

INESON LECTURE 2010

Wednesday 20 October 2010

The Geological Society, Burlington House, Piccadilly, London
A Joint Meeting of the International Association of Hydrogeologists
& the Hydrogeological Group of the Geological Society

PROGRAMME

12:45 Registration and coffee

13.15 Welcome

Willy Burgess, Chair - Hydrogeological Group, Geological Society

Introduction

Jane Dottridge, Chair – International Association of Hydrogeologists, British Chapter

13:30 Management of a Carboniferous Limestone Aquifer

Jim Grundy¹ and Rik Ingram²

¹ Environment Agency

² Entec UK, Canon Court, Abbey Lawn, Abbey Foregate, Shrewsbury, SY2 5DE

The Mendip Hills to the south of Bristol are an Area of Outstanding Natural Beauty and their numerous caves and caverns have been studied by hydrologists and speleologists since the 1930s. The limestone forming the Mendips is also an important resource for water supply – approximately 60% of the drinking water for Bristol and Bath sourced from the springs issuing from this aquifer – and for construction materials – the limestone quarried from the area is used in building projects throughout the UK. The combined pressures of hydrogeological uncertainty due to the karstic nature of the aquifer and sub-water table quarrying, mean that managing the quantity and quality of water resources in the aquifer is complex and estimates of the available water resource can be overly precautionary. The Mendips Groundwater Conceptualisation Project has been undertaken by the Environment Agency in collaboration with Bristol Water and quarry operators in order to develop a better understanding of the available resource, its vulnerability and the techniques that are appropriate for managing the aquifer into the future. This has been achieved by updating and quantifying the long-standing hydrogeological conceptual model using a combination of hydrogeological techniques, including distributed numerical modelling.

14:00 Stratigraphical and Structural Influences on Karst Hydrogeology

John Gunn & David J Lowe

Limestone Research Group, School of Geography, Earth & Environmental Sciences,
University of Birmingham, Edgbaston, Birmingham, B15 2TT

The heterogeneity of carbonate rock sequences and the difficulties this poses karst hydrogeologists is well known. It is also well known that most karstified rock sequences are characterised by a hierarchically organised drainage network grading from channels (slow, probably Darcian, flow) to conduits (turbulent flow; rapid transport of contaminants). In some, but by no means all, rock sequences the conduits may reach dimensions that allow exploration by humans, in which case they are referred to as caves. The channel/conduit/cave network forms only a very small proportion of the porosity but transports virtually all groundwater, which is discharged via springs. Boreholes that intersect conduits are likely to be productive whereas those that pass through the rock mass will commonly have a very low productivity. A key issue then is how to locate conduits. Groundwater models commonly assume either a random or a structured flow network but exploration of caves, and internal observation of smaller conduits that are tributary to the cave network, demonstrates that there are significant stratigraphical and structural influences on conduit location. The term 'inception horizon' was introduced by Lowe to describe those parts of a carbonate rock sequence that are particularly susceptible to the effects of the earliest conduit forming processes. It is argued that by virtue of physical, lithological or chemical deviation from the predominant carbonate facies within the rock sequence an inception horizon passively or actively favours localised dissolutional activity and permeability development. The importance of structural influences such as joints and faults on the planform and vertical profile of caves and their associated conduit networks is widely recognised but

subtleties in these influences are not, for example where a fault offsets an inception horizon or brings together two different inception horizons. Aspects of the inception horizon concept will be illustrated by reference to the Buxton karst, Derbyshire, where repeated water tracing experiments, and pumping tests on boreholes, have demonstrated a complex drainage network.

14:30 Modelling in Karst : Darcian Nightmare or a Pipe Dream

Paul Johnston, Laurence Gill, Dept Civil, Structural and Environmental Engineering, Trinity College Dublin 2, Ireland

Modelling hydrological flows in karst present unique challenges, not least in the construction a valid conceptual model from which the numerical modelling flows. Depending on the role of conduit flow, a Darcian equivalent porous media approach has limited value. In recent years, many other approaches have been developed, ranging from the lumped, applying linear systems analysis, to the distributed based on a network of pipes. Mixing models have also been used, based on chemistry and temperature. However, the utility of a model must relate to its purpose which may include estimation of sustainable yield, groundwater protection, ecological impact or flood estimation. The hydrology of the karst in western Ireland is characteristic of the geology and hydrometeorology of the region and has many unusual features including ephemeral lakes known as turloughs, which have a unique hydroecology and which are also subject to extremes in flooding. The evaluation of the hydrology of the system is an example of the use of modelling in karst for a number of interdependent purposes, requiring prediction of water levels at intermediate points in a conduit dominated system. The conflicting requirements of hydroecology and flood managements are central to the analysis.

15:00 Presentations

Whitaker Medal: John Aldrick (Hydrogeological Group)
John Day Bursary: Tahir Nagji (IAH)

15:20 Tea and Posters

16.00 Ineson lecture 2010

Research Frontiers and Practical Challenges in Karst Hydrogeology

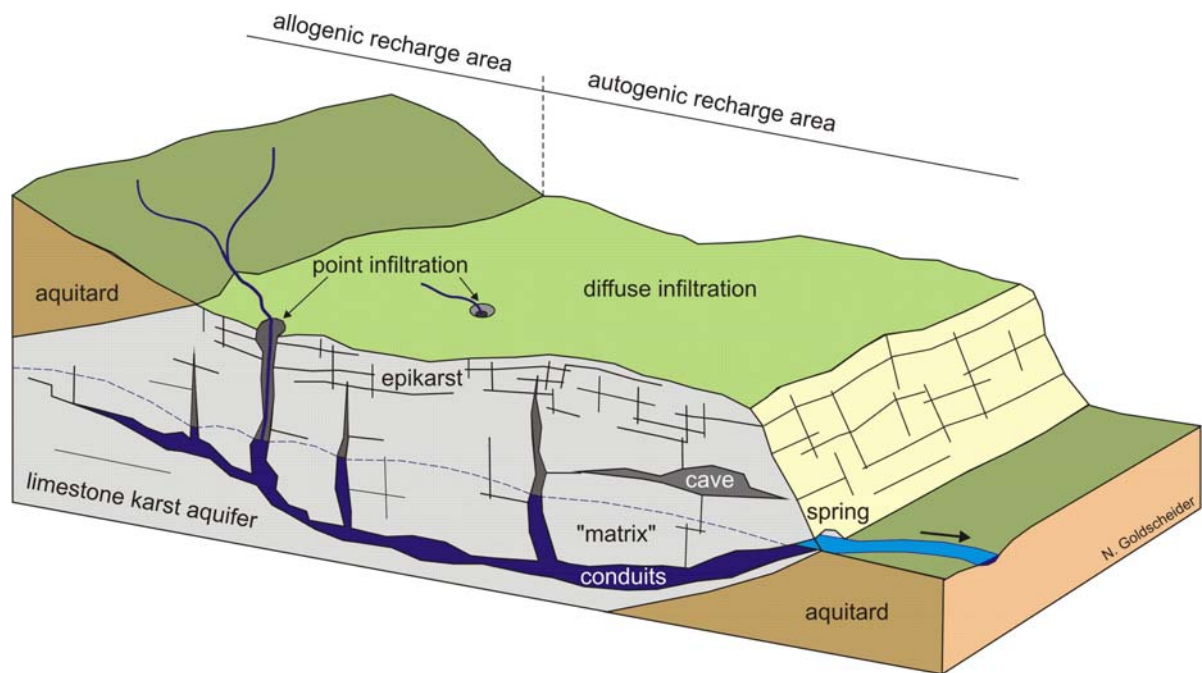
Prof. Dr. Nico Goldscheider.

Professor for Hydrogeology and Geothermics at the Technical University of Munich and Chairman of the IAH Karst Commission.

Hydrogeology and Geothermics Group, Technische Universität München (TUM), D-80333 Munich, Germany

Karst aquifers supply an estimated 25 % of the world's population with drinking water, but are particularly vulnerable to contamination and difficult to exploit and manage, as a consequence of their heterogeneity and hydrogeological characteristics. Contaminants can easily enter the aquifer through shallow soils or via swallow holes, often during intense rainfall. Inside the aquifer, turbulent flow in a hierarchically organised network of conduits and caves allows for efficient transport of contaminants towards springs, often associated with suspended mineral particles. Prolonged periods of good water quality are thus interrupted by short but intense contamination events that are often difficult to identify.

The high variability of water quantity and quality, and the need to understand and predict these variations, represents one of several research frontiers and practical challenges in karst hydrogeology discussed in this lecture. Other challenges relate to climate change impacts on alpine karst water resources, the vulnerability of ecosystems inside aquifers or dependent on karst groundwater, and problems of soil erosion that also affect groundwater quality. Last but not least, the lecture highlights the importance of deep karst aquifers as geothermal resources.



Block diagram of a karst aquifer, illustrating the duality of recharge (allogenic vs. autogenic), infiltration (diffuse vs. point-like) and porosity (matrix vs. conduits) (Goldscheider & Drew 2007).

17.00 Discussion

17.30 Drinks reception (in the Lower Library)

POSTERS

Groundwater - surface water interactions and biogeochemical conditions in forest watershed which is due to be harvested in coastal British Columbia, Canada.

Tahir Nagji^{1*}, Dr Mark Johnson², Dr Rebecca Bartlett¹, Dr Joanna Renshaw¹

¹School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, B15 2TT, UK (UoB); r.bartlett@bham.ac.uk; j.c.renshaw@bham.ac.uk

²Institute for Resource, Environment and Sustainability/Dept of Earth and Ocean Sciences, University of British Columbia, 418-2202 Main Mall, Vancouver, V6T 1Z4, Canada (UBC); mark.johnson@ubc.ca

* John Day Bursary Award Winner

Timber harvesting supports a large part of British Columbia's economic development and continues to provide the economic base for many rural communities throughout Canada. The impact of timber harvesting on local microbial community structure and functioning may have both immediate and long lasting consequence for soil and water system geochemistry.

The study was conducted at the Campbell River site on Vancouver Island, British Columbia, Canada. This study used surface and ground water chemistry to define the hydrological flow paths draining the catchment and to determine the biogeochemical conditions and processes within the forest ecosystem before harvesting. This was achieved by the use of (i) Decagon 5TE sensors to measure the electrical conductivity (EC) and water temperature to identify focal groundwater - surface water focal points along the stream and (ii) the use of the ion chromatography, TOC analyzer, and spectrophotometer to identify and quantify the organic matter fraction and other chemical species.

Field measurements of EC varied greatly across the stream indicating both focal points and changes during the course (10 – 70 $\mu\text{S}/\text{cm}$), while ground waters were consistently higher (500+ $\mu\text{S}/\text{cm}$). Laboratory analysis of the surface and ground water bodies further suggest this is due to leaching of nutrients into the ground. Conservative ions (Cl⁻, Br⁻) remained relatively constant throughout the stream. Nutrient ions (SO₄²⁻ and NO₃²⁻) were more variable indicating biogeochemical cycling.

Hydrogeological Assessment of the Buxton Karst by Tracer Testing

Eoin Wynne, John Gunn, Michael Rivett

School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, B15 2TT, UK

The hydrogeology of karstified limestones is complicated by the existence of a tertiary (conduit) porosity. Quantitative water tracing using fluorescent dyes has been recently employed to delineate and characterise such conduits in a karstic limestone area near Buxton, Derbyshire, England. These tests extend the findings of previous tracer testing of this system. 'Cyclops' fluorimeters were deployed at springs to obtain higher temporal resolution concentration data than previously obtained allowing the breakthrough curves to be quantitatively analysed using the QTRACER2 program. Only three of six tracer injections resulted in dye recoveries. This is attributed to the low-flow regime over the summer 2010 study period. A lack of continuous spring flow measurements for the analyses was mitigated by correlating available spring flow measurements with the corresponding average daily discharges in the River Wye which is largely spring fed. The river discharge is shown to give reasonable estimates of spring flow with R² values > 0.84. Analysis of the breakthrough curves showed that mass recoveries varied between 10 and 84%. The tracer tests indicate groundwater velocities of up to 41m/hr. Quantitative conceptual models for the successful traces have been developed based upon the breakthrough curve analyses. Previous tracer test studies carried out during higher flow conditions have linked two particular sinking streams with springs. The failure to establish these connections in the present study suggests the presence of overflow conduits and underflow in a deeper groundwater body.

Advances in understanding regional flow and solute transport in the Yorkshire Corallian.

Aidan Foley¹, Gerd Cachandt², Janine Franklin², Fergus Wilmore³, Tim Atkinson⁴

¹Environmental Geology and Geotechnical Consultants Ltd.

²ARUP

³Yorkshire Water Services

⁴University College London

Tracer experiments, major ion analyses, pumping tests, CFC and tritium data are used to support a qualitative conceptual model of the role of fissures and karstic voids in flow and solute transport on a regional scale within the Corallian limestone aquifer of north Yorkshire. The findings have implications for existing source protection zones and the management of public water supplies.

A Quantitative Tracer-Test Investigation of the Karstified Carboniferous Limestone Aquifer at Trollers Gill, North Yorkshire.

James Rollinson¹, Noelle Odling² & Phillip Murphy²

¹Waste Management Research Group, School of Civil Engineering & the Environment, University of Southampton. SO17 1BJ (Corresponding author)

²School of Earth & Environment, University of Leeds

The area of Trollers Gill, North Yorkshire is typical of many karst terrains; the presence of stream sinks, dolines, springs and caves all contribute to the karstic hydrogeology. The area has received little previous study, with respect to tracer tests. The only known successful tracer test is that of Murphy (1998) who reports a qualitative tracer-test. The results of Murphy are clear, if a little limited; Hell Hole and Spar Pot (two swallet caves) are linked to the Western Spring System. Nape Well (a resurgence cave on the eastern side of the valley) produces water that is characteristic of a longer travel time. All the springs flow into Skyreholme Beck.

This poster presents two quantitative tracer-test studies; dye is injected into Hell Hole, Spar Pot and Parcevall Hall stream-sink and is shown to emerge into the springs that feed Skyreholme Beck by monitoring at Parcevall Hall Bridge. The tracer-tests however were not completely successful; the injection of too little dye, a higher than expected background fluorescence and interference from turbid water, all contribute to partial failure of tracer test one. Tracer-test two was successful and produced two multi-peak breakthrough curves (see Figure 1a and 1b), the data was analysed using QTRACER2 software (Field, 2002) giving flow parameters and tracer-test accuracy parameters (Table 1). The poor recovery data is accounted for by the flashy nature of the upper-catchment stream.

The breakthrough curves and data from fluoro-captors (placed in individual springs) allowed a conceptual model to be created for the flow systems (Figure 2) along with estimates of transit time for the individual sink-spring pairs. Certain aspects of the system, however, remain undefined.

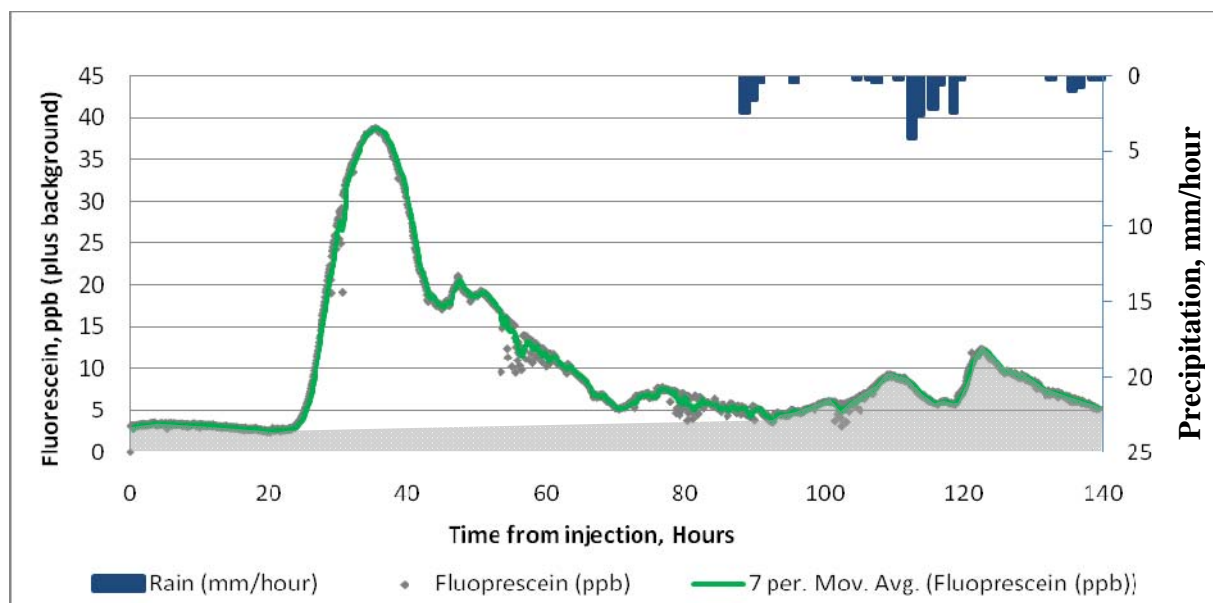


Figure 1a: Fluorescein Breakthrough Curve in Skyreholme Beck (tracer was injected into Hell Hole)

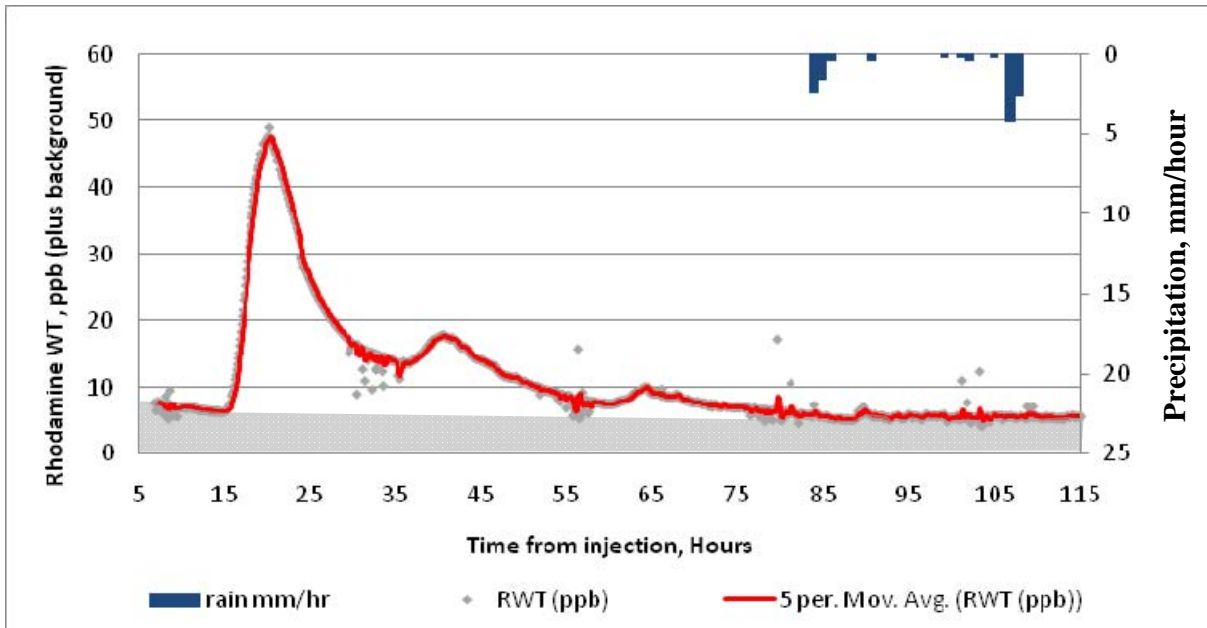


Figure 1b: Rhodamine WT Breakthrough Curve in Skyreholme Beck (tracer was injected into Skyreholme Beck Stream Sink)

Table 1: QTRACER2 Data for both Tracer Tests

Flow Parameters	Tracer test 1	Tracer test 2	
	RWT: Skyreholme Beck sink	RWT: Skyreholme Beck sink	Fluorescein: Hell Hole sink
Distance from input to outflow point (km)	1.787	1.787	1.821
Time to leading edge (first arrival) (hours)	27	16.7	24.3
Time to peak tracer concentration (hours)	40	20.3	35.3
The mean tracer transit time (hours)	55.8	23.4	44.2
The mean tracer velocity (m/hour)	32.0	76.2	41.2
Standard deviation for tracer velocity (m/hour)	9.2	15.1	12.0
The maximum tracer velocity (m/hour)	66.2	107.2	75.1
Accuracy parameters			
The quantity of tracer injected (g)	6.92	120.0	100.0
The quantity of tracer recovered (g)	3.5	51.2	159.7
Percent recovery of tracer injected (%)	50.7	43.1	159.7
Accuracy index (0.0 = Perfect Recov.)	0.49	0.57	-0.60

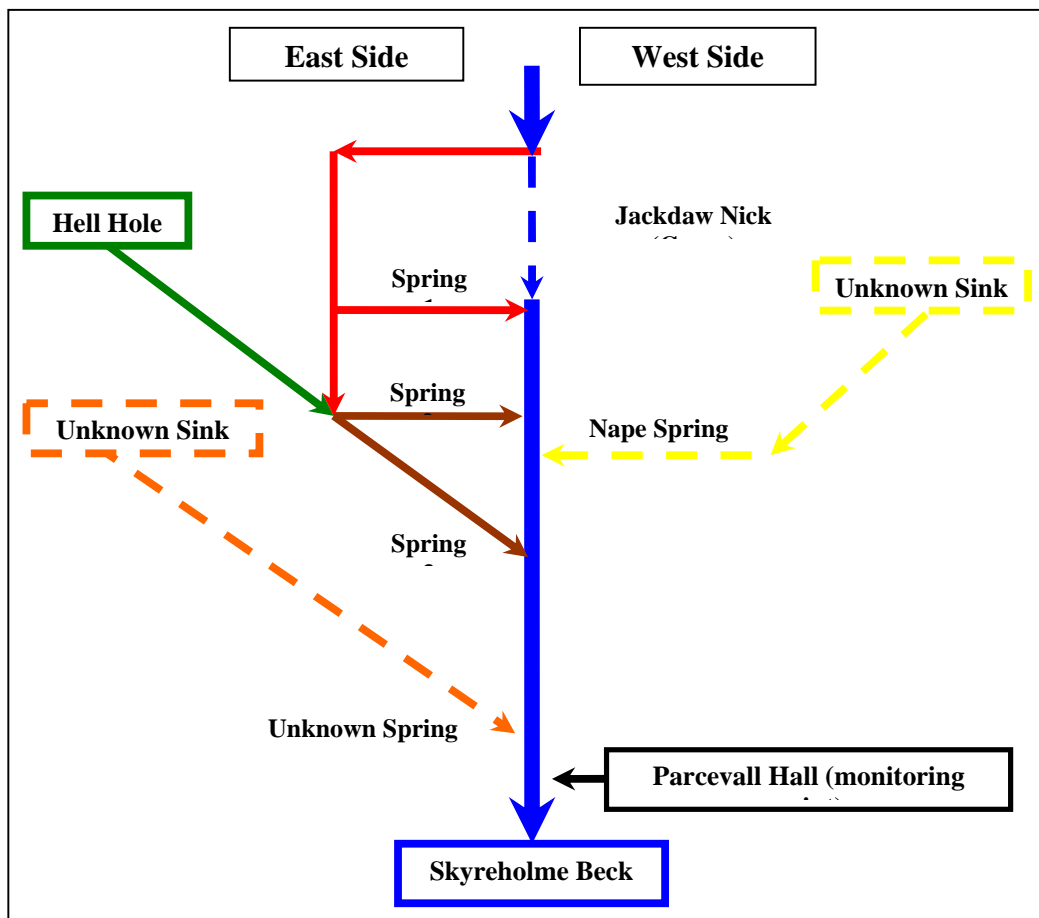


Figure 2: Conceptual model of the flow systems

References

Field M.S. (2002) The QTRACER2 program for tracer-breakthrough curve analysis for tracer tests in karstic aquifers and other hydrologic systems. 600/R-02/001, US EPA, Washington D.C.
 Murphy, P. J. (1998) Trollers Gill, Wharfedale, North Yorkshire: its geology, caves and Hydrology. Cave and Karst Science. Vol. 25. No 3. p141-144.