JS.2 Trends and sustainability of groundwater in highly stressed aquifers

ICGW, IAH, ICWQ

Population growth, urbanization and global climate change have increased urban and agricultural water demands, stressing aquifer systems where groundwater is a source of water supply. The availability and utility of groundwater may further be threatened by factors stressing the quality of groundwater, such as industrial and domestic wastes and agricultural intensification. Consequences include, for example, over-allocation of groundwater, groundwater overdraft, declining well yields and land subsidence; degraded groundwater quality due to mobilization of natural pollutants (arsenic), salt contamination caused by seawater intrusion; increased demand for conjunctively used surface water and resulting conflicts with junior users; and streamflow capture and resulting damage to ecosystems. These consequences may occur incrementally and inequitably across an aquifer. Natural environmental problems can further complicate use of groundwater and increase strain on the aquifer system: e.g. underground structures, geothermal heating (such as heat islands), and geochemical evolution (such as karst formation, excessive salinity, acidity, fluoride, radioactivity, hardness, or turbidity). This session seeks to bring together scientists, including modellers, geochemists, and hydrogeologists, with water supply managers and policy makers to discuss scientific and management ideas and approaches for improving the sustainability of highly stressed aquifers.

Convener: Makoto Taniguchi (RIHN, Japan), *makoto@chikyu.ac.jp*

Co-conveners: Alyssa Dausman (USA)
Ken Howard (Canada)
Elango Lakshmanan (India)
Maurizio Polemio (Italy)
Wolfgang Schmid (USA)

JS.3 Improving integrated surface and ground water resources management in a vulnerable and changing world

ICWRS, ICWQ, ICRS, IAH

Many parts of the world are extremely vulnerable environments with declining potable water resources and an increasing risk of extreme events due to population growth, intensification of agriculture and urbanisation, and limited development opportunities. With the increasing difficulties of meeting human demands on water resource quantity and quality, new concepts in water management need to be explored, with a move away from centralised command and control approaches to more participatory multi-stakeholder approaches that have the potential to be more flexible and responsive. New concepts, such as Integrated Water Resources Management (IWRM) and Adaptive Management (AM) are being put into practice, but their scientific basis has not been fully explored. This symposium will address a wide range of problems related to water resources management where water is scarce and/or its quality is threatened by human impact. Issues of water resources availability will be examined, as will be the impact of growing cities and the increasing demand for irrigation water, aiming at sustainable use of groundwater aquifers and surface water storage. Papers are invited that explore concepts and components of IWRM and AM, and present examples of their implementation in river basins. Also, new data to assist in IWRM will be explored by using remote sensing methods in synergetic application with ground observations and modelling. Contributions using visible, near and thermal infrared, microwave and other sources like altimetry or gravimetry are solicited. The symposium will also address the risk associated with extreme events, including floods and droughts with an emphasis on vulnerable environments, their frequencies, forecasting and management, both under present day and projected changed conditions. Strategies for assessing and reducing vulnerability from both a resource and risk perspective will be considered.

Convener: Günter Blöschl (Austria), *bloeschl@hydro.tuwien.ac.at*

Co-conveners: Olga Barron (Australia)
Nick van de Giesen (The Netherlands)
D. Muralidharan (India)
Liliang Ren (China)
Frédérique Seyler (France)
Uttam Sharma (India)
Jaroslav Vrba (Czech Republic)

JS.4 Hydroinformatics in hydrology, hydrogeology and water resources

HYINF, ICSW, ICWRS, ICRS, IAH

Hydroinformatics is a branch of Informatics which concentrates on the application of information and communication technologies (ICTs) in addressing the increasingly serious problems of the equitable and efficient use of water. The Joint Committee on Hydroinformatics represents the interests of the International Association of Hydraulics Research (IAHR), the International Water Association (IWA) and IAHS. This symposium will be focused on the problems of model coupling in complex systems, the treatment of uncertainty, the exploitation of artificial intelligence (AI) methodology and advanced GIS and visualisation techniques to the whole field of water resources and hydrology. Hydroinformatics draws on and integrates hydrology, hydraulics and environmental engineering, and many other water disciplines. It sees application at all points in the water cycle from atmosphere to ocean, and truly represents an attempt to support a "whole systems modelling philosophy". It provides support for decision making at all levels from governance and policy through management to operations. The symposium particularly welcomes contributions in the water resources area from developing countries where efficient and sustainable use of water is an imperative. A Red Book will be produced post-symposium under the editorial guidance of the conveners.

Convener: Ian Cluckie (UK), *i.d.cluckie@bristol.ac.uk*

Co-conveners: Vladan Babovic (Singapore)
Yangbo Chen (China)
Siegfried Demuth (Germany)
Lenny Konikow (USA)
Arthur Mynett (The Netherlands)
Dragan Savic (UK)

JW.1 Measuring and modelling interactions between surface water and groundwater

ICGW, ICSW, ICT, IAEA, IAH

This workshop seeks to advance the integrated analysis of surface water–groundwater systems and their interactions in different geographical, geological, and anthropogenically influenced environments. It will bring together scientists from academia, government, and consultancies, with backgrounds in physics, geology, chemistry, biology and ecology. Contributions are invited on theoretical, numerical, and experimental studies that address all components of the water and energy cycles of surface-water/groundwater systems. Integrated studies that address a wide range of time scales (diurnal to decadal) and spatial scales (column to basin and global scales) are encouraged. Emphasis is placed on coupling different processes of the surface–subsurface–land-surface system, such as rainfall–runoff transformation and stream flow generation; estimation of residence times of water and solutes in catchments; ecological responses in flood plains, coastal zones, groundwater-dependent ecosystems and unsaturated zones; and effects of climate change on surface water–groundwater systems. The symposium also welcomes contributions concerning the development of simple and robust algorithms for modelling surface water–groundwater interactions in data-poor areas (that is, ungauged basins).

Convener: Gunnar Nützmann, (Germany), *nuetzmann@igb-berlin.de*

Co-conveners: Corinna Abesser (UK)
Jianyao Chen (China)
Peter Cook (Australia)
Aldo Fiori (Italy)
Sushil Kumar Gupta (India)
David Rassam (Australia)
Jun Shimada (Japan)
V. P. Singh (USA)
Chris Soulsby (UK)

JW.2 Transboundary water management: Science and policy

Joint session with ICGW and ICSWS of IAHS, CTA of IAH, UNESCO and OSS

This session focuses on the science and policy of transboundary aquifers and their interactions with surface water. Almost 40% of the world's population lives in a transboundary river basin and nearly 60% of global fresh surface waters flow across an international boundary. A recent UN study identified 263 transboundary river basins and the International Shared Aquifer Resource Management initiative (ISARM) of UNESCO-IGRAC's global inventory has so far documented 90 transboundary aquifers in Western Europe and 60 each in the Americas and Africa. The scientific and legal issues that affect the management of these shared waters have attracted interest for years, yet intergovernmental agreements remain immature. The one international legal instrument on transboundary water developed between 1970 and 1997 by the United Nations International Law Commission (UN ILC) remains unratified. However, the ILC recently drafted legal articles on the use of transboundary aquifers for adoption by governments. This symposium seeks to improve the science and policy needed to manage transboundary aquifers and associated waters by bringing together scientists, engineers, managers, lawyers and policy makers. Suitable subjects within the context of transboundary waters include, for example, (a) quantifying natural and anthropogenically influenced flux of groundwater across political boundaries; (b) investigation of transport of contaminants; (c) impacts of increasing climate variability, especially where rivers and aquifers are currently supported by snow pack and/or glacial systems; (d) accounting for interactions between groundwater and surface water bodies such as rivers, streams and lakes; (e) socio-economic aspects of using transboundary waters; and (f) legal frameworks for transboundary waters and their consistency with scientific evaluations, (g) examples of transboundary water management. Selected contributions from the symposium will be published in a peer-reviewed IAHS Red Book following the joint IAH Congress and IAHS Scientific Assembly in Hyderabad, India.

Convener: Surin Workakijthamrong (UK), *surin.worakijthamrong@bristol.ac.uk*

Co-conveners: Eberhard Braune(South Africa)
Deborah Hathaway (USA)
Youba Sokona (Mali/Tunisia)
Clifford Voss (USA)
Surin Workakijthamrong (UK)
Yongxin Xu (South Africa)

JW.3 Rural and urban water systems: Minimising adverse impacts of global change on water resources

ICWQ, ICWRS, IAH

Hydrological regime and water quality in rivers, lakes and aquifers are dependent on climate conditions and direct and indirect human activities, such as land use, urbanization and water management. Higher temperatures and changes in the timing, intensity and duration of precipitation can affect the hydrological cycle and influence geochemical fluxes in soil and water. Changing climate could lead to alterations in runoff, streamflow and water quality characteristics. Land use patterns and agricultural practices have a very significant effect on water flows and water quality, as do management actions to control point and diffuse sources of pollution. Consumption of groundwater in large cities leads to lowering of groundwater tables, pollution of surface and groundwater, damaging the ecological systems and land subsidence. Rapid urbanization and its consequences for local and regional water systems (both quantity and quality aspects) are likely to become dramatic in the future. Therefore, water systems in the future will be very dependent on changing climate conditions, as well as on the whole spectrum of human activities. Confidence in estimates of changes in water cycle and water quality is - uncertainty is added by the current lack of understanding of other processes involved and their interface with human activities. The Workshop intends to contribute to this important field of research. Papers are welcomed that address different aspects of observed and projected trends in water regime and water quality under global change, including changing climate, land use change and urbanization.

Conveners: Valentina Krysanova (Germany), *krysanova@pik-potsdam.de*

Co-conveners: Nico Goldscheider (Switzerland)
Kate Heal (UK)
Ayorinde Olufayo (Nigeria)
Liliang Ren (China)
Frans van de Ven (The Netherlands)

JW.4 Isotope tracing for water balance, hydrodynamics and hydrological processes, including groundwater recharge, as indicators of water resources sustainability

ICT, ICSW, ICGW, PUB, IAEA, IAH

Isotopic and geochemical tracers are increasingly being applied at the watershed, basin and continental scale to study water cycling processes that influence sustainability of surface and groundwater resources. Examples include recharge and discharge estimation, quantification of aquifer residence times, surface/groundwater interaction, seawater intrusion, precipitation–runoff mechanisms, evaporation losses, and partitioning of water sources and sinks. Contributions that discuss the role of tracers as tools for integrated water management, transboundary cooperation, climate change impacts, and prediction in ungauged basins are particularly encouraged. Emphasis in the oral session will be placed on quantitative applications, modelling, uncertainty, and sensitivity analysis.

Convener: Piotr Maloszewski (Germany), *maloszewski@gsf.de*

Co-conveners: John Gibson (Canada)
Andrew Herczeg (Australia)
Balbir Singh Sukhijat (India)
Michael Stewart (New Zealand)

HS.1 High mountain snow and ice hydrology

ICSIH, ICRS, PUB, IACS

Changes in storage of water as seasonal snowpack, frozen ground, and perennial snow and glacier ice, and release of meltwater are major components of hydrological systems in the high mountain regions of the world. In such areas, the annual cycle of meltwater production from snow and ice is critical, influencing streamflow regime, soil moisture, and both terrestrial and aquatic ecosystems. Meltwater availability is crucial in cold mountain environments, and in areas downstream, for agriculture and hydropower, particularly where the areas surrounding mountains are otherwise arid and susceptible to drought. Snowpack, permafrost, glaciers and meltwater runoff will continue to be influenced strongly by climate change into the future. Detailed understanding of, and the ability to accurately model inter-relationships between climate, snowpack, ground ice and glacier dynamics coupled with intra-basin hydrological processes, are necessary in order to test hypotheses concerning contemporary and future interactions between high mountain climate, snow, ice, runoff,

biogeochemistry and water quality. This symposium addresses a broad range of topics important for better understanding of snow and ice hydrology in mountain regions and for reducing uncertainty and increasing physical realism in modelling and prediction. Contributions on the following topics are particularly welcome: measurement and monitoring techniques for snow and ice in cold mountainous regions; physical properties of snow, permafrost and ice – linking microscale properties to macroscale processes; using remote sensing for improvement of prediction of runoff from snow and ice in data-sparse mountain areas; forecasting meltwater runoff from ungauged high mountain basins; assessment of risk and prediction of glacier lake outburst floods in mountain areas, and impacts of mountain snow and ice hydrology on water resources in drier downstream areas in a changing climate.

Convener: David Collins (UK), *d.n.collins@salford.ac.uk*

Co-conveners: Alexander Gelfan (Russia)
Georg Kaser (IACS / Austria)
Danny Marks (USA)
John Pomeroy (Canada)
Pratap Singh (India)

HS.2 New approaches to hydrological prediction in data sparse regions

ICCLAS, ICSIH, ICWRS, ICRS, PUB

In many regions of the world the reliability of hydrological predictions is limited because local data are often sparse or non-existent. New strategies to help reduce the negative consequences of data scarcity are crucial to improving water resources management and to better assessing the evolving impacts of natural and anthropogenic climate change. One important way around this problem is to draw on other sources of information, including, for example: (1) coupled hydro-meteorological predictions, (2) remote sensing technology, and (3) guided monitoring network design. Strategies for improving and exploiting hydro-meteorological predictions might include novel downscaling techniques, improved representation of critical land-surface-atmosphere continuum, assessment of the effects of climate variability/-change on frequency/severity of floods and drought, and approaches to incorporate data assimilation and uncertainty assessment. Strategies for exploiting remote sensing technology might include methods that assimilate such information into water management, that improve water use effectiveness, or that monitor and understand land-use changes in relation to water availability and usage. Strategies focusing on alternatives to expensive ground-based monitoring networks might include guidance on the design of optimum network density and/or sampling strategy to address specific science problems (e.g. dominant process identification) and resource management challenges. Methods for using sparse networks to evaluate the approaches listed above are also important. This symposium seeks contributions that address how such approaches can help reduce the negative consequences of data scarcity and thereby improve hydrological predictions in data sparse regions.

Convener: Koray K. Yilmaz (Turkey and Arizona, USA), *koray@hwr.arizona.edu*

Co-conveners: Hoshin V. Gupta (USA)
Christopher Neale (USA)
John Pomeroy (Canada)
Hubert Savenije (The Netherlands)
Thorsten Wagener (USA)
Dawen Yang (China)
Ismail Yücel (Turkey)

HS.3 Hydrological theory and limits to hydrological predictability in ungauged basins

PUB, ICSW, ICGW, ICCE, ICWRS, ICCLAS

For PUB to achieve reliable predictions in ungauged basins, we need sound hydrological theory. Currently, no universal theory of catchment hydrology exists. There are different concepts for different parts of the hydrological cycle and different spatial and temporal scales. In this symposium concepts will be discussed that may help shape a theory of catchment hydrology that can support PUB. Possible contributions include concepts that represent processes simultaneously at various scales and then link them, rather than to upscale small scale processes all the way to obtain aggregate behaviour. An important theoretical and practical issue for PUB is to understand the limits to predictability in hydrology. *Inter alia* predictability may be limited by the life time of hydrological phenomena and by the non-linearity of hydrological systems, as well as lack of knowledge on initial conditions and boundary conditions. One of the issues to be identified is the relative role of these components in different hydrological settings, i.e. what are the theoretical limits to predictability, and how can we improve it in the light of increased data availability, including novel data sources. To address the generalisation issue, comparative hydrology may assist in developing a common method for assessing and quantifying hydrological similarity, through comparisons between catchments in different hydrological regimes. Contributions from all subdisciplines of hydrology are sought, including hydrological forecasting, regional estimation, assessment of hydrological change, and aquifer assessment; all components of the water cycle are addressed, including extremes (floods, low flows), erosion and water quality related parameters.

Convener: Erwin Zehe (Germany), *erwin.zehe@uni-potsdam.de*

Co-conveners: Stewart Franks (Australia)
Praveen Kumar (USA)
Lakshman Nandagiri (India)
Stan Schymanski (Germany)
Peter Troch (USA)

HW.1 Regionalisation of models for operational purposes in developing countries

ICSW, ICWRS, PUB

Developing countries often represent the most difficult situations in which to apply hydrological models. The general lack, or poor quality and reliability, of the available data suggests that there will be a relatively high degree of uncertainty in modelling results. At the same time, because of the lack of data with which to quantify available water resources, there is a great need for modelling techniques that can provide information useful to decision-makers. It should also be recognised that in many developing countries there is a lack of technical capacity as well as access to internal resources. There is therefore an urgent requirement to roll-out scientific developments and achievements of the PUB programme and to transfer these technologies to demonstrate how to make use of the science to reduce the uncertainty in water resource planning and management in regions of poor data and technical capacity. This could apply *inter alia* to regional estimates of water resource availability (under natural, present day and future scenario situations), as well as the prediction and management of extremes (floods and droughts). The workshop will therefore address issues such as access to, and the combined use of, local and global data sets, appropriate models and modelling platforms, regionalisation of parameters, how to incorporate uncertainty in water resource management, the effective transfer of technology, capacity building and training. There will be an emphasis on the practical implementation of science and technology and the need to provide sound, scientifically based estimation methods for water resource managers in developing countries throughout the world.

Convener: Denis Hughes (South Africa), *denis@iwr.ru.ac.za*

Co-conveners: András Bárdossy (Germany)
Dan Rosbjerg (Denmark)

HW.2 Sediment problems and sediment management in Asian river basins

ICCE, ISI, WASER

Sediment problems are assuming increasing importance in many areas of the world. These problems relate to the adverse effects of sediment in both water resource development and river management, and to the wider environmental impact of sediment in degrading aquatic ecosystems. Changing sediment fluxes can also have important implications for nutrient inputs to freshwater and coastal ecosystems, and for the stability of channels, and flood plains and river deltas. With their high sediment fluxes and the sensitivity of these fluxes to climate change and to land use change and other human impacts, such as dam construction and river regulation, Asian river basins currently face many sediment-related problems. There is a need for improved understanding of these problems and the sediment budgets of river basins and for the development of effective management strategies. This workshop, organised in collaboration with UNESCO ISI and WASER, will seek to review the nature and extent of sediment problems in Asian river basins and current progress towards developing effective sediment management strategies. Topics to be addressed will include the present and future impacts of climate change, the interaction of different factors causing changing sediment fluxes, sediment management strategies and their effectiveness, and the development of sediment monitoring networks to support effective sediment management.

Convener: Des Walling (UK), *d.e.walling@exeter.ac.uk*

Co-conveners: Jim Bogen (Norway)
Chunghong Hu (China)
Anil Mishra (UNESCO)
S. C. Rai (India)
Manfred Spreafico (Switzerland)

HW.3 Flood risk management

ICWRS, ICSW, WMO, IFI

Floods are the greatest cause of human suffering in the world. Since the spectacular flooding of New Orleans much attention is given to the various ways to protect people against high waters. In some countries the concept of the safety chain is applied. According to this concept threats should be confronted at all levels: pro-action, prevention, preparation, repression and recovery. Traditionally most attention is given to prevention of flooding by dikes and dams. In some cases preparation and repression is also preferred and flood warning and evacuation of the people at risk is planned in advance and applied in practice. After the flood recovery of losses and damage is a logical activity, but not well reported. In this session we would like to invite a discussion on the efficiency of the various shackles in the safety chain. Is it wise to spread the investment and the attention equally or should one shackle get all? Could insurance play a role in the recovery phase or has it only preventative effects? What is the actual damage after a flood? Can we learn from the recovery efforts from previous floods?

Convener: Han Vrijling (The Netherlands),
h.vrijling@ct.tudelft.nl

Co-conveners: Hafzullah Aksoy (Turkey)
Andreas Schumann (Germany)
Joachim Saalmüller (WMO)
Wang Wen (China)

HW.4 Space-time scaling for ET and soil moisture modelling using remote sensing

ICRS, ICCLAS

The rapid population growth in many countries together with a generally increasing standard of living is increasing demands on water for irrigation, industry and urban water supply, and is decreasing the quality of the available surface water. Recent studies in the USA have suggested possible benefit/cost ratios ranging from 75:1 to 100:1 for using remotely sensed data in hydrology and water resources. These estimates are based on savings from flood prevention and improved planning of irrigation and hydro-electric production. Extensive work has been done over the last few years in both soil moisture monitoring using remote sensing and the application of remote sensing to hydrological runoff modelling. Recent work has noted that that there have been few studies that have incorporated remote sensing soil-moisture and evaporation estimates into hydrological models. The reasons for this are many and varied and the fact that spatial and temporal time-scales for which these data are available are often not suitable for hydrological applications is a key issue. Remote sensing offers opportunities to scale these phenomena spatially and temporally. This workshop seeks to examine the state-of-the-art in remote sensing applications with respect to scaling the important state and flux variables of soil moisture and evapotranspiration, respectively. It also seeks to examine the relationship between these variables and hydrological model structure.

Convener: Giuseppe Ciraolo (Italy), *giuseppe@idra.unipa.it*

Co-conveners: Eva Bøgh (Denmark)
Yangbo Chen (China)
Ian Cluckie (UK)
Alain Pietroniro (Canada)

HW.5 Prediction in Ungauged Basins – a benchmark report

PUB, ICSW, ICGW, ICCE, ICSIH, ICWQ, ICWRS, ICRS, ICCLAS, ICT

The Predictions in Ungauged Basins (PUB) initiative has entered its third Biennium. While the first two Biennia have focused on creating intellectual momentum and building up the movement, the third Biennium will take stock of what has been achieved and at the same time look ahead. The main thrust will be to produce, over the next 2 years, a benchmark report that will assess, on a comprehensive, objective, open and transparent basis, the state of hydrological predictions in the absence of data and identify what the prediction challenges for the future are. The purpose of this workshop will be to contribute to this report, which will serve as a reference to gauge future achievements, specifically, to quantify the degree to which uncertainty in hydrological predictions can be reduced in clearly specified contexts. Disparate views for which there is significant support will be clearly identified, together with relevant arguments. One challenge will be to identify suitable criteria for measuring the performance, which will likely depend on the nature of the variability represented. Unlike conference proceedings and special journal issues, emphasis will be on coherence and the collective message. Unlike a typical monograph, emphasis will be given to quantitative assessment of the state of research, based on an endorsement by the wider hydrological science community. The report will be prepared by a team of Co-ordinating Lead Authors, Lead Authors and Review Editors.

Convener: Günter Blöschl (Austria),
bloeschl@hydro.tuwien.ac.at

Co-conveners: Berit Arheimer (Sweden)
Praveen Kumar (USA)
Jeff McDonnell (USA)
Murugesu Sivapalan (USA)
Ross Woods (New Zealand)

HW.6 Precipitation variability and water resources

PRECIP

In close relationship with the general theme of IAHS on water resources under stress, this workshop focuses on quantifying the variability of precipitation and precipitation surrogates over wide ranges of space-time scales, including

the nature of precipitation extremes, non-stationarities, and uncertainties. This requires the discussion of new observational and data processing techniques for *in situ* networks and/or for remote sensing, new modelling approaches, including climatological/meteorological models, rainfall stochastic and/or scaling models, as well as to better confront models to data. Particular attention will be paid to the various space-time scales that are involved and techniques that allow one to observe, analyse and simulate across scales.

Convener: Daniel Schertzer (ENPC/CEREVE, France), *daniel.schertzer@enpc.fr*

Co-conveners: Shaun Lovejoy (Canada)
Nityanand Singh (India)
Eric A. Smith (USA)

HW.7 New statistics in hydrology

STAHY, ICWRS

In the last 20 years many different statistical approaches were developed for the analysis of hydrological extremes, rainfall simulation in time and space, runoff forecasting and management, and other hydrological applications. The introduction of new statistical methods and procedures resulted in improved hydrological analyses. For instance, the relatively recent introduction of copula functions is potentially improving several application fields permitting multivariate analysis in case studies traditionally done by univariate analysis. This session, sponsored by the Statistics in Hydrology Working Group (STAHY-WG), has two aims: the first is to explore innovative statistical methods never applied before, and the second is to collect presentations describing the most recent theory, procedures and applications related to already known topics. The main focus is univariate and multivariate analysis (extreme value, inference procedure, copula function) and stochastic modelling (linear and non-linear models, space–time simulation procedures, time series analysis, long range dependence, non-stationarity detection, point processes). Presentations and poster contributions on theoretical innovative approaches, advanced statistical and mathematical methods, and hydrological applications of mentioned procedures are encouraged.

Convener: Salvatore Grimaldi (Italy), *salvatore.grimaldi@unitus.it*

Co-conveners: Demetris Koutsoyiannis (Greece)
George Kuczera (Australia)
Domenico Piccolo (Italy)

G.1 Groundwater resources development in hard rock terrains

Hard rock terrains make up rather complex aquifer systems that contain important groundwater resources. These aquifers are widely used for the water supply in rural areas, particularly in semi-arid and arid regions, in spite of their heterogeneous groundwater conditions and locally poor storage capacity. This theme session aims at presenting and exchanging ideas and experiences of groundwater exploration in hard rock areas, e.g. using remote sensing, geophysical, geological and geochemical investigation methods for special parameter identification. It also encompasses methods of groundwater resource evaluation, groundwater monitoring and drilling techniques. Examples of artificial recharge in hard rock terrain are invited for presentation. Finally, the importance of hard rock aquifers for environmental sustainability will be discussed.

- Groundwater exploration
- Groundwater assessment and estimation
- Parameter identification
- Techniques for extraction and monitoring of groundwater

Convener: Jiri Krasny (Czech Republik), *krasny.hg@seznam.cz*

Co-conveners: B. Jay Kumar (India)
Didier Pennequin (France)
S.V.N. Rao (India)
V.S. Singh (India)
D.C. Singhal (India)

G.2 Groundwater quality and pollution in hard rock aquifers

Because of their special nature hard rock areas show particular patterns of chemical composition of groundwaters. They are also very vulnerable for pollution, because their self-cleaning potential is considered to be rather low. The session will highlight groundwater quality issues that are specific for hard rock environments and discuss strategies and methods for the assessment of groundwater vulnerability in hard rocks. In addition the pollution of groundwater in hard rocks from various sources a well as methods for cleaning-up contaminated groundwaters, including the cost effective water treatment techniques and remedial measures to control and confine groundwater pollution, will be presented and discussed.

- Natural variation of groundwater quality
- Anthropogenic groundwater pollution
- Remedial measures to control and contain groundwater pollution
- Cost effective water treatment and sanitation techniques

Convener: V. V. S. Gurunadha Rao (India) *gurunadharao@ngri.res.in*

Co-conveners: Ian Acworth (Australia),
Al Ramnathan, (India)

G.3 Groundwater resource management in hard rock areas

Owing to the complexities in hard rock areas specific tools for the management of groundwater have to be applied, including the conjunctive use of groundwaters and surface waters. Conceptual hydrogeological and structural modelling is of prime importance in hard rock areas. The session will deal with groundwater flow and solute transport modelling in hard rock media and present and discuss decision support tools for the optimum use of water resources.

- Modelling of groundwater flow and solute transport in fractured media
- Managing aquifer recharge in fractured media
- Decision support tools for optimum use of groundwater

Convener: Shivendra Nath Rai (India), *snrai@ngri.res.in*

Co-conveners: A. Ghosh Bobba (Canada)
Peter Dillon (Australia)
A. K. Rastogi (India)
M. Sekhar (India)
B. Venkateswara Rao (India)

G.4 Socio-economic issues relevant to groundwater in hard rock areas

Hard rock aquifers present useful water resources in large rural areas that are often characterised by a lower status of development and poor conditions for living and farming. Yet groundwater is frequently used without proper understanding of the hard rock aquifer systems. Issues of groundwater governance, including legislation and regulations for groundwater protection, both in terms of quantity and quality, will be discussed. Economic, social and environmental factors governing the integrated water resource management will be highlighted. Health risk assessments specific for hard rock areas are presented. Finally the role of education and the media in awareness raising for groundwater in hard rocks will be stressed.

- Legislation and regulations for groundwater governance
- Awareness: Role of education and media
- Health risk assessment and solution to the problem

Convener: Tushar Shah (India), *t.shah@cgiar.org*

Co-conveners: Shrikant Daji Limaye (India)
Manuel Ramon Llamas (Spain)
Aditi Mukherji (Sri Lanka)