Impact of karstic flow on Chalk aquifer function and water quality
(CASE project partner: Affinity Water)

Dr Jared West (SEE) Prof Simon Bottrell* (SEE), Dr Louise Maurice (BGS), Dr Andrew Farrant (BGS), Alister Leggatt (Affinity Water, CASE supervisor)
Contact email: Jared West l.j.west@leeds.ac.uk, Simon Bottrell S.Bottrell@leeds.ac.uk

The Cretaceous Chalk aquifer represents the most important groundwater resource in the UK and is also important ecologically for chalk stream ecosystems. Similar aquifers exist in France, Belgium, Netherlands, and Israel. The extent to which chalk aquifers show development of karstic features (widened fractures and conduit development due to dissolution by groundwater flow) is of interest because where karstic features connect sources of contaminants directly to borehole abstractions, water quality may be poor. Where flow is more distributed because karst features less developed and smaller, water quality is generally better.

Karst is generally associated with distinctive and often spectacular landforms, including caves, and results in rapid groundwater flow in subsurface streams and rivers, as well as flow through smaller solutional voids, although the latter are less well understood due to their inaccessibility. The Chalk is often not considered a karst aquifer because caves are rare, and surface karst features are small and until recently not well documented. Recent work has highlighted the potential importance of karst in the Chalk enabling rapid groundwater flow over long distances, but the nature of chalk karst and how it impacts groundwater flow and contaminant transport is not well understood.

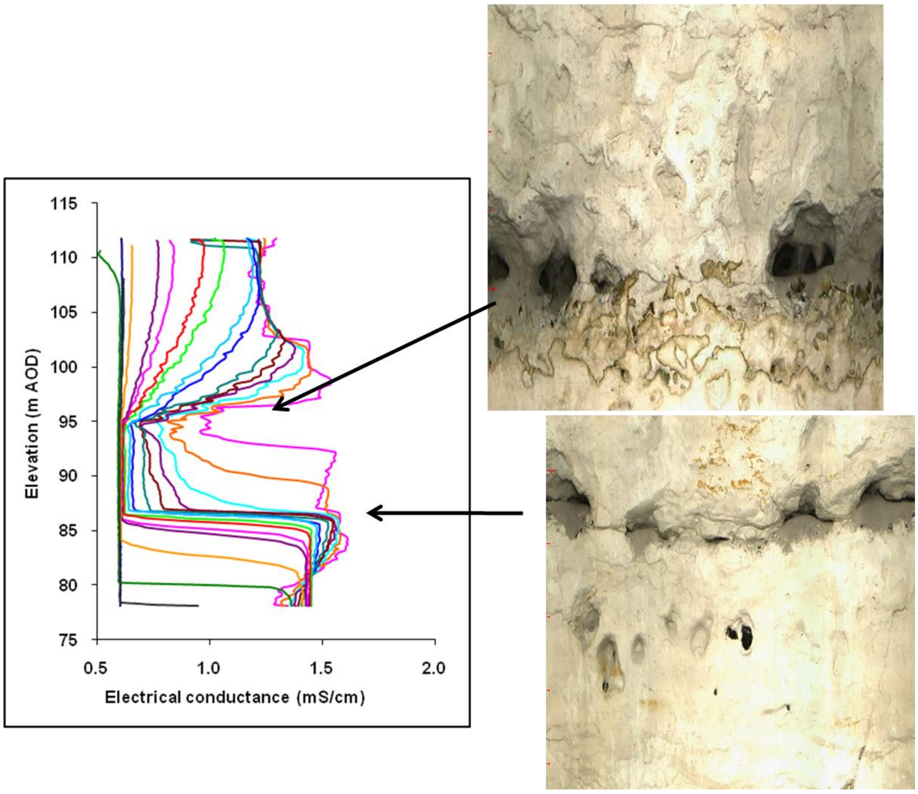

Figure 1. Chalk micro-karst features in borehole image (right) and signature in borehole dilution data (left)

Recent advances in tracer testing techniques offer the opportunity to study the smaller sized solutional voids in karst aquifers, both in classical karst aquifers and in the Chalk. The development of tracers such as bacteriophage (non-harmful virus particles small enough to pass through fractured aquifer systems) and in modelling the development of karst networks enable a new way forward via systematic investigation of the extent of karst development in aquifers like the Cretaceous Chalk. Using these approaches we aim to identify key factors controlling karst development, the importance of different void types (widened fractures, conduits etc) in the Cretaceous Chalk, and the impact of these on contaminant transport and therefore water quality.

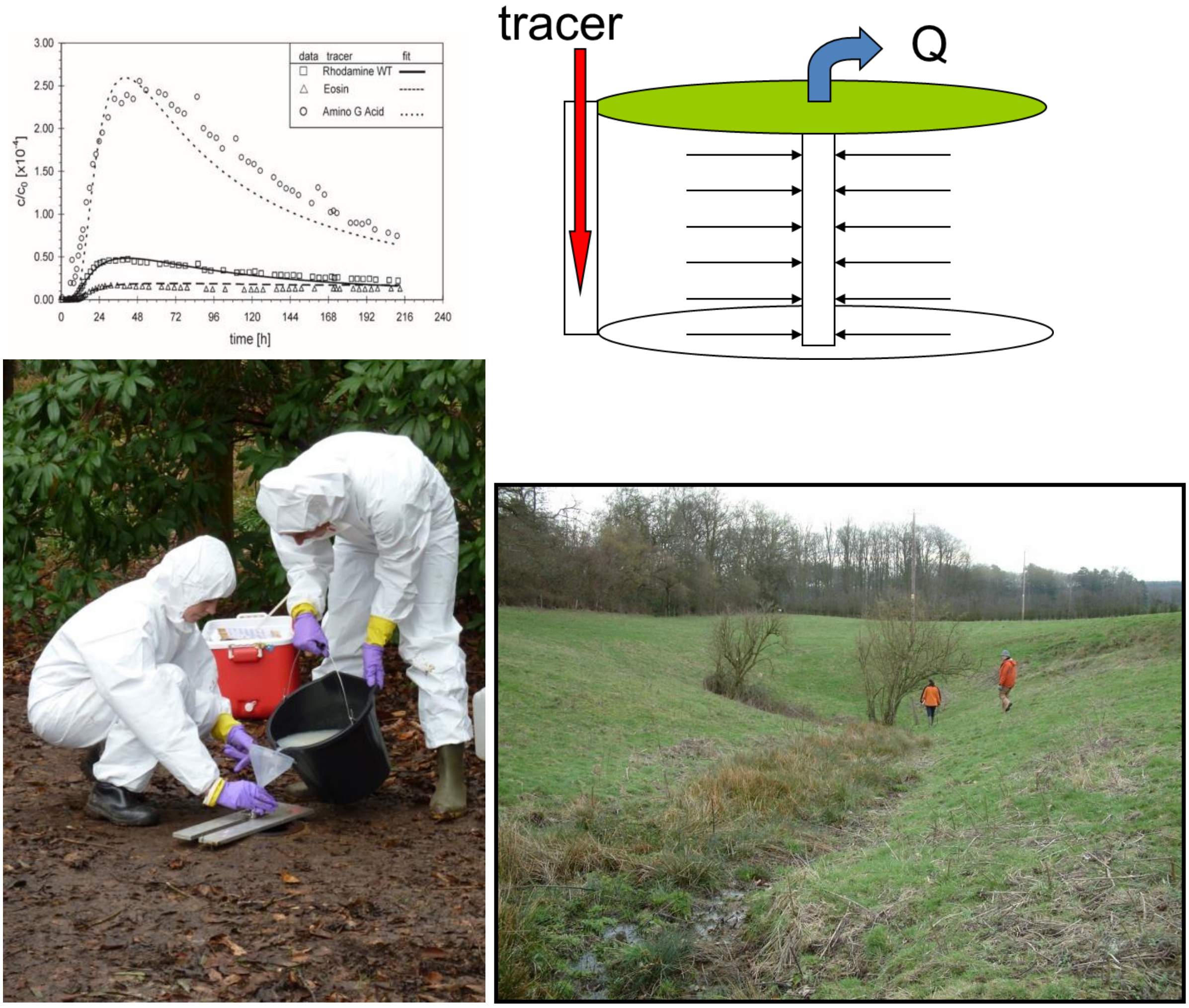

Figure 2: Upper panel - breakthrough curves for Chalk tracer test, Yorkshire (symbols – data; curves – model fits, Hartmann et al., 2007) and schematic diagram for well-to-well tracer test. Lower panel - borehole tracer injection and chalk stream sinkhole, southern England.

Objectives:

1. To identify key controls on development of karstic flow paths in soluble rocks such as the Chalk.
2. To identify extent of Chalk karst development in areas where karst swallow holes are absent, as well as where these are evident at the surface (i.e. rapid karstic flow may still be occurring).
3. To investigate vertical connectivity within the Chalk aquifer, and the extent that karst development is stratigraphically constrained (i.e. controlled by geological layering).
4. To investigate how degree of karst development is affecting nitrate and pesticide concentration trends in Chalk groundwater abstractions.

The ultimate goal is to provide a coherent explanation of karst development in chalk aquifers, within the framework of previously-developed self-organising network models for karst development in soluble rocks, and the impact of karst development on contaminant transport and therefore on the quality of abstracted groundwater.

Methods:

According to your particular research interests, work may involve the following elements:

Data collection including fieldwork:

- identification of swallow holes and boreholes for tracer testing to borehole/spring abstractions using existing data such as geophysical borehole logs, and geomorphological mapping;
- using single borehole dilution tests (SBDTs) in conjunction with borehole geophysical logs to determine whether solutional fissures/conduits are present at specific horizons;
- injecting bacteriophage tracers into suitable boreholes/swallow holes/soakaways to identify links to abstraction boreholes, followed by dye tracer tests to obtain more quantitative data; sampling of pumped abstractions and springs to identify hydraulic connections and tracer migration rates;
- Collation of existing time series and spatial data held by the CASE partner organisations, for nitrate and short residence indicators in abstracted water (turbidity, coliforms, short residence time pesticides).

Hydrogeological conceptual model development:

- determination of stratigraphy: locating flowing horizons by their stratigraphic/structural position;
- mapping karstic flow linkages between boreholes/swallow holes and springs;
- evaluation of impact of extent of karst network development on nitrate and pesticide concentrations seen in abstraction wells.

Modelling and interpretation:

- permeable reactive transport simulation of karst network development in Chalk, to understand the origin, development and distribution of karstic features.
- numerical simulation of contaminant transport via karst networks in chalk, to understand the behaviour observed in the tracer tests / groundwater quality data
- development of groundwater vulnerability mapping approaches for chalk terrains.
- using the knowledge gained to make recommendations for groundwater management in chalk terrains / karstic terrains more generally

Potential for high impact outcome

Investigation of the global environmental challenge presented by rising contaminant concentrations in abstracted groundwater is of international importance. Identification of extent of karst development in Chalk may lead to advances in fundamental understanding of karst development more widely, leading to high impact publication outputs. Solving the specific problem of prediction of future trends in contaminant concentrations in chalk aquifers may influence policy.

Training

You will work under the supervision of Dr. Jared West and Dr. Simon Bottrell within the Hydrogeology and Engineering Geology research group in the School of Earth and Environment at the University of Leeds, with additional support for fieldwork from Drs Louise Maurice and Andrew Farrant (BGS Wallingford). The CASE partner for the projects is Affinity Water. Logistical support for fieldwork and bacteriophage tracer analysis will be provided by BGS and Water Company staff, who have extensive fieldwork experience. This project provides a high level of specialist scientific training in: (i) analysis of water quality; (ii) tracer testing approaches including single borehole dilution tests and borehole/sinkhole-to-abstraction well tracer test approaches; (iii) use of specialist software for numerical simulation of flow and/or transport in fractured aquifer systems. Co-supervision will involve regular Skype meetings with the BGS and CASE supervisors, plus two field seasons for geological and hydrogeological fieldwork. There is also a requirement to undertake a minimum 3 month duration internship at CASE partner organisation (Affinity Water) premises. Internships are likely to be undertaken early, as they provides opportunities to collate background information held by the partner, for example geophysical borehole logs and water quality data. You will have access to a broad spectrum of training workshops put on by the Faculty at Leeds that include an extensive range of training workshops in technical aspects, through to managing your degree, to preparing for your viva (http://www.emeskillstraining.leeds.ac.uk/).

Student profile:

You will have a degree in Geoscience or Environmental Science background (includes Geophysics, Hydrology, and Physical Geography); ability and willingness to undertake fieldwork and wet chemical laboratory work; to analyse and interpret numerical data. Ability to apply numerical modelling and particle tracing codes (using existing modelling software), and/or ability to develop GIS-based mapping tools is an advantage. You will need to undertake fieldwork in the field areas relevant to CASE partner (i.e. South East of England), such as geomorphological mapping and tracer testing, with support from the staff at BGS Wallingford and CASE partner staff.

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Key Supervisor Publications
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