Geological Controls on Hydrodynamics and Contaminant Transport in the Hertfordshire Chalk Aquifer

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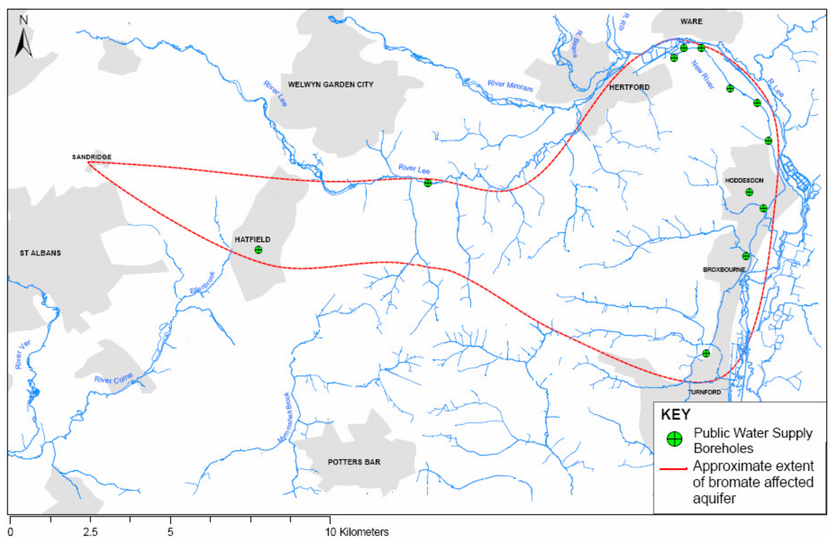
Background

The widespread occurrence of bromate contamination in the Hertfordshire Chalk aquifer over an area of more than 40km^2 between the Colne and Lee catchments constitutes an extreme example of a point source contaminant release. Unacceptable concentrations of bromate have already forced the closure of a large public supply source and present an ongoing threat to the regional water quality and to other water supply abstractions of both groundwater and surface water.



The occurrence of bromate in Hertfordshire represents one of the largest contaminant plumes in the UK extending some 20km just north of London.

Groundwater Models

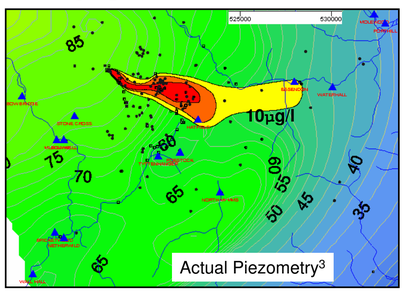
Existing groundwater transport models[2], do not adequately represent the full range of bromate transport behaviour which compromises their capacity to make predictions. Particular areas of concern are:

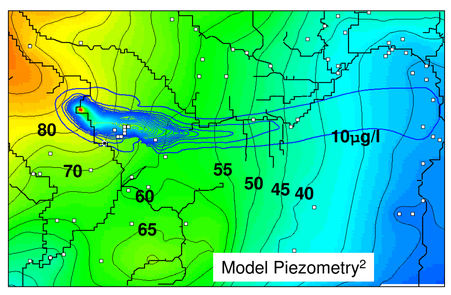
– The influence of dual porosity transport on past and future evolution of the plume

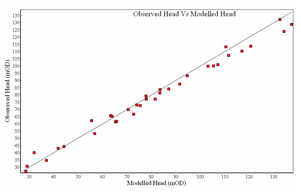
– The role of chalk karst in contaminant transport hydrodynamics

– The spatial and depth variation of transport parameters (e.g. porosity, fracture spacing and hydraulic conductivity)

This research aims to address these areas of uncertainty through an investigation of the litho-stratigraphy, structure and geomorphological evolution so to improve knowledge of the hydro-stratigraphy of the Hertfordshire Chalk Aquifer.





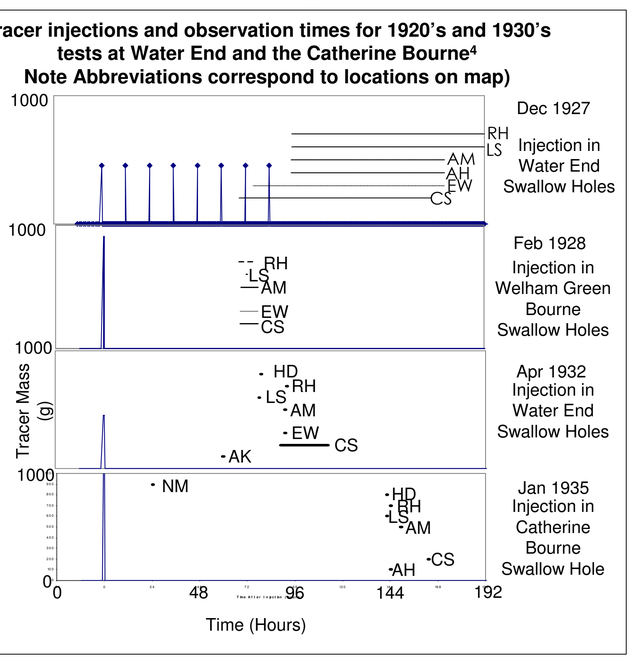


Existing Groundwater models can achieve a reasonable replication of heads and flows but show inadequacies in transport modelling, particularly between Hatfield and the Lee Valley.

The Influence of Chalk Karst

The presence of the Palaeocene Lambeth group associated with the underlying tectonic structure and geomorphological history of Hertfordshire has led to conditions highly favourable for the development of chalk karst. Field Surveys have shown a high density of active swallow holes, stream sinks, collapse features and springs developed close to the Palaeocene Feather Edge between Hatfield and the Lee Valley.

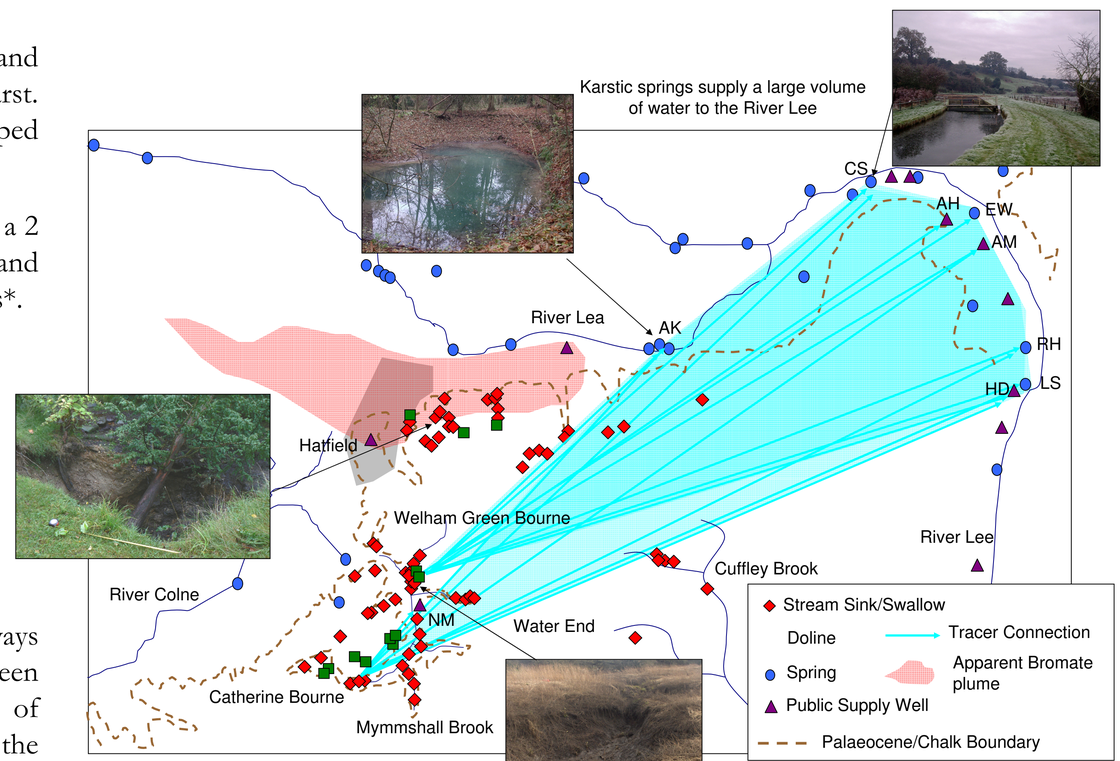
Tracer injections and observation times for 1920's and 1930's tests at Water End and the Catherine Bourne[4] Note Abbreviations correspond to locations on map)



Scavenge pumping at Hatfield PWS has indicated a 2 to 8 day lag time between changes in abstraction and observed peak changes to bromate concentrations*.

Tracer testing conducted in the 1920's and 1930's[4] provides evidence of rapid connectivity between the Mymmshall Brook catchment and the Lee Valley. Tracer travel times show a close agreement with the influence of scavenge pumping at Hatfield PWS on bromate concentrations.

It is considered that anisotropic rapid flow pathways in conduits or enhanced fractures also exist between Hatfield and the Lee Valley and transport of bromate within these features is responsible for the wide apparent dispersion and high concentrations of bromate observed at distances of some 20km from the contaminant source.

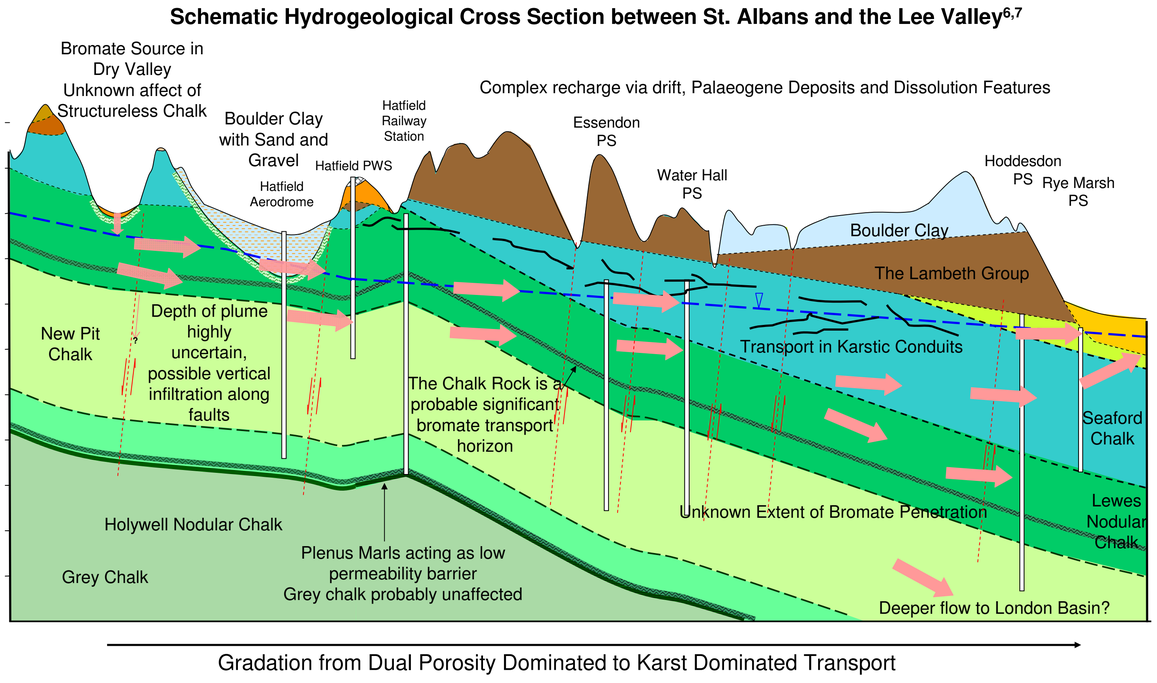


Locations of significant karst development and proven rapid connections from historical tracer testing are coincident with the leading edge of the bromate "plume"

Chalk Lithostratigraphy and Structure

Lithostratigraphy has been shown to have a significant influence on the physical properties of The Chalk[5] through sedimentary processes, diagenesis and in affecting response to stress changes. As a result lithostratigraphy controls the aquifer properties such as porosity and permeability. Consequently, it is proposed that lithostratigraphy should be used as an indicator of hydrogeological behaviour.

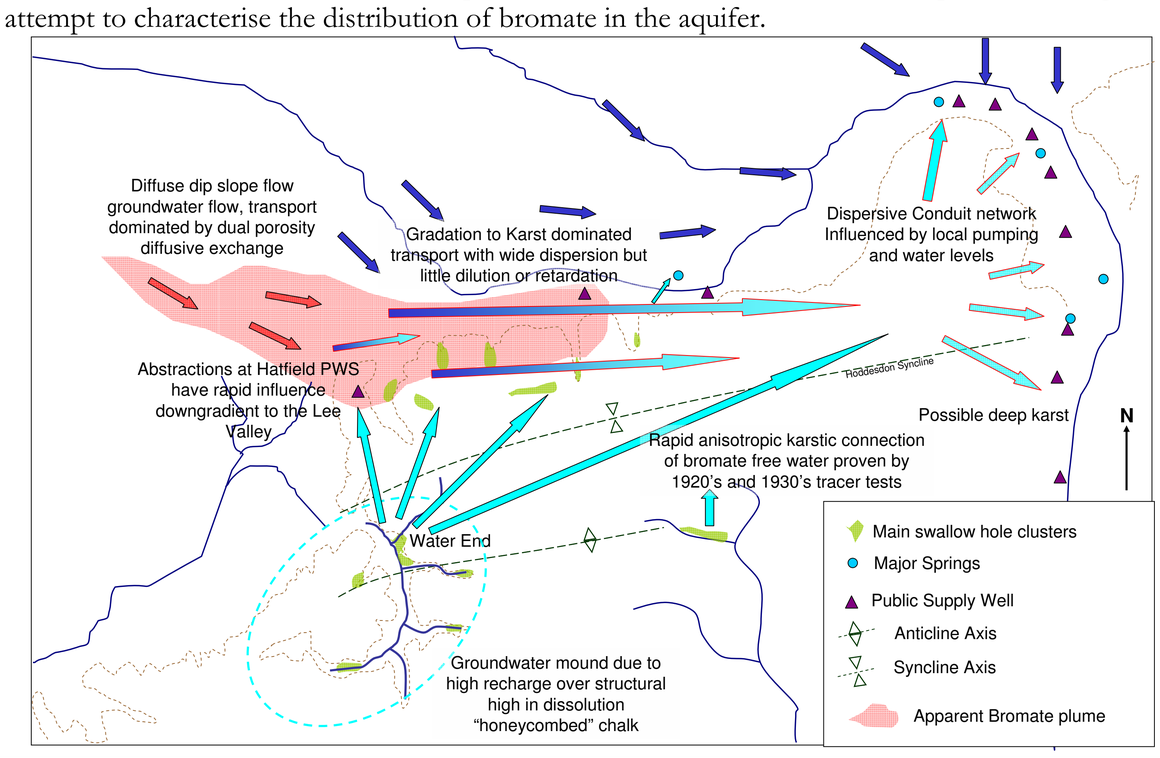
Schematic Hydrogeological Cross Section between St. Albans and the Lee Valley[6,7]



The variation of the parameters controlling dual porosity transport:- i.e. matrix porosity, fracture spacing and fracture style have been considered spatially and with depth in the aquifer. Additional information on these parameters will be obtained through borehole dilution tracer testing following the approach of the "Tilmanstone Methodology"[8]. However, detailed porewater bromate concentration profiles are required in order to add confidence to this approach and allow an estimate of the longevity of pollution in the aquifer.

Summary Conceptual Understanding

There appears to be a gradation from double porosity dominated transport west of Hatfield to a karstic dominated character between Hatfield and the Lee Valley. Coupled with a quantitative account of the source term*, this will provide the framework, for solute transport modelling in an attempt to characterise the distribution of bromate in the aquifer.



Ongoing Work

In order to be able to incorporate these hydraulic conductivity variations and the karst system appropriately in predictive transport models the hydrodynamic behaviour of the system needs to be evaluated in a more detailed way than historical tracer test data allow. This will be addressed through a new suite of tracer tests between Hatfield and the Lee Valley in combination with groundwater modelling approaches, including double porosity modelling.

References

Many Thanks to Jon Newton, of Environment Agency Thames Region for advice and provision of monitoring data.

*See Poster By Ciara Fitzpatrick – The evolution of bromate contamination in the Hertfordshire Chalk Aquifer,

References: 1. British Geological Survey, 1978 Hertford, England and Wales Sheet 239 Solid and Drift Edition 2. Assem, J. 2005, *Bromate Contamination in the Lee Valley, Phase 2: Modelling Report* 5026834/2004/104/R008. 3. Pers. Communication, L. Lytton, Three Valleys Water Ltd. 4. Harold, C. H. H. 1937, *Thirty-second annual report on The results of the Chemical and Bacteriological Examination of the London Waters for the Twelve Months ended 31st December 1937*, P.S. King and Son, London. 5. Mortimore, R. N., Pomerol, B., & Foord, R. J. 1989, "Engineering stratigraphy and palaeogeography for the Chalk of the Anglo-Paris basin", in *Chalk, Proceedings of the International Chalk Symposium held at Brighton Polytechnic on 4-7 September 1989*, 1 edn, J. Burland et al., eds., Thomas Telford, London, pp. 47-62. 6. Bloomfield, J. P., Farrant, A. R., & Cunningham, J. 2004, *Structural interpretation of the Chalk of the Hertford District based on slope aspect mapping*, British Geological Survey, Nottingham, CR/04/XXC. 7. Woods, M. A. 2003, *The stratigraphy of the Chalk Group of the Hertford district: a preliminary study for the Veolia Water Partnership*, British Geological Survey, Nottingham, CR/03/216. 8. Watson, S., 2004, *Solute Transport and Hydrodynamic Characterisation in the Chalk Aquifer at Tilmanstone Kent*, Unpublished PhD Thesis, University College London.

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