Africa, Groundwater and the Sustainable Development Goals

Wednesday 25 October 2017, Geological Society, Burlington House, London

A joint meeting of the International Association of Hydrogeologists (IAH) and the Hydrogeological Group of the Geological Society, including the 2017 Ineson Lecture. The meeting will address a range of groundwater and development issues in Africa.

09:30 – 10:30 Registration and Coffee in the Library

Morning session

10:30 Welcome by **Adrian Butler** on behalf of the **GeolSoc Hydrogeology Group**

10:40 **Guy Howard, DFID:** *Groundwater research into policy within the context of Africa & the SDGs*

11:05 **Brighid Ó Dochartaigh, British Geological Survey:** *Groundwater data in Africa*

11:30 **Debate:** *'Each time an NGO, charity or private company constructs a water well or borehole for community water supply, they should be required to pay a small levy to Government to cover the costs of the groundwater monitoring and governance activities undertaken by the relevant public sector organisation(s)'.* Convenor: **Geraint Burrows**. Speakers: **Richard Carter, Richard Carter & Associates Ltd; Robert Kalin, University of Strathclyde; Vincent Casey, WaterAid; and Callist Tindimugaya, Ministry of Water, Uganda**

12:10 **Introduction to Posters**

12:30 – 13:30 **Buffet Lunch** (provided) **& Posters** in the Library

The GeolSoc Hydro Group AGM will be held during the lunch break in the main lecture theatre. This is open to all Fellows of the Geological Society who have registered an interest in hydrogeology.

Afternoon session

13:30 Welcome back by **Tim Besien** on behalf of the **IAH British Chapter**, and presentation of the **IAH John Day Bursary** to Rachael Fletcher, University of Birmingham

13:40 **Richard Taylor, University College London:** *Groundwater and Climate in Africa: evidence from The Chronicles Consortium*

14:05 **Dan Lapworth, British Geological Survey**: *Urban groundwater & groundwater quality in Africa*

14:30 **Ineson Lecture 2017: Dr Callist Tindimugaya, Ministry of Water, Uganda**

15:30 – 16:00 **Tea/Coffee & Posters** in the Library

16:00 **Panel Discussion:** an invited panel discuss groundwater and the sustainable development goals in Africa and take audience questions. The panellists are **Dr Callist Tindimugaya, Ministry of Water, Uganda; Alan MacDonald, British Geological Survey; Vincent Casey, WaterAid;** and **Chris Leake, Hafren Water**

17:00 **Whitaker Medal presentation:** Presented to **Jane Dottridge, Mott MacDonald**, by **Adrian Butler** on behalf of the **GeolSoc Hydrogeology Group**

17:15 **Wine reception** in the Library

Posters will be displayed throughout the day in the Library.

Convenors: **Geraint Burrows, Groundwater Relief**
Alex Gallagher, WSP
Brighid Ó Dochartaigh, British Geological Survey

Speakers

Richard Carter is Director of his consultancy firm 'Richard Carter and Associates Ltd', specialising in groundwater resources and supply, sanitation, and hygiene in low-income countries. Former positions include of Professor of International Water Development at Cranfield University, Head of the Technical Support Unit at the charity WaterAid, and Chair of the Executive Steering Committee of the Rural Water Supply Network. Richard is also a co-Editor of the journal Waterlines, Senior Research Associate at the Overseas Development Institute, and Visitor in the Cambridge University Engineering Department. He is a strong proponent of the professionalisation of both conventional and manual drilling for groundwater abstraction, of the importance of groundwater monitoring, and of the evaluation of groundwater resources. His work has focused mainly on sub-Saharan Africa, although he has also worked in South Asia and Central America. He has published widely in the field of water management and community water supply and sanitation, and was given the IAH Applied Hydrogeology Award in 2016.

Vincent Casey is Technical Support Manager for WaterAid, overseeing and developing WaterAid's technical support programmes for 26 countries, to improve the sustainability of water supply and sanitation services, water security and community based water resource management. Vincent has over 15 years professional experience in the WASH sector in sub-Saharan Africa, South Asia and the Middle East, including the management of cross-cutting operational research projects. He is also a senior researcher at the World Bank.

Guy Howard is a water and sanitation expert with over 25 years experience. He is WASH Policy Team Leader at the UK Department for International Development (DFID), responsible for providing policy advice on WASH elements of DFID and the UK's positions on the Sustainable Development Goals, and drives greater coherence between WASH and water resources programming across DFID. Previous positions include providing policy guidance on water resources in DFID and leading the Government of Bangladesh Arsenic Policy Support Unit. Before joining DFID, Dr Howard worked at WEDC, Loughborough University, and Surrey University undertaking research, consultancy and training in WaSH and water resources.

Robert Kalin is Professor of Environmental Engineering for Sustainability at Strathclyde University. He has worked in the field of water resource management and human health with UN Agencies, NGO's and Governments in many countries throughout the Middle East, Far East, and Africa and is currently Director of the Climate Justice Fund Water Futures Programme for SubSaharan Africa, mainly focused on Malawi. His previous appointments include Head of the Department of Civil and Environmental Engineering at Strathclyde University, and Royal Academy of Engineering Research Professor at Queen's University in Belfast.

Dan Lapworth is a hydrogeochemist at the British Geological Survey. His research interests include water quality, groundwater vulnerability, and groundwater recharge processes within the context of environmental change. His interest lies in applied groundwater science to inform groundwater development, with a particular focus in Africa and South Asia. A large part of Dan's work has a direct ODA/development focus, and he is currently working directly with NGOs such as WaterAid, Water4People and Practical Action, and partnering with national ministries and researchers in India, Bangladesh, Kenya, Uganda, Malawi and Ethiopia.

Chris Leake, of Hafren Water, has over 27 years experience of groundwater and surface water management in relation to water resource assessment, environmental assessment, water supply and the extractive minerals industry. He has provided input to a wide range of projects in diverse fields including environmental auditing, regulatory compliance, technical assessment of dewatering schemes, environmental impact assessments for planning applications and negotiation with regulators. Chris has practical experience in many aspects of groundwater exploration and development from geophysical surveying to drilling supervision, well design and borehole testing. International experience includes site investigation, groundwater resource assessment, public presentations, and liaison with diverse audiences, from government to villagers. Chris has a long-term interest in overseas aid and development with site experience in Burkino Faso, Ghana, DRC, Ethiopia, Malawi, Tanzania and Nigeria.

Alan MacDonald is a principal hydrogeologist at the British Geological Survey and Honorary Professor at the University of Dundee. He has 25 years experience in applied groundwater science, with a particular focus on Africa and South Asia in the context of environmental change, water security and poverty reduction. Alan leads international groundwater research at BGS.

Brighid Ó Dochartaigh is a hydrogeologist at the British Geological Survey, with 20 years experience in groundwater resource and management projects in the UK and around the world, including many African countries, India and China. She currently leads the Africa Groundwater Atlas project within the UPGro research programme.

Richard Taylor is Professor of Hydrogeology at University College London. His research primarily focuses on two areas: the impact of climate change and rapid development on freshwater resources, with a specific focus on groundwater; and the role of groundwater in improving access to safe water and food security. He is currently co-chair of the IAH Commission on Groundwater and Climate Change and sits on the expert panel for the UNESCO-IHP GRAPHIC Programme (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change).

Dr Callist Tindimugaya holds a BSc in Geology and Chemistry (1990) from Makerere University, Kampala, an MSc in Hydrology and Water Resources with specialization in groundwater hydrology (2000) from IHE, Delft, a PhD in Groundwater Resources Management from University College, London (2008), and an MBA from the Management College of Southern Africa, Durban (2010). Callist began his professional career in 1990 as a hydrogeologist in the Ministry of Natural Resources and became Head of the Groundwater Section in 1999, responsible for all groundwater management activities in Uganda. Since 2007, he has been Commissioner for Water Resources Planning and Regulation in the Ministry of Water and Environment, responsible for planning, allocating and regulating water resources. He has been IAH Council Member and Regional Vice President for Sub-Saharan Africa since 2012. He is also a Regional Coordinator for the Nile Integrated Water Resources Management Network, Chairman of the Uganda Groundwater Professionals Association/National Chapter IAH, and a Steering Committee member of the African Groundwater Network.

Poster Abstracts

1 An analysis of the hydrogeological performance of sands dams in Southeastern Kenya

Ruth Quinn and Alison Parker*

CWSI, Cranfield University, Cranfield MK43 0AL, UK

* a.parker@cranfield.ac.uk

One approach to the decrease in water security caused by climate change in semi-arid and arid regions has been the sand dam. Sand dams are concrete walls constructed across seasonal riverbeds behind which sand accumulates. Water can then be abstracted from the sand and underlying aquifer by the local community through adjacent hand pumps during the dry season. Sand dams are most common in Kenya but there are examples of similar structures in Brazil, Angola and India.

This research evaluated the hydrological performance of three of these structures and the quality of the water contained within them. This field study took place in Makueni county, south east Kenya between May and August 2017 (the dry season). Measurements were taken of water level in the sand (through piezometers), evaporation (through lysimeters), sedimentology, topography, hydraulic conductivity and salinity of the water.

Sand dams were found to act as multiple use water schemes and provide the communities with water for domestic needs, agriculture, livestock and small scale industries.

The water in all three of the sand dams was found to decrease steadily over the dry period with averages of 1.45cm/day, 2cm/day and 2.5cm/day respectively. The bed slope (0.0045, 0.006 and 0.007 respectively) and clay content (11%, 31% and 41%) was found to differ between the studied dams affecting potential subsurface flow.

Lysimeters to measure evaporation were installed at two points at each dam, lysimeter one was located towards the dam wall and lysimeter two further upstream. The water table fell more slowly at lysimeter two compared to lysimeter one with maximum drops of 0.6m, 0.6m and 0.3m below the sand surface for lysimeter one and 0.25m, 0.3m and 0.25m for lysimeter 2 over a period of 14 days.

Regarding water quality, the salinity of water in the sand dams sampled through piezometers and scoop holes (averages of 1.882µS/cm, 0.81µS/cm and 0.55µS/cm) was substantially less than the water abstracted from the underlying aquifer through hand pumps (averages of 3.94µS/cm, 1.12µS/cm and 2.66µS/cm). This has caused the local populations to use unimproved water sources (scoop holes) as opposed to safer abstraction methods (hand pumps).

2 Time dynamic modelling of groundwater vulnerability at the African scale

Issoufou Ouedraogo*, Arthur Girard, Pierre Defourn and Marnik Vanclooster

Earth and Life Institute, Université Catholique de Louvain, Croix du Sud 2, Box 2, B-1348 Louvain-la-Neuve, Belgium.

* ouediss6@yahoo.fr

Groundwater vulnerability mapping is an important key for improving the planning and decision making processes in order to prevent groundwater contamination. To this regard, we filled a significant knowledge gap on groundwater pollution at the continental scale of Africa by developing method for assessing groundwater pollution risk at the pan-African scale (Ouedraogo et al. 2016) based on a "static" hypothesis. However, some of the parameters taken into account by this method may vary over time such as recharge, groundwater level, land use, etc. In the present work, through the application of the DRASTIC method to evaluate the intrinsic vulnerability at the African scale, and using the most recent continental scale data on soil, topography, land use, geology, hydrogeology and climate in a Geographical Information System at the resolution of 15 km^2, we showed that groundwater vulnerability to pollution varies from one year to another, i.e. that it is dynamic. For this, we compared the years 1990, 2000 and 2010 selected for their different land use by using Density of population (D) as a proxy for this land use. These years are chosen according to their data available to incorporate time dimension in the vulnerability modelling. The elaborated vulnerability maps show variability in the spatial distribution of vulnerability degrees between the three years. The maps reveal that areas of Nile Delta, areas around the Lake Victoria, North Africa, and coastal in West Africa changes from one map to another. The highly vulnerable areas have increased in relation to the increase of the density of population.

The temporal groundwater vulnerability proposed in this study, would constitute a new approach allowing vulnerability dynamic mapping. This can provide an important tool for the sustainable groundwater resources management in Africa, and participates indirectly to achieve SDG Goal 6 which includes a focus on preserving our freshwater resources for potential future threats.

Ouedraogo, I., Defourny, P., Vanclooster, M. (2016). Mapping the groundwater Vulnerability for pollution at the pan-African scale. Science of the Total Environment, Vol. 544, p. 939-953.DOI: 10.1016/j.scitotenv.2015.11.135.

3 Ugandan crater lakes, past and present: The unknown role of the groundwater system

Keely Mills[1*], Matthew Jones[2], David Ryves[3]

[1] British Geological Survey, Keyworth, Nottingham.

[2] School of Geography, University of Nottingham.

[3] Department of Geography, Loughborough University.

* kmil@bgs.ac.uk

Despite the provision of groundwater pumps in western Uganda, surface waters still provide drinking water to many remote communities. Exponential population growth in the region is placing unprecedented pressures on all water resources, and lakes are known to play a crucial role in the livelihoods of many people, providing services such as aquaculture, agriculture, and ecotourism.

There is much uncertainty relating to the impact of future climate change scenarios on water balance in tropical Africa, however the intensity and magnitude of land-use changes in the region are already impacting water balance and water quality. Future changes in climate will only serve to exacerbate the negative feedbacks, and this has implications for achieving a number of the UN's Sustainable Development Goals, including: zero hunger (2), clean water and sanitation (6), and life on land (15).

The sensitivity of the hydrological system (including surface and ground water) in western Uganda can be understood through contemporary monitoring, but complete records in the region are sparse, often incomplete, and are not suitable for use in hydrological mass balance models. In the absence of long-term monitoring records, analysing sediments from lake systems can provide information on past changes in hydrology and water quality (in the order of tens to thousands of years).

Previous research in the region has shown that the lakes are particularly sensitive to past changes in hydroclimate, and many phases of drought in the region have been linked to political unrest and the abandonment of settlements. Conversely, some lakes are known to have persisted during long-lived periods of rainfall deficit suggesting that groundwater plays a critical role in maintaining freshwater systems; yet the interaction of the two systems through time is rarely explored or quantified. The links between the surface and groundwater systems also has implications for the exchange of pollutants (including nitrogen and phosphorus, and heavy metals), which could lead to the contamination of groundwater, or increased nutrient enrichment in the lakes themselves (many of which are already eutrophic).

Current research is beginning to explore the surface-groundwater interactions through time. The ability to quantify the role of groundwater in the maintaining of surface water systems, or as a pollutant pathway, has major implications for the identification of areas and communities who will be particularly vulnerable to future hydrological stress.

4 Tryptophan-like fluorescence: an effective real-time indicator of faecal contamination in drinking water

James Sorensen[1*], Dan Lapworth[1], Ben Marchant[2], Steve Pedley[3]

[1] British Geological Survey, Maclean Building, Wallingford, OX10 8BB, UK
[2] British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK
[3] Department of Civil and Environmental Engineering, University of Surrey, Guildford, GU2 7XH, UK

* jare1@bgs.ac.uk

Enteric pathogens are typically inferred from the presence of cultured surrogate indicator organisms such as thermotolerant coliforms (TTCs). Their analysis requires suitable laboratories, specialist trained personnel, and is time-consuming, which can limit sampling resolution, particularly during critical pollution events. We will demonstrate the use of tryptophan-like fluorescence as a reagentless, real-time indicator of thermotolerant coliforms from a synthesis of work undertaken on African and Indian groundwater. We will show it is a significant indicator of both the presence-absence and number of these surrogate organisms, including where traditional real-time indicators of surface derived pollution like turbidity fail. The technique is now being trialled as a real-time pollution alert system at public abstraction boreholes in the UK and has potential widespread applications within the WASH and development sector globally.

5 Illuminating microbial contamination risk: How fluorimetry can improve groundwater assessment in low-resource contexts

Saskia Nowick

University of Oxford.

saskia.nowicki@smithschool.ox.ac.uk

When free from anthropogenic impact, groundwater usually has good microbial quality; however, widespread reports of contamination demonstrate that this natural state is often vulnerable and management is an ongoing challenge. Assessment of microbial risk from groundwater supplies relies primarily on Escherichia coli monitoring and sanitary inspection scores, both of which have well documented limitations. Assessments could be improved by using in-situ fluorimetry to complement the conventional approach, particularly in low-income settings. Fluorimetry is less resource-intensive and sampling requires less specialised training than for E. coli monitoring. Fluorimeters can measure tryptophan-like fluorescence, which is associated with microbial breakdown of labile organic carbon. This study explored the potential of in-situ fluorimetry for improving groundwater quality assessment in a rural, low-income setting in Kwale County, Kenya. Analysis of tryptophan-like fluorescence (TLF), E. coli and thermotolerant coliforms was conducted for 38 water points in wet (May/June 2016) and dry (March 2017) seasons. Within this study, TLF enabled differentiation between background levels and contamination

associated with high and very high E. coli based health risk categories. Furthermore, duplicate and replicate analyses demonstrated that fluorimetry provides more precise results than bacteriological techniques. It is concluded that measuring TLF in groundwater has value independent of and in addition to the information derived from E. coli monitoring. Fluorimetry has potential to improve understanding of spatiotemporal variability in microbial contamination risk and to enable better targeting of interventions and monitoring of their effectiveness.

6 Rapid detection of pathogens in drinking water supplies in rural Malawi – preliminary results

Ward, Jade[1,2*], Lapworth, Dan[1], Alan MacDonald[1], Pedley, Steve[2], Read, Dan[1], Gwengweya, Gloria[3]

[1] British Geological Survey, Wallingford, United Kingdom
[2] University of Surrey, Guildford, United Kingdom
[3] University of Malawi, Chancellor Colleg, Zomba, Malawi

* jadew@bgs.ac.uk

Drinking water supplies contaminated with bacteria and viruses cause diarrheal diseases, which kill 1.8 million people a year. Sustainable Development Goal 6 highlights the need to address this issue. Currently, pathogen presence is commonly assessed by culturing thermotolerant coliforms (TTCs) as surrogate indicator organisms, however, this is an intensive and time-consuming laboratory process. Early studies have shown that the use of tryptophan-like fluorescence (TLF) as a real-time indicator of thermotolerant coliforms in the field is promising, through comparison with established laboratory culturing methods.

This study investigates the water quality of drinking water supplies in rural Malawi, Sub-Saharan Africa, at a national scale, employing both TLF and TTC culturing methods. A rigorous hierarchical approach to the sampling (a two stage stratified randomised design) was undertaken, to ensure a representative data set was collected. A total of 183 water sources across five districts were sampled in the dry season. Results from an assessment of the variability in water quality from different sources and associated health risks will be presented.

7 Climate change and anthropogenic activities imprints in groundwater resource transformation of Nairobi aquifer system (Kenya).

Samson Oiro* and Jean-Christophe Comte

University of Aberdeen, School of Geosciences, Scotland, United Kingdom.

* Samson.Oiro@abdn.ac.uk

Combination of historical and current groundwater data including exploitation is crucial to planning of sustainable management of groundwater resources or for considering remedial approaches towards reviving depleting aquifer systems for future generation. Groundwater abstraction from the Nairobi aquifer system (NAS) provides supplementary water supply to bridge the piped water supply gap for over 5 million people. Climate change effects and increasing groundwater demand due to unprecedented population growth in the area is subjecting the aquifer to high risk of depletion in the coming years. Other human activities like infrastructure development, has changed the land cover tremendously. Over the last 40 years, infrastructure development land coverage has increased by over 11% (from 13.5% in 1990 to 24.2% in 2017) thereby sealing the land surface, increasing flooding during heavy rains, and potentially modifying groundwater recharge. NAS climatic data shows increasing trend for both rainfall and temperature at an average of 4.25 mm and 0.3 ℃ per decade respectively, and a decreasing evaporation at the rate of 6.5 mm/decade. Groundwater abstraction in the area has increased 10 times over the last 5 years from 10,000 m^3/day in 2011/2012 financial year to over 100,000 m^3/day in 2016/2017, as per abstraction records by the Water Resources Authority of Kenya (WRA). Analysis of dynamic water rest levels (DWRL) in NAS reveals a declining trend at the rate of 6.6 m/decade in average. It is obvious that human activities and climate change if not properly managed and considered in groundwater management then, the entire ecosystem is at risk. All historical and current data will be incorporated in groundwater numerical model applied to inform better management policies in different tested scenarios.

8 Hand pump functionality: drilling down through the numbers

Alan MacDonald* and Helen Bonsor

British Geological Survey, The Lyell Centre, Edinburgh EH14 4AP

* amm@bgs.ac.uk

Progress towards achieving the goal of universal access to clean water has been impressive, with the Millennium development Goals for access to clean water being met in most countries. However, these coverage figures may hide a more complicated picture where hand pumps (relied on by the rural and peri-urban poor for improved water sources) are not fully functional for part of the year. We report the results of a research project in Ethiopia, Malawi and Uganda where we have used careful survey and sampling design to accurately estimate the percentage of water points fully functional. We explore the use of

different definitions of functionality: from a simple binary measure of working at the time of the survey, to a more comprehensive assessment of yield and reliability. We find that by using a randomised sampling approach and a more nuanced definition of functionality, rates in each country drop to below 50%. By adding in water quality indicators, rates fall even further. We argue that to improve reliable access to safe water for the rural poor a more systematic and robust measure of functionality most be used to track progress than coverage figures. This can bring into focus problems of poor functionality to enable the underlying reasons to be addressed.

9 The resilience of shallow groundwater resources in Dangila woreda, northwest Ethiopia, to climate variability, increasing abstraction and land use change

David Walker[a]*, Geoff Parkin[a], John Gowing[b], Nathan Forsythe[a] and Alemseged Tamiru Haile[c]

[a] School of Engineering, Newcastle University, UK
[b] School of Agriculture, Food and Rural Development, Newcastle University, UK
[c] International Water Management Institute (IWMI), Addis Ababa, Ethiopia

* d.w.walker1@newcastle.ac.uk

Productive use of groundwater resources in sub-Saharan Africa currently remains low but is expected to increase significantly in the near future, potentially providing widespread poverty reduction. The accessibility of shallow groundwater resources means they are most likely to be used by poorer communities, but they are also the most vulnerable to over-exploitation and climatic variability. Recent studies based on climate modelling and remote sensing data have demonstrated the abundance of groundwater resources at a broad scale, however, there is a scarcity of data to support its local management to reduce vulnerability.

Field investigations in Dangila, northwest Ethiopia, between 2014 and 2017 enabled development of physically based spatially distributed models using SHETRAN that were used to evaluate resilience of shallow groundwater resources for a range of climate, land use and abstraction scenarios.

The simulations indicate an aquifer with varying potential productivity and vulnerability primarily dependent upon topography. Groundwater potential maps were produced that were validated by ground trothing. We show that groundwater storage and rates of groundwater recession are key factors in determining the potential to have a second growing season in many areas following the main rainfed growing season. Likely land use change and abstraction for smallholder irrigation does not have a significant impact on the shallow groundwater nor surface water resources. These results are valuable for government ministries and NGOs at national and district level, and by local communities, to identify where interventions could have the greatest positive impacts.

10 Understanding risks and resilience of private boreholes in Lagos, Nigeria

K. Upton[1], A. Healy[2*], S. Allan[3], G. Bristow[2], Y. Bukar[4], S. Capstick[5], K. Danert[6], I. Goni[7], A. MacDonald[1], M. Tijani[8], S. Theis[6], L. Whitmarsh[5]

[1]British Geological Survey, Lyell Centre, Edinburgh, UK
[2]School of Geography and Planning, Cardiff University, UK
[3]School of Journalism, Media and Cultural Studies, Cardiff University, UK
[4]School of Geography, University of Maiduguri, Nigeria
[5]School of Psychology, Cardiff University, UK
[6]Skat Consulting, Switzerland
[7]Department of Geology, University of Maiduguri, Nigeria
[8]Department of Geology, University of Ibadan, Nigeria

* Healya2@cardiff.ac.uk

Water security is one of the most pressing risks facing the world. Even as we move closer to meeting the Sustainable Development Goal of securing access to water for all, rising populations, ecosystem pressures, and changes in climate are heightening levels of insecurity. In urban areas, rapidly growing population coupled with rising incomes, falling costs, and often an absent or unreliable public water supply, mean that increasing numbers of households are choosing to install private boreholes to meet their domestic water needs. This trend is particularly prevalent in emerging global mega-cities such as Lagos, Nigeria. Through a series of internet, household, and water point surveys, this multidisciplinary study begins to address the question: does the proliferation of private boreholes strengthen or weaken the resilience of Lagos and its residents to future environmental shocks?

The research shows that 68% of those surveyed make use of private boreholes on a daily basis, either as their primary water source or used conjunctively with other sources. Attitudes to groundwater are overwhelmingly positive, with a majority considering this a reliable source in terms of quality and quantity, and agreeing that access to a private borehole increases households' water security, helping families to cope with possible water shortages in future. Water quality analyses show that individual's perceptions do not always reflect reality – 10% and 25% of boreholes were found to have unsafe concentrations of E. coli and iron, respectively. The majority of borehole owners perceive no risks associated with long-term groundwater availability, with 89% agreeing that water is abundant and 86% holding the view that borehole owners should be able to abstract as much water as they like.

The collective enthusiasm for unlimited and expanding groundwater extraction in the city of Lagos increases individual resilience to water shortage in the present. However, coupled with a demonstrated lack of groundwater governance and regulation, this may reach a tipping point where vulnerability is transferred to the wider community or to the future. Understanding the role of agency and communicating the potential risks associated with uncontrolled groundwater development, across a range of actors and agencies, may be critical to avoid future conflict between individual and societal resilience to environmental shocks.

11 Groundwater and Poverty: Evidence from Coastal Kenya

Jacob Katuva*, Johanna Koehler, Patrick Thomson, Tim Foster and Rob Hope

University of Oxford

* jacob.katuva@spc.ox.ac.uk

Groundwater is an increasingly important resource for economic growth, food production, drinking water security, ecosystem services and poverty reduction in sub-Saharan Africa. Understanding the links between groundwater and poverty will therefore improve efforts geared towards unlocking the potential of groundwater for poverty reduction. This work aims to provide evidence of the existing links between groundwater and poverty in sub-Saharan Africa using welfare metrics versus productive uses of water, groundwater table depth, drinking water services (i.e., affordability, reliability, safety) and groundwater dependency.

12 What is a smart handpump?

Patrick Thomson*, Rob Hope, David Clifton, Achut Manandhar, Heloise Greeff and Farah Colchester

University of Oxford

* patrick.thomson@ouce.ox.ac.uk

Smart Handpumps are applying the latest scientific advances to tackle the enduring problem of delivering reliable drinking water supplies in Africa and Asia. Developed by researchers from the University of Oxford's School of Geography and the Environment and the Department of Engineering Science, the pump is 'smart' because it houses a simple and inexpensive transmitter in the handle so usage and groundwater levels can be monitored remotely. In partnership with our funders, UNICEF, government, enterprise and local communities, we aim to improve drinking water security for millions of poor people.

13 Mulanje Mission Hospital, Malawi, Water Supply Resilience. To Drill, or Not To Drill: That is the question

Padraig Kelly

Mott MacDonald

Padraig.Kelly@mottmac.com

Mulanje Mission Hospital (MMH) in Malawi is currently supplied water by one groundwater and one surface water reservoir. During the dry season, the surface water reservoir is often dry and the staff housing and trainee hostels go without water. MMH want to increase the efficiency of the current supply or drill new boreholes to supply into the surface water reservoir and to meet the future demand predictions.

There are two existing boreholes at MMH which supply the groundwater reservoir. A desk study was carried out and indicated the Mulanje district is underlain by rocks of the deeply weathered Basement Complex. Boreholes in this weathered, saprolitic material typically yield 0.3 to 0.5 l/s.

BH1 and BH2 have an average discharge of 0.6 – 0.8 l/s and 2.0 l/s. A BH2 pumping test was carried out and indicated a transmissivity of 30 m^2/d. This is reasonably high for the area, and the borehole is quite productive for this aquifer. The condition of the borehole headworks, pipelines and the existing reservoirs were also investigated.

MMH were presented with several options, one of which included a drilling location for new boreholes to produce an extra 1.5 l/s to accommodate demand for the next 10 years.

14 Determining the Hydraulic Behaviour of a Greenschist Metasediment Aquifer, Malaysia

Rachael Fletcher

University of Birmingham. Winner of the **IAH John Day Bursary 2017**

fletch.rachael@gmail.com

The growth of industry in Shah Alam, Malaysia over the last decade has led to an increase in groundwater use. The greenschist metasediment aquifer underlying Shah Alam displays several different types of aquifer response. A mixture of standard and derivative analysis has been carried out on short-term constant rate pumping test data for 40 industrial wells in the Shah Alam area. The results of this, along with analysis and numerical modelling of data collected on the UKM campus, show that one of the major groups of aquifer response fits closely to the Theis model of an infinite two-dimensional confined aquifer. Another major group is likely due to a leaky aquifer system in between the fractured shale and weathered sandstone of the Kenny Hill Formation.