



Ineson Lecture meeting

Impacts of Land Use and Catchment Management on Groundwater

A joint meeting of the International Association of Hydrogeologists and the Hydrogeological Group of the Geological Society, including the 2011 Ineson Lecture.

Thursday 20 October 2011.

12:45pm registration and coffee; 1:15 Welcome

Geological Society, Burlington House, London

PROGRAMME

12:45 Registration and coffee

13:15 Welcome and Introduction

13:30 Prof Bob Harris, DEFRA: *Joining up the dots – how hydrogeologists can play a key role in catchment management*

13:55 Prof David Lerner, University of Sheffield: *Fitting groundwater into the landuse jigsaw*

14:20 Luke De Vial, Wessex Water: *Some problems with groundwater*

14:45 Bryan McCluskey, Highland Spring Group: *The control and management of Catchment Areas: A producer's perspective*

15:15 Presentations

Whitaker Medal: Kevin Hiscock (University of East Anglia)

John Day Bursary: James Lane (University of Leeds / IAH)

15:30 Tea and Posters

16:15 Ineson lecture 2011

Integrating Land and Groundwater Management: Experiences in Australia and the Pacific

Professor Ian White

Australian National University

17:15 Discussion

17:30 Drinks reception (in the Lower Library)

**Ineson Lecture 2011: Professor Ian White, Australian National University, on
*Integrating Land and Groundwater Management: Experiences in Australia and the Pacific***

Abstract: Threats to groundwater from overuse and from contamination are well documented in many countries. One of the key objectives of the Australian 2007 National Water Initiative is that the connectivity of surface and groundwater must be recognized and managed as a single resource. This poses significant issues in the integration of land and groundwater management. In this lecture, the use of hydrogeology in integrating land and groundwater management will be discussed using illustrations involving the acidification of ground and surface waters, salinity in upland catchments of the Murray-Darling Basin and very vulnerable freshwater lenses in small island states in the Pacific. The role of hydrogeologists in assisting with the development of policy and regulations regarding land use and water resources will also be discussed.

Biography: Ian White is Professor of Water Resources and the Australian National University and Associate Director Research in the Fenner School of Environment and Society. He is a Fellow of the American Geophysical Union (Hydrology) and a Fellow of the Australian Academy of Technological Sciences and Engineering. His area of research area is water resources with emphasis on sustainable water use and management, surface-groundwater interactions, and the mitigation of global change and land use impacts on catchment and groundwater yield and water quality.

Joining up the dots – how hydrogeologists can play a key role in catchment management

Prof Bob Harris, DEFRA

Abstract: We manage our environment in an unconsciously disjointed and myopic way to exploit the ecosystem goods and services we need. But as we begin to understand that it functions as an interlinked series of complex systems operating at different scales, the policies and management decisions we make to deliver just one service can now be seen to be influential on other services in uncertain ways. The pressures of a changing climate, globalisation and increasing demands on our natural resources means that such uncertainties require better resolution. We will have to do better. Understanding the critical linkages that drive these systems will be increasingly important if society as we know it is to survive.

The management of integrated and interlinked systems requires integrated approaches at the scales at which the systems operate – integrating the policies, integrating the science, integrating the decision-making to develop ‘win-wins’ and accept ‘trade-offs’. There are enormous barriers to integration and we are at the very start of the process in recognising them. Some of the barriers are to do with drivers, like legislation, that force policy-making and the resultant actions into a silo approach; others are to do with language and culture and the consequent mis-communication between sectors and even scientific disciplines. Yet more are to do with not understanding the scale at which we make decisions and how these cascade through the systems that operate within and between the different scales.

The scale at which we understand the environment and make decisions is particularly important. The Water Framework Directive (an early integrated piece of legislation) requires reporting at the River Basin scale, but is too large to connect with people. Most decision-making is carried out at a more human scale, at site or farm scale, and certainly this is where most of our science is undertaken. The understanding we develop and the consequences of our actions have to be scaled up if we are to make sense of outcomes at regional, national or continental levels. This bottom-up approach has now been recognised by government as their preferred option for the second round of River Basin planning for the Water Framework Directive, under the generic name of (integrated) catchment management, an approach to managing ecosystem goods and services that has had a longer gestation elsewhere.

And so to hydrogeologists... Hydrogeologists are used to: working at different scales and in four dimensions, having no data, thinking holistically, conceptualising the environment they are dealing with, and working with models, all attributes that are needed in systems understanding. They have developed approaches for tackling these. An example is the now standard, risk-based approach to remediating contamination in the soil and sub-surface, using a source-pathway-receptor paradigm, which evolved from a need to be more efficient and effective – essentially a simple systems approach. Such an approach can also be used at higher scales than contaminated land sites in the context of catchment management.

Understanding the system before you try and fix it seems a simple basic rule, but is seldom attempted at our early stage of development in catchment management, largely because we’re all still trapped in our silos. The hydrogeological community can help accelerate the change that’s needed – get stuck in!

Fitting groundwater into the landuse jigsaw

Prof David Lerner, Catchment Science Centre, University of Sheffield

Abstract: Groundwater is intimately connected with the landscape and land use that it underlies, and is vulnerable to the anthropogenic activities on the land surface above. Inappropriate land use, particularly poor land management, causes acute and chronic groundwater quality problems. Current land use instruments have been largely ineffective in protecting groundwater from diffuse pollution for several reasons including fragmentation, their general absence of teeth, and their lack of integration into the land use planning system. A more radical approach which would zone land according to its overall vulnerability and resilience to anthropogenic and climatic influence in order to sustainably support the ecosystem services it can deliver. Land use would be matched with the vulnerability of the soil, with geology and water, and with the whole ecosystem. However, the recent Foresight Land Use Futures Project identifies nine sectors of the economy which make multiple demands on land: water resources, conservation, agriculture, woodlands and forestry, flood risk management, energy infrastructure, residential and commercial development, transport infrastructure and recreation. How likely is it that protection of groundwater will be given the weight that hydrogeologists feel it deserves in competition with the other pressures?

Some problems with groundwater

Luke de Vial, Head of Water Resources and Supply, Wessex Water

Abstract: 75% of Wessex Water's water comes from groundwater. All of it was once at the surface. This creates two key problems.

Firstly on passing the surface, the water picks up contamination, "pollution" if you prefer. Traditionally water companies have spent a fortune removing the contaminants to ensure that the water supplied to customers is compliant with drinking water standards. More recently water companies have been working directly with farmers to solve the problem at source. Results are encouraging both for pesticides and nitrates, and the hydrogeology is crucial.

Secondly, water companies rarely return the water to the same surface location where it came. At worst this can result in dry stretches of rivers, however there have been a number of solutions to these low river flow problems based on abstracting yet more groundwater, but, this time taking advantage of its sticky qualities.

The control and management of Catchment Areas: A producer's perspective

Bryan McCluskey, Head of Technical & Sustainability, Highland Spring Group

Abstract: Highland Spring Group is the UK's largest producer of Naturally Sourced Bottled Water, and from producer's perspective the protection of the catchment area is of paramount importance. Treatment of the water, save for some very specific exceptions, is prohibited by law. In this short talk we will briefly touch on some of the legislation specific to bottled waters in the UK along with the experience of the Highland Spring Group built up over 30 years working with expert Hydrogeologists including: defining source protection zones, reaching agreements with land owners who often having competing priorities, and the challenges that acquisition of new businesses can bring.

Poster Abstracts:

Sources of Organic Micropollutants in a Peri-Urban Flood Plain Aquifer

Katya Manamsa, Dan Lapworth and Marianne Stuart Groundwater Science, British Geological Survey, Wallingford, UK

Abstract: This poster describes a pilot study to investigate the occurrence and distribution of “emerging organic contaminants” in groundwater in an area of mixed landuse. The study site was the peri-urban setting BGS Oxford Observatory on the Port Meadow, an area of ancient grassland on the gravels of the flood plain of the River Thames to the northwest of Oxford. The meadow is flanked on its eastern edge by a closed landfill which accepted all categories of waste from 1937 up to 1980. The leachate plume can be identified across the site by high conductivity, Cl, HCO₃, SO₄ and DOC. Part of the landfill is now used as allotments. Land to the west of the Thames is used for agriculture.

Groundwater levels suggest that the regional groundwater flow in the superficial deposits is from northeast to southwest under the main Thames. The site is periodically inundated and groundwater is predominantly reducing.

A series of shallow piezometers were sampled in July 2011 for organic micropollutants from various settings and analysed by the Environment Agency NLS using the semi-quantitative GCMS and LCMS screening methods developed for their organic micropollutant monitoring programme.

The results showed that organic micropollutants were present at all sites and included both established priority pollutants and emerging contaminants. A total of 26 compounds were detected by GCMS with N-butyl benzene sulphonamide (BBSA) being both the most frequently detected compound and with the highest maximum concentration. Four priority pollutants were detected, trichloroethene, octyl phenol, anthracene and fluoranthene, and one pesticide, metaldehyde. Some landuse discrimination was evident with the Thames and urban areas showing a different fingerprint from the landfill plume and from the agricultural area:

- Urban sites upgradient of the landfill: phthalate and BBSA plasticisers, poly-aromatic hydrocarbons (PAH), triphenyl phosphate, anti-epileptic drugs
- Portmeadow site upgradient from the landfill: BBSA only
- Sites in the plume: trichloroethene, 1,4-dioxane, barbiturates, phthalate and BBSA plasticisers, metaldehyde, crotamitron
- Agricultural site across the river: 1,4-dioxane, phthalate and BBSA plasticisers, metaldehyde
- River Thames: phthalate and BBSA plasticisers, caffeine, anti-epileptic drugs, PAH

The LCMS results were non-quantitative but showed the β -blockers atenolol, sotalol and celiprolol to be present in the Thames and a range of pesticides including carbendazim, diuron, carbetamide and terbutryn, predominantly at the site across the river, but also at the urban sites and the Thames.

The next phase of the project will aim to investigate changes in organic micropollutants as a result of higher groundwater levels in the winter as well as floodplain inundation processes.

Catchment Management Investigations for Groundwater Sources in the Severn Trent Region

Mike Carey, Susie Roy (Amec), Caroline Jameson (Grontmij), Jodie Whitehead, Amanda Coffey, Matilda Beatty (Severn Trent Water Limited)

Abstract: Severn Trent Water Ltd. (STWL) is conducting groundwater catchment investigations at a number of sites to consider the potential for reducing pollution loading in catchments to groundwater abstractions for public supply. Increasing nitrate concentrations are the main water quality issue leading to an increasing need to build more treatment processes. Pesticides and cryptosporidium also pose a risk to supply and have also been considered as part of the investigation. The aim of the investigation is to:

- Identify potential sources of pollution within the catchment, and the pathways between these and STWL groundwater abstractions;
- To forecast future concentrations and the timescale for nitrate concentrations to plateau;
- Identify possible mitigation measures to address pollution sources; and
- Determine whether catchment management is likely to be successful in reducing pollutant concentrations at the borehole source, such that capital expenditure on treatment is not required or delayed.

The abstractions are located in mainly rural catchments, and it is thought that the most significant source of diffuse and point source pollution are likely to be due to agricultural activities. Site walkovers and stakeholder consultation were undertaken to confirm current and historical nitrogen applications to land and discharge to ground within the catchment. The outcomes of this site work have been used to update national freely available land-use datasets (e.g. CORINE Land Cover Map 2000 and EDINA Agri-Census data) and information on landfills, graveyards, sports grounds and sewage effluent discharges. A conceptual understanding of how nitrate arrives at the borehole has also been developed based on abstraction, groundwater level and borehole construction records.

Two modelling tools have been used to model nitrate in the catchment:

- Source apportionment tool (developed by AMEC for SEPA, the EA and the NIEA), which estimates the proportion of loading from point and diffuse sources of agricultural and non-agricultural sources.
- Nitrate trend analysis tool, which models the variation in nitrate concentrations over time, taking account of historical changes in land management (e.g. changes in fertiliser use over time). The tool represents the catchment with 10 sub-catchments in which land use is to be specified. The model represents travel times in the unsaturated and saturated zone and can be used to predict nitrate concentrations in groundwater.

The models are calibrated against historical nitrate concentrations in abstracted groundwater and used to assess the period before which the benefits of catchment management measures are realised and whether there is a need for interim measures such as investment in treatment. Simple cost benefit assessment has shown whether implementing mitigation measures would be more cost effective than treatment.

Our holistic approach provides a method for developing a conceptual understanding of diffuse pollution sources, pathways and receptors in each catchment, and a recommendation for any necessary further work to confirm this. The assessment of modelled scenarios in terms of their possible uptake in a catchment, identification of pollution swapping and the simple cost benefit assessment will allow STWL to plan future spend on how to deal with diffuse pollution in order to meet their customer's needs.

Nitrate pollution in groundwater: a modelled approach to catchment management

Victoria Price, Maria Andersson, and Jan van Wonderen (Mott MacDonald)

Jenny Sandberg (Anglian Water)

Abstract. Diffuse pollution of groundwater by nitrates threatens the integrity of groundwater supply throughout the UK. Rising nitrate concentrations are a result of the intensification of farming practises in post-war Britain. There is considerable regulatory pressure on water companies to develop sustainable, long term solutions to this problem.

Given the economic and environmental cost of nitrate treatment plants and the falling numbers of suitable blend sources, catchment management is often considered to be the most viable option to control nitrate levels at a source.

A combination of WAVE (Water and Agrochemicals in the soil, crop and Vadose Environment), Modflow and MT3D software packages has been used to model the movement of nitrate from the soil zone, through the unsaturated zone and in groundwater to abstraction boreholes. This approach provides a cost effective options appraisal for the future management of a catchment.

A pilot study was carried out at Anglian Water's North Pickenham boreholes. In this mainly arable catchment, nitrate levels in the Chalk aquifer have been increasing since monitoring began in the 1980s; concentrations now consistently exceed the drinking water standard of 50 mg/L.

Having achieved a good fit to the observed nitrate concentrations and trends at the abstraction boreholes, the calibrated models were used to predict the impact of changing landuse upon the concentration of nitrate in groundwater. Preliminary results indicate that a 50% decrease in fertiliser application or complete landuse change is required to reduce concentrations of nitrate at the North Pickenham boreholes to below 50 mg/L by 2030.

Quantification and Monitoring of Water and Contaminant Migration to Sediment via Groundwater-Surface Water Interaction

Bart Chadwick¹, Chris Smith¹, Ron Paulsen¹, Jon Groves¹, Sabine E. Apitz² and John Radford³

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Abstract: Introduction: Many terrestrial contaminated and hazardous waste sites are located adjacent to harbours, bays, estuaries, wetlands and other coastal environments (Chadwick et al., 2003a). Whilst soil and groundwater impacts are often studied, characterization and risk assessment often ends at the water's edge. There are emerging recognition and requirements to determine if contaminants from these sites are migrating into marine and surface water systems at levels that could pose threats to aquatic ecosystems and services. The complexity of these interactions dictates the need for adaptive characterization methods and new technologies to adequately identify zones of interaction, determine if these zones are contaminated, and quantify the rates of migration and flux to surface water systems. Here we describe a methodical yet adaptive procedure, along with new technologies to improve the ability to characterize these sites.

Methods: The approach utilizes three progressive and adaptive phases of characterization that build toward a quantitative representation of migration in sediments. In the first phase, direct-push sensor technology is used to rapidly map areas of potential groundwater discharge. In the second phase, areas of potential discharge are assessed using low-flow, subsurface porewater samplers to determine if contamination is associated with discharge zones. In the final stage, areas of contaminant discharge are evaluated using ultrasonic seepage meters to determine rates of discharge and contaminant flux. Two new technologies were developed to support this approach; a direct-push screening probe for determining where groundwater may be discharging and sampling those zones (the Trident Probe), and a seepage detection system (the UltraSeep; Figure 1). The Trident rapidly distinguishes differences in conductivity and temperature that indicate areas where groundwater discharge is occurring; the integral porewater sampler can then be used to rapidly confirm the presence of target chemical constituents. The UltraSeep is an integrated seepage meter and water sampling system that allows for direct quantification of discharge rates and chemical loading (Chadwick et al., 2003b).

Results: Results from a range of demonstrations and applications are summarized to illustrate the methodology and capabilities of the new technologies. Case studies include examples of identification of discharge zones based on subsurface conductivity and temperature distributions, mapping of subsurface contaminant distributions at the groundwater surface water interface, quantification of temporally varying groundwater discharge rates, and measurement of chemical discharge concentrations and mass flux. Trident configurations for multiple-depth sensors and sampling, and deployment in conditions ranging from shallow, quiescent waters, to deep, fast moving rivers are illustrated. Results from seepage meter deployments ranging from relatively steady discharge in lakes, to coastal areas of strong tidal influence are also presented.

Discussion: The procedures and technologies presented provide a coherent strategy for assessment of coastal sites where groundwater-surface water interaction may be an important pathway of exposure and risk. The method provides an efficient means of focusing the assessment to key areas of potential concern, and developing quantitative exposure and loading estimates in those areas. Application of these technologies over a broad range of sites and conditions indicates the robust nature of the method.

References: [1] Chadwick et al. (2003a) Technical Report #1898, SSC San Diego, US Navy.; [2] Chadwick et al. (2003b) Technical Report #1903, SSC San Diego, US Navy.