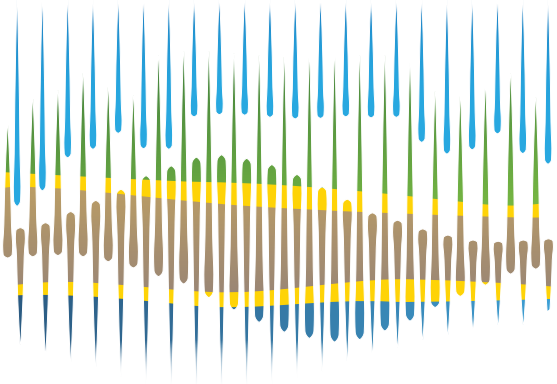
IAH 50th CONGRESS

CAPE TOWN | SOUTH AFRICA



18-22 SEPTEMBER 2023

The International Association of Hydrogeologists

Programme *and* Oral Abstracts

Click on any title in the programme
to be taken to it's abstract

IAH 2023 CONGRESS PROGRAMME – 18 to 22 SEPTEMBER 2023

MONDAY 18 September 2023	
08:00 – 17:00	Field Excursions
TUESDAY 19 September 2023	
Venue 1	**Opening Session** **K Pietersen, Programme Director**
08:00 – 17:00	Digital Posters can be viewed at the two poster kiosks in the Networking Venue in Ballroom West and can also be viewed by downloading the QR code in the venue. (Tuesday to Friday)
09:00-09:30	**Welcome to IAH 2023** **J Conrad** (IAH-SA) and **F Fourie** (GWD) **D Kreamer** (IAH President) *Opening address*
09:30-09:45	**Z Badroodien**, Mayoral Committee Member for Water, City of Cape Town, Welcome to Cape Town
09:45-10:00	**Honourable S Mchunu, Minister of Water and Sanitation:** *Official Opening of the IAH Conference*
10:00	Dignitaries depart **J Conrad,** Housekeeping notes
10:15-10:45	**Keynote: W Timms,** Deakin University Australia: *Prioritising data needs for underground projects that drawdown groundwater or drawdown carbon*
10:45-11:15	**Keynote: S Kebede Gurmessa**, University of KwaZulu Natal and IAH Vice President for Sub-Saharan Africa: *Highlights on the hydrogeology of African dryland environments.*
11:15-11:40	**COMFORT BREAK**
Venue 1	**SKYTEM Session** **The connectedness of groundwater and planetary sciences** **A Allwright, Session Chair**
11:40-11:45	**SKYTEM Presentation**
11:45-12:00	D Hohne., **S Esterhuyse***: A conceptual model for methane occurrences in the Western Karoo as part of a geochemical baseline for shale gas development.*

12:00-12:15	**L Ojeda**., Iñaki Vadillo., Pablo Jiménez-Gavilán., José Benavente., Antonio Fermín Castro-Gámez: *Platinum-Group-Elements and Total Organic Carbon in hyper alkaline springs at the Ronda peridotites (Malaga, Spain) as proxies of the origin of dissolved methane gas.*
12:15-12:30	**E Gustavo**., A Bittner: *Baseline concentrations of radionuclides in groundwater of the Namibian Uranium Province, Namib Desert, western Namibia*
12:30-12:45	**Y Xie**., C Wang: *Groundwater flow paths dictate terrestrial carbon inputs into a groundwater-dominated stream*.
12:45-13:00	**H Mbah**: *Protecting Groundwater Resources in an Era of Geological Carbon Sequestration: A Fractional Stochastic Model To Predict Pressure Buildup Due to CO_2 Injection into a Saline Aquifer.*
Venue 2	**BIOGRIP Session** **Catchment scale integrated surface water and groundwater studies** **L Boumaiza, Session Chair**
11:40-11:45	**BIOGRIP Presentation**
11:45-12:00	**R Diamond., C van Staden, M Dippenaar**: *Tracing mine water flows in a dolomite quarry in South Africa, using hydrochemistry and stable isotopes*
12:00-12:15	**A Welham**., R Chow., J van Rooyen., A Watson: *Identifying water sources of Verlorenvlei using stable isotopes and hydrochemistry*.
12:15-12:30	**B Baud**., P Lachassagne., A Fadillah., Heru Hendrayana., Nathalie Dorfliger: *Aquifers recharge in volcanic-arc area, stable isotopes insights to emphasize a multi-scale approach on a local hydrogeological conceptual model elaboration.*
12:30-12:45	**J van Rooyen**., A Watson., Jodie Miller: *Stable and Radiogenic isotopes in southern Mozambique: a window into groundwater recharge, mixing and vulnerability*
12:45-13:00	**L Ligavha-Mbelengwa**., G Madzivire., M Gomo: *Vulnerability of South African water resources to emerging organic contaminants: a case study of the Witwatersrand Goldfields, Eastern Basin*
Venue 3	**Scale aspects of groundwater flow and transport systems** **J Hamutoko, Session Chair**

11:45-12:00	**D Mudimbu**., B Brauns., K Banda., D Lapworth., A MacDonald, W Namaona., R Owen., M Sinda: *Groundwater recharge in sub-humid drylands under different agricultural systems*
12:00-12:15	**E Davies**., R Chow., S Furihmann., C Stamm: *Using passive sampling to identify trends in aquatic pesticide pollution in the Western Cape, South Africa.*
12:15-12:30	**F Beetle-Moorcroft**: *Per and Polyfluoroalkyl Substances (PFAS) Groundwater Toolkit*
12:30-12:45	**L Lalumbe**., F Ramusiya., P Fuku., T Kanyerere., Z Maswuma: *Characterisation of Groundwater Quality Monitoring Objectives and Background Values: Case Study of the Soutpansberg Region, South Africa*.
12:45-13:00	M Etuk., **V Re**., S Viaroli., I Ogbonnaya*: Nitrate vulnerability assessment in the fast-growing African district of Abuja Federal Capital Territory (Nigeria)*
Venue 4	**Council for Geoscience Session** **Critical zone sciences – a multidisciplinary, cross-scale science** **L Nhleko, Session Chair**
11:40-11:45	**Council for Geoscience Presentation**
11:45-12:00	**C Chamathong**., T Nettasana., M Hengsuwan., P Kullaboot., J Park., K Kim: *Application of Nanofiltration Membrane for Removal of VOCs and Heavy Metals in Groundwater, Ratchaburi, Thailand*
12:00-12:15	**J Loock**: *Maximising groundwater value through innovation & technology - the power of membranes*
12:15-12:30	**K Reynolds-Clausen**: *The use of Coal Combustion Residues for the stabilisation of mines and the treatment of mine drainage.*
12:30-12:45	**L Mokhahlane**: Groundwater trend analysis at an active underground coal gasification plant
12:45-13:00	**M Hengsuwan**: *In-situ Remediation of Contaminated Groundwater Using Permeable Reactive Barrier at the 16th Lum Nam Jone Reservoir, Chachoengsao, Thailand.*

Venue 5	**Special session: The future of groundwater resources research for Africa** **Convenors: UNESCO/IAH** **K Pietersen, Session Chair**
11:45-13:00	**A Makarigakos**: *The latest developments and messages from the Global perspective (UN-Water Groundwater Summit, UN-Water Conference).* **Y Xu**: Groundwater Resources in Africa Keynote speakers: **D Kreamer:** IAH**., D Mochotlhi:** Department of Water and Sanitation, South Africa**., J Sauramba:** SADC, GMI Panel discussion: • **S Kebede:** Centre for Water Resources Research, University of KwaZulu Natal**, S**outh Africa. **H Amwele:** Department of Agriculture and Natural Resources Sciences, Namibia University of Science and Technology, Namibia., **S Faye:** Faculty of Sciences and Techniques, University Cheikh Anta Diop, Senegal., **F Ramusiya:** Department of Water and Sanitation, South Africa., **M Meck:** Department of Geology, University of Zimbabwe, Zimbabwe. Young Expert Panel discussion: • **L Wedze**: Water and Sanitation Engineer at RHEC-SARL, Cameroon. **D Liu**: Youth League President of China Africa Water Association, Wuhan University, China. **J Rugendo**: University of Nairobi, Kenya. **G Mulokoshi:** Founding member of the UNESCO., Groundwater Youth Network, Ministry of Agriculture, Water and Land Reform, Namibia., **O Kgomongwe**: Department of Water and Sanitation, South Africa Audience discussions
13:00 – 14:15	**LUNCH**
Venue 1	**The connectedness of groundwater and planetary sciences** **K Banda, Session Chair**
14:15-14:30	**A Allwright**., F de Lange., R Lubbe., L Mbonambi., K Vivier., K Witthuser., S Webb., L Ashwal., F Roelofse., D. Khoza., R Trumbull: *Research-based exploration of deep groundwater within the eastern limb of the Bushveld Complex*
14:30-14:45	**L Towers**., D Blake., D McGibbon*: Groundwater resources of the Danakil Depression – hydrogeology in the hottest place on Earth*

14:45-15:00	**S Barbieri**: M. Antelmi., L Alberti: *New challenges for low-enthalpy geothermal resource management at the urban scale*
15:00-15:15	**S Meekes**: *Monitoring a deep fresh-saline water interface using repeat Vertical Electrical Soundings measurements*
15:15-15:30	**E Kayukova**: *Peculiarities of the chemical composition of the Ordovician aquifer as a source of potable water supply (St. Petersburg, Russia)*
Venue 2	**Catchment scale integrated surface water and groundwater studies** **Y van Wyk, Session Chair**
14:15-14:30	V Lorenzi., A Lacchini., M Manetta., **M Petitta**: *Distributed recharge in karst-fractured carbonate aquifers: insights from the KARMA EU project for the groundwater resource management of Gran Sasso (Central Italy)*
14:30-14:45	**K Banda**., M Mataa., M Chomba., I Nyambe: *Regional-scale identification of recharge or discharge using remote sensing and GIS: Implications towards groundwater-surface water interactions.*
14:45-15:00	**N Tuswa**., T Kanyerere., N Jovanovic., Y Xu: *A Review of potential and actual groundwater recharge: Insights and implications to groundwater use.*
15:00-15:15	**P Finini**., Thokozani Kanyerere, Dominic Mazvimavi: *Assessing the hydrogeology of springs, Heuningnes catchment South Africa*
15:15-15:30	V Banda., **T Kanyerere**., H Mengistu: *Assessment of catchment scale groundwater-surface water interaction in a non-perennial river system, Heuningnes catchment, South Africa*
Venue 3	**Scale aspects of groundwater flow and transport systems** **M Dippenaar, Session Chair**
14:15-14:30	**J Podgorski**., O Kracht., L Araguas-Araguas., J Miller., R Straub., R Kipfer., M Berg: *Assessing aquifer vulnerability using tritium and machine learning in Africa's western Sahel*
14:30-14:45	**M Berg**., D Araya., J Podgorski: *Machine learning spatial prediction modelling of groundwater salinity in the Horn of Africa*
14:45-15:00	**N Igwebuike**., S Clarke., T Kanyerere: *Application of machine learning techniques to improve groundwater level predictions and optimization, West Coast, South Africa*

15:00-15:15	**B Hunink**., R Chow., T Wöhling: *Delineating wellhead protection areas and aquifer vulnerability in the Cape Flats, South Africa*

15:15-15:30	M Llamas., J Jiménez-Martínez., P Jiménez-Gavilán., C Corada-Fernández., P Lara-Martín., I Vadillo A., **L Ojeda**: *A mixing analysis to explore the distribution and behaviour of contaminants of emerging concern and regulated organic pollutants in the hydrogeological media. Case study: the endorheic catchment of the Fuente de Piedra Lagoon (Southern Spain)*
Venue 4	**Critical zone sciences – a multidisciplinary, cross-scale science** **P Kenabatho, Session Chair**
14:15-14:30	**L Boumaiza**., J Walter., R Chesnaux., F Zahi., F Huneau., É Garel., R Stotler., G Bordeleau., K Johannesson., Y Vystavna., T Drias., V Re., K Knöller., C Stumpp*: Combined effects of seawater intrusion and nitrate contamination on groundwater quality in the coastal agricultural area of El-Nil River, Algeria.*
14:30-14:45	**S Santoni**., E Garel., M Gillon., M Babic., Jorge Spangenberg., B Bomou., D Sebag., T Adatte., R van Geldern., V Pasqualini., F Huneau: *Isotope geochemistry disentangles interactions between water and carbon cycle in Mediterranean peatland.*
14:45-15:00	**M Guzmán Rojo**., A Nogales., C Hurtado., Z Vargas: *Potential land use changes and wildfires effects over the spatiotemporal distribution of groundwater recharge at a regional scale: RAPReHS indicator accounting for SDG-13 in Bolivia*
15:00-15:15	**M Menichini**., M Burlando., L Franceschi., A Berton., L Costanza., S Trifirò., L Foresi., R Giannecchini., M Doveri: *Hydrological processes and evolution in the critical zone of a small island: the case of Pianosa Island in the Tuscan Archipelago*
15:15-15:30	**K Riemann.,** D Blake: *Water Quality of Cape Town Aquifers – The WWQA African Use Case*

Venue 5	**Special session: Transformational development of groundwater resources: Towards adaptation and resilience** **Session Sponsor and Convenor and Sponsor: Water Research Commission (WRC)** **S Adams., V Molose, Session Chair**
14:15-15:30	Changing local and global change pressures and drivers, such as urbanisation, climate change and weather variability, resource degradation (pollution and overexploitation) and inequality, continually alter the development context of water resources in general and groundwater more specifically. In many places around the world, groundwater governance is weak. This leads to either underutilisation or overexploitation of the resource. This session will introduce and solicit approaches to transform how we value and manage groundwater resources as a sole supply or conjunctive use source to adapt to the vagaries associated with local and global change drivers and build local scale resilience while improving livelihoods.
Venue 6	**Commission/Network Meetings**
14:00-14:45	Commission on Managing Aquifer Recharge - D Benedicto van Dalen
15:00-15:50	IAH Groundwater Quality Commission – D Lapworth
15:30-16:00	**COMFORT BREAK**
Venue 1	**The connectedness of groundwater and planetary sciences** **S Clarke, Session Chair**
16:00-16:15	**Z Gaffoor**., K Pietersen: *The impacts of climate change on groundwater in South Africa*
16:15-16:30	**M Demlie**., S Rajpal., N Govendor., D Naidoo: *Investigation of Seawater Intrusion due to Group-Well-Pumping of a local coastal aquifer in Durban, South Africa.*
16:30-16:45	**A David**., T Abiye: Assessment of groundwater potential of the Kalahari aquifers in Kavango East and West regions, Namibia
16:45-17:00	
Venue 2	**Catchment scale integrated surface water and groundwater studies.** **S Gurmessa, Session Chair**
16:00-16:15	**A Xaza**: *Using derivative plot analysis for diagnosing boundary conditions and flow regimes, Heuningnes, Cape Agulhas, South Africa*

16:15-16:30	**E Zarate** *How alluvial storage controls surface water – groundwater interactions in dryland intermittent and ephemeral streams: A case study from semi-arid Australia*
16:30-16:45	**A Bissoon, E Haricombe**: *Literature review on methodologies used to assess surface water and groundwater interaction*
16:45-17:00	**N Hartog**., Jan van Lopik: *Evaluation of the conditions that impact the spreading, impact and groundwater monitoring for the risk of brine leakage from wells into fresh groundwater aquifers*
Venue 3	**Scale aspects of groundwater flow and transport systems** **O Kgomongwe, Session Chair**
16:00-16:15	T James Oudega., G Lindner., A Scheidl., A Eder., P Strauss., A Blaschke., G Blösch., **M Stevenson**: *Upscaling Preferential Flow in Heterogeneous Porous Media from the Laboratory to the Field*
16:15-16:30	**N Vermaak**., S Fourie., S Esterhuyse., D Hohne: *Recharge under review: Implications for Water Resources Management*
16:30-16:45	**L Landi**., M Rotiroti., M Filippini: *Unfolding the spatial heterogeneity of the natural background level of arsenic in groundwater at the mesoscale using data from sites under remediation*
16:45-17:00	**K Dragon**., R Kruć-Fijałkowska., D Drożdzyński., J Górski: *The pharmaceutical compounds diversity at two river bank filtration sites located in Warta River valley (Poland)*
Venue 4	**Critical zone sciences – a multidisciplinary, cross-scale science** **T Kanyerere, Session Chair**
16:00-16:15	**D Shockley**., D Lapworth: *Microplastics presence in key aquifers used for drinking water supply in England: results of this first systematic study and overview of methodological development*
16:15-16:30	H Okutan., Ç Sağır., E Pekkan., B Kurtulus, M Razack., **P Le Coustumer**: *First results on the transport of polydisperse polyethene microplastics in saturated porous media*
16:30-16:45	**K Novakowski**., L Egan: *Heat and Solute Tracer Experiments in a Discrete Crystalline Rock Fracture*
16:45-17:00	
Venue 5	**Special session: IAH UN-Engagement Working Group** **Convenors: IAH** **I Davey, Session Chair**

16:00-17:00	Working Group Meeting
Venue 6	**Commission/Network Meetings**
16:00-17:00	Socio-Hydrogeology Network - V Re
17:30 – 20:00	**ECHN Welcome Reception –** Ballroom East, CTICC

WEDNESDAY	20 September 2023
08:00 – 17:00 Digital Posters can be viewed at the two poster kiosks in the Networking Venue in Ballroom West and can also be viewed by downloading the QR code in the venue	
Venue 1	**Upscaling/downscaling** **E Lukas, Session Chair**
08:30-08:45	**C Viviers**., M van der Laan., M Dippenaar*: Can open-source remote sensing data be used to accurately downscale groundwater storage estimates?*
08:45-09:00	**T Solovey**., J Śliwińska., A Brzezińska., M Przychodzka., R Janica: *Validation of algorithms for estimating changes in groundwater storage from GRACE gravity satellite data for Poland*
09:00-09:15	**T Casati**., A Navarra., M Filippini., A Gargini: *Groundwater discharge and climate change: The application of RCMs to assess long-term effects of climate change on spring flow along the Apennines*
09:15-09:30	**Z Gaffoor**., K Pietersen., T Kanyerere: *The application of artificial intelligence techniques to support groundwater management in Southern Africa*
09:30-09:45	**A Kovacs**: *A combined stochastic-analytical method for the assessment of climate change impact on spring discharge*
09:45-10:00	**N Vinograd**., A Potapov., Y Mohamed: *Formation of the groundwater chemical composition in the Quaternary aquifer of the coastal valley (North Sinai, Egypt)*
10:00-10:15	**D Benedicto van Dalen**., H van den Berg., A Fall., E Monteiro., J Baptista: *Developing and testing a Groundwater Mapping methodology to increase drilling success rates for sustainable drinking water boreholes in African Arid and Semi-Arid Lands – the case study of Cunene Province, Angola*
10:15-10:30	**P Fuku**: *Understanding the pattern of spatial and temporal variations of groundwater levels using long-term monitoring data*.
Venue 2	**Catchment scale integrated surface water and groundwater studies.** **J van Rooyen, Session Chair**
08:30-08:45	**K Mokoena**: *Mapping Groundwater Vulnerability to Drought*.
08:45-09:00	**D Lapworth**., *G Krishan., Alan MacDonald., M Rao: Groundwater recharge sources and salinity in Northwest India*

09:00-09:15	**N Mashimbye**: *Groundwater Remediation - Bushveld Igneous Complex - Western Limb, North West, RSA*
09:15-09:30	M Sanchez., C ten Velden., F Grez., B Becker., H van Duijne., **D Hendriks**: *Integrated and conjunctive Reservoir and Aquifer Management to improve water security in the Elqui Basin, Chile*
09:30-09:45	**T Kruijssen**., M Wit., M van der Ploeg., B van Breukelen., | Victor Bense: *Hydrogeological characterization of a small island catchment by combining literature and field data*
09:45-10:00	D Mazvimavi., K Pietersen., G Mundondwa., **K Mpakaira**., J Sauramba: *Investigating groundwater-surface water interaction processes in the Pungwe River Basin shared between Mozambique and Zimbabwe.*
10:00-10:15	**M Marweshi**: *Numerical Modelling of Groundwater Flow at Mogalakwena Subcatchment, Limpopo Province: Implication for Sustainability of Groundwater Supply*
10:15-10:30	
Venue 3	**Scale aspects of groundwater flow and transport systems** **F Fourie, Session Chair**
08:30-08:45	**R Lubbe**., F de Lange., J Vivier: *A review of slug tests analysis on South African aquifers in potential yield and transmissivity estimations*
08:45-09:00	**H Williams**: *Defining the Goldilocks Zone for Aquifer Thermal Energy Storage versus Unidirectional Ground Source Heat Pumps using Groundwater Flow and Heat Transport Modelling*
09:00-09:15	**M Gizzi**., A Berta., G Taddia., F Vagnon., S Lo Russo: *Open-loop Groundwater Heat Pumps diffusion in Italian Urban areas: Modelling for the hydrogeological constraints definition*
09:15-09:30	**K de Bruin**., L Towers., D Blake: *Test-pumping derivative analysis to improve conceptual understanding and abstraction yields in a complex fractured aquifer: Steenbras Wellfield (Western Cape, South Africa)*
09:30-09:45	**A Parker**: *Characterisation of the Lower Berg River Aquifer System, Western Cape, South Africa*
09:45-10:00	M Brown., J Kennel., J Munn., **C Maldaner**., B Parker: *Well-integrity assessment using fibre optic active distributed temperature sensing*

10:00-10:15	**F Barreto**., J Rusig., L Freitas., C Varnier., A Suhogusoff., R Bertolo., R Hirata: *Hydrostratigraphy of the Bauru and Guarani Aquifer Systems in the central region of the State of São Paulo (Brazil)*
10:15-10:30	
Venue 4	**Critical zone sciences – a multidisciplinary, cross-scale science** **S Matome, Session Chair**
08:30-08:45	**D Blake**., K Riemann*: Development of Table Mountain Group aquifer wellfields and monitoring networks for the City of Cape Town (Western Cape, South Africa)*
08:45-09:00	**P Galvão**., C Schuch., S Pereira., J de Oliveira., P Assunção., T Halihan: *Modeling the Impact of Groundwater Pumping on Karst Geotechnical Risks in Sete Lagoas (MG), Brazil*
09:00-09:15	**A Kuczyńska**: *Sampling procedures for PFAS and pharmaceuticals –Recommendations vs reality*
09:15-09:30	**E Egidio**., D De Luca., M Lasagna: *How groundwater temperature is affected by climate change: a systematic review and meta-analysis*
09:30-09:45	**N Van Putte**., P Meire., P Seuntjens., G Verreydt., S Temmerman: *Improving groundwater dynamics: A key factor for successful tidal marsh restoration.*
09:45-10:00	D Lookin., **C Varnier**., F Barreto., R Bertolo., R Hirata: *Hydrogeochemical and temporal nitrate variation in an unconfined urban aquifer in a tropical area in Brazil*
10:00-10:15	**E Pugliese**., S Rodani., A Dematteis., A Gargini: *Development and calibration of tools for preliminary quantification of the Hydrogeological Interference Risk of tunnels in different geological settings*
10:15-10:30	H Kupfersberger., G Rock., G Klammler., **J Vrzel**: *Coupling saturated and unsaturated groundwater models to represent the effect of intensive anthropogenic activities at the regional scale*

Venue 5	**Special Session: Enhancing inclusive groundwater governance and management in TBAs** **Session Sponsor and Convenor SADC-GMI** **G Mundondwa, Session Chair**
08:30 – 10:30	**J Sauramba**., G Mundondwa., B Gwangwawa., K Pietersen: *Inculcating TBA governance in SADC – The SADC-GMI experience* A Rivera., M Pétré., C Fraser., J PetersenPerlman., R Sanchez., L Movilla., **K Pietersen**: *Why do we need to care about transboundary aquifers, and how do we solve their issues?* **G de los Cobos**: *Radical evolution of the Geneva transboundary aquifer agreement: an example for the sustainability of TBA governance* **B Gwangwawa**., J Sauramba., K Pietersen., G Mundondwa: *The current policy, legal and institutional framework for groundwater governance in SADC* Panel discussion: • **D Mndzebele**., SADC-Water Division., **G de los Cobos**., GESDEC-DT - Canton of Geneva, Switzerland., **B Gwangwawa**., Environmental and Social Management Specialist, SADC-GMI., **J Sauramba**, Executive Director, SADC-GMI Audience discussion
10:30-11:00	**COMFORT BREAK**
Venue 1	**PLENARY PRESENTATIONS** **S Adams, Session Chair**
11:00-11:30	**M Taniguchi**: *Time scale connection of groundwater with adjacent spheres*
11:30-12:00	**C Moeck**., W Berghuijs., E Luijendijk: *Global potential groundwater recharge in response to climate variability and teleconnection*.
12:00-12:30	**J Goldin**: *Keep the flow: Applying a HOPE model*
12:30-13:00	**J King**., D Zamrsky., J Delsman., J Verkaik., M Bierkens., G Oude Essink: *Showcasing a global-scale, 3D coastal groundwater salinity model*
13:00-14:00	**LUNCH**

Venue 1	**The connectedness of groundwater and planetary sciences** **Special Session IAH-SHG: The connectedness of groundwater and human systems** **V Re., M Hammie, Session Chairs**
14:00-14:30	**M Hammie Presentation**
14:30-14:45	**S Bourke**., B Moggridge., K Wallis., D Owen., J Searle., S Bolton., M Currell: *First Nations Communities as Partners in Hydrogeology*
14:45-15:00	**A Healy**., M *Cuthbert: Making the Invisible Visible: Do Aquifers Have Agency?*
15:00-15:15	**V Re**., J Rizzi., C Tuci., C Tringali., E Mendieta., A Marcomini: *Learning from complexity: Multi-stakeholder water resources management in the island of Santa Cruz, Galápagos (Ecuador)*
15:15-15:30	**D Walker**., M Smigaj., K Moreri., T Sithabile., C Pringle., J McCosh., S Mustafa., C Hackney., N Jovanovic., W Otto: *Digging Deeper: Exploring the socio-environmental impacts of sand mining in Southern Africa*
Venue 2	**Catchment scale integrated surface water and groundwater studies** **J Conrad, Session Chair**
14:00-14:15	**B Hansen***: A new Danish groundwater mapping and modelling concept - the key to targeted agricultural N-regulation*
14:15-14:30	**M Rotiroti**., E Sacchi., M Caschetto., C Zanotti., L Fumagalli., T Bonomi: *Basin-scale transfer of nitrate pollution from groundwater to surface water in an intensively irrigated system*
14:30-14:45	**L Smit**: *Groundwater and surface water interdependencies in a water-scarce arid system, Sandveld, South Africa*
14:45-15:00	**J Liu**., P Brunner., T Tokunaga: *Evaluating dry wells for flood management in urban catchments using integrated surface-subsurface flow models*
15:00-15:15	**I Karlović**., T Marković., A Smith., A Kulaš., M Udovič., S Orlić: *Contribution of gravel pit lakes in reducing the groundwater nitrate contamination originating from agricultural land*
15:15-15:30	E Bjerre., K Thage., A Aaes., K Villholth., J Koch., R Scheider., T Sonnenborg., **K Jensen**: *Integrated Modelling of the Hydrological Dynamics of the Semi-arid Hout-Sand Catchment, South Africa*

Venue 3	**Scale aspects of groundwater flow and transport systems** **C Lasher-Scheepers, Session Chair**
14:00-14:15	**S Mofokeng**., M Gomo: *Understanding the influence of Artifacts on the Darcy Velocity Estimations from Point Dilution Tracer Tests.*
14:15-14:30	**B Karthikeyan**., E Lakshmanan., M Schneider: *Groundwater overuse and water quality challenges in a large metropolitan catchment*
14:30-14:45	**S Uugulu**., N Poulton., A Tse., M Harris: *Assessment of hydrochemistry and heavy metal contamination in the groundwater around an abandoned Copper Mine area in Klein Aub, Namibia*
14:45-15:00	**N Van Putte**., P Meire., M Grodzka-Łukaszewska., J November., G Verreydt: *Real-time iFLUX sensors reveal rapidly changing groundwater flow dynamics in wetland ecosystems.*
15:00-15:15	**K Hokanson**., K Devito., C Mendoza: *Variable-scale conceptual framework for shallow groundwater systems in the low-relief, water-limited Canadian Boreal Plains*
15:15-15:30	**C Zou**., S Zou., D Zhud: *Distribution, Formation Conditions and Genesis of High-Quality Groundwater Containing Metasilicate in Zhaojue County, Southwest China*
Venue 4	**Polycentric groundwater governance systems** **H Pienaar, Session Chair**
14:00-14:15	**C Bosman**, G Viljoen: *Some Trans-disciplinary Legal Options to Ensure the Protection of South Africa's Utilisable Groundwater Resources*
14:15-14:30	**P Kenabatho**., T Basamba., B Maheshwari., D Hagare., T Setloboko., O Mampane., N Tafesse., D Moalafhi: *Securing Water Supplies – Participatory Groundwater Monitoring and Management in Botswana and Uganda*
14:30-14:45	**F Ward**: *Ensuring the provision of sustainable water services in water scare humanitarian environments*
14:45-15:00	E Cut., K Ni'matul., B Leimona., R Anggraeni., **N Dorfliger***: How can collective groundwater resource management solutions benefit water governance at various levels? An example in a volcanic watershed in East Java, Indonesia*
15:00-15:15	**C Bosman**: *A non-anthropocentric perspective on groundwater quality and a proposed system for groundwater quality classification and regulation*

15:15-15:30	**C Monokofala:** *Groundwater resource assessment and delineation of resource unit for the Komati catchment within the Inkomati Usuthu Management Catchment area – Mpumalanga Province, South Africa*
Venue 5	**Special Session: Advancing the knowledge of strategic aquifers in SADC** **Session Sponsor and Convenor SADC-GMI** **K Pietersen, Session Chair**
14:00-15:30	J Verkaik., J van Engelen., **G Nijsten**., M Bierkens., G Essink: *Assessing groundwater fluxes of transboundary aquifers, using a high-resolution global groundwater model and implications on transboundary cooperation* **G Mundondwa**, K Pietersen., J Sauramba: Progress in SADC towards advancing our knowledge of strategic aquifers in SADC Panel discussion: ▪ **G Nijsten**., Deltares., **J Manda**., Monitoring & Evaluation Specialist, SADC-GMI Audience discussion
Venue 6	**Commission/Network Meetings**
14:00-14:45	Urban Groundwater Network – N Hartog
14:45-15:30	TBC
15:30-16:00	**COMFORT BREAK**
Venue 1	**The connectedness of groundwater and planetary sciences** **Special Session IAH-SHG: The connectedness of groundwater and human systems** **V Re., M Hammie, Session Chairs**
16:00-16:15	**B Misstear**., G Laurence., M Cora., R Foley: The connectedness of groundwater and human systems: a study of sacred wells in Ireland.
16:15-16:30	**K Hinsby**., H Broers., L Gourcy., P van der Keur: *Open access to digital groundwater and geodata supports the green transition and the spatial planning of competing subsurface uses*
16:30-16:45	**K Riemann**., D Blake: *An Overview of long-term groundwater development and management – 20 years of Hermanus wellfields*

16:45-17:00	**K Robey**., P Bauman., S Edris., L Woods., T Coultish., R Shinduke., C Rouault., A Michel: *A Case Study on Capacity Development in Rural Groundwater Supply in Acholiland, Northern Uganda*

Venue 2	**Catchment scale integrated surface water and groundwater studies** **R Diamond, Session Chair**
16:00-16:15	**A Ross**: *Risks related to groundwater resources in the Murray-Darling Basin, Australia*
16:15-16:30	**D Blake**., P Lee., G Bluff: *Celebrating hydro-geoheritage – the Table Mountain Dams Trail and Hermanus Water Walk (Western Cape, South Africa)*
16:30-16:45	**M Maseko**., S Kebede Gurmessa., B Kelbe., S Janse van Rensburg., M Toucher: *Dynamic groundwater modelling of Lake Sibaya*
16:45-17:00	
Venue 3	**Scale aspects of groundwater flow and transport systems** **N Vermaak, Session Chair**
16:00-16:15	**S Stevenazzi**., K Voudouris., D Ducci*: Application of multivariate statistical analysis as a support for the delineation of groundwater bodies: a case study in coastal plain areas of Campania Region (Southern Italy)*
16:15-16:30	D Pacios., I Coleto., P Verzier., V Gómez-Escalonilla., **P Martínez-Santos**: *Machine learning as a tool to improve groundwater monitoring networks*
16:30-16:45	**T Sarris**., A Kenny., D Scott: *Risk-corrected contaminant detection probability of monitoring well networks for flow towards pumping wells in heterogeneous aquifers*
16:45-17:00	**Y Shi**: *Analysis of Heavy Metal Sources in Groundwater and Assessment of Health Risks: An Example from the Southwest Sub-basin of the Shiqi River*
Venue 4	**Polycentric groundwater governance systems** **F Ramusiya, Session Chair**
16:00-16:15	**A Tomlinson**: *Development of multi-level groundwater governance systems and groundwater capacity development to support local municipalities in the Northern Cape Region*
16:15-16:30	K Pietersen., **J Strömgren**., M Storie., L Nzeyimana., L Itimu., T Lilja: *Understanding informal institutions' role in groundwater management – Lessons from borderland communities*

16:30-16:45	**P van der Keur**: *Development of United Nations Framework Classification for Resources (UNFC) for Groundwater Resources Management*
16:45-17:00	

Venue 5	**Special Session: Sustaining Local-scale Resilient Hubs Using Groundwater Session Sponsor and Convenor SADC-GMI** **J Sauramba, Session Chair**
16:00-17:00	**K Mulenga**., J Sauramba., G Mundondwa., B Gwangwawa: *The SADC-GMI approach to building resilient hubs.* **B Gwangwawa**., J Sauramba., K Mulenga., G Mundondwa: *Environmental and social safeguards for ensuring gender equality and social inclusion*. Audience discussion
Venue 6	**Commission/Network Meetings**
16:00-17:00	TBC
Venue 1.5	**Commission/Network Meetings**
16:00-17:00	W&C Europe Region meeting -M Abrunhosa
17:00-18:00	**IAH AGM – Venue 1**

THURSDAY	21 September 2023
08:00 – 17:00 Digital Posters can be viewed at the two poster kiosks in the Networking Venue in Ballroom West and can also be viewed by downloading the QR code in the venue	
Venue 1	**Local-scale, pore-scale, and discrete scale** **K Riemann, Session Chair**
08:30-08:45	**M Gomo**: *Experience with the electrical potential difference-audio magnetotelluric (EPD-AMT) Groundwater Detector geophysical groundwater exploration*
08:45-09:00	**Z Rademan**: *Robust Hydrogeological Conceptual Models Through Interdisciplinary Characterisation – A Case Study*
09:00-09:15	**A Lukas**., F de Lange., A Allwright: *Machine learning applied to pumping test analysis*
09:15-09:30	**M Dippenaar**: *The complexity and importance of the intermediate vadose zone - Local-scale, Pore-scale, and Discrete Scale*
09:30-09:45	**W Timms**: *Micro pore-pressure sensor (MEMs) and analysis technologies – towards a future of multi-scale groundwater monitoring*
09:45-10:00	**A Gargini**., E Pugliese., M Filippini., G Bolognesi., C Giuliani: *Tracing an arenitic aquifer by DNA-labelled nano particles*
10:00-10:15	**Y van Wyk**: *Combined Use of Environmental and Artificial Tracers to Characterise the Vadose Zone*
10:15-10:30	**M Touchahi**., S Blanks., P Tadich., W Timms: *MEMS Technology for Groundwater Monitoring*
Venue 2	**Catchment scale integrated surface water and groundwater studies.** **B Misstear, Session Chair**
08:30-08:45	**A Fadillah**., R Lubis., N Dörfliger., A Muhammad: *Water impact assessment of water stewardship activities at catchment scale: the case of the Lido Catchment in West Java, Indonesia*
08:45-09:00	**J Conrad**: *Findings from nearly three decades of groundwater monitoring in an area of intensive agriculture: Sandveld, West Coast, South Africa.*
09:00-09:15	**A MacDonald**., D MacAllister., G Krishan., M Basharat., D Lapworth., M Arran: *Long-term evolution of groundwater/surface water interactions in the Indus and Upper Ganges*

09:15-09:30	**L Franceschi**., M Menichini., B Raco., M Doveri: *Data-Driven approach to groundwater level prediction for improving water resource management: the Brenta aquifer system case study (Veneto, Italy)*
09:30-09:45	**A Umunezero***: Application of the multi-method approach to assess river-aquifer interaction in Upper Berg catchment, Western Cape, South Africa*
09:45-10:00	**J Bernasconi**., **T LaVanchy**., J Adamson: *Hydrogeological assessment for sourcing regionally significant freshwater supplies in southern Malawi*
10:00-10:15	J Nicolas., **A Gutierrez**., B Mougin., V Bault., C Lasher-Scheepers., L Fisher Jeffes., P Msimango: *From monitoring network to near real-time groundwater forecast. A case study in Cape Town Table Mountain Aquifer, South Africa.*
10:15-10:30	**N Vermaak**., P Oberholster., T Mathivha., S Mapapu., N Memela., S Fourie., A Magingi: *Groundwater Dependent Ecosystems or wetland dependent groundwater systems: A case study*
Venue 3	**GEOROC Session** **Scale aspects of groundwater flow and transport systems** **T Kanyerere, Session Chair**
08:25-08:30	**GEOROC presentation**
08:30-08:45	**A Dassargues**: *Groundwater porosities and effective porosities: definitions, physical relevance, and scale issues*
08:45-09:00	**Y Lévesque**., J Walter., R Chesnaux: *Geophysics-estimated groundwater levels to assess the accuracy of a numerical flow model*
09:00-09:15	**V Hunyek**., J Phetheet., J Yanawongsa., O Occarach: *Integrated assessment of groundwater potential zones for deep groundwater exploration in hard rock aquifers using GIS and geophysical techniques: A case study of Huai Krachao, Kanchanaburi, western Thailand*
09:15-09:30	**Y Adeotan**., M Koita., J Vouillamoz., F Lawson: Determination of the best hydrogeological target for improving the success rate and productivity of boreholes in basement rocks.
09:30-09:45	**D Sarma**., G Symons: *Role of regional scale dykes in the flow of groundwater in the Otavi Mountainland karst aquifers*
09:45-10:00	**Y Li**: *Groundwater circulation and hydrogeochemical evolution in the coastal zone of Xiamen, southeast China*

10:00-10:15	**E Kaminsky**., C Englisch., C Griebler., C Steiner., G Götzl., C Stumpp: *The impact of groundwater temperature on water quality in the urban aquifer of the city of Vienna*
10:15-10:30	**M Sinreich**: *Multiple-tool approach of combining microbial markers with artificial and natural tracers to specify the origin of faecal contamination on karst groundwater catchment scale*
Venue 4	**Special Session: Managed Aquifer Recharge** **Session Sponsor: GEOSS** **D Benedicto van Dalen., K Pietersen Chairperson**
08:25-08:30	**GEOSS Presentation**
08:30-08:45	**D Hohne**., N Vermaak., F Fourie., S Esterhuyse: *Mitigating climate change with managed aquifer recharge: 5 Case Studies*
08:45-09:00	**J Strömgren**., N Kellgren., P Johansson., K Gaboiphiwe: Managed *Aquifer Recharge as a strategy for increased water supply security in Eastern Botswana*
09:00-09:15	**H van den Berg**., A Al-Maktoumi., S de Silva., L Mammeri., M Scharnke., K Radmann., A Al-Dhahli: *Aquifer storage and recovery (ASR) applications to enhance drinking water supply security in the Sultanate of Oman*
09:15-09:30	**N Hartog**., G Schout., Thomas Sweijen: *The impact of storage and hydrogeological conditions on the design and recovery performance of small-scale urban ASR systems*
09:30-09:45	**Q Hao.**, Y Zhu., Y Li: E*valuation of the impact of artificial recharge of groundwater by river replenishment in the North China Plain using a numerical model*
09:45-10:00	**A Ross**: *Benefits and costs of managed aquifer recharge: An integrated water governance solution*
10:15-10:30	**A Lindhe., L Rosén:** *Assessment of Water Supply Security and Sustainability of Managed Aquifer Recharge in Botswana*

Venue 5	**Special session: Near real-time Groundwater Level Forecasting** Session sponsor and convenor – BRGM **A Gutierrez, Session Chair**
08:30-09:45	**A Gutierrez*:*** *Workshop introduction* **J Nicolas:** *Introduction to Groundwater Monitoring* • What is quantitative groundwater monitoring, and why is it important for resource management? • What methods are used for monitoring: frequency, *techniques, and equipment**?*** ***J Nicolas:*** *Groundwater data management and valorisation* • Collection, validation and qualification, interoperability; • Banking and dissemination of data and associated delays; • Valuation: current (SPI) and forecasting analytical tools. **B Mougin*:*** *Groundwater Level forecasting* • Introduction to lumped hydrological modelling. Presentation of the GARDENIA©brgm software • Data requirements for groundwater global modelling • Interest and principles of short/mid-term groundwater level forecasting • Common challenges and limitations of forecasting models **B Mougin*:*** *Introduction to BRGM's tool for groundwater level forecasting: "MétéEAU Nappes."* • Presentation of the MétéEAU Nappes tool • Case study: MétéEAU Nappes for the Table Mountain Group Aquifer in South Africa • Other case studies *Experience feedback from the City of Cape Town on the MétéEauxNappes tool deployed at CoCT* Audience discussion
Venue 5	**Special session: Education and outreach** Session convenor – IAH
09:45-10:30	Working meeting
10:30-11:00	**COMFORT BREAK**
Venue 1	**KEYNOTE PRESENTATIONS** **K Pietersen, Session Chair**

11:00-11:30	**F Bertone**: *Groundwater governance: making the case and being heard*
11:30-12:00	**V Matta**: *Making Groundwater a National Priority*
12:00-12:30	**G Kode**: *Sustainable establishment of localised groundwater supply systems at critical infrastructure for disaster preparedness*
12:30-13:00	**M Killick**: *Cape Town Water Strategy*
13:00-14:00	**LUNCH**
Venue 1	**Improving shared sustainable use of groundwater resources that cross two or more jurisdictional borders** **J Sauramba, Session Chair**
14:00-14:15	T Solovey., R Janica., V Harasymchuk., H Medvid., L Yanush., **M Przychodzka**: *Transboundary groundwater flows between Poland and Ukraine: The role of joint assessments and international frameworks on water resources management*
14:15-14:30	**B Flem**., L Stalsberg., P Gundersen*: Harmonized groundwater data in International River Basins under the Water Framework Directive (2000/60/EC) – Challenges*
14:30-14:45	M Hunt., D Borozdins., **A Marandi**: *Basin Water Balance modelling with the aim to make transboundary groundwater flow visible*
14:45-15:00	**P Tungkidwanichakul**: *Water allocation and economic analysis for developing groundwater resources*
15:00-15:15	**H Wazaz**., A Micallef., C Bertoni., M Giustiniani., K Schwalenberg., A Thomas., E Quiroga-Jordan., W Hong., D Chiacchieri: *OFF-SOURCE: A network to address the potential use of offshore freshened groundwater as an unconventional source of potable water in coastal cities*.
15:15-15:30	**D MacDonald**: Continental-scale mapping of groundwater yield from basement aquifers in Africa
Venue 2	**Catchment scale integrated surface water and groundwater studies.** **E Masemola, Session Chair**
14:00-14:15	**A Elçi**., C Meisina., C Guardiola-Albert., R Tomas., P Teatini., J Valdés-Abellán., K Shatanawi., T Letterio., A Hakan Ören*: Groundwater Flow Modeling for Investigation of Exploitation Induced Land Subsidence*
14:15-14:30	**L Alberti**., P Mazzon., P Colombo: *Winter irrigation as climate change adaptation strategy in northern Italy*

14:30-14:45	**A Fadillah**., N Dörfliger., B Baud., H Hendrayana., P Lachassagne., H Wibowo., A Muhammad., A Harijoko., A Putra: *Improved hydrogeological conceptual model through additional ERT profiles in medial-distal facies of andesitic volcanic area: Case study of Pandaan, East Java, Indonesia*.
14:45-15:00	**R Aissat**., G Picot-Colbeaux., C Herivaux., M Parmentier., A Manlay., P Audigane., J Vergnes., F Mathurin., J Mossmann: E*xploring the Role of Land Use evolution in Groundwater Modeling for Sustainable Management: A Case Study of the Lille Metropolitan Area*
15:15-15:30	**G Mohale**: *Integrated Modeling to Simulate Groundwater and Surface Water Interaction in the Letaba River Catchment, Limpopo Province, South Africa*
Venue 3	**Scale aspects of groundwater flow and transport systems** **A Johnstone, Session Chair**
14:00-14:15	**A Dassargues**., P Orban: *Thermal energy storage in old flooded mines: how to tackle the hydrogeological issues*
14:15-14:30	**A Johnson**., S Rziki: Mine dewatering case study at a gold mine in Mandiana Region, Eastern Guinea.
14:30-14:45	**S Mahlangu**: *Hydrogeological Conceptual Model of Kinsevere Mine*
14:45-15:00	H Levanon., **A Burg**., I Gavrieli., Y Rosenberg.,. R Gersman., Y Bartov., Y Livshitz., A Starinsky., I Reznik: *Paleo-hydrogeological reconstruction of a complex deep groundwater system in a tectonically active region*
15:00-15:15	**C Rivera Villarreyes**: *A methodology for uncertainty quantification of dewatering volumes under the context of opencast mining*
15:15-15:30	**J Gunnink**, S Meekes: *Electromagnetic measurements in the Netherlands using an All Terrain Vehicle to rapidly characterize groundwater salinity and clay distribution in 3D*
Venue 4	**Special Session: Managed Aquifer Recharge** **D Benedicto van Dalen, J Conrad Chairperson**
14:00-14:15	**T Halihan**., W Andrews: *Electrical Hydrogeology of Managed Aquifer Recharge from Metre to Kilometre Scales*
14:15-14:30	I de Groot-Wallast., I America., **J King**., G Oude Essink., K Raat: *Planning for increased water security and preventing salinisation in coastal areas of the Netherlands: A study on the suitability for managed aquifer recharge and extraction of brackish water, including quantification of potential extractable volumes*.

14:30-14:45	**M Holloway**., P Lourens: *Managed Aquifer Recharge within the Greater Kruger National Park and Implementation of Recharge Scheme*
14:45-15:00	**L Towers**., K Riemann: *The Atlantis Water Resource Management Scheme – Lessons in Resilience*
15:00-15:15	**J van Rooyen**., O Schilling: *Tracer applications in an urban MAR (Rhine) scheme: Identifying the presence of regional groundwater in a complex geological setting*
15:15-15:30	T van Dooren., G Zwolsman., K Raat., **N Hartog**., S Huizer*: Optimizing managed aquifer recharge in coastal dunes by extracting brackish groundwater: results of a field pilot in the Netherlands*
Venue 5	**Special session: Municipal Groundwater Supply** Session Convenor – City of Cape Town **Y Van Wyk, Session Chair**
14:00-15:30	Video Cape Town Water Supply Systems **D Allpass**: Setting the scene **C Lasher-Scheepers**: *Groundwater provisions in the water strategy – making it work.* Panel discussion: Audience discussion:
Venue 6	**Commission/Network Meetings**
14:00-14:45	TBC
14:45-15:30	TBC
15:30-16:00	**COMFORT BREAK**
Venue 1	**Improving shared sustainable use of groundwater resources that cross two or more jurisdictional borders** **D Mndzebele, Session Chair**
16:00-16:15	A Fernald., A Atkins., C Kirkpatrick., C Tang., J Kaminsky., **I Zaslavsky**: *The connectedness of transboundary groundwater researchers: from network analysis to network-building*
16:15-16:30	**S Mustafa**., A Matano., F Franchi., S Tirivarombo., *A Van Loon., J Comte: Enhancing resilience to hydrological extremes in the Limpopo River Basin: a collaborative modelling approach*
16:30-16:45	**H Meaški**., R Biondić., J Loborec., K Leskovar: *How to manage the Plitvice Lakes National Park (Croatia) as part of transboundary groundwater resources?*
16:45-17:00	

Venue 2	**Catchment scale integrated surface water and groundwater studies.** **G Nijsten, Session Chair**
16:00-16:15	**G Picot-Colbeaux**., N Devau., A Manlay., V Debois., P Goderniaux., L Jehanno., B Meire: *Characterization of groundwater dynamics to identify the risks of flooding of the sewerage network of the urban communities of Lens-Liévin (northern France).*
16:15-16:30	**S Musy**., C Friederike., N Teresa., T Yama., S Yuji., S: Oliver *Water resource management in tectonically active volcanic regions: Towards an in-depth understanding of Mt. Fuji's hydrogeology*
16:30-16:45	**M Doveri**., I Baneschi., L Franceschi., M Menichini., A Vergnano., F Pace., G Romano., A Godio., A Santilano., L Capozzoli: *Hydrological processes in the Arctic catchment of Bayelva River (Western Svalbard-Norway)*
16:45-17:00	

Venue 3	**Scale aspects of groundwater flow and transport systems** **K Majola, Session Chair**
16:00-16:15	**S Van den Broeck**., S Six: *Balancing qualitative and quantitative issues of the groundwater extraction at the drinking water production site of Velm (Central Belgium)*
16:15-16:30	**D Di Curzio**., C Ottosen., G Lemaire., M Laureni., P Bjerg., D Weissbrodt., M Broholm., B van Breukelen: *Integrating reductive dehalogenase enzyme production into reactive transport modelling to simulate chloroethene biodegradation in groundwater pollution plumes*
16:30-16:45	**V Dall' Alba**., S Lanini., Y Caballero., P Renard: *The Roussillon coastal aquifer: using multiple-point statistics aSarrisnd multi-model ensemble to characterize geological uncertainty impact on water resources estimation*.
16:45-17:00	**J Labbe**., H Celle., P Nevers., V Klaba., J Devidal., M Clauzet., G Mailhot: *Alluvial aquifer modelling with MODFLOW in a case of a wellfield in a climate change context (Clermont-Ferrand, France).*
Venue 4	**Special Session: Managed Aquifer Recharge** D Benedicto van Dalen, J Conrad Chairperson
16:00-16:15	**Y Ganot**., E Valdman., E Farber., N Amir., Y Amiaz., T Kamai: *Evaluating Karst Drywells for Urban Stormwater Management and Aquifer Recharge*

16:15:16:30	**K Daranond**., J Chimpalee., A Pongsatitpat., P Klahan*: Experiments of the artificial-recharge rate of sand and gravel aquifer through shallow recharge wells in the Chao Phraya River basin region*
16:30-16:45	**L Nhleko**., Z Phikiso., C Musekiwa., R Grow: *Managed aquifer recharge (MAR) suitability mapping Using GIS-MCDA: The South African perspective***.**
16:45-17:00	
Venue 5	**Special session: Young Professionals Programme** **Session convenor – Water Research Commission** **H Cele, Session Chair**
16:00-17:00	The special session provides a space for young hydrogeologists from different parts of South Africa and mostly from historically disadvantaged institutions of higher learning to showcase their work and network with the hydrogeology community of practice. • **Programme Director**, Welcome and Introductions and purpose of the session Programme Director • **S Adams**, Executive Manager, Water Research Commission: Opening remarks and setting the scene - WRC role and direction in building the young hydrology cohort • **T Sawunyama** SAHS President: Opportunities for young hydrogeologists in the sector. A case of Inkomati-Usuthu Catchment Management Agency Dr Session Facilitator: **A Eilers**, Young Water Professionals • **C Viviers,** University of Pretoria: Outlining of challenges and opportunities while studying at university • **O Kgomongwe,** Department of Water and Sanitation: Earlier stages of science career path, how to handle challenges and expectations of the sector from young scientists. **T Shakane**, IUCMA: Experiences and tips to grow and become a seasoned scientist in the water sector **Panellists** - All presenters Facilitated by **A Eilers** **S Adams** and T Samwunyama: Closing remarks and Closure Networking: All
Venue 6	**Commission/Network Meetings**

16:00-17:00	IAH Groundwater and Climate Change Commission - T Stigter
Venue 1.5	**Commission/Network Meetings**
16:00-17:00	IAH BGID Network - A MacDonald
18:30	Delegates must meet at the CTICC for coaches departing promptly at 18:45 to the Gala Dinner.

(We encourage delegates to use the coaches provided by the organizers or to Uber to the restaurant as there is no parking available at the restaurant.)

19:30 Delegates arrive at the Gala Dinner

20:00 Gala Dinner – Welcome

22.30/23:00 First full coach to depart for the CTICC.

FRIDAY	22 September 2023
08:00 – 17:00 Digital Posters can be viewed at the two poster kiosks in the Networking Venue in Ballroom West and can also be viewed by downloading the QR code in the venue	
Venue 1	**Improving shared sustainable use of groundwater resources that cross two or more jurisdictional borders** **D Kreamer, Session Chair**
08:30-08:45	**D Kibirige**: *Pock Marks as a Nature-based solution for enhancing water availability in African marginal drylands?*
08:45-09:00	**A Love**., R Purtschert., Y Xie., D Wohling., S Fulton., J McCallum., M Chmielarski., W Ziang., Z Lu., G Yang., P Shand., W Aeschbach., L Broder., P Mueller., Y Tosaki: *Coupling environmental tracers and modelling and what can they tell us about groundwater sustainability and example from the southwestern Great Artesian Basin (GAB) of Australia*
09:00-09:15	**C Morales**., T Stigter., C Fraser., B van Breukelen., G Jewitt: *Units for joint management of cross-border groundwater impacts in Transboundary Aquifers: an overview of concepts and methodologies*
09:15-09:30	**K Majola**., Y Xu., T Kanyerere*: Groundwater-dependent ecosystems dynamics in transboundary aquifer settings - a case study in the Tuli-Karoo aquifer*
Venue 1	**Scale aspects of groundwater flow and transport systems** **D Barrow, Session Chair**
09:30-09:45	**D McGibbon**., L Towers., K Riemann: *Cape Flats Aquifer Management Scheme – the City of Cape Town's groundwater abstraction and MAR scheme for a resilient future (South Africa)*
09:45-10:00	V Price., **J Dottridge**: *Groundwater models for water resources assessment at regional, local and site scales*
10:00-10:15	**T Sarris**., A Kenny., D Scott., C Moore: *Source protection zone delineation: numerical insights on the effect of heterogeneity*
10:15-10:30	**J Weitz**., N Jovanovic: *Numerical groundwater modelling of the Windhoek Aquifer (Namibia) for wellfield management*
10:30-10:45	**K Gibson**., D McGibbon., T Flügel: *Design and Implementation of Groundwater Protection Schemes in Different Aquifer Settings*

10:45-11:00	**M Mukhawana**: *Review of In-Situ and Remote Sensing-Based Indices and Their Applicability for Integrated Drought Monitoring in South Africa*

Venue 2	**Catchment scale integrated surface water and groundwater studies.** **S Esterhuyse, Session Chair**
08:30-08:45	D Grombache., **V Matta**: *Highly productive geophysical mapping of groundwater systems in water-scare countries*
08:45-09:00	**A Neven**., L Schorpp., J Straubhaar., P Renard: *A stochastic data integration approach to generate geologically consistent hydrogeological models from geophysical and hydrogeological data*
09:00-09:15	B van Wyk., **D Sarma**: *Springs of the Otavi Mountainland. Could they teach us something significant?*
09:15-09:30	**D Benedicto van Dalen**., A Ketema., G Zeleke: *Building evidence through hydrogeological survey and monitoring for the conjunctive development and management of water resources in Kunzila catchment area – Amhara Region, Ethiopia*
09:30-09:45	**G van Dyk**: *Monitor and determine local groundwater impacts from increased mining activities in the Kalahari iron manganese field of the Northern Cape, South Africa*.
09:45-10:00	**F Fourie**: *Using the Groundwater Level Status approach for climate impacts*
10:00-10:15	**P Saveca**., T Stigter., F Fourie., E Lukas: *Groundwater potential and lateral connectivity of the Limpopo sand river system mitigating water scarcity and salinity in semi-arid Mozambique*
10:15-10:30	**N Nungu**: *The National Integrated Water Information System (NIWIS) for geohydrology in South Africa*
10:30-10:45	A Farahmand., M Hussaini., **M Abrunhosa**: *Impact of urbanization on groundwater quantity and quality in Kabul city, Afghanistan*
10:45-11:00	
Venue 3	**Scale aspects of groundwater flow and transport systems** **W Nomquphu, Session Chair**
08:30-08:45	A Brugeron., A Soulignac., **A Gutierrez**., B Swartz: *From the national hydrogeological map to regional ones. How to identify a suitable level of detail to work with? An application in Kunene and Omusati Regions in Northwestern Namibia*

08:45-09:00	**S Lu**., Y Xie., A Love., W Jiang., G Yang., Z Lu: *Use of krypton-81 to constrain the reliability of carbon-14 in estimating groundwater ages*
09:00-09:15	**D Aind**., A Mukherjee: *Hydrostratigraphic controls on groundwater arsenic enrichment in the Brahmaputra river basin aquifers*
09:15-09:30	**L Shen**: *Study on the Relationship between Water Quality and Wetland Plant Community in Huixian Karst Wetland*
09:30-09:45	L Gourcy., **A Gutierrez**., B Swartz., F Soetaert: *What decision-making information can be obtained from chemical data on a large scale? A case study in Kunene and Omusati regions in Namibia*
09:45-10:00	**I Muchingami**., J Hamutoko., T Kanyerere., S Uugulu., J Mutjida: *An assessment of hydrogeophysics application for groundwater resource assessment in Kalahari sands aquifers and crystalline basement aquifers with case studies from Namibia and South Africa.*
10:00-10:15	**N Maluleke**: *Using analytical models to examine groundwater abstraction impacts on surface water levels.*
10:15-10:30	**L Baloyi**., T Kanyerere, M Butler*: Quantification of river-aquifer interactions using multiple measuring methods for improved water abstraction in the Lower Vaal River catchment, South Africa*
10:30-10:45	**A van Niekerk:** *Regional Scale Groundwater Monitoring Status Reporting: A mapping series within the Vanrhynsdorp aquifer system*
10:45-11:00	
Venue 4	**Polycentric groundwater governance systems** **S Gaebee, Session Chair**
08:30-08:45	**G Nijsten**., S Vermooten., J Delsman., P de Louw., J Gunnink., J Buma., J Zaadnoordijk: *Netherlands National Groundwater reserves: 3D mapping and development of management policies as part of a multi-level strategy to secure water supply for disasters and the far future*.
08:45-09:00	**A Taylor**., F Atkins: *Governing groundwater in city regions: Water metabolism and actor networks in the cases of Cape Town and Nelson Mandela Bay*
09:00-09:15	**H Loaiciga**: *Groundwater for people and the environment: A globally threatened resource*
09:15-09:30	**T Halihan**., C Barnes: *Building a Groundwater Educational Pipeline from Elementary to Continuing Education*

09:30-09:45	**B Cencur Curk**., P Banovec., A Papadopoulou., V Kanakoudis., N Guyennon., E Romano: *Management of water-related risks in drinking water supplies*
09:45-10:00	**F de Lange**: *Researching Fracking in the Karoo: Summary of lessons learned*
10:00-10:15	**A Healy**: *The role of groundwater in urban resilience*
10:15-10:30	**I Rodriguez-Levy** ., M Centellas-Levy., W Ferreira., L Rivera-Rodriguez., S Mustafa., C Apaza-Coria., M Soruco., A Amaya., M Huymans: *Alternative approaches for integrated groundwater management in the rural basins of Central Bolivia*
10:30-10:45	
10:45-11:00	
Venue 5	**Special session: Groundwater Project** **Session Chair – J Cherry, K Pietersen: Groundwater Project**
08:30-11:00	**J Cherry**: *Groundwater Project* **K Pietersen**: *Groundwater Governance* Braune E., **S Clarke**: *Managed Aquifer Recharge: Southern Africa* **R Diamond**: *Stable Isotope Hydrology* L van Rooy., **M Dippenaar**: *Hazardous Karst*
11:00-11:30	**COMFORT BREAK**
Venue 1	**Closing session** **Programme Director: A Vicente**
11:30-12:00	Keynote address - Young Water Professional
12:00-12:30	**H Pienaar**: *Circular economy and implications for groundwater*
12:30-13:00	IAH Speaker
13:00-13:15	Water Ceremony and hand over to following conference organisers
13:15-13:30	Vote of thanks and close conference

- **Biographies of the keynote presenters and convenors available at:** https://iah2023.org.za/keynote-presenters/
- **The organizers reserves the right to make changes to the programme without prior notice.**

A conceptual model for methane occurrences in the Western Karoo as part of a geochemical baseline for shale gas development

D Hohne[1]., S Esterhuyse[2]

[1]Department of Water and Sanitation, South Africa; [2]Centre for Environmental Management, University of the Free State, South Africa

Although methane occurrences have been documented in Karoo groundwater in the past, the advent of possible unconventional oil and gas extraction now made it important to determine the type and origin of this methane to assess the possibility of shallow-deep groundwater interaction. During groundwater surveys from 2016-2021, methane was detected at three sites in the Western Karoo: the Soekor sites KL1/65, QU1/65 and an unidentified shallow groundwater borehole (BHA). The Soekor wells were drilled in the 1960-1970s to depths of between 2500-3500 meters in South Africa's search for oil. On the other hand, Borehole BHA was drilled in 1998 and only up to a depth of 298m. This study aimed to determine methane's origin through gas and isotope analyses. To do this, groundwater, rock and soil samples were analysed to determine whether the methane is thermogenic or biogenic and its origin. We determined that methane was both thermogenic and biogenic and probably originated from different layers of the Karoo formations and that mixing occurs between deep and shallow aquifer systems at these Soekor sites. This information was used to develop a final conceptual model of what the Karoo underground system might look like and to make recommendations for establishing a groundwater baseline.

Keywords: Western Karoo, shale gas development, shallow and deep groundwater, thermogenic and biogenic methane; isotopes

Platinum-Group-Elements and Total Organic Carbon in hyperalkaline springs at the Ronda peridotites (Malaga, Spain) as proxies of the origin of dissolved methane gas

L Ojeda[1]., Iñaki Vadillo[1]., Pablo Jiménez-Gavilán[1]., José Benavente[2]., Antonio Fermín Castro-Gámez[1]

[1]Department of Geology, Faculty of Science, University of Malaga, Malaga, Spain; [2]Department of Geodynamics and Water Research Institute, University of Granada, Spain

The serpentinization of ultramafic rocks is a process in which minerals of ferromagnesian nature (e.g., olivine) are transformed into serpentine and produce groundwater with a very high pH. In these settings, CH_4 can be produced by combining H_2 from serpentinization and CO_2 from the atmosphere, soil, carbon-bearing rocks, or mantle, although the microbial generation of CH_4, mediated by methanogens utilizing CO_2, formate and/or acetate can be another source in these aquifers. In this sense, the hydrochemistry of hyperalkaline springs can provide valuable information about gas origin. The Ronda peridotites (Malaga province, Spain) are one of the world's largest outcrops of the subcontinental mantle (~450 km_2). Hyperalkaline springs (pH>10) emerging along faults present a permanent low outflow (<1 L/s), Ca^{2+}- OH^- facies and residence times exceeding 2,000 years. The fluids, poor in Mg^{2+} and rich in K^+, Na^+, Ca^{2+} and Cl^-, also contain significant concentrations of dissolved CH_4 and other hydrocarbons. Water samples have been collected from eight hyperalkaline springs and analyzed for major, minor and trace elements, including Platinum Group Elements (PGE) and Total Organic Carbon (TOC). The most mobile PGEs (Pd and Rh) are present in all the springs, indicating the existence of potential catalysts for the abiotic synthesis of CH_4. High TOC concentrations are observed in some studied springs where previous analyses (i.e., bulk CH_4 isotopes) have indicated a microbial CH_4 origin.

Keywords: Hyperalkaline springs, Methane, Platinum-Group-Elements, Ronda peridotites, Total Organic Carbon

CLICK TO RETURN TO THE PROGRAMME

Baseline concentrations of radionuclides in groundwater of the Namibian Uranium Province, Namib Desert, western Namibia

E Gustavo., A Bittner

SLR Environmental Consulting (Namibia) (Pty) Ltd, Windhoek, Namibia

The Namibian uranium province, located in the Namib Desert, derives its name from the local presence of almost ten uranium tenements. The mines conduct monitoring of natural radionuclide concentrations of Ra_{226}, Ra_{228}, Pb_{210}, U_{234}, U_{238}, Th_{232} and Po_{210} in local aquifers. This data is useful in mine rehabilitation and developing closure criteria, as only radiation doses additional to natural doses are usually considered 'controllable' for radiation protection purposes. An accredited laboratory analyzed the baseline data collected through quarterly groundwater sampling with submersible pumps. The uranium deposits are hosted in Damara age granites or as secondary mineralization in Tertiary calcareous paleochannels. The analysis of the long-term baseline data provides the background radionuclide concentrations of three aquifer types in the province, i.e., the Quaternary saturated alluvium of the Khan and Swakop ephemeral Rivers, the Tertiary paleochannel sediments, and Proterozoic basement aquifers. The ephemeral rivers are important because they supply groundwater downstream of the mines for agricultural use. The analysis demonstrated that the alluvial aquifers have the lowest natural radionuclide content, with the U_{234} concentrations ranging between 0.03 and 3.4 Bq/l, while paleochannel and basement aquifers show intermittent U_{234} concentrations ranging between 0.25 and 5.1 Bq/l. The groundwater in the immediate ore zones shows the highest U_{234} concentrations, ranging between 44.8 and 86.3 Bq/l, exceedingly higher than the WHO standards of 1 Bq/l. This study illuminates that radioactivity is a natural phenomenon and that groundwater baseline data is paramount to groundwater protection.

Keywords: Namib Desert, baseline, groundwater, radionuclides, uranium province

Groundwater flow paths dictate terrestrial carbon inputs into a groundwater-dominated stream

Y Xie., C Wang

Key Laboratory of Surficial Geochemistry, Ministry of Education, School of Earth Sciences and Engineering Nanjing University, Nanjing, China

Groundwater discharge is crucial for transporting terrestrial carbon into streams and rivers, but the effects of groundwater flow paths on terrestrial carbon inputs are poorly understood. Here, we investigated environmental tracers (EC, Cl^-, ^2H, ^{18}O, ^{220}Rn, and ^{222}Rn) and carbon concentrations in riparian groundwater, streambed groundwater, and stream water over six groundwater-stream monitoring sites. Significantly high ^{220}Rn and ^{222}Rn activities in the stream and endmember analysis results of the environmental tracers reveal that vertical groundwater discharge from the streambed (VGD) and lateral groundwater discharge from the riparian zone (LGD) is of equal importance for the stream. We quantified VGD by modelling the detailed ^{222}Rn and Cl^- profiles at the streambed and then combined differential flow gauging to estimate LGD. VGD (2.9 ± 1.4 $m^2 d^{-1}$) prevailed in relatively wide and shallow channels, while LGD (2.6 ± 2.6 $m^2 d^{-1}$) dominated narrow and deep channels. Carbon measurements indicate that LGD had the highest CO_2, CH_4, DIC, and DOC, while VGD had relatively higher CO_2 but lower CH_4, DIC, and DOC than stream water. Our findings suggest that LGD is the primary carbon source for the stream, while VGD mainly dilutes the stream (except CO_2). Finally, we observed that groundwater discharge and temperature overrode metabolism in controlling stream carbon dynamics, implying the importance of groundwater discharge for understanding stream carbon cycling. Overall, this study identified the impacts of groundwater flow paths on carbon exchanges between terrestrial and stream ecosystems.

Keywords: Groundwater discharge; groundwater flowpaths; dissolved carbon; environmental tracers

CLICK TO RETURN TO THE PROGRAMME

Protecting groundwater resources in an era of geological carbon sequestration: A fractional stochastic model to predict pressure buildup due to CO_2 injection into a saline aquifer

H Mbah
Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa

Carbon Capture and Storage (CCS) in deep saline aquifers is a viable option for Green House Gas (GHG) mitigation. However, industrial-scale scenarios may induce large-scale reservoir pressurization and displacement of native fluids. Especially in closed systems, the pressure buildup can quickly elevate beyond the reservoir fracture threshold and potentially fracture/reactivate existing faults on the cap rock. This can create pathways, which could act as conduits for focused leakage of brine and/or CO_2 up-dip and mobilization of trace elements into capture zones of freshwater wells. Careful pressure management can ensure the reservoir's hydraulic integrity. This can theoretically be achieved through simulation with appropriate mathematical tools. This research aims to quantify pressure buildup at a CO_2 injection well by applying fractional derivatives to the pressure diffusivity Differential Equation (PDE). A numerical solution has been developed to (1) predict and assess the consequence of pressure buildup within the storage formation on groundwater flow in shallow aquifers and (2) assess the impact of pressure-mobilized contaminants (CO_2, brine and/or trace elements) on the quality of usable groundwater, if there is a leakage. The efficiency of each derivative is shown to depend on the type of reservoir heterogeneity. The Caputo derivative captured the long tail dependence characteristic of fracture flow, while the ABC derivative was able to model the cross-over from matric into the fracture flow. The numerical tools presented here are useful for successful risk assessments during geo-sequestration in basins with freshwater aquifers.

Keywords: Carbon Capture and Storage (CCS), fractional operator, geological heterogeneity., injectivity, pressure buildup, saline aquifer

Tracing mine water flows in a dolomite quarry, South Africa, using hydrochemistry and stable isotopes

R Diamond[1]., C van Staden[2], M Dippenaar[2]
[1]BIOGRIP, University of Cape Town, Cape Town, South Africa; [2]Department of Engineering Geology and Hydrogeology, University of Pretoria, Pretoria, South Africa

Water resources, including groundwater, are under threat globally from abstraction and pollution, making studies of water flows ever more urgent. South Africa has a growing population, a relatively dry climate and abundant mining activity, all of which increase the importance of water management. Mooiplaas Dolomite Quarry, southeast of Pretoria, has been mining metallurgical grade dolomite since 1969 and is located in the productive karst aquifers of the Malmani Subgroup, Transvaal Supergroup. The site was investigated by sampling precipitation, surface water, groundwater and mine water for hydrochemical and stable isotope analysis from 2011 to 2017, totalling over 400 samples. Nitrate levels in groundwater and mine water were marginally above drinking water limits from explosives residues, and ammonia in the nearby Hennops River was unacceptably high due to municipal sewage outfalls, but otherwise, water quality was very good. Alkalinity from rock weathering, aided by the crushing of dolomite, was the main control on water chemistry. Combined analysis of dissolved matter (TDS, nitrate, Mg, etc.) suggested that the dewatering of the mine and resultant recharge from slime dams caused an aerated zone of groundwater, which mixed with regional groundwater flowing beneath the site. Stable isotopes, with an evaporated signature from mine open water bodies, also showed how mine operations cause recharge to groundwater and subsequent seepage back into the pit lakes. The mine appears not to contaminate the regional groundwater. However, mine designs should avoid situations where process water flows via groundwater back into pits, causing excessive dewatering costs.

Keywords: dewatering, hydrochemistry, karst, mining, stable isotopes

CLICK TO RETURN TO THE PROGRAMME

Identifying water sources of Verlorenvlei using stable isotopes and hydrochemistry

A Welham[1]., R Chow[1]., J van Rooyen[1,2]., A Watson[3]

[1]Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa; [2]Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland; [3]School for Climate Studies, Stellenbosch University, Stellenbosch, South Africa

Natural processes (e.g., El Nio) and anthropogenic activities (e.g., land-use modification and groundwater abstraction) drive local and global hydrological changes. Consequently, these changes threaten the role of wetlands in the hydrological and ecological functioning of a catchment. Verlorenvlei is a vulnerable RAMSAR-listed estuarine lake located on the west coast of South Africa in Elands Bay. Since the 2015-2018 Western Cape drought, Verlorenvlei has experienced drier-than-normal conditions with less rainfall, negatively impacting the surrounding ecology. Seasonal and spatial changes of the water sources (e.g., rainfall, surface water, and groundwater) supporting the wetland and the interconnectivity between these reservoirs were investigated using O/H stable isotopes and hydrochemistry analysis. The study collected event-based rainfall (57 samples), surface water (18 samples), and groundwater (108 samples) in February, April, and June 2022. Stable isotope ratios and hydrochemistry indicate that groundwater outside the watershed (topographically and surface water delineated) supports the wetlands, suggesting that local and regional groundwater flow systems influence the Verlorenvlei.

Furthermore, the Verlorenvlei is subjected to high evaporation compared to other surface waters and, in return, is reliant on baseflow supporting its hydrological functioning. The Krom Antonies and Hol sub-catchments exhibit overlapping groundwater isotope ratios and water types compared to the Verloren sub-catchment, suggesting a disproportionately high groundwater contribution from both sub-catchments into the wetland. Understanding Verlorenvlei's water balance is necessary to improve ecological reserve determination studies to help ensure environmental and socio-economic sustainable water use.

Keywords: Groundwater, rainwater, semi-arid, stable isotope, surface water, Verlorenvlei, water chemistry, wetland

CLICK TO RETURN TO THE PROGRAMME

Aquifers recharge in volcanic-arc area, stable isotopes insights to emphasize a multi-scale approach on a local hydrogeological conceptual model elaboration

B Baud[1]., P Lachassagne[1]., A Fadillah[2]., H Hendrayana[3]., N Dorfliger[4]

[1]HSM, Univ. Montpellier, CNRS, IRD, Montpellier, France; [2]AQUA Danone, Jakarta, Indonesia; [3]Universitas Gadjah Mada, Geological Engineering Department, Yogyakarta, Indonesia; [4]DANONE, Water Institute by Evian, Evian-les-Bains, France

Stable isotopes of the water are widely used in volcanic contexts to identify the recharge area, thanks to a strong orographic effect. Such data help improve the study areas' conceptual model, especially to identify flow paths through the volcanic edifice. The most common pattern considered is a high to medium-elevation recharge area on a flank of the volcano, feeding both local perched aquifers and a deep basal aquifer. This is quite common for "shield volcanoes", with the flank comprising a thick accumulation of lava flows. On composite volcanoes, especially in a volcanic arc context, the large diversity of lithologies (effusive/destructive events dynamics) along the flanks may create a compartmented aquifers system.

The Arjuno-Welirang-Ringgit volcanic complex (East Java) has been studied to elaborate a hydrogeological conceptual model. Stable isotopes of the water show significant results in identifying the recharge areas of several aquifers that are outflowing at a similar range of elevation. These results help to propose a water flow pattern from the recharge areas to the main springs with juxtaposed and superposed aquifers. This also leads to constraining the geometry of the aquifers and concluding that one volcanic complex with several recharge areas can feed juxtaposed aquifers. These results also highlight the need to adapt the study scale to each "point of interest" in the volcanic context, as each spring shows a different flowing pattern, preferential recharge elevation, and surface area. These are mandatory data to propose an adapted groundwater management.

Keywords: Stable Isotopes, recharge area, aquifers, volcano, conceptual model

Stable and Radiogenic isotopes in southern Mozambique: a window into groundwater recharge, mixing and vulnerability

J van Rooyen[1]., A Watson[1]., Jodie Miller[2]

[1]School for Climate Studies, Stellenbosch University. Stellenbosch, South Africa; [2]Depament of Earth Science, Stellenbosch University, Stellenbosch, South Africa

The use of radiogenic isotope tracers, produced through bomb testing (e.g. 3H and 14C), and the application of these isotopes is yet to be fully explored now that atmospheric abundances have returned to background levels. New isotope-enabled institutions and laboratories have recently been established in developing countries to apply isotopes in practical research. This study utilized several laboratories in South Africa and in Europe to compile a robust hydrochemical (major cations and anions) and isotope (d18O, d2H, 3H, 14C, 86Sr/87Sr) dataset of groundwater from 95 sample locations in the Maputo province of Mozambique. Groundwater is hosted in different aquifers and recharged through variable mechanisms ranging from direct infiltration of exposed alluvial soils to inter-aquifer transfer between fractured aquifer systems in the mountainous regions and the weathered bedrock in the lowlands. A combination of hydrochemistry and isotopes provided insight into the heterogeneous nature of recharge, mixing of modern and fossil groundwaters, and aquifer vulnerabilities when combined with other physical parameters in the region. However, it is also clear that grab sampling over a regional spatial extent and two sampling seasons (wet and dry) did not capture all the system variability, and more regular monitoring would uncover details in the system's behaviour not captured in this study.

Keywords: Isotopes, recharge, residence time, SADC, vulnerability

CLICK TO RETURN TO THE PROGRAMME

Vulnerability of South African water resources to emerging organic contaminants: a case study of the Witwatersrand Goldfields, Eastern Basin

L Ligavha-Mbelengwa[1]., G Madzivire[1]., M Gomo[2]

[1]Council for Geoscience, Pretoria, South Africa; [2]University of the Free State, Bloemfontein, South Africa

The occurrence of emerging organic contaminants (EOCs) in the aquatic environment is of no surprise since these are applied for various purposes daily. This study investigated the changes in EOCs concentrations in the water between 2019 and 2020. During rainy seasons, samples were collected from dams and surrounding boreholes in the Eastern Basin of the Witwatersrand Goldfields. During the first and second laboratory analyses, 24 and 11 analytes were screened in the water samples. The findings indicated that in 2020, compounds such as caffeine, sulfamethoxazole, atrazine and metolachlor displayed detection frequency exceeding 2019. This indicates that the occurrence of these compounds in the aquatic system has increased within a year. Whilst carbamazepine was still traced in 12 sites as previously observed in 2019, compounds estradiol, estrone, bisphenol A and ibuprofen were traced in fewer sites than they were detected in 2019. Compounds 4-nonylphenol, methylparaben, caffeine and atrazine were detected in all the samples analysed for 2019 and 2020, respectively. Antiretrovirals (ARVs) were analysed once and were detected in most sites, with efavirenz registering the highest (12/18) detection frequency. Assessing the occurrence of EOCs in boreholes according to the depth indicated that bisphenol A and estrone were traced in greater concentrations in deep than shallow aquifers, whilst the opposite was observed for atrazine. This study showed groundwater susceptibility to contamination by EOCs, with concentrations of most compounds increasing with time due to their high usage and improper sewer systems in the area.

Keywords: bisphenol A, caffeine, emerging organic contaminants, estrone, groundwater

CLICK TO RETURN TO THE PROGRAMME

Groundwater recharge in sub-humid drylands under different agricultural systems

D Mudimbu[1]., B Brauns[2]., K Banda[3]., D Lapworth[2]., A MacDonald[2], W Namaona[4]., R Owen[5]., M Sinda[6]

[1]Department of Chemistry and Earth Sciences, Faculty of Science, University of Zimbabwe, Harare, Zimbabwe; [2]British Geological Survey, United Kingdom; [3]Department of Geology, School of Mines, University of Zambia, P.O. Box 32379, Lusaka, Zambia; [4]Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi; [5]Department of Civil Engineering, School of Engineering, University of Zimbabwe, Harare, Zimbabwe; [6]Department of Soil Science, School of Agricultural Sciences, University of Zambia, P.O. Box 32379, Lusaka, Zambia

Groundwater is a strategic long-term water resource used by an estimated 70% of the populations in sub-Saharan Africa for drinking, irrigation and a wide range of economic activities. Understanding groundwater recharge processes is key for effectively using and managing water resources. Very few studies have used direct groundwater observations to assess the impact of different farming systems on groundwater recharge processes. This study focused on assessing basement aquifer recharge in 4 instrumented catchments in Malawi (Chitedze), Zambia (Liempe and Kabeleka) and Zimbabwe (Domboshawa) within the SADC region between 2019-2022. Employing a range of methods, including direct field observations (groundwater hydrographs, precipitation data, stable isotopes, chloride mass balance and residence time tracer data), we quantify the amount of groundwater recharge as well as the timing and nature of recharge processes under both conservation and conventional tillage systems in these four study sites. Groundwater recharge was measured in most years across the study sites. The study reveals the strong climate controls on seasonal groundwater recharge volumes, the influence of low permeability layers in the unsaturated zone, and the likely magnitude of impact from different farming practices. Groundwater residence times are high (i.e. low fractions of modern recharge, interquartile range 1-5%, n=46), even in shallow piezometers, suggesting these unpumped systems may be highly stratified. The results provide an evidence-based suite of data that reveals much about key controls on groundwater recharge in basement aquifers in sub-humid drylands and will inform the development and management of such groundwater systems.

Keywords: Groundwater recharge, basement aquifers, Southern Africa Development Community (SADC)

CLICK TO RETURN TO THE PROGRAMME

Using passive sampling to identify trends in aquatic pesticide pollution in the Western Cape, South Africa

E Davies[1]., R Chow[1]., S Furihmann[2]., C Stamm[3]

[1]Stellenbosch University, Stellenbosch, South Africa; [2]Swiss Tropical and Public Health Institute, Switzerland; [3]Swiss Federal Institute of Aquatic Science and Technology, Switzerland

South Africa is the leading user of pesticides in Sub-Saharan Africa, but data on pesticide occurrence in (ground)water is limited. Consequently, there is a need to improve knowledge on transport pathways that cause pesticides to enter the aquatic environment. This research monitored pesticide concentrations in three agricultural catchments in the Western Cape, South Africa, including Grabouw (pome fruit), Hex River Valley (table grapes), and Piketberg (wheat). Passive samplers were deployed in rivers from March 2022- March 2023, adding to a 2017-2019 dataset of analytical and pesticide application data. Field and laboratory methods were developed at Stellenbosch University to measure pesticides using Liquid Chromatography-Mass Spectrometry. For quality control, duplicate samples were analyzed at Eawag, Switzerland. 30 compounds were detected, yet two/three comprise most of the total mass, including an analyte not considered in earlier investigations (dimethomorph).

Rainfall-flow relationships and agricultural application could only partially explain detection levels, suggesting that other factors, including non-agricultural application or groundwater input, might influence detections. Two compounds exceeded European Environmental Quality Standards (chlorpyrifos and imidacloprid). Imidacloprid is particularly concerning because it exceeded consistently despite few recorded applications. 2017-2022 imidacloprid data indicates a decreasing concentration trend in Hex River Valley and increasing trends in Piketberg and Grabouw. Consistently high detections during wet and dry periods suggest groundwater input. However, such pesticide transport pathways are poorly understood due to a lack of local evidence. Local authorities must establish a long-term monitoring program to understand better the risk pesticides pose to the aquatic environment and human health.

Keywords: Imidacloprid, passive water sampling, pesticide, South Africa, surface water, Sustainable Development Goal 6

CLICK TO RETURN TO THE PROGRAMME

Per and Polyfluoroalkyl Substances (PFAS) Groundwater Toolkit

F Beetle-Moorcroft
HRS Water Consultants, Inc, United States

Per and Polyfluoroalkyl substances (PFAS) are ubiquitous on our planet and in aquifers. Understanding PFAS transport in aquifers is critical but can be highly uncertain due to unknown or variable source conditions, hydrophobic sorption to solid organic aquifer matter, ionic sorption on mineral surfaces, changing regulatory requirements, and unprecedentedly low drinking water standards. Thus, a PFAS toolkit has been developed to enable decision makers to collect the hydrogeologic data necessary to understand and better predict PFAS transport in aquifers for the purpose of managing water resources. This toolkit has been tested at a significant alluvial aquifer system in the western United States, which provides water for 50,000 people. Here, the toolkit has provided decision makers with the data necessary to optimize water pumping, treatment and distribution systems. The toolkit describes (1) the design and implementation of a sentinel well network to measure and track PFAS concentrations in the alluvial aquifer over time in response to variable pumping conditions, (2) data collection used to empirically derive input parameters for groundwater fate and transport models, which include the collection of paired aquifer matrix and groundwater samples, to measure PFAS distribution coefficients (Kds) and modified borehole dilution tests to measure groundwater flux (Darcy Velocity) and (3) the use of data collection techniques to reduce cross contamination, including PFAS-free, disposable bailers and a triple-rinse decontamination procedure for reusable equipment. The PRAS transport toolkit has the potential to assist decision makers responsible for managing PFAS contaminated aquifers.

Keywords: PFAS, fate and transport, groundwater, sampling

Characterisation of Groundwater Quality Monitoring Objectives and Background Values: Case Study of the Soutpansberg Region, South Africa

[1]L Lalumbe., [1]F Ramusiya., [1]P Fuku., [2]T Kanyerere., [1]Z Maswuma
[1]Department of Water and Sanitation, South Africa; [2]University of the Western Cape, Bellville, South Africa

Natural water-rock interaction processes and anthropogenic inputs from various sources usually influence groundwater chemistry. There is a need to assess and characterise groundwater quality monitoring objectives and background values to improve groundwater resource monitoring, protection and management. This study aims to determine monitoring objectives and characterise monitoring background values for all monitoring points within the Soutpansberg region. This study used long-term groundwater quality monitoring data (1995-2022) from 12 boreholes and 2 geothermal springs. Monitoring objectives were determined from land-use activities, allocated groundwater use, and water use sectors. Monitoring background values were determined from the physio-chemical parameters from each of the 14 monitoring points. This study determined monitoring objectives and background values of all monitoring points and all physio-chemical parameters in the Soutpansberg region. This study recommends reviewing the determined monitoring objectives and background values every 5 to 10 years to assess any change in land use, groundwater use and sector and monitoring data trends.

Keywords: Background values, groundwater quality, groundwater use, land use, monitoring objectives

CLICK TO RETURN TO THE PROGRAMME

Nitrate vulnerability assessment in the fast-growing African district of Abuja Federal Capital Territory (Nigeria)

[1]M Etuk., [2]V Re., [2]S Viaroli., [1]I Ogbonnaya.,

[1]Department of Earth Science, University of Nigeria, University Road Nsukka, Nigeria

[2]University of Pisa, Earth Sciences Department, Via Santa, Maria 53, Pisa, Italy

In the Federal Capital Territory of Abuja (Abuja FCT, Nigeria), a population growth of about 400% between 2000 and 2020 has been reported. This trend, coupled with the persisting urban sprawling, is likely to result in severe groundwater quality depletion and contamination, thus undermining one of the area's main freshwater supplies for drinking purposes. In fact, groundwater in Nigeria and Abuja FCT provides over 70% of the drinking purposes. Results of a groundwater vulnerability assessment that compared land use data from 2000 and 2020 showed that the region had been affected by a dramatic change with an increase in urbanized (+5%) and agricultural (+27%) areas that caused nitrate concentrations to exceed the statutory limit for drinking purposes in more than 30% of the monitored wells in 2021 and 40% in 2022. Although fertilizers are generally considered the main source of nitrate contamination, results suggest a possible mixed (urban and agricultural) pollution origin and a legacy of previous nitrogen pollution sources. The comparison between the DRASTIC-LU map and nitrate concentrations shows that the highest values are found in urban/peri-urban areas, in both shallow and deep wells. This investigation is the first step of a comprehensive nitrate pollution assessment in the region, which will provide decision-makers with adequate information for urban planning given the expected population growth in the area.

Keywords: DRASTIC-LU model, groundwater contamination, population growth

CLICK TO RETURN TO THE PROGRAMME

Application of Nanofiltration Membrane for Removal of VOCs and Heavy Metals in Groundwater, Ratchaburi, Thailand

C Chamathong., T Nettasana., M Hengsuwan., P Kullaboot., J Park., K Kim

Department of Groundwater Resource, Thailand; International Environmental Research Institute Gwangju Institute of Science and Technology (GIST), Korea

The Namphu and Rangbua subdistricts in Ratchaburi province, in western Thailand, are affected by groundwater contamination. According to site characterization results, the aquifer has been contaminated with volatile organic compounds and heavy metals since 2014. Membrane filtration technology is an alternative method for treating groundwater to produce safe drinking water for household use. Nanofiltration membrane is a relatively recent development in membrane technology with characteristics that fall between ultrafiltration and reverse osmosis (RO). This study aimed to determine the hydrochemistry of contaminated groundwater and examine the efficiency of nanofiltration membranes for removing pollutants in groundwater and the potential implementation of the membrane.

The membrane module used in this study is cylindrical in shape of 101.6 cm long and 6.4 cm in diameter, and the membrane surface charge is negative with monovalent rejection (NaCl) of 85-95%. The filtration experiments were conducted at a pressure of 0.4-0.6 MPa, which yielded flow rates of approximately 2 L/min. To examine the nanofiltration membrane efficiency, groundwater samples were extracted from four monitoring wells and were used as feed water. According to laboratory results, the nanofiltration maximum removal efficiencies for 1,2-dichloroethylene, vinyl chloride, benzene, nickel, and manganese were 97, 99, 98, 99, and 99%, respectively. However, the treatment efficiency depends on several factors, including pretreatment requirements, influent water quality and the lifespan of the membrane. Further research should be conducted to determine the maximum concentration of VOCs and heavy metals in the feed water before applying this treatment method to a large scale.

Keywords: Heavy metals, Nanofiltration membrane, VOCs

CLICK TO RETURN TO THE PROGRAMME

Maximising groundwater value through innovation and technology - the power of membranes

J Loock
Greenchain Group, South Africa

The SADC region has vast potential to alleviate water scarcity and promote growth through the responsible development of groundwater resources. To achieve this, it is crucial to understand the resource's value, implement sustainable abstraction programs, protect its quality, optimize its usage for regional development, and implement innovative aquifer management programs, including artificial recharge. Greenchain Group is a water treatment company that recognizes the value of water and strategically deploys its expertise to maximize the potential of each drop. As membrane technology specialists and local manufacturers of this advanced technology, we understand how to design integrated solutions to safeguard water quality and accessibility. Our wide range of filtration technologies allows us to select the technology suited to the application and regional groundwater context and to produce high-quality water from various sources, including groundwater.

Additionally, by removing contaminants/unwanted constituents from groundwater, we enhance the value of each drop of water for local potable consumption, eliminate the need for overwatering in agriculture, and allow for the creation of new agriculture/industries in regions with poor groundwater quality. This same technology can also treat wastewater and remove contaminants (e.g. chemical of emerging concern, PFAS) and thus is critical to water reuse applications and responsible Managed Aquifer Recharge. Greenchain Group's treatment systems have been used in various industries, including agriculture, mining, energy, medical, food and beverage, and remote and mobile settings.

Keywords: Membrane Technology, Quality, Reticulation, Sustainability, Water Treatment

The use of Coal Combustion Residues for the stabilisation of mines and the treatment of mine drainage

Kelley Reynolds-Clausen
Senior Consultant, Eskom, South Africa

Coal Ash Beneficiation is a government imperative for South Africa, and Eskom generates approximately 34 million tons of coal ash annually from their 14 pulverised coal fuel plants. It is estimated that there are approximately 6,000 abandoned coal mines in South Africa, of which 2,322 are classified as high risk, contributing to subsidence and the generation of acidic mine drainage. It is envisaged that coal ash could offer a support medium for the mines and neutralise the acidic mine water due to its alkaline nature. The Department of Fisheries, Forestry and the Environment has supported the initiative but has requested a means of modelling possible contamination due to placing the coal ash in these environments. To this end, laboratory trials were completed to generate the initial model and a controlled pilot site was established to validate the model's accuracy. This trial evaluated stabilised and unstabilised coal ash as a means of acid water management. The laboratory trials showed that the ash could neutralise the pH of the mine water from approximately 2 to 7; this was sustained for the test period. In addition, sulphate and iron were significantly reduced in the treated water. The laboratory and site work results will be detailed in this presentation.

Keywords: CCP, coal combustion residue, coal ash, mine backfilling

CLICK TO RETURN TO THE PROGRAMME

Groundwater trend analysis at an active underground coal gasification plant

L Mokhahlane
Wits University, Johannesburg, South Africa

Underground coal gasification (UCG) is a high-temperature mining method that gasifies coal in situ to produce a synthetic gas that can be used as feedstock for industrial purposes. Coal conversion leads to mineral transformation in the gasifier, which ultimately interacts with the rebounding groundwater post-gasification. This poses a groundwater contamination risk, the biggest environmental risk from a UCG geo reactor. There is currently no model for UCG operators and regulators to assess the total risk of groundwater contamination from UCG operations. This study collates literature on groundwater contamination from UCG operations and presents a workable but comprehensive groundwater risk assessment model for a spent UCG chamber. The model follows the source-pathway-receptor arrangement where groundwater contamination sources are identified as ash, char, roof and floor. All possible pathways are assessed for hydraulic connections with the spent geo-reactor via acceptable geochemical tests, including stable isotopes, hydrochemistry and stratification analysis. Finally, the receptor aquifers (e.g. shallow aquifers) are monitored periodically to determine if contamination has occurred.

Keywords: Underground coal gasification (UCG), gasifier, groundwater risk assessment model, spent georeactor

In-situ Remediation of Contaminated Groundwater Using Permeable Reactive Barrier at the 16th Lum Nam Jone Reservoir, Chachoengsao, Thailand

M Hengsuwan
Department of Groundwater Resources, Thailand

The 16th Lum Nam Jone reservoir is located in Chachoengsao Province, Thailand. Since 2019, water has become highly acidic with a pH of 2.5-3.5 and contaminated by heavy metals. The groundwater plume is associated with high concentrations of Iron (60 – 3,327 mg/L), Manganese (38 – 803 mg/L), Copper (5 –500 mg/L), Zinc (11 –340 mg/L), and high Total Dissolved Solids (2,600 –23,000 mg/L). The hydrogeochemical assessment confirmed that the contamination is related to the molybdenum ore processing plant located upgradient. The industrial wastewater was illegally discharged underground and flowed to the reservoir due to a hydraulic gradient. The main objective of this research is to evaluate the efficiency of different reactive materials for In-situ remediation using a permeable reactive barrier (PRB). The experiment column setup showed that marl has the highest efficiency in elevating pH by 3.6 units. The Fe, Cu, and Zn removal rates by crushed shells were 100, 98, and 60%, respectively. The Fe, Cu, and Zn removal rates by limestone were 100, 73, and 32%, respectively. The Fe, Cu, and Zn removal rates by marl were 100, 100, and 48%, respectively. Regarding the laboratory-scale experiment, the pilot PRB was installed upstream of the reservoir. The PRB was filled with marl at the bottom, overlain by limestone, and then covered with the uppermost rice straw layer. The pH increased by 2.6 units inside PRB (from pH 3.1 to 5.7). A reduction of about 50% in Fe, 85% in Cu, and 50% in Zn had been achieved.

Keywords: Thailand, contamination, permeable reactive barrier, remediation

CLICK TO RETURN TO THE PROGRAMME

Research-based exploration of deep groundwater within the eastern limb of the Bushveld Complex

A Allwright[1]., F de Lange[1]., R Lubbe[1]., L Mbonambi[1]., K Vivier[2]., K Witthuser[3]., S Webb[4]., L Ashwal[4]., F Roelofse[5]., D. Khoza[6]., R Trumbull[7]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa; [2]Artesium Consulting Services (Pty) Ltd; South Africa; [3]Delta-H Water Systems Modelling (Pty) Ltd, South Africa; [4]University of the Witwatersrand, Johannesburg, South Africa; [5]Department of Geology, University of the Free State, Bloemfontein, Free State, South Africa; [6]Council for Geoscience, Pretoria, South Africa; [7]GFZ German Research Centre for Geosciences Potsdam, Germany

The current understanding of groundwater within the larger Bushveld Complex (BC) is evaluated to gauge the potential for deep groundwater, specifically emphasising the lesser investigated eastern limb. From the review of publicly available literature and data, geohydrological databases and statistical analyses are presented as a collation of the current understanding of groundwater in the eastern limb of the BC. Unfortunately, information on deep groundwater (> 300 m) is scarce due to the cost associated with deep drilling, mining exploration holes often neglecting hydrogeological data collection, or lack of public access to this information. Nevertheless, the conceptual model developed from the available information highlights deep groundwater's variable and structurally controlled nature and the uncertainty associated with groundwater characterisation of the deeper groundwater systems. This uncertainty supports the need for research-based scientific drilling of the deeper fractured lithologies in the eastern limb of the Bushveld Complex. The Bushveld Complex Drilling Project (BVDP) established an opportunity to perform such research-based drilling and was funded by the International Continental Scientific Drilling Program (ICDP). While the main focus of the BVDP is to produce a continuous vertical stratigraphic sequence of the BC, there is a sub-component to collect geohydrological information. The planned borehole, 2 500 m deep, will provide an opportunity to collect information from the deeper systems within the Bushveld Complex and the underlying Transvaal Supergroup, which will inform on the connection between shallow and deeper groundwater.

Keywords: Bushveld Complex, Deep groundwater, deep scientific drilling

Groundwater resources of the Danakil Depression – hydrogeology in the hottest place on Earth

L Towers., D Blake., D McGibbon

Umvoto

The Danakil Depression of the Afar Rift forms part of the north/south-trending Ethiopia-Eritrean arm of the East African Rift System, whereas the western margin of the depression forms part of an active plate boundary between the western Nubian and eastern Danakil tectonic blocks. Dallol (within the Danakil Depression) currently holds the record for the highest average temperature for an inhabited place on Earth, with annual average temperatures of ~35-36°C. The isolated area was initially explored geologically in the late 1960s, with recent geological and hydrogeological interest in its northeast Ethiopian portion due to easier access, geo-tourism and potash-ore exploration. Potash mining is proposed via solution-extraction techniques, requiring large volumes of water in one of the driest hyper-arid regions. Various hydrogeological investigations were therefore conducted between 2014 and 2016 as part of a feasibility and water resource study towards developing a water resource estimate for the region and proposed mining operations. Alluvial fans on the west side of the rift basin form a major, regional primary aquifer – fan boreholes have yields of 50 litres per second, although groundwater is highly saline (up to 3-5 times the salinity of seawater) and can reach temperatures of 50°C. Groundwater yields of hundreds of millions of cubic metres per annum are potentially available from the saline alluvial fan primary aquifers for potash solution mining. In contrast, groundwater from karstic limestone aquifers could provide a freshwater resource to settlements within the Lelegheddi River basin and the Danakil.

Keywords: Danakil Depression, alluvial aquifer, potash, rift basin, solution mining

CLICK TO RETURN TO THE PROGRAMME

New challenges for low-enthalpy geothermal resource management at the urban scale

S Barbieri: M. Antelmi., L Alberti
Politecnico di Milano, Milan, Italy

The study focuses on the overlapping effects of low-enthalpy geothermal plants in urbanized areas, showing the importance of quantifying thermal groundwater exploitation to manage the resource adequately. Geothermal energy connects groundwater use to one of the ever-growing needs nowadays: energy. For low-temperature geothermal, the form of energy we can harness is thermal energy for building heating or cooling, one of the most polluting sectors, representing 34% of CO_2 emissions in Europe. As in the main European cities, geothermal energy use is constantly growing, and understanding the status of groundwater exploitation for geothermal purposes is essential for proper resource management. To this end, the study's first phase focused on quantifying geothermal use in the study area selected in Milan city-Italy. Knowing the characteristics of geothermal plants in the area allows us to understand the extent of the resource exploitation and the consequences of its mismanagement at a large scale. In fact, the plant designers often focus on the local scale, not considering the presence of neighbouring plants, which risks decreasing the plant's efficiency or amplifying its subsurface thermal effect. To minimize the thermal effects/interferences of geothermal plants in the subsoil, the study of the application of D-ATES systems (Dynamic Aquifer Thermal Energy Storage) with significant groundwater flow is promising. A numerical model of the study area is then implemented with MODFLOW-USG for thermal transport in porous media to evaluate the advantages of installing D-ATES systems instead of typical open-loop systems.

Keywords: MODFLOW-USG, geothermal energy, heat transport, numerical modelling, resource management

Monitoring a deep fresh-saline water interface using repeatVertical Electrical Soundings measurements

S Meekes
TNO, The Netherlands

Monitoring deep (~100 – 200 m) fresh-saline water interface is a challenge because of the low spatial density of deep boreholes. In this project, Vertical Electrical Soundings measurements were used to evaluate changes in the depth of the interface over various decades. Water quality monitoring is a well-known application of geo-electrical measurements but generally applies to the relatively shallow subsurface. In this case study, the saline groundwater interface is around 120 -200 m deep, and the time interval between the measurements is several tens of years. Several locations showing good-quality existing VES-measurements acquired in the last century were selected to see whether repeat measurements could be performed. The number of locations where a repeat measurement could be performed was limited due to the construction of new neighbourhoods and greenhouse complexes. When interpreting the measurements for the change in the depth of the fresh-salt interface, it is assumed that the transition from fresh to saline groundwater occurs over a small depth range and that the electrical conductivity of the fresh water above this interface has not changed. However, it turned out that the ion concentration of the groundwater in the layers above the fresh-saline interface had increased sharply at almost all locations. This complicated the approach, but still, useful results could be obtained. Based on the measurements, it can be said that the fresh-saline water interface has shifted downwards at 3 locations, and hardly any change has occurred at 5 locations.

Keywords: Fresh-saline interface, Geo-electrical, Monitoring, Vertical Electrical Sounding

CLICK TO RETURN TO THE PROGRAMME

Peculiarities of the chemical composition of the Ordovician aquifer as a source of potable water supply (St. Petersburg, Russia)

E Kayukova

The Ordovician aquifer of the Izhora deposit is widely used for drinking by the population of St. Petersburg and its suburbs. Carbonate Ordovician rocks are intensively karstified. The water is fresh (0,5-0,8 g/l), bicarbonate-calcium on the predominant ions, pH 7.6; calcium content is 50-80 mg/l, magnesium content is 30-60 mg/l and the total hardness is 7,6-8,0 mg-equ./l. Western, northern and northeastern boundaries of the Izhora deposit go along the Baltic Klint, which is evident on the relief. Its southern boundary is along the zone of the dip of Ordovician limestone beneath the Devonian sandstone.

The territory of the Izhora plateau belongs to the areas of intensive economic activity. Often, objects of human economic activity are located near drinking water intakes. Almost all sites are marked by excess sanitary norms of chemical elements. Pollution of groundwater in the Ordovician aquifer has been identified in some areas. Priority substances have been identified for assessing the quality of groundwater: total hardness, Fe, Mn, Ba, and B. According to hydrochemical modelling data, Ordovician groundwater is saturated with calcite over most territory. There are many springs of underground water along the Baltic Klint, for example, near the village of Lopukhinka, Duderhof springs and others. The springs waters have natural radioactivity (due to the contact of groundwater with dictyonema shales), which makes their use hazardous to human health.

Keywords: aquifer properties, ground water contamination, radon (Rn), saturation index (SI)

Distributed recharge in karst-fractured carbonate aquifers: insights from the KARMA EU project for the groundwater resource management of Gran Sasso (Central Italy)

V Lorenzi., A Lacchini., M Manetta., M Petitta

Earth Sciences Department, Sapienza University of Rome, Italy

Water budget assessment and related recharge in karstified and fractured mountainous aquifers suffer a large uncertainty due to variable infiltration rates related to karst features. The KARMA project (karma-project.org), funded by the European Commission, has addressed this knowledge gap. The increase in human withdrawals and the effect of climate change can modify the recharge rate and, consequently, the spring discharge. The regional aquifer of Gran Sasso mountain, Central Italy, has been investigated by monitoring spring discharge isotope composition and calculating the inflow using a GIS approach on 100x100 m cells, considering local conditions, including karst features. The results for the 2000-2022 period highlight the preferential recharge area of the endorheic basin of Campo Imperatore (up to 75% of precipitation) and a mean infiltration of about 50% of rainfall. Different methods applied for recharge evaluation (Turc, Thornthwaite and APLIS) agree with a recharge rate close to 600 mm/year. This amount roughly corresponds to the spring discharge, evidencing: i) a “memory effect” in spring discharge, which is higher than previewed during dry years; ii) a variation in discharge due to rainy and drought year distribution, frequently recorded at springs with delay (1-2 years); iii) no significant trends of spring depletion since last 20 years; iv) the risk of lowering of snow contribution to recharge due to the temperature rise. The results provide updated information to the drinking water companies and the National Park Authority for sustainable management of the available groundwater resources.

Keywords: groundwater management, karst aquifers, recharge assessment

CLICK TO RETURN TO THE PROGRAMME

Regional-scale identification of recharge or discharge using remote sensing and GIS: Implications towards groundwater-surface water interactions

K Banda., M Mataa., M Chomba., I Nyambe

Integrated Water Resource Management Centre, Department of Geology School of Mines, University of Zambia, Lusaka, Zambia

Identifying groundwater recharge and discharge areas across catchments is critical for implementing effective strategies for salinity mitigation, surface water and groundwater resource management, and ecosystem protection. This study seeks to identify potential GW-SW discharge and recharge areas around the Barotse Floodplain. The results of remote sensing analysis using the Normalised Difference Vegetation Index (NDVI) show that the vegetation is sensitive to the dynamics of groundwater level, with shallower levels (< 10 m) in the lower reaches compared to deeper levels (>10 m) in the upper catchment). These zones are further investigated and likely represent geological variability, aquifer confinement and the degree of GW-SW interactions. GW-SW interactions likely are influenced by an interplay of factors such as water levels in the groundwater and surface level and hydrogeological conditions. Based on the findings, the wetland hosts riparian vegetation species responsive to the groundwater dynamic. NDVI can thus be used as a proxy to infer groundwater in the catchment. Therefore, effective water resources management of the floodplain should be implemented through conjunctive management of groundwater and surface water.

Keywords: Barotse Floodplain, Groundwater-Surface water, Zambezi River, Zambia, ecosystems

A Review of potential and actual groundwater recharge: Insights and implications to groundwater use

N Tuswa., T Kanyerere., N Jovanovic., Y Xu

University of the Western, Bellville, South Africa

Recharge is one of the most significant parameters in determining the sustainability volume of groundwater that can be abstracted from an aquifer system. This paper provides an updated overview and understanding of potential and actual groundwater recharge and its implications for informing decision-makers on efficiently managing groundwater resources. The paper argues that the issue of potential and actual recharge has not been adequately addressed in many groundwater recharge studies, and if not properly addressed, this may lead to erroneous interpretation and poor implementation of groundwater resource allocations. Groundwater recharge has been estimated using various methods, revised and improved over the last decade. However, despite numerous recharge methods, many studies still fail to distinguish that some assess potential recharge while others estimate actual recharge. The application of multiple recharge methods usually provides a wide range of recharge rates, which should be interpreted in relation to the type of recharge they represent; as a result, the wide range of recharge findings from different methods does not necessarily imply that any of them are erroneous. A precise distinction should, therefore, be made between the potential amount of water available for recharge from the vadose zone and the actual recharge reaching the water table. This study cautions groundwater practitioners against using "potential recharge values" to allocate groundwater resources to users. The results of this paper may be useful in developing sustainable groundwater resource management plans for water managers.

Keywords: Groundwater allocation, capture principle, semi-arid region, water resource management

CLICK TO RETURN TO THE PROGRAMME

Assessing the hydrogeology of springs, Heuningnes catchment, South Africa

P Finini., T Kanyerere, D Mazvimavi
University of the Western Cape, Bellville, South Africa

Springs are examples of groundwater discharges. This paper reports on findings from cold springs groundwater discharges that have served as important water sources for sustaining domestic and agricultural supply. This study assessed the hydrogeology of springs to inform practical measures for the protection, utilization, and governance of such discharges. The research assessed the hydrogeology of springs in terms of conditions in the subsurface responsible for occurrences of springs spatially and their flow paths to the surface. Spring locations were mapped and validated for spatiotemporal assessment. The study examined the flow dynamics and hydrogeochemistry of spring discharges. In-situ and laboratory measurements of spring discharges were carried out using standard methods.

Results showed that shallow and deep circulating systems of springs existed in the study area, being controlled by lithology and faults. All springs had fresh water of Na-Cl type, and rock-water interaction was the dominant geochemical process that influenced spring water chemistry. Radon-222 analysis showed high values detected in spring waters that confirmed recent groundwater seepage on the surface. The drum-and-stopwatch technique was used to estimate yield from spring discharges because it's only effective and reliable for yields of less than 2 l/s. Results suggest that some springs were locally recharged with some regionally recharged. Based on results from estimated yield and quality, it was concluded that spring waters had low discharges. A comprehensive assessment of spring discharges should be conducted to generate large datasets to inform practical measures for protection, utilization, and governance.

Keywords: Spring yield, conceptual model, confirmatory analysis, volumetric analysis

Assessment of catchment scale groundwater-surface water interaction in a non-perennial river system, Heuningnes catchment, South Africa

V Banda., T Kanyerere., H Mengistu
University of the Western Cape, Bellville. Cape Town, South Africa

This study assessed aquifer-river interaction using a combination of geological, hydrological, environmental stable isotope, and hydrochemical data in a non-perennial river system in the Heuningnes catchment. Results showed the depth to groundwater levels ranging from 3 to 10 m below ground level and aquifer transmissivity values of 0.17 to 1.74 m^2 /day. The analytical data indicated that Na-Cl-type water dominates most groundwater and river water samples. Environmental stable isotope data of river samples in upstream areas showed depleted δ18O (-4.3 to -5.12 ‰) and δ2H (-22.9 to -19.3 ‰) signatures similar to the groundwater data, indicating a continuous influx of groundwater into the river water. Conversely, high evaporative enrichment of δ18O (1.13 to 7.08 ‰) and δ2H (38.8 to 7.5 ‰) were evident in downstream river samples. It is evident from the local geological structures that the fault in the northeastern part of the study area passing Boskloof most likely acts as a conduit to groundwater flow in the NE-SW direction, thereby supplying water to upstream river flow. In contrast, the Bredasdorpberge fault likely impedes groundwater flow, resulting in hydraulic discontinuity between upstream and downstream areas. Relatively low conductive formation coupled with an average hydraulic gradient of 8.4 × 10−4 suggests a slow flow rate, resulting in less flushing and high groundwater salinisation in downstream areas. The results underscore the significance of using various data sets to understand groundwater-river interaction, providing a relevant water management platform for managing non-perennial river systems in water-stressed regions.

Keywords: Aquifer-river interaction, Environmental stable isotope, Geological fault, Hydrochemistry, South Africa

CLICK TO RETURN TO THE PROGRAMME

Assessing aquifer vulnerability using tritium and machine learning in Africa's western Sahel

J Podgorski[1]., O Kracht[2]., L Araguas-Araguas[2]., J Miller[2]., R Straub[3]., R Kipfer[1]., M Berg[1]

[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland; [2]IAEA, International Atomic Energy Agency, Austria; [3]SFOE, Swiss Federal Office of Energy, Switzerland

Understanding the sensitivity of groundwater resources to surface pollution and changing climatic conditions is essential to ensure its quality and sustainable use. However, it can be difficult to predict the vulnerability of groundwater where no contamination has taken place or where data are limited. This is particularly true in the western Sahel of Africa, which has a rapidly growing population and increasing water demands. To investigate aquifer vulnerability in the Sahel, we have used over 1200 measurements of tritium (3H) in groundwater with random forest modelling to create an aquifer vulnerability map of the region. In addition, more detailed vulnerability maps were made separately of the areas around Senegal (low vulnerability), Burkina Faso (high vulnerability) and Lake Chad (mixed vulnerability). Model results indicate that areas with greater aridity, precipitation seasonality, permeability, and a deeper water table are generally less vulnerable to surface pollution or near-term climate change. Although well depth could not be used to create an aquifer vulnerability map due to being point data, its inclusion improves model performance only slightly as the influence of water table depth appears to be captured by the other spatially continuous variables.

Keywords: groundwater, groundwater mapping, groundwater recharge, groundwater vulnerability, isotopes, machine learning, tritium

Machine learning spatial prediction modelling of groundwater salinity in the Horn of Africa

M Berg., D Araya., J Podgorski

Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland

Salinization is one of the main threats to groundwater quality worldwide, affecting water security, crop productivity and biodiversity. The Horn of Africa, including eastern Ethiopia, northeast Kenya, Eritrea, Djibouti, and Somalia, has natural characteristics favouring high groundwater salinity. However, available salinity data are widely scattered, lacking a comprehensive overview of this hazard. To fill this gap, machine learning modelling was used to spatially predict patterns of high salinity with a dataset of 6300 groundwater quality measurements and various environmental predictors. Maps of groundwater salinity were produced for thresholds of 800, 1500 and 2500 µS/cm. The main drivers include precipitation, groundwater recharge, evaporation, ocean proximity, and fractured rocks. The combined overall model accuracy and area under the curve of multiple runs were both ~81%. The salinity maps highlight the uneven spatial distribution of salinity, with the affected areas mainly located in arid, flat lowlands. These novel and high-resolution hazard maps (1 km2 resolution) further enable estimating the population potentially exposed to hazardous salinity levels. This analysis shows that about 11.5 million people (~7% of the total population) living in high-salinity areas, including 400,000 infants and half a million pregnant women, rely on groundwater for drinking. Somalia is the most affected country, with an estimated 5 million people potentially exposed. The created hazard maps are valuable decision-support tools for government agencies and water resource managers in helping direct salinity mitigation efforts.

Keywords: Djibouti, Eritrea, Ethiopia, Kenya, Salinity hazard maps, Somalia, affected population, drinking water resources, groundwater, machine learning, random forest modelling

CLICK TO RETURN TO THE PROGRAMME

Application of machine learning techniques to improve groundwater level predictions and optimization, West Coast, South Africa

N Igwebuike., S Clarke., T Kanyerere
University of the Western Cape, Bellville. Cape Town, South Africa

Groundwater systems are complex and subject to climate change, abstraction, and land use stresses, making quantifying their impacts on aquifers difficult. Groundwater models aim to balance abstraction and aquifer sustainability by simulating the responses of an aquifer to hydrological stresses through groundwater levels. However, these models require extensive spatial data on geological and hydrological properties, which can be challenging to obtain. To address this issue, data-driven machine learning models are used to predict and optimize groundwater levels using available data. This paper argues that using machine learning to model groundwater level data improves predicting and optimizing groundwater levels for setting up a managed aquifer recharge scheme. The West Coast Aquifer System in South Africa was used as a case study. The neural network autoregression model was used for the analysis. Multiple variables such as rainfall, temperature, and groundwater usage were input parameters in the mode to facilitate predictions. Outputs from the model showed how machine learning models can enhance the interpretation of observed and modelled results on groundwater levels to support groundwater monitoring and utilization. In areas with high dependence on groundwater and where data on abstraction (use) and monitoring were scarce, results showed that feasible measures were available to improve groundwater security. Although the simulation results were inconclusive, the results provided insights into how the use of machine learning can provide information to inform setting up a managed aquifer recharge scheme.

Keywords: Groundwater modelling, groundwater level., machine learning, managed aquifer recharge, water security

Delineating wellhead protection areas and aquifer vulnerability in the Cape Flats, South Africa

B Hunink[1]., R Chow[1]., T Wöhling[2,3]
[1]Stellenbosch University, Department of Earth Sciences, South Africa; [2]Technische Universität, Dresden, Chair of Hydrology, Germany; [3]Lincoln Agritech, Lincoln, New Zealand

Prevention of threats to the quality and quantity of groundwater supply is critical to ensure its sustainability. Several African studies have shown that contamination of aquifers is primarily caused by improper placement of land-based human activities. Therefore, adequate preventative measures are required to safeguard the water quality of African aquifers to avoid long-term deterioration. Spatially explicit, 3D numerical groundwater modelling is a common methodology to assess contaminant transport. However, model development is time-consuming and complex. Contrastingly, DRASTIC-L is a 2D, GIS-based aquifer vulnerability mapping technique. The method is simple to apply, but analyses are qualitative and subjective. The study aims to compare both methods and to combine their strengths using GIS overlay. Overall, aquifer vulnerability was determined using the DRASTIC-L method, while wellhead protection areas were delineated using steady-state numerical modelling. This study focuses on the Cape Flats area due to its rapid development and growing municipal water supply supplementation needs. DRASTIC-L mapping revealed that aquifers in the Cape Flats are highly vulnerable to contamination due to the region's unconfined hydrogeological properties, shallow water table and high-risk land use types. Moreover, groundwater vulnerability mapping combined with the delineation of wellhead protection areas allows for reduced uncertainty in the contamination potential of delineated groundwater protection zones. As a result, this study highlights the need for overall resource protection of the Cape Flats aquifers and provides insights into mapping out potential source protection areas of existing water supply wells.

Keywords: Aquifer vulnerability mapping, groundwater sustainability, resource protection, Source protection, Wellhead protection areas

CLICK TO RETURN TO THE PROGRAMME

A mixing analysis to explore the distribution and behaviour of contaminants of emerging concern and regulated organic pollutants in the hydrogeological media. Case study: the endorheic catchment of the Fuente de Piedra Lagoon (Southern Spain)

M Llamas[1]., J Jiménez-Martínez[2,3]., P Jiménez-Gavilán[3]., C Corada-Fernández[4]., P Lara-Martín[4]., I Vadillo A[1]., L Ojeda[1]

[1]Group of Hydrogeology Department of Geology, Faculty of Science, University of Málaga, 29071, Málaga, Spain; [2]Eawag, Dübendorf, Switzerland; [3]ETH Zürich, Zurich, Switzerland; [4]Faculty of Marine and Environmental Sciences, University of Cadiz 11510, Puerto Real, Cádiz, Spain

An end-member mixing analysis has been conducted for the hydrogeological system of the endorheic catchment of the Fuente de Piedra lagoon (Malaga, Southern Spain). Three end-members have been considered because of the three main groundwater types related to the different kinds of aquifers found in the catchment. The model's objective is to help understand the distribution of the organic contaminants (including contaminants of emerging concern [CECs]) detected in groundwater samples from the catchment. Results suggest that some contaminants can be related to long groundwater residence time fluxes, where contaminant attenuation can be limited due to low oxygen levels and microbial activity. The three main aquifer types are: (i) unconfined carbonate aquifers with low mineralized water corresponding to two mountain ranges with no human activities over theirs surface; (ii) an unconfined porous aquifer formed by Quaternary and Miocene deposits, exposed to pollution from anthropogenic activities (agriculture and urban sources); and (iii) a karstic-type aquifer formed by blocks of limestones and dolostones confined by a clayey, marly and evaporite matrix from Upper Triassic. The groundwater monitoring campaign for the analysis of organic contaminants was carried out in March 2018. Target organic contaminants included pharmaceuticals, personal care products, polyaromatic hydrocarbons, pesticides, flame retardants and plasticizers. For the mixing model, a dataset was built with the hydrochemistry and isotopic results ($\delta^{2}H$, $\delta^{18}O$) from the monitoring campaign conducted in March 2018 and from campaigns carried out in previous years and retrieved from the literature.

Keywords: emerging contaminants, groundwater, mixing model

CLICK TO RETURN TO THE PROGRAMME

Combined effects of seawater intrusion and nitrate contamination on groundwater quality in the coastal agricultural area of El-Nil River, Algeria

L Boumaiza[1]., J Walter[2]., R Chesnaux[2]., F Zahi[3]., F Huneau[4]., É Garel[4]., R Stotler[1]., G Bordeleau[5]., K Johannesson[6]., Y Vystavna[7]., T Drias[8]., V Re[9]., K Knöller[10]., C Stumpp[11]

[1]University of Waterloo, Canada; [2]Université du Québec à Chicoutimi, Canada; [3]Université Mohammed Seddik Ben Yahia, Algeria; [4]Université de Corse Pascal Paoli, France; [5]Institut National de la Recherche Scientifique, Canada; [6]University of Massachusetts Boston, United States of America; [7]International Atomic Energy Agency, Austria; [8]Université Mustapha Benboulaïd, Algeria; [9]University of Pisa, Italy; [10]Helmholtz Centre for Environmental Research, Germany; [11]University of Natural Resources and Life Sciences, Austria

This study focuses on the coastal agricultural area of El-Nil River (Algeria), where anthropogenic activities heavily impact groundwater resources. A multi-tracer approach, integrating hydrogeochemical and isotopic tracers (δ2HH2O, δ18OH2O, δ15NNO3 and δ18ONO3), is combined with a hydrochemical facies evolution diagram and a Bayesian isotope mixing model (MixSIAR) to assess seawater contamination and distinguish the nitrate sources and their apportionment. A total of 27 groundwater samples and 7 surface water samples distributed over the entire study area were collected. Results show classic inland intrusion combined with an upstream seawater impact through the river mouth connected to the Mediterranean Sea. Results from nitrate isotopic composition, NO3 and Cl concentrations, and the MixSIAR model show that nitrate concentrations chiefly originate from sewage and manure sources. Nitrate derived from sewage is related to wastewater discharge, whereas nitrate derived from manure is attributed to an excessive use of animal manure to fertilise agricultural areas. The outcomes of this study are expected to help decision-makers prepare suitable environmental strategies for effective and sustainable water resources management in the study area.

Keywords: Coastal aquifer, Groundwater quality, nitrate contamination, seawater intrusion, stable isotopes

CLICK TO RETURN TO THE PROGRAMME

Isotope geochemistry disentangles interactions between water and carbon cycle in Mediterranean peatland

S Santoni[1]., E Garel[1]., M Gillon[2]., M Babic[2]., J Spangenberg[3]., B Bomou[3]., D Sebag[4]., T Adatte[3]., R van Geldern[5]., V Pasqualini[1]., F Huneau[1]

[1]Université de Corse Pascal Paoli., UMR CNRS 6134 SPE, Hydrogéologie Campus Grimaldi, BP52, 20250 Corte, France; [2]Avignon Université, UMR 1114 EMMAH, INRAE, 301 rue Baruch de Spinoza, BP21239, 84916 Avignon, France ; [3]University of Lausanne, Institute of Earth Surface Dynamics (IDYST), Géopolis, 1022 Chavannes-près-Renens, Lausanne 1015, Switzerland; [4]IFP Energies Nouvelles, Earth Sciences and Environmental Technologies Division, 1-4 Avenue du bois Préau, 92852 Rueil-Malmaison, France; [5]Friedrich-Alexander-Universität Erlangen-Nürnberg, Department of Geography and Geosciences, GeoZentrum Nordbayern, Schlossgarten 5, 91054 Erlangen, Germany

This research aims to evaluate the carbon storage function of a Mediterranean peatland in changing climate conditions. The scientific strategy relies on a seasonal geochemical survey sourcing the carbon origin by considering the hydrosphere, lithosphere, biosphere, and atmosphere. This unprecedented research on a Mediterranean peatland reveals the seasonality of dissolved carbon inputs from primary production, organic matter oxidation, and time-changing recharge components within the catchment (rainwater, river water, shallow groundwater, deep groundwater). Based on the mixing proportions of all recharge water components, the study applies a reverse end-member mixing analysis to define the theoretical peat water $d^{13}C_{DIC}$ value and compare it to the measured ones. The model explains 65 % of the data, demonstrating the water flow influence on peatland carbon content. In 35% of the cases, peatland processes such as primary production and organic matter oxidation drive the peat water's carbon content. Peat organic and inorganic properties, $d^{13}C_{TOC}$, and $d^{13}C_{CO2}$ data demonstrate the role of groundwater as a CO_2 source and the dominance of *in situ* primary production that argues in favour of carbon storage within such Mediterranean peatland. This research proves the relevance of geochemistry and isotope hydrology tools to disentangle and rank peatland water and carbon processes within peatland hydro-ecosystems. Overall, it reveals the necessity to take into account the interactions between water and carbon cycle processes, with particular consideration for groundwater as a CO_2 source at the peatland-atmosphere interface, to build better models for the future evolution of the global climate.

Keywords: Groundwater-Dependent Ecosystem, origin of carbon, peatland-atmosphere interface, peatland-carbon-water system, sources and sinks of carbon

CLICK TO RETURN TO THE PROGRAMME

Potential land use changes and wildfires effects over the spatiotemporal distribution of groundwater recharge at a regional scale: RAPReHS indicator accounting for SDG-13 in Bolivia

M Guzmán Rojo[1,2]., A Nogales[2]., C Hurtado[2]., Z Vargas[3,2]

[1]Vrije Universiteit Brussel, Belgium; [2]Bolivian Catholic University , Bolivia; [3]Ghent University, Belgium

Having knowledge of spatiotemporal groundwater recharge is crucial for optimizing regional water management practices. However, the lack of consistent ground hydrometeorological data at regional and global scales has led to the use of alternative proxies and indicators to estimate impacts on groundwater recharge, enabling effective management of future water resources. This study explores the impact of land use changes and wildfires on groundwater recharge at a regional scale in Bolivia, using an alternative indicator to estimate variations in groundwater recharge rates. Based on a study by de Freitas L. in 2021, the methodology developed the annual groundwater recharge reduction rate (RAPReHS) utilizing remotely sensed data from the FLDAS and TERRACLIMATE datasets. The RAPReHS employs a simplified version of the water balance equation, estimating direct vertical groundwater recharge by considering the difference between precipitation, evapotranspiration, and runoff. The methodology was upscaled to improve data processing and analysis efficiency using an open-source cloud-computing platform (Google Earth Engine) over a 20-year period. The first results reveal a strong correlation between decreasing groundwater recharge rates and natural vegetation in the eastern region. By utilizing the RAPReHS index, forest preservation strategies can be prioritized. This study is in the framework of SDG 13 (Climate Action), which aims to mitigate the impacts of climate change on the environment and society. By exploring the impact of land use changes and wildfires on groundwater recharge at a regional scale in Bolivia, this research contributes to the inclusion of groundwater in policy guidelines for sustainable water management.

Keywords: Climate change, Groundwater recharge, SDG

CLICK TO RETURN TO THE PROGRAMME

Hydrological processes and evolution in the critical zone of a small island: the case of Pianosa Island in the Tuscan Archipelago

M Menichini[1]., M Burlando[2]., L Franceschi[1]., A Berton[1]., L Costanza[1]., S Trifirò[1]., L Foresi[3]., R Giannecchini[1]., M Doveri[1]

[1]Institute of Geosciences and Earth Resources – CNR, Pisa, Italy; [2]Tuscan Archipelago National Park and Tuscan Islands Biosphere Reserve - MAB UNESCO; [3]Department of Physical Sciences, Earth and Environment, University of Siena

Understanding and quantifying hydrology processes represent a mandatory step in semi-arid/arid regions for defining the vulnerability of these environments to climate change and human pressure and providing useful data to steer mitigation and resilience strategies. This generally valid concept becomes even more stringent for highly sensitive ecosystems, such as small islands like Pianosa. The project intends to deploy a multi-disciplinary approach for better understanding and quantifying the hydrological processes affecting water availability and their evolution, possibly suggesting best practices for water sustainability. First results pointed out as over the last decade the precipitation regime has led to a major rate of evapotranspiration and minor effective infiltration that caused a decreasing of piezometric level over several years. Quantity and chemical-isotopic features of rainfall and effective infiltration water measured/collected by a raingauge and a high precision lysimeter describe the hydrological processes at soil level and characterize the rate and seasonality of groundwater recharge. Hydrogeological and geochemical data of groundwater are highlighting the distribution and relationship among different groundwater components, including the seawater intrusion. Furthermore, the comparative analyses of continuative data monitoring in wells and weather station showed the presence of possible concentrated water infiltration processes during rainfall extreme events that induce a quick response of shallow groundwater system in terms of water level rise and decrease of electrical conductivity. Thus, elements of vulnerability of the aquifer to pollution are pointed out, as well as the possibility to provide technical solutions for enhancing water infiltration and groundwater availability.

Keywords: Unsaturated zone, high-precision lysimeter, effective infiltration, shallow aquifer

CLICK TO RETURN TO THE PROGRAMME

Water Quality of Cape Town Aquifers – The WWQA African Use Case

K Riemann., D Blake

The Umvoto Foundation, South Africa

Globally, rivers, lakes and groundwater face complex anthropogenic water quality alterations posing risks to human health, food security and ecosystems. The World Water Quality Alliance (WWQA) forms an open, global consortium, pooling expertise on water quality science and technology innovation and providing a participatory platform for water quality assessments and co-designing tailored and demand-driven services. It addresses priority topics relevant to water governance, scalable water solutions and emerging issues in water management. The African Use Cases provided an initial testbed that puts the quality of surface water and groundwater into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals. Central to the initial Africa Use Cases was the integration of in-situ, remote sensing-based earth observation and modelling data to derive the best possible current state of water quality (baseline). Of the three African Use Cases, "Cape Town's Major Aquifer Systems" focused mainly on groundwater quality in an urban environment. One of the success factors for the Cape Town Aquifer Use Case was the ability of the team to integrate the three different data types of the triangle approach on a sub-catchment scale. This required understanding the complex surface and groundwater systems and their interaction (flow paths and fluxes) in the urban environment. A robust stakeholder engagement process and the introduction of transformative art also drove the success of the Cape Town Use Case. The outcomes of this process will be presented and discussed in this presentation.

Keywords: WWQA, Water quality, awareness

The impacts of climate change on groundwater in South Africa

Z Gaffoor[1]., K Pietersen[2]

[1]IBM Research Africa, Johannesburg, South Africa; [2]Institute for Water Studies, University of the Western Cape, South Africa

Climate change is expected to have a significant impact on freshwater resources across the globe. Changes in the distribution and quantities of rainfall over the coming decade will impact various earth systems, such as vegetation, contributions to streamflow, sub-surface infiltration and recharge. While groundwater resources are expected to act as a buffer, changes in rainfall will ultimately impact the recharge process and, thus, groundwater reserves. Understanding these changes is a crucial step to adapt better and mitigate climate change's impacts on water resources. This is valid in South Africa, where much of the population depends on groundwater as a freshwater supply. Hence, this research presents the status quo regarding climate change's impacts on South Africa's groundwater resources. Reviewing relevant literature, the impacts on recharge, groundwater quantity (storage changes), discharge and groundwater-surface water interactions, groundwater quality, and groundwater-dependent ecosystems are discussed. In addition, utilizing factors such as rainfall, slope and vegetation cover collected from CMIP6 climate projections, changes in groundwater recharge potential from the past through the present and future are demonstrated. The findings illustrate uncertainty over the long-term impacts of climate change on groundwater for different regions and various aquifers. However, global warming could lead to reduced recharge, which impacts groundwater reserves.

Keywords: CMIP6, GRACE data, groundwater recharge potential

CLICK TO RETURN TO THE PROGRAMME

Investigation of Seawater Intrusion due to Group-Well- Pumping of a local coastal aquifer in Durban, South Africa.

M Demlie[1]., S Rajpal[1]., N Govendor[2]., D Naidoo[2]
[1]University of KwaZulu-Natal, School of Agriculture, Earth and Environmental Sciences, South Africa, University of KwaZulu-Natal; [2]Geosure (Pty) Ltd, South Africa

The response of an alluvial and estuarine deposit aquifer, locally known as the Harbour Beds Formation, located in the coastal area of the Durban Metropolitan District to 48 hours of group well pumping is studied to understand its potential for groundwater supply and consequent seawater intrusion. Groundwater levels were monitored from the three pumped boreholes and piezometers. Similarly, EC, TDS and pH were monitored every hour from the boreholes and piezometers. Hydrochemical and water isotopes (2H and 18O) samples of groundwater were taken at 12, 18, 24, 36, 42 and 48 hours during pumping. The results indicate that the aquifer has a transmissivity, hydraulic conductivity and storativity of 48.97 m2/d, 1.7 m/day and 0.0032, respectively. The generally monitored EC, TDS, and pH have been fairly constant during the pumping period and didn't show any seawater intrusion. Similarly, the hydrochemical data monitored for the three boreholes show general Na-Ca-HCO3-Cl-dominated groundwater throughout the pumping duration. However, uneven drawdown distribution and complex groundwater flow conditions indicate that the aquifer structure and hydraulic properties are heterogeneous. The water isotopes (2H and 18O) monitoring during the test pumping suggests spatial variability regarding water recharging the Harbour Beds aquifer. Though limited in area extent, the Harbour Beds Formation aquifer is a productive aquifer with acceptable water quality and can be a viable water source for domestic and industrial uses. However, continuous long-term monitoring of water quality and groundwater levels using data loggers is recommended to prevent induced seawater intrusion and contamination.

Keywords: Eastern South Africa, environmental isotopes, group-well-pumping, Harbour Beds Formation, hydrochemistry

Assessment of groundwater potential of the Kalahari aquifers in Kavango East and West regions, Namibia

A David., T Abiye
School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The Kavango West and East regions are situated in a semi-arid area northeast of Namibia and bounded by the perennial Okavango River on the northern border. Groundwater in the area is the main source of water supply for the inhabitants living further from the river. In addition, most bulk water users along the river have boreholes for their water supply. With a semi-arid climate, drought in the regions is common and inflicts devastating effects on local communities. More drought relief boreholes are being drilled to sustain communities, increasing the dependency of the inhabitants on groundwater. The complexity of the behaviour and nature of the groundwater in the regions is poorly understood, and there are no strategies to manage these aquifers properly. As a result, an attempt was made to better understand the groundwater potential by examining several hydrogeological factors involved. A basic water-balance approach was used in determining the groundwater potential of the middle and lower Kalahari aquifers. The total resource potential for the entire region is estimated at 144 447.16 x 10^6 m^3/a, demonstrating great resource potential with significant storage space. The greatest potential is shown in the middle Kalahari aquifers, comprising about 94% of the total resource. Groundwater recharge, as one of the hydrogeological factors, was determined using the chloride mass balance method, giving an average of 6.03 mm/a for the entire study area. If utilized sustainably, the Kalahari aquifers can sustain most communities within the two regions, especially those further from the Okavango River.

Keywords: Groundwater potential, Kalahari aquifers, recharge, water-balance

CLICK TO RETURN TO THE PROGRAMME

Using derivative plot analysis for diagnosing boundary conditions and flow regimes, Heuningnes, Cape Agulhas, South Africa

A Xaza

Department of Earth Sciences, University of the Western Cape, Bellville 7535, South Africa

This study focused on improving the understanding of flow regimes and boundary conditions in complex aquifer systems with unusual behavioural responses to pumping tests. In addition, the purpose was to provide a novel analysis of the hydrogeological properties of aquifers to deduce inferences about the general expected aquifer types to inform new practices for managing groundwater. In this paper, we report that using derivative analysis to improve understanding of complexities in aquifer flow systems is difficult and rarely used in groundwater hydraulics research work. Thus, we argue that if derivatives are not considered in the characterizing flow regime. The heterogeneity of aquifers, boundary conditions and flow regimes of such aquifers cannot be assessed for groundwater availability, and the decision to allocate such water for use can be impaired. A comprehensive database was accessed to obtain pumping tests and geological data sets. The sequential analysis approach alongside derivative analysis was used to systematically perform a flow dimension analysis in which straight segments on drawdown-log derivative time series were interpreted as successive, specific, and independent flow regimes. The complexity of using derivatives analyses was confirmed. The complexity of hydraulic signatures was observed by pointing out n sequential signals and noninteger n values frequently observed in the database. We suggest detailed research on groundwater flow systems using tracer methods like isotopes and numeric models must be considered, especially in multilayered aquifer systems such as the Heuningnes catchment.

Keywords: Flow regimes, boundary conditions, flow dynamics

CLICK TO RETURN TO THE PROGRAMME

How alluvial storage controls surface water – groundwater interactions in dryland intermittent and ephemeral streams: A case study from semi-arid Australia

M Zarate

British Geological Survey, United Kingdom

Water balance partitioning within dryland intermittent and ephemeral streams controls water availability to riparian ecosystems, the magnitude of peak storm discharge and groundwater replenishment. Poorly understood is how superficial geology can play a role in governing the spatiotemporal complexity in flow processes. We combine a new and unusually rich set of integrated surface water and groundwater observations from a catchment in semi-arid Australia with targeted geophysical characterisation of the subsurface to elucidate how configurations of superficial geology surrounding the stream control the variability in streamflow and groundwater responses. We show how periods of stable stream stage consistently follow episodic streamflow peaks before subsequent rapid recession and channel drying. The duration of the stable phases increases in duration downstream to a maximum of 44±3 days before reducing abruptly further downstream. The remarkable consistency in the flow duration of the stable flow periods, regardless of the size of the preceding streamflow peak, suggests a geological control. By integrating the surface water, groundwater and geological investigations, we developed a conceptual model that proposes two primary controls on this behaviour which influence the partitioning of runoff: (1) variations in the permeability contrast between recent channel alluvium and surrounding deposits, (2) the longitudinal variations in the volume of the recent channel alluvial storage. We hypothesise optimal combinations of these controls can create a 'Goldilocks zone' that maximises riparian water availability and potential for groundwater recharge in certain landscape settings and that these controls likely exist as a continuum in many dryland catchments globally.

Keywords: Groundwater, groundwater recharge, drylands, ephemeral streams, focused recharge, intermittent, semi-arid, streamflow, surface water, water balance

CLICK TO RETURN TO THE PROGRAMME

Literature review on methodologies used to assess surface water and groundwater interaction

A Bissoon, E Haricombe
WSP, South Africa

A major surface water–groundwater interaction difficulty is the complex nature of groundwater resources due to heterogenic aquifer parameters. Wholistic research is needed to inform the conceptual understanding of hydrological processes occurring at surface and groundwater interfaces and their interactions at watershed scales. Sustainable water resource use and protection depend on integrated management solutions involving cross-disciplinary studies and integrated hydrological modelling. Choosing appropriate methods such as spatial and temporal scales, measurable indicators, differences in software parameters, and limitations in application often results in uncertainties. The study aims to conduct a comparative literature analysis, integrating case studies focusing on surface water–groundwater interaction. Literature reviews from case studies focus on several factors, including soils and vegetation studies, hydrochemical signatures, hydrodynamics of the main stem channels, desktop land use assessments, surface water quality profiling, conceptual hydrogeological modelling and numerical modelling in support of understanding surface water – groundwater interaction and highlight the challenges of methods used to indicate baseflow transition. This paper considers the methodologies demonstrated in the literature and their use in numerical modelling to obtain measurable indicators related to the two hydrological disciplines comprising (i) the surface water component and (ii) the groundwater component. These outcomes should be used to inform the potential future impacts on water quality from activities such as mining, irrigation, and industrial development. Water management protocols related to integrated surface water and groundwater studies for the future are critical in ensuring sustainable water management methods on a catchment scale.

Keywords: Groundwater, case studies, methodologies, surface water, sustainable

Evaluation of the conditions that impact the spreading, impact and groundwater monitoring for the risk of brine leakage from wells into fresh groundwater aquifers

N Hartog., J van Lopik
KWR Water Research Institute, The Netherlands

Contamination of fresh groundwater aquifers by leakage of saline water (brine) from wells may result from various activities, such as salt mining, wastewater or concentrate injection and geothermal heat production. Here, the brine transport and consequences for groundwater monitoring have been explored for a wide range of brine compositions, leakage and hydrogeological conditions using numerical simulations that considered buoyancy impacts from both temperature and density differences. Results show that at close distances to the leak (up to 3-5 meters away), breakthroughs of the salt (at 1,000 mg/L) occurred within one month of leakage in all modelled scenarios. At a radial distance of 10 meters, with a leak rate of 2 m^3/d, it took three to six months in most cases. For the leakage of relatively warm brines, the heat transport is separated from the salinity due to thermal retardation resulting in monitoring the breakthrough of heat more closely to the depth of the leakage point than the salinity breakthrough.

In summary, this study indicates that the mode of dispersion of leaking geothermal brine strongly depends on the brine properties and the leakage and hydrogeological conditions. At the same time, vertical monitoring of temperature and conductivity at a limited distance from brine injection wells (<5m) appears to be a robust method for detecting a possible leak relatively quickly (within a month) and after limited contamination. The monitoring signal in the event of leakage is also sufficiently distinctive to prevent false positives.

Keywords: Groundwater contamination, brines, density-driven flow, groundwater monitoring, leakage risk

CLICK TO RETURN TO THE PROGRAMME

Upscaling Preferential Flow in Heterogeneous Porous Media from the Laboratory to the Field

[1]T James Oudega., [2]G Lindner., [3]A Scheidl., [3]A Eder., [3]P Strauss., [1]A Blaschke., [1]G Blösch., M [1]Stevenson

[1]Vienna University of Technology, Austria; [2]Medical University of Vienna, Austria; [3]Federal Agency for Water Management, Austria

Due to public health or environmental concerns, performing tracer tests in the field by injecting pathogenic microorganisms or contaminants of emerging concern into groundwater is not permitted. Therefore, examining the effects of preferential flow processes on these contaminants under controlled saturated conditions must be done in the laboratory, but the resulting transport parameters cannot be directly applied to field-scale groundwater models. This research considers how an upscaling relationship can be found using a colloidal tracer and three different scales: small laboratory columns (0.1 m scale), a large intact core (1 m scale), and a real-world gravel aquifer (10 m scale). The small columns were filled with gravel from boreholes at the field site, an alluvial gravel aquifer close to Vienna, Austria. The mesoscale consists of an undisturbed gravel column from a gravel pit near Neuhofen an der Ybbs, Austria. Results showed that a certain pattern emerges after an initial scale-dependent threshold, regardless of differences due to the small columns being repacked with aquifer material and the large column and field site being “undisturbed”. In this way, the mesoscale column allows us to gain insight into upscaling processes by incorporating an in-between step when comparing groundwater transport at the column- to the field scale.

Keywords: Heterogeneity, preferential flow, upscaling

Recharge under review: Implications for Water Resources Management

[1]N Vermaak., [2]S Fourie., [1]S Esterhuyse., [2]D Hohne

[1]Centre for Environmental Management, UFS, South Africa; [2]Department of Water and Sanitation, South Africa

Recharge is an important factor in Water Resources Management as it is often used as a measure for sustainable groundwater abstraction and resource allocation. The recharge estimation is, however, linked to a specific time, area and conditions and then generalised over seasons and years. Current climate change estimations predict a warmer and drier future for western parts of southern Africa. Groundwater recharge estimation methods do not consider changes in climate over the short term and do not consider the longer trends of a changing climate. This article looks at the various methodologies used in recharge estimations and their application in a changing world, where rainfall period, pattern and intensity have changed, where higher temperatures lead to higher actual evapotranspiration and where there is a greater need for water resources for use in agriculture, industry and domestic use. Our study considers the implications of current recharge estimation methods over the long term for water allocation and water resources management of groundwater resources from local and aquifer catchment scale estimations.

Keywords: Recharge; groundwater availability; groundwater management

CLICK TO RETURN TO THE PROGRAMME

Unfolding the spatial heterogeneity of the natural background level of arsenic in groundwater at the mesoscale using data from sites under remediation

[1]L Landi., [2]M Rotiroti., [1]M Filippini
[1]Department of Biological, Geological and Environmental Sciences, Alma Mater Studiorum, University of Bologna, Italy; [2]Department of Earth and Environmental Sciences, University of Milano-Bicocca, Italy

The Natural Background Level (NBL) of contaminants in groundwater is typically determined using regional-scale monitoring networks or site-specific studies. However, regional scale values are limited in their ability to capture natural heterogeneities that affect contaminant mobility at smaller scales, potentially leading to local over- or underestimation of the natural contaminant concentration. Conversely, site-specific studies can be expensive and time-consuming, with limited use outside the specified case study. To overcome this issue, a study was conducted in a 2600 km^2 area, analyzing arsenic concentration values from monitoring networks of sites under remediation as an alternative source of information. The main drawbacks of the alternative dataset were the lack of information on monitoring procedures at the remediation sites or potential anthropogenic influences on the concentration data. However, these limitations were adequately managed with a thorough data pre-treatment procedure informed by a conceptual model of the study area. The NBLs estimated with the alternative dataset were more reliable than that from the regional monitoring network, which, in the worst case (i.e., in the area with the highest geological and geochemical heterogeneity), the NBL of one order of magnitude was underestimated. As a future step, the project seeks to incorporate geological and geochemical heterogeneities as secondary variables in a geostatistical analysis to produce a continuous distribution of arsenic concentrations at the mesoscale. This would provide a useful tool for managing contaminated sites and a reproducible protocol for NBL derivation in different areas, overcoming the scale issue.

Keywords: Arsenic, Natural Background Level, heterogeneity, sites under remediation

The pharmaceutical compounds diversity at two river bank filtration sites located in Warta River valley (Poland)

K Dragon[1]., R Kruć-Fijałkowska1., D Drożdzyński[2]., J Górski[1]
[1]Adam Mickiewicz University in Poznan, Poland; [2]Institute of Plant Protection-National Research Institute Poznań, Poland

Emerging contaminants (e.g. pharmaceuticals or pesticides) are increasingly detected in aquatic environments. The most apparent contamination source of river water pollution by pharmaceuticals is sewage treatment plant stations that discharge treated sewage effluent to the rivers. The river bank filtration systems (RBF) can effectively remove these contaminants. The two RBF sites were examined for pharmaceuticals: Śrem and Gorzów waterworks. The water samples for pharmaceuticals investigation were taken from the river and four continuously pumped wells at each site. Two wells near the river were chosen at each site (40-50 m) and two at a greater distance from the river (70 m in Śrem and 110 m in Gorzów). A visible increase in pharmaceutical concentrations was observed along the river. The sum of pharmaceuticals concentration is 8151 ng/l in Śrem (upstream), while in Gorzów (downstream) concentration is 9142 ng/l. A very big differentiation in pharmaceutical occurrence was observed. In Śrem, the sum of pharmaceuticals concentration is between 657 and 3290 ng/l, while in Gorzów, despite the higher concentrations of pharmaceuticals in the river, these substances were detected only in one well located at a close distance from the river (two substances at a concentration of 92 ng/l). The research proves a very big differentiation of pharmaceutical concentration even on sites located at similar hydrogeological conditions and demonstrates the necessity of its monitoring, especially in groundwater strongly influenced by river water contamination (like at RBF sites). This work has received funding from the National Science Centre Poland (grant no. 2021/41/B/ST10/00094).
Keywords pharmaceuticals compounds; river bank filtration sites

CLICK TO RETURN TO THE PROGRAMME

Can open-source remote sensing data be used to accurately downscale groundwater storage estimates?

C Viviers[1]., M van der Laan[2]., M Dippenaar[3]
[1]Department of Plant and Soil Sciences. University of Pretoria, Pretoria, South Africa; [2]Agricultural Research Council, Natural Resources and Engineering, Pretoria, South Africa; [3]Department of Engineering Geology and Hydrogeology, University of Pretoria, Pretoria, South Africa

The lack of reliable groundwater level monitoring data hinders the comprehensive understanding and sustainable management of our aquifers. New remotely sensed data products could present novel possibilities to fill *in situ* data gaps. For example, continuous monthly groundwater storage anomaly estimates at a spatial resolution of 0.25° (28 km) are made available through the Global Data Assimilation System Version 2.2 (GLDAS-2.2) data products that assimilate Gravity Recovery and Climate Experiment (GRACE) data. In this study, it was hypothesised that the open-source, higher resolution Climate Hazards Group InfraRed Precipitation With Station Data (CHIRPS) precipitation data and Moderate Resolution Imaging Spectroradiometer (MODIS) evapotranspiration data could be used to downscale groundwater storage anomalies (GWSA) for local scale investigations. Using an intergranular and fractured aquifer, as well as a karst aquifer as case studies, both enclosed within the Steenkoppies Catchment (A21F), two respective random forest regression (RFR) models were developed to downscale GLDAS-2.2 GWSA. Sampling monthly training data without accounting for temporal lagging resulted in an increased correlation, index of agreement (IA) and improved RMSE for the intergranular and fractured aquifer. Where the correlation between the observed groundwater storage changes and the GLDAS-2.2 groundwater storage estimates were weaker, however, accounting for the temporal lags resulted in an improved RMSE. The final product is a 0.05° (5.5 km) grid of monthly time-series GWSA estimates that can improve groundwater resource assessments, understanding aquifer recharge, modelling accuracies and better overall decision-making regarding Integrated Water Resource Management (IWRM).

Keywords: GLDAS-2.2, GRACE, Google Earth Engine, machine learning

Validation of algorithms for estimating changes in groundwater storage from GRACE gravity satellite data for Poland

[1]T Solovey., [2]J Śliwińska., [1]A Brzezińska., [1]M Przychodzka
[1]Polish Geological Institute, Poland; [2]Space Research Centre, Polish Academy of Sciences, Poland

The development of satellite technologies creates more and more opportunities to build modern tools for monitoring the state of groundwater. The use of the GRACE satellites to monitor GWS changes has become widespread, but the degree of accuracy with which remote sensing data can estimate these changes is unclear. In this study, we quantified changes in the GWS in Poland from 2009 to 2022 using GRACE observations, in-situ data, and GLDAS. Long-term trends and seasonality were calculated and analysed for each time series. The correlation analysis between GRACE TWS, GWS obtained from GRACE and GLDAS, and GWS in situ was performed using linear regression. Pearson and Spearman's methods show that GRACE performance is good in the region of shallow (up to 3 m) presence of thick (above 5 m) unconfined porous aquifers; however, performance is worse in a region with multiple aquifer systems, including fissured and karst aquifers. In addition, an unrepresentative groundwater GRACE signal is obtained in regions with surface water storage, such as the Baltic Sea area. It was also found that there is very high consistency between the GRACE observations and wells water level changes, while the GWS series obtained from GRACE and GLDAS do not provide adequate compatibility. According to the GRACE data, the results suggest that evapotranspiration and the hydrodynamic system have the greatest impact on the sensitivity of the GWS estimation. The results are important for better processing the GRACE data to obtain a representative signal for the GWS assessment.

Keywords: GRACE, groundwater storage assessment, validation

CLICK TO RETURN TO THE PROGRAMME

Groundwater discharge and climate change: The application of RCMs to assess long-term effects of climate change on spring flow along the Apennines

T Casati[1]., A Navarra[1,2]., M Filippini1., A Gargini[1]

[1]Department of Biological, Geological and Environmental Sciences, Alma Mater Studiorum, University of Bologna. Italy; [2]Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, CMCC, Bologna, Italy

Global warming affects atmospheric and oceanic energy budgets, modifying the Earth's water cycle with consequent changes to precipitation patterns. The effects on groundwater discharge are still uncertain at a global and local scale. The most critical step to assess future spring flow scenarios is quantifying the recharge-discharge connection. This research aims to predict the long-term effects of climate change on the discharge of seven main springs with long hydrologic series of discharge values located in different hydrogeological settings along the Apenninic chain (Italy). The investigated springs are strategic for either public water supply or mineral water bottling. The Apennines stretch along the Italian peninsula in a Northwest-Southeast direction, crossing the Mediterranean area that represents a critical zone for climate change due to a decreased recharge and increased frequency and severity of droughts over the last two to three decades. In this communication, the data of one of the chosen springs, called Ermicciolo (42°55'25.8"N, 11°38'29.5"E; 1020 m ASL), discharging out from the volcanic aquifer of Mount Amiata, are presented. Statistical and numerical tools have been applied to analyse the time series of recharge-related parameters in the spring's contribution area and the spring discharge from 1939 to 2022. To estimate the impact of climate change on the Ermicciolo's outflow, a regional atmospheric circulation model has been downscaled to the spring catchment area and used to derive the expected discharge at the 2040-2060 time span, according to the build-up data-driven model of the recharge-discharge relationship in the past.

Keywords: Climate change, downscaling, forecasting, GCMs, groundwater discharge

The application of artificial intelligence techniques to support groundwater management in Southern Africa

Z Gaffoor., K Pietersen., T Kanyerere

IBM Research Africa, South Africa; Institute for Water Studies, University of the Western Cape, South Africa

The beneficial groundwater use in the Southern African Development Community (SADC) is well documented. Groundwater plays a vital role in the freshwater supply mix and, in some cases, is the only source of freshwater, especially in the arid region of SADC. However, the management of this resource is hampered by numerous challenges, such as lack of data, limited tools to leverage available data, lack of resources, institutional mismanagement, and climate change, amongst others. Of these challenges, the lack of data and the tools needed to transform this data into information has consequences for the decision-making process. Hence, this research attempts to address this challenge by demonstrating the use of big data and artificial intelligence (AI) to fill data gaps with new unconventional sources and model groundwater processes to transform data into actionable information. The presentation focuses on introducing the landscape of groundwater big data in SADC, followed by a review of regional AI applications. After that, novel approaches to using AI in various aquifers across SADC are demonstrated in their applicability to support groundwater management. Finally, the challenges facing the use of AI in SADC are discussed, followed by opportunities for new research based on the current state-of-the-art AI techniques. The results illustrate that AI can be a helpful tool for supporting groundwater management in SADC. However, the need for enhanced data collection is evident for these techniques to be generally applicable.

Keywords: Big data analytics, machine learning, transboundary aquifers

CLICK TO RETURN TO THE PROGRAMME

A combined stochastic-analytical method for the assessment of climate change impact on spring discharge

A Kovacs

Senior Researcher, University of Miskolc, Hungary

This study describes a novel methodology for predicting spring hydrographs based on Regional Climate Model (RCM) projections to evaluate climate change impact on karstic spring discharge. A combined stochastic-analytical modelling methodology was developed and demonstrated on the Bukovica karst spring catchment at the Durmitor National Park, Montenegro. As a first step, climate model projections of the EURO-CORDEX ensemble were selected, and bias correction was applied based on historical climate data. The regression function between rainfall and peak discharge was established using historical data. The baseflow recession was described using a double-component exponential model, where hydrograph decomposition and parameter fitting were performed on the Master Recession Curve.

Rainfall time series from two selected RCM scenarios were applied to predict future spring discharge time series. Bias correction of simulated hydrographs was performed, and bias-corrected combined stochastic-analytical models were applied to predict spring hydrographs based on RCM simulated rainfall data. Simulated climate scenarios predict increasing peak discharges and decreasing baseflow discharges throughout the 21st century. Model results suggest that climate change will likely exaggerate the extremities regarding climate parameters and spring discharge by the end of the century. The annual number of drought days shows a large variation over time. Extremely dry years are periodic, with a frequency between 5-7 years. The number of drought days seems to increase over time during these extreme years. The study confirmed that the applied methodology can successfully be applied for spring discharge prediction.

Keywords: Spring hydrograph, analytical model, climate change, stochastic model

CLICK TO RETURN TO THE PROGRAMME

Formation of the groundwater chemical composition in the Quaternary aquifer of the coastal valley (North Sinai, Egypt)

N Vinograd[1]., A Potapov[2]., Y Mohamed[3]

[1]St.Petersburg, State University, Russia; [2]Mining Institute of the Ural Branch of the Russian Academy of Sciences, Russia; [3]Zagazig University, Egypt

The research aims to reveal possible ways of formation of the chemical composition of mineral and fresh groundwater in Quaternary sediments of the coastal plain of Northern Sinai. Statistical assessment of the distribution of various hydrochemical indicators of mineral and fresh groundwater has been carried out according to the following data samples: 1) the general population for all Quaternary deposits (164 wells); 2) the central zone (74 wells); the eastern zone (25 wells); the western zone (65 wells). The following variables were assessed: total dissolved solids (TDS) (in ppm), concentrations of major components (in epm and % epm), pH value and the depth of the sampled well (ds) (in meters). The physicochemical equilibria between the groundwater and rock–forming carbonate and sulfate minerals were calculated using the PHREEQC software. Saturation indices (SI) for groundwater of three zones in relation to various rock-forming minerals were analyzed. Correlation relationships were obtained for TDS, major components and some genetic coefficients ($(R_{equ}=(Na^{+}+K^{+})/(Ca^{2+}+Mg^{2+})$; Na^{+}/Cl^{-}; SO_4^{2-}/Cl^{-}; Ca^{2+}/SO_4^{2-}). It was concluded that the groundwater chemical composition is defined by infiltration recharge and/or intrusion of Mediterranean seawater. Most likely, during short-term flood periods, the infiltration into aquifers significantly exceeds the evaporation. Despite the relatively high evaporation rate, the degree of groundwater metamorphization is below the saturation level in relation to sulfates and carbonates. The research is of great practical importance for assessing freshwater resources to provide potable water supply.

Keywords: Quaternary sediments, Sinai Peninsula, fresh water, groundwater, groundwater–rock system, mineral water, physicochemical equilibrium

CLICK TO RETURN TO THE PROGRAMME

Developing and testing a Groundwater Mapping methodology to increase drilling success rates for sustainable drinking water boreholes in African Arid and Semi-Arid Lands – the case study of Cunene Province, Angola

D Benedicto van Dalen[1]., H van den Berg[1]., A Fall[2]., E Monteiro[2]., J Baptista[3]
[1]Acacia Water bv, Gouda, The Netherlands; [2]UNICEF, Angola; [3]SEGEO, Luanda, Angola

In recent years, practical applications of vector and raster multi-layers overlay analysis to enhance outcomes of conventional hydrogeological methods for allocation of productive boreholes have been applied in arid and semi-arid lands and is currently being tested in Ethiopia, Kenya, Somalia and Angola in cooperation with UNICEF. Advanced Remote Sensing (RS) and Geographic Information Systems (GIS) techniques combined with traditional geological, hydrogeological and geophysical methods are being used for improved access to sustainable drinking water supply boreholes in the scope of a WASH program. Identifying suitable areas with a good potential for sustainable groundwater resources exploitation mainly depends on a) consistent/reliable aquifer recharge and b) favourable hydrogeological conditions for groundwater abstraction. Multi-layer analyses and attribution of layer scores to the hydrogeological information layers – aquifer recharge, aquifer class, lineaments, slope, land cover, and presence of streams – combine into a qualitative *Groundwater Suitability Map*, using pairwise comparison (weights) to determine their relative importance with the Analytic Hierarchy Process (AHP). Additionally, traditional field methods enhance the quality of outputs and delineate *Target Areas* for detailed investigations: validation of hydrogeological conceptual models, hydrogeological assessment, groundwater sampling and finally, geophysical methods. Downscaling the remote sensed information of the groundwater suitability map with field verifications is required to recommend borehole drilling sites. The engagement of stakeholders is vital for the data collection and validation of the weighting criteria analyses (AHP method), as well as for the cooperation on the ground, validation of the *Target Areas* selection and implementation.

Keywords: Analytic Hierarchy Process, WASH program, groundwater mapping, remote sensing

Understanding the pattern of spatial and temporal variations of groundwater levels using long-term monitoring data

P Fuku
Department of Water and Sanitation. South Africa

Monitoring regional groundwater levels provides crucial information for quantifying groundwater depletion and assessing environmental impacts. Temporal variation of groundwater levels is the response of the groundwater system to natural and artificial stresses in terms of groundwater recharge and discharge. The complexity and extent of the variation rest on the nature and storage properties of the aquifer system. High groundwater levels are usually found in the recharge zones and low in the discharge zones, resulting in groundwater flow from recharge areas to discharge areas. Continuous decline of groundwater levels has been observed in some of the monitoring boreholes within the National Monitoring Network. Groundwater level decline has been caused either by over-exploitation or reduction of groundwater recharge. Generally, the pattern of spatial and temporal variations of groundwater levels is the consequence of incorporating climatic, hydrological, geological, ecological, topographical, and anthropogenic factors. Therefore, understanding the pattern of spatial and temporal variations in groundwater levels requires a combined approach. A combination approach of National long-term groundwater level monitoring data, Hydrological stresses, Anthropogenic interferences, and characteristics of the groundwater system was used to understand the continuous decline of groundwater levels in selected monitoring stations across the country.

Keywords: Groundwater decline, Hydrological stresses, long-term monitoring data

CLICK TO RETURN TO THE PROGRAMME

A review of slug tests analysis on South African aquifers in potential yield and transmissivity estimations

R Lubbe., F de Lange., J Vivier

Slug tests are preliminary tests applied to determine the hydraulic conductivity and whether it is necessary to perform a pumping test on the borehole under investigation and should never be recommended as a substitute for a pumping test. For this reason, slug tests cannot be related to sustainable yield because slug tests cannot detect boundary conditions. The aim was to develop a methodology to relate slug tests to a potential yield estimation, investigating and reviewing the applicability and accuracy of the slug test methodology in South Africa, applied on fractured rock aquifers as established in 1995. The aim was achieved by reviewing the methodology applied for slug tests that are related to potential yield estimations, identifying the limitations of slug tests, investigating the possibility of updating the potential yield estimation method of 1995, and investigating the possibility of relating slug tests, to potential yield and transmissivity estimations through groundwater modelling. The investigation revealed that using transmissivity values determined through slug test homogenous modelling can be utilised to estimate the potential yield of a borehole under investigation by implementing correlation statistics. Note that this is not an absolute and is subject to limitations.

Keywords: Slug test; Potential yield; Transmissivity; Limitations; Modelling

Defining the Goldilocks Zone for Aquifer Thermal Energy Storage versus Unidirectional Ground Source Heat Pumps using Groundwater Flow and Heat Transport Modelling

H Williams

Agua Enodo Ltd, Spain

Aquifer Thermal Energy Storage (ATES) is increasingly utilised to optimise the efficiency of Ground Source Heat Pump (GSHP) systems. However, the criteria for selecting ATES over Unidirectional GSHP is not well-defined. Inappropriate selection of AETS can adversely impact the long-term viability and the GSHP system itself, as well as regional hydraulic and thermal sustainability due to adverse groundwater levels and temperature change. This is a concern in urban aquifers, where GSHP systems are increasingly common. There is a perception that ATES is always the most efficient; however, there is no clear definition of efficiency and how it can be readily assessed at the GSHP design stage. It is proposed and demonstrated herein that GSHP efficiency can be assessed by modelling borehole pumping in lieu of complex Coefficient of Performance calculations for the whole GSHP system. Borehole pumping is a more readily definable modelling outcome for comparing options at an individual site but is also a suitable proxy for comparing efficiency at different sites when given as a flow per unit rate of pumping. Operational efficiencies for ATES versus Unidirectional systems are presented using the pumping rate criteria for modelled scenarios. Here, three model inputs are varied: 1) the balance of heating and cooling, 2) the configuration of a single borehole pair across a hydraulic gradient and 3) the hydraulic gradient itself. These were assessed using coupled groundwater flow and heat transport modelling in Feflow to refine the Goldilocks Zone, the perfect balance, for these variables.

Keywords: Aquifer Thermal Energy Storage, Ground Source Heat Pump, Urban Groundwater

CLICK TO RETURN TO THE PROGRAMME

Open-loop Groundwater Heat Pumps (GWHPs) diffusion in Italian Urban areas: Modelling for the hydrogeological constraints definition

M Gizzi., A Berta., G Taddia., F Vagnon., S Lo Russo

Environment, Land, and Infrastructure Department DIATI, Politecnico Di Torino, Italy

Italian urban areas are characterized by centuries-old infrastructure: 35% of the building stock was built before 1970, and about 75% is thermally inefficient. Besides, between 60% and 80% of buildings' energy consumption is attributed to space heating. Open-loop Groundwater Heat Pumps (GWHPs) represent one of the most suitable solutions for increasing the percentage of energy consumption from Renewable Energy Sources (RES) in cities such as Turin city (NW Italy). However, allowing the diffusion of GWHPs cannot be disregarded by the knowledge about hydrogeological urban settings. As the thermally affected zone (TAZ) development could affect energetically adjacent systems, the TAZ extension must be well-predicted to guarantee the systems' long-term sustainable use. Different buildings of the Politecnico di Torino are cooled during the summer by 3 different GWHP systems. To investigate possible interactions with other neighbouring plants and to preserve the water resource by capturing its positive and productive aspects from an energy point of view, a complex urban-scale numerical model was set up for comprehensively analysing the impact of the geothermal plants on the shallow aquifer. Different simulation scenarios have been performed to define possible criteria for improving the energy functionality of the groundwater resource. Besides, the extent of the TAZ generated was defined as a function of the specific functioning modes of the different GWHP systems. Numerical simulations, legally required by competent authorities, represent a fundamental tool to be applied for defining hydrogeological constraints derived from the GWHPs diffusion in Italian cities.

Keywords: Groundwater Heat Pump System, Hydrogeology, Italy, Numerical Modeling, Renewable Energy

CLICK TO RETURN TO THE PROGRAMME

Test-pumping derivative analysis to improve conceptual understanding and abstraction yields in a complex fractured aquifer: Steenbras Wellfield (Western Cape, South Africa)

K de Bruin., L Towers., D Blake
Umvoto, South Africa

Test-pumping drawdown curves do not always sufficiently indicate aquifer characteristics and geometry and should never be analysed in isolation. Using derivative analysis and flow dimension theory, inferring the regional geometries and flow characteristics of fractured aquifers that are otherwise unknown or inconclusive is possible. As the drawdown and/or pressure front propagates through the aquifer, it reaches various hydrogeological objects that influence flow regimes and imprints a sequence of signatures in the drawdown derivative curve. The conjunctive interpretation of these flow regime sequences and hydrogeological data results in a robust, well-informed conceptual model (in terms of both local groundwater flow and the aquifer), which is vital for sustainable groundwater resource management. Derivative and flow regime analysis was applied to the test-pumping data of confined and unconfined Nardouw Aquifer (Table Mountain Group) boreholes within Steenbras Wellfield (Western Cape). Major NE-SW trending folding and transtensional Steenbras-Brandvlei Megafault Zone, in association with cross-cutting faults/fractures and younger False Bay Suite dykes, make the Nardouw Aquifer (and deeper Peninsula Aquifer) hydrogeologically complex. The sequential flow regime analyses reveal domains of conceptual flow models, including open vertical fractures, T-shaped channels, double (triple) porosity models, and leaky/recharge boundary models, amongst others. Appropriate analytical flow models (type curve fitting) are then applied for accurate aquifer parameter estimations, which are used to evaluate recommended long-term yields through predictive pumping scenarios. The outcome is an improved hydrogeological understanding and enhanced conceptual model of the aquifer, which informs numerical modelling, ecological protection, and groundwater resource management.

Keywords: Table Mountain Group, conceptual model, derivative analysis, fractured aquifer, groundwater resource management, recommended yield, test-pumping

Characterisation of the Lower Berg River Aquifer System, Western Cape, South Africa

A Parker
GEOSS, South Africa

The Lower Berg River Aquifer System, situated in the Western Cape province of South Africa, is important to the towns that overlay it, as they rely on the aquifer for water supply, which supplements industrial development and residential growth. This aquifer system is important because surface water resources in the area are finite and fully allocated. Despite studies on the Lower Berg River Aquifer System since 1976, knowledge of the geological layers, recharge and discharge areas, and groundwater flow paths remain limited. This study aimed to provide greater insight and understanding of the aquifer to assist in better management. Investigations included a Time Domain Electromagnetic airborne geophysical survey, the assessment of groundwater levels, infiltration tests, hydrochemical analyses, and stable and radioactive isotope analyses. These methods allowed for the identification of the aquifer's layers and extent, determination of water quality in different parts of the aquifer, delineation of flow paths through the saturated and unsaturated zones, identification of inter-aquifer flow, as well as different modes of recharge.

Keywords: Lower Berg River, aquifer, discharge, geophysics, groundwater, isotopes, recharge, tritium

CLICK TO RETURN TO THE PROGRAMME

Well integrity assessment using fibre optic active distributed temperature sensing

M Brown., J Kennel., J Munn., C Maldaner., B Parker
University of Guelph, Canada

Groundwater quality and groundwater sample representativeness depend on the integrity of the water supply and monitoring wells. Well-integrity issues can occur by improper placement of grout seals behind the protective casing and/or by improper backfilling processes between ports. Multi-level monitoring systems are becoming common in the industry, providing depth-discrete groundwater samples and hydraulic head data from a single borehole. However, isolation between the monitoring intervals can be challenging when backfilled methods are used. No independent verification method exists to confirm seal placement for isolating monitoring intervals in such multi-level wells. A new approach using a hybrid fibre optic cable for adding heat, referred to as Active Distributed Temperature Sensing (A-DTS), is deployed in the annular space of a backfilled multi-level well. This new method is used to quantify the position of bentonite used as seals and sand packs that define the monitoring interval lengths and to identify issues associated with backfilling. A-DTS data from three boreholes with back-filled multilevel systems to 85 mbgs in a dolostone aquifer in Guelph, Ontario, Canada, demonstrates clear boundaries between backfill materials. In one interval, a deviation in the thermal data suggests a bridge in the bentonite seal, and this interval coincides with challenges in the backfilling from the field notes. The proposed method verifies well completion details, is repeatable and provides an efficient and effective way to assess well integrity impacting measurement uncertainty in a range of well types.

Keywords: Active Distributed Temperature Sensing (A-DTS), fibre optic, multilevel monitoring well, well integrity

Hydrostratigraphy of the Bauru and Guarani Aquifer Systems in the central region of the State of São Paulo (Brazil)

F Barreto., J Rusig., L Freitas., C Varnier., A Suhogusoff., R Bertolo., R Hirata
University of São Paulo, Environmental Research Institute (IPA/SEMIL), Brazil

The Guarani Aquifer System (SAG) is the main public water supply source in Bauru City (Brazil). It mostly consists of sandstones and is a confined unit of fossil waters (~600 thousand years); therefore, it is a non-renewable and finite resource. SAG is overlaid by the Bauru Aquifer System (SAB), predominantly consisting of sandstones, siltstones, and mudstones, and is essential for private water supply in the municipality. In recent decades, constant drops in water levels in SAG and increases in contaminant loads in SAB have been observed in production wells, generating the need to understand the geometry of those aquifer systems. This work presents the preliminary results of the analysis and review of hydrogeological and geophysical data from 59 deep wells and 3D geological modelling using Leapfrog Works® to represent a conceptual model of the study area. SAG has a thickness of up to 356 m in the wells and is represented, from bottom to top, by Teresina, Piramboia, and Botucatu formations. In the north and northeast regions, SAG is covered by a layer of basalts from the Serra Geral Aquifer System (SASG) with a thickness of up to 190 m. The thickness of SASG is variable (or even null) due to the action of important faults with vertical displacements that created structural windows in the region. SAB covers the Araçatuba (basal portion), Adamantina (144 m), and Marília (65 m) formations. The lower contact of SAB is made with SASG or SAG (central region). Project funded by FAPESP (2020/15434-0).

Keywords: 3D Modelling, Bauru Aquifer System, Guarani Aquifer System, Hydrostratigraphy

CLICK TO RETURN TO THE PROGRAMME

Development of Table Mountain Group aquifer wellfields and monitoring networks for the City of Cape Town (Western Cape, South Africa)

D Blake., K Riemann

Umvoto, South Africa

The City of Cape Town (CCT) initiated its "New Water Programme" in 2017 (during the major 2015-2018 "Day Zero" drought) to diversify its bulk water supply, thereby improving long-term water security and resilience against future droughts. This includes bulk groundwater abstraction from the major fractured Peninsula and Nardouw Aquifers of the Table Mountain Group (TMG) in the mountain catchments east of the CCT. The TMG aquifers are essential in sustaining groundwater-dependent ecosystems associated with the Cape Floral Kingdom – a global biodiversity (but also extinction) hotspot with exceptional endemic diversity. A strong geoethical, "no-regrets" approach is therefore required to develop TMG wellfield schemes for the CCT (and other towns/cities in the Western/Eastern Cape) to reduce the risk of any negative ecological and environmental impacts while still enhancing the drought resilience of the city, providing water for future urban growth, and meeting Sustainable Development Goals 6 and 11. To this extent, the CCT has developed an extensive regional (and local, in terms of Steenbras Wellfield) environmental monitoring network, incorporating a range of in-situ and remote sensing-based measurements across the Earth's "Critical Zone" – this includes current groundwater, surface water, ecological, soil and meteorological monitoring stations, and future seismo-geodetic monitoring. An ongoing ambition is to include this CCT TMG monitoring network into the "Greater Cape Town Landscape", which is currently in development as one of six national South African landscapes under the "Expanded Freshwater and Terrestrial Environmental Observation Network" (EFTEON) platform being hosted by the South African Environmental Observation Network.

Keywords: Critical Zone, Table Mountain Group aquifers, environmental monitoring, wellfield development, "no-regrets" approach

CLICK TO RETURN TO THE PROGRAMME

Modelling the Impact of Groundwater Pumping on Karst Geotechnical Risks in Sete Lagoas (MG), Brazil

P Galvão., C Schuch[1]., S Pereira[2]., J de Oliveira[2]., P Assunção[1]., T Halihan[3]

[1]Department of Geology, Institute of Geosciences, Federal University of Minas Gerais - Av. Pres., Antônio Carlos 6627 - Pampulha, Belo Horizonte - MG, 31270-901, Brazil; [2]Department of Geology, Federal University of Ouro Preto, Morro do Cruzeiro Campus, Ouro Preto/MG 35400-000, Brazil; [3]Oklahoma State University, School of Geology, 105 Noble Research Center, Stillwater, OK 74078, USA

Urban karst terrains can experience geotechnical issues such as subsidence or collapse induced/accelerated by groundwater withdrawal and civil works. Sete Lagoas, Brazil, is notable for overexploiting a karst aquifer, resulting in drying lakes and geotechnical issues. This study aims to evaluate the progression of geotechnical risk areas from 1940 to 2020 and to simulate future scenarios until 2100. Historical hydraulic head data from the 1940s (when the first pumping well was installed) to the 2000s, a 3D geological model, and a karst-geotechnical risk matrix for defining risk levels were employed to develop a calibrated Feflow numerical model. The results indicate that, before the first well in 1942, the groundwater flow direction was primarily towards the northeast. In the 1980s, due to the concentration of pumping wells in the central area, a cone of depression emerged, causing the flow directions to converge towards the centre of the cone, forming a zone of influence (ZOI) of approximately 30 km². All 20 geotechnical events recorded between 1940 and 2020 have occurred in high or considerable-risk zones where limestone outcrops or is mantled in association with the ZOI. For future scenarios, if the current global well pumping rate (Q = 144,675 m³/d) from 2020 remains constant until 2100, the high and considerable geotechnical risk zones will continue to expand. A 40% decrease in the global rate (Q = 85,200 m³/d) is necessary to achieve a sustainable state, defined by reduced and stabilized risk zones.

Keywords: Karst hydrogeology; numerical model; water management; subsidence; overexploitation

Sampling procedures for PFAS and pharmaceuticals –Recommendations vs. reality

A Kuczyńska

Polish Geological Institute-National Research Institute, Poland

PFAS and pharmaceuticals in groundwater are two of many synthetic compounds currently under the attention of many researchers and environmental administration in Europe, especially in light of the revision of the EU Groundwater Directive 2006/118/EU. The two types of substances were first included in the voluntary groundwater watch list and were first formally regulated at the EU scale. This regulation implies that they will be obligatory to be monitored within national monitoring programmes for groundwater body status assessment procedures across the EU. While there is no doubt about the need to regulate the presence of these substances in groundwater, sampling procedures and QC/QA protocols may be challenging to implement as no official guidelines exist. Although scientific literature allows us to define protocols usually based on precautionary principle, these may be too difficult and expensive to implement at the national scale monitoring. This article describes a work that the Polish Geological Institute – National Research Institute undertook to define an optimal sampling process for PFAS and pharmaceuticals in groundwater. Experimentally tested factors included cleaning pumps between sampling sites, the need for using protective suits during sampling and the influence of ambient air on sample quality. Results showed that sampling protocols for PFAS and pharmaceuticals do not need to be modified concerning current protocols as these seem to be sufficient to protect groundwater samples from unintentional cross-contamination.

Keywords: emerging contaminants, groundwater monitoring, sampling protocols

CLICK TO RETURN TO THE PROGRAMME

How groundwater temperature is affected by climate change: a systematic review and meta-analysis

E Egidio., D De Luca., M Lasagna

University of Torino, Italy

Groundwater (GW) is a target of climate change (CC), and the effects become progressively more evident in recent years. Many studies reported the effects on GW quantity, but of extreme interest is also the assessment of qualitative impacts, especially on GW temperature (GWT), because of the consequences they could have. This study aims to systematically review the published papers dealing with CC and GWT, to determine the impacts of CC on GWT, and to highlight possible consequences. Scopus and Web of Science databases were consulted, obtaining 144 papers. However, only 45 studies were considered for this review after a screening concerning eliminating duplicate papers, a first selection based on title and abstract, and an analysis of topic compatibility through examination of the full texts. The analysed scientific production from all five continents covers 1995-2023 and was published in 29 journals. As a result of the review, GWT variations due to CC emerged as of global interest and have attracted attention, especially over the past two decades, with a multidisciplinary approach. A general increase in GWTs is noted as a primary effect of CC (especially in urban areas); furthermore, the implications of the temperature increase for contaminants and groundwater-dependent ecosystems were analysed, and various industrial applications for this increase (e.g. geothermy) are evaluated. It's evident from the review that GWT is vulnerable to CC, and the consequences can be serious and worthy of further investigation.

Keywords: climate change, groundwater, groundwater temperature, review, temperature

Improving groundwater dynamics: A key factor for successful tidal marsh restoration.

N Van Putte[1,2]., P Meire[1]., P Seuntjens[1,3,4]., G Verreydt[1,2]., S Temmerman[1]

[1]ECOSPHERE research group, University of Antwerp, Antwerp, Belgium; [2]iFLUX, Niel, Belgium; [3]VITO (Flemish Institute for Technological Research), Mol, Belgium; [4]Department of Mathematics and Data Analysis, Biomath, Ghent University, Ghent, Belgium

Along estuaries and coasts, tidal wetlands are increasingly restored on formerly embanked agricultural land to regain the ecosystem services provided by tidal marshes. One of these ecosystem services is the contribution to estuarine water quality improvement, mediated by tidally induced shallow groundwater dynamics from and to tidal creeks. However, in restored tidal marshes, these groundwater dynamics are often limited by compacted subsoil resulting from the former agricultural land use in these areas. Where the soil is compacted, we found a significant reduction of micro- and macroporosity and hydraulic conductivity. To quantify the effect of soil compaction on groundwater dynamics, we set up a numerical model for variably saturated groundwater flow and transport in a marsh and creek cross-section, which was parametrized with lab and field measurements. Simulated results were in good agreement with *in situ* measured groundwater levels. Where a compacted subsoil is present (at 60 cm depth), 6 times less groundwater and solutes seep out of the marsh soil each tide, compared to a reference situation without a compact layer. Increasing the creek density (e.g., through creek excavation) and increasing the soil porosity (e.g., by organic soil amendments) resulted in a significant increase in soil aeration depth and groundwater and solute transport. As such, these design measures are advised to optimize the contribution to water quality in future tidal marsh restoration projects.

Keywords: HYDRUS, groundwater dynamics, macroporosity, tidal marsh restoration, water quality improvement

CLICK TO RETURN TO THE PROGRAMME

Hydrogeochemical and temporal nitrate variation in an unconfined urban aquifer in a tropical area in Brazil

D Lookin[1]., C Varnier[2]., F Barreto[1]., R Bertolo[1]., R Hirata[1]
[1]CEPAS|USP: Groundwater Research Center. Rua do Lago, 562, Cidade Universitária, São Paulo, SP, Brazil. Zip Code: 05508-080; [2]Environmental Research Institute (IPA/SEMIL). Rua Joaquim Távora, 822, Vila Mariana, São Paulo, SP, Brazil. Zip Code: 04015-011

The Bauru Aquifer System (BAS) is a significant source of water supply in the urban area of Bauru city. Over the last decades, BAS has been widely affected by human activities. This study evaluates the nitrate plume in groundwater from 1999 to 2021 and how it relates to urbanization. The methods used were analysis of the data of 602 wells, survey of the sewer network and urbanization, and reassessment of nitrate concentration data. The seasonal analysis of 267 groundwater samples allowed the identification of concentrations up to 15.1 mg/L N-NO_3^- mainly from the area's central region, where the medium to high-density urban occupation dates back to 1910. Otherwise, the sewage system was installed before 1976. The reactions controlling the nitrogen species are oxidation of dissolved organic carbon, dissolution of carbonates, mineralization, and nitrification.

Wells, with a nitrate-increasing trend, occur mainly in the central and northern regions, settled from 1910 to 1980-1990, when no legislation required the installation of the sewage network before urbanization. In turn, wells with stable or decreasing nitrate concentrations occupy the southwestern areas. Over the years, the concentrations of these wells have shown erratic behaviour, possibly caused by the wastewater that leaks from the sewer network. The bivariate statistical analysis confirms a high positive correlation between nitrate, sanitation age, and urban occupation density, which could serve as a basis for the solution of sustainable groundwater use in the region. Project supported by FAPESP (2020/15434-0) and IPA/SEMIL (SIMA.088890/2022-02).
Keywords: Bauru Aquifer System, Hydrogeochemistry, Nitrate, Urban Area

Development and calibration of tools for preliminary quantification of the Hydrogeological Interference Risk of tunnels in different geological settings

E Pugliese[1]., S Rodani[2]., A Dematteis[3]., A Gargini[1]
[1]Alma Mater Studiorum – University of Bologna, Italy; [2]Italferr Spa – Gruppo ferrovie dello Stato Italiano, Italy; [3]Lombardi SA, 6512 Bellinzona-Giubiasco, Switzerland

Predicting and quantifying the hydrogeological interference of big underground works is a complex effort. This is due to the considerable uncertainty in estimating the key geomechanical and hydrogeological parameters affecting the area of potential interference of the projects. Moreover, the pattern of involved groundwater flow systems is hardly identified, either in natural or disturbed conditions. Base tunnels through mountain ridges are particularly complex in their interactions with groundwater. Several approaches and tools have been published to predict the magnitude and distribution of water inflows inside tunnels and their impact on many receptors (springs, rivers, lakes, wells, groundwater-dependent ecosystems). The research, co-funded by Italferr Spa (Italian railway national company for tunnel design), deals with calibrating and validating these methods based on huge datasets. Main engineering companies provided data from completed base tunnel projects. In particular, in this study, the Drawdown Hazard Index (DHI) method has been calibrated with a dataset of a 15 km long sector of the Gotthard base tunnel drilled through a crystalline geological setting. The calibration involved only the Potential Inflow (PI) parameter to verify the matching between the probability of inflow and the actual output of the excavation, according to the available data in the preliminary stage of the project. An alternative tool based on a machine-learning approach was then applied to the same dataset, and a comparison was presented.
Keywords: Hydrogeological Risk, potential inflow, tunnel, machine Learning

CLICK TO RETURN TO THE PROGRAMME

Coupling saturated and unsaturated groundwater models to represent the effect of intensive anthropogenic activities at the regional scale

H Kupfersberger., G Rock., G Klammler., J Vrzel

JR-AquaConSol GmbH, Steyrergasse 21, 8010 Graz, Austria

The abstract presents a 2D modelling approach alternative to a 3D variable saturated groundwater model of solute or heat transport at the regional scale. We use FEFLOW to represent processes in the saturated zone, coupled with various models describing the unsaturated zone. The choice of the latter depends on modelling needs, i.e. simulation of the movement of seepage water and nitrate fate with respect to crop rotation patterns and dynamic characteristics of heat gradients, respectively. The flexibility of coupling specialized models of different subsurface compartments provides the opportunity to investigate the effects of land use changes on groundwater characteristics, considering the relevant drivers in sufficient detail, which is important in regions with intensive anthropogenic activities. The coupling can be operated either with (direct coupling) or without (sequential coupling) including the feedback between the saturated and the unsaturated zones depending on the depth of the groundwater table below the surface. Thus, the approach allows for reasonable computational times. The Westliches Leibnitzer Feld aquifer in Austria (43 km²; Klammler et al., 2013; Rock and Kupfersberger, 2018) will be presented as an example highlighting the needed input data, the modelling workflow and the validation against measurements.

Keywords: Groundwater flow model, solute/heat transport model, saturated-unsaturated zone coupling, Leibnizer Feld aquifer, FEFLOW, land use

Radical evolution of the Geneva transboundary aquifer agreement: an example for the sustainability of TBA governance?

G de los Cobos

GESDEC-DT - Canton of Geneva, Switzerland

The Geneva aquifer is internationally recognized for its transboundary resource management agreement between Switzerland and France, described as the first groundwater management agreement in the world. Signed in 1978 and renewed in 2008, this agreement on managing a shared underground resource has long been an example for establishing other agreements worldwide, particularly by UNESCO and its hydrological program via the TBA commission of the IAH. Like many countries worldwide, Switzerland and France experienced a critical summer of 2022 concerning the use of water resources, both surface and underground. The system applied in the cross-border agreement for using the aquifer involves French participation in the costs of managing aquifer recharge (MAR), depending on the total pumping. It shows that the French part, having consumed more water to compensate for the extreme drought of 2022, has seen its bills increase considerably. Development plans show that the population of Greater Geneva will increase considerably by 2030-2040, requiring significant medium-term water availability (30% additional water). Therefore, the French institutions' political leaders have formally asked the authorities of the canton of Geneva to review the conditions linked to the quotas and calculation methods included in the 2008 agreement. A new agreement could be a real example of positive cross-border coordination for decision-makers finding themselves in a blocked or even conflicting situation due to differences in managing a shared resource revived by the effects of climate change.

Keywords: Geneva aquifer, MAR, climate change, governance, transboundary aquifer agreement

CLICK TO RETURN TO THE PROGRAMME

Time scale connection of groundwater with adjacent spheres

M Taniguchi
Research Institute for Humanity and Nature, Japan

Groundwater is connected with the earth's interior, atmosphere, ocean sphere, and human sphere. Fluid, heat, and dissolved materials are crossed over the boundaries of adjacent spheres with different time scales in dynamics. These different time scales include event scales such as earthquakes and Tsunami, seasonal scales such as precipitation seasonality, a decade or longer scales such as climate change, and human scales such as groundwater pumping, land cover/use changes, and social revolutions such as industrialization, green revolution, urbanization, and globalization in Anthropocene. This study shows two examples of groundwater connected with different time scales. The first is thermal signals preserved in groundwater by earthquake, climate change, and anthropogenic impacts with different time scales. Thermal signals in groundwater from the Kumamoto earthquake in 2016 revealed evidence of fluid flow from the earth interior and Aso mountain. The thermal signal in groundwater in Kumamoto also showed the impacts of global warming and urbanization, as well as changes in precipitation and land use. The second example is the connectivity between residence time of groundwater and groundwater consumption in social revolutions such as industrialization and urbanization in the Anthropocene, as well as World War II as an example of groundwater for emergency situations.

Keywords: Anthropocene, Kumamoto, adjacent spheres, social revolution, time scale

Global potential groundwater recharge in response to climate variability and teleconnection

C Moeck[1]., W Berghuijs[2]., E Luijendijk[3]
[1]Eawag (Swiss Federal Institute of Aquatic Science and Technology), Switzerland; [2]Free University Amsterdam, The Netherlands; [3]University of Bergen, Norway

Periodic climate variability, such as that caused by climate teleconnections, can significantly impact groundwater, and the ability to predict groundwater variability in space and time is critical for effective water resource management. However, the relationship between climate variability on a global scale and groundwater recharge and levels remains poorly understood due to incomplete groundwater records and anthropogenic impacts. Moreover, the nonlinear relationship between subsurface properties and surface infiltration makes it difficult to understand climate variability's influence on groundwater resources systematically. This study presents a global assessment of the impact of climate teleconnections on groundwater recharge and groundwater levels using an analytical solution derived from the Richards equation. The propagation of climate variability through the unsaturated zone by considering global-scale climate variability consistent with climate teleconnections such as the Pacific-North American Oscillation (PNA) and the El Niño/Southern Oscillation (ENSO) is evaluated, and it is shown when and where climate teleconnections are expected to affect groundwater levels. The results demonstrate the dampening effect of surface infiltration variability with depth in the vadose zone. Guidance for predicting long-term groundwater levels and highlighting the importance of climate teleconnections in groundwater management is provided. The obtained insights into the spatial and temporal variability of groundwater recharge and groundwater levels due to climate variability can contribute to sustainable water resource management.

Keywords: climate variability, global, groundwater recharge, teleconnections, unsaturated zone

CLICK TO RETURN TO THE PROGRAMME

Keep the flow: Applying a HOPE model

J Goldin
University of the Western Cape, South Africa

Top-down governance systems are not well designed to secure the protection, use and management of groundwater at the local level and, on the contrary, perpetuate 'wicked' problems of poor groundwater management and protection. Citizen science promises solutions to these 'wicked' problems. We present findings from a project in the Hout Catchment, Limpopo, where citizen scientists monitor water in wells in remote rural settings. We redress the bias towards the natural sciences and pay attention to human systems as it is through engaging with people's 'ordinary' citizens that they will protect their environment for better planetary health. To better understand these human systems that impact groundwater, we emphasise diversity and difference and argue for a HOPE model (heralding optimal participatory equity). HOPE has intrinsic and extrinsic value (equity) (addressing a hydrological void and understanding groundwater features). To achieve this, we open up a toolkit providing very practical methods. Using these tools, we propose that citizen science - taking science away from remote institutions, out of libraries and laboratories - and bringing it close to people is emancipatory and addresses new ways of understanding polycentric governance. Citizen science is transformative; citizens move from a passive state of non-engagement with science to acting as scientists. Disempowered people now have a sense of being part of the betterment of their world and improved water resources management. Narrowing the natural and social sciences divide is crucial for improved polycentric governance.

Keywords: citizen science, community engagement, governance, social justice, transformative

Showcasing a global-scale, 3D coastal groundwater salinity model

J King[1]., D Zamrsky[2]., J Delsman[1]., J Verkaik[1]., M Bierkens[2]., G Oude Essink[1,2]
[1]Deltares, The Netherlands; [2]Utrecht University, The Netherlands

Being extensively available and of high quality, groundwater is the primary source of freshwater in coastal regions globally. However, due to anthropogenic and natural drivers, groundwater salinisation is a growing threat to this resource's long- and short-term viability. The causes and timescales of aquifer salinisation are complex and difficult to quantify, information essential for suitably timed mitigation strategies. One way to inform these strategies and develop storylines of future freshwater (un)availability is through 3D groundwater salinity modelling. These models can predict current groundwater distributions and quantitatively assess the impacts of a projected increase in groundwater extraction rates and sea-level rise. Until recently, detailed 3D models on this scale have been largely unattainable due to computational burdens and a shortage of in-situ data. Fortunately, recent developments in code parallelization, reproducible modelling techniques, and access to high-performance computing (e.g., via parallel SEAWAT) have made this feasible. Machine learning and data mining developments have also allowed an unprecedented opportunity to constrain and calibrate those models. With this in mind, we present our progress towards global 3D salinity modelling by showcasing a regional-scale model in the Mediterranean Sea area. This test case uses newly developed, automated geological and salinity interpolation methods to create initial conditions while implemented in a parallelized version of SEAWAT. The modelling outcomes highlight the potential of supra-regional scale modelling in the context of global (planetary) processes and localised anthropogenic effects.

Keywords: Coastal aquifers, global modelling, groundwater salinity, paleo-reconstruction, parallel. SEAWAT, sea level rise

CLICK TO RETURN TO THE PROGRAMME

First Nations Communities as Partners in Hydrogeology

S Bourke[1]., B Moggridge[2]., K Wallis[3]., D Owen[3]., J Searle[3]., S Bolton[3]., M Currell[4]
[1]University of Western Australia, Australia; [2]University of Canberra, Australia; [3]IAH Australia; [4]RMIT, Australia

Aboriginal and Torres Strait Islander people have inhabited the lands now known as Australia for over 65,000 years. Their communities are intricately connected to the land and waters through culture and tradition. However, there are few examples of integrated water resource management that serve Aboriginal and Torres Strait Islander communities or cultural interests. This is particularly the case for groundwater. In Australia, Indigenous connections to groundwater have historically been overlooked or, in some cases, assumed not to exist.

On the contrary, many Aboriginal and Torres Strait Islander cultures have longstanding physical and spiritual connections to a range of artesian and subartesian groundwater resources. These cultures also house accurate records of groundwater systems. Despite this, groundwater management in Australia remains dominated by Western scientific perspectives, and the groundwater sector poorly integrates Indigenous stakeholder concerns or knowledge into groundwater management and planning. IAH Australia has prepared and signed an Indigenous Groundwater Declaration intending to raise awareness among the groundwater community of the value of Indigenous perspectives and knowledge of groundwater systems. This Declaration can be viewed and signed at http://declaration.iah.org.au. This presentation provides examples of effective partnerships between Indigenous Communities and Government or Academic groundwater professionals. While progress has been made, challenges must be overcome to integrate Indigenous knowledge and connections into groundwater resource management.

Keywords: Cultural Water Values, First Nations Groundwater Connections, Social Hydrogeology

Making the Invisible Visible: Do Aquifers Have Agency?

A Healy., M Cuthbert
Cardiff University, Wales

In the social sciences, there has been a ‘posthuman’ turn, which seeks to emphasise the role of non-human agents as co-determining social behaviours. In adopting a ‘more-than-human’ approach, the academy seeks to avoid claims of human exceptionalism and extend the social to other entities. In this paper, we explore the extent to which the more-than-human approach might be applied to groundwater and aquifers and the implications that this may have for groundwater science. The role of groundwater in complex adaptive socio-ecological systems at different scales is increasingly well-documented. Access to groundwater resources positively influences societal welfare and economic development opportunities, particularly in areas where surface waters are scarce. The potential adverse effects of human activities on the quantity or quality of groundwaters are also widely reported. Adopting a ‘properties’ approach, traditional social science perspectives typically describe aquifers as structuring the agency of human actors. To what extent might aquifers also have agency, exhibited in their capacity to act and exert power? Drawing on insights from 5 cities across sub-Saharan Africa, we argue for the agency of aquifers in light of their capacity to evoke change and response in human societies. In doing so, we draw on the concept of the more-than-human to argue for a more conscious consideration of the interaction between the human and non-human water worlds whilst acknowledging the critical role played by researchers in shaping these interactions.

Keywords: agency, groundwater, more-than-human, social, socio-hydrogeology

CLICK TO RETURN TO THE PROGRAMME

Learning from complexity: Multi-stakeholder water resources management in the island of Santa Cruz, Galápagos (Ecuador)

V Re[1]., J Rizzi[2]., C Tuci[3]., C Tringali[4]., E Mendieta[5]., A Marcomini[6]

[1]Earth Sciences Department, Via Santa Maria 53, Pisa, Italy; [2]Norwegian Institute of Bioeconomy Research, Raveien 9, 1430 Ås, Norway; [3]Universidad International del Ecuador, Jorge Fernández S/N, Quito 170411, Ecuador; [4]Independent researcher, Trieste, Italy; [5]Independent, Arquitect, Loja, Ecuador; [6]Ca' Foscari University of Venice, Department of Environmental Sciences, Informatics and Statistics, Via Torino 155 30172 Venezia-Mestre, Italy

The Galápagos Archipelago (Ecuador), traditionally considered a living museum and a showcase of evolution, is increasingly subject to anthropogenic pressures affecting the local population who has to deal with the challenges of accessing safe and sustainable water resources. Over the years, numerous national and international projects have attempted to assess the impact of human activities on both the water quality and quantity in the islands. However, the complexity of the stakeholders' structure (i.e., multiple agents with competing interests and overlapping functions) and the numerous international institutions and agencies temporarily working in the islands make information sharing and coordination particularly challenging. A comprehensive assessment of water quality data (physico-chemical parameters, major elements, trace elements and coliforms) collected since 1985 in the Santa Cruz Island revealed the need to optimise monitoring efforts to fill knowledge gaps and better target decision-making processes. Results from a participatory approach involving all stakeholders dealing with water resources highlighted the gaps and potentials of water resources management in complex environments. Particularly, it demonstrated the criticalities related to data acquisition, sustainability of the monitoring plan and translation of scientific outcomes into common ground policies for water protection. Shared procedures for data collection, sample analysis, evaluation and data assessment by an open-access geodatabase were proposed and implemented for the first time as a prototype to improve accountability and outreach towards civil society and water users. The results reveal the high potential of a well-structured and effective joint monitoring approach within a complex, multi-stakeholder framework.

Keywords: Socio-hydrogeology, sustainability, technical cooperation, transdisciplinarity

CLICK TO RETURN TO THE PROGRAMME

Digging Deeper: Exploring the socio-environmental impacts of sand mining in Southern Africa

D Walker[1]., M Smigaj[2]., K Moreri[2]., T Sithabile[3]., C Pringle[4]., J McCosh[5]., S Mustafa[1]., C Hackney[6]., N Jovanovic[7]., W Otto7

[1]Wageningen University. The Netherlands; [2]University of Botswana, Botswana; [3]Botswana International University of Science & Technology, Botswana; [4]Resilient Systems Institute (RSI); [5]Institute of Natural Resources (INR), South Africa; [6]Newcastle University, United Kingdom; [7]University of Western Cape, South Africa

Sand mining in southern Africa is on the rise, fuelled largely by rapid urbanisation. This creates a range of societal and biophysical challenges and supports livelihoods in regions with high unemployment. Relevant scientific studies are scarce. This study explores the impacts of sand mining from ephemeral rivers on Botswana, South Africa and Mozambique communities through field visits, interviews, modelling, remote sensing and legislative analysis. What was expected to be a hydrogeology project focussing on water resources identified a broader range of issues that should be considered. Initial results uncovered a range of negative biophysical impacts, including alteration of hydrological regimes, which in turn affect groundwater recharge and exacerbate drought and flood risks, destruction of riparian vegetation, increased erosion, damage to infrastructure (including bridges and roads), reduced water quality, and the spread of invasive plant species. Equally important are the range of social impacts, such as drowning people and livestock, loss of agricultural land, increased traffic, dust, noise and crime. Complex governance arrangements influence these social and environmental challenges. The findings highlight the need to adopt an inter- and trans-disciplinary approach that considers linkages between human and natural systems. This approach is essential for finding sustainable solutions for the provision of construction materials that limit detrimental impacts on water resources, ecosystems and livelihoods.

Keywords: extraction industry, governance, interdisciplinarity, livelihoods

A new Danish groundwater mapping and modelling concept for targeted agricultural N-regulation

B Hansen.,

Geological Survey of Denmark and Greenland (GEUS), Denmark

Globally, losses of excess nitrogen (N) from agriculture are affecting our air and water quality. This is a well-known environmental threat and is caused by food production for an ever-growing population. Since the 1980s, many European countries, such as Denmark, have successfully combatted N pollution in the aquatic environment by regulating and introducing national agricultural one-size-fits-all mitigation measures. However, further reduction of the N load is still required to meet the demands of, e.g., the EU water directives. Scientifically and politically, implementing additional targeted N regulation of agriculture is a way forward. A comprehensive Danish groundwater and modelling concept has been developed to produce high-resolution groundwater N retention maps showing the potential for natural denitrification in the subsurface. The concept's implementation aims to make future targeted N regulation successful environmentally and economically. Quaternary deposits, formed by a wide range of glacial processes and abundant in many parts of the world, often have a very complex geological and geochemical architecture. The results show that the subsurface complexity of these geological settings in selected Danish catchments results in large local differences in groundwater N retention. This indicates a high potential for targeted N regulation at the field scale. A prioritization tool is presented that has been developed for cost-efficient implementation at a national level to select promising areas for targeted N regulation.

Keywords: Groundwater, agriculture, denitrification, modelling, nitrogen, regulation, surface waters

CLICK TO RETURN TO THE PROGRAMME

Basin-scale transfer of nitrate pollution from groundwater to surface water in an intensively irrigated system

M Rotiroti[1]., E Sacchi[2]., M Caschetto[1]., C Zanotti[1]., L Fumagalli[1]., T Bonomi[1]

[1]University of Milano-Bicocca, Italy; [2]University of Pavia, Italy

Basin-scale studies addressing the transfer of pollutants among groundwater and surface water bodies are essential to support local authorities in the sustainable management of freshwater resources. This work revealed that, in the hydro-system of the Oglio River basin (Northern Italy), nitrate pollution in groundwater, originated by overfertilization, is transferred downstream to surface water bodies via outflow through lowland springs and baseflow to gaining rivers. Downstream groundwater is unaffected due to reducing conditions that facilitate denitrification. It follows that efficient measures to reduce nitrate pollution in surface water bodies should not be applied solely to rivers/streams but, instead, they should include the upstream groundwater body. The work aimed at understanding nitrate pollution dynamics in an intensively irrigated hydro-system, focusing on the role played by the complex interaction among irrigation water, surface water and groundwater. The study relied on nitrate concentration, Cl/Br ratio, stable isotopic composition of water, nitrate and boron in groundwater, river, lake, spring, and rainwater samples. Results highlighted a well-defined spatial distribution of nitrate concentrations in groundwater, mainly driven by irrigation practices: (1) where groundwater-fed irrigation is done, return flow promotes high nitrate concentrations (>50 mg/L) due to groundwater recirculation; (2) where intensive surface-water-irrigation is practised, fed by low-nitrate river water, return flow generates lower nitrate concentrations (<50 mg/L) due to dilution. This work highlighted the importance of a holistic approach jointly investigating surface water, groundwater, and irrigation water when nitrate pollution is examined at a basin scale.

Keywords: Cl/Br ratio, Irrigation return flow, Po Plain, boron, dilution, stable isotopes

Groundwater and surface water interdependencies in a water-scarce arid system, Sandveld, South Africa

L Smit

GEOSS, South Africa

The largely groundwater-dependent Sandveld region's water resources have been put under severe strain due to increased agricultural and town development and recent increased interest in mineral exploration within these catchments. The area known locally as the Sandveld consists of the coastal plain along the west coast of South Africa, bordered by the Olifants River to the north and east, the Berg River to the south and the Atlantic Ocean coastline to the west. Groundwater is considered an essential source of fresh water for the town and agricultural supply. It also plays a major role in maintaining the functionality of the natural environment, especially concerning the coastal wetlands, such as the Verlorenvlei Wetland, designated as a Wetland of International Importance (Ramsar Site). Monitoring boreholes displayed a general drop in water levels, and a decrease in surface water flow has been reported. This has resulted in the drying up of wetland areas within the catchments. This investigation focused on conceptualising the geohydrological setting and defining the groundwater-surface water interactions and interdependencies. The assessment entailed a complete review and analyses of available hydrogeological and hydrochemical data and reports obtained through Stellenbosch University, the Department of Water and Sanitation and the private consulting sector. The priority groundwater areas were delineated, and recommendations on the regional management of these aquifers were made. The research characterised the geohydrological setting and outlined the Sandveld surface water systems' dependency on groundwater baseflow and spring flow.

Keywords: Catchment, coastal wetlands, groundwater, hydrogeology, management, surface water

CLICK TO RETURN TO THE PROGRAMME

Evaluating dry wells for flood management in urban catchments using integrated surface-subsurface flow models

J Liu[1]., P Brunner[2]., T Tokunaga[3]

[1]Department of Environment Systems, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Chiba 277–8563, Japan;
[2]Centre for Hydrogeology and Geothermics, University of Neuchâtel, Rue Emile Argand 11, 2000 Neuchâtel, Switzerland

Floods result in significant human and economic losses worldwide every year. Urbanization leads to the conversion of natural or agricultural land covers to low-permeability surfaces, reducing the infiltration capacity of the land surface. This amplifies the severity and frequency of floods, increasing the vulnerability of communities. Drywells are subsurface structures built in the unsaturated zone that act as managed aquifer recharge facilities to capture stormwater runoff. They are particularly well-suited for the urban environment because of their low land occupancy. In this study, we utilized an integrated surface-subsurface flow modelling approach to evaluate the effectiveness of dry wells in reducing urban runoff at a catchment scale. We developed a 3D model with HydroGeoSphere, characterizing a synthetic unconfined aquifer covered by a layer of low-permeability materials. Sensitivity analyses of land surface conditions, aquifer properties, dry well designs, and rainfall conditions were performed. Model results indicated that dry wells are more effective in reducing runoff when the land surface has a higher Manning roughness coefficient or the aquifer material has a higher hydraulic conductivity. Dry wells should be situated beneath drainage routes with high runoff flux to achieve optimal performance. Increases in dry well radius or depth enhance the infiltration capacity, but deeper dry wells can contaminate groundwater through infiltrating stormwater. Dry well performance declines with higher rainfall intensity, emphasizing the need for local rainfall intensity–duration–frequency (IDF) data to inform the design level of dry wells in specific catchments.

Keywords: Drywell, flood, surface-subsurface flow model, urban catchment

CLICK TO RETURN TO THE PROGRAMME

Contribution of gravel pit lakes in reducing the groundwater nitrate contamination originating from agricultural land

I Karlović[1]., T Marković[1]., A Smith[2]., A Kulaš[3]., M Udovič[3]., S Orlić[4]

[1]Croatian Geological Survey, Milana Sachsa 2, 10000 Zagreb, Croatia; [2]British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 5GG, United Kingdom; [3]Department of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, 10000 Zagreb, Croatia; [4]Ruđer Bošković Institute, Bijenička cesta 54, 10000 Zagreb, Croatia

The alluvial aquifer in the Varaždin region has a long-standing problem with high groundwater nitrate concentrations, mainly from agricultural activities. Since groundwater is used in public water supply networks, it is important to ensure its sustainable use. The aquifer is also used to exploit gravel and sand, and the increased demand for this valuable construction material causes the excavation of gravel pit lakes, making groundwater more vulnerable. Although engineered processes can remove nitrate from groundwater, natural attenuation processes should be investigated to understand the nitrogen behaviour and additional mechanisms for groundwater remediation. Previous research has shown nitrate is a conservative contaminant in the critical zone. Aerobic conditions within an aquifer system prevent significant denitrification. Thus, nitrification is the main process controlling nitrogen dynamics in groundwater. Since groundwater and gravel pit lakes are hydraulically connected, and natural nitrate attenuation exists in these lakes, an additional mechanism for groundwater remediation is possible. This work used isotope hydrochemistry and groundwater modelling to investigate gravel pit lakes as possible sites to reduce nitrate concentration in groundwater. Based on the isotopic composition of groundwater and nitrate concentrations, water balance and solute mass balance were calculated, which made it possible to estimate the nitrate attenuation rate in gravel pit lakes. The gained retardation factor was applied to the groundwater flow and nitrate transport model through several scenarios to evaluate the contribution of gravel pit lakes in reducing the groundwater nitrate concentrations.

Keywords: Varaždin aquifer, gravel pit lakes, groundwater, groundwater remediation, nitrate

CLICK TO RETURN TO THE PROGRAMME

Integrated Modelling of the Hydrological Dynamics of the Semi-arid Hout-Sand Catchment, South Africa

E Bjerre[1]., K Thage[1]., A Aaes[1]., K Villholth[2]., J Koch[3]., R Scheider[3]., T Sonnenborg[3]., K Jensen[1]
[1]University of Copenhagen, Denmark; [2]Water Cycle Innovation, South Africa; [3]Geological Survey of Denmark and Greenland, Denmark

The interaction between dryland hydrological fluxes and the high spatial and seasonal climate variability is inherently complex. Groundwater recharge is episodic, and rivers are ephemeral. When flow occurs in the river network, water is lost through the riverbed, giving rise to focused recharge, which could be a significant part of total recharge. We have used the integrated and physically based MIKE SHE modelling system to analyze the hydrological processes and fluxes in the 7,715 km2 Hout-Sand catchment in the South African part of the Limpopo River Basin. The discharge hydrograph measured at the outlet station is highly episodic, with a small baseline flow component superimposed by high flow events in response to intense rainfall. Likewise, the groundwater hydrographs from the area are characterized by rapid increases in groundwater levels in response to high rainfall events with recurrence intervals of several years. Due to the scarcity of basic measurements and information, we used data products from satellite platforms to supplement the information on rainfall, evapotranspiration, soil moisture, land use and irrigated areas. We applied MIKE SHE to test different conceptual flow models of the catchment by calibrating the different models against direct measurements of river discharge and groundwater levels and indirect estimates of evapotranspiration and soil moisture from satellite products. By analyzing the simulated model dynamics and the resulting values for the calibration parameters, we identified the most plausible conceptual model, which then forms the basis for water resources assessment and management recommendations for the Hout-Sand catchment.

Keywords: Drylands, conceptual flow model, integrated dynamic hydrological modelling, water resources, assessment and management

Understanding the influence of Artefacts on the Darcy Velocity Estimations from Point Dilution Tracer Tests

S Mofokeng[1]., M Gomo[2]
[1]Department of Water and Sanitation, South Africa; [2]Institute for Groundwater, Bloemfontein, South Africa

Darcy Velocity (Vd) is often estimated through a single-borehole Point Dilution Tracer Test (PDTT). Vd is used in the investigation of contaminant transport and distribution in aquifers. The tracer dilution rate in groundwater is controlled by horizontal groundwater flux. However, it can be affected by other artefacts, such as diffusion and density effects. Although there are studies on tracer tests, there has not been much done to gain an understanding of how these artefacts affect the correct Vd estimation. This study, therefore, aims to investigate and provide an understanding of the influence of artefacts on the PDTT through laboratory experiments conducted using a physical model representing a porous media. A total of 18 experiments were performed with different NaCl tracer concentrations under constant horizontal groundwater flow and no-flow conditions. The study results show that the density sinking effect affects an early period of tracer dilution, which can lead to overestimation of Vd; therefore, these stages should not be used to estimate Vd. The study, therefore, proposes a way in which PDTT data should be analysed to understand the effects of artefacts on Darcy velocity estimation.

Keywords: Contaminant transport, Darcy velocity, groundwater, horizontal groundwater flow, point, dilution tracer test

CLICK TO RETURN TO THE PROGRAMME

Groundwater overuse and water quality challenges in a large metropolitan catchment

B Karthikeyan[1]., E Lakshmanan[2]., 1M Schneider[1]

[1]Hydrogeology Research Group, Institute of Geological Sciences, Freie Universität Berlin, 12249 Berlin, Germany; [2]Department of Geology, Anna University, Chennai 600 025, India

Conjunctive use of surface water and groundwater plays a pivotal role in sustainably managing water resources. An increase in population, especially in the cities, increases the demand for water supply. Additional infrastructure to meet the needs and treatment techniques to remove the pollutants should be updated from time to time. Closing the urban water cycle by recycling and reusing treated sewage in the water sector can significantly reduce excessive groundwater extraction. However, this method is being implemented in only a few cities in developed countries. In the closed urban water cycle, treated sewage is discharged to rivers or other surface water bodies and used for managed aquifer recharge (MAR). Bank filtration, soil aquifer treatment and infiltration ponds are available MAR methods that augment the groundwater resources and remove pollutants during the natural infiltration process. These cost-effective natural treatment methods serve as a pre-treatment technique before public water supply to remove turbidity, algal toxins, bulk dissolved organic carbon and pathogenic microorganisms. The successful performance of these treatment methods depends on the need and feasibility for MAR, suitable hydrogeological conditions, sub-surface storage capacity of the aquifers, availability of suitable areas for MAR, type of MAR, source of recharge water, quality criteria, assessing the past, present and future climatic conditions. Case studies on groundwater resources management and water quality assessment, including for organic micropollutants from a large urban catchment in India, are presented.

Keywords: managed aquifer recharge, megacity, persistent organic pollutants, urban catchment

Assessment of hydrochemistry and heavy metal contamination in the groundwater around an abandoned Copper Mine area in Klein Aub, Namibia

S Uugulu., N Poulton., A Tse., M Harris

University of Namibia, Namibia

The long mining history in Namibia has resulted in numerous abandoned mines scattered throughout the country. Past research around the Klein Aub abandoned Copper mine highlighted environmental concerns related to past mining. Considering that residents of Klein Aub depend solely on groundwater, there is a need to thoroughly investigate groundwater quality in the area to ascertain the extent of the contamination. This study made considerable effort to characterise groundwater quality using a comprehensive approach of quality assessment and geostatistical analysis. Onsite parameters reveal that pH ranges between 6.82-7.8, electrical conductivity ranges between 678 - 2270 µS/cm, and dissolved oxygen ranges between 1.4 -5.77 mg/L. With an exemption of two samples, the onsite parameters indicate that water is of excellent quality according to the Namibian guidelines. The stable isotopic composition ranges from −7.26 to -5.82‰ and −45.1 to -35.9‰ for δ18O and δ2H, respectively—the groundwater plots on and above the Global Meteoric Water Line, implying no evaporation effect. Hydrochemical analyses show bicarbonate and chloride as dominant anions, while calcium and sodium are dominant cations, indicating groundwater dissolving halite and mixing with water from a recharge zone. The heavy metal pollution index of the groundwater is far below the threshold value of 100, which signals pollution; it contrasts the heavy metal evaluation index, which clustered around 3, implying that the heavy metals moderately affected groundwater. Copper, lead and Arsenic were the main contributors to the values of the indices.

Keywords: Contamination, Copper, Heavy metal, Klein Aub

CLICK TO RETURN TO THE PROGRAMME

Real-time iFLUX sensors reveal rapidly changing groundwater flow dynamics in wetland ecosystems

N Van Putte[1,2]., P Meire[1]., M Grodzka-Łukaszewska[3]., J November[2]., G Verreydt[1,2]

[1]ECOSPHERE research group, University of Antwerp, Antwerp, Belgium; [2]iFLUX, Niel, Belgium; [3]Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology, Warsaw, Poland

Shallow groundwater dynamics play a crucial role in wetland ecosystems and are key to climate change resilience. Therefore, conserving and restoring wetland areas requires excellent knowledge of groundwater flow dynamics, which are often rapidly changing following extreme weather events and anthropogenic impacts such as groundwater extraction. Traditional methods to estimate groundwater flow require extensive modelling or rely on point measurements, missing the effect of crucial short-term events and impeding quick actions to conserve the wetlands' ecohydrological status. Here, we present a newly developed sensor that can measure real-time groundwater flow velocity and direction. The sensor probe consists of two bidirectional flow sensors that are superimposed. It is installed in a dedicated pre-pack filter and can measure a broad range of groundwater flow velocities from 0.5 cm/day to 2000 cm/day. With an IoT (Internet of Things) system, sensor data is wirelessly transmitted and visualized in real-time on an online dashboard. In addition, we show a selection of results from a case study in the Biebrza National Park (Poland) and a nature reserve in Damme (Belgium). In both ecosystems, we could capture changes in groundwater flow velocity and direction resulting from precipitation and evapotranspiration events. As such, we are confident that our sensors provide new insights into rapidly changing groundwater dynamics and will become an invaluable tool in ecohydrological studies worldwide, ultimately leading to more integrated management strategies to protect and conserve remaining wetlands.

Keywords: Internet of Things, ecohydrology, groundwater flow, sensor development, wetland conservation

CLICK TO RETURN TO THE PROGRAMME

Variable-scale conceptual framework for shallow groundwater systems in the low-relief, water-limited Canadian Boreal Plains

K Hokanson[1]., K Devito[2]., C Mendoza[1]

[1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada; [2]Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada

Case studies illustrate a conceptual framework for shallow groundwater flow systems' temporal and spatial variability with groundwater-surface water interactions in the Boreal Plains of Canada. The framework was developed using a twenty-year hydrometric dataset (*e.g.*, climatological and streamflow data, hydraulic heads, vertical hydraulic head gradients, geochemical and isotopic signatures). The region is characterized by low-relief glacial landscapes, with a mosaic of forestlands and peatlands, and a subhumid climate, resulting in spatially heterogeneous storage and transmission properties, variable recharge and evapotranspiration potentials, and highly complex patterns of water movement. Two primary spatiotemporal scales were examined to create a holistic, variable-scale conceptual model of groundwater movement: the large scale (*e.g.*, glacial landforms, regional topography, decadal climate cycles) and the small scale (*e.g.*, individual landcover, local hummocks, annual moisture deficits). Water table behaviour, evapotranspiration rates, and runoff were controlled by a hierarchy of interactions between hydrological processes occurring at different spatiotemporal scales; however, the specific order of controls depends on the hydrogeological setting. The case studies, supported by empirical and numerical modelling, demonstrate that smaller-scale heterogeneities in geology and recharge can dominate over topographic controls, particularly in areas with high conductivity or hummocky terrain, where the climate, geology, and topographic relief are similar. Many hydrogeological studies rely on surface topography as a first-order control; however, with field observations and modelling, this conceptual framework demonstrates the need to consider the potential dominance of subsurface characteristics and processes, plus climate, especially in landscapes with low recharge and low relief.

Keywords: Groundwater-surface water interactions, long-term study, recharge, spatiotemporal scales, subsurface connectivity

CLICK TO RETURN TO THE PROGRAMME

Distribution, Formation Conditions and Genesis of High-Quality Groundwater Containing Metasilicate in Zhaojue County, Southwest China

C Zou[1,2]., S Zou[2]., D Zhud[2]

[1]School of Environment Science and Spatial Informatics, China University of Mining and Technology, Xuzhou 221116, China; [2]Key Laboratory of Karst Dynamics of Ministry of Land and Resources, Guangxi Karst Resources and Environment Research Center of Engineering Technology, Institute of Karst Geology, Chinese Academy of Geological Sciences, Guilin 541004, China

The drinking water health issues have been considered due to improved living standards in recent years. Finding and developing high-quality groundwater with high-level minerals has become key to improving human health. The hydrochemical test data of 66 springs in Zhaojue County were analyzed using various methods, and the spatial distributions of H_2SiO_3-rich groundwater, hydrogeochemical characteristics, formation conditions and genesis were revealed. The main results including: 1) the groundwater with H_2SiO_3 (≥25mg / L) was identified as the low salinity and alkaline water, which distributed in the six areas with the basement rocks of basalt,with a distribution area of about 79 square kilometers. The H_2SiO_3 concentration was generally 25.74~46.04 mg/L; the low mineralization characterized the H_2SiO_3-rich groundwater of study area while the main hydrochemical types of groundwater are HCO_3-Ca·Mg, HCO_3-Ca, and HCO_3-Na; the Pearson correlation coefficient between the content of H_2SiO_3 in groundwater and the content of pH is relatively high, indicating that the level of H_2SiO_3 in groundwater in the study area is significantly affected by the pH value of the solution; the H_2SiO_3-rich groundwater was influenced by the water-rock interactions, the distribution range and solubility of silicate minerals ,the development of surrounding rock fissures, and water conservation and recharge conditions in the county, among which the water-rock interactions play a critical role. The results can provide a basis for the development of mineral water industry and the construction of urban and rural high-quality water sources in Zhaojue County.

Keywords: Groundwater; H_2SiO_3; distribution; formation condition; Zhaojue County; Southwest China

Some Trans-disciplinary Legal Options to Ensure the Protection of South Africa's Utilisable Groundwater Resources

[1]C Bosman., [2G] Viljoen

[1]CBSS cc; [2]North-West University, Faculty of Law

South Africa faces serious water scarcity challenges not only because it is a semi-arid country but also due to climate change. One of the most significant effects of climate change is an increase in temperature, which inevitably increases evaporation. Increased evaporation directly reduces the availability of surface water resources. Groundwater is less susceptible than surface water resources to evaporation and thus offers resilience against the impacts of climate change. Many South African cities, communities, and farmers depend on groundwater for domestic or other socio-economic purposes. This implies that groundwater resources which are currently or potentially utilisable should be identified, and suitable legal measures should be implemented to protect these resources from potential risks of harm or damage posed by anthropogenic activity. First, This article evaluates the effectiveness of the country's existing regulatory framework to effectively protect South Africa's groundwater resources and finds that the framework can be improved significantly. Secondly, it explores regulatory opportunities within the existing legal framework to strengthen South Africa's groundwater governance regime, including using land use planning instruments to facilitate the implementation of groundwater protection zones.

Keywords: Groundwater governance; water law; protection; land use activities; hydrogeology; aquifer protection zones

CLICK TO RETURN TO THE PROGRAMME

Securing Water Supplies – Participatory Groundwater Monitoring and Management in Botswana and Uganda

P Kenabatho[1]., T Basamba[2]., B Maheshwari[3]., D Hagare[3]., T Setloboko[4]., O Mampane[4]., N Tafesse[5]., D Moalafhi[6]

[1]Department of Environmental Science; University of Botswana; Botswana; [2]Department of Agricultural Production, School of Agricultural Sciences, College of Agriculture and Environmental Sciences, Makerere University, Kampala, Uganda; [3]Western Sydney University, Hawkesbury Campus, Australia; [4]Department of Water and Sanitation, Botswana; [5]Department of Geology, University of Botswana, Gaborone, Botswana; [6]Department of Wildlife and Aquatic Resources, Botswana, University of Agriculture and Natural Resources, Gaborone, Botswana

Groundwater resources in Africa face increasing threats of over-exploitation and pollution due to urbanization, agricultural and mining activities, yet monitoring remains challenging. Conventional approaches to monitoring groundwater at the exclusion of communities have not been successful. To overcome this, it is important to fully engage and train local communities in monitoring Groundwater Levels (GWLs), Rainfall and Water Quality (RWQ), which are important for understanding groundwater dynamics in wellfields. In this way, villagers can better understand groundwater issues and convey this information to others to cooperatively manage groundwater. A pilot program to monitor GWLs and RWQ by locals was initiated in two villages each in Botswana and Uganda to learn about its effectiveness. Through continuous stakeholder engagement, the local communities in the two case studies have been facilitated, trained and supported in monitoring groundwater and using the information collected to understand groundwater trends and their sustainability. Preliminary results indicate improvement in understanding the importance of groundwater monitoring by the communities and the implications on groundwater sustainability for improved livelihoods. This has become useful to one of the communities engaged in a village-level irrigation project which depends on groundwater resources. This project builds on a successful village-level participatory approach developed in the MARVI project (www.marvi.org.in). It seeks to contribute to the United Nation's 2022 call on *"Groundwater: making the invisible visible"* to highlight the importance of better monitoring and managing this vital resource.

Keywords: Citizen Science, Livelihoods and Pollution, Participatory groundwater monitoring

CLICK TO RETURN TO THE PROGRAMME

Ensuring the provision of sustainable water services in water-scarce humanitarian environments

F Ward

Unicef

Annually, UNICEF spends approximately US$1B in water, sanitation and hygiene programming (WASH), approximately half of which is spent in humanitarian contexts. In emergencies, UNICEF supports the delivery of water, sanitation and hygiene programming under very difficult programming contexts – interruptions to access, power supply and a lack of reliable data. Many of these humanitarian situations are in contexts where water scarcity is prevalent and where the demand and competition for water are increasing, contributing to tension between and within communities. While water scarcity is not new to many of these water-scarce areas, climate change is compounding the already grave challenges related to ensuring access to safe and sustainable water services, changing recharge patterns, destroying water systems and increasing water demand. Incorrectly designed and implemented water systems can contribute to conflict, tension, and migration. Ensuring a comprehensive approach to water security and resilient WASH services can reduce the potential for conflict and use water as a channel for peace and community resilience. This presents an enormous opportunity for both humanitarian and development stakeholders to design water service programmes to ensure community resilience through a four-part approach: 1. Groundwater resource assessments 2. Sustainable yield assessments (taking into consideration future conditions) 3. Climate risk assessments 4. Groundwater monitoring/early warning systems UNICEF promotes this approach across its WASH programming and the sector through technical briefs, support and capacity building.

Keywords: Water scarcity, groundwater, climate change, assessments, monitoring, system strengthening, resilience

How can collective groundwater resource management solutions benefit water governance at various levels? An example in a volcanic watershed in East Java, Indonesia

E Cut[1]., K Ni'matul[2]., B Leimona[2]., R Anggraeni[1]., N Dorfliger[3]

[1]Danone Indonesia, Sustainability team, General Secretary, Jakarta, Indonesia; [2]CGIAR – ICRAF World Agroforestry, Bogor, Indonesia; [3]Danone, Water institute by evian, Evian, France

On the slopes of Mount Bromo, East Java (Indonesia), the land use of the Rejoso watershed is dominated by rice fields and sugarcane (lowland area), agroforestry (midstream) and horticulture and pine plantation in the upstream part. During the last three decades, some land changes driven by socio-economic development, with conversion of agroforests to rice fields, tree monoculture and horticulture, and the development of urban areas nearby, increased pressure on the watershed. Intensive irrigated rice cultivation is using groundwater from free-flowing artesian wells. Due to a lack of management, the hydraulic head and discharge of the major spring are decreasing. Rejoso watershed, like others in urban and rural areas in Indonesia, is facing challenges to guarantee sustainable integrated water resources management. Collective solutions have been implemented between 2016 and 2022 within this watershed. In the downstream, sustainable paddy cultivation and wells management with local stakeholders, aiming at improving water efficiency, have been piloted on 65 ha with 184 farmers. Water governance at the district level was re-activated and strengthened thanks to the project. Various capacity-building tools were used via radio talk shows and workshops. Members of the watershed forum of Pasuruan took some actions to reshape the structure and set up a roadmap. The implementation of collective solutions in the field was a real catalyst and serves all levels of water governance, as it is replicable. This example will be explained and illustrated after the presentation of the socio-hydrogeological context.

Keywords: groundwater governance, district level, collective solutions, stakeholders, volcanic watershed, Java Indonesia

CLICK TO RETURN TO THE PROGRAMME

Endah Setya Handayaningsih Cut.,Kasanah Ni\'matul.,Beria Leimona., Ratih Anggraeni., Dorfliger

A non-anthropocentric perspective on groundwater quality and a proposed system for groundwater quality classification and regulation

C Bosman
CBSS cc

In many countries, groundwater quality is measured against drinking water limit values or standards. While that makes sense from a water supply perspective, it is not a scientifically correct yardstick to use to classify groundwater resources or even to determine whether groundwater has been "polluted". Using this incorrect anthropocentric yardstick has led in some cases to legal action against industries, with significant liability implications, whilst the industry's activities did not at all influence the quality of the groundwater but were reflecting the conditions under which the lithology of the aquifer was deposited. A case study in KZN demonstrating this will be discussed. We are, therefore, in a situation where regulatory decisions regarding groundwater quality and the regulation of the potential impact of human activities on groundwater systems are unfair, not scientifically credible, and not legitimate. This situation hampers the effective management and regulation of groundwater use and the prevention of detrimental impacts on groundwater, even saline groundwater systems. This paper argues that it is necessary to develop a groundwater quality classification system that will categorise aquifers based on their natural quality, not just from the perspective of their usefulness as a potable supply source but would recognise the important role that aquifers with more saline natural qualities play in maintaining ecosystems that require such salinity for its survival. It concludes by considering international approaches and proposing aspects to consider in developing such a system for groundwater regulation.

Keywords: groundwater quality, groundwater quality classification system, regulation, water quality standards

Groundwater resource assessment and delineation of resource unit for the Komati catchment within the Inkomati Usuthu Management Catchment area – Mpumalanga Province, South Africa

C Monokofala

The recent uncertainties in rainfall patterns have resulted in shortages in the availability of water resources, posing significant risk to the sustainability of all living organisms, livelihoods and economic prosperity. The fact that hidden groundwater resources in semi-arid regions present a challenge to understanding and managing the resources. Various groundwater studies have been undertaken; however, the quantification is generally over-simplified due to a limited understanding of the groundwater flow regime and consideration being mostly given to water supply. Thus, the data is often not comprehensive enough and generally limited in determining how much groundwater is available to supply rural areas. The Komati catchment area is dominated by coal mining in the upper reaches and irrigation and agriculture in the lower reaches, with human settlements competing for these water resources. Five significant dams in the Komati catchment are constructed to deal with the increasing water demand for commercial agriculture in the region. However, given uncertain weather patterns, the water mix approach is imperative. This study focused on understanding the groundwater potential, characterised the aquifer system, delineated the groundwater resource units, quantified baseflow and calculated the groundwater balance that can be used as a guide for the groundwater management protocol for the catchment area. The box model approach (surface-groundwater interaction) was used to characterize the groundwater regime and understand the spatial distribution of the aquifer types, water quality and significant aquifers of interest to protect this important resource.

Keywords: Catchment scale integrated surface water and groundwater studies

CLICK TO RETURN TO THE PROGRAMME

Assessing groundwater fluxes of transboundary aquifers, using a high-resolution global groundwater model and implications on transboundary cooperation

J Verkaik[1,2]., J van Engelen[1]., G Nijsten[1]., M Bierkens[2]., G Essink[1,2]

[1]Deltares, The Netherlands; [2]Utrecht University, The Netherlands

Worldwide, more than 400 transboundary aquifers (TBAs) have been identified. Only a small number of these aquifers have been assessed in detail. Consequently, little is known about (potential) transboundary impacts. Changes in transboundary groundwater fluxes can indicate potential transboundary impacts as groundwater abstractions can affect such fluxes, indicating potential risks of transboundary contamination. To our knowledge, a quantitative assessment of transboundary aquifer fluxes (TBAFs) is not available because national groundwater models (if existing) often lack a good interaction with surrounding countries. In recent years, a high-resolution global groundwater model (GGM) has been developed as part of the PCR-GLOBWB family of models, having a 5 arcmin (~10*10km^2) resolution. PCR-GLOBWB has previously been used to quantify environmental flows, assess global droughts, and assess climate impacts on global water resources. Recently the 5 arcmin GGM has been updated to 30 arcsec (~1*1km^2) using high performance computing (referred to as GLOBGM). We present an application of GLOBGM to assess TBAFs of major TBAs.

Results show that even though hydrogeological data are often scarce, a rough order of magnitude of the TBAFs can be assessed. TBA fluxes are compared with groundwater recharge. Although GLOBGM cannot replace assessments of TBAs based on local hydrogeological information and information on groundwater use, the analysis provides valuable information. GLOBGM can be used to quantify the relevance of TBAFs in relation to other fluxes such as from rivers or (future) abstractions. TBAF analyses can also assist in prioritising scarce funds and capacity between TBAs.

Keywords: Global model, transboundary aquifers, transboundary fluxes; comparative assessment

The connectedness of groundwater and human systems: a study of sacred wells in Ireland.

B Misstear[1]., G Laurence[1]., M Cora[1]., R Foley[2]

[1]Trinity College, Dublin, Ireland, [2]Maynooth University, Ireland

Sacred wells are found across the world yet are rarely studied by hydrogeologists. This paper will present the results of a 5-year hydrogeological study of holy wells in Ireland, a country with a relatively large number of these wells (perhaps as many as 3,000). It was shown that holy wells occur in all the main lithology and aquifer types but are more numerous in areas with extreme or high groundwater vulnerability. Water samples were collected from 167 wells and tested for up to 60 chemical parameters, including a large range of trace elements. Statistical analyses were performed to see if there were any statistically significant associations between the chemical constituents and the reputed health cures for the different well waters, and the results will be presented here. One of the issues in communicating the research findings to the general public is in explaining the small concentrations involved and the likely very small doses pilgrims at holy wells receive during their performances of faith. The spiritual dimension, including the therapeutic value of the landscape where the well is located, is likely an important aspect of the healing reputation.

Keywords: Groundwater heritage, communication, holy wells, water and health

CLICK TO RETURN TO THE PROGRAMME

Open access to digital groundwater and geodata supports the green transition and the spatial planning of competing subsurface uses

K Hinsby., H Broers[2]., L Gourcy[3]., P van der Keur[1]

[1]GEUS, Denmark; [2]TNO, The Netherlands.,[3]BRGM, France

Modern societies rely heavily on subsurface resources and need open access to accurate and standardized scientific digital data that describe the subsurface's infrastructure and geology, including the distribution of local and regional aquifers up to a depth of five kilometres. These data are essential for assessing and reducing climate change's impact and enabling the green transition. Digital maps, 3D and 4D models of the subsurface are necessary to investigate and address issues such as groundwater quality and quantity, flood and drought impacts, renewable geo-energy solutions, availability of critical raw materials, resilient city planning, carbon capture and storage, disaster risk assessment and adaptation, and protection of groundwater-dependent terrestrial and associated aquatic ecosystems and biodiversity. For over a decade, EuroGeoSurveys, the Geological Surveys of Europe, has been working on providing harmonized digital European subsurface data through the European Geological Data Infrastructure, EGDI. These data are invaluable for informed decision-making and policy implementation regarding the green transition, Sustainable Development Goals, and future Digital Twins in earth sciences. The database is continuously developed and improved in collaboration with relevant stakeholders to meet societal needs and facilitate sustainable, secure, and integrated management of sometimes competing uses of surface and subsurface resources.

Keywords: FAIR data, UN SDGs, digital geoinformation, digital twins, geohazards, groundwater, resources management, subsurface, sustainability

An Overview of long-term groundwater development and management – 20 years of Hermanus wellfields

K Riemann., D Blake

Umvoto Africa, South Africa

Hermanus was originally supplied from springs and groundwater until the De Bos Dam was built in the 1950s. Due to increasing water demand, the municipality commenced wellfield development in 2002. The first wellfield comprised 3 boreholes, of which one borehole was later decommissioned due to reduced yield. Three additional boreholes were drilled recently to ensure abstraction capacity within the licence limits. A second wellfield was developed in the Hemel-en-Aarde Valley north of Hermanus. To ensure the sustainable management of the shared resource and minimise environmental impacts, a monitoring committee was established with all relevant roleplayers, other users, civil society, environmental groups and various commenting and regulatory authorities. A comprehensive monitoring network was established to assist with the scheme's management and ensure that environmental impacts are minimized. The long-term monitoring (up to 20 years) shows that the groundwater abstraction from the Gateway Wellfield does not impact the environment and other users or increase the risk of saline intrusion. Identified impacts have been mitigated with the assistance of the monitoring committee. The municipality aims to provide at least half of the town's water demand from groundwater and establish conjunctive use operation between surface water from the De Bos Dam and groundwater from these wellfields. The wellfields ensured sufficient water for the municipality when De Bos Dam's water levels declined significantly during the Western Cape droughts in 2011 and 2017. The presentation will provide examples of the long-term monitoring records and trends.

Keywords: Monitoring, groundwater management, wellfield development

CLICK TO RETURN TO THE PROGRAMME

A Case Study on Capacity Development in Rural Groundwater Supply in Acholiland, Northern Uganda

K Robey[1]., P Baumana[1]., S Edris[2]., L Woods[1]., T Coultish[1]., R Shinduke[1]., C Rouault[3]
[1]BGC Engineering, Canada; [2]IsraAID; [3]Queen's University, Canada

Groundwater is the most important source of potable water in rural areas of Acholiland, a sub-region of northern Uganda. Installation of handpumps has been the focus of local government and international aid to provide safe drinking water in Uganda. However, non-functional handpumps are one reason for the abandonment of groundwater resources. For handpumps to be sustainable for years, appropriate siting and construction is required, as well as monitoring. This is common knowledge to specialists working in rural supply, but gaps in knowledge transfer and field skills may exist for the persons installing and maintaining handpump wells. This is a case study of a ten-day field campaign designed to train local participants who actively work in the rural groundwater supply sector. Nine non-functional handpump sites were identified for repair and hydrogeology and geophysical studies. A non-governmental organization, IsraAID, along with Gulu University implemented training by hydrogeology specialists to build local capacity. The training included handpump functionality tests, downhole inspections, electrical resistivity tomography surveys, and water quality sampling, including a novel Escherichia coli test that did not require an incubator. Functionality tests and downhole inspections provided simple but effective ways to assess handpump and well issues. Training in water quality empowered the participants to complete rapid assessments of the quality of the water and start monitoring programs. The success of the project was based on collaboration with multiple organizations focusing on the development of local capacity. The lessons learnt from this campaign should be considered for other rural groundwater supply scenarios.

Keywords: Uganda, capacity development, geophysics, handpump functionality assessments, rural groundwater supply, water quality

Risks related to groundwater resources in the Murray-Darling Basin, Australia

A Ross
Fenner School of Environment and Society, Australian National University

Groundwater governance and risk management in the Murray-Darling Basin in Australia (MDB) are being challenged by the increasing demand for water and the growing scarcity and variability of water supply owing to climate change. Over the past 20 years, consideration of risk related to groundwater in the MDB has evolved from concerns about the impact of groundwater extraction on surface water resources to an integrated assessment of risks to connected water resources and ecosystems. The Basin Plan includes a comprehensive framework for assessing risks to Basin water resources and ecosystems, but further scientific and policy developments are required to implement the plan. Consistent definition and improved assessment of groundwater-surface water connectivity are required, together with longer planning timeframes. Multi-year planning rules and policies must be developed to exploit opportunities for integrated management of groundwater and surface water resources and storage to manage droughts and floods. Risks to groundwater quality and groundwater-dependent ecosystems must be adequately assessed and monitored to avoid adverse impacts on communities and long-term loss of ecosystem services.

Further improvements can be made in assessing cumulative risks from coal seam gas and coal mining. Additional research can be targeted towards knowledge gaps and uncertainties that pose the greatest risk to connected groundwater and surface water resources and ecosystem viability. Most importantly, further training and capacity building in water management agencies is critical to enable effective and transparent monitoring and management of Basin water resources.

Keywords: Groundwater, Murray-Darling Basin Plan, ecosystems, implementation, policies, research priorities, risks, surface water

CLICK TO RETURN TO THE PROGRAMME

Celebrating hydro-geoheritage – the Table Mountain Dams Trail and Hermanus Water Walk (Western Cape, South Africa)

D Blake., P Lee., G Bluff

The Umvoto Foundation, South Africa

Hydrogeology and hydrology are commonly overlooked aspects of geoheritage, despite strong geological links. Water in all its forms has played a critical role in the development of Earth, and the shaping of its landforms (in addition to sustaining all life on the planet), and access to water has been the core reason for the establishment of numerous human settlements. The evolution of a settlement's water supply tracks its development history across the Holocene, providing an excellent tool for teaching the public about human interactions with the Earth and our shared future going forward in a changing climate. To this extent, two self-guided trails (with associated guidebooks and mobile apps) have been developed in areas of the Western Cape province of South Africa with rich water supply histories and hydro-geoheritage – the Table Mountain Dams Trail in Cape Town and the Hermanus Water Walk in the Overberg region. The surface and groundwater supply systems that both trails cover have an inherently unique link with the Ordovician-Devonian Table Mountain Group fractured aquifer systems (including the complex tectonic and geomorphic evolutionary history that has led to the present landscapes), which most residents and international visitors are generally unaware of (despite being major tourist regions in South Africa). It is envisioned that through these guides/trails, the reader/walker will gain a better understanding of/appreciation for the value of water, a greater feeling of ownership for the natural history of the city/region they reside in, and will strive to preserve associated hydro-geoheritage for future generations.

Keywords: Hydro-geoheritage, water supply, Table Mountain Group aquifers, Cape Town, Hermanus, social hydrogeology

Dynamic groundwater modelling of Lake Sibaya

M Maseko[1]., S Gurmessa[1]., B Kelbe[2]., S Janse van Rensburg[2]., M Toucher[2]

[1]Department of Hydrology, University of KwaZulu-Natal, Private Bag X01, Pietermaritzburg, 3209, South Africa; [2]Grasslands-Forests-Wetlands Node, South African Environmental Observation Network, P.O.Box 13053, Pietermaritzburg, 3209

The Lake Sibaya groundwater-dependent catchment in uMhlabuyalingana (KwaZulu-Natal) has been the focus of hydrological research since the 1970s. The continuous decline in lake water levels and groundwater stores has prompted recent efforts. To increase confidence in the relative attribution of known causes of declines, an existing MODFLOW groundwater model was updated based on reviewed and extended hydrological input datasets and more accurate land-use and land cover (LULC) change data. A novel approach was used in this study, which involved running the ACRU surface-water model in distributed mode to provide dynamic recharge outputs for the groundwater model. This approach considers LULC changes, improved spatial and temporal distribution of climatic data, and land-surface hydrological processes. The refined groundwater model provided satisfactory simulations of the water system in the Lake Sibaya catchment. This study reports on the advances and limitations discovered in this approach, which was used to reassess past to current status quo model simulations for the region. The model was then used, as part of a multidisciplinary project, to assess the response of the lake water system under various LULC preferences based on inputs from local communities under two future climate scenarios (warmer wetter and warmer drier) in the current ongoing WRC project. The ultimate goal is to advise water resources management in the catchment.

Keywords: Groundwater/surface-water relations, climate change, groundwater model, land-use landcover,surface-water model

CLICK TO RETURN TO THE PROGRAMME

Application of multivariate statistical analysis as a support for the delineation of groundwater bodies: a case study in coastal plain areas of Campania Region (Southern Italy)

S Stevenazzi[1]., K Voudouris[2]., D Ducci[1]

[1]Università degli Studi di Napoli Federico II, Dipartimento di Ingegneria Civile, Edile e Ambientale, Italy; [2]Aristotle University of Thessaloniki, Faculty of Sciences, School of Geology, Department of Structural, Historical & Applied Geology, Laboratory of Engineering Geology & Hydrogeology

The identification of hydrogeological boundaries and the assessment of groundwater's quantitative and qualitative status are necessary for delineating groundwater bodies, according to the European Guidelines. In this context, this study tries to verify the current delineation of groundwater bodies (GWBs) through hydrogeochemical methods and multicriteria statistical analyses. The areas of interest are three GWBs located in the northern part of Campania Region (Southern Italy): the Volturno Plain, a coastal plain constituted of fluvial, pyroclastic and marine sediments; the Plain of Naples, an innermost plain of fluvial and pyroclastic sediments and the Phlegrean Fields, an active volcanic area with a series of monogenic volcanic edifices. Hydrogeochemical methods (i.e., classical and modified Piper Diagram) and multivariate statistical analyses (i.e., factor analysis, FA) were performed to differentiate among the main hydrochemical processes occurring in the area. FA allowed the handling many geochemical and physical parameters measured in groundwater samples collected at about 200 sampling points in the decade of the 2010s. Results reveal five hydrogeochemical processes variably influencing the chemical characteristics of the three GWBs: salinization, carbonate rocks dissolution, natural or anthropogenic inputs, redox conditions, and volcanic product contribution. Hydrogeochemical methods and FA allow the identification of areas characterised by one or more hydrogeochemical processes, mostly reflecting known processes and highlighting the influence of groundwater flow paths on water chemistry. According to the current delineation of the three GWBs, some processes are peculiar to one GWB, but others are in common between two or more GWBs.

Keywords: Coastal aquifers, statistical analysis, volcanic areas, water chemistry

Machine learning as a tool to improve groundwater monitoring networks

D Pacios[1]., I Coleto[1]., P Verzier[1]., V Gómez-Escalonilla[2]., P Martínez-Santos[2]

[1]Talantia S.L, Spain; [2]Universidad Complutense de Madrid, Spain

Machine learning techniques are gaining recognition as tools to underpin water resources management. Applications range widely, from groundwater potential mapping to the calibration of groundwater models. This research applies machine learning techniques to map and predict nitrate contamination across a large multilayer aquifer in central Spain. The overall intent is to use the results to improve the groundwater monitoring network. Twenty supervised classifiers of different families were trained and tested on a dataset of fifteen explanatory variables and approximately two thousand points. Tree-based classifiers, such as random forests, with predictive values above 0.9, rendered the best results. The most important explanatory variables were slope, the unsaturated zone's estimated thickness, and lithology. The outcomes lead to three major conclusions: (a) the method is accurate enough at the regional scale and is versatile enough to export to other settings; (b) local-scale information is lost in the absence of detailed knowledge of certain variables, such as recharge; (c) incorporating the time scale to the spatial scale remains a challenge for the future.

Keywords: groundwater, machine learning, monitoring networks, nitrate, random forest, Spain

CLICK TO RETURN TO THE PROGRAMME

Risk-corrected contaminant detection probability of monitoring well networks for flow towards pumping wells in heterogeneous aquifers

T Sarris., A Kenny., D Scott
ESR, New Zealand

A groundwater monitoring network surrounding a pumping well (such as a public water supply) allows for early contaminant detection and mitigation where possible contaminant source locations are often unknown. This numerical study investigates how the contaminant detection probability of a hypothetical sentinel-well monitoring network consisting of one to four monitoring wells is affected by aquifer spatial heterogeneity and dispersion characteristics, where the contaminant source location is randomized. This is achieved through a stochastic framework using a Monte Carlo approach. A single production well is considered, resulting in converging non-uniform flow close to the well. Optimal network arrangements are obtained by maximizing a weighted risk function that considers true and false positive detection rates, sampling frequency, early detection, and contaminant travel time uncertainty. Aquifer dispersivity is found to be the dominant parameter for the quantification of network performance. For the range of parameters considered, a single monitoring well screening the full aquifer thickness is expected to correctly and timely identify at least 12% of all incidents resulting in contaminants reaching the production well. Irrespective of network size and sampling frequency, more dispersive transport conditions result in higher detection rates. Increasing aquifer heterogeneity and decreasing spatial continuity also lead to higher detection rates, though these effects are diminished for networks of 3 or more wells. Earlier detection, critical for remedial action and supply safety, comes with a significant cost in terms of detection rate and should be carefully considered when a monitoring network is being designed.

Keywords: Contaminant Transport, Dispersion, Groundwater contamination, Heterogeneity, Monitoring networks, Risk corrected detection rate

Analysis of Heavy Metal Sources in Groundwater and Assessment of Health Risks: An Example from the Southwest Sub-basin of the Shiqi River

Yu Shi.,
Ministry of Natural Resources and Guangxi, Institute of Karst Geology, Chinese Academy of Geological Sciences, China

To explore the sources of pollution and health risk profile of heavy metal elements in groundwater,41 sets of representative groundwater samples from the southwest subbasin of the Shiqi River were examined for 10 heavy metal elements, correlation analysis and principal component analysis were used to resolve the possible sources of heavy metal contamination in groundwater. The concentration characteristics and health risk levels of the 10 heavy metals were assessed using the single factor contamination index (*P*i), the Nemerow comprehensive contamination index (*P*N) and the health risk model. The results show that: 1) The average values of heavy metal elements of the groundwater in the study area all met the limit of class III water standard in the quality standard for groundwater; only the maximum value of Al was exceeded, followed by a large variation in the concentrations of Al, Mn and Cr. The heavy metal element with the largest average contribution was Al (65.74%). 2) The results of the single factor contamination index evaluation show that only the heavy metal element Al exceeds the level, and the results of the Nemerow comprehensive contamination index evaluation show that the study area is basically at low pollution levels and the quality of groundwater is good. 3) The results of the multivariate statistical analysis show that Zn, Co and Mn are mixed sources of geological formation and domestic waste, Al, As, and Cu are agricultural sources, Cd, Cr and Ni are industrial sources, and Hg comes from long-range atmospheric transport.

Keywords: Groundwater; heavy metal elments; source analysis; health risk assessment

CLICK TO RETURN TO THE PROGRAMME

Development of multi-level groundwater governance systems and groundwater capacity development to support local municipalities in the Northern Cape Region

A Tomlinson
GEOSS South Africa

The Anglo-American Municipal Capability & Partnership Program (MCPP) has partnered with the Council for Scientific and Industrial Research (CSIR) to implement programs focused on Strategic Water Management and Strategic Planning within the Gamagara and Tsantsabane Local municipalities within the Northern Cape Region. The CSIR appointed GEOSS South Africa (Pty) Ltd to assist with Municipal Groundwater Capacity Development and Support for these two municipalities. This work explores multi-level groundwater governance systems between the local municipality, government, the mining industry, and the private groundwater sector. The scope of the work focused on developing a comprehensive and practical groundwater management plan detailing the standard operating procedures for each municipality. These operating procedures have been drawn up using principles of best practice guidelines for groundwater monitoring and management but have taken site-specific details of the groundwater supply to the respective Municipalities into account. Workshops were conducted where Municipal staff were trained in basic principles pertaining to groundwater and practical skills in monitoring and managing their supply. This has proved very successful in informing Municipalities about their local groundwater system and aquifer. The capacity-building development aspect will ensure that Municipalities have the resources and the knowledge to manage their groundwater resource effectively. GEOSS has undergone several training workshops and offers weekly technical support to the two Municipalities. As the confidence of the municipal staff to manage their resource grows, their independence from the mining companies should lessen.

Keywords: groundwater capacity development, groundwater governance, groundwater management, groundwater management plan, standard operating procedures

CLICK TO RETURN TO THE PROGRAMME

Understanding informal institutions' role in groundwater management – Lessons from borderland communities

K Pietersen[1]., J Strömgren[2]., M Storie[3]., L Nzeyimana[2]., L Itimu[3]., T Lilja[2]

[1]University of the Western Cape, South Africa; [2]Sweco, Sweden, [3]Pegasys, South Africa

Across Africa, given the pressing challenges of climate change and widespread water, food and livelihood insecurity and poverty, there is an ever-increasing expanding role for groundwater in resilience building, especially in borderland communities. This situation is being investigated in several projects and geographies. This paper's groundwater management analysis was based on literature reviews, key informant interviews (KIIs), and focus group discussions (FGDs) in selected case study areas throughout sub-Saharan Africa. The KIIs included representatives of water management institutions, community leaders, international development partners, the private sector and non-governmental organisations (NGOs) involved in the use or management of groundwater. The FGDs occurred in borderland communities in Ethiopia, Kenya, and Somalia (with these three countries sharing borders) and Mozambique, South Africa and Zimbabwe (with these three also sharing borders). The findings show that informal institutions such as clan, tribal or ethnic affiliations dictate access to natural resources such as groundwater in borderlands. These same Institutions also play a significant role in conflict resolution in the borderland areas. In addition, informal institutions play an essential role in groundwater management and should also be recognised – in engagements and formal water policies and legislation. Formal organisations, institutions and government structures should strengthen their focus on ensuring that discussions and decisions include informal role players. Further developing and enforcing conventions, land-use plans, and by-laws governing access to and use of groundwater should ensure engagement and co-creation of solutions towards effective water resource management.

Keywords: groundwater governance, informal institutions, transboundary aquifers

CLICK TO RETURN TO THE PROGRAMME

Development of United Nations Framework Classification for Resources (UNFC) for Groundwater Resources Management

P van der Keur
Geological Survey of Denmark and Greenland (GEUS), Denmark

There is an urgent need to support the sustainable development of groundwater resources, which are under increasing pressure from competing uses of subsurface geo-resources, compounded by land use and climate change impacts. Management of groundwater resources is crucial for enabling the green transition and attaining the Sustainable Development Goals. The United Nations Framework Classification for Resources (UNFC) is a project-based classification system for defining the environmental-socio-economic viability and technical feasibility of projects to develop resources and recently extended for groundwater. UNFC provides a consistent framework to describe the level of confidence in groundwater resources by the project and is designed to meet the needs of applications pertaining to (i) Policy formulation based on geo-resource studies, (ii) Geo-resource management functions, (iii) Business processes; and (iv) Financial capital allocation. To extend use in groundwater resources management, supplemental specifications have been developed for the UNFC that provide technical guidance to the community of groundwater professionals to enhance sustainable resource management based on improved decision-making. This includes addressing barriers to sustainably exploiting groundwater resources, avoiding lack of access to water and also related to 'common pool resources' in which multiple allocations are competing with domestic water supply (e.g. geo-energy, minerals, agriculture and ecosystems, and transboundary allocation of natural resources). UNFC for groundwater resources is designed to enhance governance to protect the environment and traditional users while ensuring socio-economic benefits to society. Consequently, it is a valid and promising tool for assessing both the sustainability and feasibility of groundwater management at local, national and international levels.

Keywords: SDGs, UNFC, common pool resources, subsurface geo-resources, sustainable groundwater resources management

Experience with the electrical potential difference-audio magnetotelluric (EPD-AMT) Groundwater Detector geophysical groundwater exploration

M Gomo
Institute for Groundwater Studies, University of the Free State, South Africa

Various electrical potential difference-audio magnetotelluric (EPD-AMT) geophysical equipment is now available in the market for groundwater exploration, and the Groundwater Detector is one of them. Due to their low cost, deeper penetration, and real-time measurement, the technology has been widely received in many developing and underdeveloped countries. However, research to understand the application of the EPD-AMT surface geophysics approach in groundwater exploration is very limited. This research gap needs urgent attention to promote the technology's meaningful and wider application. The lack of published case studies to demonstrate the capabilities of the EPD-AMT approach is a limiting factor to its application. Research on different hydrogeological settings is paramount as part of the efforts to improve the practical understanding of the application of the EPD-AMT geophysical approach in groundwater exploration. This study shares field experience from applying the EPD-AMT Groundwater Detector geophysical technique to explore groundwater in dolomite, granite, and Karoo sandstone hardrock aquifers in Southern Africa.

Keywords: Audio Magnetotelluric (AMT); Electrical potential difference (EPD); Dolomite aquifers; Geophysics groundwater exploration; Granite aquifers; Karoo aquifers

CLICK TO RETURN TO THE PROGRAMME

Robust Hydrogeological Conceptual Models Through Interdisciplinary Characterisation – A Case Study

Z Rademan

Jones & Wagener (Pty) Ltd, South Africa

The basis of a hydrogeological conceptual model is the comprehensive characterisation of the groundwater system. This ranges from discrete hydraulic feature analysis to local-scale testing to integrated regional-scale aquifer system conceptualisation. Interdisciplinary data integration is critical to each level of characterisation to gain a realistic, yet simplified representation of the hydrogeological system based on various data sources. Incorporation of geological datasets, including (but not limited to) structural and lithological mapping, geotechnical core logs and geophysical surveys, in conjunction with a tailored selection of hydraulic testing techniques, are often underutilised by hydrogeologists. Yet, the contribution of these alternative hydraulic datasets cannot be overstated. A recent hydrogeological assessment and feasibility study forming part of the planned expansion project for a base-metal mine in the Northern Cape, South Africa, offers an ideal, practical example. The localised nature of the project area and the inherently complex geological setting required a more detailed conceptual model and hydrostratigraphic domaining approach. Highly heterogeneous stratigraphy and strong structural aquifer controls necessitated characterisation by reviewing, testing and analysing various datasets. Exploratory core datasets, hydraulic aquifer tests, geological and downhole geophysical datasets, and statistical Rock Quality Designation—hydraulic conductivity relationships were interpreted to produce meaningful, refined hydraulic process identifications. A comprehensive local groundwater framework, discretised into various hydrostratigraphic units and structural domains with specified hydraulic parameters, was incorporated to provide a novel, more robust conceptual understanding of the unique hydrogeological system.

Keywords: conceptual model, geophysics, geotechnical, hydraulic testing, interdisciplinary

Machine learning applied to pumping test analysis

A Lukas., F de Lange., A Allwright

Institute for Groundwater Studies, University of the Free State, South Africa

Aquifer test analysis is complex, and in many regards, the interpretation resembles an art more than a science. Under the best circumstances, aquifer test analysis is still plagued by ambiguity and uncertainty, compounded by the general lack of information on the subsurface. An approach which has seen widespread adoption in other fields that need to classify time series data is machine learning. A Python script that generates numerical groundwater flow models by interfacing directly with the modelling software produces training data for deep learning. Production yielded 3,220 models of aquifer tests with varying hydrogeological conditions, including fracture, no-flow and recharge boundary geometries. Post-processing exports the model results, and the Bourdet derivative is plotted and labelled for image classification. The image classifier is constructed as a simple three-layer convolutional neural network, with ReLU as the activation function and stochastic gradient descent as the optimizer. The dataset provided sufficient examples for the model to obtain over 99% accuracy in identifying the complexities present inside the numerical model. The classification of groundproofing data illustrates the model's effectiveness while supporting synthetically prepared data using modern groundwater modelling software.

Keywords: Numerical modelling, aquifer test analysis, deep learning, derivative analysis, machine learning

CLICK TO RETURN TO THE PROGRAMME

The complexity and importance of the intermediate vadose zone - Local-scale, Pore-scale, and Discrete Scale

M Dippenaar
University of Pretoria, South Africa

The intermediate vadose zone underlies the plant root zone and comprises soil and rock. Different soils have different hydraulic and mechanical properties, and the vertical and spatial distributions are variable at a small scale. In South Africa, except for the Cenozoic and Quaternary deserts and coastal deposits, rock forms most of the vadose zone, and the rock fractures exacerbate the complexity. The vadose zone is observed at a small scale and dictates what happens in large scale, as adhesion to mineral surfaces happens first, and cohesion between water molecules is next. The original consideration of the intermediate vadose zone was a black box approach measuring what goes in from the surface and what goes out as groundwater recharge, not accounting for the movement of the vast majority of the freshwater supplied through precipitation. That doesn't address the preferential flow, velocity, and pore water changes in the medium. Soil science addresses the soil or plant root zone very well. This zone governs the vertical movement of water and controls the ecosystems and biodiversity. However, all evapotranspiration disappears below this zone, and capillarity and gravity both move water into and through the intermediate vadose zone. Movement is no longer solely vertical and will be affected by soil types, intergranular porosity in soil and rock, changing water content, and secondary fractures with different properties in rock. This presentation will cover concepts and advances in this field, emphasising how and why water moves in the intermediate vadose zone.

Keywords: adhesion, saturated zone, capillarity, cohesion, fracture flow, moisture content

Micro pore-pressure sensor (MEMs) and analysis technologies – towards a future of multi-scale groundwater monitoring

W Timms
Deakin University, Australia

Micro-electro-mechanical system (MEMs) technologies coupled with Python data analysis can provide in-situ, multiple-point monitoring of pore pressure at discrete and local scales for engineering projects. MEMs sensors are tiny, robust, inexpensive, and can provide wireless sensing measurements in many electrical and geomechanical engineering applications. We demonstrate the development of MEMs pressure sensors for pore pressure monitoring in open boreholes and grouted in piezometers. MEMs sensors with a 60 m hydraulic head range and centimetre vertical resolution were subject to stability and drawdown tests in open boreholes and in various sand and grouts (permeability 10^{-8} to 10^{-2} m/s). The resulting accuracy and precision of the MEMs sensors, with optimal calibration models, were similar to conventional pore pressure sensors. We also demonstrate a framework for estimating in-situ hydrogeological properties for analysis from vented pore pressure sensors. This framework method included Python code analysis of hourly pore pressure data at the millimetre vertical resolution, which was combined with barometric data and modelled earth tides for each borehole. Results for pore pressure analysis in confined boreholes (>50 m depth) included specific storage, horizontal hydraulic conductivity and geomechanical properties. Future improvements in the vertical resolution of MEMs pore pressure sensors and combined these two technologies will enable groundwater monitoring at multiple scales. This could include the deployment of numerous MEMs, at sub-meter discrete scale in boreholes and evaluating local site scale variations in pore pressure responses to recharge, groundwater pumping and excavations in complex sub-surface geological conditions.

Keywords: multi-scale, pore pressure, sensors, analysis

CLICK TO RETURN TO THE PROGRAMME

Tracing an arenitic aquifer by DNA-labelled nano particles

A Gargini[1]., E Pugliese[1]., M Filippini[1]., G Bolognesi[2]., C Giulian[1]

[1]Department of Biological, Geological and Environmental Sciences; Alma Mater Studiorum; University of Bologna, Italy; [2]Department of Medical and Surgical Sciences, Alma Mater Studiorum University of Bologna, Italy

The results of a full field application of a DNA-based nano tracer in an arenitic aquifer are presented along with the comparison with the breakthrough of a classical tracer injected in parallel. DNA is encapsulated into amorphous silica spheres (nanoparticles), protecting the molecule from chemical and physical stresses. The main advantages of using DNA with classical tracers, like ionic or fluorescent, are the lower detection concentration and the chance to perform multi-tracer tests with many distinct signatures of injection. To the authors' best knowledge, this is the first tracing adopting nano-particles on full field conditions in a sedimentary fractured aquifer. Preliminary tests in the lab were performed adopting either deionized water or groundwater collected at the experimental site: a set of nanoparticles at a known concentration was dissolved by adding a buffered fluoride solution, and DNA was then quantified by qPCR reaction (SYBR green). The hydrogeological setting is represented by a Miocenic marine arenitic aquifer (Pantano formation) outcropping extensively in Northern Apennines (Italy) and the main groundwater reservoir for public water supply through the uptake of many perennial springs. The main purpose of the tracing was to verify the transmissive capacity of fractures with high aperture (15-20 cm) identified by optical and acoustic televiewers inside an 80 m deep borehole. The injection was performed inside the borehole, and the tracer's recovery was between 5-15 m, both in the uptake points of two perennial springs and in another borehole drilled nearby.

Keywords: nanotechnology; DNA-labelled nano particles; arenite; groundwater; tracer test; Northern Apennines

Combined Use of Environmental and Artificial Tracers to Characterise the Vadose Zone

Yazeed van Wyk[1,2]

[1]Water Research Commission, South Africa; [2]University of Pretoria, South Africa

Water and contaminant transport processes in the vadose zone through preferential flow paths can be understood using environmental and artificial tracer methods. Further improvement in tracer techniques can be achieved by applying numerical modelling techniques of both water and solute transport, accounting for additional information on water movement and the matric potential of the vadose zone. The vadose zone is often ignored as a key component linking the land surface to the groundwater table, even though it acts as a filter that removes or stores potential contaminants. The water transit time between the surface and the groundwater table is frequently investigated using artificial tracers that normally show conservative behaviour. The main advantage is that the input function can be clearly defined, even though artificial tracers can generally only be applied over a relatively small area. The research is expected to provide insight into the selection and use of environmental and artificial tracers as markers for detecting and understanding the contaminant transport processes and pathways of contaminants in altered vadose zone environments (open-pit quarry). The impact is improved characterisation of the pathways, transport and migration processes of contaminants, and residence times, leading to the development of appropriate conceptual and numerical models of vadose zone flow processes that consider various contaminant sources. The principal aim is, therefore, to systematically examine the transport mechanisms and associated pathways of different environmental and artificial tracers in an open-pit quarry.

Keywords: Vadose zone, contaminant transport processes, environmental and artificial tracers

CLICK TO RETURN TO THE PROGRAMME

MEMS Technology for Groundwater Monitoring

M Touchahi1., S Blanks2., P Tadich2., W Timms1

[1]Deakin University, Australia; [2]Fluid Potential Pty Ltd, Australia

Technological advances in recent years provide a unique opportunity to adopt new instruments for groundwater monitoring to reduce operating costs, obtain higher measuring accuracy and reliability, and accomplish comprehensive real-time monitoring. Microelectromechanical system (MEMS) technology enables small and low-cost energy-saving microsensors and integration with IOT for real-time monitoring. This presentation will discuss the findings of the performance of a newly developed instrument based on a MEMS piezoresistive pressure sensor. We demonstrate a path forward for the expansion of this research. The sensor is designed to be applicable to both open and closed systems for measuring groundwater level and pore water pressure. Tests show that MEMs (0-689 kPa range) can obtain full-scale accuracy between 0.2-0.3% in groundwater level prediction. However, the measurement result mainly depends on the appropriateness of the calibration method.

Regarding pore pressure measurement under sealed conditions by gravel sand and cement-bentonite grout, a full-scale accuracy between 0.3% and 0.725% is accessible, depending on the backfill material. However, it was evident that backfill materials have considerable effects on the response time and accuracy of measurement, in which a stiff and less permeable grout can increase inaccuracy and time lag in measurement. Overall, the initial results have shown a promising future for this technology in groundwater monitoring. However, more tests and analyses are still required to improve sensor design, energy consumption for IOT applications, wireless module, installation system and its specifications such as accuracy, conformance, precision, and stability.

Keywords: MEMS calibration, MEMS pressure sensor, groundwater monitoring, measurement error, pore pressure monitoring

Water impact assessment of water stewardship activities at catchment scale: the case of the Lido Catchment in West Java, Indonesia

A Fadillah[1]., R Lubis[2]., N Dörfliger[3]., A Muhammad[1]

[1]Danone Aqua; [2]Indonesia National Research and Innovation Agency, Indonesia; [3]Danone D2D

Water stewardship is achieved through a stakeholder's inclusive process. It aims to guarantee long-term water security for all uses, including nature. Various actions can occur in the watershed's recharge area, such as land cover restoration and artificial recharges. To measure the effectiveness of these actions, it is crucial to quantify their impact on water and communities. The common method for assessing the benefits of water stewardship activities is the volumetric water benefit accounting (VWBA) method. It allows for comparing the positive impact on water to the extracted groundwater volume for operations. We present the validation of the Positive Water Impact of DANONE Aqua operation at the Lido Site in West Java, Indonesia, within the VWBA framework. Different methods were used to evaluate three main water impact activities: (1) land cover restoration with reforestation, (2) artificial recharge with infiltration trenches and wells, and (3) water access. The curve number of the SWAT model was used to measure the reduced runoff impact of the land conservation action. The water table fluctuation method was employed to assess artificial recharge volume. The volume of pump discharge rates was used for water access. Results highlight the water impact at the Lido site, with the volumetric accounting of the three main activities. The discrepancy in the final calculation can be related to the variation in the field's validated activities. VWBA framework is useful to validate water stewardship activities' impact and plan further impactful actions.

Keywords: Artificial recharge, land restoration, water access, water stewardship, sustainability

CLICK TO RETURN TO THE PROGRAMME

Findings from nearly three decades of groundwater monitoring in an area of intensive agriculture: Sandveld, West Coast, South Africa

J Conrad

GEOSS South Africa (Pty) Ltd, South Africa

The Sandveld (Western Cape, South Africa) is a critical potato production area on the national production scale, especially for table potatoes. As the area is situated on the continent's West Coast, it is a dry area of low rainfall (less than 300 mm /a). The bulk of the irrigation water for agriculture in the region is derived from groundwater. Approximately 60 Mm^3/a of groundwater is abstracted for irrigation of potatoes in the broader Sandveld, assuming a 4-year rotation cycle. The abstraction of groundwater is a sensitive issue in the Sandveld as groundwater also plays a critical role in supplying water to towns in the area, water for domestic use, and it also plays a critical role in sustaining sensitive ecosystems (such as the coastal lake Velorenvlei). The groundwater resources have been monitored for nearly thirty years now. The results indicate areas where a slow but consistent decline in groundwater levels and groundwater quality is occurring. The trends can also predict when the aquifers will become depleted, and the groundwater will become too saline for use. This is critical information for management interventions to be implemented now to protect the area from irreversible damage.

Keywords: groundwater monitoring agricultural impact

Long-term evolution of groundwater/surface water interactions in the Indus and Upper Ganges

A MacDonald[1]., D MacAllister[1]., G Krishan[2]., M Basharat[3]., D Lapworth[1]., M Arran[1]

[1]British Geological Survey, United Kingdom; [2]National Institute of Hydrology; [3]International Waterlogging and Salinity Research Institute

Northern India and Pakistan face some of the world's most challenging surface water and groundwater management issues over the coming decades. High groundwater abstraction, widespread canal irrigation, increases in glacier melt and changes to rainfall impact the dynamics of surface water/groundwater interactions in the Indus Basin and Upper Ganges. Studies using newly available data from long-term hydrographs, high-frequency stable isotope sampling and campaign sampling for groundwater residence time indicators are shedding light on the complex interactions between groundwater, surface water and rainfall. Interactions vary spatially: (1) with distance down the catchment, related to the prevailing rainfall gradient, and (2) with position in the canal command, both distance from barrage and distance from feeder canals. Interactions are also observed to vary with time due to (1) the historical evolution of the canal network, (2) patterns in precipitation over the past 120 years, (3) changes in river flow due to glacial melting, and (4) increased pumping, which has also led to increased capture of surface water. Only by understanding and quantifying the different processes affecting groundwater/surface water coupling in the Indus and Upper Ganges is it possible to forecast future groundwater storage changes.

Keywords: Groundwater surface water interaction; irrigation; groundwater abstraction; recharge; climate change

CLICK TO RETURN TO THE PROGRAMME

Data-Driven approach to groundwater level prediction for improving water resource management: the Brenta aquifer system case study (Veneto, Italy)

L Franceschi[1]., M Menichini[2]., B Raco[2]., M Doveri[2]

[1]University of Pisa and IGG – CNR (Pisa), Italy; [2]IGG – CNR (Pisa), Italy

In the context of climate change, this work aims to model the piezometric levels of the foothill aquifer located in the middle-high Brenta river plain (Veneto, Italy) to support managing a groundwater system that provides drinking water for most of the Veneto Region. Using a Data-Driven approach, predictive Multiple Linear Regression Models were developed for the piezometric level at different wells, and scenarios of groundwater level evolution were achieved under dry periods. Results highlighted the high sensitivity of the aquifer to climate extremes, as well as the need to plan actions for mitigating the effects on such a strategic water supply system. Groundwater hosted in the foothill aquifer represents an important resource. However, these systems are highly sensitive to the variation of Meteo-climatic regimes. At the same time, the exploitations can lead to excessive groundwater drawdown and consequent threats of water scarcity. The Data-Driven approach adopted using long time series of meteorological, hydrometric and piezometric data can represent a valid example in these terms. The groundwater level evolution has been well-reproduced by these models. The equations describing models show the close dependence of groundwater from the Brenta River and the high sensitivity of the aquifer to meteo-climate regimes. Given this sensitivity, the forecast of groundwater level evolution under a dry period, similar to 2022, was performed. Results point out a progressive drawdown of groundwater level. These predictive models can be useful for local authorities to maintain these levels over specific critical values.

Keywords: Foothill aquifer system, climate change, groundwater management, predictive models

Application of the multi-method approach to assess river aquifer interaction in Upper Berg catchment, Western Cape, South Africa

A Umunezero

To better understand the role of groundwater contribution to baseflow and EWR in groundwater protection and allocation, groundwater contribution must be quantified. Groundwater contribution to baseflow remains a challenge. Baseflow values have been widely used as groundwater contribution to surface water, which overestimates or underestimates the role of groundwater in the ecological ecosystem sustainability. To achieve the aim of the study, which was to estimate groundwater contribution to baseflow in a perennial river system at a catchment scale of the Upper Berg catchment, three objectives were taken into consideration: 1) To describe the hydrogeology of river morphology for groundwater-surface water interaction, 2) To estimate groundwater contribution to baseflow 3) To demonstrate the use of the background condition in setting resource quality objectives**.** Baseflow separation method using the Lynne & Hollick and Chapman algorithms, mass balance equation using EC as the tracer, field observation, and hydrochemical analysis methods were used to determine groundwater contribution to baseflow. Based on the hydrogeological cross-section presented, the fractures and faults of the peninsula geological formation dominating the study area predicted groundwater contribution to baseflow, which was confirmed by the calculations. The mass balance equation showed that 2,397 % of the 7.9 % baseflow index calculated at G1H076 and 19,093% of the 7.2% baseflow index calculated at G1H077 was groundwater. The background condition of the Upper Berg catchment was determined to be pristine with clean water.

Keywords: Baseflow, EWR, Groundwater contribution, background condition, filtering base-flow separation method, hydrological cross-section

CLICK TO RETURN TO THE PROGRAMME

Hydrogeological assessment for sourcing regionally significant freshwater supplies in southern Malawi

J Bernasconi[1]., T LaVanchy[2]., J Adamson[1]

[1]Northwater International; [2]Oklahoma State University, USA

Communities in the Lower Shire River Valley in the Chikwawa District of southern Malawi face extreme development challenges due to highly variable climate, including floods and droughts, that trap them in poverty and food insecurity. The area has been the focus of numerous studies and data collection campaigns to understand better the causes and processes associated with brackish groundwater (in alluvial aquifers) and dry boreholes. An applied groundwater assessment was performed to evaluate water supply alternatives and solutions to deliver potable water to approximately 15% of the district without water access after a multi-year campaign to reach 100%. The assessment synthesized a significant volume of water quality data collected by researchers and nongovernment organizations, larger scale geological interpretations published in segmented literature, multi-spectral satellite imagery datasets, and combined field reconnaissance to investigate areas of interest further and address pertinent data gaps. Improved understanding of geologic structure and lithology, complex aquifer recharge, and evapotranspiration processes supported identifying areas unsuitable for groundwater development and yielded recommendations for groundwater exploration and other solutions. A high permeability zone and strong surface-groundwater connection was identified along the Gungu River. Data collected throughout the area of interest corroborated that significant freshwater recharge occurs in the alluvial aquifer, promoting an aquifer zone where freshwater and higher yields are likely. Exploratory drilling resulted in a very high-yielding freshwater well that supported the development of a piped water system serving several villages.

Keywords: Brackish Groundwater, Development, Lower Shire River Valley, Malawi, Satellite Imagery/Field Survey, Water Quality Data Clustering

CLICK TO RETURN TO THE PROGRAMME

From monitoring networks to near real-time groundwater forecast. A case study in Cape Town Table Mountain Aquifer, South Africa

J Nicolas[1]., A Gutierrez[1]., B Mougin[1]., V Bault[1]., C Lasher-Scheepers[2]., L Fisher Jeffes[2]., P Msimango[2]

[1]BRGM, France; [2]CoCT, South Africa

Groundwater level monitoring is essential for assessing groundwater's availability, behaviour and trend. Associated with a modelling tool, groundwater level fluctuations can be predicted in the short to middle term using precipitation probabilities or meteorological forecasts. This is the purpose of the MétéEAU Nappes tool implemented by BRGM for the City of Cape Town (CoCT) in the Table Mountain Group Aquifer (TMGA). This case study shows how near real-time groundwater level monitoring can support the municipality in managing its future groundwater withdrawals. The TMGA is an important source of groundwater in the Western Cape region of South Africa. The upper Nardouw Sub-Aquifer of the TMGA is an unconfined aquifer recharged by rainfall. It had been monitored in the Steenbras area for over 10 years before CoCT started groundwater production from the Steenbras wellfield in 2021.

The MétéEAU Nappes forecasting tool is already implemented on many observation wells of the French national piezometric network, where it is used for decision-making by the French administration. It allows, in particular, to anticipate several threshold levels of drought and take appropriate measures. It combines real-time water cycle measurement data with a groundwater level lumped model (e.g. Gardenia model) and extrapolates observations for the next 6 months from statistical meteorological scenarios completed with abstraction scenarios. This tool can help protect the Steenbras wellfield as a critical water source for CoCT in the TMGA. This study was financed by the French Agency for Development (AFD).

Keywords: Gardénia, MétéEau Nappes, Table Mountain Group, forecast, groundwater monitoring, modelling, near real-time

Groundwater Dependent Ecosystems or wetland dependent groundwater systems: A case study

N Vermaak[1]., P Oberholster[1]., T Mathivha[2]., S Mapapu[1]., N Memela[3]., S Fourie[3]

[1]Centre for Environmental Management, UFS, South Africa; [2]Scientific Services, Water and Sanitation, City of Cape Town, South Africa; [3]Department of Water and Sanitation, South Africa

The interaction between groundwater and wetlands is poorly understood, even though it has been the topic of many research projects, like the study done at the Langebaan Lagoon. This interaction is complex as it lies at the intersection between groundwater and surface water, but each situation is unique, with different conditions regulating the interaction. Wetlands can be the source of water that recharges groundwater systems on the one hand, while the other is dependent on the groundwater systems. This interaction became part of the project looking at how to implement Managed Aquifer Recharge for Saldanha Bay Local Municipality without having a negative impact on the groundwater-dependent ecosystems, such as the springs and wetlands in the area. Ten wetlands were identified on the Langebaan Road Aquifer Unit, and a monitoring programme was developed. The purpose of the monitoring was to determine the status of the wetlands as a baseline before the implementation of managed aquifer recharge and to determine the level of groundwater dependence. The latter was done by hydrochemical analysis of rainwater, groundwater and water from the wetlands and stable isotope analysis. The ability of the wetlands to act as a recharge point to the groundwater system will be investigated through column experiments and lithostratigraphic analysis of soil columns taken at the wetlands. Groundwater levels will also be plotted as contour lines to determine the intersection of the water table with the wetlands in the area.

Keywords: Wetlands; groundwater-dependent ecosystems; recharge; groundwater surface water interaction

CLICK TO RETURN TO THE PROGRAMME

Groundwater porosities and effective porosities: definitions, physical relevance, and scale issues

A Dassargues

Hydrogeology & Environmental Geology, Urban and Environmental Engineering Unit, University of Liège, 4000 Liège, Belgium

Porosity describes the ratio between the volume of pores, cracks, and fissures and the total volume of a studied geological medium. This notion implies a volume averaging of the medium characteristics using the concept of Representative Elementary Volume (REV). Small volumes can contain only pores, while larger volumes typically contain both pores and fissures. Porosity can be highly scale-dependent, and different porosity values can be measured for the same geological formation. Furthermore, groundwater in the pores and cracks can be partly immobile or mobile. So, the porosity actively involved in groundwater flow can be discussed. A 'mobile water porosity' can be defined, but this remains highly dependent on the existing pressure conditions in the geological medium. In unconfined conditions, the term 'effective porosity' usually corresponds to the drainage porosity corresponding to the specific yield or storage coefficient. When dealing with solute transport and remediation of contaminated sites, another 'effective porosity' is needed to describe the advection velocity of the contaminant. This 'mobile water porosity' acting in solute transport processes typically takes lower values than drainage's 'effective porosity'. Scale issues must also be expected, as shown by field and lab tracer tests. The term 'Darcy velocity' will be banished herein because it induces much confusion. For clarity, we propose to distinguish 'drainage effective porosity' and 'transport effective porosity'. The physical meaning of both terms is discussed, and examples of supporting observations are presented for illustration and discussion.

Keywords: REV, drainage effective porosity, effective porosity, porosity, scale issue, transport effective Porosity

Geophysics-estimated groundwater levels to assess the accuracy of a numerical flow model

Y Lévesque., J Walter., R Chesnaux

University of Québec at Chicoutimi (UQAC), Canada

Two numerical simulations using Feflow® software were conducted to demonstrate the utility of geophysical data to accurately determine groundwater levels and provide additional data to the groundwater modelling community to improve the model's accuracy. One simulation is based on regional piezometric data, and the other uses geophysical data acquired through transient electromagnetic (TEM), electrical resistivity (ERT), and ground-penetrating radar (GPR) surveys. After both numerical analyses, the root mean square errors (RMS) obtained from the piezometric data and the multiple geophysical techniques to confirm the correlation between observed and simulated water levels were similar at 3.81 m and 2.76 m, respectively. Through a discrete modelling approach, this study shows that groundwater levels estimated using geophysical tools and methods and those determined by direct observation are comparable. In addition, before the 3D numerical flow model, a 3D geological model was built to fully represent this highly complex, heterogeneous, and anisotropic hydrological environment of the Saint-Narcisse moraine glacial deposits in eastern Mauricie, Québec. This stratigraphic reconstruction with Leapfrog software was necessary to provide a more detailed and realistic representation of this complex aquifer system. This study illustrates how geophysical data can complement direct observations to provide additional hydraulic information to hydrologic modellers. Geophysical surveys provide an extensive set of soft data that can be leveraged to improve groundwater flow models and determine water-table heights, particularly in areas characterized by limited direct piezometric information.

Keywords: Eastern Canada, aquifer properties, geophysical methods, groundwater monitoring, numerical modelling, regional piezometry

CLICK TO RETURN TO THE PROGRAMME

Integrated assessment of groundwater potential zones for deep groundwater exploration in hard rock aquifers using GIS and geophysical techniques: A case study of Huai Krachao, Kanchanaburi, western Thailand

V Hunyek., J Phetheet., J Yanawongsa., O Occarach
Department of Groundwater Resources, Thailand

Groundwater is an important freshwater supply that has a significant role in the economy. However, water is increasingly becoming scarce in several regions. Huai Krachao Subdistrict in Kanchanaburi Province is an example of an area that has been experiencing a severe drought for decades due to the impacts of climate change. This study was conducted to delineate the groundwater potential zones in hard-rock terrains using geographic information system (GIS) techniques. The study aims to explore deep groundwater resources in challenging areas and propose alternative methods supporting traditional groundwater exploration. This finding revealed that the groundwater potential zones were classified into high, moderate, and low potential zones based on the groundwater potential index (GWPI), integrated using the Weighted Index Overlay Analysis. The computed weights from the Analytical Hierarchy Process were acceptable and consistent. The high potential zones mainly occur in the Silurian-Devonian metamorphic rocks. The GIS-based analytical results were later prepared for detailed field investigation, including collecting well information and conducting the 2-dimensional geophysical survey. To prove the GWPI map, 9 groundwater wells were drilled in the high potential zones.

Consequently, well yields obtained from the pumping-test analysis ranged from 24-40 m^3/hr, some of which are springs rich in dissolved minerals. Accordingly, a significant amount of water could meet the water demand, supplying about 1 million m^3/year. Under these circumstances, discovering new groundwater resources can support roughly 5,000 people and agricultural lands no less than 480 hectares (4.8 km^2).

Keywords: Deep groundwater exploration; Hard rock aquifer; groundwater potential zones; Analytical Hierarchy Process; weighted overlay analysis; spring

Determination of the best hydrogeological target for improving the success rate and productivity of boreholes in basement rocks

Y Adeotan[1]., M Koita[1]., J Vouillamoz[2]., F Lawson[3]
[1]International Institute for water and environmental engineering; [2]IRD; [3]INE Benin

Access to safe water is not yet universal in Burkina because 30% of Burkinabes do not yet have access to drinking water. The objective of universal access to drinking water (ODD 6.1) is difficult to achieve in the context of population growth and climate change. Basement rocks underline 80% of Burkina Faso. However, about 40% of the boreholes drilled in the Burkina Faso basement rocks do not deliver enough water (Q < 0.2l/s) and are discarded. This study focuses on determining the appropriate hydrogeological target that can be searched to improve the currently low drilling success rate. We set up a well-documented new database of 2150 boreholes based on borehole drilling, pumping tests, geophysical measurements, and geological analysis results. Our first results show that the success rate at 0.2l/s (i.e. 700 l/h) is 63% at the end of the drilling against 54% at the end of borehole development: the yield of 8% of the boreholes lowers significantly after only a few hours of development. We also found that the yield of the water intakes encountered during the drilling process slightly decreases with depth; beyond 60m, it is rare (only 15% of cases) to find water occurrences. We found clear relationships between the productivity of the borehole (yield after drilling and transmissivity obtained from the pumping test) and the thickness of the weathering rocks, indicating that the appropriate target to obtain a productive borehole is a regolith of about 35 meters thick.

Keywords: basement rock aquifers, boreholes properties, hydrogeological targets

CLICK TO RETURN TO THE PROGRAMME

Role of regional scale dykes in the flow of groundwater in the Otavi Mountainland karst aquifers

D Sarma[1]., G Symons[2]
[1]Namib Hydrosearch CC, Namibia; [2]Gregory Symons Geophysics

The work presented relates to the influence of regional scale dykes in groundwater flow in karst aquifers of northern Namibia's Otavi Mountainland around the towns of Tsumeb, Otavi and Grootfontein. The aquifers are well studied and are an important water source locally and for populated central areas of the country during drought. The area has parallel, east-west trending elongated valleys and ranges shaped by the underlying synclines and anticlines of folded carbonate units of the Damara Supergroup. The role of the regional scale dolerite dykes that cut across the dolomitic aquifers has not been fully appreciated till recently. Aeromagnetic data is effective in mapping the dykes in detail. The dykes trend in a north-easterly to northerly direction into the Otavi Platform carbonate rocks. The dykes are normally magnetised with the odd remanent dyke. They consist mainly of dolerite, although in some cases are described as tectonic with hydrothermal magnetite and no dolerite material. The dykes appear to focus southwest of the Otavi Mountainland near the Paresis Alkaline Intrusive (137Ma). Examination of existing hydrogeological data reveals different characteristics of the dykes that influence groundwater flow, forming: a) conduits that enhance flow along contact zones, b) barrier to flow with compartmentalization and c) partial barrier to flow. An advantage has been taken of the understanding gained to manage mines' dewatering and pumped water management. Future water resources management and contaminant studies will need to recognise the compartmentalised nature of the aquifer.

Keywords: Namibia, Otavi Mountainland, compartmentalization, conceptual model, dykes, groundwater flow, karst

Groundwater circulation and hydrogeochemical evolution in the coastal zone of Xiamen, southeast China

Y Li
Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Science, China

This study aims to investigate the groundwater circulation and hydrogeochemical evolution in the coastal zone of Xiamen, southeast China, which can provide a reference for the development of water resources and the protection of soil and water environment in the coastal areas. A close connection between mountains and the sea characterizes the southeast coast of China. Although rainfall is abundant, the topography limits it, and water resources quickly run into the sea. Coupled with a concentrated population, water is scarce. In addition, this area's water and sediment environment are influenced by human activities and geological conditions. Its changing trend also needs further study. Therefore, using hydrochemical analysis, isotope technology, numerical simulation and other techniques, this study took Xiamen City on the southeast coast as an example to study the groundwater circulation and the environmental evolution of water and sediment. The results show that although the aquifer is thinner, there is still deep groundwater circulation, and the seawater intrusion range of deep aquifer is much further than that of shallow aquifer. In addition to geological causes, human activities have become the main factors affecting groundwater quality, especially nitrate and lead. The nitrate content even exceeds the content of the major ionic components. Introducing land-based pollutants has also contributed to declining seawater and sediment quality in the Bay area. In general, the main pollutants in coastal areas include nutrients, heavy metals and new pollutants.

Keywords: Groundwater flow, Hydrogeochemical evolution, Seawater intrusion

CLICK TO RETURN TO THE PROGRAMME

The impact of groundwater temperature on water quality in the urban aquifer of the city of Vienna

E Kaminsky[1,2]., C Englisch[3]., C Griebler[3]., C Steiner[4]., G Götzl[4]., C Stumpp[1,2]

[1]University of Natural Resources and Life Sciences, Vienna, Department of Water, Atmosphere and Environment; [2]Institute of Soil Physics and Rural Water Management, Muthgasse 18, 1190 Vienna, Austria; [3]University of Vienna, Vienna, Austria, [4]GeoSphere Austria, Vienna, Austria

Rising shallow groundwater temperatures are observed in many cities worldwide and are expected to increase further over the next century due to anthropogenic activities and climate change. The impact of groundwater temperature increase on groundwater quality is poorly understood. This study conducted two high-spatial-resolution campaigns in Vienna (Austria, autumn 2021/ spring 2022). At 150 wells, a comprehensive parameter set (e.g. major ions, nutrients, and water stable isotopes) was analyzed in groundwater collected, and at 812 wells, the water temperature was measured. Results are compared to available long-term data on groundwater chemistry (1991-2020). In theory, temperature triggers a cascade of effects, where, finally, the depletion of dissolved oxygen (DO) causes a switch to anaerobic microbial processes and a deterioration of water quality. No direct relation between DO and water temperature was observed between 10 and 20 °C. However, many wells delivered anoxic groundwater, including the one with the highest measured temperature (27 °C). The highest temperatures were consistently observed near potential heat sources (local scale), with a rapid decrease in temperature with increasing distance from these sources. Long-term data from particular high-temperature wells revealed decreased dissolved oxygen after sudden temperature changes of > 5 K. On a regional scale, it is observed that groundwater-surface water interactions and aquifer properties play a pivotal role in oxygen availability and redox conditions. In conclusion, high-spatial-resolution sampling combined with long-term data analysis is needed to determine the impact of temperature on water quality.

Keywords: groundwater temperature, groundwater-surface water interaction, trends, water chemistry

CLICK TO RETURN TO THE PROGRAMME

Multiple-tool approach of combining microbial markers with artificial and natural tracers to specify the origin of faecal contamination on karst groundwater catchment scale

M Sinreich.,
Swiss Hydrogeological Society, Bern, Switzerland

Diverse tools exist to study the transfer of contamination from its source to groundwater and related springs. A backward approach, i.e. sampling spring water to determine the origin of contamination, is more complex and requires multiple information. Microbial source tracking (MST) using host-specific markers is one of the tools, which, however, has shown to be insufficient as a stand-alone method, particularly in karst groundwater catchments. A karst spring in the Swiss Jura Mountains was studied concerning the occurrence and correlation of a set of faecal indicators, including classical parameters and bacteroidal markers. Sporadic monitoring proved the impact on spring water quality, mainly during high water stages. Additional event-focused sampling evidenced a more detailed and divergent pattern of individual indicators. A multiple-tool approach, complementing faecal indicator monitoring with artificial tracer experiments and measuring natural tracers, could specify the origin of ruminant and human faecal contaminations. Natural tracers allowed for distinguishing between water components from the saturated zone, the soil/epikarst storage, or freshly infiltrated rainwater.

Additionally, the breakthrough of injected dye tracers and their remobilization during subsequent recharge events were correlated with the occurrence of faecal markers. The findings hypothesize that human faecal contamination is related to septic tanks overflowing at moderate rainfall intensities. Linkage with vulnerability assessment and land-use information can finally better locate the potential point sources. Such a toolbox provides useful basics for groundwater protection and catchment management and insight into general processes governing the fate and transport of faecal contaminants in karst environments.

Keywords: Karst spring, MST, catchment, faecal indicators, toolbox, tracers

Mitigating climate change with managed aquifer recharge: 5 Case Studies

D Hohne[1]., N Vermaak[2]., F Fourie[1]., S Esterhuyse[2]
[1]Department of Water and Sanitation, South Africa; [2]Centre for Environmental Management, University of the Free State, South Africa

In the past decade, Southern Africa has experienced periods of extreme drought. This was especially true in the western Karoo in South Africa. Continuous drought and limited rainfall led to declining aquifer water levels that curtailed sustainable water supply for towns and livestock. The western Karoo is almost completely dependent on groundwater. Managed aquifer recharge (MAR) is being used to reduce the effects of droughts and mitigate climate change impacts. A good understanding of the geology and the behaviour of the aquifers is needed for implementing various MAR designs, including nature-based solutions, which are used to recharge aquifers with limited rainfall. This paper discusses 5 active MAR case studies in the Western Karoo. Here, site-specific MAR methods that use small rainfall events deliver reasonable results, whereas the implemented MAR options keep most aquifers functional. Observations at the MAR sites also showed improved water quality and less bacterial clogging. This improves the environment around the managed aquifer recharge sites. The MAR methods and designs discussed in this paper can be used on a larger scale for a town or a smaller scale for a farm. Maintenance costs are low, which makes these options cost-effective for less wealthy areas.

Keywords: Climate change; drought; MAR; nature-based solution; case studies

CLICK TO RETURN TO THE PROGRAMME

Managed Aquifer Recharge as a strategy for increased water supply security in Eastern Botswana

J Strömgren[1]., N Kellgren[1]., P Johansson[2]., K Gaboiphiwe3

[1]Sweco International AB, Sweden; [2]Artesia grundvattenkonsult AB; [3]Department of Water and Sanitation, Botswana

The joint application of water supply system security, groundwater modelling, and multicriteria analysis (MCA) indicated the potential of Managed Aquifer Recharge (MAR) to increase water supply security in Eastern Botswana substantially. Botswana faces increased water stress due to decreased water availability as climate change exacerbates variability in rainfall and increases evaporation losses and water demand. The water supply for Eastern Botswana is based on the bulk water supply system of the North-South Carrier (NSC) connecting dams in the northeast to the main demand centres, including Gaborone. The potential of MAR to increase the water security of the NSC by storing water that otherwise would have been lost to spillover and evaporation and contribute to the provision of water during droughts was studied. Large-scale MAR in the Ntane sandstone aquifer at a wellfield by the NSC was evaluated in terms of hydrogeology and national water supply perspective. Comprehensive hydrogeological surveys and assessments included borehole injection tests and hydrogeological and geochemical modelling to evaluate risks of losing recharged water and clogging of boreholes. Probabilistic water supply system modelling analysed the impact of different MAR scenarios on the water supply security of the NSC, and an MCA tool assessed the sustainability of the different scenarios. The analysis showed that large-scale MAR is feasible, and a scheme with a capacity of 40,000 m^3/d is the most sustainable from technical, social, economic and environmental perspectives and could potentially reduce the number of months with water shortage by 50% in Gaborone.

Keywords: Botswana, MAR, groundwater modelling, multi-criteria analysis, probabilistic water supply system modelling, water security

CLICK TO RETURN TO THE PROGRAMME

Aquifer storage and recovery (ASR) applications to enhance drinking water supply security in the Sultanate of Oman

H van den Berg[1]., A Al-Maktoumi[2]., S de Silva[3]., L Mammeri[3]., M Scharnke[4]., K Radmann[4]., A Al-Dhahli[5]

[1]Acacia Water, The Netherlands; [2]Water Research Center, Sultan Qaboos, University, Muscat, Oman; [3]AZD Engineering Consultancy Muscat, Oman; [4]Consulaqua, Hamburg, Germany; [5]Water and Wastewater Services Company, Muscat, Oman

Water scarcity has driven many countries in arid regions, such as Oman, to desalinate seawater for freshwater supply. Episodic problems with seawater quality (e.g., harmful algae), extreme weather events that affect energy supply and hence the desalination process have nurtured the urgent need to store desalinated seawater (DSW) in the aquifers for use during emergency and peak demand time. Aquifer Storage and Recovery (ASR) using injection wells is a possible strategic option for Oman Water and Wastewater Services Company (OWWSC) to augment aquifer storage using excess desalinated water during low demand times. ASR strategically serves as a water supply backup to optimize production capacities against seasonal demand patterns. The technical-economic feasibility of implementing ASR schemes was investigated in Jaalan, Oman, using hydrogeological and geophysical field measurements, groundwater flow and hydraulic modelling, and economic analysis. Analysis of modelled scenarios results revealed that the Jaalan aquifer is suitable for storing and recovering about 4,000 m^3/hr in 2045. Various well field designs have been tested and optimized numerically using MODFLOW 6, showing that with 160 dual-purpose wells, 7.9 Mm^3 can be injected and abstracted within the constraints defined for a robust and sustainable ASR system. Simulations with the density-dependent flow model (MF6 BUY) show that the injected volume can be fully recovered considering the drinking water quality standard. Other sites were also studied. ASR capacity was found to be site-specific, and the groundwater developments near the ASR site governed its feasibility.

Keywords: Aquifer Storage and Recovery (ASR), Oman, desalinated seawater, drinking water supply, groundwater flow modelling, hydrogeology, recovery efficiency

CLICK TO RETURN TO THE PROGRAMME

The impact of storage and hydrogeological conditions on the design and recovery performance of small-scale urban ASR systems

N Hartog[1]., G Schout[1]., Thomas Sweijen[2]

[1]KWR Water Research Institute, The Netherlands; [2]Crux Engineering BV

Aquifer storage and recovery (ASR) can play a vital role in sustaining water availability to cope with increasing weather extremes. In urban areas, ASR systems may provide flooding risk mitigation and support urban greenery. However, such systems are often relatively small and therefore, their recovery performance depends more strongly on site-specific storage conditions such as dispersion and displacement by ambient groundwater flow. In this study, we evaluated the impact of these factors by adapting and developing analytical solutions and numerical modelling, with recently established Urban ASR systems as a reference for a wide range of realistic field conditions. We validated the accuracy and usefulness of the analytical solutions for performance anticipation. Results showed that a simple, analytically derived formula describing dispersion losses solely based on the dispersion coefficient (α) and the hydraulic radius of the injected volume (Rh) provided a very good match for all conditions tested where $\alpha/Rh<0.2$. An expansion of the formula to include the development of recovery efficiency with subsequent cycles (i) was also derived and in keeping with simulation results. Also, displacement losses were found to be significant at groundwater flow velocities that are typically considered negligible, particularly as displacement and dispersion losses disproportionally enforced each other. For specific conditions where the displacement losses are dominant, using a downgradient abstraction well, effectively resulting in an ASTR system, might be beneficial to increase recovery efficiencies despite increased construction costs and design uncertainty.

Keywords: Urban groundwater, Managed Aquifer Recharge, Aquifer Storage and Recovery, MAR, ASR

Evaluation of the impact of artificial recharge of groundwater by river replenishment in the North China Plain using a numerical model

Q Hao., Y Zhu., Y Li

Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences

Since 2018, the North China Plain has started a large-scale ecological water replenishment project for rivers and lakes, with 17.5 billion cubic meters total from the South–North Water Transfer Project and other water sources. It is a key question of how much water infiltration into aquifers will affect groundwater and how to characterize and evaluate this effect quantitatively. The groundwater numerical model of the Beijing-Tianjin- Hebei region as the main part of the North China Plain was established using a numerical simulation method, and the groundwater level variation under the replenishment condition was simulated and predicted. By comparing the two scenarios, the relative rise method of groundwater level was proposed to characterize the influence of river water infiltration on groundwater level, and the unstructured grid method was used to refine cells near the river to improve simulation accuracy. Simulation results show that the groundwater level around some rivers has risen significantly in the past four years, especially in the alluvial fan regions with better infiltration properties. Accordingly, at the Piedmont alluvial fan region, there is also a large influence range on groundwater level. The maximum influence distance is more than 10km (0.1m relative rise of groundwater level was taken as the influential boundary). According to the prediction, if the water replenishment project continues, the range of influence can continue to expand, but the expansion rate will slow down due to the reduction of the hydraulic gradient.

Keywords: Artificial recharge, groundwater management, river water replenishment, the North China Plain

CLICK TO RETURN TO THE PROGRAMME

Benefits and costs of managed aquifer recharge: An integrated water governance solution

A Ross
Fenner School of Environment and Society, Australian National University

Managed Aquifer Recharge (MAR) provides an integrated water governance solution that improves water security for communities and farmers by storing water in aquifers and managing groundwater extractions to ensure water supplies are available during droughts. Quantitative analysis of levelised costs and benefit-cost ratios (BCRs) of 21 MAR schemes from 15 countries and qualitative assessment of additional social and environmental benefits demonstrates the benefits of MAR compared to water supply alternatives. Cost-benefit analysis provides a systematic method for comparing alternative water infrastructure options. Levelised cost is a widely accepted method of comparing MAR with alternative water infrastructure solutions when market valuations of water are unavailable. The benefits of MAR can be estimated by the cost of the cheapest alternative source of supply or the production value using water recovered from aquifer storage. MAR schemes recharging aquifers with natural water using infiltration basins or riverbank filtration are relatively cheap with high BCRs. Schemes using recycled water and/or requiring wells with substantial drilling infrastructure and or water treatment are more expensive while offering positive BCRs. Most MAR schemes have positive or neutral effects on aquifer conditions, water levels, water quality, and environmental flows. Energy requirements are competitive with alternative sources of supply. This analysis demonstrates strong returns to investment in the reported MAR schemes. MAR provides valuable social and environmental benefits and contributes to sustaining groundwater resources where extraction is managed.

Keywords: Managed aquifer recharge; aquifer storage; water infrastructure; cost-benefit analysis; levelized cost; benefit-cost ratio

Assessment of Water Supply Security and Sustainability of Managed Aquifer Recharge in Botswana

A Lindhe., L Rosén
Chalmers University of Technology, Sweden

An approach for evaluating the sustainability of managed aquifer recharge (MAR) has been developed and applied in Botswana. Numerical groundwater modelling, water supply security modelling (SWWM) and multi-criteria decision analysis (MCDA) are combined to thoroughly assess hydrogeological conditions, supply and demand over time and identify the most sustainable options. Botswana is experiencing water stress due to natural conditions, climate change and increasing water demand. MAR has been identified as a potential solution to increase water supply security, and the Palla Road aquifer, located 150 km northeast of the capital, Gaborone, has been identified as a potential site. To evaluate the potential of MAR and if it is suitable for improving water supply security, three full-scale MAR scenarios were evaluated based on their technical, economic, social and environmental performance relative to a scenario without MAR. The numerical groundwater model and the WSSM were used iteratively to provide necessary input data. The WSSM is a probabilistic and dynamic water balance model used to simulate the magnitude and probability of water shortages based on source water availability, dynamic storage in dams and aquifers, reliability of infrastructure components, and water demand. The modelling results were used as input to the MCDA to determine the sustainability of alternative MAR scenarios. The results provide useful decision support and show that MAR can increase water supply security. For the Palla Road aquifer, storage and recovery with a capacity of 40 000 m^3/d is the most sustainable option.

Keywords: managed aquifer recharge, multi-criteria decision analysis, sustainability assessment, water supply security model

CLICK TO RETURN TO THE PROGRAMME

Making groundwater a National Priority

Jay Matta
Unicef

Unicef is the WASH sector lead globally and is, present at the country level, the main counterpart of government, especially regarding the component of the water balance utilised for potable safe water supplies. This mandate means that Unicef then has a role in looking at water resources nationally and not just as individual projects, and in doing so, contributes to good water governance as an integral part of system strengthening. Ensure this is done in partnership with other ministries and stakeholders that support them through advocacy for humanitarian and developmental access and support in technical areas such as groundwater assessments and monitoring. The focus on groundwater is especially linked with the fact that groundwater plays a major role due to its buffering capacity to climate variations, easier access and global coverage. Since groundwater is the most significant component of accessible freshwater resources, it is in the interest of UNICEF to make this resource more visible to meet both development and humanitarian goals, strengthen national systems and ultimately build resilience in mitigating water scarcity to scale or at the National level. Therefore, examples will be presented where Unicef has engaged on this journey with nations such as Afghanistan, Yemen, Mozambique and Rwanda to understand their water resources better. The overall objective at the National level is to adapt the capacity to withstand and recover as quickly as possible from external stresses and shocks or build resilience.

Keywords: Unicef, groundwater, resilience, scaling up

Sustainable establishment of localised groundwater supply systems at critical infrastructure for disaster preparedness

G Kode
Department of Earth Science, University of the Western Cape, Cape Town, South Africa

Given the challenging global water outlook due to climate change and urbanisation, there is a heightened necessity for greater water resilience at critical facilities to tackle water disasters or disasters that lead to water crises. In 2017, the Western Cape Province of South Africa experienced an extended drought with the risk of acute water shortages. The Western Cape Government (WCG) developed business continuity plans and implemented a programme to ensure water supply to certain critical service delivery facilities, utilising the strategy of developing localised groundwater supply systems. The case study research of the WCG program enabled the development of an evaluation framework that assessed this strategy's effectiveness in improving water resilience levels at critical facilities. From the lessons learnt in the WCG programme, the research also crystallised the critical success factors in sustainably implementing this strategy. The research showed that this is an effective strategy for its purposes and provides both current and future disaster preparedness planners with an improved understanding of the levels of water resilience achievable through this strategy and the methodology to achieve it best.

Keywords: Western Cape Province, business continuity planning, critical facilities, disaster planning, localised groundwater supply systems, water resilience

CLICK TO RETURN TO THE PROGRAMME

Transboundary groundwater flows between Poland and Ukraine: The role of joint assessments and international frameworks on water resources management

T Solovey[1]., R Janica[1]., V Harasymchuk[2]., H Medvid[2]., L Yanush[3]., M Przychodzka[1]

[1]Polish Geological Institute, Poland; [2]Institute of Geology and Geochemistry of Combustible Minerals of National Academy of Sciences of Ukraine; [3]State Enterprise Zahidukrgeologiya

There is a transboundary groundwater reservoir on the Polish–Ukrainian borderlands, which is of key importance in shaping strategic groundwater resources. Due to the particular importance of this reservoir, the two neighbouring countries are obliged to undertake joint actions to protect it. One of the main difficulties in building a common platform for the management of TBAs in the Polish-Ukrainian border area is the differences in the approach to the identification of GWB, monitoring methodologies and assessment of the condition of GWB, and the inconsistent hydrogeological databases between the two countries. A transboundary numerical groundwater flow model was developed to support internationally integrated management. The model research helped diagnose potential problems by determining the scope of the area with cross-border flows and quantifying the flows between Poland and Ukraine. In addition, the numerical model was used to define the optimal cross-border management unit and the conditions needed to exploit the Lublin–Lviv Reservoir sustainably. Abstraction on a current level slightly increased the transboundary groundwater flow from Poland to Ukraine and minimally reduced the flow in the opposite direction but did not reverse the direction of water flow at the border. The simulated drawdowns do not have a transboundary range, but negative effects on surface water resources are noticeable. Joint management should focus on a broader legal consensus, improvement of institutional relations, and integration of monitoring and groundwater status assessment systems.

Keywords: Cross-border groundwater flow, Numerical modelling, Sustainable exploitation, Transboundary aquifer, Water management

Harmonized groundwater data in International River Basins under the Water Framework Directive (2000/60/EC) – Challenges

B Flem[1]., L Stalsberg[2]., P Gundersen[1]

[1]Geological Survey of Norway; [2]The Norwegian Water Resources and Energy Directorate

Transboundary aquifers in Europe are managed according to the Water Framework Directive (WFD) through international river basin districts (IRBD) management plans. Paragraph 11 in the WFD states that each Member State shall ensure the establishment of a programme of measures, PoM, for each river basin district, RBD, or part of an IRBD within its territory. Easy access to harmonized data from neighbouring countries part of the aquifer is essential to analyse the groundwater status and make proper PoMs. The datasets must be available in machine-readable format via an Application Programming Interface (API) and, where relevant, as a bulk download. The metadata describing the data shall be within the scope of the Infrastructure for Spatial Information in the European Community (INSPIRE) data themes set. The datasets must also be described in a complete and publicly available online documentation describing the data structure. Using a questionnaire survey of nine European countries, groundwater sampling and analysis routines are compared to evaluate if data are comparable and accessible across borders.

Keywords: Harmonized data; monitoring; sampling techniques; analysis

CLICK TO RETURN TO THE PROGRAMME

Basin Water Balance modelling with the aim to make transboundary groundwater flow visible

M Hunt[1]., D Borozdins[2]., A Marandi[1]

[1]Geological Survey of Estonia; [2]Latvian Environment, Geology and Meteorology Center

A conceptual water budget model is required to "make groundwater visible" in the shared transboundary area of Estonia and Latvia, which doesn't face any significant water management issues. Despite having a water management agreement since 2003, it wasn't until 2018 that cooperation on groundwater began. In the EU-WATERRES project, the water balance modelling of the ~9,500 km^2 transboundary (TB) area with MODFLOW 6 was performed. Based on budget calculations, the area's average precipitation is 203 m^3/s, with ~50% (102 m^3/s) of it discharging to the sea as surface water. The infiltration share (7%, 14.4 m3/s) is a small fraction of overall precipitation, but as an average, it forms ~14% of surface water flow, with 98% of infiltrated groundwater forming the baseflow. Modelling produced two main conclusions: surface water and groundwater form a joint system in the upper ~150 m cross-section depth, and there is no preferred regional TB flow direction due to flat topography. This makes cross-border flow highly dependent on pumping close to the border area. The results of recent studies provide valuable information on groundwater's importance in EE-LV TB areas and a basis for simple conceptual models to make groundwater visible to the general audience and decision-makers. These findings are critical for specialists in managing water resources in the region and will inform decisions related to the use and protection of groundwater in transboundary areas.

Keywords: EUWaterres, Modflow6, Transboundary aquifers, surface water groundwater interactions, water balance modelling

Water allocation and economic analysis for developing groundwater resources

P Tungkidwanichakul

Department of Groundwater Resources, Thailand

Thailand has been grappling with a water scarcity problem every year, leading to insufficient water supply for consumption in many areas. To tackle this issue, groundwater is developed from large sources, making water allocation and economic analysis essential for measuring investments in water supply projects. This research study analyzes the water allocation for consumption and irrigation, including the water sent to hospitals, in two areas, Si Somdet & Roi Et Province and Nong Fai. The study uses the WUSMO program to analyze irrigation water and the EPANET program to analyze the entire water allocation system. The expected results include the appropriate allocation of water for maximum benefit, considering both delivery time and the amount of water to ensure adequate delivery. The study provides a guideline for effective and sustainable water allocation and management, including appropriate and sufficient water costs for managing the water distribution system in both areas. The results show that a water rate of 19 baht per cubic meter in Si Somdet & Roi Et Province results in a B/C value of 1.04 and an EIRR of 6.48%, while a water tariff of 15 baht per cubic meter in Nong Fai results in a B/C of 1.01 and an EIRR of 6.16%. The study highlights the importance of regular analysis of water allocation and cost-effectiveness of projects to ensure sustainable and efficient water management for the people.

Keywords: Epanet, WUSMO, groundwater management

CLICK TO RETURN TO THE PROGRAMME

OFF-SOURCE: A network to address the potential use of offshore freshened groundwater as an unconventional source of potable water in coastal cities.

H Wazaz[1]., A Micallef[1]., C Bertoni[2]., M Giustiniani[3]., K Schwalenberg[4]., A Thomas[1]., E Quiroga-Jordan[5]., W Hong[6]., D Chiacchieri[7]

[1]University of Malta, Department of Geosciences; [2]University of Oxford; [3]National Institute of Oceanography and Applied Geophysics – OGS; [4]BGR-Federal Institute for Geoscience and Natural Resources, Section B1.4 Marine Resources; [5]Ruden AS; [6]Stockholm University; [7]University of Roma Tre

One-third of the world faces water insecurity, and freshwater resources in coastal regions are under enormous stress due to population growth, pollution, climate change and political conflicts. Meanwhile, several aquifers in coastal regions extending offshore remain unexplored. Interdisciplinary researchers from 33 countries joined their effort to understand better if and how offshore freshened groundwater (OFG) can be used as a source of potable water. This scientific network intends to 1) estimate where OFG is present and in which volumes, 2) delineate the most appropriate approaches to characterise it, and 3) investigate the legal implications of sustainable exploitation of the offshore extension of transboundary aquifers. Besides identifying the environmental impact of OFG pumping, the network will review existing policies for onshore aquifers to outline recommendations for policies, action plans, protocols and legislation for OFG exploitation at the local to international levels. Experienced and early-career scientists and stakeholders from diverse disciplines carry out these activities. The Action leads activities to foster cross-disciplinary and intersectoral collaboration and provides high-quality training and funded scientific exchange missions to develop a pool of experts to address future scientific, societal, and legal challenges related to OFG. This interaction will foster new ideas and concepts that will lead to OFG characterisation and utilisation breakthroughs, translate into future market applications, and deliver recommendations to support effective water resource management. The first exchange mission explored the Gela platform carbonate reservoir (Sicily), built a preliminary 3D geometrical model, and identified the location of freshened groundwater.

Keywords: Offshore groundwater, COST Action, scientific networking, unconventional water resources, transboundary aquifer

CLICK TO RETURN TO THE PROGRAMME

Continental-scale mapping of groundwater yield from basement aquifers in Africa

D MacDonald
British Geological Survey

Crystalline basement underlies much of Africa, and the groundwater within the shallow, weathered layer provides reliable drinking water for many people. This resource is key in adapting to changing climate, particularly in providing reliable water for drinking and small-scale irrigation. However, this requires higher yields from boreholes than currently abstracted. Renewed research is required to investigate sustainable yields from this type of aquifer and how it varies spatially. Recent work on crystalline basement rocks in Africa has shown that there are a number of important geological and geomorphological controls on shallow aquifer parameters; variability of geological properties and the impact of the landscape history is likely to have a strong control. Typically, the basement has experienced high metamorphic grades, which reduces intergranular porosity.

Consequently, the aquifer relies on the presence of fault/ fracture zones; and the regolith's depth and nature, which can have significantly higher porosity and permeability than the underlying bedrock. The interaction and variability of these key factors and climatic and land-use variables are likely to impact shallow aquifer productivity strongly. Here, we report on an ongoing study by UK and African scientists to understand how to represent the variability of geological, regolith and landscape factors across African crystalline basements. In tandem, a data-driven modelling approach is being used to examine these controls' influence on groundwater yields. Continental-scale mapping of basement groundwater yield is planned, supporting those planning further aquifer development, including the growing use of solar-powered pumps.

Keywords: Africa, aquifer mapping, basement aquifers, groundwater yield

Groundwater Flow Modeling for Investigation of Exploitation Induced Land Subsidence

A Elçi[1]., C Meisina[2]., C Guardiola-Albert[3]., R Tomas[4]., P Teatini[5]., J Valdés-Abellán[4]., K Shatanawi[6]., T Letterio[7]., A Hakan Ören[1]

[1]Dokuz Eylul University, Izmi, Turkiye; [2]University of Pavia, Italy; [3]Instituto Geológico y Minero de España-CSIC, Madrid, Spain; [4]University of Alicante, Alicante, Spain; [5]University of Padova, Padova, Italy; [6]The University of Jordan, Amman, Jordan; [7]Consorzio di Bonifica di Secondo Grado per il Canale Emiliano Romagnolo, Italy

This paper presents the results of groundwater flow modelling studies that were conducted within the scope of the PRIMA RESERVOIR project. The project's main goal is to develop an innovative methodology to mitigate land subsidence due to excessive groundwater exploitation in water-stressed Mediterranean watersheds. This objective is achieved by integrating earth-observation-derived land subsidence rates with a coupled implementation of numerical groundwater flow and geomechanical modelling. MODFLOWbased 3-D transient flow models were constructed for the four pilot sites (the coastland of Comacchio in Italy, the Alto Guadalentín aquifer in Spain, the Gediz River basin alluvial aquifer in Turkiye and the Azraq basin in Jordan) that have different hydrogeological properties and pose different challenges concerning water management. Models were calibrated and run for similar simulation periods (2013-2021) to obtain hydraulic head drawdowns and changes in groundwater storage. Land subsidence at these sites was evaluated using Advanced Differential Radar Interferometry (A-DInSAR) on image stacks from the Sentinel-1 satellite. Subsidence rates were then compared to hydraulic head drawdown rates to identify groundwater pumping-induced subsidence areas. The comparison for all study areas suggested that locations of maximum displacements do not necessarily coincide with areas that display the largest head drawdown calculated by the flow models. Other triggering factors, such as the thickness of compressible materials, are also related to high subsidence areas.

Keywords: MODFLOW, Mediterranean, earth observation, land subsidence, over-exploitation

CLICK TO RETURN TO THE PROGRAMME

Winter irrigation as climate change adaptation strategy in northern Italy

L Alberti., P Mazzon., P Colombo
Politecnico di Milano, Italy

In 2021-23, northern Italy suffered a severe drought due to the absence of rainfall, which strongly affected the pre-alpine lake levels, affecting energy production, agriculture and sustainable river flows. This led to harsh consequences on agriculture, which in the Lombardy region almost completely relied on flooding irrigation methods using water from lakes through Ticino and Adda rivers. As part of the INTERREG Central- Europe project "MAURICE", which focuses on Integrated Water Resources Management, the winter irrigation practice is proposed as a climate change adaptation strategy. The main project idea is to store surface water in aquifers in periods of exceedance (autumn/winter) using the very dense channels irrigation network as a "natural" infiltration system. The underground storage would increase the groundwater levels, bringing two main advantages during the spring/summer seasons: a good flow rate at plain springs and, in periods of water scarcity, the possibility to extract groundwater for agricultural purposes. Relying on the slow groundwater velocity (about 350 m/y), this practice keeps water stored in the subsoil just below the irrigated areas where the water is needed. In the early project stage, a basin-scale numerical model is presented to test the potentiality of such practice. A specified water volume was distributed on the crop fields during the winter period, and the effects of such managed recharge were evaluated, also considering the possible problems deriving from the groundwater levels increase. The model demonstrates the adaptation measure feasibility, which will be tested at a field scale in a Pilot Area.

Keywords: Adaptation strategies, Climate change, Integrated Water Resources Management, Irrigation, Managed Aquifer Recharge, flow modelling

Improved hydrogeological conceptual model through additional ERT profiles in medial-distal facies of andesitic volcanic area: Case study of Pandaan, East Java, Indonesia

A Fadillah[1]., N Dörfliger[2]., B Baud[3]., H Hendrayana[4]., P Lachassagne[3]., H Wibowo[4]., A Muhammad[5]., A Harijoko[4]., A Putra[1]
[1]Danone; [2]Danone D2D; [3]University of Montpellier; [4]Universitas Gadjah Mada; [5]Danone Aqua

In Java Island, Indonesia, andesitic volcanic aquifers are the main water resource for domestic, agricultural, and industrial use. To guarantee sustainable management, a hydrogeological conceptual model is key. Electrical resistivity tomography (ERT) survey is one tool to characterize aquifer structures and extension, specifically in the medial facies of the Arjuno Welirang volcano. Fadillah et al. (2023) proposed a hydrogeological interpretation of the aquifers in the central to proximal-medial transition zone of the Arjuno Welirang volcano. This interpretation was based on geology, hydrogeology, and ERT and focused on major springs and boreholes. Nine additional ERT profiles and borehole data were collected downstream to enhance the medial facies' understanding further. Seven ERT lines were conducted throughout the midstream part of the watershed. The results confirm the presence of two superimposed aquifers, a first unconfined aquifer made of volcanic sandstone and breccia with a vertical extension of 25 meters and a confined aquifer from 35 to 120 meters (maximum depth of investigation). This last one consists of tuffaceous breccia and volcanic sandstone and includes lava layers as well. A clayey layer with an average thickness of 10 meters constitutes the aquiclude/aquitard between those two aquifers. Furthermore, two ERT lines were conducted in the vicinity of the major spring located in the distal part of volcanic deposits, highlighting the development of a multi-layer alluvial aquifer system.

Keywords: Andesitic stratovolcanoes, Electrical Resistivity Tomography, Groundwater, Hydrogeological, conceptual model, sustainability

CLICK TO RETURN TO THE PROGRAMME

Exploring the Role of Land Use evolution in Groundwater Modeling for Sustainable Management: A Case Study of the Lille Metropolitan Area

R Aissat., G Picot-Colbeaux., C Herivaux., M Parmentier., A Manlay., P Audigane., J Vergnes., F Mathurin., J Mossmann
BRGM, France

Groundwater represents a crucial source of drinking water in the Lille metropolitan area. Despite its importance, the resource is vulnerable to the potential evolution of land use: recharge, runoff and evapotranspiration processes in a soil-sealing context and changes in cultural practices. As a result, stakeholders emphasized the importance of exploring the influence of land use on groundwater to ensure sustainable resource management and enhance territorial planning. The 3D hydrodynamic model helped manage groundwater resources, but the (MARTHE code) has a significant limitation in that it does not consider the impact of land use evolution. We propose to investigate the contribution of a hydrological distributed numerical approach incorporating land cover data in groundwater modelling compared to a global approach at the scale of a peri-urban territory. To do so, we use the HELP code by considering the temporal and spatial evolution of land use and their associated characteristics, such as vegetation and soil properties, to detail recharge and runoff over more than 20 years that we incorporate into the initial groundwater model. The two approaches yielded comparable global water balance results. However, at the local scale, the model accounting for land use showed significantly different hydric components. Choosing the appropriate model depends on the specific research question and spatial scale, and considering land use evolution is crucial for accurate urban planning impact assessments, especially at the district level.

Keywords: Land use change, groundwater flow modelling, groundwater sustainability, recharge, runoff

Integrated Modeling to Simulate Groundwater and Surface Water Interaction in the Letaba River Catchment, Limpopo Province, South Africa

G Mohale

The current study investigates the spatial patterns and temporal dynamics of the groundwater and surface water interactions for integrated water resource management practices. This follows the results of the groundwater flow conceptual and numerical models developed for the Middle Letaba sub-catchment, indicating that groundwater and surface water interactions play a fundamental role in determining the hydrological water balance. The study area is an example of a fully allocated surface water resource in the northeastern part of South Africa, extensively developed for domestic use and agricultural farming. As a result of the semi-arid nature of the climate, limited surface water resources and increasing water demand, the situation has contributed to groundwater as the only dependable source of water supply for various uses. However, in the last few decades, periodic water level measurements in several boreholes indicated a continuous drop in the piezometric surface over time. This study utilised HydroGeoSphere to simulate water flow processes in a fully integrated and physically based model. The results of the steady-state groundwater flow simulation indicated that recharge from the rainfall and river leakages are the most important components of the inflows that control the availability of groundwater. Water resources management scenarios suggest a continuous decline in water level, which strongly influences the groundwater flow dynamics and future availability of fresh water. Regular monitoring and management of groundwater level and abstraction are required to avoid overexploitation and possible groundwater contamination due to the strong interaction between surface water and groundwater.

Keywords: Catchment., groundwater, HydroGeoSphere, interaction, surface water

CLICK TO RETURN TO THE PROGRAMME

Thermal energy storage in old flooded mines: how to tackle the hydrogeological issues

A Dassargues., P Orban.

Hydrogeology and Environmental Geology, Urban and Environmental Engineering
University of Liège, B52 Sart Tilman 4000, Liège, Belgium

Groundwater in flooded abandoned mines could be used for geothermal purposes using heat pumps and an open loop involving pumping and re-injection. Hydraulic conductivity values of the mined rock zones have been artificially increased. However, long-term efficiency and the possible impacts of geothermal doublets must be studied involving a series of hydrogeological challenges. Hot water would be pumped from the deep parts of the mine works, and cold water would be re-injected in a shallower gallery or shallow fractured rocks, with a seasonal flow inversion for building cooling during the hot season. Indeed, a 'short-cut' groundwater flow is to be avoided between the mine's deep and shallow parts. The true geometry of the interconnected network of open galleries and shafts can be highly complex and must be conceptualized realistically to ensure that the model is feasible and reliable. This model must involve groundwater flow and heat transport, with temperature-dependent density and viscosity, in a complex 3D heterogeneous domain of highly fractured rocks and partially collapsed exploitation zones, galleries, and shafts. Such a model is nevertheless widely recommended to design and optimize the short--, mid-, and long-term efficiency of the geothermal system and assess possible environmental impacts. An example of simulations on a synthetic case will be used for illustration and preparation work before further application in a real case study.

Keywords: doublets, energy storage, flooded mines, geothermal system, heat transport, modelling, old mines, open geothermal energy

Mine dewatering case study at a gold mine in Mandiana Region, Eastern Guinea

A Johnson[1]., S Rziki[2]

[1]GCS Water and Environmental Consultants (Pty) Ltd; [2]Reminex (PTY) Ltd

A hydrogeological investigation was conducted at a gold mine in the Mandiana region, northeast Guinea. The objectives of the investigation included: 1) Review the efficiency of the current dewatering system and 2) Assess potential dewatering impacts on neighbouring groundwater users. Historical and current hydrogeological information were reviewed and assessed to address the project objectives. The site geological succession contains laterites, saprolites, saprock, dolorite sill and fresh fractured bedrock below. A review of the borehole lithological logs, pump test and monitoring data confirmed that the contact zone between the saprock and the dolorite sill is the major aquifer zone with hydraulic conductivity up to 25 m/d, with a minor alluvial aquifer with hydraulic conductivity ~ 0.05 m/d. The current dewatering system is not as effective as it should be due to electrical issues causing seepage into the current pit floor. A combination of in-pit sumps and dewatering boreholes is recommended to ensure the mine pit's dry working conditions. The neighbouring groundwater users tap into the alluvial aquifer with water levels ranging between 0-10 mbgl and are not at risk from mine dewatering impacts due to the dewatering boreholes tapping into the deeper saprock-dolorite contact zone. The shallow and deeper aquifers are hydraulically disconnected. The following is recommended: 1) Drilling of replacement dewatering boreholes and implementing continuous water level and abstraction rate monitoring, and 2) Discharge the in-pit sumps (alluvial aquifer inflow and rainfall) into the river downgradient of the mine to supplement recharge to the alluvial aquifer.

Keywords: Mine dewatering, monitoring

CLICK TO RETURN TO THE PROGRAMME

Hydrogeological Conceptual Model of Kinsevere Mine

Sarah Mahlangu
MMG Limited

Kinsevere Mine is an open pit copper mine located within the Central African Copper Belt, experiencing common water challenges as mining occurs below the natural water table. The site's conceptual model is developed and updated as one of the tools to manage and overcome the water challenges at and around the mining operations. The natural groundwater level mimics topography but is also affected by the operations. The pits act as sinks. The water table is raised below the waste dumps due to recharge in these areas, and the general groundwater flow direction is to the east. The site is drained by the Kifumashi River, located to the north of the site. Water levels from dewatering boreholes and natural surface water bodies define the site's piezometric surface. The geological model is adopted to define the aquifers and groundwater controls. The Cherty Dolomites, a highly fractured Laminated Magnesite Unit, contribute the highest inflows into the mine workings. The Central Pit Shear Zone acts as a conduit and compartment for groundwater between Mashi and Central Pits. Hydraulic tests have been conducted over the years, and these data are used to estimate possible aquifer property values. The high-yielding aquifer on the west is dewatered using vertical wells, and the low-yielding breccia on the east is depressurized using horizontal drain holes. The site's water management strategy is reviewed and improved through refinement of the conceptual model.

Keywords: Groundwater; Conceptual Model; Copperbelt; Dewatering; Hydrogeology

Paleo-hydrogeological reconstruction of a complex deep groundwater system in a tectonically active region

H Levanon[1,2]., A Burg[2]., I Gavrieli[2]., Y Rosenberg[2].,. R Gersman[3]., Y Bartov[4]., Y Livshitz[5,6]., A Starinsky[1]., I Reznik[2]

[1]Institute of Earth Sciences, The Hebrew University of Jerusalem; [2]Geological Survey of Israel; [3]Genie Oil and Gas Ltd; [4]MOSESTRO Exploration LLP; [5]Israeli Hydrological Service; [6]Israeli Water Authority

The geochemical study of deep aquitard water in the southern Golan-Heights (GH), Israel, reveals the complex paleo-hydrological history affected by the intensive tectonic activity of the Dead Sea Rift (DSR). The sampled water collected from new research boreholes exhibits relatively high salinities (2,000-10,000 mg Cl/L), low Na/Cl (<0.7) and Mg/Ca (<0.3) equivalent ratios, and a Ca-Chloride composition ($Ca>(HCO_3+SO_4)$). $\delta^{18}O_{V\text{-}SMOW}$ and $\delta D_{V\text{-}SMOW}$ values are relatively depleted (~-7‰ and ~-42‰, respectively), while $^{87}Sr/^{86}Sr$ ratios are enriched compared to the host rocks. Lagoonary brines with similar characteristics (excluding the water isotopic compositions) are known to exist along the DSR. These brines formed 10-5 Ma ago from seawater that transgressed into the DSR and subsequently underwent evaporation, mineral precipitation and water-rock interactions. These hypersaline brines intruded into the rocks surrounding the DSR and based on the current study, also extended as far as the southern GH. Further, following their subsurface intrusion into the GH, the brines have been gradually diluted by isotopically depleted freshwater, leaving only traces of brines nowadays. The depleted isotopic composition suggests that the groundwater system is recharged at high elevations in the north. It is also shown that variable hydraulic conductivities in different formations controlled the dilution rates and subsequently the preservation of the entrapped brines. The paleo-hydrological reconstruction presented here shows that the flow direction has reversed over time. Brines that initially intruded from the rift have since been gradually flushed back to the rift by younger fresh groundwater.

Keywords: Dead Sea Rift, Golan Heights, Lagoonary brines, Paleo-hydrology, intrusion/backflow

CLICK TO RETURN TO THE PROGRAMME

A methodology for uncertainty quantification of dewatering volumes under the context of open-cast mining

C Rivera Villarreyes
DHI

Groundwater modelling at the mine sites involves assumptions from the geological model, mining stages, parametrization, and fractures, among others. Modelling work mainly focuses on calibrating against historical measurements before operations (pre-mining) or afterwards (transient calibration). Calibration is carried out mainly with gradient-based algorithms. However, the majorlimitation is the number of model runs, since the number of parameters can easily reach hundreds or more. PEST has become the common tool for parameter estimation. The Jacobin calculation required for the Levenberg Marquardt algorithm requires several model runs. This, a limited factor for the calibration and, subsequently, uncertainty quantification. The next generation of PEST, named PESTPP, is gained popularity in the groundwater community. The great advantage of PESTPP,, compared to the classical PEST, is its new module, Iterative Ensemble Smoother (IES). PESTPP-IES covers both parameter estimation and uncertainty quantification in one goal. Its empirical formulation of the Jacobian matrix reduces the number of runs; thus, the numerical bottleneck can be significantly reduced. PESTPP-IES has been extensively tested in an open-pit mine at the geological complex conditions in the Peruvian Andes. The work involves the task of model simplification, e.g., from a regional model to a detailed local pit model, calibration and uncertainty quantification of pit dewatering volumes. Detailed model was kept calibrated based on hydraulic-head measurements, and dewatering volumes were predicted. All these consider transient changes in the mining plan within the same FEFLOW model. Results validate the methodology and practicability in mining applications.

Keywords: FEFLOW, Groundwater modelling, Mining, PEST, PESTPP

Electromagnetic measurements in the Netherlands using an All Terrain Vehicle to rapidly characterize groundwater salinity and clay distribution in 3D

J Gunnink[1], S Meekes[2]
[1]TNO; [2]Geological Survey of the Netherlands

Electromagnetic (EM) techniques were used to map groundwater salinity and clay layers in the Netherlands. The EM method used the so-called time domain system, is towed behind an ATV and is therefore called towed TEM. The results revealed a detailed 3-dimensional insight into the subsurface's sequence of clay and sandy layers. Also, shallow saline groundwater, far from the coast, has been detected related to a subsurface salt dome. The rapid, non-destructive data acquisition makes the tTEM a unique tool. Electromagnetic (EM) techniques detect electrical conductivity contrasts in the subsurface with depth. EM data can often be interpolated into a 3D model of electrical conductivity. Expert knowledge of the regional geohydrologist, together with existing (borehole) data, is paramount for the interpretation. The towed Transient Electro-Magnetic system (tTEM) is developed to acquire data up to 60-80m depth by driving a transmitter and a receiver behind an ATV. With a speed of 10-15 km/h, measurements are collected every 5m. On fields, the distance between lines is typically 20m, resulting in a dense network of data that is inverted into 1D resistivity models, showing the variation of conductivity with depth. Interpolating 1D resistivity models into a 3D model allows for further interpretation in terms of geology, lithology, and groundwater quality. The tTEM technique bridges the gap between point measurements and more expensive and lower-resolution airborne EM data collection. The technique is sensitive to disturbance by man-made conducting infrastructure.

Keywords: 3d-mapping, clay distribution, electromagnetics, groundwater salinity

CLICK TO RETURN TO THE PROGRAMME

Electrical Hydrogeology of Managed Aquifer Recharge from Meter to Kilometer Scales

T Halihan., W Andrews
Oklahoma State University, USA

While traditional well and spring sampling are limited to the integration of point data and the interpolation of the data across large scales. Electrical measurements of aquifers can be extended across a range of scales and integrated to provide an improved quantitative understanding of groundwater systems. At a site in Oklahoma, USA, a karst-managed aquifer recharge research site is being used to test electrical techniques for aquifer characterization on the kilometer scale and monitoring the aquifer on the meter scale. At the kilometer scale, the data illustrate fault locations, siphons in flow paths, and previously uncharacterized conduits. At the metre scale, the monitoring data illustrate porosity structure, flow paths, and potential biological changes in the subsurface. The results indicate that electrical approaches can significantly change aquifer conceptual models and provide targeted sampling locations in karstic bedrock aquifers.

Keywords: Byrds Mill Spring, carbonate, electrical resistivity imaging, enhanced aquifer recharge, karst

Planning for increased water security and preventing salinisation in coastal areas of the Netherlands: A study on the suitability for managed aquifer recharge and extraction of brackish water, including quantification of potential extractable volumes

I de Groot-Wallast[1]., I America[1]., J King[1]., G Oude Essink[1,2]., K Raat[3]
[1]Deltares, The Netherlands; [2]Utrecht University; [3]KWR, The Netherlands

Year-round water security is at risk as socio-economic developments lead to increasing water demands, while climate change affects water availability through higher-intensity rainfall and prolonged periods of drought. Coastal zones and deltas with often high population densities experience additional risks of salinisation and land subsidence. These developments ask for creative solutions to secure sustainable and year-round access to fresh water. The subsurface provides storage capacity to actively infiltrate freshwater, bridging the time-gap between demand and supply. Combining infiltration with extraction and desalination of brackish water prevents the salinisation of aquifers whilst providing an additional water source. We call this COASTAR. A Dutch research consortium with partners like water companies and water boards develops COASTAR. Among COASTAR results are suitability maps for Aquifer Storage and Recovery (ASR) and Brackish Water Extraction (BWE) in the coastal zone of the Netherlands. The maps are based on geohydrological factors. A quick-scan analysis was also performed to quantify the nation-wide potential extractable ASR and BWE volumes. COASTAR develops case study models and local scale pilots on ASR and BWE. For two water supply regions, an analysis has been made to geographically match development in water demand with suitability for ASR and BWE as a step in the search for strategic locations to develop ASR and BWE. The suitability maps provide guidance for initiatives' development and practical experiences from pilot projects; this provides important information for further upscaling of COASTAR approaches.

Keywords: Aquifer Storage and Recovery (ASR), Managed Aquifer Recharge (MAR), aquifer salinisation, brackish water extraction, suitability maps, water supply

CLICK TO RETURN TO THE PROGRAMME

Managed Aquifer Recharge within the Greater Kruger National Park and Implementation of Recharge Scheme.

M Holloway., P Lourens
University of Freestate, South Africa

West of the world-renowned conservation site, Kruger National Park, lies the larger extent of the Greater Kruger National Park within the Limpopo province. Boreholes have been drilled for decades to provide water to game lodges, large resorts, and watering holes for game viewing and livestock. The area contains both primary and secondary aquifers classified as having yields between 0.5 and 5.0 l/s, based on the geological setting, which consists of gneiss intruded by dolerite dyke swarms. A geohydrological assessment revealed that groundwater quality within the project area has an EC of 100 - 350 mS/m, linked to borehole proximity to surface water systems. The Makhutswi Gneiss and Doleritic Dyke swarms are the major controlling geology of the area, with higher-yielding boreholes close to dykes and major structural lineaments (faulted / weathered zones). A concern identified through geohydrological assessment observations is that boreholes frequently dry up after a few years, requiring deeper drilling/redrilling or drilling a new borehole. Aggressive calcium hardness in the water frequently damages equipment and increases maintenance costs. This project investigated the feasibility of increasing recharge to the aquifer with seasonal flooding/rainfall events by constructing artificially enhanced recharge locations overlaying doleritic dykes. This is expected to decrease the groundwater's salinity and hardness, reducing operational costs. This pre-feasibility assessment has been completed, and the project has continued through a gradual implementation phase.

Keywords: Aquifer, Dolerite, Feasibility, Gneiss, Increased, Managed, Recharge

The Atlantis Water Resource Management Scheme – Lessons in Resilience

L Towers., K Riemann
Umvoto, South Africa

The Atlantis Water Resource Management Scheme (AWRMS) has operated since the 1970s. It demonstrates cost-effective and wise water use and recycling through visionary town planning and Managed Aquifer Recharge (MAR), offering water security to Atlantis's residential and industrial sectors. For the AWRMS to succeed, it required integrating its water supply, wastewater and stormwater systems. Each of these water systems is complex and requires a multidisciplinary management approach. Adding to the challenges of inter-departmental co-operation and communication within a municipal system is the complexity and vulnerability of the coastal, primary Atlantis Aquifer. A combination of operational difficulties, biofouling, vandalism and readily available surplus surface water (leading to scheme augmentation from surface water) were negative drivers to decrease the reliance on groundwater supply from the scheme's two wellfields. In response to the 2015-2018 drought experienced in the Western Cape of South Africa, the City of Cape Town has improved assurance of supply from the scheme and successfully built resilience by upgrading knowledge and insight through improved investigative techniques, monitoring, modelling and adaptive management of the various water resources and associated infrastructure systems. An integrated and adaptive management approach is essential to ensure continued water security and resilience to the effects of on-going urban expansion, population growth and climate change. Resilience is assured by institutions, individuals and communities taking timely and appropriate decisions, while the long-term sustainability of the AWRMS depends on proper management of all actors coupled with a high level of scientific confidence.

Keywords: adaptive management, drought, managed aquifer recharge, resilience

CLICK TO RETURN TO THE PROGRAMME

Tracer applications in an urban MAR (Rhine) scheme: Identifying the presence of regional groundwater in a complex geological setting

J van Rooyen[1,2]., O Schilling[2]
[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland; [2]Hydrogeology, Department of Environmental Sciences, University of Basel, Switzerland

Managed aquifer recharge (MAR) has become increasingly popular in Central Europe as a sustainable, clean, and efficient method for managing domestic water supply. In these schemes, river water is artificially infiltrated into shallow aquifers for storage and natural purification of domestic water supply, while the resulting groundwater mound can simultaneously be designed to suppress the inflow of regional groundwater from contaminated areas. MAR schemes are typically not managed based on automated optimization algorithms, especially in complex urban and geological settings. However, such automated managing procedures are critical to guarantee safe drinking water. With (seasonal) water scarcity predicted to increase in Central Europe, improving the efficiency of MAR schemes will contribute to achieving several of the UN SDGs and EU agendas. Physico-chemical and isotope data has been collected over the last 3-4 decades around Switzerland's largest MAR scheme in Basel, Switzerland, where 100 km^3/d of Rhine river water is infiltrated, and 40 km^3/d is extracted for drinking water. The other 60 km^3/d is used to maintain the groundwater mound that keeps locally contaminated groundwater from industrial heritage sites out of the drinking water. The hydrochemical/isotope data from past and ongoing studies were consolidated to contextualize all the contributing water sources of the scheme before online noble gas and regular tritium monitoring commenced in the region. The historical and the new continuous tracer monitoring data is now used to inform new sampling protocols and create tracer-enabled/assimilated groundwater-surface water flow models, vastly helping algorithm-supported MAR optimization.

Keywords: Isotopes, MAR, Online monitoring, Urban groundwater

Optimizing managed aquifer recharge in coastal dunes by extracting brackish groundwater: results of a field pilot in the Netherlands

T van Dooren[1,2]., G Zwolsman[3]., K Raat[4]., N Hartog[4]., S Huizer[5]
[1]KWR Water Research Institute, Nieuwegein; [2]The Netherlands & Technical University of Delft, Delft, The Netherlands; [3]Dunea; [4]KWR Water Research Institute, Nieuwegein, The Netherland; [5]Arcadis, Arnhem, The Netherlands

Faced with climate change and population growth, Dutch drinking water company Dunea is looking for additional water resources to secure the drinking water supply for the coastal city of The Hague. One of the options is to enhance the existing managed aquifer recharge (MAR) system in the coastal dunes by extracting brackish groundwater. Extracting brackish groundwater provides an additional drinking water source, can protect existing production wells from salinization, and can effectively stabilise or even grow the freshwater reserves in the coastal dunes, according to numerical groundwater modelling. To test this concept in the field, a three-year pilot commenced in January 2022 at Dunea's primary drinking water production site, Scheveningen. Brackish groundwater is extracted at a rate of 50 m^3/h with multiple well screens placed in a single borehole within the brackish transition zone (85-105 meters below sea level). The extracted groundwater is desalinated by reverse osmosis, whilst the flow rate and quality of extracted groundwater are continuously monitored. The hydraulic effects and the dynamic interfaces between fresh, brackish and saline groundwater are monitored with a dense network of piezometers, hydraulic head loggers and geo-electrical measurement techniques. At the IAH conference, the monitoring results of the pilot will be presented. Based on the results of the field pilot and additional numerical modelling, the feasibility of upscaling and replicating the concept of brackish groundwater extraction to optimize MAR and increase the availability of fresh groundwater in coastal areas is reflected.

Keywords: Brackish groundwater extraction, managed aquifer recharge (MAR), drinking water production, field pilot, coastal dunes

CLICK TO RETURN TO THE PROGRAMME

The connectedness of transboundary groundwater researchers: from network analysis to network-building

A Fernald[1,2]., A Atkins[3,4]., C Kirkpatrick[5,6]., C Tang[1,2]., J Kaminsky[5,6]., I Zaslavsky[5,6]

[1]New Mexico State University; [2]New Mexico Water Resources Research Institute; [3]UC Berkeley; [4]West Big Data Innovation Hub; [5]UC San Diego; [6]San Diego Supercomputer Center

The Transboundary Groundwater Resilience (TGR) Network-of-Networks project brings together researchers from multiple countries to address the challenges of groundwater scarcity and continuing depletion. Improving groundwater resilience through international research collaborations and engaging professionals from hydrology, social science, data science, and related fields is a crucial strategy enabling better decision-making at the transboundary level. As a component of the underlying data infrastructure, the TGR project applies visual analytics and graph-theoretical approaches to explore the international academic network of transboundary groundwater research. This enables the identification of research clusters around specific topic areas within transboundary groundwater research, understanding how the network evolved over the years, and finding partners with matching or complementary research interests. Novel online software for analysing co-authorship networks, built on the online SuAVE (Survey Analysis via Visual Exploration, suave.sdsc.edu) visual analytics platform, will be demonstrated. The application uses OpenAlex, a new open-access bibliographic data source, to extract publications that mention transboundary aquifers or transboundary groundwater and automatically tag them with groundwater-specific keywords and names of studied aquifers. The analytics platform includes a series of data views and maps to help the user view the entire academic landscape of transboundary groundwater research, compute network fragmentation characteristics, focus on individual clusters or authors, view individual researchers' profiles and publications, and determine their centrality and network role using betweenness, eigenvector centrality, key player fragmentation, and other network measures. This information helps guide the project's data-driven international networking, making it more comprehensive and efficient.

Keywords: network analysis, network-of-networks, transboundary groundwater

CLICK TO RETURN TO THE PROGRAMME

Enhancing resilience to hydrological extremes in the Limpopo River Basin: a collaborative modelling approach

S Mustafa[1,2]., A Matano[3]., F Franchi[4]., S Tirivarombo[4]., A Van Loon[3]., J Comte[5]

[1]Hydrology and Quantitative Water Management Group Wageningen University; [2]Research Wageningen, The Netherlands; [3]Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands; [4]Department of Earth and Environmental Science, Botswana, International University of Science and Technology (BIUST), Palapye, Botswana | Department of Earth; [5]School of Geosciences, University of Aberdeen, Aberdeen, UK

The Limpopo River Basin (LRB) is highly vulnerable to recurrent floods and droughts, significantly threatening its water and food security. Sustainable groundwater management is necessary to improve resilience. Scientists and stakeholders must collaborate to evaluate management scenarios that can identify sustainable practices. A transboundary basin-scale management instrument was developed using a multisector collaborative modelling approach to identify the role of groundwater in building resilience. The approach used an integrated hydro(geo)logical model, co-created through stakeholder workshops. The model assessed management scenarios identified during a series of local, national and transboundary stakeholders workshops, focusing on improving groundwater storage during wet periods for use during dry periods in a context of population growth and increasing groundwater reliance across the basin. Management scenarios: (1) increasing groundwater abstraction; (2) deforestation; (3) afforestation; and (4) managed aquifer recharge (MAR) using injection wells capturing excess water from major dams, rainwater harvesting through local ponds/wells, and small water reservoirs. Analysis of scenario outputs suggested that local groundwater storage techniques, especially water harvesting and storage through small-scale water well recharge, were the most effective strategy in reducing the risk and impact of floods and drought at the basin scale. Upscaling this strategy can significantly increase groundwater levels across the basin, supporting increasing groundwater reliance. The study showed that the multisector collaborative modelling approach effectively co-creates management strategies and identifies appropriate and inclusive strategies to improve resilience in data-limiting conditions. The proposed modelling outcomes are useful in making informed decisions regarding water management and transboundary cooperation in the LRB.

Keywords: Limpopo River Basin (LRB), climate resilience, collaborative modelling approach, hydrological extremes and stakeholders workshops

CLICK TO RETURN TO THE PROGRAMME

How to manage the Plitvice Lakes National Park (Croatia) as part of transboundary groundwater resources?

H Meaški., R Biondić., J Loborec., K Leskovar
University of Zagreb, Faculty of Geotechnical Engineering, Croatia

The National Park Plitvice Lakes (NPPL) in the Republic of Croatia was declared in 1949 due to its exceptional natural beauty. However, in addition to its attraction, the NPPL also encompasses an area of significant karstic water resources in the Dinaric karst region, on the border between the Black Sea and the Adriatic Sea catchment. In some parts, groundwater connections to the Klokot Spring and Una River in Bosnia and Herzegovina have been assumed by hydrogeological research and proven by tracing tests, which confirm transboundary aquifer. Assessing transboundary aquifer systems already presents challenges in managing this area, considering not only the well-defined physical catchment. Therefore, comprehensive protection is necessary, which must reconcile people's aspirations for spatial development with the sustainability of natural systems. Protecting karstic water resources can be achieved through separate analyses of the natural vulnerability of surface and groundwater and their integration into a comprehensive protection system. Protection should be layered through three levels: (1) protecting the area from the impact of the upstream catchment, (2) protecting surface water in the catchment that is most affected by anthropogenic influences, and (3) protecting the surrounding area from the impact of the NPPL, which with numerous visitors every year and tourist facilities, also represents significant pressure on downstream catchments. The ultimate goal is a scientifically based proposal for sustainable development of the protected area, in line with the needs of protection and spatial use, and based on an assessment of the overall risk to water resources.

Keywords: Groundwater protection, Karstic water resources, Plitvice Lakes, Transboundary aquifer

Characterization of groundwater dynamics to identify the risks of flooding of the sewerage network of the urban communities of Lens-Liévin (northern France)

G Picot-Colbeaux[1]., N Devau[1]., A Manlay[1]., V Debois[2]., P Goderniaux[2]., L Jehanno[1]., B Meire[1]
[1]BRGM, French Geological Survey, France; [2]UMons, Mons University, Belgium

The interactions between groundwater and the sewerage networks of the Lens-Liévin urban communities, located in the north of France, locally lead to non-compliance in the operation of the network and the wastewater treatment plants, questioning the city's economic development policy. Indeed, the infiltration of groundwater inflow in the sewerage network could be the cause. Based on the piezometric measurements carried out in 2022, the surface elevation of the groundwater table is carried out using a kriging approach. The comparison of altitudes between network position and piezometry made it possible to identify the pipes most at risk of the infiltration of groundwater inflow and correspond to those indicated as non-compliant by network managers according to the national decree. Outside this period, the network vulnerability indicators are defined based on simulated piezometry by a 3D hydrodynamic model of the chalky hydrosystem (MARTHE code) established in a transient state. For two past extreme situations, the network would have been flooded at 1.20% in the dry period (1997) and up to 8.30% in the wet period (2001), highlighting the existence of a part of the network systematically flooded. Using the hydrodynamic model according to different prospective scenarios makes it possible to anticipate the actions deployed on the network to guide management and adaptation solutions. However, a modelling methodology that considers the feedback between the dynamics of the groundwater and the flows passing through the networks remains to be developed.

Keywords: aquifer, groundwater, groundwater inflow, hydrodynamic modelling, piezometry, sewerage network, urban hydrogeology

CLICK TO RETURN TO THE PROGRAMME

Water resource management in tectonically active volcanic regions: Towards an in-depth understanding of Mt. Fuji's hydrogeology

S Musy[1]., C Friederike[1]., N Teresa[2]., T Yama[1,3]., S Yuji[2]., S Oliver[4]

[1]Hydrogeology, Department of Environmental Sciences, University of Basel, Switzerland; [2]Center for Advanced Marine Core Research, Kochi University, Japan; [3]Entracers GmbH, Dübendorf, Switzerland; [4]Department Water Resources and Drinking Water, Eawag–Swiss, Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland

Mt. Fuji is the iconic centrepiece of a large, tectonically active volcanic watershed (100 km^2), which plays a vital role in supplying safe drinking water to millions of people through groundwater and numerous freshwater springs. Situated at the top of the sole known continental triple-trench junction, the Fuji watershed experiences significant tectonic instability and pictures complex geology. Recently, the conventional understanding of Mt. Fuji catchment being conceptually simple, laminar groundwater flow system with three isolated aquifers was challenged: the combined use of noble gases, vanadium, and microbial eDNA as measured in different waters around Fuji revealed the presence of substantial deep groundwater water upwelling along Japan's tectonically most active fault system, the Fujikawa Kako Fault Zone [1]. These findings call for even deeper investigations of the hydrogeology and the mixing dynamics within large-scale volcanic watersheds, typically characterized by complex geologies and extensive networks of fractures and faults. In our current study, we approach these questions by integrating existing and emerging methodologies, such as continuous, high-resolution monitoring of dissolved gases (GE-MIMS [2]) and microbes [3], eDNA, trace elements, and integrated 3-D hydrogeological modelling [4]. The collected tracer time series and hydraulic and seismic observations are used to develop an integrated SW-GW flow model of the Mt. Fuji watershed. Climate change projections will further inform predictive modelling and facilitate the design of resilient and sustainable water resource management strategies in tectonically active volcanic regions.

Keywords: SW-GW interactions; tracers; modelling

CLICK TO RETURN TO THE PROGRAMME

Hydrological processes in the Arctic catchment of Bayelva River (Western Svalbard-Norway)

M Doveri[1]., I Baneschi[1]., L Franceschi[1]., M Menichini[1]., A Vergnano[2]., F Pace.[2], G Romano[3]., A Godio[2]., A Santilano[1]., L Capozzoli[4]

[1]Institute of Geosciences and Earth Resources, CNR, Pisa, Italy; [2]Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, Torino, Italy; [3]Department of Earth and GeoEnvironmental Sciences, University of Bari Aldo Moro, Bari, Italy; [4]Institute of Methodologies for Environmental Analysis-National Research Council, (IMAA-CNR), Potenza, Italy

Streamwater and groundwater are changing in the Arctic region because of significant climate warming. Arctic amplification has intensified the melting of snow cover, glaciers and permafrost, leading to a prominent variation in the annual discharge of rivers, the groundwater occurrence, and their relationships. In high-latitude regions, evaluating groundwater flux/storage and river discharge is challenging due to a lack of hydrogeological data. Changes in river flows and groundwater discharge will alter freshwater and terrigenous material flux, with implications for freshwater and marine ecosystems. Consequently, a more timely and accurate evaluation of surface and groundwater is required. In this framework, through the ICEtoFLUX project (MUR/PRA2021/project-0027), hydrology, geophysics and geochemical-isotopic surveys have been started during 2022 in the Bayelva River catchment (W-Svalbard) from its glaciers and periglacial/proglacial systems up to the Kongsfjorden. The study aims to quantify hydrologic processes and related transport of matter (solid transport, chemical solutes flux) and investigate how subsurface and surface waters interact during active layer development. The first results suggest that electrical conductivity and total suspended solids increase from glaciers to the Bayelva monitoring station, about 1 km from the coast. Seasonal evolution of physical-chemical features was also observed. Results from geophysics data and piezometers indicate that the underground flow is spatially and temporally heterogeneous, both quantitatively and from a physicochemical-isotopic point of view. Springwater characteristics testify to a deep and well-organized groundwater flow path system. This study highlights the high complexity of these systems and their high sensitivity to the meteo-climatic regimes.

Keywords: Arctic hydrology, climate change, groundwater-surface water evolution, melting water

Balancing qualitative and quantitative issues of the groundwater extraction at the drinking water production site of Velm (Central Belgium)

S Van den Broeck., S Six

De Watergroep

Recent findings allow a better insight into the interaction between two aquifers and their vulnerabilities at the groundwater extraction site of Velm, which produces drinking water for around 55,000 households. The shallow aquifer that is exploited is situated in the Formation of Hannut. This aquifer is vulnerable to pollution, especially from the agricultural lands close to the extraction site and is sensitive to natural recharge. In this case, the groundwater is captured in a basin via a naturally occurring spring flow. The second aquifer is situated in the Cretaceous at 50 to 100 m below the surface and is pumped by four wells. The drinking water quality is guaranteed by mixing and treating these two waters. To optimize the central decalcification and the pollution risks, the production volume in the deep aquifer was increased from 2017 to 2021 at the expense of the shallow aquifer. This led to a decrease in the available volumes of the shallow aquifer, which indicated a leakage from the shallow to the deeper aquifer, which was unexpected. Groundwater modelling and time series analysis have been used to assess the impact of the increased production volumes and the longer dry periods. Based on this data, a maximum production volume of 1,000,000 m^3/year is considered best for the cretaceous aquifer. With this extraction rate in the Cretaceous, it is possible to supply sufficient drinking water and limit the impact on the Formation of Hannut.

Keywords: Belgium, Drinking water, drought, pollution, sustainability, time series analysis

CLICK TO RETURN TO THE PROGRAMME

Integrating reductive dehalogenase enzyme production into reactive transport modelling to simulate chloroethene biodegradation in groundwater pollution plumes

D Di Curzio[1]., C Ottosen[2]., G Lemaire[2]., M Laureni[1]., P Bjerg[2]., D Weissbrodt[3]., M Broholm[2]., B van Breukelen[2]

[1]Delft University of Technology, Department of Water Management, Delft, Netherlands; [2]Technical University of Denmark, Department of Environmental and Resource Engineering, Kongens Lyngby, Denmark; [3]Norwegian University of Science and Technology, Department of Biotechnology and Food Science, Trondheim, Norway

Degradation of chloroethene in groundwater primarily occurs via microbially-mediated reductive dechlorination (RD). Anaerobic organohalide-respiring bacteria (OHRB) use chloroethenes as electron acceptors to gain energy. They produce reductive dehalogenase enzymes (RDases) to perform this function by transcription of functional genes into mRNA and translation to proteins (metabolic regulation). However, how hydrodynamics and hydrogeochemistry control the metabolic efficiency of OHRB in biodegrading chloroethene is essential for effective bioremediation design yet an under-investigated topic. For this reason, we implemented a virtual experiment (1D reactive transport model) to investigate the effects of site conditions on transcription-translation and, hence, biodegradation processes within chloroethene plumes. In the model, RD was simulated using Enzyme-Based Kinetics, explicitly mimicking the production of RDases via metabolic regulation, calibrated on microcosm experimental data gained from literature. Features of an actual contaminated site (Grindsted, Denmark) were then used to set up the virtual experiment. Here, chloroethene leaked from a former pharmaceutical factory migrates through a sandy aquifer and gets discharged into the Grindsted stream. Preliminary results show that substrate (electron donors) limiting conditions caused by competing electron acceptors and dispersion and high flow rates represent the key factors controlling biodegradation via RDase production.

Keywords: Biodegradation; Chloroethenes plume; Reactive Transport Modeling; Enzyme-Based Kinetics; Reductive dehalogenase enzymes; Groundwater

CLICK TO RETURN TO THE PROGRAMME

The Roussillon coastal aquifer: using multiple-point statistics and multi-model ensemble to characterize geological uncertainty impact on water resources estimation

V Dall' Alba[1]., S Lanini[2]., Y Caballero[2]., P Renard[1]
[1]University of Neuchâtel; [2]BRGM

Coastal groundwater is a vulnerable resource, estimated to sustain the water needs of about 40% of the world's population. The Roussillon aquifer is a regional aquifer near Perpignan (southern France). It covers over 800 km^2 of land and is used for irrigation, drinking water, and industrial purposes. The aquifer has experienced significant piezometric lowering in the last decades, weakening the regional resource. An important aspect of modelling the hydrodynamic of this aquifer is the need to integrate data from agriculture and drinking water abstraction, natural and anthropogenic recharge, and account for the aquifer's complex sedimentary arrangement.

An ensemble of groundwater models has been constructed to understand the spatial evolution of the saline/freshwater interface and evaluate the impact of groundwater abstraction. Three sets of physical parameter modelling approaches were used. The first is based on the direct interpolation of pumping tests. The second uses sequential indicator simulations to represent the geological uncertainty. The third is based on a detailed conceptual geological model and multiple-point statistics to represent the detailed geological structure. These models provide parameter fields that can be input for the transient state hydrodynamic simulations. Overall, the ensemble approach allowed us to understand the Roussillon plain's hydrological system better and quantify the uncertainty on the possible evolution of the main groundwater fluxes and water resources over the last 20 years. These models can help to inform management decisions and support sustainable water resource development in the region.

Keywords: Coastal aquifer, Groundwater modelling, Multi-model ensemble, Uncertainty analysis

Alluvial aquifer modelling with MODFLOW in a case of a wellfield in a climate change context (Clermont-Ferrand, France)

J Labbe[1]., H Celle[2]., P Nevers[2]., V Klaba[2]., J Devidal[1]., M Clauzet[3]., G Mailhot[1]
[1]Université Clermont Auvergne,,CNRS UMR 6296, Institut de Chimie de Clermont-Ferrand, Aubière, France; [2]Université de Franche-Comté, NRS UMR 6249, Chrono-Environnement, Besançon, France; [3]Laboratoire Contrôle des Eaux de Clermont-Ferrand

This work is part of the AUVERWATCH project (AUVERgne WATer CHemistry), which aims to better characterise some Auvergne water bodies, specifically the alluvial hydrosystem of Allier River (France). Alluvial aquifers constitute worldwide a productive water resource, superficial and easily exploitable. In France, 45% of the groundwater use comes from these aquifers. The study site is a wellfield that withdraws 8.5 million m^3 of water annually from an alluvial aquifer to produce domestic water for 80% of the local population. At the watershed scale, precipitations have decreased by -11.8 mm/y, air temperatures have increased by 0.06°C/y and the river flow has declined by 20.8 Mm^3/y on 2000 – 2020. In the summer period, at least 50% of the river flow is ensured by the Naussac dam (upstream catchment part), but the recent winter droughts have not allowed the dam to replenish. Thus, water stakeholders are concerned that the productivity of the wellfield could be soon compromised. Based on geological, geophysical, hydrochemical, and hydrodynamic surveys, a numerical model of the wellfield is being developed using MODFLOW. The calibration in natural flow regime is successful using a range of hydraulic conductivities going from 1×10^{-3} to 1×10^{-4} m/s (pilot points method), consistent with the pumping tests. Preliminary results show that the river entirely controls the groundwater levels at all observation points. The perspective is now to calibrate this model in a transient regime by integrating domestic water withdrawals to determine how low the river can go without affecting the wellfield productivity.

Keywords: Alluvial aquifer, groundwater modelling, climate change, water management

CLICK TO RETURN TO THE PROGRAMME

Evaluating Karst Drywells for Urban Stormwater Management and Aquifer Recharge

Y Ganot[1]., E Valdman[1,2]., E Farber[3]., N Amir[4]., Y Amiaz[4]., T Kamai[2]

[1]Bar-Ilan University, Ramat-Gan, Israel; [2]Agricultural Research Organization, Rishon LeZion, Israel; [3]Hydrogeology consultant, Ramat-Gan, Israel; [4]Israel Water Authority, Jerusalem, Israel

Drywells are extremely useful for coping with excess surface water in areas where drainage and diversion of storm flows are limited, facilitating stormwater infiltration and groundwater recharge. Drywells have been used for stormwater management in locations that receive high precipitation volumes, naturally or due to climate change; however, to date, they have not been developed in urban areas overlying karst landscapes. To test the performance of karst drywells, we constructed a pilot system for collecting, filtering, and recharging urban stormwater through drywells in karst rock. The study site is in the Judaean Mountains, an urban residential area in Jerusalem, Israel. The infiltration capacity of the drywells was evaluated using continuous and graduated water injection tests, and its effective hydraulic conductivity (*K*) was estimated. Drywells' infiltration capacity was up to 22 m^3/hour (the maximum discharge delivered by a nearby fire hydrant), while monitored water levels in the drywells were relatively stable. Calculated hydraulic conductivities were in the range of *K*=0.1-100 m/day, and generally, *K* was inversely proportional to the rock quality designation (RQD) index (obtained from rock cores during the drilling of the drywells). The pilot system performance was tested in the recent winter: during 9 days with a total rainfall of 295 mm, a cumulative volume of 45 m^3 was recharged through the drywell, with a maximum discharge of 13 m^3/hour. High-conductivity karst drywells and adequate pre-treatment filtration can be valuable techniques for urban flood mitigation and stormwater recharge.

Keywords: Drywell, Karst, MAR, RQD, Unsaturated zone

Experiments of the artificial-recharge rate of sand and gravel aquifer through shallow recharge wells in the Chao Phraya River basin region

K Daranond., J Chimpalee., A Pongsatitpat., P Klahan

Department of Groundwater Resources, Bureau of Groundwater Reservation and Restoration, Latyao, Chatuchak, Bangkok 10900, Thailand

The aquifers in the Chao Phraya River basin region were abundant in groundwater. Lately, the groundwater level has been declining due to agricultural activities. While in the wet season, these areas frequently suffered from flooding due to lower elevation than their surroundings. The Managed Aquifer Recharge (MAR) methods were applied to ease problems by constructing artificial recharge wells which can detain stormwater runoff and let it gradually infiltrate into the aquifer directly. For decades, the Department of Groundwater Resources started the MAR project to alleviate groundwater depletion and flooding over specific areas. However, most of the projects in the past lacked follow-up results and evaluation. Thus, later projects attempted to study recharge processes to evaluate the volume of recharged water through structures and calculate the infiltration rate through filter layers within the structures. Recently, the field experiments of artificial groundwater recharge were conducted as 8-hour and 20-day experiments with shallow recharge wells in the Chao Phraya River basin regions. These two types of experiments provided similar results. The average recharge rates of 8-hour and 20-day experiments are 2.22 m3/hr and 2.57 m3/hr, respectively. Recharge rates of each well were independently distinct depending on sedimentation characteristics, aquifer thickness, and volume of dry voids. During the test, the recharge well continuously encountered the problem of sediment clogging due to using untreated water from neighbouring streams and ponds. This clogging issue needed to be treated regularly to maintain the efficiency of the recharge well.

Keywords: MAR, Managed Aquifer Recharge, clogging, recharge rate

CLICK TO RETURN TO THE PROGRAMME

Managed aquifer recharge (MAR) suitability mapping Using GIS-MCDA: The South African perspective

L Nhleko., Z Phikiso., C Musekiwa., R Grow
Council for Geoscience

To increase the security of groundwater resources, managed aquifer recharge (MAR) programs have been developed and implemented globally. MAR is the intentional recharge and storage of water in an aquifer, which will be recovered later. It was previously known and implemented as Artificial Recharge (AR). In South Africa, the documented practice dates back 40 years. There are five main MAR methods: Well-Shaft-Borehole, Spreading-induced bank infiltration, In-channel modifications, and Runoff harvesting. Two regional-scale MAR suitability maps for the Spreading Method (SM) and the Well-Shaft-Borehole (WSB) Method were compiled for South Africa, using the Geographic Information System combined with Multi-Criteria Decision Analysis (GIS-MCDA) methodology. Parameters used to compute the maps included the nature of the different aquifers, groundwater level, water quality (EC), distance to river, terrain slope, mean annual rainfall, land cover, soil moisture availability and clogging (Fe-iron content). To create a suitability map, the parameters were combined using the weighted overlay method and the Analytic Hierarchy Process (AHP – specifically the pairwise comparison). The site suitability maps indicated that most areas in South Africa are suitable for the Spreading and Well-Shaft-Borehole methods. The results were verified with the location of existing MAR schemes and were found to agree. However, these maps are not applicable for siting projects at a local scale but can serve as a guide and screening tool for site-specific studies looking for highly suitable or target areas for MAR implementation.

Keywords: Managed Aquifer Recharge, Multi-Criteria Decision Analysis, Regional Scale, Suitability mapping

Pock Marks as a Nature-based solution for enhancing water availability in African marginal drylands?

D Kibirige
University KwaZulu Natal, South Africa

Nearly 1.9 billion people live in marginal environments, including drylands, semiarid, arid, and hyperarid environments. Obscure but ubiquitous circular pockmark depressions dot these lands. These circular depressions can range from a few meters to kilometers, and the depth of these depressions varies from a few centimeters to over 10 m. However, the genesis of the circles has been investigated among scientists for many years because of their obscure nature. Some researchers believe that termites cause fairy circles, while others believe they are caused by plants competing for water and nutrients. This study documented the Africa-wide prevalence and extent of the pockmarks for the first time, and it further classified the pockmarks according to their genesis and hydrological roles. We further investigated their relevance in serving as nature-based solutions to overcome water scarcity in dryland regions. So far, field evidence in Ethiopia and Somalia showed that these features potentially have water security significance in a) organizing surface water flows over arid/semi-arid landscapes, b) serving as the site of temporary surface water storage, and c) serving as the site of focused groundwater recharge into the underlying aquifers. This presentation will highlight the spatial prevalence, extent, and genesis model of the pockmarks across the drylands in Africa (South Africa, Namibia, Somalia, Ethiopia, Kenya, Chad, Senegal, Mali, Niger, etc.).

Keywords: Pockmarks, groundwater, nature-based solutions

CLICK TO RETURN TO THE PROGRAMME

Coupling environmental tracers and modelling and what can they tell us about groundwater sustainability and example from the southwestern Great Artesian Basin (GAB) of Australia

A Love[1]., R Purtschert[2]., Y Xie[3]., D Wohling[4]., S Fulton[5]., J McCallum[6]., M Chmielarski[6]., W Ziang[7]., Z Lu[7]., G Yang[8]., P Shand[1]., W Aeschbach[8]., L Broder[9]., P Mueller[10]., Y Tosaki[11]

[1]Flinders University; [2]University of Bern; [3]University of Nanjing; [4]Innovative Groundwater Solutions; [5]Fulton Consultancy; [6]University of Western Australia; [7]University of Science and Technology; [8]University of Heidelberg; [9]ETHZ; [10]ANL; [11]Geological Survey of Japan

Recent advances in groundwater dating provide valuable information about groundwater recharge rates and groundwater velocities that inform groundwater sustainability and management. This talk presents a range of groundwater residence time indicators (^{85}Kr, CFCS ^{14}C, ^{81}Kr, ^{36}Cl and ^{4}He) combined with analytical and numerical models to unravel sustainability parameters. Our study site is the southwestern Great Artesian Basin of Australia where we study an unconfined confined aquifer system that dates groundwater from modern times up to 400 kyr BP. The study area is arid with a rainfall of <200 mm/yr and evaporation in the order of 3 m/yr. Despite these arid conditions we observe modern recharge rates in the order of 400 mm/yr. This occurs via rapid ephemeral recharge beneath isolated riverbeds where the sandstone aquifer directly outcrops. Groundwater dating and stable isotopes of the water molecule indicates that this recharge comes from monsoonal activity in the north of the continent that travel some 1500 kms. Furthermore, this is restricted to recharge in the Holocene.as we move down the hydraulic gradient groundwater “ages” increase and recharge rates dramatically decrease by orders of magnitude. We conclude that there has been a significant decline in monsoonal precipitation and hence recharge in the deserts of central Australia over this time. We present a couple environmental numerical model that describes how to estimate temporal recharge rates and estimates of hydraulic conductivity from groundwater age data that can be used for groundwater management.

Keywords: Great Artesian Basin, environmental tracers, recharge rates

Units for joint management of cross-border groundwater impacts in Transboundary Aquifers: An overview of concepts and methodologies

C Morales[1]., T Stigter[1]., C Fraser[2]., B van Breukelen[3]., G Jewitt[1]

[1]IHE Delft Institute for Water Education; [2]Independent researcher; [3]Delft University of Technology

This study aims to contribute to the conceptual and methodological development of units of joint management in transboundary aquifers (TBAs) to prevent and mitigate cross-border groundwater impacts (GWIs) in quantity and/or quality. Joint management units are a relatively new but growing topic in the field of TBAs, and their conceptualisation and appropriate identification are still at an early stage. By reviewing the literature on the subject and elaborating on its terminology, main features, and current methodological progress, a comparison of the existing methodologies for identifying such units is analysed. On this basis, trends and recommendations for further research and application of such methodologies to the joint management of TBAs are presented. The literature on this issue is scarce and has been published mainly in the last five years. These publications lack consistency in the use of concepts and terminology. The above has led to miscommunication and semantic issues in the concept behind such units and in comprehending the particular challenges of identifying them. Still, some directions and methodologies for identifying or directly delineating these management units have been proposed in the literature. However, no analysis from these methodological attempts has been conducted; thus, there are no lessons to be learned about this progress. This research looks forward to closing these gaps and making headway toward dealing with cross-border GWIs in TBAs, thus helping countries meet international law responsibilities and maintaining stable relationships among them.

Keywords: cross-border groundwater impacts, hotspots identification, joint management units, time and space scales factor, transboundary aquifers, zoning

CLICK TO RETURN TO THE PROGRAMME

Groundwater-dependent ecosystem dynamics in transboundary aquifer settings - a case study in the Tuli-Karoo aquifer

K Majola[1]., Y Xu[2]., T Kanyerere[2]

[1]Department of Water and Sanitation, South Africa; [2]University of the Western Cape, South Africa

Knowledge of the nature and extent of groundwater-dependent ecosystems (GDE) at an aquifer scale enables incorporating ecological water requirements in integrated groundwater resource management activities, including transboundary aquifer cases (TBA). This way, sustainable groundwater management and functional ecosystem services can be achieved. Therefore, understanding groundwater- ecosystems-surface water interactions is crucial for assessing resources' resilience or susceptibility towards certain impacts. Unfortunately, this subject is widely under-researched with fragmented information, especially in southern Africa. This study was thus initiated to understand groundwater processes controlling the maintenance of Tuli-Karoo TBA (Botswana, South Africa, Zimbabwe) GDEs towards developing a model that can be utilised in impact assessments, especially in climate change. The employed approach included stable isotope analysis (mainly ^{2}H and ^{18}O) for groundwater, streams, springs, rainwater, vegetation, and soil; spatial imagery and GIS classification (incl. NDVI, NDRE, NDWI); and plant moisture stress techniques. Identified GDEs in the study area (characterized by intergranular alluvium aquifer underlain by the Karoo sandstone of intergranular and fractured secondary aquifer type) are riparian vegetation, floodplain and depression wetlands, and springs. Precipitation recharged alluvium aquifer's contribution to Limpopo River baseflow is negligible as the discharge is mainly through springs and evapotranspiration. Monitoring data scarcity and skewed availability among sharing countries hamper research and its output applicability to TBA's entirety. Therefore, data generation, exchange, and joint databases development are crucial for sustainable comanagement of groundwater and supported ecosystems and science-based decision-making.

Keywords: groundwater-dependent ecosystem, interactions, transboundary aquifer

Cape Flats Aquifer Management Scheme – the City of Cape Town's groundwater abstraction and MAR scheme for a resilient future (South Africa)

D McGibbon., L Towers., K Riemann

Umvoto, South Africa

In response to the Western Cape's worst drought experienced during 2015-2018, the City of Cape Town implemented various projects to augment its water supply, including desalination, re-use and groundwater. The Cape Flats Aquifer Management Scheme (CFAMS) forms one of the groundwater projects that includes groundwater abstraction and managed aquifer recharge (MAR). The Cape Flats Aquifer (CFA) is a coastal, unconfined, primary aquifer within an urban and peri-urban environment. As such, it is well situated to take advantage of enhanced recharge using high-quality advanced treated effluent but also has challenges related to seawater intrusion (SWI) and risk of contamination. MAR is currently being tested and implemented with a three-fold purpose: (1) to create hydraulic barriers against seawater intrusion and other contamination sources, (2) to protect groundwater-dependent ecosystems harbouring biodiversity, and (3) to increase storage and improve water quality to enhance resilience to effects of drought. As no legislation for MAR exists in South Africa, international guidelines are used to determine water quality requirements related to clogging environmental and health concerns. Further consideration includes aquifer-scale design, the interaction of multiple abstraction and injection wellfields within an area, and the design of individual boreholes to enhance yield and limit clogging. We aim to present progress made to date that includes exploration, wellfield development, monitoring, numerical modelling, aquifer protection, and the lessons learnt.

Keywords: groundwater supply, managed aquifer recharge, primary aquifer, resilience, urban

CLICK TO RETURN TO THE PROGRAMME

Groundwater models for water resources assessment at regional, local and site scales

V Price., J Dottridge
Mott MacDonald

For 25 years, the UK's Environment Agency has commissioned groundwater flow models of the main aquifers in England. These regional-scale models are regularly updated, occasionally recalibrated and used for water resources management, regulatory decisions and impact assessment of groundwater abstractions. This range of uses requires consideration of the appropriate scale of data collection and modelling and adaptation of the groundwater models, with refinement where local impacts on individual springs and seasonal streams are considered and combination and simplification for strategic national water resources planning. The Cretaceous Chalk, a soft white limestone, is the major aquifer of southern and eastern England, supplying up to 80% of the drinking water in this densely populated region. Springs and baseflow of good quality groundwater feed Chalk streams, which are a rare and valuable habitat with a high public profile, but face significant challenges in the 21st century, worsened by climate change and population growth. The modelling informs strategic planning and regulatory decisions, but the model's scale needs to be appropriate for each issue. The presentation defines these issues and presents examples, ranging from the large-scale, strategic Water Resources East to impact assessment for individual groundwater abstractions and more bespoke local investigations, including simulation of groundwater flood risks. As the scale of investigations reduces, there is increasing importance on the accuracy of information, both temporally and spatially. Model refinement made during local investigations can be incorporated into larger-scale models to ensure that this understanding is captured.

Keywords: England, groundwater/surface-water relations, numerical modelling, scale, water-resources Management

Source protection zone delineation: Numerical insights on the effect of heterogeneity

T Sarris[1]., A Kenny[1]., D Scott[1], C Moore[2]
[1]ESR; [2]GNS

Source protection area delineation has evolved over the last decades from fixed radius, analytical and numerical methods which do not consider uncertainty to more complex stochastic numerical approaches where uncertainties are often considered in a Monte Carlo framework. The representation of aquifer heterogeneity in these studies is typically based on a geostatistical representation of hydraulic properties. This presentation compares results from complex stochastic flow and transport simulations, simple homogeneous models, and existing analytical expressions. As a case study, we use the existing drinking supply wells in West Melton located Canterbury's Selwyn District in New Zealand. Monte Carlo realisations are parameterised in MODFLOW6 so that the prior knowledge of the aquifer's effective, large scale flow characteristics is honoured. Homogenous simulations are based on the same grid, using the aquifer's effective properties to parameterise the numerical flow model. In both cases, conservative transport of pathogens is undertaken using Modpath7, using both forward and backward particle tracking. The numerical results are compared with analytical expressions from the international literature. Our results suggest that aquifer heterogeneity needs to be explicitly addressed in all cases. Homogeneous simulations almost certainly underestimate contamination risk and produce unrealistically small source protection areas. Parameterisation of the stochastic heterogeneous realisations also affects the size and extent of the source protection area, suggesting that these need to be carefully considered for practical applications.

Keywords: Drinking water, Flow and transport modelling, Heterogeneity, Source protection zone delineation, Transition probability

CLICK TO RETURN TO THE PROGRAMME

Numerical groundwater modelling of the Windhoek Aquifer (Namibia) for wellfield management

J Weitz[1]., N Jovanovic[2]
[1]Umvoto Africa, Sout Africa; [2]University of Western Cape, South Africa

The City of Windhoek in Namibia has developed wellfields and a managed aquifer recharge scheme within the fractured Windhoek Aquifer to ensure a sustainable potable water supply to the city during drought. A three-dimensional numerical groundwater model of the aquifer was developed using the finite-difference code MODFLOW to determine the potential impacts of varying pump inlet depth elevations and varying production borehole abstraction rates for optimal wellfield and aquifer management. The initial steady-state numerical model was calibrated to September 2011 groundwater levels, representing the best approximation of "aquifer full" conditions (following a good rainfall period and best available data). The subsequent transient numerical model was calibrated against groundwater level fluctuations from September 2011 to August 2019, the period after steady-state calibration for which data was available (and during which monitored groundwater abstraction occurred). The calibrated transient model was used to run various predictive scenarios related to increased emergency groundwater abstraction and estimate potential impacts on the Windhoek Aquifer. These predictive scenarios assessed groundwater level drawdown and recovery, aquifer storage potential, and potential abstraction rates under different pump elevations. Model results indicated a sharp initial groundwater level drop followed by a gradual decrease as groundwater levels approached the 100 m saturated depth mark. Pumping elevations were subsequently updated with recommended abstraction rates and volumes for the entire Windhoek Aquifer. The numerical groundwater model, in association with extensive groundwater monitoring, will be used to assess/manage the long-term sustainable and optimal utilisation of the Windhoek Aquifer.

Keywords: MODFLOW, Windhoek Aquifer, numerical groundwater modelling

Design and Implementation of Groundwater Protection Schemes in Different Aquifer Settings

K Gibson., D McGibbon., T Flügel
Umvoto Africa, South Africa

Groundwater is a vital freshwater source, and its role in meeting water demands will become pivotal under future climate change and population growth. However, groundwater supply to meet this demand is at risk as aquifers can be rapidly contaminated, and the cost of aquifer rehabilitation and/or sourcing alternative water supplies can be high. The development of groundwater protection schemes is required to ensure long-term protection of groundwater quality and sustainable groundwater supply. A groundwater protection scheme is a practical and proactive means to maintain groundwater quality and forms an additional methodology for groundwater resource management/protection. There are no legislative guidelines on establishing groundwater protection schemes in water-scarce South Africa, despite groundwater being used extensively. Three groundwater protection schemes were designed and implemented to protect abstraction from a fractured aquifer in an undeveloped natural mountain catchment and two primary aquifers within different urban settings. The approach incorporated protection zone delineation (comprising four zones), aquifer vulnerability mapping/ranking using the DRASTIC method (with the primary and fractured aquifer systems having varying vulnerabilities), and identification of potentially contaminating activities (which also vary significantly between the urban areas overlying the two primary aquifers, and the generally undeveloped natural mountain catchment fractured aquifer is situated within). Additionally, a protection response was established to determine monitoring frequencies. Practical insights into the design and implementation of these three groundwater protection schemes can serve as a model for implementation in other African aquifer systems.

Keywords: Groundwater Protection Scheme, Groundwater Protection Zone, Aquifer Vulnerability, Aquifer Contamination

CLICK TO RETURN TO THE PROGRAMME

Review of In-Situ and Remote Sensing-Based Indices and Their Applicability for Integrated Drought Monitoring in South Africa

M Mukhawana
Department of Water and Sanitation, 178 Francis Baard Street, Pretoria 0001, South Africa

The devastating socioeconomic impacts of recent droughts have intensified the need for improved drought monitoring in South Africa (SA). This study has shown that not all indices can be universally applicable to all regions worldwide, and no single index can represent all aspects of droughts. This study aimed to review the performance and applicability of the Palmer drought severity index (PDSI), surface water supply index (SWSI), vegetation condition index (VCI), standardised precipitation index (SPI), standardised precipitation evapotranspiration index (SPEI), standardised streamflow index (SSI), standardised groundwater index (SGI), and GRACE (Gravity Recovery and Climate Experiment)-based drought indices in SA and provide guidelines for selecting feasible candidates for integrated drought monitoring. The review is based on the 2016 World Meteorological Organization (WMO) Handbook of Drought Indicators and Indices guidelines. The PDSI and SWSI are not feasible in SA, mainly because they are relatively complex to compute and interpret and cannot use readily available and accessible data. Combining the SPI, SPEI, VCI, SSI, and SGI using multi-index or hybrid methods is recommended. Hence, with best fitting probability distribution functions (PDFs) used and an informed choice between parametric and non-parametric approaches, this combination has the potential for integrated drought monitoring. Due to the scarcity of groundwater data, investigations using GRACE-based groundwater drought indices must be carried out. These findings may contribute to improved drought early warning and monitoring in SA.

Keywords: multivariate drought indices; PDSI; SWSI; SPI; SPEI; VCI; SSI; SGI; GRACE

Highly productive geophysical mapping of groundwater systems in water-scare countries

D Grombache., V Matta
HydroGeophysics Group, Aarhus University

Groundwater is a hidden resource, so as part of making it more visible, geophysical methods can be very useful in inferring the delineation of aquifers and/or more productive zones to target in fractured rock environments. The most commonly used techniques to assist groundwater studies or exploration are still resistivity profiles or sections known as ERT or electrical resistivity tomography and vertical electrical soundings or VES. One of the limiting factors with this technique is the scale of what surveys can be conducted, resulting in, at best, some kilometers per day. The Hydrogeophysics group of Aarhus University have developed the towed transient electromagnetic (tTEM) system as a cost-efficient tool for characterizing regional hydrological systems to depths of up to 70 m as an alternative to these more traditional methods - which is highly productive in that collection of 40- to-80-line kilometers of data per day is feasible. The system is based on the transient electromagnetic (TEM) method, which involves using a transmitter and receiver coil to measure the electrical resistivity of the subsurface. The hydrological value in electrical resistivity images stems from the ability to delineate different hydrogeological units based on their contrasting electrical properties.

Consequently, 3D electrical resistivity images can infer the subsurface hydrogeology and enhance the success of installing productive boreholes. This work presents case studies from several African countries (e.g., South Africa, Zimbabwe, Ethiopia, Senegal, and Togo). It demonstrates how the tTEM method can identify reliable drinking water sources in these countries.

Keywords: geophysics, groundwater, hydrogeology, transient electromagnetics

CLICK TO RETURN TO THE PROGRAMME

A stochastic data integration approach to generate geologically consistent hydrogeological models from geophysical and hydrogeological data

A Neven., L Schorpp., J Straubhaar., P Renard
University of Neuchâtel, Switzerland

This study presents a novel approach for developing geologically and hydrogeologically consistent groundwater models at large valley scales. Integrating geological, geophysical, and hydrogeological data into a single model is often challenging, but our methodology overcomes this challenge by combining the Ensemble Smoother with Multiple Data Assimilation algorithm (ESMDA) with a hierarchical geological modelling approach (ArchPy). The ESMDA framework assimilates geophysical and hydrogeological field data jointly. To diminish the computational cost, the forward geophysical and groundwater responses are computed in lower-dimensional spaces relevant to each physical problem, alleviating the computational burden and accelerating the inversion process. Combining multiple data sources and regional conceptual geological knowledge in a stochastic framework makes the resulting model accurate and incorporates robust uncertainty estimation. We demonstrate the applicability of our approach using actual data from the upper Aare Valley in Switzerland. Our results show that integrating different data types, each sensitive to different spatial dimensions enhances the global quality of the model within a reasonable computing time. This automatic generation of groundwater models with a robust uncertainty estimation has potential applications in a wide variety of hydrogeological issues. Our methodology provides a framework for efficiently integrating multiple data sources in geologically consistent models, facilitating the development of hydrogeological models that can inform sustainable water resource management.

Keywords: Hydrogeophysics; Inversion; Data-Integration; Groundwater

Springs of the Otavi Mountainland. Could they teach us something significant?

B van Wyk[1]., D Sarma[2]
[1]BVW Groundwater Consulting Services; [2]Namib Hydrosearch CC

The work presented in this paper incorporates spring data for further conceptualizing the hydrogeology of northern Namibia's so-called "Karst Area", an area around the towns of Tsumeb, Otavi and Grootfontein. Also called the Otavi Mountainland, it can be described as a mountainous highland of parallel, east-west trending elongated valleys and ranges shaped by the underlying folded units of carbonate rocks of the Damara Supergroup. The karst aquifers are a supplementary source to the central areas of the country during drought. Most of these 35 springs are often found near hilltop crests or high up on the mountain flanks rather than lower down at the valley floors. If flows are generated locally as gravity or contact overflow springs, studying them would not add much to conceptualizing the regional groundwater flow. Fundamental insights are provided if flows arise due to hydraulic pressure from deeper down. As artesian boreholes do not occur as a rule in the Karst Area, artesian springs might indicate the presence of deeper aquifers out of reach at normal drilling depth. One such hypothesis is that the bottom of the dolomitic synclines, structurally weaker at the fold axis, had been subjected to deep-seated karstification. The work presented here investigates that possibility and argues for and against it. In addition, established concepts of groundwater flow mechanisms for the area have been revisited. A conclusion has not yet been reached, but the balance of the arguments is presented.

Keywords: Karst, Namibia, Otavi Mountainland, Springs, conceptual model, groundwater flow

CLICK TO RETURN TO THE PROGRAMME

Building evidence through hydrogeological survey and monitoring for the conjunctive development and management of water resources in Kunzila catchment area – Amhara Region, Ethiopia

D Benedicto van Dalen[1]., A Ketema[2]., G Zeleke[3]

[1]Acacia Water bv, Gouda, The Netherlands; [2]Acacia Water - Addis Ababa, Ethiopia; [3]Water & Land Resource Centre, Addis Ababa University, Ethiopia

Deploying a participatory approach for surveying the complex geohydrological system and defining the status of the groundwater resources in the Kunzila catchment area has crucial importance towards conjunctive use of its water and land resources for sustainable economic growth, social well-being, and environmental protection. Several initiatives are being undertaken to pilot the 'Integrated Landscape Management and WASH' project in this community to implement evidence-based approaches. A comprehensive hydrogeological study has been carried out to understand the hydrogeological system, propose ecosystem restoration measures, identify suitable locations for drilling boreholes and design a groundwater and surface water monitoring network. The first results pointed out the central area of the catchment as holding the best potential for groundwater abstraction, a productive Late Quaternary basalt aquifer. As this area is in use by private floriculture farms, several other borehole locations were sited to meet the domestic and livelihood demand across the watershed. In addition to the drinking water supply goals, the project proposed catchment intervention for soil and water conservation based on the *Landscape Approach* and 3R measures implementation - Retain, Recharge, Reuse. Such measures include but were not limited to riparian vegetation restoration, terracing and contour bunds, agroforestry, controlled grazing, etc. A telemetric monitoring network has been designed and installed to support the conjunctive management of shallow and deep groundwater water resources, streams and Lake Tana, together with a functional dashboard for data registrations and sharing. The monitoring program gauges the impact of groundwater abstraction and the quality parameters.

Keywords: catchment management, conjunctive use, groundwater monitoring, participatory landscape Approach

Monitor and determine local groundwater impacts from increased mining activities in the Kalahari iron manganese field of the Northern Cape, South Africa.

G van Dyk

The Kalahari iron manganese field (KIMF) in the Northern Cape, South Africa, was historically exploited by only three mines, with Hotazel the only town and the rest of the area being largely rural, with agricultural stock/ game farming the major activity. Since 2010, mining activities have increased to more than 10 operational mines with increased water demand and environmental impacts on groundwater. The area is within catchments of the Matlhwaring, Moshaweng, Kuruman and Gamogara rivers that drain to the Molopo River in the Northern Cape. All the rivers are non-perennial, with annual flow occurrence in the upstream areas that reach this downstream area once every 10 years. The area is semi-arid, with annual evaporation nearly five times the annual precipitation. The precipitation is less than 300mm, with summer precipitation in the form of thunderstorms. Vegetation is sparse, consisting mainly of grasslands, shrubs and some thorn trees, notably the majestic camel thorns. The Vaal Gamagara Government Water Supply Scheme imports 11 Ml/d or 4Mm^3/a water for mining and domestic purposes in the KIMF section. The area is covered with Kalahari Group formation of 30 to 150 m thick with primary aquifers developed in the basal Wessels gravels and Eden sandstones for local use. The middle Boudin clay forms an aquitard that isolates and reduces recharge. Water levels range from 25 to 70m, and monitoring indicates local dewatering sinks and pollution. This study will report on the water uses, monitoring and observed groundwater impacts within the current climatic conditions.

Keywords: aquitards, environmental impacts on groundwater, increased water demand, monitoring, primary aquifers, reduced recharge

CLICK TO RETURN TO THE PROGRAMME

Using the Groundwater Level Status approach for climate Impacts

F Fourie

Department of Water and Sanitation, South Africa

South Africa is known for droughts and their effect on groundwater. Water levels decrease, and some boreholes run dry during low recharge periods. Groundwater level fluctuations result from various factors, and comparing the levels can be challenging if not well understood. Fourie developed the "Groundwater Level Status" approach in 2020 to simplify the analysis of groundwater level fluctuations. Groundwater levels of two boreholes within different hydrogeological settings can thus be compared. The "Status" can now indicate the severity of the drought and thus be used as a possible groundwater restriction level indicator. The reasons for the groundwater level or the primary stress driver can only be determined if the assessment is done on individual boreholes and the boreholes according to hydrogeological characteristics. The analysis is used to identify areas of risk and inform the authorities' management to make timely decisions to prevent damage or loss of life or livelihoods. The applicability of this approach from a borehole to an aquifer level is showcased through practical examples of the recent droughts that hit South Africa from 2010-2018.

Keywords: Groundwater level; Status; water level fluctuation; risk; climate change; recharge

Groundwater potential and lateral connectivity of the Limpopo sand river system mitigating water scarcity and salinity in semi-arid Mozambique

P Saveca[1]., T Stigter[2]., F Fourie[3]., E Lukas[3]

[1]Division of Agriculture, Instituto Superior Politécnico de Gaza, Campus Politécnico de Lionde, Gaza, Mozambique; [2]Department of Water Resources and Ecosystems, IHE Delft Institute for Water Education, Delft, Netherlands; [3]Faculty of Natural and Agricultural Sciences, Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa

In this study, we assess the potential of large riverbed aquifers in semi-arid Africa, known as sand rivers, to mitigate water scarcity and salinity for multiple-use water supply through a case study of the Limpopo River in Mozambique. Such sand river systems are widespread and still heavily underused at a regional scale, particularly in Mozambique, with the riparian vegetation currently being the primary user, though only consuming a minor fraction of available water. At a local scale, we performed geoelectrical surveys, water level measurements (in river and groundwater), as well as field physicochemical measurements and hydrochemical and isotopic sampling at 38 locations in the river channel, margins and up to 6 km away from the river, over five years. Results show that these shallow systems can be up to a kilometer wide and 15 m thick and, at some locations, can extend laterally beyond the river channel, below thin layers of clay and silt. Large areas of the sand river channel carry runoff yearly, providing optimal conditions for rapid recharge into the coarse sands with a high storage capacity. Connectivity between the river margin and channel is clearly shown at the local scale, even though sand pockets located further away appear isolated (revealed by geophysics), isotopically different and more brackish. Recharge, evapotranspiration and mixing processes are confirmed through hydrogeochemical modelling. The proven connectivity is highly relevant as groundwater is abstracted locally, promoting socio-economic development in water-scarce regions.

Keywords: Limpopo, aquifer connectivity, groundwater potential, salinity mitigation, sand river, semi-arid regions

CLICK TO RETURN TO THE PROGRAMME

The National Integrated Water Information System (NIWIS) for geohydrology in South Africa

N Nungu

For the Department of Water and Sanitation (DWS) to better leverage the wealth of information being collected by various “silo” operational source water information systems, a high-priority initiative was launched to establish a National Integrated Water Information System (NIWIS), which currently consists of over 40 web-accessible dashboards including groundwater related dashboards mostly accessible to the public. Dispersed and disintegrated data and information stored in different sources and formats would hinder decision support in the water sector and deter improvement in service delivery by the DWS. The DWS undertook an extensive and rigorous business requirements analysis exercise within the DWS to ensure that the proposed system does not become a white elephant and facilitate the prioritization of system deliverables. A prototype (waterfall) approach was adopted to develop the NIWIS to ensure the development was still within the suggested business requirements. NIWIS has enabled mostly DWS managers to establish one trusted source of decision-making information for timeous, effective and efficient responses to service delivery. The number of NIWIS dashboards continues to grow as improved data-related business processes are adopted. The unavailability of reliable data from DWS data sources and the exclusion of business requirements from organizations external to DWS were identified as the main challenges to NIWIS disseminating comprehensive, credible information. Therefore, this paper aims to provide some details of the geohydrological information that NIWIS provides and seek feedback from this International Hydrogeologists community for further development of NIWIS.

Keywords: Data, Decision Making, Groundwater, Information, Information System, Integration, South Africa

Impact of urbanization on groundwater quantity and quality in Kabul city, Afghanistan

A Farahmand[1]., M Hussaini[2]., M Abrunhosa[3]

[1]Groundwater Resources Department, Ministry of Energy and Water, Kabul, Afghanistan; [2]Department of Engineering Geology and Hydrogeology, Kabul Polytechnic University, Kabul, Afghanistan; [3]Centre for Earth and Space Research of the University of Coimbra, Portugal (CITEUC), Coimbra, Portugal

Groundwater quantity and quality of shallow aquifers have deteriorated in recent years due to rapid development that has created an increased demand for drinking water, which is increasingly being fulfilled by groundwater abstraction. The study evaluates the hydrogeological framework of the Quaternary aquifer of the Kabul basin, Afghanistan, and the impact of urbanization on the groundwater resources around the Kabul city plain. Time series of Landsat satellite LCLU images indicate that the urban area increased by 40% between 2000 and 2020, while the agricultural area decreased by 32% and bare land decreased from about 67% to 52% during this period. The assumed groundwater overdraft 2019 was 301.4×103 m^3/day, while the recharge was 153.4×103 m^3/day, meaning a negative balance of about 54 million cubic meters (MCM) this year. Due to the long-term decline of water levels at 80 90 cm/year, and locally (Khairkhana, Dasht-e-Barchi) 30-50m during 2005-2019, a considerable groundwater drawdown is shown. Groundwater quality, on the other hand, reveals that chloride concentrations and salinity increased throughout the aquifer between 2005 and 2020. The nitrate concentration decreased in most Kabul Plain places over the period. In conclusion, the quantity and quality situation of urban groundwater in Kabul is worrying; urgent scientific and sustainable solutions and measures should be considered to manage this situation.

Keywords: Kabul basin, Urbanization, ground subsidence, groundwater quality, land use, land cover

CLICK TO RETURN TO THE PROGRAMME

From the national hydrogeological map to regional ones. How to identify a suitable level of detail to work with? An application in Kunene and Omusati Regions in Northwestern Namibia

A Brugeron[1]., A Soulignac[2]., A Gutierrez[1]., B Swartz[3]
[1]BRGM; [2]ECORESIL; [3]MAWLR

Groundwater is a critical resource in Namibia, particularly in the Kunene and Omusati Regions, which are among the driest in Sub-Saharan Africa. Hydrogeological mapping is essential to ensure this resource's sustainable use and management. The hydrogeological map of Namibia was updated recently (2021). However, the details of a 1:1M map are too coarse for regional groundwater management. An ongoing study of groundwater potential assessment in the two regions required downscaling the information to 1:250 000. This work made use of geological maps 1:250 000 from the Geological Survey of Namibia, about 430 selected wells including 20 recent boreholes, 117 reinterpreted pumping tests, some existing reports from private companies, academic works including a PhD thesis, interviews with local water resource experts and statistical analysis of 6 500 wells from the National Groundwater Database (GROWAS II) maintained by the Ministry of Agriculture, Water and Land Reform (MAWLR). The regional hydrogeological map obtained was then associated with the recharge evaluated in a separate task of the same project to assess the available groundwater sustainability. By assessing abstraction costs and water demand, the work gives insights into areas where groundwater abstraction can be increased or restricted to ensure sustainable use. As conscientious and serious as this study may be, it does not replace a master plan but allows a global vision of the development potential of groundwater at a regional scale. This study was financed by the French Agency for Development (AFD) under a tripartite agreement (MAWLR-MEFT-AFD).

Keywords: Kunene, Namibia, Omusati, economic assessment, groundwater potential

Use of krypton-81 to constrain the reliability of carbon-14 in estimating groundwater ages

S Lu[1]., Y Xie[1]., A Love[2]., W Jiang[3]., G Yang[3]., Z Lu[4]
[1]Key Laboratory of Surficial Geochemistry, Ministry of Education, School of Earth Sciences and Engineering, Nanjing University, China; [2]National Centre for Groundwater Research and Training, College of Science & Engineering, Flinders University; Adelaide, Australia; [3]CAS Center for Excellence in Quantum Information and Quantum Physics, Hefei National Laboratory, University of Science and Technology of China, Hefei 230026, China; [4]CAS Center for Excellence in Quantum Information and Quantum Physics, Hefei National Laboratory, University of Science

Advances in groundwater age dating provide key information for groundwater recharge history and rates, which is of great significance for groundwater sustainable development and management. By far the, radioisotope ^{14}C is the most frequently used in routine investigations. However, groundwater age can be misinterpreted given its dating range of up to 40 ka and its chemically active in nature. In comparison, ^{81}Kr is less frequently used but chemically inert with a dating range of up to 1,300 ka, which overcomes the limit of ^{14}C. Although it is not as precise as ^{14}C when the groundwater age is younger than 40 ka, it may be helpful to determine the reliability of ^{14}C dating results. In this study, we collected eight field samples from coastal aquifers in Nantong, China and analyzed them for ^{81}Kr, ^{85}Kr, and ^{14}C. The ^{14}C results show that all groundwater ages range from 2,400 to 35,300 years, with different correction methods yielding uncertainties of 1,500 to 3,300 years. Four of the ^{81}Kr ages provided upper bounds, while three yielded groundwater ages which are consistent with the ^{14}C dating results within measurement uncertainties. Interestingly, one ^{81}Kr result gave an age of 189^{+11}_{12}ka, whereas the corresponding corrected ^{14}C age was less than 29,200 years. The great difference may indicate modern contamination in the sampling process or mixing between young and old groundwaters. Further investigation is needed to shed more lights in this case. Moreover, it shows the benefits of introducing ^{81}Kr in routine hydrogeological investigations and the groundwater studies.

Keywords: groundwater dating, krypton-81 isotope, radiocarbon

CLICK TO RETURN TO THE PROGRAMME

Hydrostratigraphic controls on groundwater arsenic enrichment in the Brahmaputra river basin aquifers

D Aind., A Mukherjee
Indian Institute of Technology, Kharagpur, India

Groundwater arsenic (As) distribution in alluvial floodplains is complex and spatially heterogeneous. Floodplain evolution plays a crucial role in the fate and mobilization of As in the groundwater. This study presents how groundwater As enrichment is controlled by the spatial disposition of subsurface sand, silt, and clay layers along an N-S transect across the Brahmaputra river basin aquifer. Six boreholes were drilled in the shallow aquifer (up to 60 m) along this transect, and 56 groundwater samples were collected and analysed for their major and trace elements, SO4, PO4, dissolved organic carbon (DOC), and dissolved oxygen (DO). Groundwater As ranges from 0.1 to 218 µg/L on the northern bank while from 0.2 to 440 µg/L on the southern bank of the Brahmaputra. Groundwater in the southern bank is highly reduced (Eh -9.8 mV) with low DO and low SO4 (2 mg/L), while groundwater in the north is less reduced (Eh 142 mV) with low DO and higher SO4 (11 mg/L). Subsurface lithologies show that the aquifer on the southern bank has a very thick clay layer, while the aquifer on the northern bank is heterogeneous and interlayered with intermediate clay layers. Depth comparison of the groundwater arsenic concentrations with subsurface lithological variations reveals that groundwater wells overlain by thick clay layers have higher arsenic, while groundwater wells devoid of clay capping have lesser arsenic. Detailed aquifer mapping could be decisive in exploring potentially safe groundwater from geogenic contamination.

Keywords: aquifer composition, arsenic, clays, groundwater

Study on the Relationship between Water Quality and Wetland Plant Community in Huixian Karst Wetland

L Shen
Institute of Karst Geology, CAGS

Huixian Karst National Wetland Park is the most typical karst wetland in the middle and low latitudes of the world and has become an internationally important wetland. The relationship between water quality and aquatic organisms in Huixian Wetland is a hot research topic in wetland ecology. This article focuses on the relationship between the current water quality situation in Guilin Huixian Karst Wetland and the growth of wetland plants. Sixteen sampling points are set up in the wetland to monitor and analyze water quality in wet, normal, and dry seasons. The Kriging index interpolation method is used to obtain a comprehensive water quality interpolation map in the survey area during normal water periods and in combination with the wetland plant survey sample data and the landscape status. A comprehensive analysis of the relationship between wetland plant growth and water quality. The results show that the centre of Huixian Wetland receives recharge from surrounding groundwater, which is greatly affected by the surrounding water quality. The comprehensive water quality is relatively good in the dry season, relatively poor in the normal season, and the worst in the wet season. Agricultural production, non-point source pollution, rural domestic sewage, and human interference affect wetland water quality, which directly affects the structure and function of plant communities and the ecological service function of wetlands.

Keywords: Huixian Karst Wetland, Water Quality, Wetland Plant Community

CLICK TO RETURN TO THE PROGRAMME

What decision-making information can be obtained from chemical data on a large-scale? A case study in Kunene and Omusati regions in Namibia

L Gourcy[1]., A Gutierrez[1]., B Swartz[2]., F Soetaert[3]

[1]BRGM; [2]MAWLR; [3]Bordeaux III University

Since the end of the 1970's, the Ministry of Agriculture, Water and Land Reform (MAWLR), through the development of the groundwater database (GROWAS II), gathered a great number of data on groundwater quality. In an ongoing study (MAWLR-MEFT-AFD-BRGM, 2023), an opportunity was presented to compile chemical data for groundwater in the two most north-western regions of Namibia, Kunene and Omusati, to elaborate and support decision-making with the available information. A selection of 3256 data presenting a good ionic balance (± 10%) was selected from a large dataset, using metadata from previous BGR projects and the Geological Survey of Namibia at a 1:250,000 scale as supporting information. During the assessment of chemical data, it was depicted that most of the good quality water for human consumption and irrigation is located in the carbonated sedimentary formations at the southeastern part of Kunene and a great part of the northern part of the Kunene region. With more detailed data treatment, it allowed for confirming a natural origin for high fluoride concentration linked to granite, gneiss, old volcanic rocks and high sulphate concentration due to evaporates (gypscrete) in the eastern part of Omusati. In contrast, high nitrate concentrations were found in various lithologies across the two regions confirming local anthropogenic contamination. These results were compared to information obtained through the few published works of local studies to evaluate the accuracy of this large-scale assessment of chemical data.

Keywords: Kunene, Namibia, Omusati, chemical processes, groundwater quality, major dissolved elements

An assessment of hydrogeophysics application for groundwater resource assessment in Kalahari sands aquifers and crystalline basement aquifers with case studies from Namibia and South Africa

I Muchingami[1]., J Hamutoko[1]., T Kanyerere[2]., S Uugulu[1]., J Mutjida[1]

[1]University of Namibia, Department of Geosciences, Namibia; [2]University of the Western Cape, CapeTown, South Africa

Integrated geophysical methods can be useful tools in mapping the subsurface characteristics likely to control groundwater occurrence and hence are useful in identifying potential drill targets in different aquifer formations in Southern Africa. This study applied hydrogeophysical methods (natural, electrical, and electromagnetic) to identify potential groundwater-bearing targets within the Kalahari sand aquifers in Namibia and the crystalline basement aquifer system in Namibia and South Africa. The results suggest that hydrogeophysical assessments in Kalahari sandstone aquifers could clearly show that the system exhibits a well-defined layered aquifer formation likely recharged from surface water. On the other hand, crystalline basement formations could be combined with geological observations and used to identify groundwater controls like lineaments and depths to fractured zones. The magnetic method, horizontal and vertical frequency domain electromagnetic geophysical methods presented herein managed to delineate the main dykes and lineament features associated with groundwater occurrence in typical crystalline basement aquifers, while the natural magneto telluric investigations managed to delineate the deep and shallow aquifer formation in Kalahari sandstone aquifer formation. The study also advocates for integrating geophysical methods with local and regional geology for groundwater evaluation to provide a more detailed approach to resource assessment in some of the vulnerable aquifer systems in Southern Africa. Results from this study are useful for technical groundwater management and promoting the utilization of groundwater as a climate-resilient strategy in Southern Africa.

Keywords: Crystalline basement, Hydrogeophysics, Kalahari sand aquifer, groundwater assessment, groundwater controls

CLICK TO RETURN TO THE PROGRAMME

Using analytical models to examine groundwater abstraction impacts on surface water levels

N Maluleke

Studies have examined the effects of groundwater pumping on nearby streams. Groundwater pumping affects streamflow, surface water rights, and aquatic ecosystems. This study investigates the impact of groundwater abstraction on surface water bodies. A secondary objective aims to develop a conceptual model to evaluate alternative approaches for streamflow depletion. The study area is a previous UFS/WRC test site along Modder River, Free State, South Africa. Streamflow depletion was simulated using four (4) analytical solutions, i.e., Jenkins (1968), Hantush (1964), Hunt (1999) and Hunt (2003). STRMDEPL08 analytical computer program tool is used to evaluate streamflow depletion. The aquifer parameters: distance of the boreholes to the stream; pumping periods analyzed in steady states conditions for a simulation period of 1 year; transmissivity with an average of 71 m/d; storativity of 0.02; specific yield of the aquitard range between 0.1 to 0.3; and abstraction rate of 2 l/s are defined for the hypothetical model. The average distances tested range from 10 m to 6,000 m. Pumping rate scenarios for an order of magnitude lower (0.2 l/s), 1 l/s; 4 l/s, and an order of magnitude larger (20 l/s) were simulated. Simulated graphs indicate that streamflow depletion rates are largest if the borehole is closer to the stream and decrease as the distance of the pumped borehole from the stream increases. Cumulative volume graphs for both analytical solutions decrease streamflow depletion volume

Keywords: Groundwater-surface water interaction, streamflow depletion, model coupling

Quantification of river-aquifer interactions using multiple measuring methods for improved water abstraction in the Lower Vaal River catchment, South Africa

L Baloyi[1]., T Kanyerere[2], M Butler[3]

[1]Department of Water and Sanitation, 178 Frances Baard Street, Pretoria, 001, South Africa; [2]Department of Earth Science, University of the Western Cape, Belville, 7535, South Africa; [3]Themba Laboratory for Accelerator-Based Science, Private Bag 11, Wits 2050, South Africa

Previous studies have shown that river-aquifer connectivity exists. However, an integrated approach that consists of multiple measuring methods to quantify and characterise such connectivity still needs improved scientific understanding due to the underlying principles and assumptions of such methods, mainly when such methods are applied in a semi-arid environment. Three techniques (hydrogeochemistry, stable water isotopes, and baseflow separations) were applied to quantify and characterize river-aquifer interactions. The study's objective was to improve knowledge and understanding of the implications of the results from the three methods. Field measurement, laboratory assessment, and record review were used to collect primary and secondary data. Results showed that Na- HCO3 water type dominated the upper stream, discharging onto the surface and forming stream sources. Na-HCO3 water type was an outlier when the area's geology and land use activities were assessed. The isotope results showed that the studied aquifer had 9% recently recharged water. Being the upstream, the freshwater in such a mountainous aquifer was expected. The baseflow index (BFI) results showed that the dependency of the total river flow to aquifer discharge contributed 7.24 % in the upper stream, 7.31% in the middle stream, and 7.32% in the lower stream. These findings provided empirical evidence that hydrochemistry, stable isotopes, and baseflow separation methods provide key insights into aquifer-stream connectivity. Such findings inform choosing appropriate and relevant measures for protecting, monitoring, and allocating water resources in the catchments.

Keywords: Baseflow, discharge areas, hydrochemistry, multi-methods approach, stable isotopes

CLICK TO RETURN TO THE PROGRAMME

Regional Scale Groundwater Monitoring Status Reporting: A mapping series within the Vanrhynsdorp aquifer system

A van Niekerk
Department of Water and Sanitation, South Africa

A mapping series was generated using the Vanrhynsdorp aquifer system to illustrate an improved standardization groundwater monitoring status reporting, that includes a progressive conceptual site model linked with spatial and temporal groundwater monitoring network assessment on an aquifer scale. The report consists of 4 segments: Base map provides a conceptual site model of a groundwater resource unit (GRU) delineating an area of 1456 km^2 representing the geology and geological structures that make up the Vanrhynsdorp aquifer system. The Groundwater Availability Map illustrated over a long-term trend analysis, the measured water levels indicate an 83% decreasing trend over an average period of 21.83 years, the water levels have declined by an average linear progression of 11.54 m (ranging 0.48-35.76 m) or 0.64 m per year, which equates to an estimated decline in storage of 218 Tm^3 - 21 Mm^3 within the GRU. The Groundwater EC map illustrated over the long-term analysis of an average period 24 years the average EC ranged between 57 - 791 mS/m, with certain areas tracking at a constant increasing trend beyond 1200 mS/m. The Groundwater Quality Characterization map provides EC contours and spatial Stiff diagram plots. The Stiff diagrams illustrate three aquifer water types namely, Na-Cl (Table Mountain Group Sandstones), Na-Cl with high SO_4 concentration (Blouport and Aties Formation) and Na-Cl-HCO_3 (Widouw Formation). These four segments of information products inform Resource Quality Objectives and the need for surveillance monitoring in conjunction with annual compliance monitoring and enforcement groundwater use audits.

Keywords: Aquifer scale, groundwater availability, groundwater quality, spatial-temporal, trend analysis

Netherlands National Groundwater reserves: 3D mapping and development of management policies as part of a multilevel strategy to secure water supply for disasters and the far future.

G Nijsten[1]., S Vermooten[1]., J Delsman[1]., P de Louw[1]., J Gunnink[2]., J Buma[2]., J Zaadnoordijk[2]
[1]Deltares, The Netherlands; [2]TNO-Geological Survey, The Netherlands

The Netherlands produces about 2/3 of drinking water from groundwater. Although there is seemingly abundant groundwater, the resource needs to be carefully managed and used wisely to safeguard the resource for future generations and in case of disasters whilst also preventing negative impacts from groundwater extraction on other sectors such as nature. Provincial governments are responsible for the protection of existing groundwater abstractions for water supply against pollution. To secure groundwater resources for the future, two additional policy levels have been introduced: Provincial governments have been made responsible for mapping and protecting *Additional Strategic Reserves.* These allow for additional groundwater abstractions to meet growing demands in coming decades (horizon 2040/2050). The National Government is responsible for mapping and protecting the *National Groundwater Reserves* (NGRs) as a third level of resource protection. NGRs serve multiple goals: to protect natural groundwater capital for future generations, to provide reserves for large-scale disasters affecting water supply and to provide reserves for possible use as structural water supply in the far future (horizon 2100 and beyond). NGRs are being delineated in 3D using detailed existing geological models and the Netherlands' national (fresh-saline) hydrological model. The dynamics of the groundwater system are analysed through scenario analyses. Reserves for potential structural use are selected such that negative impacts on nature are prevented if future abstractions are to be realised. The policies being developed must balance interests of water supply against other sectoral interests such as the green-energy transition with increased use of geothermal energy and aquifer-thermal-energy-storage.

Keywords: 3-D mapping, Groundwater protection, Multi-layer governance, National fresh-salt groundwater model, Water supply strategies

CLICK TO RETURN TO THE PROGRAMME

Governing groundwater in city regions: Water metabolism and actor networks in the cases of Cape Town and Nelson Mandela Bay

A Taylor., F Atkins
University of Cape Town

Groundwater is increasingly being exploited in South African cities as a drought crisis response, yet there is poorly coordinated regulation of increasing urban users and usage and fragmented management of aquifers. Designing interventions and innovations that ensure sustainable management of these resources requires systems thinking, where the city is understood as an integrated, interdependent set of actors and flows of water. This paper presents a study that applied and integrated an urban water metabolism (UWM) analysis with a governance network analysis for two major South African cities facing severe drought risk, Cape Town and Nelson Mandela Bay. 'Learning Laboratories' in each city brought together stakeholders from various groundwater-related domains to build a shared understanding of how groundwater fits into the larger system and how various actors shape urban groundwater flows and the health of local aquifers. The UWM quantified all hydrological and anthropogenic flows into and out of each city (or urban system) to conduct an integrated mass balance. How this mass balance changes under varying climate change scenarios and land use was used as a focal point of stakeholder discussions. The governance network analysis highlighted that many state and non-state actors have a stake in shaping the quantity and quality of urban groundwater, such as regulators, service providers, water users, knowledge providers, investors in infrastructure, and emergency responders.

Keywords: actor networks, drought risk, multi-level governance, urban metabolism

Groundwater for people and the environment: A globally threatened resource

H Loaiciga
University of California

Groundwater is an essential source of water worldwide. The increased reliance on groundwater has caused the mining of many aquifers, a situation compounded by climate change, rising surface-air temperature, declining precipitation, and reduced groundwater recharge in many regions. The global annual intensity of groundwater use rose from 128 to 155 m^3 per capita between 1950 (when the world population was 2.5 billion people) and 2021 (when the population was 7.9 billion people) and is herein projected to rise to 178 m^3 per capita by 2050 as the world's population is projected to increase (to 9.7 billion people by 2050) throughout the rest of the 21st century and beyond. This study projects a global annual groundwater depletion of 1,008 km^3 by 2050, representing a 256% rise from the estimated 2010 depletion. This projection is most likely a lower bound of the actual groundwater depletion that would be realized considering environmental flows, historical trends of global economic growth, and climate-change impacts, thus being a harbinger of rising environmental degradation (e.g., land subsidence, seawater intrusion, streamflow reduction, aridification). Measures to achieve groundwater sustainability are herein identified.

Keywords: groundwater, groundwater sustainability, overdraft, population growth, recharge, safe yield

CLICK TO RETURN TO THE PROGRAMME

Building a Groundwater Educational Pipeline from Elementary to Continuing Education

T Halihan., C Barnes
Oklahoma State University

Water resources worldwide are stressed, and the number of groundwater professionals required to manage those resources is not being generated in sufficient numbers. Groundwater educational resources must be placed in schools to generate excitement and raise awareness. Additionally, people entering the workforce need training throughout their professional careers. Oklahoma State University partnered with the U.S. National Ground Water Association to develop a framework for providing education and training programs in groundwater that allow for interactive online education at all levels. The Awesome Aquifer 360 program targets grades 5-8, allowing students to conceptually explore aquifers and the people who manage them. The Drilling Basics Online program provides a 40-hour basic safety and drilling training to recruit professionals into the groundwater industry and reinforce safe operations. These programs and future plans for the technique will be discussed.

Keywords: K-12, PSM, drilling, online education, professional master's programs

Management of water-related risks in drinking water supplies

B Cencur Curk[1]., P Banovec1., A Papadopoulou[2]., V Kanakoudis[2]., N Guyennon[3]., E Romano[3]
[1]University of Ljubljana, Faculty of Natural Sciences and Engineering, 1000 Ljubljana, Slovenia; [2]University of Thessaly, Civil Engineering Department, 38334 Volos, Greece; [3]National Research Council of Italy, Water Research Institute, 00010 Rome, Italy

With the revision of the European Drinking Water Directive (Directive on the quality of water intended for human consumption 2020/2184) in December 2020, the preparation of Water Safety Plans (WSP) is foreseen according to the guidelines of WHO. Within the EU Interreg Adrion MUHA project, a decision support tool (DST) has been developed to provide a holistic approach to drinking water infrastructure risk analysis. The project mainly addresses four water-related risks: accidental pollution, floods, droughts and earthquakes. The core of the DST is the inventory of hazardous events (causes, their consequences and impacts) for each component of the drinking water supply chain: (1) drinking water source - catchment area, (2) water supply system, and (3) domestic distribution system. For each identified potential hazard, the type of hazard was determined (e.g., biological, chemical, radiological, or physical hazard (including turbidity), inadequate availability of water supplied to customers, safety to personnel, external harm to third parties, including liability). The DST was tested in the partner countries (Italy, Slovenia, Croatia, Serbia, Montenegro and Greece) to verify the resilience of the measures and elaborate the WSP. In the end, the REWAS-ADRION strategy was elaborated, aiming to increase the resilience of drinking water supplies to floods, droughts, accidental pollution, and earthquake-related failures by improving the water safety planning mechanism based on the concept of inter-agency cooperation to support water utilities, civil protection organizations, and water authorities.

Keywords: risk analysis, water-related hazards, water safety plan, water supply system

CLICK TO RETURN TO THE PROGRAMME

Researching Fracking in the Karoo: Summary of lessons learned

Fde Lange
University of the Free State, South Africa

Research on Fracking in the Karoo basin yielded results that, if not considered "unexpected", can be considered as "should have been foreseen". Some aspects substantially impacting research on fracking are often overlooked when undertaking scientific research on an emotional topic such as fracking. This presentation aims to provide insights and recommendations based on the experiences and outcomes of current research on hydraulic fracturing or "fracking" in the Karoo basin of South Africa. Fracking has been a subject of significant research and debate over the past decade. Topics, each with its challenges, include 1) The scale of exploration/production extent (Site specifics), 2) Importance of robust and independent research, 3) Need for stakeholder engagement and participation, 4) The complexity of environmental risks and impacts, 5) The need for a precautionary approach, 6) Regulatory and policy challenges. Several methodologies can be relied upon to compare outcomes of different aspects of fracking research in the Karoo, such as 1) Comparative analysis, 2) Meta-analysis, 3) Stakeholder mapping and analysis and 4) Data visualisation. A combination of these methodologies can be used to compare outcomes of different aspects of fracking research in the Karoo and provide insights and recommendations for future decision-making and planning. Ultimately, the decision to allow Fracking should be based on a balanced assessment of potential risks and benefits, considering long-term impacts on the environment, economy, and communities.

Keywords: Challenges, Fracking, Independent, Policy, Precautionary, Regulatory, Research, Risks, Scale, Stakeholders

The role of groundwater in urban resilience

A Healy
Cardiff University, Wales

The potential role of groundwater in supporting the resilience of human societies is garnering increased attention in the context of climate change. Much of this attention focuses on the resilience of the groundwater resource itself. Less attention has been given to the way that groundwater is used by society and how this may influence human-centred resilience outcomes, particularly in urban settings. In this paper, I explore how questions of scale are fundamental to the role of groundwater in the resilience of urban areas, from the scale of individual households to more regional and catchment-based notions of scale. It is these variations in the geographies of urban groundwater exploitation that provide for the challenges of groundwater governance. Drawing on the practices revealed across 5 diverse cities in sub-Saharan Africa; the paper highlights the variety of ways that groundwater promotes the resilience of urban areas to water stress. The paper finds that groundwater can accommodate a prevalence of 'self-supply' and market-based models as urban populations seek to counter failings in public supply provision. Whilst these actions promote the resilience of the urban setting in the short to medium term, they raise important questions for the longer-term sustainability of the resource. The paper considers the implications of these questions for the future governance of resilient groundwater resources and the role of groundwater as part of a wider strategy for urban resilience.

Keywords: Groundwater, governance, household, resilience, urban

CLICK TO RETURN TO THE PROGRAMME

Alternative approaches for integrated groundwater management in the rural basins of central Bolivia

I Rodriguez-Levy[1]., M Centellas-Levy[2]., W Ferreira[1]., L Rivera-Rodriguez[1]., S Mustafa[3]., C Apaza-Coria[1]., M Soruco[1]., A Amaya4., M Huymans[5]

[1]Universidad Católica Boliviana.,"San Pablo"; [2]Fundación Abril; [3]Wageningen University ; [4]Universidad Mayor de San Simón; [5]Vrije Universiteit Brussel

Due to technical, social, and economic limitations, integrated groundwater management presents a significant challenge in developing countries. The significance of this issue becomes even more pronounced in groundwater management, as this resource is often overlooked and undervalued by decision-makers due to its status as a "hidden resource," despite the fact that it provides multiple ecosystem services. This study aims to establish the technical hydrogeological foundation in rural basins of central Bolivia through alternative, simplified, and cost-effective methods and tools. The study includes applying geophysical techniques, such as Electrical Resistivity Tomography, to determine the conceptual hydrogeological model of a micro-basin. In addition, a soil water balance approach was applied, characterizing 24 biophysical variables to identify groundwater recharge zones, while global circulation models provided a substitute for unreliable meteorological data.

Furthermore, a participatory model was developed to identify recharge areas in upper basin areas within the framework of developing a municipal policy for their protection. The participatory model included local knowledge in all stages of methodology development, considering the characteristics of the local plant communities and the spatial distribution of local rainfall. The research findings have already contributed to resolving socio-environmental conflicts in Bolivia and establishing a foundation for effective water governance by empowering local rural communities. This study has demonstrated the feasibility of using alternative, simplified, and low-cost methods and tools to establish the technical hydrogeological basis, which can inform public policies to promote sustainable groundwater management in developing countries.

Keywords: Bolivia, Socio-hydrogeology, geophysics, groundwater protection, groundwater recharge, soil water balance

CLICK TO RETURN TO THE PROGRAMME