, Southern Highlands District. *Niugini Caver*, 3(1), 4.

Environment Agency. 2020. *Perspectives on protection of deep groundwater*. Environment Agency, Bristol, UK (https://www.gov.uk/government/publications/perspectives-on-protection-of-deep-groundwater).

Farrant, A.R., Maurice, L., Ballesteros, D. & Nehme, C. 2023. The genesis and evolution of karstic conduit systems in the Chalk. *Geological Society, London, Special Publication*, 517, 15-37.

Ford, D.C. &Williams, P.W. 1989. *Karst Geomorphology and Hydrology*. Unwin Hyman, London, UK.

Ford, D.C. &Williams, P.W. 1989. *Karst Hydrogeology and Geomorphology*. John Wiley & Sons, Chichester, UK..

Gabriel, J., Specht, J., Leavesley, M., Kelly, M., Wood, M., Foale, S., Filer, C., McIntyre-Tamwoy, S., Bourke, R. M., Gill, D., & Sounier, J-P. 2018. *The Nakanai Ranges of East New Britain, Papua New Guinea*. James Cook University, Cairns,Australia.

Gunn, J. & Bradley, C. 2023. Characterising Rhythmic and Episodic Pulsing Behaviour in the Castleton Karst, Derbyshire (UK), Using High Resolution in-Cave Monitoring. *Water*, 15, 2301.https://doi.org/10.3390/w15122301.

Kresic, N. 2024. *Notable springs of the United States*. https://iah.org/wp-content/uploads/2024/12/Notable-Springs-of-US_Kresic-1.pdf

Maire,R. 1981. Inventory and general features of PNG karsts. *Spelunca*, supplement 3, 7.

Maurice, L., Farrant, A.R., Mathewson, E. and Atkinson, T. 2023. Karst hydrogeology of the Chalk and implications for groundwater protection. *Geological Society, London, Special Publications*, 517, 39-62.