

**2008 Ineson Meeting
'Water scarcity and water security'**

8th October 2008
at The Geological Society, Burlington House, Piccadilly, London

A Joint Meeting of the
International Association of Hydrogeologists (IAH)
& The Hydrogeological Group of The Geological Society

Programme

- 0915 Registration and Coffee
- 1000 Introduction Jane Dottridge, Chair, IAH British National Committee
- 1010 Dr John Chilton (Executive Manager, IAH) - Overview of experience with UN bodies
- 1040 Prof Tony Allan (King's College) - Water trading and economics
- 1110 Break
- 1130 Dr Jinxia Wang (Chinese Academy of Sciences)
The 2008 Ineson Lecture – Water scarcity and water security
- 1240 Lunch
- 1340 Poster presentations
- 1400 Geoff Wright (UNEP) - Case studies from Darfur
- 1430 Dr John Aldrick (Environment Agency) - The UK regulatory perspective
- 1500 Break
- 1520 Ian Stevens (Yorkshire Water) - The UK water industry perspective
- 1550 Discussion Forum chaired by Prof Richard Carter, Cranfield University
- 1700 Close

Water Scarcity and Water Security: Some experiences from the international arena

John Chilton, International Association of Hydrogeologists

The presentation provides an overview of the general concepts of water scarcity and water security, illustrating them as far as possible from a groundwater perspective. Historical and widely used definitions of water shortage, scarcity and stress, and water security are given. However, achieving water security means both harnessing the productive capacity of water and limiting its destructive potential, and a broader definition of water security which captures this duality is given.

Water security is a function of the hydrological and socio-economic environment, and of the changes that are likely to occur to these over time. One of the major future changes that is likely to compromise water security where it has already been achieved, and make achieving water security more difficult is the impact of climate change. The scope of the uncertainties associated with climate change is illustrated with respect to groundwater in Africa, drawing on material presented at the recent Kampala conference. African climates are already highly variable, and the variability will increase under current climate change predictions. Improving water storage is a key component of strategies for achieving water security, and groundwater storage can play an important role in providing buffering capacity against the impacts of climatic variability. This can reduce the potential for water stress, but better hydrogeological understanding and fuller incorporation of groundwater into resource management are needed.

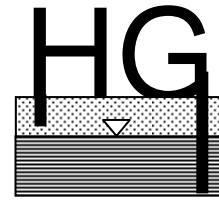
The task of achieving water security can be made significantly more complicated where national boundaries cross river basins and aquifers, and some current activities related to transboundary waters are briefly illustrated.

Virtual water: its role in achieving water security and sustainable water management in a global system

Tony Allan, King's College London and SOAS

The presentation will highlight the role of virtual water in the global hydro-economic cycle where water security and sustainable water management will have to be achieved. The significance of freshwater, soil water, manufactured water, re-used water and virtual water will be identified. Virtual water in international 'trade' - that is the 'trade' in water intensive commodities such as food, accounts for about 20 per cent of global food consumption. Most food commodities are raised from soil water. Food water accounts for 90 per cent of the water use of an individual and of the global population. The water footprint concept will be used to illustrate and compare the use of water in different societies.

The main focus of the presentation will be on the role of consumer behaviour on levels of water use and consumption - locally and globally. Bad news about consumer impacts on current and future water availability is not conveyed to them with any enthusiasm by either politicians or those in the market who provide food and other commodities. Politicians want to be re-elected. Corporations want to sell more goods. Facing the juggernaut of emotion associated water and food entitlements is an impossible political challenge. It is a problem that virtual water 'trade' is economically invisible and politically silent.



The Ineson Lecture 2008-10-06

Presented by Jinxia Wang, Chinese Academy of Sciences

Understanding the Water Crisis in Northern China: What Government and Farmers are Doing

Jinxia Wang, Jikun Huang, Scott Rozelle, Qiuqiong Huang and Lijuan Zhang

The overall goal of this presentation is to get the facts right, to make clear whether there is a water crisis in China, and if there is, to identify the responses of the different stakeholders—government water officials, community leaders and farmers. In order to achieve the overall goal, we will pursue several specific objectives. First, we will evaluate the status of China's groundwater economy—examining whether or not the groundwater table is systematically falling across space. Second, in the parts of China that do face a water crisis (or potential crisis), we document the regulations and policies that the government—both local and regional—have implemented and discuss whether they have been successfully implemented. Third, we describe how farmers have responded to the water crisis and try to assess whether or not their roles have helped alleviate the water scarcities or exacerbated the crisis.

To meet these objectives, we use two large field surveys that cover 7 provinces in northern China. Our findings demonstrate that, although the water table is not falling everywhere in northern China, there are still a substantial number of communities that appear to be facing a water crisis. When there is a water crisis, our data show that the government in China has begun to make a number of policy responses, but the implementation is not always effective. Where water is becoming scarce, farmers and community leaders also have made many responses. However, farmers do not always respond in ways that saves water. The major reason is that farmers do not always face good incentives. When they face good incentives, our research shows that they do save water. Hence, the government cannot ignore the way that farmers respond. In fact, good policy needs to use this responsiveness to reduce the adverse effects of water scarcities and encourage conservation.

Water scarcity and drought in a conflict zone: Darfur

Geoff Wright, UNEP

In the conflict zone of Darfur today, the roots of water scarcity can be summarised under five headings:

- Climate – the challenge of the semi-arid zone
- Hydrogeology – primarily the problems of the African Basement Complex
- Recharge – largely depending on runoff concentrated in wadis and depressions
- Population – which has increased markedly in recent decades
- Effects of the conflict

The Darfur conflict has resulted in unprecedented concentrations of population in camps around major urban centres, and many of these camps depend largely or entirely on wells in the Basement Complex, which is not normally expected to be able to sustain supplies to tens of thousands of people. The rainy seasons of the past few years have generally been at or above average, but there is concern about the vulnerability of camps to groundwater depletion when the rains fail. Since 2007 several humanitarian agencies, led by UNICEF, UNEP, Tearfund and Oxfam, have initiated a programme of water resource assessment and monitoring with the aim of preparing camp operators to cope with drought. Understanding the hydrogeology of the Basement Complex in Darfur will be a key element in this.

The UK Regulatory Perspective

John Aldrick, Environment Agency

- How we have arrived at the current UK regulatory position on water resources management which also involves how the Public Water Supply System developed.
- Some of the results of the analysis of Abstraction Pressures for Catchment Abstraction Management Strategies and the Water Framework Directive.
- How Groundwater fits into the analysis.
- The rise of environmental awareness and sustainable development.
- Some of the immediate issues that face water resources management.
- Alternative models of water resources regulation/management.

The UK Water Industry Perspective

Ian Stevens, Yorkshire Water

Water Companies are currently preparing their first Statutory Water Resource Management Plans, at a time when the understanding of the future climate is uncertain. We live in a century when water scarcity and water security are a constant pressure, and this is as true in Yorkshire as it is in the rest of the world. Ian Stevens will present a water industry view of scarcity and security, the issues and the industry response. The presentation will focus on drought , water resource management and the development of resilient water supply systems.

Is groundwater in NW China a renewable resource?

W Mike Edmunds, John Gates (Oxford University), Ma Jinzhu (Lanzhou University)

Approximately 22% of the land surface of the People's Republic of China is desert. This represents an area of 2.1 million km², roughly the same size as the Arabian deserts, or as Western Europe. Along with low soil fertility and extreme climate, fresh water scarcity is a limiting factor for agriculture and economic development in this region, which presently contains only 2% of the Chinese population despite its large expanse. There is current bureaucratic focus on settlement and development of China's mainly arid western provinces, which are less economically developed relative to the eastern China. However, the environmental challenges of this development have become apparent from high rates of desertification, falling water tables and soil salinization, and some villages and agricultural lands have been abandoned due to a combination of these factors.

The limits to groundwater recharge and aquifer renewability in Gansu, Inner Mongolia have been investigated using three separate approaches using isotopic and geochemical indicators:

Regional aquifer studies of the terminal lake basins: Results from the Minqin Basin are typical of many aquifers in the north-west arid regions. The groundwaters' decline in excess of 1m yr⁻¹ can be linked to a dense well-field using water-irrigated agriculture. Geochemical indicators (stable isotopes, noble gases, radiocarbon and chemistry) show conclusively that the developed groundwater was recharged predominantly from water recharged in a cooler climate than the present day. These resources have a limited life and scientific evidence points to the need for policy changes.

Investigations of the spatial variability of recharge using chloride mass balance: chloride profiles of the vadose zone moisture have now been obtained for over 20 sites in NW China, focused on the Badain Jaran desert. These results demonstrate the uniformity and low recharge rates (1-2 mm yr⁻¹) in dune sands in areas where the mean annual rainfall is around 100 mm yr⁻¹. These dunes overlie fresh water reserves which are proven to be palaeowaters which feed an ecologically fragile shallow lake system. Negligible present day recharge highlights the need to protect these resources.

Recharge history. Unsaturated zone chloride profiles from the Badain Jaran desert allow the reconstruction of the recharge history and climate over a period of up to 2000 years BP. Trends in the time series of 1/Cl serve as an indicator of relative moisture changes over time for the case that 1/Cl is proportional to recharge. Periods of above-average recharge include AD 1510-1640, 1700-1775, 1820-1830, 1880-1900, and much of 1960-present. A smaller peak is apparent in ~1377, which represents a slight rise above the average 1/Cl value of 0.012 prior to an extended dry phase from 1380-1550. Other periods of low recharge include AD 1640-1710, 1780-1820, 1830-1850 and 1890-1960. The results compare well with other proxy data derived from ice cores and tree rings

Edmunds, W.M, Ma Jinzhu, Aeschbach-Hertig, W., Kipfer, R., Darbyshire D P F (2006). Groundwater recharge history and hydrogeochemical evolution in the Minqin basin, North West China. *Applied Geochemistry*, 21, 2148-2170.

John B. Gates, W.M. Edmunds, Jinzhu Ma and Bridget R. Scanlon (2008). Estimating groundwater recharge in a cold desert environment in northern China using chloride. *Hydrogeology Journal*. 16, 893-910.

John B. Gates, W. Mike Edmunds, Jinzhu Ma and Paul R. Sheppard (in press). A 700-year history of groundwater recharge in the drylands of NW China and links to East Asian monsoon variability. *The Holocene*.

Poster

Basin-scale variations in shallow groundwater levels in Bangladesh over the last 40 years: assessing the impacts of groundwater-fed irrigation

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Bangladesh occupies much of the Ganges-Brahmaputra-Meghna (GBM) delta – one of the largest delta systems in the world that forms highly productive aquifers. To meet increasing demand for food of the country's rapidly growing population, groundwater-fed agriculture was introduced during the 1960s. Boro rice, grown on 40,650 sq km of land, accounted for 53% of the country's total rice production during 2005-06. About 80% of groundwater abstracted in Bangladesh is used for irrigation of which cultivation of dry-season boro rice is the largest consumer. Sustainable use of groundwater for boro-rice cultivation is essential to the future food security of Bangladesh and other South Asian countries including India.

To investigate the basin-scale (100s of km) impacts of climate variability and abstraction for irrigation, we compiled weekly water level records starting in the early 1960s to 2005 from 1200 monitoring wells throughout Bangladesh that are managed by Bangladesh Water Development Board. Hydraulic-head distributions from the monitoring well network over a median period of 22 years indicate that, regionally, groundwater in shallow aquifers (< 50 m below ground level) flows from the northwest to the southeast and from the northeast to south-central regions. Ultimately, all groundwater flows into the Bay of Bengal through the Bengal submarine canyon. Median monthly hydraulic heads in shallow aquifers show that water levels are shallowest during September at the end of the monsoon period and deepest during April following sustained groundwater-fed irrigation at the end of the dry season.

Spatial head distributions in shallow aquifers are controlled mainly by surface elevation, regional depressions, and confluences of the major rivers. Groundwater-level fluctuations ranging from 3 to 6 m between the driest and wettest months occur in north-western and north-central hydrogeological units whereas seasonal fluctuations are comparatively lower (< 3 m) in the As-contaminated GBM delta and the subsiding Sylhet basin. Time-series analyses of both dry-period hydraulic heads and the entire data series show declining groundwater levels of > 0.2 m per year in areas of high abstraction for irrigation and urban areas; groundwater levels are stable with occasional rising trends (0.02 to 0.05 m per year) in the GBM delta region and major floodplains.

Our historical analyses reveal the scale and magnitude of the impacts of groundwater-fed irrigation for dry-season boro-rice cultivation. Current research seeks to resolve the relationship between groundwater-fed irrigation and arsenic mobilisation as well as the future response of the shallow groundwater system to fewer but more intense rainfall events that are predicted to result from global warming.

Sustainability of family wells in sub-Saharan Africa

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In sub-Saharan Africa (SSA) many families rely on shallow (< 10 m), unimproved wells for their main source of domestic water. There is a growing movement amongst donors and NGOs to encourage the development of these family wells, as a first rung on the water supply ladder, rather than opting first for a community water supply. To date, little research has been undertaken on the sustainability of these shallow wells.

To investigate the security of water supply from a shallow well, data from a 6.3 m deep hand-dug well, in SE Nigeria have been examined (Figure 1). The well is 1.5 m in diameter and penetrates 3 m of laterite overlying fractured mudstone. The following data were recorded: water-level data in the well and a nearby observation borehole (5 m away), abstraction data, and rainfall. The data were collected by the British Geological Survey (BGS) during an ongoing rural water supply project. The work indicates:

- the well is sustained by shallow groundwater within the laterite;
- the well fails in the late dry season and is linked to increased demand from the well and decoupling of the laterite, rather than wholesale depletion of shallow groundwater;
- laterite transmissivity is of pronounced seasonality and varies non-linearly with saturated thickness (<0.1 m²/d to > 100 m²/d).

Modelling of the system indicates that the sustainability of these shallow wells depends critically on demand. By reducing the demand on individual shallow wells, adopting a two-phase daily pumping regime and increasing the well storage area family wells from this laterite layer could provide year-round, daily access to ~100 litres of water per day. During the wet season, however, the high permeability of the laterite can lead to contamination from nearby pit latrines.

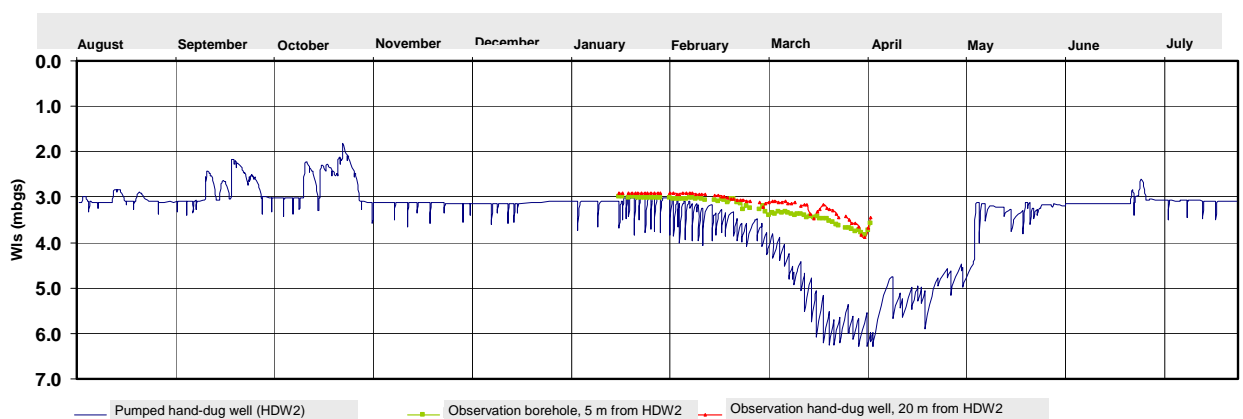


Figure 1 Water levels in a shallow (6.3 m deep) family well.

Poster

Quantifying the impacts of climate change on basin-scale water resources

Daniel Kingston, Richard Taylor, Martin Todd, Julian Thompson
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Studies of potential climate change impacts on freshwater resources commonly employ a wide range of socio-economic and climate scenarios. Such variability complicates comparisons of impacts for different socio-economic and climate futures, and prevents a systematic understanding of the effects of proposed adaptation and mitigation policies. This study seeks to address this issue of scenario uncertainty by using a wide range of climate, emissions and developmental scenarios to drive basin-scale hydrological models, and thus estimates of future freshwater availability (both surface and sub-surface). Research is primarily focused on the basin-scale, because mitigation and adaptation to climate change will normally be conducted at the basin level. Furthermore, hydrological models at the basin scale allow for more explicit representations of available freshwater resources (e.g. soil water, groundwater) and demand than is permitted by macro-scale hydrological models, and also aid evaluation of projections of freshwater availability produced by macro-scale models. Basin-scale studies also provide an excellent forum to assess indicator metrics of adaptation, risk and vulnerability defined at the global scale. Study basins have been selected to cover a broad range of spatial scales and climatic, environmental and developmental conditions, and comprise the Mekong, Okavango, and tributaries of the Mackenzie, Parana, Nile, Yangtze and Yellow Rivers. High-resolution ($0.5^\circ \times 0.5^\circ$) climate scenarios are used to drive the basin-scale hydrological models. Scenarios are produced by a scenario generator (ClimGen), which uses a pattern-scaling approach to generate scenarios based on data from several IPCC AR4 GCMs. Scenarios are produced based on SRES emissions projections, and uniquely, according to prescribed levels of change in global mean temperature. The latter scenarios are of particular interest given recent focus on avoiding so-called 'dangerous climate change'. The combination of data from different GCMs and different forms of scenarios means that, in combination with investigation of uncertainty in the parameterisation of the hydrological models and use of different socio-economic scenarios (the IMAGE implementation of the SRES scenarios), a wide-ranging assessment of uncertainty in the impacts of climate change on future water scarcity can be examined.

Poster

Hydrostratigraphical analysis of the fluvio-deltaic aquifer system in eastern Bengal Basin – a basis for assessing vulnerability of a ‘deeper’ aquifer

Mohammad A. Hoque and William G. Burgess

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In heterogeneous geological environments, understanding hydrogeology at the necessary scale is a difficult task. In fluvio-deltaic terrains depositional elements are often arranged in a linear fashion and are spatially discontinuous and varied in nature. These characteristics have implication for groundwater flow and hence for considering the vulnerability of groundwater to contaminant migration.

The upper few hundred meters of the floodplain deposits of Bangladesh contain unconsolidated Quaternary fluvio-deltaic sediments that hold an essential source of water, meeting almost 80% of the national water-demand. Throughout much of southern Bangladesh' shallow groundwater in the floodplain areas contains high concentrations of arsenic, and there has been much recent interest in the 'deeper aquifer' as a potential source of arsenic-safe water. However, many issues concerning the hydrogeological framework remain poorly understood. Many 'deep' tubewells have been drilled beyond the shallow aquifer system in the past few years, yet the existence of a deeper aquifer as a separate entity has been questioned. In a study of about 5000 km² area in the eastern Bangladesh we have used 10 deep logs from the petroleum industry, 576 drillers' logs, and 12 borehole geophysical logs to delineate the hydrogeological basement, to characterise the upper 250 m of the sedimentary column - the exploited part of the aquifer system, and to investigate the local scale spatial variability.

Petroleum industry logs indicate some structure on the hydraulic basement with a surface at between 600 and 1500 m depth. The surface of the 'Upper Marine Shale' of Miocene age extending across the region as indicated in existing literature. For the uppermost 250 m drillers' logs are used to interpret 'lithofacies' and 'hydrofacies' in 3D. Two broad hydrofacies were coded numerically in order to identify internal variability within the aquifer materials and to investigate potential layering of the finer grained sediments. A single aquifer is observed across the region with the potential for hydraulic connection between a shallower and a deeper zone. Intermediate finer materials between these zones do not form a continuous layer of low permeability. Three dimensional curvilinear features containing coarser sediments identified within the aquifer may correspond to paleo-channels and be acting as preferential groundwater flow paths. Geophysical logs are interpreted in terms of sedimentary-facies. Thin clay layers are present locally but they are not laterally persistent. The poster will present a conceptual basis for incorporating this hydrogeological variability into groundwater flow models for assessing the vulnerability of the deep aquifer to arsenic breakthrough from the shallow aquifer.

Poster

Hydro-Economic Models for Better Management of Water Scarcity

Julien Harou

University College London

Including both hydrologic and economic concepts and parameters in analysis can help water managers design, operate and expand water resource systems efficiently and in accord with social values and priorities. Hydro-economic models represent spatially distributed water resource systems, infrastructure, management options and economic values in an integrated manner. In these tools water allocations and management are either driven by the economic value of water or evaluated by that measure to provide policy insights and reveal opportunities for better management. A central concept is that water demands are not fixed requirements but rather functions where quantities of water use at different times have varying total and marginal economic values. The models use various formulations, levels of integration, spatial and temporal scales, and solution techniques and have been in use for more than 45-years. Two such models developed at UC Davis and applied to California are briefly described. Promising management strategies and policy insights are identified.

Poster

Groundwater Assessment of the Mampong area, Ashanti Region, Ghana

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Ashanti Development (a London-based charity) approached Arup to help provide a groundwater assessment of the area around the town of Mampong in the Ashanti region of Ghana. The objective of the assessment was to study the groundwater regime and resources of the study area and determine the potential for sustainable groundwater supply. Arup provided a hydrogeologist and a geochemist on a 50% funded, 50% voluntary basis through its charitable initiative ArupCause.

The outputs of the groundwater assessment were: to understand the environmental setting and identify the project stakeholders; refine the hydrogeological model and determine the key groundwater resource issues; and to assess the viability of the groundwater sources and consider potential opportunities for safe water supply. The principal activities undertaken to achieve the outputs were a UK-based desk study focussing on the environmental setting of the study area and a two week field visit to meet stakeholders, collect local data and refine the conceptual model of the area's groundwater regime.

The findings of the study indicated that locating and providing sustainable groundwater supplies in the study area is complex. Previous phases of borehole installation in the area have had an average success rate of 30 - 50% of installing productive boreholes. The results of the study suggest that this is primarily due to the difficulty in locating fracture networks in the sandstone bedrock. The natural problems are compounded by handpump maintenance and mechanical problems. In conclusion, the study found that to improve the likelihood of gaining a productive borehole an installation methodology that incorporates pre-installation vegetation, topographic and surface geophysics surveys and post-installation hydrofracturing can be employed. To aid the sustainability of a productive borehole, community training on handpump maintenance and a maintenance network should be implemented and fostered.

Additional recommendations included ensuring that a groundwater quality monitoring programme is initiated and the results compared to relevant standards for potable supply. Alternative opportunities for safe water supply include: community rainwater harvesting, improvement of current surface water sources, installation of deep boreholes to the granite basement rocks or pipework installation to surface water sources.